INTERNATIONAL STANDARD

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Petroleum and natural gas industries — Reciprocating compressors

Industries du pétrole et du gaz naturel — Compresseurs alternatifs

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard, ISO 13707, was prepared by Technical Committee ISO/TC 118, *Compressors, pneumatic tools and pneumatic machines* in collaboration with ISO/TC 67, *Materials, equipment and offshore structures for petroleum and natural gas industries*, Subcommittee SC 6, *Processing equipment and systems*.

Annexes A to Q of this International Standard are for information only.

Introduction

This International Standard is based upon the accumulated knowledge and experience of manufacturers and users of reciprocating compressors. The objective of this International Standard is to provide a purchase specification to facilitate the manufacture and procurement of reciprocating compressors for general petroleum and natural gas industry services but its use is not limited to these services.

This International Standard is based on API standard 618, 4th edition, 1995.

The purpose of this International Standard is to establish minimum requirements for design and construction so that the equipment will be suitable for the purpose for which it is required. This limitation in scope is one of charter rather than interest and concern. Energy conservation and protection of environment are matters of increasing concern and are important in all aspects of equipment design, application and operation. The manufacturers and users of equipment should aggressively pursue alternative innovative approaches which improve energy utilisation and/or minimize the environmental impact without sacrificing safety or reliability. Such approaches should be thoroughly investigated and purchase options should increasingly be based on the estimation of whole life costs and the environmental consequences rather than acquisition costs alone.

This International Standard requires the purchaser to specify certain details and features.

A bullet (●) at the beginning of a clause or sub-clause indicates that either a decision is required or further information is to be provided by the purchaser. This information should be indicated on the data sheets; otherwise it should be stated in the quotation request or in the order.

For effective use of this International Standard and ease of reference to the text the use of the data sheets in annex A is recommended.

Users of this International Standard should be aware that further or differing requirements may be needed for individual applications. This International Standard is not intended to inhibit a vendor from offering, or the purchaser from accepting, alternative equipment or engineering solutions for the individual application. This may be particularly applicable where there is innovative or developing technology. Where an alternative is offered, the vendor should identify any variations from this International Standard and provide details.

Petroleum and natural gas industries — Reciprocating compressors

1 Scope

This International Standard covers the minimum requirements for reciprocating compressors and their drivers used in the petroleum and natural gas industries with either lubricated or nonlubricated cylinders. This International Standard may be used for other services or in other industries by agreement. Compressors covered by this International Standard are moderate to low-speed and in critical services. Also included are related lubricating systems, controls, instrumentation, intercoolers, aftercoolers, pulsation suppression devices and other auxiliary equipment. Excluded are integral gas-engine driven compressors, packaged high-speed separable engine-driven reciprocating gas compressors, compressors with single-acting trunk-type (automotive-type) pistons that also serve as crossheads and either plant or instrument air compressors that discharge at gauge pressures of 9 bar or below. Also excluded are gas engine and steam engine drivers.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 7-1, *Pipe threads where pressure-tight joints are made on the threads — Part 1: Dimensions, Tolerances and Designation.*

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

ISO 262, *ISO general-purpose metric screw threads — Selected sizes for screws, bolts and nuts.*

ISO 281-1, *Rolling bearings — Dynamic load ratings and rating life — Part 1: Calculation methods.*

ISO 1217, *Displacement compressors — Acceptance tests.*

ISO 7005-1, *Metallic flanges — Part 1: Steel flanges.*

ISO 7005-2, *Metallic flanges — Part 2: Cast iron flanges.*

ISO 8501-1, *Preparation of steel substrates before application of paints and related products — Visual assessment of surfaces cleanliness. Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings.*

ISO 10436, *Petroleum and natural gas industries — General-purpose steam turbines for refinery service.*

ISO 10437, *Petroleum and natural gas industries — Special-purpose steam turbines for refinery service.*

ISO 10438-2, *Petroleum and natural gas industries — Lubrication, shaft-sealing and control-oil systems and auxiliaries — Part 2: Special-purpose oil systems.*

ISO 10441, *Petroleum and natural gas industries — Flexible couplings for mechanical power transmission — Special-purpose applications.*

ISO 13691, *Gears — High-speed special-purpose gear units for the petroleum, chemical and gas industries.*

ISO 13706, *Petroleum and natural gas industries — Air-cooled heat exchangers.*

ISO 14691, *Petroleum and natural gas industries — Flexible couplings for mechanical power transmission — General purpose applications.*

ISO 16812, *Petroleum and natural gas industries — Shell and tube heat exchangers.*

IEC 60034-1, *Rotating electrical machines — Part 1: Rating and performance.*

IEC 60079-0, *Electrical apparatus for explosive gas atmospheres — Part 0: General requirements.*

IEC 60529, *Degrees of protection provided by enclosures (IP codes).*

IEC 60848, *Preparation of function charts for control systems.*

ANSI[1)] B 1.20.1, *Pipe Threads, General Purpose (Inch).*

ANSI B 16.5, *Pipe Flanges and Flanged Fittings.*

ANSI B 31.3, *Process Piping.*

API[2)] RP 520/1, *Sizing, Selection and Installation of Pressure Relieving Devices in Refineries — Part 1: Sizing and selection.*

API RP 520/2, *Sizing, Selection and Installation of Pressure Relieving Devices in Refineries — Part 2: Installation.*

API Std 526, *Flanged Steel Pressure Relief Valves.*

API Std 614, *Lubrication, Shaft Sealing and Control Oil Systems And Auxiliaries For Petroleum, Chemical and Gas Industry Service.*

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

ASME[3)], *Boiler and Pressure Vessel Code 1998.*

ASTM[4)] A 106, *Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service.*

ASTM A 193M, *Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service.*

ASTM A 194M, *Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High-Pressure or High-Temperature Service or Both.*

ASTM A 216M, *Standard Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service.*

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1) American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

2) American Petroleum Institute, 1220 L Street, N.W., Washington, DC 20005-4070, USA.

3) American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017, U.S.A.

4) American Society for Testing and Materials, Barr Harbor Drive, West Conshohocken, PA 19428-2959, U.S.A.

ASTM A 247, *Standard Test Method for Evaluating the Microstructure of Graphite in Iron Castings.*

ASTM A 269, *Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service.*

ASTM A 278M, *Standard Specification for Gray Iron Castings for Pressure-Containing Parts for Temperatures Up to 650 °F.*

ASTM A 307, *Standard Specification for Carbon Steel Bolts and Studs, 60 000 PSI Tensile Strength.*

ASTM A 312M, *Standard Specification for Seamless and Welded Austenitic Stainless Steel Pipes.*

ASTM A 320M, *Standard Specification for Alloy Steel Bolting Materials for Low-Temperature Service.*

ASTM A 388M, *Standard Practice for Ultrasonic Examination of Heavy Steel Forgings.*

ASTM A 395M, *Standard Specification for Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures.*

ASTM A 503, *Standard Specification for Ultrasonic Examination of Large Forged Crankshafts.*

ASTM A 536, *Standard Specification for Ductile Iron Castings.*

ASTM A 668, *Standard Specification for Steel Forgings, Carbon and Alloy, for General Industrial Use.*

ASTM E 94, *Standard Guide for Radiographic Testing.*

ASTM E 125, *Standard Reference Photographs for Magnetic Particle Indications on Ferrous Castings.*

ASTM E 142, *Standard Method for Controlling Quality of Radiographic Testing.*

ASTM E 709, *Standard Guide for Magnetic Particle Examination.*

AWS[5)] D1.1, Structural Welding Code — Steel.

NACE[6)] MR 0175, Sulfide Stress Cracking Resistant Metallic Materials for Oilfield Equipment.

NEMA[7)] SM 23, Steam Turbines for Mechanical Drive Service.

TEMA[8)], *Standards.*

3 Terms and definitions

For the purposes of this International Standard, the following terms and definitions apply:

3.1
acoustic simulation
process whereby the one-dimensional acoustic characteristics of fluids and the reciprocating compressor dynamic flow influence on these characteristics are modelled

5) American Welding Society, 550 N W LeJeune Road, PO Box 35104, Miami, Florida 33135, U.S.A.

6) National Association of Corrosion Engineers, PO Box 218340, Houston, Texas 77218-8340, U.S.A.

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

8) Tubular Exchanger Manufacturers Association, 25 North Broadway, Tarrytown, New York 10591, U.S.A.

NOTE The model is mathematically based upon the governing differential equations (motion, continuity, etc.). The simulation should allow for determination of pressure/flow modulations at any point in the piping model resulting from any generalized compressor excitation (see 3.4 and 3.7).

3.2
active analysis
portion of the acoustic simulation in which the pressure pulsation amplitudes due to imposed compressor operation for the anticipated loading, speed range and state conditions are simulated (see 3.1)

3.3
alarm point
preset value of a parameter at which an alarm is actuated to warn of a condition that requires corrective action

3.4
analogue simulation
method using electrical components (inductances, capacitors, resistances and current supply devices) to achieve the acoustic simulation (see 3.1).

3.5
capacity
quantity of gas taken into the compressor at the specified inlet conditions, compressed and delivered at the specified discharge pressure

NOTE The capacity of a compessor does not include any gas that leaks out of the compressor during the compression process nor any air that leaks into a compressor used as a vacuum pump.

3.6
combined rod load
algebraic sum of gas load and inertia force on the crosshead pin

NOTE Gas load is the force resulting from differential gas pressure acting on the piston differential area. Inertia force is that force resulting from the acceleration of reciprocating mass. The inertia force with respect to the crosshead pin is the summation of the products of all reciprocating masses (piston and rod assembly, and crosshead assembly including pin) and their respective acceleration.

3.7
design
word used by the designer or manufacturer in terms such as, design power, design pressure, design temperature and design speed

NOTE Use of this word in the purchaser's specifications should be avoided.

3.8
digital simulation
method using various mathematical techniques on digital computers to achieve the acoustic simulation (see 3.1)

3.9
fail safe mode of operation for control systems
arrangement such that failure of any component or loss of energy supply will not result in unsafe or potentially unsafe situations

3.10
gauge board
unenclosed bracket or plate used to support and display gauges, switches and other instruments

3.11
inlet volume flow
flow rate expressed in volume flow units at the conditions of pressure, temperature, compressibility and gas composition, including moisture content, at the compressor inlet flange

NOTE To determine inlet volume flow, allowance must be made for pressure drop across pulsation suppression devices and for interstage liquid knockout.

3.12
local (adj.)
applies to any device mounted on or near the equipment or console

3.13
manufacturer
organisation responsible for the design and manufacture of the equipment — not necessarily the vendor

3.14
manufacturer's rated capacity
capacity used to size the compressor

3.15
maximum permissible continuous combined rod load
highest combined rod load at which none of the forces in the running gear (piston, piston rod, crosshead assembly, connecting rod, crankshaft, bearings etc.) and the compressor frame exceed the values in any component that the manufacturer's design will permit for continuous operation

3.16
maximum permissible continuous gas load
highest force that a manufacturer will permit for continuous operation on the static components (e.g., frame, distance piece, cylinder and bolting) of the compressor

3.17
maximum permissible speed
highest speed at which the manufacturer's design will permit continuous operation

3.18
maximum permissible temperature
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

3.19
maximum permissible working gauge pressure (MPWGP)
maximum continuous pressure for which the manufacturer has designed the equipment (or any part to which the term is referred) when handling the specified fluid at the specified temperature

3.20
minimum permissible speed
lowest speed at which the manufacturer's design will permit continuous operation

3.21
minimum permissible suction pressure (for each stage)
lowest pressure (measured at the inlet flange of the cylinder) below which the combined rod load or gas load or discharge temperature, or crankshaft torque load (whichever is governing) will exceed the maximum permitted during operation at the setpoint pressure of the discharge relief valve and other specified gas conditions for the stage

3.22
minimum permissible temperature
lowest temperature for which the manufacturer has designed the equipment (or any part to which the term is referred)

3.23
mode shape (of an acoustic pulsation resonance)
description of the pulsation amplitudes and phase angle relationship at various points in the piping system

NOTE Knowledge of the mode shape allows the analyst to understand the pulsation patterns in the piping system (see 3.1).

3.24
normal operating point
point at which usual operation is expected and optimum efficiency is desired

NOTE This point is usually the point at which the manufacturer certifies that performance is within the tolerances stated in this International Standard.

3.25
normally open and normally closed
both on-the-shelf positions and de-energized positions of devices such as automatically controlled electrical switches and valves

NOTE The normal operating position of such a device is not necessarily the same as the device's on-the-shelf position.

3.26
owner
final recipient of the equipment

NOTE The owner may delegate another body or agent as the purchaser of the equipment.

3.27
panel
enclosure used to mount, display and protect gauges, switches and other instruments

3.28
passive analysis
portion of the acoustic simulation in which a constant flow amplitude modulation over an arbitrary frequency range is imposed on the system, normally at the cylinder valve locations

NOTE The resulting transfer function defines the acoustic natural frequencies and the mode shapes over the frequency range of interest (see 3.1).

3.29
pressure design code
recognized pressure vessel standard or code specified or agreed by the purchaser (e.g. ASME, *Boiler and Pressure Vessel Code 1998*, Section VIII)

3.30
purchaser
individual or organization that issues the order and specification to the vendor

NOTE The purchaser may be the owner or the owner's agent.

3.31
rated discharge pressure
highest pressure required to meet the conditions specified by the purchaser for the intended service

3.32
rated discharge temperature
highest predicted operating temperature resulting from any specified operating condition

3.33
rated power (of the compressor)
maximum power the compressor plus any shaft-driven appurtenances require for any of the specified operating conditions

NOTE 1 The rated power includes the effect of equipment such as pulsation suppression devices, process piping, intercoolers and separators.

NOTE 2 Driver and transmission losses are not included in the rated power of the compressor. Losses incurred in outboard bearings (e.g. as used to support large flywheels) are included.

3.34
rated speed
highest speed required to meet any of the specified operating conditions

3.35
remote (adj.)
applies to any device located away from the equipment or console, typically in a control room

3.36
required capacity
rated process capacity specified by the purchaser to meet process conditions, with no-negative-tolerance (NNT) permitted

NOTE See annex B for an explanation of the term no-negative tolerance.

3.37
rod reversal
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

3.38
shut-down point
preset value of a parameter at which automatic or manual shut-down of the system is required

3.39
spectral frequency distribution
description of the pressure pulsation harmonic amplitudes versus frequency at a selected test point location for an active or passive acoustic analysis (see 3.1)

3.40
standard flow
flow rate expressed in volume flow units at ISO standard conditions which are an absolute pressure of 1,013 bar and a temperature of 0 °C

3.41
trip speed
speed at which the independent emergency overspeed device operates to shut down a variable speed prime mover

3.42
unit responsibility
responsibility for co-ordinating the technical aspects of the equipment and all auxiliary systems included in the scope of the order

NOTE It includes responsibility for reviewing such factors as the power requirements, speed, rotation, general arrangement, couplings, dynamics, noise, lubrication, sealing system, material test reports, instrumentation, piping and testing of components.

3.43
vendor
organization that supplies the equipment

NOTE The vendor may be the manufacturer or the manufacturer’s agent and is normally responsible for service support.

4 Statutory requirements

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

5 Basic design

5.1 General

5.1.1 The equipment (including auxiliaries) covered by this International Standard shall be designed and constructed for a minimum service life of 20 years and at least 3 years of uninterrupted operation. It is recognized that this is a design criterion. It is accepted that interruptions to the continuous operation may occur due to exceeding the lifetime of wearing parts. The expected life-time of wearing parts shall be defined by the vendor.

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

5.1.3 Unless otherwise specified, cooling water systems shall be designed in accordance with the conditions given in Table 1.

Table 1 — Cooling water system design conditions

Design condition	Heat exchangers	Cylinder jackets and packing cases
Velocity in exchanger tubes	1,5 to 2,5 m/s	—
Maximum permissible working pressure	> 7 bar (gauge)	> 5 bar (gauge)
Hydrostatic test pressure	1,5 × MPWGP [a]	1,5 × MPWGP [a]
Maximum pressure drop	1 bar	—
Maximum inlet temperature	30 °C	—
Maximum outlet temperature	50 °C	—
Maximum temperature rise	20 K	—
Minimum temperature rise	10 K	—
Fouling factor water side	0,35 m^2K/kW	—
Shell corrosion allowance for carbon steel	3 mm	—

[a] Maximum permissible working gauge pressure.

The vendor shall notify the purchaser if the criteria for minimum temperature rise and velocity over heat exchange surfaces are in conflct. The prchaser will approve the final selection.

NOTE 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.

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

5.1.4 To avoid excitation of torsional, acoustic and/or mechanical resonances, reciprocating compressors should normally be specified for constant-speed operation. When variable speed drivers are used, all equipment shall be designed to run safely up 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 5.5 and 10.2.

5.1.5 Equipment shall be designed to run up to the trip speed and up to the relief valve settings (see 10.4.5) without damage. Unless otherwise specified, trip speeds shall be assumed to be in accordance with Table 2.

Table 2 — Driver trip speeds

Driver type	Trip speed % of rated speed
Steam turbine	
NEMA Class A[a]	115
NEMA Classes B, C, D[a]	110
Gas turbine	105
Variable-speed motor	110
Constant-speed motor	Synchronous speed
Reciprocating engine	110

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

5.1.6 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.

• **5.1.7** Motors, electrical components, and electrical installations shall be suitable for the area classification specified by the purchaser and shall meet the requirements of the IEC 60079-0 and other standards specified by the purchaser and shall comply with all applicable local codes and regulations.

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

5.1.9 All equipment shall be designed to permit rapid and economical maintenance. Major parts, such as cylinders and compressor frames, shall be designed (shouldered or cylindrically dowelled) and manufactured to ensure accurate alignment on re-assembly.

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

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

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

- **5.1.12** The purchaser shall specify the equipment's normal operating point. Unless otherwise specified, the capacity at the normal operating point shall have no negative tolerance.

NOTE 1 See annex B for a discussion of capacity and the term "no negative tolerance".

NOTE 2 To accommodate normal manufacturing tolerances, the manufacturer's rated capacity should exceed the required capacity by not less than 3 %.

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

- **5.1.14** The purchaser shall specify whether the installation is indoors (heated or unheated) or outdoors (with or without a roof), as well as the weather and environmental conditions in which the equipment must operate, including maximum and minimum temperatures and unusual humidity, dust or corrosive conditions. The unit and its auxiliaries shall be suitable for operation under these specified conditions.

5.1.15 The vendor shall use the specified values of mass flow, the specified gas composition and the gas conditions to calculate average molar mass, ratio of specific heats (c_p/c_v), compressibility factors (Z) and inlet volume flow. The compressor vendor shall indicate his values on the data sheets with the proposal and use them to calculate performance data.

5.1.16 If any of the compressor cylinders are to be operated partially or fully unloaded for extended periods of time, the purchaser and the vendor shall jointly determine the method to be used (e.g. periodic momentary loading to purge accumulation of lubricating oil in the compressor cylinders), in order to prevent overheating and liquid damage.

5.1.17 Compressors shall be capable of developing the maximum differential pressure specified by the purchaser. The compressor vendor shall confirm that the unit is capable of continuous operation at any full load, part load (refer to 5.4.1 and 5.4.2) or fully unloaded conditions (refer to 5.1.16) and also capable of start-up according to the agreed procedure (refer to 9.1.1.3).

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

5.1.19 Spare parts for the machine and all furnished auxiliaries shall meet all the criteria of this International Standard.

5.2 Permissible speeds

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

NOTE Generally, the rotative and piston speeds of compressors in non-lubricated services should be less than those in equivalent lubricated services.

5.3 Permissible discharge temperature

5.3.1 Unless otherwise specified and agreed the maximum predicted discharge temperature shall not exceed 150 °C (302 °F). This limit applies to all specified operating and load conditions. The vendor shall provide the purchaser with both the predicted and adiabatic discharge temperature rise.

Special consideration shall be given to services (e.g. high pressure hydrogen or applications requiring non-lubricated cylinders) where temperature limitations should be lower. Predicted discharge temperatures shall not exceed 135 °C (275 °F) for hydrogen rich services (molar mass of 12 or less).

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

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

- **5.3.2** A high discharge temperature alarm and shut-down device is required for each compressor cylinder. When specified, 100 % unloading shall be furnished as part of the system. The supplier of these devices, the setpoints and the mode of operation shall be mutually agreed upon between the purchaser and the compressor vendor.

The recommended discharge temperature alarm and trip setpoints are 20 K and 30 K respectively above the maximum predicted discharge temperature; but in no case should temperature trip setpoints exceed 180 °C (356 ^{o}F). To prevent auto-ignition, lower temperature limits should be considered for air, due to oxygen content, if the discharge gauge pressure exceeds 20 bar (290 psig). Use of synthetic oils, although not intended as a means to increase the permissible discharge temperature, is recommended for additional safety (see 8.2.1.9).

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

5.4 Rod and gas loads

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

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

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

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

5.5 Critical speeds

5.5.1 The compressor vendor shall provide the necessary lateral and torsional studies required to demonstrate the elimination of any lateral or torsional vibrations that may hinder the operation of the complete unit within the specified operating speed range in any specified load step. The vendor shall inform the purchaser of all critical speeds from zero to trip speed or synchronous speed that occur during acceleration or deceleration (see 15.2.3, r).

5.5.2 Except for belt driven units, the vendor shall provide a torsional analysis of the complete train. Torsional natural frequencies of the driver-compressor system (including couplings and any gear unit) shall not be within

10 % of any operating speed nor within 5 % of any multiple of any operating shaft speed in the rotating system up to and including the tenth multiple. For motor driven compressors, torsional natural frequencies shall be separated from the first and second multiples of the electrical power frequency by 10 % and 5 % respectively.

5.5.3 Where the compressor is to be driven by a turbine or through a gear, the requirements in the reference standards for those items as regards critical speeds shall also be complied with. For units requiring the use of a low-speed quill shaft, a separate lateral critical speed analysis shall be performed. Any lateral critical speed of the quill shaft shall be separated by at least 20 % from any operating speed of any shaft in the system.

5.5.4 When torsional resonances are calculated to fall within the margin specified in 5.5.2 (and the purchaser and the vendor have agreed that all efforts to remove the critical from within the limiting frequency range have been exhausted), a stress analysis shall be performed to demonstrate that the resonances have no adverse affect on the complete train. The assumptions used in such analysis shall be agreed between purchaser and vendor.

6 Compressor components

6.1 Compressor cylinders

6.1.1 General

6.1.1.1 The maximum permissible working pressure shall exceed the rated discharge pressure by at least 10 % or 1,7 bar (25 psi), whichever is greater. The maximum permissible working pressure shall be at least equal to the specified relief valve set pressure not including accumulation. See 10.4.5.3 for setting of relief valves.

6.1.1.2 Horizontal cylinders are required for compressing saturated gases or for gases carrying liquids. For such services horizontal cylinders shall have bottom discharge connections. Other cylinder arrangements able to safely handle condensable/saturated gases may be considered.

NOTE Under certain atmospheric conditions, air may be at or close to saturated conditions; multistage air or hydrocarbon gas compressors will usually exhibit saturated conditions following intercooling.

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

6.1.1.4 Single acting, step-piston or tandem cylinder arrangements may be furnished with the purchaser's approval. For such cylinder arrangements, special consideration must be given to ensure rod load reversals. See 5.4.4.

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

6.1.2 Cylinder appurtenances

6.1.2.1 Cylinder supports shall be designed to avoid misalignment and excessive rod runout during the warm-up period and at actual operating temperature. The support shall not be attached to the outboard cylinder head. The pulsation suppressor shall not be used to support the compressor cylinder.

The vendor shall calculate the expected minimum and maximum cold vertical rod runout. When required, the manufacturer shall disclose the details of his calculations and the assumptions on which they are based. The expected cold vertical rod runout shall be confirmed by the shop bar-over test and shown on the rod runout table by the vendor. Design and construction shall be aimed to achieve an expected hot vertical rod runout not exceeding 0,015 % of the stroke.

Horizontal (side) piston rod runout, as measured by dial indicators during the shop bar-over test, shall not exceed 0,065 mm (0,002 5 in or 2,5 thou), regardless of length of stroke, see 13.3.4.1. See 6.3.8 when tailrod construction is used.

Piston rod runout shall be measured directly adjacent to the cylinder packing case flange.

See Annex C for clarification of rod runout and typical rod runout table.

6.1.2.2 The vendor shall define the maximum flange load permissible at the nozzle interfaces. These loads shall refer to a coordinate system as shown on a drawing.

6.1.2.3 Unless otherwise specified, each cylinder shall have a replaceable, dry type liner, not contacted by the coolant. Liners shall be at least 9,5 mm (3/8 in) thick for piston diameters up to and including 250 mm (10 in). For piston diameters larger than 250 mm, the minimum liner thickness shall be 12,5 mm (1/2 in).

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

6.1.2.4 The walls of cylinders without liners shall be thick enough to provide for reboring to a total of 3 mm (1/8 inch) increase over the original diameter without encroaching upon the maximum permissible working pressure, the maximum permissible continuous gas load or the maximum permissible continuous combined rod load.

6.1.2.5 The surface finish of the running bore of the cylinder liners and cylinders without liners shall be 0,2 μm to 0,6 μm (8 μin to 24 μin) *Ra* (arithmetic average roughness).

● **6.1.2.6** When specified, the running bore of the cylinder shall be coated. The material (e.g. tetrafluoroethylene, TFE) and the method of application shall be agreed upon by the purchaser and the vendor.

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

NOTE Exceeding the manufacturer’s torque values may cause damage to the valve assembly and cylinder valve seat.

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

6.1.2.9 The surface finish of valve port “o”-ring sealing surfaces shall not exceed an arithmetic average roughness (*Ra*) of 1,6 μm (64 μin). Valve ports using “o”-rings shall include an entering bevel for the “o”-ring.

6.1.2.10 Studded connections shall be furnished with studs installed. Blind stud holes shall only be drilled deep enough to allow a preferred tap depth of 1,5 times the major diameter of the stud; the first 1,5 threads at both ends of each stud shall be removed to allow the stud end to bottom in the hole.

6.1.2.11 Bolting shall be furnished as specified in 6.1.2.11.1 to 6.1.2.11.5.

6.1.2.11.1 Details of threading shall conform to ISO 261 and ISO 262. The use of fine pitch threads shall be avoided in cast irons and in external fasteners subject to routine maintenance, including pressure-containing parts.

6.1.2.11.2 Studs are preferred to cap screws.

6.1.2.11.3 Stud material shall be ASTM A 193 Grade B7 for steel and ductile iron cylinders. ASTM A 193 Grade B7 or ASTM A 307 Grade B may be used for cast iron cylinders. ASTM A 320 shall be used for minimum permissible temperatures of – 30 °C (– 22 °F) and below. Stud markings shall be located on the nut end of the exposed stud. With low temperature studs use ASTM A 194 Grade 4 or Grade 7 nuts. Acceptable nuts for use with ASTM A 193 or A 307 studs are ASTM A 194 Grade 2H.

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

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

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

6.1.2.13 If drain connections are provided on external bottles used as clearance pockets, drain valves shall be provided. (See 11.6 for piping material between clearance pocket and drain valve).

6.1.3 Cylinder cooling

6.1.3.1 Cylinders shall have cooling provisions as required by the conditions of service described in 6.1.3.1.1 to 6.1.3.1.4. (See 11.4 and Figure G.2).

6.1.3.1.1 Static-filled coolant systems (see Figure G.2, Plan A) may be supplied where cylinders will not be required to operate fully unloaded for extended periods of time, the expected maximum discharge temperature is less than 90 °C (193 °F), and the adiabatic gas temperature rise (difference between suction temperature and discharge temperature based on adiabatic compression) is less than 85 K.

6.1.3.1.2 Atmospheric thermosyphon coolant systems (see Figure G.2, Plan B) may be supplied where cylinders will not be required to operate fully unloaded for extended periods of time and

a) the expected maximum discharge temperature is below 100 °C (212 °F)

b) the adiabatic gas temperature rise is less than 85 K.

6.1.3.1.3 By mutual agreement between the purchaser and vendor, a pressurized thermosyphon system may be used. The expected maximum discharge temperature shall not to exceed 105 °C (221 °F). The system shall be supplied with a thermal relief valve set at a gauge pressure of 1,7 bar (25 psig) maximum.

6.1.3.1.4 Forced circulation liquid coolant systems (see Figure G.2, Plan C) shall be provided where cylinders will operate unloaded for extended periods of time or either

a) the expected maximum discharge temperature is above 100 °C (212 °F) or

b) the adiabatic gas temperature rise is 85 K or greater.

NOTE For sites with ambient temperatures of 45 °C (113 °F) or higher, thermosyphon or static filled systems may not be suitable. See 5.1.16 for fully unloaded extended operation.

6.1.3.2 Air-cooled cylinders shall not be furnished without the express written approval of the purchaser.

6.1.3.3 To prevent condensation, the coolant inlet temperature to cylinders with forced circulation cooling shall be at least 5 K above the dew point of the inlet gas. In the case of wet gas, or gas that has been in contact with liquid in the vessel from which the particular compressor stage takes suction, unless otherwise agreed the dew point shall be assumed to be at least 5 K above the suction temperature to allow for carry-over of liquid and/or cooling of the gas before entering the cylinder. Therefore, in such cases, the coolant inlet temperature shall be at least 10 K above the gas inlet temperature.

The coolant system shall be such that the above requirements are satisfied under all operating and transient conditions including start-up from cold. If necessary the system should include a coolant recycle pump and heater for start-up.

Coolant flow velocities shall be sufficiently high to avoid fouling of jackets and passages.

NOTE Excessively high coolant exit temperatures (more than 17 K above the gas inlet temperature) may result in loss of capacity and efficiency and should therefore be avoided.

6.1.3.4 The arrangement of the cooling jackets shall be such that failure of a gasket or other seal will not result in leakage of coolant into the cylinder or gas into the cooling system.

• **6.1.3.5** When specified, a self-contained, forced circulation, closed jacket coolant system shall be furnished. It shall meet the requirements of 6.1.3.5.1 to 6.1.3.5.3. (See Figure G.2, Plan D.)

6.1.3.5.1 The coolant system shall be such that the requirements of 6.1.3.3 are satisfied.

6.1.3.5.2 If possible, the coolant circulated should be controlled to maintain a rise in coolant temperature across any individual cylinder, including the cylinder heads if cooled, of between 5 K and 10 K.

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

6.1.4 Cylinder connections

6.1.4.1 The main inlet and outlet gas connections and all other process gas connections shall be flanged or machined and studded and shall be suitable for the maximum permissible working pressure of the cylinder as specified in 6.1.1.1.

6.1.4.2 Studs shall be supplied unless capscrews are specifically approved by the purchaser.

6.1.4.3 The facing and bolting of the main inlet and outlet flanges and tapped auxiliary connections shall conform to the dimensional requirements ISO 7005-1 or ISO 7005-2 as applicable. Alternative standards are acceptable by mutual agreement. See 6.1.4.4 for facing finish requirements. The details of any special connections, such as a lens joint, shall be submitted to the purchaser for review (see annex F). For low pressure cylinders, where non-circular connections are used, the vendor shall supply inlet and discharge transition pieces with the termination flange to ANSI or other agreed standards. The transition pieces shall be the same or higher grade material as the cylinder. The vendor shall supply all gaskets, studs and nuts between the cylinder and transition piece.

6.1.4.4 The finish of the gasket contact surface of cast iron, ductile iron or steel connections (flanged or machined bosses), other than ring-type joints, shall be between 3,2 µm and 6,4 µm (125 µin and 250 µin) arithmetic average roughness (*Ra*). Either a serrated-concentric or serrated-spiral finish having 0,6 mm to 1,0 mm pitch (24 to 40 grooves per inch) shall be used. The surface finish of the gasket grooves for ring joint connections shall conform to ANSI B16.5.

6.1.4.5 For utilities, threaded connections in accordance with ISO 7-1 are permissible in sizes not greater than DN 40 ($1^1/_2$ NPS).

Threaded openings not required for the service shall be plugged with solid metal plugs. These plugs shall be of a material compatible with the fluids contained and having properties at least as good as the material of the cylinder. Plugs that may later require removal shall be of corrosion-resistant material. A suitable thread lubricant shall be used. Thread tape shall not be used. Plastic plugs are not acceptable.

• **6.1.4.6** When specified each cylinder shall be provided with a DN 12 ($^1/_2$ NPT) indicator tap at each end. Designs similar to Figure G.5, with a corrosion resistant sleeve arrangement inside a continuous cast-in membrane to provide a positive gas-tight seal, are acceptable for cast iron and nodular iron cylinders. Materials shall be compatible with the gas. Unless indicator valves are specified by the purchaser, threaded holes shall be plugged in accordance with 6.1.4.5.

6.2 Valves and unloaders

6.2.1 Valve average gas velocity shall be calculated as follows:

$$v = \frac{A}{F} c_{\mathrm{m}}$$

where:

- v is the average gas velocity, in metres per second (feet per second);
- A is the effective piston area of the cylinder end or ends concerned in square centimetres (square inches);
- F is product of the actual lift, the valve opening periphery and number of inlet or discharge valves in square centimetres (square inches);
- c_{m} is the average piston speed, in metres per second (feet per second).

NOTE The valve lift used in the above equation shall be shown on the data sheets.

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

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

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

6.2.4 Valve assemblies (seat and guard) shall be removable for maintenance. Valve-seat-to-cylinder gaskets shall be solid metal or metal jacketed. Valve-cover-to-cylinder gaskets shall be either solid metal, metal jacketed or “o”-ring type. Other gasket types may be used with the purchaser’s approval.

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

6.2.6 When the mass of valve assemblies exceeds 15 kg (35 lbs), the vendor shall provide a device to facilitate removal and installation of valve assemblies for maintenance. On all underslung valves, an arrangement shall be provided to hold the complete valve assembly and any cage or chair in position whilst the cover is fitted.

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

6.2.8 Valve hold-downs shall bear at not less than three points on the valve assembly. The bearing points shall be arranged as symmetrically as possible.

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

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

6.2.10 Metal valve discs or plates, when furnished, shall be suitable for installation with either side sealing and shall be finished on both sides to 0,4 μm (16 μin) *Ra* or better. Edges shall be suitably finished to remove stress raisers. Valve seats and sealing surfaces shall also be finished to 0,4 μm (16 μin) *Ra* or better. When non-metallic valve plates or discs are furnished, flatness and surface finish shall be controlled such that adequate sealing occurs in operation. When polyether-ether-ketone (PEEK) plates are furnished, the grade shall be crystalline.

• **6.2.11** When specified, valve seats for use with metallic valve plates shall have a minimum finished hardness of RC32 and shall be either through-hardened or induction hardened to a minimum case depth of 1,6 mm ($^1/_{16}$ inch). See 7.1.10.

• **6.2.12** When unloading is specified it shall be accomplished by either valve plate depressors or plug-type unloaders. Valve assembly lifters shall not be used. When valve plate depressors are used for capacity control, all inlet valves of the cylinder end involved shall be so equipped. Use of less than a full complement of suction valve plate depressors requires the purchaser's approval.

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

6.2.13 Where plug-type unloaders are used for capacity control, the number of unloaders is determined by the opening area per plug, 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. The unloader assembly shall positively guide the plug to the seat.

6.2.14 When valve plate depressors or plug unloaders are used only for start-up, and never for capacity control, consideration shall be given to using a reduced number of unloaders.

6.2.15 Unless otherwise specified, pneumatically operated unloaders shall be used. Individual hand-operated unloaders or manual overrides on pneumatically operated unloaders are not permitted unless specifically required by the purchaser. Remotely operated unloaders shall be connected by the vendor in such a manner that the correct sequence of operation between stages and cylinder ends is achieved. The vendor shall provide the user with information regarding the proper sequencing for unloader operation.

NOTE Maloperation and incorrect sequencing of unloaders may result in overload or unbalance of the compressor.

6.2.16 Pneumatic unloaders shall be designed so that the air used for unloading cannot mix with the gases being compressed, even in the event of failure of the diaphragm or other sealing component. A gas vent connection shall be provided at the stem packing. Unloader sliding push rods exposed to atmospheric conditions shall be of corrosion-resistant material.

6.3 Pistons, piston rods and piston rings

6.3.1 Pistons that are removable from the rod shall be attached to the rod by a shoulder-and-locknut design or by a multi-through-bolt design. All nuts shall be positively locked in place see 6.1.2.11.5. Nuts attaching the piston rod to the piston and to the crosshead shall be tightened in accordance with the manufacturer's standard. The rod shall be positively locked to the crosshead to prevent rotation. As a minimum, the manufacturer's tightening procedure must ensure a minimum thread root pre-stress level of one and one half times the rod's thread root stress at maximum permissible continuous rod loading. Hydraulic or thermal methods are preferred for tightening piston rod nuts. Use of slugging-type wrenches is unacceptable for this purpose. See 6.6.9.

6.3.2 Hollow pistons (single piece or multi-piece) shall be continuously self-venting, that is, they shall depressure when the cylinder is depressured. Acceptable methods of venting are a hole located in the head-end face of the piston 3 mm ($^1/_8$ inch) in diameter, a hole at the bottom of the piston ring groove or a spring loaded relief plug in the outer-end face of the piston.

• **6.3.3** Wear bands, if required by the manufacturer or specified by the purchaser, shall be of single or multi-piece construction designed to prevent underside pressurization (action similar to a piston ring). If feasible, pistons shall be segmented to facilitate wear band installation. Piston ring carriers for multi-piece pistons shall be furnished in wear-resistant material. Non-metallic wear bands shall not over-run fully-open single-hole valve ports or liner counterbores by more than one-half the width of the wear band. Where the cylinder design requires the wear band to over-run the valve ports by more than one-half the band width, the port design shall be of the multiple-drilled-hole type to provide sufficient support for the wear band. For non-lubricated service, the bearing load of non-metallic wear bands shall not exceed 0,035 N/mm^2 [9)] (5 psi) based on the mass of the entire piston assembly plus one-half the mass of the rod divided by the projected area of a 120° arc of all wear bands (0,866 *DW*, where *D* is the piston diameter and *W* is the total width of all wear bands).

For lubricated service, the bearing load on wear bands, if used, shall not exceed 0,07 N/mm^2 (10 psi) based on the same criteria.

6.3.4 The material and surface treatment of piston rods shall be proposed by the vendor for the purchaser's approval. Consideration should be given to the use of hard coatings to increase the wear resistance. When coatings are used, piston rods shall be continuously coated from the piston rod packing through the oil wiper travel areas. The coating material must be properly sealed to prevent corrosion of the base material at the interface of the coating. Fusion techniques that require temperatures high enough to permanently affect the mechanical characteristics of the base material are unacceptable.

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

High velocity and high impact thermal coating processes are acceptable for coating of piston rods. Metal spray techniques requiring roughening of the surface of the base material are not recommended because of the potentially destructive stress risers left in the surface. Use of subcoating under the main coating is not recommended. Piston rods that have been previously induction hardened shall not be coated with a wear resistant material over the induction hardened case.

6.3.5 The base material of piston rods used in sour gas service shall be in accordance with NACE MR 0175, see 7.1.10. When this requirement results in insufficient surface hardness for wear resistance, a proven surface treatment or coating shall be proposed for purchaser's approval.

6.3.6 Typical tolerances for finished rods are 12,5 micrometrs (0,000 5 in or 0,5 thou) for roundness and 25 μm (0,001 in or 1 thou) for diametral variation over the length of the rod.

The surface finish in the packing areas for lubricated and non-lubricated services shall be 0,2 μm to 0,4 μm (8 μin to 16 μin) *Ra*. Superior finishes should be considered for high pressures or for particular material combinations where experience indicates that such finishes may result in improved performance.

6.3.7 Piston rods shall be furnished with rolled threads having polished thread relief area. The vendor shall state on the data sheets the rod material, the yield strength (tensile) and the stress at the thread root diameter at the maximum permissible continuous combined rod load.

6.3.8 Tailrods shall be used only with purchaser's specific approval. Tailrod packing assemblies shall be equal in design and quality to packing assemblies for piston rods. Tailrod surface treatment and finish shall be the same as for the piston rod. Tailrod design shall include a device to positively prevent the tailrod from being ejected in the event that it becomes disconnected from the piston/piston rod. Rod runout measured at the tailrod packing assembly shall not exceed the limits defined in 6.1.2.1.

6.4 Crankcases, crankshafts, connecting rods, bearings and crossheads

6.4.1 Crankshafts shall be forged in one piece (but may have provision for removable counterweights) and shall be heat treated and machined on all working surfaces and fits. They shall be free of sharp corners. Main and crank pin journals shall be ground to size. Drilled holes or changes in section shall be finished with generous radii and shall be highly polished. Forced lubrication passages in crankshafts shall be drilled. See 13.2.2.3.3 for ultrasonic testing of crankshafts.

6.4.2 Replaceable, precision-bored shell (sleeve) crankpin bearings and main bearings shall be used; however, tapered roller-type bearings are acceptable for main bearings in compressors with nominal frame ratings of 150 kW

9) 1 N/mm^2 = 10 bar.

(200 hp) or less. Other bearing types or tapered-roller-type bearings for higher power may be used with the purchaser's specific approval.

NOTE Purchasers should recognize that the use of rolling element bearings may affect the service life of the compressor.

6.4.3 All tapered roller-type bearings shall be suitable for belt drive and shall give an L10 rated life (see ISO 281-1) of either 50 000 hours with continuous operation at rated conditions or 25 000 hours at maximum axial and radial loads and rated speed. (The rating life is the number of hours at rated bearing load and speed that 90 % of the group of identical bearings will complete or exceed before the first evidence of failure).

6.4.4 Rolling element bearings shall be in accordance with ISO 281-1 and shall be retained on the shaft and fitted into housings in accordance with the bearing manufacturer's recommendation.

6.4.5 Connecting rods shall be forged steel with removable caps. They shall be free of sharp corners. Forced lubrication passages shall be drilled. Drilled holes or changes in section shall be finished with generous radii, and shall be highly polished. Crosshead pin bushings shall be replaceable precision-bored type and securely locked in place. All connecting rod bolts and nuts shall be securely locked with cotter pins or wire after assembly. Connecting rod big-end bolts shall have rolled threads and should preferably be designed to be hydraulically tensioned.

6.4.6 Crossheads for horizontal compressors with nominal frame ratings greater than 150 kW (200 hp) shall be steel. ASTM A 536 Grade 80-55-06 ductile iron is acceptable for crossheads in frames nominally rated at 150 kW (200 hp) or less. The crosshead top and bottom shoes or guides shall be replaceable. Facilities shall be provided for the adjustment of crosshead clearance and alignment. Adequate openings shall be provided to service crosshead assemblies.

• **6.4.7** If specified, the crankcase shall be provided with relief devices to protect against rapid pressure rises. These devices shall incorporate downward-directed apertures (away from the operator's face), a flame-arresting mechanism and a rapid closure device to minimize reverse flow.

NOTE It is recommended that the total throat area of these devices should be not less than 70 mm^2 for each dm^3 (3 square inches per cubic foot) of crankcase free volume.

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

6.5 Distance pieces

• **6.5.1** The purchaser shall indicate on the data sheets which of the types of distance piece listed in 6.5.1.1 to 6.5.1.4 is required (Figures I.2 and I.3).

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

NOTE Type "A" distance pieces are used for non-inflammable or non-hazardous gases.

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

6.5.1.3 Type "C": Long/long two-compartment distance piece designed to contain inflammable, hazardous or toxic gases. No part of the piston rod shall alternately enter the gas cylinder pressure packing, intermediate seal packing and the wiper packing.

Segmental packing shall be provided between the two compartments. Provisions for lubrication of this segmental packing, if necessary, and when specified for the injection of sealing gas, shall be furnished by the vendor.

• **6.5.1.4** Type "D": Long/short two compartment distance piece designed to contain inflammable, hazardous or toxic gases. No part of the piston rod shall alternately enter the intermediate seal packing and the wiper packing. Segmental packing shall be provided between the two compartments. Provisions for lubrication of this segmental packing, if necessary and, when specified, for the injection of sealing gas, shall be furnished by the vendor.

• **6.5.2** Access openings of adequate size shall be provided in all distance pieces to permit removal of the assembled packing case. On Type D two-compartment distance pieces, the compartment adjacent to the cylinder (the outboard compartment) may be accessible through a removable partition. Distance pieces (or compartments) shall be equipped with screened safety guards, louvered weather covers or gasketed solid metal covers as specified on the data sheet. All access openings shall be surfaced and drilled to accommodate solid metal covers. Non-metallic covers are not permitted.

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

6.5.4 Where solid metal distance piece covers are provided or specified, distance piece, partitions, covers, bolting and the intermediate seal packing shall be designed for a minimum compartment differential pressure of 2 bar (30 psi) or higher if specified. The vendor shall indicate the maximum permissible working pressure of the distance piece on the data sheet.

6.5.5 Each distance piece compartment shall be provided with a bottom drain connection and a top vent connection for the purchaser's piping. A distance piece compartment with internal reinforcing ribs shall have internal drain provisions through the ribs. A separate top vent or purge connection shall be provided for each distance piece compartment. Vent connections shall be at least DN 40 ($1^1/_2$ NPS). See annex I for vent and purge system schematic. All other external connections shall be at least DN 25 (1 NPS). Internal packing vent tubing and fittings shall be of stainless steel. A packing vent connection shall be provided below the rod to facilitate liquid draining of the packing case. Where packing gland cooling is required or specified, inlet and outlet connections shall be provided on the distance piece arranged to facilitate draining and venting. See Figures I.1, I.2 and I.3.

Unless otherwise specified, all external drain, vent and purge piping and equipment will be provided by the purchaser. Closed, sealed or purged cylinder end distance pieces not utilizing the vent connection freely connected to an atmospheric vent, shall be equipped with a relief device.

The vendor shall confirm that the vent connection (if connected to an open atmospheric vent) or relief device is adequate to prevent overpressuring of the distance piece in the event of a packing case failure.

6.5.6 For Types A and B distance pieces with solid metal covers, positive seal rings shall be provided at the wiper packings. For Types C and D distance pieces with solid metal covers, positive seal rings shall be provided at both the wiper packings and the partitions. These seal rings shall be of the side-loaded segmental type that will seal at atmospheric pressure (without purge) to prevent contamination of the crankcase oil by leakage from the gas cylinder pressure packing. See 6.6.8.

6.6 Packing cases and pressure packing

• **6.6.1** All oil-wiper, intermediate-seal and gas-cylinder pressure packings shall be segmental rings with corrosion resistant garter springs. In sour gas services garter springs shall be made of nickel-chromium alloy such as Inconel 600 or X750. When specified, shields shall be provided in the crosshead housings over the oil return drains from the wiper packing stuffing boxes to prevent splash flooding.

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

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

6.6.4 Unless otherwise specified on the data sheets, the criteria given in 6.6.4.1 to 6.6.4.4 shall be followed for the cooling of the pressure packing cases.

6.6.4.1 The manufacturer's standard design may be used for cylinder discharge gauge pressures up to 100 bar (1450 psig).

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

a) Non-lubricated non-metallic packing rings, when the maximum permissible working gauge pressure (MPWGP) of the cylinder is above 17 bar (250 psig).

b) Lubricated non-metallic rings, when the cylinder MPWGP is above 35 bar (500 psig).

c) All materials, lubricated or non-lubricated, when the cylinder MPWGP is above 100 bar.

In these cases:

— "o"-rings shall be used to seal coolant passages between cups.

— "o"-rings shall be fully captured in grooves, both on the inside and outside diameter of the "o"-ring. A small relief recess of 0,5 mm to 1 mm shall be provided around the captured "o"-ring to detect leakage. "o"-rings that span the piston rod are not allowed.

— Liquid cooled cases are to be tested for leakage on the coolant side to a gauge pressure not less than 7,5 bar (110 psig).

6.6.4.3 Packing cases for pressure packings of non-lubricated compressors that have cylinder MPWGP below 17 bar (250 psig) shall be suitable for the addition of liquid cooling and shall be plugged with threaded steel plugs at the packing case.

6.6.4.4 When packing is cooled by forced circulation, the vendor shall supply a suitable filter, of 125 μm nominal rating or better, located external to the distance piece. (See the note under 8.1.6 for the definition of nominal rating.) Internal tubing and forged fittings of austenitic stainless steel shall be furnished by the vendor. If external tubing is provided by the vendor it shall be of austenitic stainless steel.

• **6.6.5** When cooling of packing is required, the vendor shall be responsible for determining and informing the purchaser of minimum requirements such as flow, pressure, pressure drop and temperature, as well as any filtration and corrosion protection criteria. The coolant pressure drop through the packing case shall not exceed 1,7 bar (25 psi). If specified, the vendor shall supply a closed liquid cooling system. For toxic gas services or when specified, this system shall be separate from the cylinder jacket cooling system. See Figure G.3 for additional details on self-contained cooling systems for packing.

NOTE The inlet coolant temperature to the packing case should not exceed 35 °C (95 °F). Packing efficiency is improved with low coolant temperature.

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

6.6.7 Crosshead housings shall incorporate packing boxes with oil wiper packing to effectively minimize oil leakage from the crankcase.

• **6.6.8** When specified, to reduce process gas emissions to an absolute minimum, the gas cylinder pressure packing case shall include venting and buffer gas cups, with side-loaded packing rings in the adjacent sealing cups. See the arrangements in Figures I.1, I.2 and I.3.

6.6.9 Unless otherwise specified the manufacturer shall provide suitable devices and instructions to enable the piston rod to be passed through the completely assembled cylinder pressure packing without damage.

6.7 Nameplates and rotation arrows

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

6.7.2 Rotation arrows shall be cast in or attached to each major item of rotating equipment in a readily visible location. Nameplates and rotation arrows (if attached) shall be of austenitic stainless steel or of nickel-copper alloy. Attachment pins shall be of the same material. Welding is not permitted.

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

6.7.4 Nameplates on compressor cylinders shall include the rated pressure, the serial number, the bore, the stroke, the maximum permissible working pressure and temperature, the hydrostatic test pressure, the volumetric clearance of each end (as a percentage of the displacement of that end) and the cold clearance setting for each end. Cylinder nameplates shall also show the minimum design metal temperature, where this has been specified to be lower than 0 °C (32 °F).

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

NOTE The standard motor nameplate current is normally based on steady-state loads and may not be valid for the variable torque loads imposed by reciprocating compressors.

7 Materials

7.1 General

• **7.1.1** Materials of construction shall be the manufacturer's standard for the specified operating conditions, except as required by the data sheets or this International Standard.

Annex H lists general classes of materials for the compressor which, when used with appropriate heat treatment and/or impact testing requirements, are considered acceptable for major component parts. See 11 for requirements for auxiliary piping materials.

7.1.2 Materials shall be identified by reference to International (ISO) Standards if such standards exist and are technically suitable. If a technically suitable ISO Standard does not exist, then the material shall be specified by reference to a technically suitable and publicly available standard. If no such standard exists, the vendor shall specify the necessary details of the material (including at least the mechanical properties, chemical composition and test requirements) and include this specification in the proposal.

• **7.1.3** The vendor shall specify the tests and inspection procedures necessary to ensure that materials are satisfactory for the service. Such tests and inspection shall be listed in the proposal and reviewed at the co-ordination meeting The purchaser should consider specifying additional tests and inspections, especially for materials in critical service.

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

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

• **7.1.6** It is the responsibility of the purchaser to identify the presence and maximum amounts of corrosive, reactive or hazardous agents or components in the process fluids or in the environment such as: hydrogen sulfide, chlorides or other constituents which may cause corrosion-related cracking, or constituents which may be reactive with copper of copper alloys and notify the vendor of these.

7.1.7 Copper and copper alloys shall not be used for parts of compressors or auxiliaries in contact with corrosive gas or with gases capable of forming explosive copper compounds. Bearing babbit and precipitation-hardened stainless steels are excluded from this requirement. Where mutually agreed, between the vendor and purchaser, copper-containing materials may be used for packing on lubricated compressors or for other specific purposes.

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

NOTE Overlays or hard facings that contain more than 0,1 % carbon can sensitize both low-carbon and stabilized grades of austenitic stainless steel unless a buffer layer that is not sensitive to intergranular corrosion is applied. If chlorides exist in the process gas stream to any extent, extreme care should be taken with the selection of materials in contact with the process gas. Caution should be given to components of aluminium and austenitic stainless steel.

7.1.9 All construction materials in contact with process gases shall be compatible with the gases handled. The corrosion allowance for separate carbon steel knockout pots shall be a minimum of 3 mm ($^1/_8$ inch). The corrosion allowance for heat exchangers and alloy parts required for special services shall be agreed upon by the purchaser and the vendor.

• **7.1.10** All materials exposed to hydrogen sulfide gas service as defined by NACE MR 0175 shall be in accordance with the requirements of that standard.

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

NOTE 1 It is the responsibility of the purchaser to determine the amount of hydrogen sulfide which may be present, considering normal operation, startup, shutdown, idle standby, upsets or unusual operating conditions such as catalyst regeneration. In many applications, small amounts of hydrogen sulfide are sufficient to require NACE materials.

When trace quantities of hydrogen sulfide are known to be present, or if there is any uncertainty about the amount of hydrogen sulfide which may be present, then the purchaser should note on the data sheet that NACE materials are required.

Components to which NACE requirements apply shall include, as a minimum: all pressure-containing cylinder parts (such as the cylinder, heads, clearance pockets, valve covers) and all fasteners directly associated with those parts; all components within the cylinder (such as piston, piston rod, valves, unloaders, fasteners); components within the outboard distance piece (such as packing box, packing, fasteners). Fasteners manufactured in accordance with NACE material requirements shall be clearly and permanently marked as such and their correct locations shall be identified in the installation and maintenance manuals. For reference see annex P. On multistage machines NACE requirements shall apply to all cylinders handling the same gas.

NOTE 2 On multiple service machines where NACE materials have not been used for all cylinders, the purchaser/user should recognize the danger of possible inadvertent interchange of parts.

Exceptions to NACE requirements for hardness are acceptable for valve seats (see 6.2.11) and piston rod surface (see 6.3.4). Other exceptions may be valve plates and springs where greater hardness has been proven necessary. Mutual agreement shall be reached between manufacturer and purchaser on alternative alloys or special heat treatment as required.

7.1.11 Where mating parts such as studs and nuts of austenitic stainless steel or materials with similar galling tendencies are used, they shall be lubricated with an anti-seizure compound of the appropriate temperature specification.

NOTE Torque loading values (for the same bolt stress) will be considerably different with and without the anti-seizure compound.

7.1.12 Coarse grain steel plates can be notch sensitive and prone to brittle fracture at ambient temperatures. Therefore such materials shall not be used for pressure-containing parts.

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

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

7.2 Pressure-containing parts

7.2.1 Unless otherwise specified, materials for pressure containing parts shall be used with the limitation of the maximum permissible working gauge pressure (MPWGP) indicated in Table 3. All materials selection shall be reviewed by the purchaser.

Table 3 — Maximum permissible working pressures for cylinder materials

Material	MPWGP	
	bar	psig
Grey cast iron	70	1 000
Nodular iron	100	1 450
Cast steel	180	2 600
Forged steel	no limitation	
Fabricated steel	85	1 250

7.2.2 Steel compressor cylinders shall be equipped with steel heads.

7.2.3 The use of fabricated cylinders requires the purchaser’s written approval.

7.2.4 Materials and the quality of all welding shall be equal to those required by the agreed pressure design code. The manufacturer’s data report forms, as required by some codes, are not required.

7.2.5 The vendor shall specify the materials of those pressure-containing parts shown on the data sheets.

7.3 Castings

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

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

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

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

7.3.5 Nodular iron castings shall be produced in accordance with ASTM A 395. The production of the castings shall also conform to the conditions specified in 7.3.5.1 to 7.3.5.4.

7.3.5.1 A minimum of one set (three samples) of Charpy V-notch impact specimens shall be made from material adjacent to the tensile specimen on each keel or Y block. These specimens shall have a minimum impact value of 12 J (9 ft lbs) and an average impact value of 13,5 J (10 ft lbs) at room temperature.

7.3.5.2 The tensile and keel block cast at the end of the pour shall have a thickness not less than the thickness of critical sections of the main casting. These test blocks shall be tested for tensile strength and hardness and shall be microscopically examined. Classification of graphite nodules shall be in accordance with ASTM A 247.

7.3.5.3 An as-cast sample from each ladle shall be chemically analysed.

7.3.5.4 To verify the uniformity of the casting, Brinell hardness readings shall be made on the actual castings at section changes, flanges and other accessible locations such as the cylinder bore and valve ports. Sufficient surface material shall be removed before hardness readings are made to eliminate any skin effect. Readings shall also be made at the extremities of castings at locations that represent the sections poured first and last. These shall be made in addition to Brinell readings on the keel and Y blocks.

7.4 Forgings

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

7.5 Fabricated cylinders and cylinder heads

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

7.5.2 Gas pressure containing parts of cylinders and cylinder heads made of wrought materials or combination of wrought and cast materials shall conform to the conditions specified in 7.5.2.1 to 7.5.2.8.

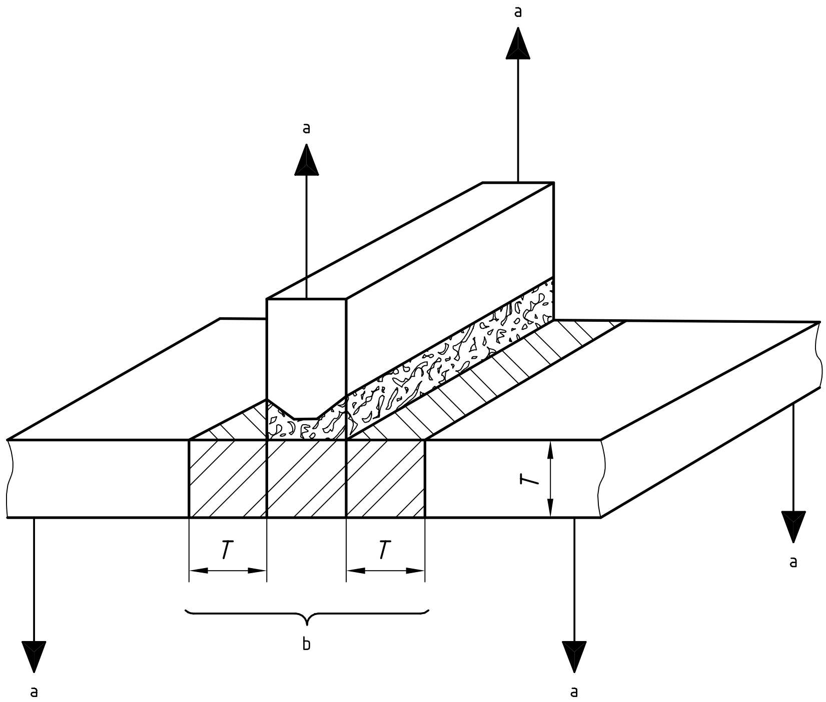
7.5.2.1 Plate subjected to alternating pressure loads used in cylinders and cylinder heads shall be subjected to the procedures in paragraphs 7.5.2.1.1 to 7.5.2.1.3 after being cut to shape and prior to weld joint preparation.

7.5.2.1.1 If the plate is loaded in tension in the through thickness direction, the plate shall be 100 % ultrasonically inspected in the area one plate thickness either side of the load-imposing members. (See Figure 1).

7.5.2.1.2 If the plate is loaded in bending, the plate shall be 100 % ultrasonically tested in the area one plate thickness either side of the load-imposing member. (See Figure 2).

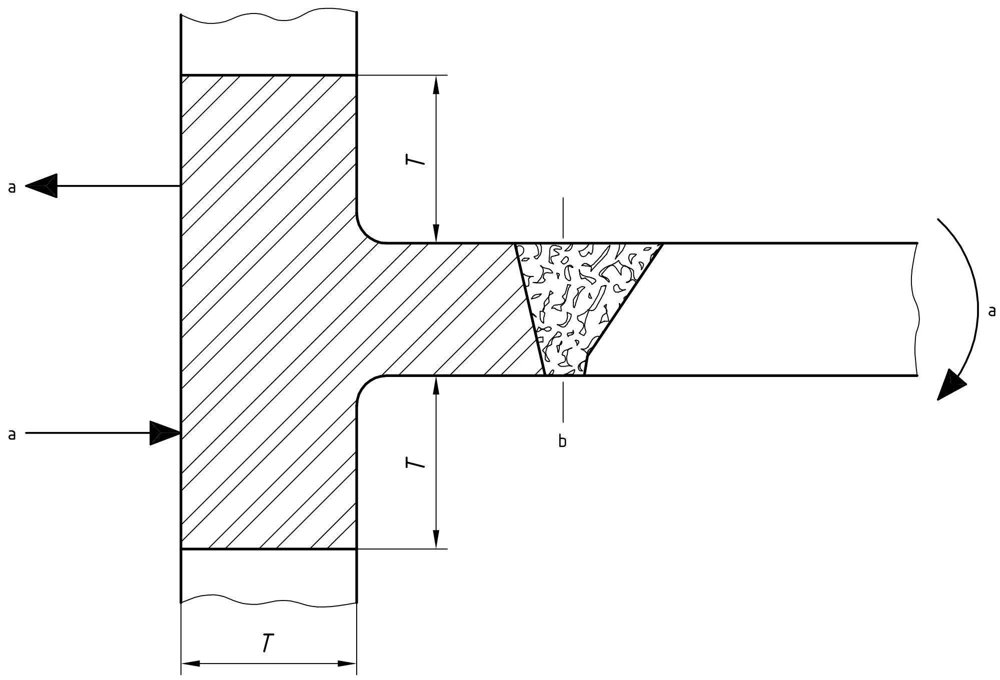
7.5.2.1.3 If the plate is axially loaded, ultrasonic inspection is not required. (See Figure 3).

NOTE These procedures are intended to discover laminations or inclusions which would affect the load-carrying ability of the components.



a The arrows indicate the direction of loading.
b The cross-hatched area indicates the extent of ultrasonic testing.

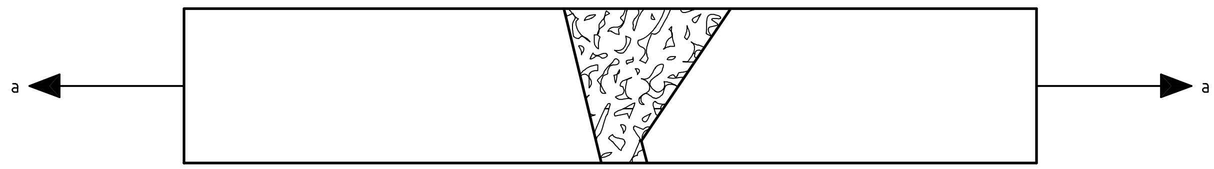
Figure 1 — Plate loaded in tension through the thickness



a The arrows indicate the direction of loading.

b The cross-hatched area indicates the extent of ultrasonic testing.

Figure 2 — Plate loaded in bending



a The arrows indicate the direction of loading.

Figure 3 — Plate loaded in tension axially

7.5.2.2 After preparation for welding, plate edges shall be inspected by magnetic particle or liquid penetration examination in accordance with the pressure design code.

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

• **7.5.2.4** When specified, the quality control of welds which will be inaccessible upon completion of the fabrication shall be mutually agreed between purchaser and vendor prior to fabrication.

7.5.2.5 Pressure-containing welds shall be full-penetration (complete-joint) welds unless otherwise approved by the purchaser prior to any fabrication.

7.5.2.6 All fabricated cylinders and cylinder heads shall be post-weld heat treated. The vendor shall specify the post-weld heat treatment procedure.

Both the thickness of the welds and section thickness of the component attachments shall be considered in the selection of heat treatment procedure. See 7.7.6.

7.5.2.7 All butt welds on the inner barrel of welded cylinders shall be 100 % examined radiographically. When radiographic examination of such welds can only be performed prior to complete fabrication, final inspection shall be carried out with other acceptable methods, such as ultrasonic examination. (See 13.2.2).

• **7.5.2.8** When specified, proposed welding designs shall be made available for review by the purchaser for approval before fabrication. The drawings shall show weld designs, size, materials and pre- and post-weld heat treatments.

7.6 Repairs to castings and forgings

7.6.1 Major repairs to pressure-containing parts and all repairs to moving parts subject to load reversals and crankshafts shall not be undertaken without the written authorization of the purchaser. This could include, but not be limited to, cylinder parts, piston and rod assembly components and crosshead assembly components. Repair of steel castings within the permissible parameters of the material standard are not considered as major repairs. However all repairs to pressure-containing parts carried out after hydrostatic testing shall be considered as major repairs.

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

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

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

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

7.6.2 Pressure-containing castings shall not be repaired by peening, burning-in or impregnating. Pressure-containing castings and forgings shall not be repaired by welding, plating or plugging except as specified in 7.6.2.1 to 7.6.2.2.

- **7.6.2.1** Weldable grades of steel castings and forgings may be repaired by welding using qualified welding procedures based on the requirements of the pressure design code, or other recognized standards, if specified by the purchaser. After major weld repairs and prior to hydrotest, the complete casting or forging shall be given a post-weld heat treatment to ensure stress relief and continuity of mechanical properties of both weld and parent metals.

7.6.2.2 Grey cast iron or nodular iron may be repaired by plugging within the limits specified in ASTM A 278 or ASTM A 395; but shall not be repaired by welding.

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

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

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

7.7 Welding

7.7.1 Welding of piping and pressure-containing parts, as well as any dissimilar-metal welds and weld repairs, shall be performed and inspected by operators and procedures qualified in accordance with the pressure design code, or other recognized standards, if specified by the purchaser.

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

7.7.3 Welding not covered by 7.7.1 such as welding on base plates, non-pressure ducting, lagging and control panels shall be performed by welders, qualified in accordance with an appropriate recognized standard such as AWS D 1.1.

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

7.7.5 Connections welded to pressure-containing parts shall be installed as specified in 7.7.5.1 through 7.7.5.3.

- **7.7.5.1** When specified, in addition to the requirements of 7.7.1, 100 % radiography of butt welds or magnetic particle inspection or liquid penetrant inspection of welds is required.

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

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

7.7.6 When required by the applicable code or 7.5.2.6 all welds shall be heat treated in accordance with the methods described in the applied standards. For steels in H_2S service, heat treatment shall also be in accordance with NACE MR 0175. See 7.1.10.

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

7.8 Low temperature service

• To avoid brittle failures, materials and constructions intended for low temperature service shall be in accordance with the codes and other requirements specified on the data sheets. The purchaser shall specify the minimum design metal temperature (MDMT) related to the expected operating conditions. The vendor and purchaser shall agree any special precautions necessary with regard to conditions that may occur during transportation, erection and commissioning.

8 Lubrication

8.1 Compressor frame lubrication

8.1.1 The frame lubrication system shall be a pressurized system; however splash lubrication systems may be used on horizontal compressors with rolling element bearings when the compressor's nominal frame rating is 150 kW (200 hp) or less. The crankcase oil temperature shall not exceed 70 °C (158 °F) for pressurized oil systems and 80 °C (176 °F) for splash systems. Cooling coils shall not be used in crankcases or oil reservoirs.

• **8.1.2** If specified, pressure lubrication systems shall be designed and funished in accordance with ISO 10438-2 (or chapter 2 of API Std 614).

NOTE ISO 10438-2 (or API Std 614) is typically applied only to reciprocating compressor trains involving a large turbine driver and gear unit.

8.1.3 All pressure lubrication systems shall, as a minimum, consist of an oil pump with a suction strainer, a supply-and-return system (see 11.2), an oil cooler (when required), a full-flow filter, and the necessary instruments. (See Figure G.4 for a typical schematic drawing of a lubricating oil system). The requirements of 8.1.3.1 to 8.1.3.3 shall apply.

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

• **8.1.3.2** For each unit having a nominal frame rating of more than 150 kW (200 hp), the vendor shall provide a separate, independently driven, full-capacity, full pressure auxiliary oil pump with an automatic start feature activated by low lubricating oil pressure and include provisions for post-lubrication after shut-down. The type of driver will be specified on the data sheets. Unless otherwise specified, pump drivers shall be sized for the pump power and required starting torque at an oil kinematic viscosity of 1 000 mm^2/s (5 000 SSU).

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

Continuously operating flowing oil return lines shall enter the sump or an external reservoir in such a way to avoid adverse effect on pump suction and electrostatic discharge.

8.1.3.4 The rated gauge pressure of the frame lubrication system shall be not less than 10 bar (150 psig)

8.1.3.5 Lubricating oil consoles shall have a steel base plate with a rim and drip lip for drainage.

• **8.1.4** An oil cooler shall be provided to maintain oil supply temperature at or below 55 °C (131 °F). The cooler shall be a water-cooled, shell-and-tube type or plate type or of a suitable air-cooled type, as specified.

Shell-and-tube coolers shall have water on the tube side. A removable-bundle design is required with coolers with more than 0,5 m^2 (5 ft^2) of surface, unless otherwise specified. Removable-bundle coolers shall be in accordance with TEMA Class C and shall be constructed with a removable channel cover. Tubes shall have an outside diameter of not less than 16 mm ($^5/_8$ inch), and the tube shall have a wall thickness of not less than 1,2 mm

(18 BWG[10])). Unless otherwise specified, cooler shells, channels and covers shall be steel; tube sheets shall be brass; and tubes shall be bronze or copper-nickel. U-bend tubes are not permitted.

Each cooler shall be sized to accommodate the total cooling load.

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, in order to prevent contamination of the lubricating oil in case of cooler failure. Coolers shall be equipped with vent and drain connections on their oil and water sides. The vendor shall include in the proposal complete details of any proposed plate-type or air-cooled cooler. Internal oil coolers are not acceptable.

8.1.5 A temperature regulating valve shall be provided to maintain the temperature of the oil above the minimum temperature specified by the vendor by allowing oil to bypass the cooler. (See Figure G.4 for a typical schematic drawing of a lubricating oil system).

8.1.6 Full-flow filters with replaceable elements shall be supplied, with filtration of 10 µm (nominal) or finer. The filters shall be located downstream of the cooler. Filters having covers with a mass greater than 16 kg (35 lbs) shall have cover lifters. Filters shall not be equipped with a bypass. Filter cartridge materials shall be corrosion resistant. Metal-mesh or sintered-metal filter elements are unacceptable. Flow shall be from the outside toward the centre of the filter cartridge. The design of the filter-cartridge assembly shall assure that internal bypassing cannot occur due to filter-to-cartridge or cartridge-to-cartridge misalignment, inadequate end cover sealing or other sealing deficiencies. The pressure drop for clean filter elements shall not exceed 0,3 bar (5 psi) at an operating temperature of 40 °C (104 °F) and normal flow. Cartridges shall have a minimum collapsing differential pressure of 5 bar (75 psi). Each filter shall be equipped with a vent and, if size permits, clean-and dirty-side drain connections. The MPWGP of filter casings shall be not less than the system relief valve setting. The relief valve setting shall be no greater than the sum of the normal bearing supply pressure, the equipment and piping pressure losses upstream of the filter and the cartridge collapsing differential pressure drop at a minimum oil temperature of 27 °C (81 °F) and the normal flow rate to the bearings. For required start-up oil temperatures above 27 °C (81 °F), a heater in accordance with 8.1.7 shall be supplied.

- When specified, dual filters shall be supplied complete with a separate or integral continuous-flow transfer valve that provides tight shutoff of the idle filter. The system shall be designed to permit cartridge replacement and repressuring during operation.

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

- **8.1.7** When specified, a removable steam-heating element external to the reservoir, or a thermostatically controlled electric immersion heater with a sheath of austenitic stainless steel, shall be provided for heating the charge capacity of oil before start up in cold weather. The heating device shall have sufficient capacity to heat the oil in the reservoir from the specified minimum site ambient temperature to the manufacturer's required start up temperature within 12 h. If an electric immersion heater is used, the specific heat flow rate shall not exceed 2,3 W/cm^2 (15 W/in^2). Each electric heater shall be protected against being energized when not completely immersed in oil.

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

10) Birmingham Wire Gauge.

8.2 Cylinder and packing lubrication

8.2.1 General

• **8.2.1.1** The purchaser shall specify either a single plunger-per-point or a divider-block mechanical lubricator system for compressor cylinder and packing lubrication.

• **8.2.1.2** Lubricators shall be driven by the crankshaft or driven independently as specified. Lubricators shall be separate from the frame lubrication pump(s) and complete with necessary tubing or piping (see 11.3). Ratchet lubricator drives are unacceptable.

8.2.1.3 Pumps shall be sized to permit a 100 % increase and a 25 % decrease in design flow. The pumping rate shall be adjustable while the compressor is operating.

• **8.2.1.4** When specified, a heating device with thermostatic control for the lubricator reservoir oil shall be provided. The specific heat flow rate of the device shall be limited to 2,3 W/cm^2 (15 watts per square inch). The size of heating system and temperature control instrumentation shall be as agreed by the purchaser and vendor.

When an internal heater is used it shall be fully immersed even at minimum level. (See 8.2.2.3).

8.2.1.5 Unless otherwise specified, lubricators shall have provisions for pre-lubrication of the compressor prior to compressor start up.

• **8.2.1.6** Alarm functions shall be provided if specified by the purchaser.

8.2.1.7 A lubrication point (or points) shall be provided for each compressor cylinder bore and packing. A stainless steel integral double-ball check valve shall be provided as close as possible to each lubrication point. Check valve, tubing and fittings shall be rated for the maximum permissible working gauge pressure of the lubricator.

8.2.1.8 Lubricating oil injection passages to the cylinder bore shall be drilled through metal provided in the cylinder water jacket casting or weldment. Lubrication pipes or tubes (similar to Figure G.5) running through that metal in the water jacket are acceptable. Pipe or tubing shall be of austenitic stainless steel (see 11.3) and may be used in the gas passages if the materials are compatible with the gas composition. Lubricating oil injection passages shall be drilled and tapped for all cylinders including non-lubricated services. Unused holes shall be plugged with threaded stainless steel solid plugs. Tubing connections shall be match tagged for identification at the disassembly points for all compressor components in order to facilitate re-assembly.

• **8.2.1.9** The purchaser will indicate if the compressor cylinders are to be lubricated by synthetic lubricants. The lubricant specifications shall be entered on the data sheet by the purchaser unless the vendor's recommendation is desired. Interior surfaces of the lubricating system coming into contact with the synthetic lubricant shall be of compatible materials agreed upon by the compressor manufacturer and the lubricant manufacturer. Interior surfaces coming into contact with synthetic lubricant shall be left unpainted. If other interior surfaces (e.g. of distance pieces) must be painted, a synthetic-lubricant-resistant coating recommended by the lubricant manufacturer shall be used.

8.2.1.10 Lubricator reservoir capacity shall be adequate for 30 h at normal flow.

8.2.2 Point-to-point lubrication

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

8.2.2.2 Feed rate to each point shall be individually adjustable while the compressor is operating.

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

8.2.3 Divider block lubrication

Protection devices shall be as agreed by the purchaser and the vendor. For example, each outlet of the primary divider block may be equipped with a resetable spring-loaded indicator pin for indicating when the outlet is plugged. The system may be protected from overpressure with a rupture disk located downstream of the pump(s). A pressure gauge may also be provided indicating pump discharge pressure. For protection against loss of flow, a cycle monitor may be provided with a digital display showing total flow and shall be equipped with an alarm indicating no flow. The cycle monitor may be driven by a proximity switch mounted on the primary divider block.

9 Accessories

9.1 Drivers

9.1.1 General

• **9.1.1.1** The type of driver shall be specified by the purchaser. The driver and power transmission equipment shall be furnished by the compressor vendor unless specified otherwise. The driver shall be sized to meet the maximum specified operating conditions, including gear and/or coupling losses and shall be in accordance with applicable specifications as stated in the inquiry and order. All driver units shall be suitable for satisfactory operation under the specified utility and site conditions. The driver shall be capable of driving the compressor with all stages at full flow and discharging at the relevant relief valve set pressure.

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

• **9.1.1.3** The starting conditions for the driven equipment shall 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 starting-torque requirements of the driven equipment.

9.1.1.4 The inertias of the rotating parts of the compressor and the drive train shall be such that rotational oscillations will be minimized. Objectionable oscillations include those that cause damage, undue wear of parts or interference with the governor or governing system of the driver and those that result in harmful torsional and/or electrical system disturbances. For initial design purposes, peak to peak speed oscillation of the rotating system shall be limited to $1^1/_2$ % of rated speed at full load and partial cylinder loads if step unloading is specified. The compressor vendor shall inform the driver manufacturer of the nature of the application including vibratory torque characteristics and shall obtain confirmation from the driver manufacturer that the driver is suitable for this service.

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

9.1.1.6 For V-belt-driven compressors the peak to peak speed variation shall not exceed 3 % of rated compressor speed at any operating condition (see 9.4).

9.1.2 Motor drivers

9.1.2.1 For motor-driven units, the motor rating shall be not less than 110 % of the greatest power required (including gear and coupling losses) for any of the specified operating conditions.

• **9.1.2.2** Motor drivers for reciprocating compressors may be either synchronous or induction machines, and shall be one of the following types as specified by the purchaser:

— cantilevered (overhung) type in which the motor rotor is mounted on an extension of the compressor crankshaft with no additional bearings (see 9.1.2.10);

- single bearing motor with the single outboard bearing supported in a separate pedestal;
- single bearing motor with an integral bearing;
- two-bearing motor with separate bearing pedestals;
- two-bearing motor with integral bearings.

The shaft of a single bearing motor shall be rigidly coupled to the compressor crankshaft. Unless otherwise agreed upon the connection shall be with forged flanges integral with the motor shaft and crankshaft.

A two-bearing motor may be directly coupled to the compressor or may drive the compressor through a reduction gear or through belts as specified by the purchaser.

When specified, single bearing motors shall be provided with a temporary inboard support device to facilitate erection and alignment.

• **9.1.2.3** The purchaser will specify the type of motor driver, electrical characteristics, starting conditions (including expected voltage drop on starting), type of enclosure, sound pressure level, area classification in accordance with IEC 60079-0, insulation class and maximum temperature rise, ambient temperature and elevation above sea level, electrical transmission losses and any power factor requirement, temperature detectors, vibration sensors, space heaters and auxiliaries such as motor-generator sets, ventilation blower and instrumentation. Refer to 9.4.3 when belt drives are to be used.

Totally enclosed motors installed in hazardous areas other than explosion-proof or pressurized types shall be provided with purge connections.

NOTE Purging with dry air or inert gas of motors which are neither explosion-proof nor pressurized is recommended to avoid build up of inflammable gas in the motor enclosure, which may lead to explosions.

• **9.1.2.4** The system'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. The motor starting torque shall be sufficient for starting the compressor without the need to depressurize any stage from its normal suction pressure as long as all cylinder ends are unloaded or all stages are 100 % bypassed. Special agreement may be necessary in the following circumstances: low ratios of piston-to-rod diameter, high suction pressure, high settling-out gas pressure specified by the purchaser or high pressure unloaded starts when compressor valve flow areas are low. Unless otherwise specified, the purchaser shall supply the necessary motor starting apparatus.

NOTE Settling out pressure is defined as the pressure of the compressor system when the compressor is shut down without depressurising the system.

9.1.2.5 Unless otherwise specified, the design of the motor shall conform to IEC 60529, IEC 60079-0 and IEC 60034-1.

• **9.1.2.6** The combined inertia of rotating parts of synchronous-motor-compressor installations shall be sufficient to limit motor current variations to a value not exceeding 66 % of the full load current (see IEC 60034-1) for all specified loading conditions, including unloaded operation with cylinders pressurized to their normal suction pressures. For induction-motor-compressor installations, motor current variations shall not exceed 40 % of the full load current using the method as described in IEC 60034-1. 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 in order to protect other equipment in the electrical system. Standard motor performance data are based on steady-state load conditions and may not reflect actual performance under the variable torque conditions encountered when driving reciprocating compressors. With induction motor drivers, the effects of variable torque and resultant current pulsations are more pronounced and require closer evaluation. See 6.7.5.

9.1.2.7 When the motor is supplied by the purchaser, the compressor vendor shall furnish the purchaser with the following.

a) The required motor rotor inertia to satisfy the flywheel requirements of the compressor for all specified operating conditions.

b) Starting torque requirements.

c) Mounting or coupling details, or both.

9.1.2.8 Where a synchronous motor is to be connected to an electrical bus system that feeds existing synchronous motors, the purchaser shall consider performing an electrical system analysis and supply the compressor vendor (and the motor vendor if the motor is separately purchased) with all data necessary to permit proper design.

9.1.2.9 For synchronous-motor-driven compressors, the torsional stiffness and the inertia of all rotating parts shall provide at least a 20 % difference between any inherent exciting frequency of the compressor and the natural frequency of the motor rotor oscillation with respect to the rotating magnetic field.

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

9.1.2.11 The motor manufacturer's drawing shall show the permissible tolerance for setting the air gap. All sections of the motor stator (and rotary exciter, if applicable) shall be dowelled after internal alignment is completed to ensure maintenance of the proper air gap. The exciter housing shall be mounted with sufficient lateral and axial rigidity to prevent excessive motion of the stator relative to the rotor. Motors without thrust bearings shall be provided with a permanent and evident indication of the position of the rotor relative to the axial magnetic centre.

9.1.2.12 The bearings of motors that are to be rigidly coupled to a compressor shall be of the same generic type (hydrodynamic or rolling element) as the main bearings of the driven compressor. The use of rolling element bearings in other cases requires the purchaser's approval. The design of direct coupled motors shall be such that the bearings can be inspected, removed and replaced in-situ.

Bearings shall be electrically insulated to prevent the circulation of stray electrical currents. Hydrodynamic bearings shall be self-lubricated or, when specified by the purchaser, shall be supplied with oil from the compressor frame lubrication system.

Bearing housings shall be provided with shaft seals to prevent the ingress of dirt and moisture into the bearings or leakage of oil into the motor wirings.

9.1.2.13 The motors for auxiliary equipment shall be suitable for the specified area classification in accordance with IEC 60079-0 and IEC 60529. Motor rating shall be at least 110 % of the maximum power required for any operating condition.

9.1.3 Turbine drivers

• **9.1.3.1** Turbine drivers shall conform to ISO 10436 or ISO 10437 as specified by the purchaser. Unless otherwise specified, turbine drivers shall be rated to continuously deliver at least 120 % of the rated compressor power plus transmission losses.

• **9.1.3.2** When specified, a separate lubricating oil system in accordance with ISO 10 438 (or API Std 614) shall be furnished for a turbine drive train.

9.2 Couplings and guards

9.2.1 Couplings

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

- **9.2.1.2** The coupling make, type and mounting arrangement shall be agreed upon by the purchaser and the vendors of the driver and driven equipment. A spacer coupling shall be used when specified. Flexible couplings shall be of the all steel, flexible membrane, torsionally rigid spacer type, except that low speed couplings may be of the elastomeric type where necessary to avoid torsional resonance problems.

- When specified, the coupling or couplings shall be in accordance with ISO 10441.

9.2.1.3 For compressors rated at 1 500 kW (2 000 hp) or more and driven by a double-reduction gear, the low-speed coupling may be a quill shaft. In such cases, the quill shaft shall be directly coupled to the compressor flywheel.

Stresses in the quill shaft shall be given careful consideration. A typical value for the mean torsional stress is approximately 15 % of the yield strength of the material. The alternating stress is typically held to a value no greater than one third of the mean torsional stress.

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

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

- **9.2.1.6** When specified, couplings for auxiliary drives shall be in accordance with ISO 14691.

9.2.2 Guards

- **9.2.2.1** Guards shall be provided for all moving parts which might be hazardous to personnel. Guards shall comply with specified applicable safety codes. Openings shall be provided in flywheel guards used for barring-over the machine and provide access to indicator timing marks, wheel centre (if available) and to any other parts which may require attention.

Unless otherwise specified, guards shall be supplied by the vendor. They shall be easily removable, weatherproof, of non-sparking construction, with continuous welding and sufficiently rigid to withstand deflection and prevent rubbing as a result of body contact. This also applies to auxiliary coupling guards.

- Where aluminium is not considered an acceptable non-sparking material, it shall be so specified by the purchaser.

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

9.3 Reduction gears

- **9.3.1** Gear units shall comply with ISO 13691, or as specified by the purchaser.

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

9.4 Belt drives

9.4.1 Belt drives shall be limited to compressors of rated power no greater than 150 kW (200 hp). If more than one belt is required, the vendor shall furnish matched belt lengths. All belt drives shall be static-conducting type and oil resistant. The drive system shall be selected on the basis of 1,75 times the driver power rating.

The details of belt tension, centre distance, belt wrap and crankshaft web deflection and testing shall be mutually agreed upon by the vendor and purchaser.

9.4.2 The vendor shall provide a positive belt-tensioning device on all belt drives. All bearing lubrication points shall be accessible.

9.4.3 The compressor manufacturer shall inform the driver manufacturer whenever the driver is to be used to belt-drive the compressor. The driver manufacturer shall be provided with, and take into account, the radial load and vibratory torque conditions associated with reciprocating compressors and shall provide bearings with a life at least equivalent to that specified in 6.4.3.

9.4.4 Belt drives shall meet the requirements of 9.4.4.1 to 9.4.4.4.

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

9.4.4.2 The length of a shaft key fitting used to mount a sheave shall be no less than the length of a sheave bore.

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

9.4.4.4 To reduce the overhung moment on shafts due to belt tension the sheave overhang distance from the adjacent bearing shall be minimized.

9.5 Mounting plates

9.5.1 General

- **9.5.1.1** The equipment shall be furnished with a base plate, skid, sole-plates or rails as specified by the purchaser.

NOTE In 9.5.1.2 to 9.5.1.16 the term "mounting plates" refers to base plates, skids, sole-plates and rails.

9.5.1.2 When equipment is mounted directly on machined metal surfaces integral with mounting plates, such surfaces shall be machined flat and parallel to all other mounting surfaces to within 0,15 mm/m (0,002 in/ft).

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

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

9.5.1.5 When the drive equipment mass exceeds 450 kg (1 000 lbs), the mounting plates shall be furnished with horizontal jackscrews the same size as, or larger than, the vertical jackscrews. The lugs holding these jackscrews shall be attached to the mounting plates so that they do not interfere with the installation or removal of the drive equipment and shims.

9.5.1.6 Anchor bolts shall not be used to fasten equipment to mounting plates.

9.5.1.7 Base plates and skids shall not be drilled for equipment to be mounted by others. Base plates and skids intended for installation on concrete shall be supplied with levelling screws. Mounting plates that are to be grouted shall have 50 mm (2 ins) radiused outside corners (in the plan view).

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

9.5.1.9 The vendor of the mounting plates shall furnish stainless steel shim packs of at least 3 mm ($^1/_8$ inch) total thickness between the drive equipment feet and the mounting plates. All shim packs shall straddle the hold-down bolts.

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

• **9.5.1.11** When specified, chock blocks shall be supplied by the vendor, (see annex L).

9.5.1.12 Unless otherwise agreed, anchor bolts shall be furnished by the purchaser. Anchor bolts supplied by others shall require vendor's review and approval.

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

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

• **9.5.1.15** When epoxy grout is specified, the vendor shall commercially blast-clean, in accordance with ISO 8501-1 Grade Sa 2, all the grouting surfaces of the mounting plates and shall precoat these surfaces with inorganic zinc silicate primer.

• **9.5.1.16** When levelling plates are specified they shall be steel plates at least 19 mm thick (see annex L).

9.5.2 Base plates and skids

9.5.2.1 Base plates are fabricated steel structures designed to provide support, when specified, to the complete compressor and/or the drive equipment and other ancillaries.

9.5.2.2 Skids are base plates that have sled type runners for ease of relocation.

• **9.5.2.3** When a base plate is specified, the data sheets shall indicate the major equipment to be mounted on it. A base plate 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 base plates shall have machined and dowelled mating surfaces to ensure accurate field reassembly.

NOTE A base plate may have to be fabricated in multiple sections because of shipping restrictions.

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

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

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

9.5.2.7 Base plates shall be designed and built to adequately support the weight of the compressor, driver and accessories and to avoid resonance with any possible excitation frequency. The base plate shall be able to transmit all forces and moments generated by the compressor and driver to the foundation.

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

• **9.5.2.9** When specified, the base plate shall be suitable for column mounting (i.e., of sufficient rigidity to be supported at specified points) without continuous grouting under structural members. The base plate design shall be agreed by the purchaser and the vendor.

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

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

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

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

9.5.2.14 Driver and compressor base plate mounting pads shall be machined after the base plate is fabricated. See 9.5.1.2.

9.5.3 Sole-plates and rails

9.5.3.1 Sole-plates are grouted plates installed under motors, bearing pedestals, gearboxes, turbine feet, cylinder supports, crosshead pedestals and compressor frames (see annex L).

9.5.3.2 Rails are sole-plates extending the full length of each side of the equipment.

• **9.5.3.3** When sole-plates or rails are specified, they shall be provided by the vendor.

9.5.3.4 Sole-plates shall be steel plates thick enough to transmit the expected loads from the equipment feet to the foundation and to facilitate grouting. In no case shall they be less than 25 mm (1 in) thick.

9.6 Intercoolers and aftercoolers

• **9.6.1** When specified, the vendor shall furnish an intercooler between each compressor stage. Such coolers shall be water-cooled shell-and-tube type, air cooled type or other type specified by the purchaser and agreed by the vendor.

• **9.6.2** The purchaser will specify whether aftercoolers shall be furnished by the vendor and if so, of which type.

• **9.6.3** Water-cooled shell-and-tube intercoolers and aftercoolers shall be designed and constructed in accordance with TEMA Class C or R, as specified by the purchaser on the data sheets. Intercoolers and aftercoolers shall be furnished in accordance with the specified pressure vessel code. When TEMA Class R is specified, the heat exchanger shall be in accordance with ISO 16812.

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

9.6.4 Unless otherwise specified, the water side of shell-and-tube heat exchangers shall be designed in accordance with 5.1.3.

9.6.5 Unless otherwise approved by the purchaser, shell-and-tube intercoolers and aftercoolers shall be constructed and arranged to allow removal of tube bundles without dismantling piping or compressor components.

NOTE Intercooling and aftercooling of gases from reciprocating compressors present some unique phenomena to be considered in the design of exchangers. Consideration should be given to whether the gas should be on the tube side or on the shell side. Very small pressure pulsation levels multiplied by the larger areas of the pass separation plates can possibly produce very high vibratory forces in the tube bundle. Consideration should also be given to the application of shell side rupture discs, relief valves or similar devices.

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

• **9.6.7** When air coolers are specified, these shall be in accordance with ISO 13706 and with the specified pressure vessel code.

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

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

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

9.6.10 Intercoolers may be either machine mounted or separately mounted, subject to the approval of the purchaser.

• **9.6.11** Materials of construction shall be those specified on the data sheets.

9.6.12 Unless otherwise specified and agreed, liquid separation and collection facilities shall be provided after every intercooler and shall be in accordance with 9.6.12.1 to 9.6.12.4.

9.6.12.1 Agreement shall be reached on the type of liquid separation device and whether this is to be integral with the intercooler or arranged in a separate vessel.

9.6.12.2 Where the separation and collection facilities are integral with the intercooler, a drain sump or boot into which the separated liquid is directed shall be provided. Unless otherwise agreed the capacity of this sump or boot shall be sufficient to contain the maximum expected liquid flow from any specified operating condition for not less than 15 min.

9.6.12.3 Unless otherwise specified or agreed, an automatic drainage system shall be provided. For air or inert gas service, this automatic drainage system may comprise a float-operated trap with a manual bypass. In all other cases, the drainage system shall comprise a separate level control valve with a manual bypass, operated by a level controller of an agreed type.

9.6.12.4 The drain sump or boot or lower part of the separate separation vessel shall be provided with a level indicator and alarm and shut-down devices as specified on the data sheet and in accordance with 10.5. Where a high level alarm and a high level shut-down are specified the capacity of the vessel or boot between the levels shall be equivalent to the maximum expected liquid flow for not less than 5 min.

• **9.6.13** When specified, the vendor shall furnish the fabricated piping between the compressor stages and the intercoolers and aftercoolers. Interstage piping shall conform to the requirements of 11.6.

9.7 Air intake filters

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

The vendor shall bring to the purchaser's attention any hazards that he believes could result from complying with the purchaser's specification. As a minimum, the following features should be considered in the design of the filter-silencer:

a) micron particle rating;

b) in-service cleanability;

c) corrosion protection of filter and of internal surfaces of inlet piping;

d) avoidance of internal threaded fasteners;

e) connections for measuring filter pressure differential.

9.8 Special tools

9.8.1 When special tools and fixtures are required to disassemble, assemble or maintain the unit, they shall be included in the quotation and furnished as part of the initial supply of the machine, together with complete instructions for their use. For multiple-unit installation, the requirements for quantities of special tools and fixtures shall be agreed by the purchaser and the vendor. These or similar special tools shall be used during shop assembly and post-test disassembly of the equipment.

• **9.8.2** Special tools for reciprocating compressors shall include:

— mandrel for fitting wear bands on non-segmental pistons;

— lifting and lowering device for removal and insertion of valve assemblies that weigh more than 15 kg;

— crosshead removal and installation tool;

— sleeve/cone to enable piston rod to be passed through completely assembled packing;

— hydraulic tensioning tools (when specified).

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

9.8.4 All compressors shall be provided with suitable means of barring for maintenance. For compressors with a rated power of 750 kW (1 000 hp) or greater a power-driven barring device shall be furnished. Power-driven barring devices should also be considered for compressors with a peak bar-over torque requirement of 1 600 N·m (1 200 ft lbs) or more. The vendor shall furnish a complete description of the barring device including such factors as method of operation (e.g., manual engagement and automatic disengagement on start of compressor), lockout signals required, location, guards and power required.

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

NOTE The purchaser should interlock this limit switch with the driver.

10 Controls and instrumentation

10.1 General

• **10.1.1** Compressor control systems may be pneumatic, hydraulic, electrical or electronic and may be operated either manually or automatically. The purchaser shall specify the control signal, the type of control system (manual, automatic or programmable), the control range and the equipment to be furnished by the vendor. The purchaser shall specify which process sensing lines handling inflammable, toxic, corrosive or high-temperature fluids require transduced signals to the instrumentation. The purchaser shall also specify the source of the control signal and its sensitivity and range. The vendor shall describe the complete control system (including alarms and shut-downs) in this scope of supply by means of logic diagrams in accordance with IEC 848.

When the control system is supplied by others the vendor shall provide logic diagrams of the critical functions associated with the compressor operation (starting, stopping, capacity control, shut-downs, etc.)

Examples of typical logic diagrams of critical functions are given in annex E.

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

10.1.3 All controls and instrumentation shall be certified suitable for the area classification specified on the data sheet and shall comply with the standards specified and with any local codes and regulations.

10.1.4 All controls and instrumentation shall be located and arranged for ease of visibility, access and maintenance.

• **10.1.5** The vendor shall provide all auxiliary system instrumentation as specified in the data sheet.

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

10.1.7 Some controls may be shipped loose for field installation in the purchaser's piping as agreed between the purchaser and the vendor. See 14.3.11 for shipment.

• **10.1.8** Unless otherwise specified, all instruments and controls, other than shut-down sensing devices, shall be installed with sufficient valving to permit replacement while the system is in operation. When shut-off valves are specified for shut-down sensing devices, the vendor shall provide a means of locking the valves in the open position.

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

10.2 Control systems

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

10.2.2 Capacity control for constant-speed units will normally be achieved by suction valve unloading, clearance pockets, or bypass (internal-plug type or external) or a combination of these methods. Stepless reverse-flow capacity control acting on suction valves requires purchaser's approval. Control operation shall be either automatic or manual as specified on the data sheet. Unless otherwise specified, five-step unloading shall provide nominal capacities of 100 %, 75 %, 50 %, 25 % and 0 %; three-step unloading shall provide nominal capacities of 100 %, 50 % and 0 %, and two-step unloading shall provide capacities of 100 % and 0 %.

10.2.3 Capacity control on variable-speed units is usually accomplished by speed control, but this can be supplemented by one or more of the control methods specified in 10.2.

NOTE Reciprocating compressors are usually specified for constant-speed operation (see 5.1.4).

10.2.4 For variable speed control the speed of the compressor shall vary linearly with the control signal and an increase in signal shall increase speed. Unless otherwise specified, the full range of the purchaser's signal shall correspond to the required operating range of the compressor for all specified operating conditions.

10.2.5 Clearance pockets shall normally be of the fixed type (pocket either open or closed). The use of variable volume clearance pockets requires purchaser's approval. Each added clearance volume shall be included in the data sheets to indicate the clearance it adds to the cylinder.

10.2.6 When a machine-mounted capacity control system is specified, the vendor shall provide a panel complete with:

a) a positive-detent-type master selector device (one for each service on multi-service compressors) to provide the specified load steps and

b) indicators to show at which step the machine is operating.

10.3 Instrument and control panels

• **10.3.1** When specified, panels shall be provided and shall include all panel-mounted instruments for the equipment to be supplied by the vendor. Such panels shall be designed and fabricated in accordance with the purchaser's description. The instruments on the panels shall be clearly visible to the operator from the driver control point.

• **10.3.2** Unless otherwise specified panels shall be made of steel plate at least 3 mm ($^1/_8$ inch) thick, reinforced, self-supporting and closed on the top and sides. When specified, the backs of panels shall be enclosed to minimize electrical hazards, to protect equipment against tampering or to allow purging for safety or corrosion prevention. All instruments shall be flush-mounted on the front of the panel and all fasteners shall be of corrosion-resistant material.

• **10.3.3** Panels shall be completely assembled requiring only connection to the purchaser's external piping and wiring circuits. When more than one wiring point is required on a unit for control or instrumentation, the wiring to each switch or instrument shall be provided from a single terminal box with terminal posts. The box shall be mounted on the unit (or its base, if any).

Wiring within panels shall be installed in conduit or supported on cable trays. All wiring, not inside fully enclosed panels, shall be in the form of armoured cable supported in cable trays or be run in a metal conduit as specified by the purchaser.

All instruments, leads and posts on terminal strips and switches shall be provided with permanent non-corrosive tags or labels for identification.

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

10.4 Instrumentation

10.4.1 Tachometers

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

10.4.2 Temperature measurement

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

10.4.2.2 Dial-type temperature gauges shall be heavy duty and corrosion resistant. They shall be at least 100 mm (4 in) in diameter and bimetallic or liquid filled. Black printing on a white background is standard for gauges.

10.4.2.3 The temperature sensing elements shall be in the flowing fluid. This is particularly important for lines that may run partially full.

10.4.2.4 Temperature sensing elements that are in contact with inflammable or toxic fluids or that are located in pressurized or flooded lines shall be furnished with austenitic stainless steel separable-flange-type solid-bar thermowells at least 19 mm ($^3/_4$ in) in diameter.

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

- **10.4.2.6** Packing or piston rod temperature indication according to the manufacturer's experience, shall be provided for cylinders operating at or above a gauge pressure of 35 bar (500 psig) and for all cylinders with liquid cooled packing (see 6.6.4). The purchaser shall specify whether this temperature indication shall be by means of thermocouples or resistance temperature detectors.

10.4.2.7 Where practical, the design and location of thermocouples and resistance temperature detectors shall permit replacement while the unit is operating. The lead wires of thermocouples and resistance temperature detectors shall be installed as continuous leads between the thermowell or detector and the terminal box.

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

10.4.3 Pressure measurement

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

- **10.4.3.2** When pressure indication in services other than instrument air is by means of gauges (direct acting devices), these shall be furnished with austenitic stainless steel bourdon tubes and stainless steel movements, dials at least 100 mm (4 in) in diameter and ISO 7-1 R$^1/_2$ male alloy steel connections. Black printing on a white background is standard for gauges. When specified, oil-filled gauges shall be furnished in locations subject to vibration. Gauge ranges should be selected so that the normal operating pressure is at the middle of the gauge's range. In no case, however, shall the maximum reading on the dial be less than the applicable relief valve setting plus 10 %. Each pressure gauge shall be provided with a device such as a disc insert or blowout back designed to relieve excessive case pressure.

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

10.4.4 Solenoid valves

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

10.4.5 Relief valves

- **10.4.5.1** When specified, the vendor shall furnish relief valves that are to be installed on equipment or in piping that the vendor is supplying. Other relief valves will be furnished by the purchaser. Relief valves for all operating equipment shall comply with all relevant local codes and regulations and shall meet the limiting relief valve requirements defined in API RP 520/1, API RP 520/2 and in API Std 526, providing these requirements do not conflict with the above codes and regulations. The vendor shall determine the size and the set pressure of all relief valves related to the equipment. The vendor's proposal shall list all relief valves and shall clearly indicate those to be furnished by the vendor. Relief valve location and settings, including accumulation, shall take into consideration all possible types of equipment failure, misoperation and the protection of piping systems.

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

10.4.5.3 Relief valves shall be set to operate at not more than the maximum permissible working pressure, but not less that the values listed in Table 4.

Table 4 — Relief valve settings

Rated discharge gauge pressure (each stage) bar	psig	Minimum relief valve set pressure margin above rated discharge gauge pressure
< 10	< 150	1 bar (15 psi)
10 to 170	150 to 2 500	10 %
170 to 240	2 501 to 3 500	8 %
240 to 345	3 501 to 5 000	6 %
> 345	> 5 000	to be agreed by purchaser and vendor

10.5 Alarms and shut-downs

10.5.1 An alarm/shut-down system shall be provided that will initiate an alarm if any one of the conditions specified by the purchaser or recommended by the vendor as alarm conditions reaches an agreed alarm level. This system shall also initiate shut-down of the compressor when any of the conditions specified or recommended as shut-down conditions reaches an agreed shut-down level. As a minimum these alarms and shut-downs shall include those listed in Table 5.

Table 5 — Minimum alarm and shut-down requirements

Condition	Alarm	Shut-down
High gas discharge temperature - each cylinder	X	X
Low frame lubricating-oil pressure	X	X
Low frame lubricating-oil level	X	—
Cylinder lubricator system failure	X	—
High oil-filter differential pressure	X	—
High frame vibration	—	X
High level in separator	X	X
Jacket water system failure	X	—
NOTE Consideration should be given to protect the compressor against excessive stage differential pressure, by monitoring either suction/discharge pressures or differential pressure across the stage.		

- **10.5.2** The extent to which this alarm/shut-down system is to be supplied by the compressor vendor shall be specified by the purchaser.

10.5.3 Alarm/shut-down systems shall be designed to achieve the objectives in 10.5.3.1 to 10.5.3.7.

10.5.3.1 Unless otherwise agreed, for every shut-down function an alarm function shall be provided and set at a value which represents a deviation from the normal condition less than the setting of the shut-down. Additional alarms, not associated with shut-downs, shall be provided as specified (see 10.5.1).

- **10.5.3.2** Any measured condition for which an alarm is specified, reaching the alarm level shall initiate an audible warning or a flashing light or both as specified.

• **10.5.3.3** Any measured condition for which a shut-down is specified, reaching the shut-down level shall initiate an audible warning or a flashing light or both as specified that shall be distinguishable from those associated with an alarm condition and shall cause the compressor to shut-down.

10.5.3.4 The shut-down system shall be designed with the objective that failure of any one component that results in the system being unable to recognize a shut-down condition shall initiate an alarm, cause the compressor to shut down and shall not result in the inability to recognise the associated alarm condition or any other shut-down condition.

10.5.3.5 The alarm system shall be designed with the objective that failure of any one component that results in the system being unable to recognize an alarm condition shall initiate an alarm and shall not result in the inability to recognize any shut-down condition.

10.5.3.6 When self diagnostic systems are used to achieve the objectives of 10.5.3.4 and 10.5.3.5 alarms initiated by failure of components of the alarm/shut-down system shall be distinguishable from alarms initiated by true failures of the compressor system.

10.5.3.7 It shall be possible to test every component of every alarm facility whilst the compressor is in operation. Where an alarm is associated with a shut-down, this shall be possible without disarming or interfering in any way with the associated shut-down facility.

10.5.4 The objectives specified above can be achieved in a number of ways. Examples of possible arrangements are described in annex Q. Other arrangements or combinations of parts of these suggested alternatives may be acceptable. The arrangement to be used shall be specified by the purchaser or shall be jointly developed by the purchaser and the vendor.

10.5.5 Unless otherwise specified, switches shall be suitable for operation on both alternating current (AC) and direct current (DC) and shall have dry-type, single-pole, double-throw contacts rated for 5 amp at 120 V AC and ½ amp at 120 V DC. Hermetically sealed switches are preferred. Mercury switches shall not be used. Switch sensing elements for services other than instrument air service shall be of austenitic stainless steel.

• **10.5.6** The vendor shall furnish a first-out annunciator when an annuciator system is specified. The annunciator shall contain approximately 25 % spare points. Connections shall be provided for actuation of a remote signal when any function alarms or trips. The sequence of operation shall be as specified in 10.5.6.1 to 10.5.6.4 unless otherwise agreed.

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

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

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

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

10.5.7 Compressor protections (all trips and alarms without an associated trip) shall be wired to operate in a fail safe mode. See annex E for a typical logic diagram and annex Q for possible arrangements.

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

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

10.6 Electrical systems

10.6.1 All electrical components and their installation shall conform to the requirements of 5.1.7.

• **10.6.2** When panels are supplied by the vendor, electrical power supply characteristics for motors, heaters and instrumentation shall be specified by the purchaser. A pilot light shall be provided on the incoming side of each supply circuit to indicate that the circuit is energized. The pilot lights shall be installed on the control panels.

10.6.3 Power and control wiring within the confines of the main unit base area, any console base area or any auxiliary base area shall be resistant to oil, heat, moisture and abrasion. Stranded conductors shall be used within the confines of the base plate and in other areas subject to vibration. Measurement and remote-control panel wiring may be solid conductors. Where rubber insulation is used, high-temperature thermoplastic sheaths shall be provided for insulation protection. Wiring shall be suitable for environmental temperatures.

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

10.6.5 To facilitate maintenance, liberal clearances shall be provided for all energized parts (such as terminal blocks and relays) on all equipment regardless of the voltage level.

• **10.6.6** All electric materials, including insulation, shall be corrosion resistant and non-hygroscopic insofar as is possible. When specified for tropical location, all material shall be given the treatments specified in 10.6.6.1 and 10.6.6.2.

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

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

10.6.7 All wiring including that for power and instrumentation, within limits or any base area shall be protected against mechanical damage, properly bracketed to minimize vibration and isolated or shielded to prevent interference between voltage levels. When used, conduits may terminate (and in the case of temperature element leads, shall terminate) with a flexible metallic conduit of sufficient length to permit access to the unit for maintenance without removal of the conduit.

10.6.8 Flexible metallic conduits, where used, shall be liquid-tight and suitable for the specified area classification.

10.7 Vibration and position detectors

• **10.7.1** When specified, the vendor shall furnish and mount one or more vibration detection and transducing devices. Each device shall have a velocity or accelerometer type detector and shall provide for each of the following functions:

a) continuous vibration measurement;

b) alarm;

c) shut-down.

Each device and its mounting shall conform to API Std 670. The purchaser and the vendor shall agree on the type, number and location of the devices to be mounted on the compressor frame (and on gear units, if applicable).

• **10.7.2** When specified, a non-contacting device shall be installed to measure the vertical movement of each piston rod. If a proximity-type probe is used for this purpose, the probe and the associated oscillator–demodulator and connecting cable shall be installed and calibrated in accordance with API Std 670. Unless otherwise specified, each probe shall be mounted adjacent to the packing. Terminal boxes containing oscillator–demodulators shall not be mounted on the machine. If the piston rod is coated, calibration of the device shall take account of the coating. See annex C.

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

• **10.7.4** When specified, the vendor shall furnish and mount piston rod drop detectors of the contact type, such as mechanical roller or fuse metal plug (eutectic) type. The detail of the system shall be agreed between the vendor and the purchaser. Diaphragm type pressure switches shall be used to sense loss of pressure.

11 Piping and appurtenances

11.1 General

11.1.1 Piping design and joint fabrication, examination and inspection shall be in accordance with ANSI B31.3 unless otherwise specified.

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

a) Group I

1) Purge or buffer gas

2) Fuel gas or oil

3) Distance piece and packing vents and drains

4) Drains and vents

b) Group II

1) Sealing steam

2) Drains and vents

c) Group III

1) Cooling water

2) Drains and vents

3) Packing cooling systems

4) Instrument and control air or inert gas

5) Bar-over air

d) Group IV

1) Lubricating oil

2) Control oil

3) Drains and vents

The minimum requirements for piping materials for auxiliary systems shall be as specified by Table 6 and 11.1.12.

NOTE Cylinder connections are covered in 6.1.4.

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

11.1.4 If flanges not in accordance with the specified standards are unavoidable at purchaser's connection, the vendor shall supply a welding neck companion flange, bolting and gasket to be installed by the purchaser. The purchaser shall be advised of this situation in the proposal.

• **11.1.5** When specified, piping, pulsation suppression devices and knockout vessels at the initial and interstage suction points shall be arranged for heat tracing and insulation.

Table 6 — Minimum requirements for piping materials

Category	**Group I (Auxiliary process fluid)**		**Group II (Steam)**	**Group III Cooling water, air ⩽ 10 bar**	**Group IV (Lubricating and control oil)**
System	Nonflammable/ nontoxic	Inflammable/ toxic			
Pipe	Seamless	Seamless	Seamless	Carbon steel	Seamless stainless steel (see 11.2.5)
Tubing	Seamless stainless steel	Seamless stainless steel	Stainless steel	Seamless stainless steel	Seamless stainless steel (see 11.2.5)
All valves	Class 800	Class 800	Class 800	Carbon steel	Carbon steel Class 800
Pipe fittings and unions	Forged Class 3000	Forged Class 3000	Forged Class 3000	Carbon steel	Stainless steel (see 11.2.4)
Fabricated joints ⩽ DN 40	Threaded, socket welded or flanged	Socket welded or flanged	Threaded	Threaded, socket welded or flanged	Stainless steel flanged
Fabricated joints ⩾ DN 50	Flanged	Flanged	Threaded, socket welded or flanged	Flanged	Stainless steel flanged

• **11.1.6** The extent of each piping system to be supplied by the vendor shall be specified by the purchaser. Vendor supplied piping systems shall terminate in flanged connections. Instrument tubing connections shall terminate in a flange or a threaded connection to the specified standard. Piping and component drains and vents shall terminate with a plugged or blind-flanged valve, accessible from the edge of the base or from a work area. This is to keep work areas and walkways as free as possible from obstructions. All piping supplied by the vendor shall be prefabricated. Any piping that cannot be shipped in the assembled state shall be preserved, match marked and tagged to facilitate field assembly.

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

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

11.1.9 Connections DN 40 ($1^1/_2$ NPS) and smaller shall be designed to minimize overhung weight and shall be made of forged fittings or shall be braced back to the main pipe in at least two planes to avoid breakage due to pulsation-induced vibration. Bracing shall be arranged to occupy minimum space.

11.1.10 The design of piping systems shall achieve the following.

a) Proper support and protection to prevent damage from vibration or during shipment, operation and maintenance. Supports shall not be directly welded to process or auxiliary piping (except bracing of small connections as required by 11.1.9).

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

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

d) Elimination of air pockets in liquid systems by the use of valved vents or non-accumulating piping arrangements.

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

f) Elimination of low points in the inlet process piping that could trap liquid.

g) All compressor cylinder coolant piping shall be equipped with valved vents and drains. See Figure G.2.

11.1.11 Piping shall preferably be fabricated by bending and welding to minimize the use of flanges and fittings. Flanges are permitted only at equipment connections, at the edge of any base and for ease of maintenance. The use of flanges at other points is permitted only with the purchaser's specific approval. Other than tees and reducers, welded fittings are permitted only to facilitate pipe layout in congested areas. Threaded connections shall be held to a minimum and shall not be used for sizes greater than DN 40 ($1^1/_2$ NPS). Pipe bushings shall not be used.

11.1.12 The requirements of 11.1.12.1 to 11.1.12.24 shall be applied to piping systems within the scope of this International Standard.

• **11.1.12.1** Pipe threads shall be taper threads in accordance with ISO 7-1 or ANSI B1.20.1, as specified. Unless otherwise specified, flanges shall be in accordance with ISO 7005-1 except that lap-joint and slip-on flanges shall not be used. For socket-welded construction, a 2 mm gap shall be left between the pipe end and the bottom of the socket.

NOTE Slip-on flanges are not used on piping and appurtenances around reciprocating compressors due to their reduced fatigue life.

The attention of the user of this International Standard is drawn to the possibility of hazardous situations arising from the incompatibility of ISO and ANSI pipe thread standards.

11.1.12.2 Connections, pipe, valves and fittings that are DN 32, DN 65, DN 90, DN 125, DN 175 or DN 225 ($1^1/_4$, $2^1/_2$, $3^1/_2$, 5, 7 or 9 NPS) in size shall not be used.

11.1.12.3 Where space does not permit the use of pipe, for sizes not greater than DN 25 (1 NPS), seamless tubing may be furnished.

11.1.12.4 The minimum size of any pipe connections shall be DN 15 ($^1/_2$ NPS).

11.1.12.5 All pipe flanges mating with cast iron compressor flanges shall be flat faced and used with full faced gaskets.

NOTE The term compressor flanges does not include faced and studded bosses.

11.1.12.6 Pipe threads shall be coated with a non-locking pipe thread sealant. PTFE pipe tape is not acceptable.

11.1.12.7 Welding shall be performed by operators and procedures qualified in accordance with the specified standards; or where no standards have been specified, in accordance with appropriate recognized standards.

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

11.1.12.9 Threaded joints shall not be used for inflammable or toxic fluids, unless otherwise agreed. Where threaded joints are permitted, they shall not be seal welded.

11.1.12.10 Valves shall be in accordance with appropriate recognized standards or as specified by the purchaser. Gate and globe valves shall have bolted bonnets and bolted glands. For ANSI service ratings Class 900 and above, block valves may be of welded bonnet or no-bonnet construction with a bolted gland: these valves shall be suitable for repacking under pressure. Valves of sizes DN 50 (2 NPS) and above shall be flanged. For ANSI Class 900 and above, butt welded construction may be substituted with purchaser's approval. Wafer check valves may be used in sizes DN 50 (2 NPS) and larger. Butterfly valves shall not be used unless approved by the purchaser.

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

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

11.1.12.13 Bleed valves provided on instruments may be the manufacturer's standard bleed fitting. Where test valves are provided as described in 11.5.3, bleed valves may be omitted.

11.1.12.14 Control valves shall have steel bodies, stainless steel trim and flanged ends as required in 11.1.12.10.

11.1.12.15 The bolting for pressure joints, valves and piping shall be based on the actual service temperature of the bolting. Through studs shall be used. Bolting shall be in accordance with 6.1.2.11.

11.1.12.16 Pipe flange gaskets, except where ring type joints are required or specified, shall be flat, asbestos-free gaskets up to and including ANSI Class 300 pressure ratings and spiral wound gaskets for higher ratings. Spiral wound gaskets shall have external centering rings and windings of austenitic stainless steel or other suitable corrosion resistant materials (Monel, Inconel etc.) depending on the fluids handled.

11.1.12.17 Combination stop/check valves shall not be used.

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

• **11.1.12.19** Stainless steel piping and all piping carrying the process gas, shall be seamless. Piping shall conform to appropriate recognized standards, such as ASTM A 106 Grade B or ASTM A 312 or as specified by the purchaser. Pipe wall thickness shall be in accordance with Table 7.

11.1.12.20 All tubing shall be seamless stainless steel tubing and shall conform to appropriate recognized standards, such as ASTM A 269. Tubing wall thickness shall be in accordance with table 8.

Table 7 — Minimum pipe wall thickness

Material	Nominal Pipe Size		Minimum Schedule
	ISO	NPS	(ANSI)
Carbon steel	⩽ DN 20	⩽ $^{3}/_{4}$	160 (XXS)
Carbon steel	DN 25 ÷ DN 40	1 ÷ 1 $^{1}/_{2}$	80 (XS)
Carbon steel	⩾ DN 50	⩾ 2	40 (STD)
Stainless steel	⩽ DN 25	⩽ 1	80S
Stainless steel	DN 40 ÷ DN 80	1 $^{1}/_{2}$ ÷3	40S
Stainless steel	⩾ DN 100	⩾ 4	10S

Table 8 — Minimum tubing wall thickness

Metric sizes		US customary (imperial) sizes	
Nominal tubing size OD in mm	**Minimum wall thickness** mm	**Nominal tubing size** OD in inches	**Minimum wall thickness** inches
6 [a]	1	1 / 4 [a]	0,04
8 [a]	1		
10 [a]	1	3 / 8 [a]	0,04
12	1,5	1 / 2	0,06
20	2	3 /4	0,08
25	3	1	0,12

[a] These sizes are permitted for instrument and control air and inert gas purge only. For cylinder lubrication see 8.2.

11.1.12.21 Tube fittings shall be stainless steel, manufacturer's standard, unless otherwise specified.

11.1.12.22 Valves in tubing systems shall be manufacturer's standard tube and valves or instrument valves shall be stainless steel unless otherwise specified.

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

11.1.12.24 Flanges and other fittings shall be in accordance with the appropriate recognized standards or as specified by the purchaser.

Acceptable ASTM material standards are shown in Table 9. Socket weld or threaded fittings shall be minimum Class 3000.

Table 9 — ASTM piping material standards

Material	Flanges	Buttwelded fittings	Socket weld or threaded fittings
Carbon steel	A 105	A 234 Gr WPB	A 105
	A 181	A 420	A 350
	A 350		
Stainless steel	A 182	A 403	A 182 Class 3000
	Type 304L	Type 304L	Type 3041 or 316L
	316L	316L	Type 304 or 316 for threaded fittings only

11.1.13 Bolt holes for flanged connections shall straddle lines parallel to the main horizontal or vertical centrelines of the equipment.

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

11.2 Frame lubrication oil piping

11.2.1 The vendor shall supply a complete lubricating oil piping system (with its mounted appurtenances) if it is to be located within the confines of the main unit base area or of any assembly (console) base or packaged unit accessory. The vendor shall provide interconnecting piping when auxiliary equipment is specified, to be located immediately adjacent to the compresssor in the vendor's recommended location. See 8.1.2, 8.1.3 and 11.1.6.

11.2.2 Gravity return lines shall be sized to run no more than half full when flowing at a velocity of 0,3 m/s (1 ft/s) and shall be arranged to ensure good drainage (recognizing the possibility of foaming conditions). Gravity return lines shall have a downward slope towards the reservoir of not less than 4 %. If possible, laterals (not more than one in any transverse plane) should enter drain headers at 45-degree angles in the direction of the flow.

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

11.2.4 Non-consumable back-up rings and sleeve-type joints shall not be used. Pressure piping downstream of oil filters shall be free from internal obstructions that could accumulate dirt. Socket-welded fittings shall not be used in pressure piping downstream of oil filters. (See Table 6)

11.2.5 Unless otherwise specified, oil piping (with the exception of cast-in-frame lines or passages) and tubing, including fittings, shall be of stainless steel. (Table 6)

11.2.6 After fabrication, oil lines shall be thoroughly cleaned.

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

11.3 Forced-feed lubricator tubing

11.3.1 Oil feed lines from force-feed lubricators to cylinder and packing lubrication points shall be at least 6 mm ($^1/_4$ in) outside diameter with a minimum wall thickness of 1,5 mm (0,065 in). Tubing shall be seamless austenitic stainless steel. Fittings shall be austenitic stainless steel. See 8.2 for check valves.

NOTE For high pressure compressors heavier wall thickness tubing may be required.

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

11.4 Coolant piping

11.4.1 If the purchaser does not specify the extent of coolant piping, the vendor shall supply piping with a single inlet and a single outlet connection on each cylinder requiring cooling. See Figure G.2, Plan C.

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

- **11.4.3** When coolant piping on the compressor is specified to be furnished by the vendor, the vendor shall supply a piping system for all equipment mounted on the compressor or compressor base. The piping shall be arranged to provide a single inlet connection and a single outlet connection for each water circuit operating at different inlet temperature levels and shall include a coolant control valve and a flow indicator as noted in 11.4.2. Series-type circuits shall have the necessary valved bypasses to provide temperature control.

11.4.4 Where a thermosyphon or a static cooling system is provided (see 6.1.3.1), the vendor shall furnish piping with a drain valve at its lowest point and an expansion tank (complete with fill-and-vent connections and level indication) sized to prevent overflow of coolant. See Figure G.2, Plans A and B. A thermometer is required for a thermosyphon system.

11.4.5 For coolant connections, purchaser's connections shall be flanged. Cylinder connections of DN 40 ($1^1/_2$ NPS) and smaller may be threaded.

11.5 Intrument piping

11.5.1 The vendor shall supply all necessary piping, valves and fittings for all instruments and instrument panels (see 10.3.4).

11.5.2 Connections on equipment and piping for pressure instruments and test points shall conform to 10.1.8. Initial connections for remote mounted pressure instruments shall comprise an isolation valve to the same standard as the system to which it is connected. Beyond the initial isolation valve, tubing of not less than 10 mm ($^3/_8$ inch) outside diameter with appropriate valves and fittings may be used. When convenient, a common connection may be used for remotely mounted instruments that measure the same pressure. Separate secondary isolating valves are required for each instrument on a common connection. Where a pressure gauge is to be used for testing pressure alarm or shut-down switches, common connections are required for the pressure gauge and associated switches.

• **11.5.3** When specified, a test valve shall be supplied adjacent to all instruments. Test valves shall terminate with a plugged connection to the specified standards. Test valves may be combined with instrument valves supplied as described in 11.1.12.12 and 11.1.12.13.

11.6 Process piping

• **11.6.1** The extent of process piping to be supplied by the vendor shall be specified by the purchaser.

11.6.2 The requirements of 11.1 shall apply to process piping supplied by the vendor.

• **11.6.3** When compressor process inlet piping and pulsation suppression equipment are furnished by the vendor, provisions shall be made for the insertion of temporary start-up screens just upstream of the suction pulsation suppression device. The design of the piping system, the suction pulsation suppression device and the temporary start-up screens shall afford easy removal and reinsertion of the screens without the necessity of pipe springing. The design, location and orientation of the screens shall be agreed upon by both the purchaser and the vendor prior to manufacture or purchase. When specified, the vendor shall supply the removable spool pieces that accommodate temporary start-up screens. Sufficient pressure taps to allow monitoring of the pressure drop across the screen shall be provided.

12 Pulsation and vibration control

12.1 General

The basic techniques used for control of detrimental pulsations and vibrations are the following:

a) Pulsation suppression devices such as pulsation filters and attenuators, volume bottles without internals, choke tubes, orifice systems and selected piping configurations.

b) System design based on studies of the interactive effects of pulsations and the attenuation requirements for satisfactory level of piping vibration, compressor performance and valve life.

c) Mechanical restraints including such things as type, location and number of pipe hold-downs.

NOTE Completion of purchaser requirements for pulsation suppressors (data sheet page 4, lines 12 to 23 and pages 13 and 14) is essential for the vendor to quote and fabricate these accessories. See annex A.

12.2 Design approaches

- **12.2.1** The purchaser shall specify the design approach for pulsation and vibration control. The purchaser shall also indicate when existing compressors and their associated piping systems are to be included in the acoustic simulation (see 12.2.8). One of the following techniques is normally used.

— **Design approach 1:** Pulsation control through the use of pulsation suppression devices designed using proprietary and/or empirical analytical techniques to meet pulsation levels required in 12.2.5 based on the normal operating condition. If specified, a simplified analysis of the purchaser's piping system shall be performed to determine critical piping length that may be in resonance with acoustic harmonics. Acoustic simulation analysis is not required.

— **Design approach 2:** Pulsation control through the use of pulsation suppression devices using proven acoustic techniques in conjunction with mechanical analysis of pipe runs and anchoring systems (clamp design and spacing) to achieve control of vibrational response. This approach includes the evaluation of acoustic interaction between compressor, suppression devices and piping, including pulsation effects on compressor performance and an evaluation of acoustic shaking forces as specified in 12.2.6, items a) and b), to meet the requirements of 12.2.7. Thermal flexibility effects should be considered in the piping design.

NOTE 1 The interactive acoustic studies may be analogue simulation, digital simulation or a combination of the two.

— **Design approach 3:** The same as design approach 2, but in addition using a mechanical analysis of the compressor cylinder, compressor manifold and associated piping systems including interaction between acoustic and mechanical system responses as specified in 12.2.6. In addition, this approach includes a study of the acoustic effects of the compressor valves and gas passages interaction and verification of the compressor performance. Both acoustic and mechanical methods are used to arrive at the most efficient and cost effective plant design in compliance with the requirements of 12.2.7.

NOTE 2 A detailed description of the three design approaches is given in annex M. See also annex N.

12.2.2 Pulsation suppression devices and techniques shall satisfy the criteria listed in 12.2.2.1 to 12.2.2.5.

12.2.2.1 Pulsation and/or mechanically-induced vibration shall not cause a cyclic stress level in excess of the endurance limits of materials used for components subject to these cyclic loads. (For carbon steel pipe with an operating temperature below 370 °C (698 °F), the peak-to-peak cyclic stress range shall be less than 180 N/mm^2 (26 000 psi) considering all stress concentration factors present and with all other stresses within applicable code limits.)

NOTE It is not considered necessary to demonstrate compliance with this sub-clause for design approaches 1 and 2.

12.2.2.2 For design approach 1 and for initial commercial sizing, pulsation suppression devices on the suction and discharge side shall have minimum surge volumes, excluding liquid collection chambers, determined from equations (1) and (2), but in no case shall either volume be less than 0,03 m^3 (1 ft^3).

$$V_S = 8V_{TD}\left(\frac{kT_S}{M}\right)^{1/4} \qquad (1)$$

or in US customary (imperial) units:

$$V_S = 7V_{TD}\left(\frac{kT_S}{M}\right)^{1/4}$$

$$V_d = 1.6\frac{V_S}{r1/K} \qquad (2)$$

But no larger than V_S

where:

V_s is the minimum required suction surge volume in cubic metres (cubic feet);

V_d is the minimum required discharge surge volume in cubic metres (cubic feet);

k is the average isentropic compression exponent;

T_s is the suction temperature in kelvin (degrees Rankine).;

M is the molar mass;

V_{TD} is the total net displaced volume, in cubic metres (cubic feet) per revolution of all compressor cylinders to be manifolded in the surge volume;

r is the stage pressure ratio at cylinder flanges (absolute discharge pressure divided by absolute suction pressure).

When, by appropriate mathematical models, it is predictable that the simulation study required by design approach 2 and 3 will alter these sizes, the vendor may select this alternate sizing giving full description of the assumptions, methods and sizes in his proposal.

The internal diameter of the surge volume shall be based on the minimum surge volume and the overall length required to manifold the compressor cylinders. For single-cylinder surge volume, the ratio of surge volume length to internal diameter shall not exceed 4. The inside diameter of spherical volumes shall be calculated directly from the volume determined by equations (1) and (2).

NOTE Equations (1) and (2) are intended to ensure that reasonably sized pulsation suppression devices are included with the compressor vendor's proposal and should provide satisfactory sizes for most applications. In some instances however, it will be necessary to alter the sizes based on the simulation study employed by design approach 2 and 3. Sizing requirements may be substantially influenced by the effects of operating parameters, interaction among elements of the overall system and mechanical characteristics of the compressor manifold system. The magnitude of these effects cannot be accurately predicted at the outset.

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

12.2.2.3 Unless other criteria (such as loss in compressor efficiency) are specified, the unfiltered peak-to-peak pulsation level at the compressor cylinder flange, as a percentage of average absolute line pressure, shall be limited to 7 % or that determined by equation (3), whichever is lower.

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

where:

P_{cf} is the maximum permissible unfiltered peak-to-peak pulsation level expressed as a percentage of average absolute line pressure at the compressor cylinder flange;

r is the stage pressure ratio.

For those special cases where maximum pulsation levels exceed these values with the use of reasonable modifications, higher limits may then be used as agreed by the purchaser and compressor vendor.

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

12.2.2.4 Unless otherwise specified, the pressure drop, based on steady flow through a pulsation suppression device at the manufacturer's rated capacity, shall not exceed 0,25 % of average absolute line pressure at the device, or the percentage determined by equation (4), whichever is higher.

$$\Delta p = 1{,}67 \frac{r-1}{r} \% \qquad (4)$$

Where:

Δp is the maximum pressure drop based on steady flow through a pulsation suppression device expressed as a %age of the average absolute line pressure at the inlet of the device;

r is the stage pressure ratio.

When a moisture separator is an integral part of the pulsation suppression device, the pressure drop based on steady flow through such a device at manufacturer's rated capacity, shall not exceed 0,33 % of the average absolute line pressure at the device, or the percentage determined by equation (5), whichever is higher.

$$\Delta p = 2{,}17 \frac{r-1}{r} \% \qquad (5)$$

Pressure drops specified in this subclause may be exceeded by mutual agreement between purchaser and vendor, when this is the consequence of the preferred solution to piping resonance problems (see annex M, Item C).

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

12.2.3 The following limits shall apply to the normal operating conditions.

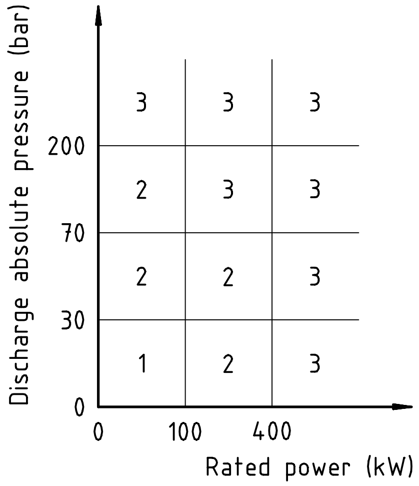
a) For design approaches 1, 2 and 3 permissible pulsations at cylinder flanges shall not exceed equation (3).

b) For design approach 1 permissible pulsations at the line side of the suppressor shall not exceed equation (6).

c) For design approaches 2 and 3 permissible pulsations in the piping system shall not exceed that allowed by 12.2.7.

NOTE The purchaser should be aware that the application of the pulsation limits to a new compressor that will operate in parallel with existing compressor(s) could result in pulsation levels higher than those allowed in this International Standard. (See 12.2.8).

12.2.4 The chart below gives guidelines in specifying the appropriate design approach.



NOTE Confirmation by knowledgeable personnel, of the design approach selected, should be encouraged. This is particularly important if there is interaction with another compressor and/or the compressor is required to operate on gases of significantly different molar masses or other critical applications.

12.2.5 Pulsation suppression devices used in accordance with design approach 1 shall limit peak-to-peak pulsation levels at the line side of the pulsation suppression device to a value determined by use of equation (6).

$$p_1 = \frac{4}{p_L^{1/3}} \qquad (6)$$

or in US customary (imperial) units:

$$p_1 = \frac{10}{p_L^{1/3}}$$

where:

p_1 is the maximum permissible peak-to-peak pulsation level at any discrete frequency, expressed as a percentage of mean absolute line pressure;

p_L is the mean absolute line pressure in bar (pounds per square inch absolute).

12.2.6 Acoustic evaluation for design approaches 2 and 3 shall be accomplished with proven acoustic simulation techniques that model the compressor cylinders, pulsation suppression devices, piping and equipment system and that consider dynamic interaction among these elements. Mechanical evaluation for design approach 3 shall include an analysis of compressor cylinder manifold and piping systems, including pulsation suppression devices and the study of the interaction between acoustic and mechanical system responses at specified operating conditions. In addition to the requirements stipulated in 12.2.2, the following steps are required to accomplish the proper evaluation for design approaches 2 and 3. (See also annex M.)

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

b) Determination and control of acoustic unbalanced forces produced within the pulsation suppression devices, piping, heat exchangers or vessels with internals: location of inlet and outlet nozzles, internal baffles and choke tubes shall be arranged to minimize these forces. See 12.3.9, 12.3.17 and 12.4.

c) Determination and control of significant pulsation amplitudes at the compressor cylinder valves: of particular importance are the frequencies that fall within the range of the mechanical natural frequencies of the valves, generally in the range of 50 to 100 Hz. Acoustic response within this range in the valve ports or at the valves has been known to cause valve failures.

d) For design approach 3, determination of the mechanical response of the system, including, but not limited to, the following factors:

— mechanical natural frequencies and mode shapes of the piping and supports;

— mechanical natural frequencies and mode shapes of the cylinder manifold systems;

— mechanical natural frequencies of major supporting steelwork, such as pipe racks, air cooled exchangers etc.

This analysis shall also establish permissible limits for pulsation-induced shaking forces in the system based on the cyclic stress levels they can produce.

e) For design approach 3, determination of the required pulsation suppression based on acoustic and mechanical responses and their interactions: to obtain the desired vibration/pulsation control, selective use should be made of both acoustic and mechanical control techniques. These techniques include the elimination of coincidences between acoustic and mechanical resonant frequencies, the use of acoustic filtering techniques and changes in mechanical configurations.

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

12.2.6 For design approaches 2 and 3 based on normal operating conditions, the peak-to-peak pulsation levels in the initial suction, interstage and final discharge piping systems beyond pulsation suppression devices shall satisfy the requirements of 12.2.2.

12.2.7.1 For systems operating at absolute line pressures between 3,5 bar and 200 bar, this requirement is usually satisfied when the peak-to-peak pulsation level of each individual pulsation component is limited to that calculated by use of equation (7).

$$p_1 = \frac{400}{\sqrt{p_L} \times d_i \times f} \qquad (7)$$

or in US customary (imperial) units:

$$p_1 = \frac{300}{\sqrt{p_L} \times d_i \times f}$$

where:

p_1 is the maximum permissible peak-to-peak level of individual pulsation components corresponding to the fundamental and harmonic frequencies, expressed as a percentage of mean absolute line pressure;

p_L is the mean absoute line pressure in bar (pounds per square absolute);

d_i is the inside diameter of line pipe in millimetres (inches);

f is the pulsation frequency in hertz.

$$f = \frac{v \times z}{60}$$

where:

v is the shaft speed in s^{-1} (rpm);

z is 1, 2, 3,…, corresponding to the fundamental frequency and harmonics thereof.

For absolute pressures lower than 3,5 bar (50 psia), the peak-to-peak levels in bar of individual pulsation components shall not exceed the value calculated for an absolute pressure of 3,5 bar (50 psia). For absolute pressures greater than 200 bar (2 900 psia), the corresponding calculated cyclic stresses shall be carefully evaluated to ensure compliance with 12.2.2.1.

NOTE Pulsation limits may exceed the levels defined by 12.2.7, provided that all requirements in 12.2.2 are satisfied. In particular, exceeding these levels with gases having high sonic velocity is less likely to result in unacceptable stresses, because of the lower forces generated in the system.

12.2.7.2 It may also be necessary to limit flow pulsations in systems which include elements sensitive to such phenomena, e.g., flow meters, cyclone separators etc. The purchaser shall advise the vendor of the presence of any such sensitive elements outside the vendor's scope of supply.

- **12.2.7** When the compressor unit is to be operated in parallel with other compressor units, an interactive simulation study of the whole system should normally be specified. In such a case it may be necessary to impose tighter limits for each new compressor other than those defined in 12.2.7 in order to satisfy the requirements of 12.2.2. If the interactive study indicates a requirement for modifications to the existing system, such modifications shall be based on agreement between the purchaser and the vendor.

12.2.8 A written report on the control of pulsation and vibration shall be furnished to the purchaser. Compliance with the requirements of clause 12 for the specified design approach shall be documented.

12.3 Pulsation suppression devices

12.3.1 Pulsation suppression devices shall be designed and constructed in accordance with the agreed pressure design code.

12.3.2 The maximum permissible working pressure for any component shall not be less than the set pressure of the relief valve serving that component, and in any case shall not be less than a gauge pressure of 4 bar (60 psig).

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

12.3.3 All materials in contact with process gases shall be compatible with the gases handled. The corrosion allowance for carbon steel pulsation suppression equipment shall be a minimum of 3 mm ($^1/_8$ in) unless otherwise specified on the data sheet. Regardless of materials, all baffles and partitions shall have a minimum thickness of 9 mm ($^3/_8$ in). Welding procedure shall be submitted for purchaser's review [see vendor data sheet, F.3, 17)].

- **12.3.4** When specified, all butt welds shall be 100 % radiographed.

12.3.5 All flanged branch connections shall be reinforced in accordance with the applicable pressure vessel code. Additional reinforcement and/or local stress analysis may be required to take into account fatigue loads resulting from pulsations and vibrations. Stress concentration factors shall be considered to ensure compliance with 12.2.2.

- **12.3.6** Suction pulsation suppression devices, not provided with a moisture removal section, shall be designed to prevent the generation of liquid slugs. When specified, the suction pulsation suppression device(s) shall include a final moisture removal section as an integral part of the vessel. The moisture removal section shall have a reservoir extending below the device shell and shall be equipped with a drain connection of not less than DN 25, gauge glass connections and shut-down level switch connection. These connections shall be flanged and fitted with blinds. When specified, the drain valve, gauge glass and shut-down switch shall be furnished by the vendor. Pressure drop shall be as defined in 12.2.2.4.

NOTE Moisture removal sections of pulsation suppression devices have demonstrated a low separation efficiency. In the case of cylinders handling gases that are or can become saturated, it is recommended that appropriate means be used, in addition to the integral moisture removal section, to prevent liquid carry-over into the compressor cylinder.

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

12.3.8 Manufacturing tolerances and fit-up procedures for pulsation suppression device/compressor cylinder nozzle connections and line connections shall be adequate to allow bolting of flanges without strain, which may result in excessive stresses, misalignment or rod runout. This is particularly important when two or more cylinders are to be connected to the same pulsation suppression device. The forces induced by thermal expansion of the pulsation suppression devices shall be taken into account to avoid intolerable misalignment and excessive stresses during operation.

12.3.9 Orientation of the pulsation suppression devices and their nozzles shall be approved by the purchaser. Ratings, types and arrangements of all connections shall be agreed by the purchaser and the vendor.

- **12.3.10** A DN 20 ($^3/_4$ NPS) pressure test connection shall be provided at each pulsation suppressor line-side nozzle and, when specified, at each cylinder connection nozzle. An external drain connection at least DN 25, shall be provided for each compartment where practical. Where multiple drains are impractical, circular notched openings in the baffles, located at the low point of the vessel wall may be used with the purchaser’s approval. The effect of such drain openings on the performance of the pulsation suppression device must be considered. Arrangement of internals shall ensure that liquids flow to drain connections under all operating conditions.

- **12.3.11** The cylinder side nozzle of each discharge pulsation suppression device shall be provided with two connections located to permit, without interference, the purchaser’s installation of thermowells of at least 19 mm ($^3/_4$ in) in diameter, for a high-temperature alarm or shut-down element and a dial thermometer. When specified a similar thermowell connection shall also be provided for the cylinder side nozzle of each suction pulsation suppressor.

12.3.12 Main connections for compressor cylinder and process line shall be fitted with welding neck flanges unless otherwise specified by the purchaser. Flanged connections DN 40 ($1^1/_2$ NPS) and smaller shall be in accordance with 11.1.9.

12.3.13 Pulsation suppressors 450 mm (18 in) and greater in internal diameter shall have studded pad-type inspection openings at least 150 mm (6 in) in diameter, complete with blind flanges and gaskets to provide access to each compartment. For suppressors less than 450 mm (18 in) internal diameter, 100 mm (4 in) studded pad-type inspection openings are permitted.

Inspection openings shall be located in a position that provides maximum visual inspection capability of critical welds such as both sides of the baffles.

12.3.14 Pulsation suppression device connections other than those covered by 12.3.13 shall be flanged or threaded as specified on the data sheets. All threaded fittings shall have a minimum rating of Class 6000.

12.3.15 Unless otherwise specified, flanges shall be in accordance with ISO 7005-1, except that lap-joint and slip on flanges are not allowed. The finish of the gasket contact surface (flanged or machined bosses), other than ring-type joints, shall be between 3,2 μm and 6,4 μm (125 μin and 250 μin) arithmetic average roughness (*Ra*). Either a serrated-concentric or serrated-spiral finish having 0,6 mm to 1 mm pitch (24-40 grooves per inch) shall be used. The surface finish of the gasket grooves for ring joint connections shall conform to ANSI B16.5.

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

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

12.3.18 All butt welds shall be full penetration welds.

12.3.19 When agreed, internal surfaces of carbon steel pulsation suppression devices shall be covered with a coating of phenolic or vinyl resins suitable for the service conditions.

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

12.4 Supports for pulsation suppression devices

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

NOTE As far as possible, the foundation of the supports should be integral with the compressor foundation. When non-compliant adjustable supports are used, they should be adjusted by the purchaser to normal operating conditions.

13 Inspection and testing

13.1 General

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

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

13.1.3 The vendor shall provide sufficient advance notice to the purchaser before conducting any inspection or test that the purchaser has specified to be witnessed or observed.

- **13.1.4** The purchaser shall specify the extent of his participation in the inspection and testing and the amount of advance notification he requires.

NOTE Five working days is usually considered adequate notice for inspections and tests (see 13.3.1.3.).

13.1.4.1 When shop inspection and testing have been specified by the purchaser, the purchaser and the vendor shall meet to co-ordinate manufacturing hold points and inspector's visits.

13.1.4.2 "Witnessed" means that a hold point shall be applied to the production schedule and that the inspection or test shall be carried out with the purchaser or his representative in attendance. For mechanical running or performance tests, this requires during or after the advance notification, confirmation of successful preliminary tests carried out by the vendor.

13.1.4.3 "Observed" means that the purchaser shall be notified of the timing of the inspection or test, however, the inspection or test shall be performed as scheduled. If the purchaser or his representative is not present, the vendor shall proceed to the next step.

NOTE The purchaser should expect to be in the factory longer than for a witnessed test.

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

• **13.1.6** When specified, the purchaser's representative, the vendor's representative or both shall indicate compliance in accordance with the inspector's check-list (annex K) by initialling, dating and submitting the complete check-list to the purchaser before shipment.

13.1.7 The purchaser's representative shall have access to the vendor's quality-control programme for review.

13.2 Inspection

13.2.1 General

13.2.1.1 The vendor shall keep the following data available for at least 20 a (20 y) for examination by the purchaser or the purchaser's representative upon request, or for reproduction if necessary.

a) Necessary certification of materials, such as mill test reports.

b) Purchase specifications for all items on the bill of materials.

c) Test data to verify that the requirements of the specification have been met.

d) Results of documented tests and inspections including fully identified records of all heat treatment and radiography.

e) When specified, final-assembly, maintenance and running clearances.

f) A complete set of manuals with drawings and schematics.

NOTE The purchaser may specify or local regulations may require that these data be retained for a longer period.

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

• **13.2.1.3** In addition to the requirements of 13.2.2, the purchaser may specify the following:

a) Parts that shall be subjected to surface and subsurface examination.

b) The type of examination required, such as magnetic particle, liquid penetrant, radiographic and ultrasonic examination.

13.2.2 Material inspection

Regardless of the generalized limits in 13.2.2.1 to 13.2.2.5 it shall be the vendor's responsibility to review the design limits of the equipment in the event that more stringent requirements are necessary. Defects that exceed the limits imposed in 13.2.2.1 to 13.2.2.5 shall be removed in order to meet the quality standards cited, as determined by the inspection method specified.

13.2.2.1 General

When radiographic, ultrasonic, magnetic particle or liquid penetrant inspection of welds or materials is required or specified, the criteria in 13.2.2.2 to 13.2.2.5 shall apply unless other criteria are specified or agreed.

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

13.2.2.2 Radiography

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

13.2.2.2.2 The acceptance standard used for welded fabrications shall be Section VIII, Division 1, UW-5 of the ASME Code. The acceptance standard used for castings shall be Section VIII, Division 1, Appendix 7, of the ASME Code.

13.2.2.3 Unltrasonic inspection

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

13.2.2.3.2 The acceptance standard used for welded fabrications shall be Section VIII, Division 1, Appendix 12, of the ASME Code. The acceptance standard for steel castings shall be Section VIII, Division 1, Appendix 7, of the ASME Code. The acceptance criteria for steel forgings shall be determined by the manufacturer in accordance with ASTM A 388M.

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

13.2.2.4 Magnetic particle inspection

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

13.2.2.4.2 The acceptance standard used for welded fabrications shall be Section VIII, Division 1, Appendix 7 and Section V, Article 25 of the ASME Code. The acceptability of defects in castings shall be based on a comparison with the photographs in ASTM E 125. For each type of defect, the degree of severity shall not exceed the limits specified in Table 10.

Table 10 — Maximum severity of defects in castings

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

13.2.2.5 Liquid penetrant inspection

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

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

13.2.3 Mechanical inspection

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

• **13.2.3.2** When the oil system is specified to be run in the manufacturer's shop, it shall meet the test screen cleanliness requirements specified in ISO 10 438 (or API Std 614).

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

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

13.2.3.5 Unless otherwise specified, the equipment components or surfaces subject to corrosion shall be coated with the vendor's standard rust preventive immediately after inspection. Temporary rust preventive shall be easily removable with common petroleum solvents. The equipment shall be closed promptly upon the purchaser's acceptance thereof. See 14.3 for details.

13.3 Testing

13.3.1 General

13.3.1.1 Equipment shall be tested in accordance with 13.3.2 and 13.3.3. Other tests that may be specified by the purchaser are described in 13.3.4.

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

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

13.3.2 Hydrostatic and gas leakage tests

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

a) cylinder gas passages and bore: 1½ times maximum permissible working pressure, but not less than gauge pressure of 1,5 bar (20 psig);

b) cylinder cooling jackets and packing cases: 1½ times maximum permissible working pressure;

c) piping, pressure vessels, filters and other pressure-containing components: 1½ times maximum permissible working pressure or in accordance with applicable code, but not less than gauge pressure of 1,5 bar (20 psig).

Tests a) and b) shall be performed prior to the installation of the cylinder liner and utilizing job fasteners.

NOTE For gas pressure-containing parts, the hydrostatic test is not considered to be an acceptable or valid gas leak test.

13.3.2.2 The following gas test shall be performed to ensure that the components do not leak process gas. The leakage tests shall be conducted with the components thoroughly dried and unpainted. Compressor cylinders shall be leak-tested without liners, but with the following job components: heads, valve covers, clearance pockets and fasteners.

a) Pressure-containing parts such as compressor cylinders and clearance pockets handling gases with a molar mass of 12 or less or gases containing more than 0,1 mol % hydrogen sulfide, shall have, in addition to the hydrostatic test specified in 13.3.2.1, a pressure test using helium performed at the maximum permissible working pressure. Leak detection shall be by helium probe or by submergence in water. The water shall be at a higher temperature than the nil-ductility transition temperature of the material being tested. The internal pressure shall be maintained, while submerged, at the maximum permissible working pressure. Zero leakage is required (see 13.3.2.6). In the case of testing by helium probe, the procedure, the sensitivity of the instrument and the acceptance criteria shall be agreed upon.

b) Cylinders handling gases other than those described in a), shall undergo a gas leakage test as described in a), except the test gas may be air or nitrogen.

13.3.2.3 If the part tested is to operate at a temperature at which the strength of a material is below that at room temperature, the hydrostatic test pressure shall be multiplied by a factor obtained by dividing the permissible working stress for the material at room temperature by that at operating temperature. The pressure thus obtained shall then be the minimum pressure at which the hydrostatic test shall be performed. The data sheets shall list actual hydrostatic test pressures.

13.3.2.4 Tests shall be in accordance with the applicable recognized standard. In the event of a discrepancy exist between the code test pressure and the pressure in this International Standard, the higher pressure shall govern.

13.3.2.5 The chloride content of liquids used to test austenitic stainless steel materials shall not exceed 0,005 % (50 ppm). To prevent deposition of chlorides as a result of evaporative drying, all residual liquid shall be removed from tested parts at the conclusion of the test.

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

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

13.3.3 Mechanical running test

• **13.3.3.1** All compressors, drivers, and gear units shall be shop tested in accordance with the vendor's standard. When specified the shop test of the compressor shall comprise a 4 h unloaded running test.

13.3.3.2 When specified packaged units, including integral auxiliary system packages, shall receive a 4 h mechanical running test prior to shipment. The test shall prove mechanical operation of all auxiliary equipment, as well as the compressor, reduction gear, if any, and driver as a complete unit. The compressor need not be pressure-loaded for this test. The procedure for this running test shall be agreed upon by the purchaser and the vendor.

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

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

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

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

13.3.4 Other tests

13.3.4.1 A bar-over test of the frame and cylinder shall be made in the vendor's shop to verify piston end clearances and rod runout. All compressor cylinder valves shall be in place for the final bar-over test in order to demonstrate no piston interference. Vertical and horizontal piston rod runout (cold) at packing case flanges shall be measured during this test. See 6.1.2.1 and 6.3.6. Bar-over test results shall become a part of the purchaser's records [see F.4 60)].

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

13.3.4.3 All compressor suction and discharge cylinder valves shall be leak-tested in accordance with the vendor's standard procedure.

• **13.3.4.4** When specified, the compressor shall be subject to a performance test in accordance with ISO 1217.

14 Preparation for shipment

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

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

NOTE It is recognized that failure to follow these instructions may jeopardize successful operation of the equipment.

14.3 The equipment shall be prepared for shipment after all testing and inspection has been completed and the equipment has been released by the purchaser. The preparation shall include that specified in 14.3.1 to 14.3.14.

14.3.1 Equipment shall be completely free of water prior to any shipment preparation.

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

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

14.3.4 The interior of the equipment, including pulsation suppression devices, shall be clean, free from scale, welding spatter and foreign objects, and sprayed or flushed with a suitable rust preventive that is oil-soluble or can be removed with solvent. In lieu of a soluble rust preventive, a permanently applied rust preventive may be used with the prior approval of the purchaser.

14.3.5 Any paint exposed to lubricants shall be oil-resistant. When synthetic lubricants are used, special precautions shall be taken to ensure compatibility with the paint.

14.3.6 Flanged openings shall be sealed against the ingress of moisture and dirt and the joint surfaces shall be adequately protected against corrosion and mechanical damage. An acceptable method is the use of a 5 mm minimum thickness metal closure with an elastomeric gasket and attached with not less than four bolts. For studded openings, all nuts needed for the intended service shall be used to secure closures.

14.3.7 Threaded openings shall be sealed against the ingress of moisture and dirt and the thread shall be adequately protected against corrosion and mechanical damage. Adequate arrangements shall be made to ensure that temporary plugs or other closures cannot be accidentally left in place.

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

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

• **14.3.10** The equipment shall be packed for domestic or export shipment as specified. Lifting, load-out and handling instructions shall be securely attached to the exterior of the largest package in a well-marked weatherproof container. Where special lifting devices, such as spreader bars, are required the supply of these shall be subject to agreement. Upright position, lifting points, weight and dimensions shall be clearly marked on each package.

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

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

14.3.13 Exposed shafts and shaft couplings shall be wrapped with water-proof mouldable waxed cloth or volatile-corrosion-inhibitor paper. The seams shall be sealed with oil-proof adhesive tape.

14.3.14 Exterior surfaces of pulsation suppressors, piping and vessels shall be cleaned free of pipe scale, welding spatter and other foreign objects. Immediately after cleaning, external surfaces shall be painted with at least one coat of lead and chromate free primer.

14.4 Auxiliary piping connections furnished on the purchased equipment shall be impression stamped or permanently tagged to agree with the vendor's connection table or general arrangement drawing. Service and connection designations shall be indicated.

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

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

14.7 One copy of the manufacturer's installation manual as described in 15.3.7.2 shall be packed and shipped with the equipment.

15 Vendor's data

15.1 General

15.1.1 The information to be furnished by the vendor is specified in 15.2 and 15.3. The vendor shall complete and return the Vendor Drawing and Data Requirements (VDDR) form (see Annex F) to the address(es) noted on the inquiry or order. This form shall detail the schedule for transmission of drawings, curves, data and manuals as agreed to at the time of the proposal or order as well as the number and type of copies required by the purchaser.

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

a) purchaser/user's corporate name;

b) job/project number;

c) equipment item number and service name;

d) inquiry or purchase order number;

e) any other identification specified in the inquiry or purchase order;

f) vendor's identifying proposal number, shop order number, serial number or other reference required to completely identify return correspondence.

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

a) the purchase order, scope of supply and subvendor items (including spare parts);

b) a review of applicable specifications and previously agreed-upon exceptions to specifications;

c) the data sheets;

d) compressor performance (including operating limitations);

e) pulsation suppression devices;

f) schematics and bills of material (for major items) of lubricating-oil systems, cooling systems, distance pieces and similar auxiliaries;

g) the preliminary physical orientation of the equipment, piping and auxiliary systems;

h) drive arrangement and driver details;

i) instrumentation and controls;

j) scope and detail of pulsation and vibration analysis and control requirements (See Annexes M and N and 12.2.1);

k) identification of items for stress analysis review by purchaser. (See 7.5.1);

l) inspection, expediting and testing;

m) details of functional testing;

n) other technical items;

o) startup planning and training;

p) schedules for:

- transmittal of data;
- production;
- testing;
- delivery.

15.2 Proposals

15.2.1 General

The vendor shall forward the original and the specified number of copies of the proposal to the addressee stated on the inquiry documents. This proposal shall contain as a minimum the data specified in 15.2.2 and 15.2.3 and a specific statement that the system and all its components are in strict accordance with this International Standard. If the system and components are not in strict accordance, the vendor shall include a specific list that details and explains each deviation. The vendor shall provide details to evaluate any alternative designs proposed. All correspondence shall be clearly identified as listed in 15.1.2.

15.2.2 Drawings

• As a minimum the data listed in 15.2.2.1 to 15.2.2.3 shall be furnished. If the purchaser requires additional drawings with the proposal, this shall be clearly specified in the inquiry.

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

15.2.2.1 A preliminary general arrangement or outline drawing for each major skid or system showing overall dimensions, maintenance clearance dimensions, overall weight, erection weights and maintenance weights (indicate piece). Direction of rotation and size and location of major purchaser connections shall also be indicated.

15.2.2.2 Typical cross-sectional drawing(s) of the compressor proposed.

15.2.2.3 Schematics of all auxiliary systems including: lubricating-oil, cooling and distance piece vent and drain (when supplied). Auxiliary system schematic diagrams shall be marked to show which portions of the system are integral with or mounted on the major equipment and which are separate.

15.2.3 Technical data

The data described below shall be included.

a) Copies of the purchaser's data sheets complete with the vendor's information required for the proposal and literature to fully describe details of the offer(s).

b) The noise data as required by the purchaser in the inquiry.

c) A copy of the Vendor Drawing and Data Requirements form (see annex F) indicating the schedule according to which the vendor agrees to furnish the data requested by the purchaser (see 15.3).

d) Net and maximum operating weights, maximum shipping and erection weights with identification of the item and the maximum normal maintenance weight with identification of the item. These data shall be stated individually where separate shipments, packages or assemblies are involved. Approximate data shall be clearly identified as such. These data shall be entered on the data sheets where applicable.

e) For a compressor with a variable-speed drive, the speed range over which the unit can be operated continuously under the specified operating conditions.

f) The vendor shall specifically identify volumetric efficiency of the active end of any cylinder if it is less than 40 % at any specified operating condition.

NOTE Performance predictions with volumetric efficiencies below 40 % may not be reliable.

g) A schedule for shipment of the equipment expressed in weeks after receipt of the order.

h) A list of major wearing components showing interchangeability with other purchaser units.

i) A list of "start-up" spares, to include as a minimum, three lubricating-oil filter cartridge sets, plates and springs for each valve, one set of packing rings for each rod, one set of rings and wear bands for each piston, plus all "o"-rings and gaskets necessary for a complete changeout of all packing rings, all piston rings and all valves. The vendor shall add any items that his experience indicates are likely to be required on start-up.

j) Complete tabulation of utility requirements, such as steam, water, electricity, air, gas and lubricating oil; including the quantity of lubricating oil required and the supply pressure, the heat load to be removed by the oil and the nameplate power rating and operating power requirements of auxiliary drivers. Approximate data shall be defined and clearly identified as such. This information shall be entered on the data sheets.

k) A description of the tests and inspection procedures of materials as required by 13.2.2.

l) Complete details of any proposed air-cooled oil cooler.

m) A list of spare parts recommended that the purchaser should stock for normal maintenance purpose. The purchaser shall specify any special requirements for long term storage.

n) An itemized list of the special tools included in the offer.

o) A clear description of the metallurgy of all major components of the compressor (see 7.1.1 and 7.1.2).

p) A full description of the standard shop tests required in 13.3. Special tests as specified shall also be fully described.

q) A list of relief valves, specifying those furnished by the vendor, as required by 10.4.5.1.

r) A description of the vendor's intended response to any special requirements, such as those outlined in 5.5.1.

s) When specified, a list of similar machines installed and operating under analogous conditions to that proposed.

t) Any start-up, shut-down, or operating restrictions required to protect the integrity of the equipment.

u) An outline of all necessary special weather and winterizing protection required by the equipment, its auxiliaries and the driver (if furnished by the vendor) for start-up, operation and idleness. The vendor shall list separately the protective items he proposes to furnish.

v) Preliminary rod and gas load tabulation as described in 5.4.3.

15.3 Contract data

15.3.1 General

15.3.1.1 The contract information shall be furnished by the vendor as specified in the agreed VDDR form. Each drawing shall have a title block in the lower right hand corner with date of certification, reference to all identification data specified in 15.1.2, revision number and date and title. Similar information shall be provided on all other documents.

15.3.1.2 The purchaser shall return reviewed data submitted per the schedule agreed in the Vendor Drawing and Data Requirements (VDDR) with any comments.

15.3.1.3 Review does not constitute permission from the purchaser for the vendor to deviate from any requirements in the order unless specifically agreed upon in writing.

15.3.1.4 A complete list of all vendor data shall be included with the first issue of major drawings. The list will contain titles, drawing numbers and a schedule for transmission of all data the vendor will furnish. (See annex F). This list shall cross-reference data with respect to the items listed in the VDDR form.

15.3.2 Drawings

The drawing(s) furnished shall contain sufficient information so that when combined with the manuals covered in 15.3.7, the purchaser may properly install, operate and maintain the ordered equipment. Drawings shall be clearly legible and reproducible. Drawings made specifically for the order shall be identified as described in 15.1.2.

15.3.3 Performance data

• **15.3.3.1** When specified, the vendor shall submit performance curves or tables of power and capacity versus suction pressure with parameters of discharge pressure, showing the effects of unloading devices and showing any operating limitation and with calculation input and output data identified, all as mutually agreed between the vendor and the purchaser.

• **15.3.3.2** Rod-load and gas-load charts for each load step, complete in accordance with 5.4, including inertial forces and rod reversal magnitude and duration shall be furnished. When specified, the vendor shall furnish the data required for independent rod-load, gas-load and reversal calculations.

• **15.3.3.3** When specified, the effect of valve failure on rod loads and reversals shall be calculated and furnished. The required specifics of this study shall be mutually agreed upon by the purchaser and vendor.

15.3.3.4 Curves of starting torque versus speed shall be furnished for the compressor, for the motor at rated voltage and for the motor at the specified voltage reduction. The curve sheet shall also state separately the moment of inertia of the motor alone and the resultant moment of inertia of the driven equipment referred to the motor shaft speed plus the calculated time for acceleration to full speed at the specified voltages (see 9.1.2) and specified operating conditions (see 9.1.1.3 and 9.1.2.3). All curves shall be scaled in finite values. Percentages are not acceptable.

15.3.4 Technical data

Data shall be submitted in accordance with the VDDR form. The vendor shall provide full information to enable completion of the data sheets, first “as purchased” and then “as built”. This shall be done by correcting and filling in the data sheets and submitting copies.

If any drawing comments or specification revisions necessitate a change in the data, the vendor shall re-issue data sheets which will result in re-issue of the complete, corrected data sheets by the purchaser as part of the order specifications.

15.3.5 Progress reports

• When specified, the vendor shall submit progress reports to the purchaser at the interval specified on the VDDR form (annex F). The reports shall include engineering and manufacturing information for all major components. "planned” and “actual” dates for each separate milestone activity shall be indicated.

15.3.6 Recommended spares

The vendor shall submit a complete list of spare parts including those shown in his original proposal. This list shall include recommended spare parts for all equipment and accessories supplied, with cross-sectional or assembly type identification drawings, part numbers and conditions of delivery. Part numbers shall identify each part for interchangeability purposes. Standard purchased items shall be identified by the original manufacturer’s numbers. The vendor shall forward this list to the purchaser promptly after receipt of the reviewed drawings and in time to permit order and delivery of parts before field start-up. The transmittal letter shall be identified by the data listed in 15.1.2.

15.3.7 Manuals

15.3.7.1 General

The vendor shall provide sufficient written instructions and all drawings in order to enable the purchaser to correctly install, operate and maintain all the equipment ordered. This information shall be compiled in a manual (or manuals) with a cover sheet containing all reference-identifying data required in 15.1.2, an index sheet containing section titles and a complete list of referenced and enclosed drawings by title and drawing number. The manual shall be prepared specifically for this installation and shall not be “typical”.

15.3.7.2 Installation manual

Any special information required for proper installation, that is not on the drawings shall be compiled in a manual that may be separate from operating and maintenance instructions. This manual shall be forwarded at a time mutually agreed upon in the order, but not later than 30 days prior to shipment. An additional copy shall be shipped with equipment as required by 14.7. The manual shall contain, but not be limited to, information such as listed in annex F, all installation design data and any pertinent drawings/data.

15.3.7.3 Operating and maintenance manuals

The manual containing operating and maintenance data shall be forwarded in accordance with the requirements of the VDDR form, but no later than 30 d after shipment. The manual shall include sections to cover limiting operating conditions and special instructions for operations at specified extreme environmental conditions, such as temperatures. In addition it shall include, but not be limited to, the information listed in annex F.

15.3.7.4 Technical data manual

A manual containing technical data relevant to the equipment shall be submitted to the purchaser within 30 d of shipment. The manual shall include, but not be limited to, the information listed in annex F.

NOTE These data may have been previously issued for review as required by the VDDR.

Annex A
(informative)

Data sheets and check-list

A.1 Data sheets

	JOB NO. ______ ITEM NO. ______
	PURCHASE ORDER NO. ______
	SPECIFICATION NO. ______
RECIPROCATING COMPRESSOR	REVISION NO. ______ DATE ______
DATA SHEET	PAGE 1 OF 22 BY ______
ISO 13707 Appendix A	

Revision

NOTE: ○ INDICATES INFO. TO BE COMPLETED BY PURCH. □ BY MANUFACTURER WITH PROPOSAL ◇ BY MANUFACTURER AFTER ORDER ⌼ BY MANUFACTURER OR PURCHASER AS APPLICABLE

DATA SHEET STATUS: ○ PROPOSALS ○ PURCHASE ○ AS BUILT

FOR/USER ______ SITE/LOCATION ______ SERVICE ______ NO. REQ'D ______

COMPRESSOR MANUFACTURER ______ TYPE MODEL NO(S) ______ SERIAL NO(S) ______

COMPRESSOR THROWS: TOTAL NO. ______ NO. WITH CYLS. ______ NOMINAL FRAME RATING ______ BkW @ RATED RPM OF ______

□ MAXIMUM/MINIMUM ALLOWABLE SPEED ______ / ______ RPM

DRIVER MFGR. ______ DRIVER RATING/OPERATING SPEED ______ Kw / ______ RPM

DRIVE SYSTEM: ○ DIRECT COUPLED ○ GEARED & COUPLED ○ V-BELT

TYPE OF DRIVER: ○ IND. MOTOR ○ SYN. MOTOR ○ STEAM TURBINE ○ GAS TURBINE ○ ENGINE ○ OTHER ......

NO NEGATIVE TOLERANCE APPLIES: (NNT) ○ YES - PURCHASER TO FILL IN "REQUIRED CAPACITY" LINES. ○ NO - PURCHASER TO FILL IN "MANUFACTURER'S RATED CAPACITY" LINES

CYLINDERS: ○ LUBE ○ NON-LUBE

○ MAX ACCEPTABLE AVG PISTON SPEED ______ m/s MAX ACCEPTABLE ROTATIVE SPEED ______ RPM

OPERATING CONDITIONS (EACH MACHINE)

○ SERVICE OR ITEM NO.						
○ STAGE						
○ NORMAL OR ALTERNATE CONDITION						
○ CERTIFIED POINT (**X**) MARK ONE						
○ MOLAR MASS						
○ Cp/Cv (K) @ 65°C OR ______ °C						

INLET CONDITIONS: AT INLET TO: ○ PULSATION DEVICES ○ COMPRESSOR CYLINDER FLANGES

NOTE: ○ SIDE STREAM TO ______ STAGE(S), THESE INLET PRESSURES ARE FIXED

○ ABSOLUTE PRESSURE (bar) @ PULSATION SUPRESSOR INLET						
⌼ ABSOLUTE PRESSURE (bar) @ CYLINDER FLANGE						
○ TEMPERATURE (°C)						
○ REF: SIDE STREAM TEMPERATURES (°C)						
□ COMPRESSIBILITY (Z_S)						

INTERSTAGE: INTERSTAGE Δ P INCLUDES: ○ PULSE DEVICES ○ PIPING ○ COOLERS ○ SEPARATORS ○ OTHER ______

⌼ Δ P BETWEEN STAGES, %/bar	/	/	/	/	/

DISCHARGE CONDITIONS: AT OUTLET FROM: ○ PULSE DEVICE ○ COMPRESSOR CYLINDER FLANGES ○ OTHER ______

⌼ ABSOLUTE PRESSURE (bar) @ CYLINDER FLANGE						
○ ABSOLUTE PRESSURE (bar) @PULSATION SUPRESSOR OUTLET						
□ TEMPERATURE, ADIABATIC, °C						
□ TEMPERATURE, PREDICTED, °C						
□ COMPRESSIBILITY (Z_2) OR (Z_{AVG})						

*** REQUIRED CAPACITY,** RATED FOR PROCESS, AT INLET TO COMPRESSOR, NO NEGATIVE TOLERANCE (-0%)

○ kg/h CAPACITY SPECIFIED IS ○ WET ○ DRY						
○ STANDARD FLOW m³/h (1,013mb @ 0°C)						

*** MANUFACTURER'S RATED CAPACITY** (AT INLET TO COMPRESSSOR) & kW @ CERTIFIED TOLERANCE OF ±3% FOR CAP. & ±3% FOR kW

⌼ kg/h CAPACITY SPECIFIED IS ○ WET ○ DRY						
⌼ INLET VOLUME FLOW m³/h						
⌼ STANDARD FLOW m³/h (1,013 mb @ 0°C)						
□ POWER/STAGE Kw						
□ TOTAL POWER @ COMPRESSOR SHAFT Kw						
□ TOTAL POWER INCLUDING V-BELT & GEAR LOSSES Kw						

*** CAPACITY FOR NNT**

MANUFACTURER'S = REQUIRED ÷ 0.97

THEREFORE REQUIRED = MANUFATURER'S x 0.97

REMARKS: ______

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GAS ANALYSIS AT OPERATING CONDITIONS
MOLE % (BY VOLUME) ONLY

		M.W.					
○ SERVICE/ITEM NO.							
○ STAGE							
○ NORMAL OR ALTERNATE							
AIR		28.966					
OXYGEN	O_2	32.000					
NITROGEN	N_2	28.016					
WATER VAPOR	H_2O	18.016					
CARBON MONOX.	CO	28.010					
CARBON DIOX.	CO_2	44.010					
HYDRO. SULFIDE	H_2S	34.076					
HYDROGEN	H_2	2.016					
METHANE	CH_4	16.042					
ETHYLENE	C_2H_4	28.052					
ETHANE	C_2H_6	30.068					
PROPYLENE	C_3H_6	42.078					
PROPANE	C_3H_8	44.094					
I-BUTANE	C_4H_{10}	58.120					
n-BUTANE	C_4H_{10}	58.120					
I-PENTANE	C_5H_{12}	72.146					
n-PENTANE	C_5H_{12}	72.146					
HEXANE PLUS							
AMMONIA	NH_3	17.031					
HYDRO. CHLOR.	HCl	36.461					
CHLORINE	Cl_2	70.914					
CHLORIDES - TRACES							
☐ CALCULATED MOL. MASS kg/kmol							
☐ Cp/Cv (K) @ 65°C OR ______ °C							

NOTE: IF WATER VAPOR AND/OR CHLORIDES ARE PRESENT, EVEN MINUTE TRACES, IN THE GAS BEING COMPRESSED, IT MUST BE INCLUED ABOVE.

REMARKS

APPLICABLE SPECIFICATIONS

○ ISO 13707-
PETROLEUM AND NATURAL GAS INDUSTRIES
RECIPROCATING COMPRESSORS

○ NACE MR-O175 (2.14.1.10)

○ ______
○ ______
○ ______
○ ______
○ ______
○ ______
○ ______
○ ______

○ SITE/LOCATION CONDITIONS

ELEVATION ______ m BAROMETER ______ bar AMBIENT TEMPS: MAX ______ °C MIN ______ °C

○ MIN DESIGN METAL TEMPERATURE ____ °C RELATIVE HUMIDITY: MAX ______ % MIN ______ %

COMPRESSOR LOCATION: ○ INDOOR ○ HEATED ○ UNHEATED ○ AT GRADE LEVEL ○ ELEVATED: ______ m

○ OUTDOOR ○ NO ROOF ○ UNDER ROOF ○ PARTIAL SIDES ○ PLATFORM: ○ ON-SHORE

○ OFF-SHORE ○ WEATHER PROTECTION REQUIRED ○ TROPICALIZATION REQUIRED

○ WINTERIZATION REQUIRED

UNUSUAL CONDITIONS: ○ CORROSIVES ○ DUST ○ FUMES ○ OTHER ______

SITE ELECTRICAL CLASSIFICATION: ○ NON-HAZARDOUS ○ HAZARDOUS, ZONE .... GAS GROUP .... TEMPERATURE, CLASS

REMARKS/SPECIAL REQUIREMENTS: ______

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PART LOAD OPERATING CONDITIONS

1 CAPACITY CONTROL BY: ○ MANUFACTURER'S CAP. CONTROL ○ PURCHASERS BY-PASS ○ BOTH ○ OTHER ______
2 FOR: ○ PART LOAD CONDITIONS ○ START-UP ONLY ○ BOTH
3 WITH: ○ AUTO LOADING DELAY INTERLOCK (3.6.2.2) ○ AUTO IMMEDIATE UNLOADING
4 USING: ○ FIXED VOLUME POCK. ○ SUCTION VALVE UNLOADERS: ○ FINGER ○ PLUG ○ OTHER
5 ACTION: ○ DIRECT (AIR-TO-UNLOAD) ○ REVERSE (AIR-TO-LOAD/FAIL SAFE)
6 NUMBER OF STEPS: ○ TWO ○ THREE ○ FIVE ○ OTHER ______
7 ○ RAIN COVER REQUIRED OVER UNLOADERS
8 **ALL UNLOADING STEPS BASIS MANUFACTURERS CAPACITY SHOWN ON PAGE 1.**
9 **INLET AND DISCHARGE PRESSURE ARE** ○ **AT CYLINDER FLANGES** ○ **PULSATION SUPPRESSOR FLANGES**

10	○ SERVICE OR ITEM NO.						
11	[○] STAGE						
12	[○] NORMAL OR ALTERNATE CONDITION						
13	○ PERCENT CAPACITY						
14	○ WEIGHT FLOW, kg/h						
15	[○] STANDARD FLOW m³/h (1,013 bar @ 0°C)						
16	□ POCKETS/VALVES OPERATION *						
17	□ POCKET CLEARANCE ADDED %						
18	□ TYPE UNLOADERS, PLUG/FINGER						
19	[○] INLET TEMPERATURE, °C						
20	[○] INLET ABSOLUTE PRESSURE bar						
21	[○] DISCHARGE ABSOLUTE PRESSURE bar						
22	□ DISCHARGE TEMPERATURE, ADIABATIC °C						
23	□ DISCHARGE TEMPERATURE, PREDICTED °C						
24	□ VOLUMETRIC EFFICIENCY %HE / %CE	/	/	/	/	/	/
25	□ CALCULATED GAS ROD LOAD, C * kN						
26	□ CALCULATED GAS ROD LOAD, T **, kN						
27	◇ COMBINED ROD LOAD (GAS & INERTIA), C * kN						
28	◇ COMBINED ROD LOAD (GAS & INERTIA), T ** kN						
29	◇ ROD REVERSAL, DEGREES MIN @ X-HD PIN ***						
30	□ POWER PER STAGE kW						
31	□ TOTAL POWER @ COMPRESSOR SHAFT Kw						
32	□ TOTAL POWER INCL. V-BELT & GEAR LOSSES Kw						
33							

34 * SHOW OPERATION WITH THE FOLLOWING SYMBOLS:
35 SUCTION VALVE(S) UNLOADED = S
36 HEAD END = HE OR
37 OR PLUS FIXED POCKET OPEN = F
38 CRANK END = CE OR
39 VARIABLE POCKET OPEN = V
40
41 EXAMPLE: HE-F/CE-S = HEAD END FIXED POCKET OPEN / CRANK END SUCTION VALVE(S) UNLOADED.
42 * C = COMPRESSION **T = TENSION *** X - HD = CROSSHEAD
43 □ MINIMUM GAUGE PRESSURE REQUIRED TO OPERATE CYLINDER UNLOADING DEVICES, ______ bar
44 CYLINDER UNLOADING MEDIUM: ○ AIR ○ NITROGEN ○ OTHER ______
45 ○ GAUGE PRESSURE AVAILABLE FOR CYLINDER UNLOADING DEVICES, MAX/MIN ______ / ______ bar
46 **REMARKS, SPECIAL REQUIREMENTS, AND/OR SKETCH**
47
48
49
50
51

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○ **SCOPE OF BASIC SUPPLY**

1 PURCHASER TO FILL IN (□ ○ ⬡) AFTER COMMODITY TO INDICATE: □ BY COMPR. MFR. ○ BY PURCH. ⬡ BY OTHERS
2 ○ DRIVER (□ ○ ⬡): VARIABLE SPEED SPEED RANGE ______ RPM TO ______ RPM
3 ○ INDUCTION MOTOR ○ SYNCHRONOUS MOTOR ○ STEAM TURBINE ○ ENGINE ○ OTHER ______
4 ○ ISO 10436 ○ ISO 10437
5 ○ OUTBOARD BEARING ○ PROVISION FOR DRY AIR PURGE FOR OUTBOARD BEARING.
6 ○ SLIDE BASE FOR DRIVER (□ ○ ⬡) SOLE PLATE FOR DRIVER (□ ○ ⬡)
7 ○ MOTOR STARTING EQUIPMENT (□ ○ ⬡); DEFINE ______
8 ○ GEAR (□ ○ ⬡): ○ BASEPLATE FOR GEAR ○ ISO 13711
9 ○ COUPLING(S) (□ ○ ⬡): ○ LOW SPEED ○ HI-SPEED ○ QUILL SHAFT ○ KEY-LESS DRIVE ○ KEYED DRIVE
10 ○ OTHER ______ ○ ISO 10441
11 ○ V-BELT DRIVE (□ ○ ⬡): ○ SHEAVES & V-BELTS (□ ○ ⬡) ○ STATIC CONDUCTING V-BELTS ○ BANDED V-BELTS
12 ○ DRIVE GUARD(S) (□ ○ ⬡): ○ MANUFACTURER'S STD. ○ NON-SPARKING ○ CALIF CODE ○ ISO 10441 APPENDIX E
13 ○ AMUMINIUM PERMITTED ○ OTHER ______
14 ○ PULSATION SUPPRESSORS WITH INTERNALS (□ ○ ⬡): ○ INITIAL INLET & FINAL DISCHARGE ○ SUPPORTS (□ ○ ⬡)
15 ○ INTERSTAGE ○ SUPPORTS (□ ○ ⬡)
16 ○ PULSATION SUPPRESSORS WITHOUT INTERNALS (□ ○ ⬡): ○ INITIAL INLET & FINAL DISCHARGE ○ SUPPORTS (□ ○ ⬡)
17 ○ INTERSTAGE ○ SUPPORTS (□ ○ ⬡)
18 ○ SUPPRESSOR(S) TO HAVE MOISTURE REMOVAL SECTION: ○ INITIAL INLET ONLY ○ ALL INLET SUPPRESSORS
19 ○ ACOUSTICAL SIMUL. STUDY (□ ○ ⬡): DESIGN ○ 1, W/SIMPLIFIED ANALYSIS OF PIPING SYSTEM
20 ○ DIGITAL ○ ANALOG APPROACH ○ 2, SEE 12.2 AND ANNEX N
21 (Check Only One) ○ 3, SEE 12.2 AND ANNEX N
22 NOTE: SEE ANNEX N FOR STUDY TO ALL SPECIFIED LOAD COND., INCL. ○ SINGLE ACT., PLUS
23 INFORMATION REQUIRED FOR STUDY CONSIDER: ○ COMP.OPER.IN PARALLEL ○ ALTERNATE GASES
24 ○ WITH EXISTING COMP. AND PIPING SYSTEMS
25 ○ STUDY TO BE WITNESSED ○ COMPRESSOR VALVE DYNAMIC RESPONSE
26 ○ VENDOR REVIEW OF PURCHASER'S PIPING ARRANGEMENT ○ PULSATION SUPRESS'N DEVICE LOW CYCLE FATIGUE ANALYSIS
27 ○ PIPING SYSTEM FLEXIBILITY
28 PACKAGED: ○ NO ○ YES (□ ○ ⬡) DEFINE BASIC SCOPE OF PACKAGING IN REMARKS SECTION, PAGE 5
29 ○ SKID ○ SOLEPLATE ○ BASEPLATE ○ BOLTS OR STUDS FOR SOLEPLT. TO FRAME ○ RAILS ○ CHOCK BLOCKS ○ SHIMS
30 ○ SUITABLE FOR COLUMN MOUNTING (UNDER SKID AND/OR BASEPLATE)
31 ○ LEVELING SCREWS ○ NON-SKID DECKING ○ LEVELLING PLATES
32 ○ DIRECT GROUTED ○ CEMENTED/MORTAR GROUT ○ EPOXY GROUT. MFR/TYPE ______ / ______
33 ○ INTERCLR(S) (□ ○ ⬡) ○ SEPARATOR(S) (□ ○ ⬡) ○ AFTERCLR(S) (□ ○ ⬡) **INTERCOOLERS:**
34 ○ INTERSTAGE PIP. (□ ○ ⬡): ○ PIPING MATCHMARKED ○ SHOP FITTED ○ MACHINE MTD.
35 ○ CONDENSATE SEPARATION & COLLECTION FACILITY SYSTEM PER 3.8.12 ○ OFF MOUNTED
36 ○ INLET STRAINER(S) (□ ○ ⬡): ○ INITIAL INLET ○ SIDESTREAM INLET ○ SPOOL PIECE FOR INLET STRAINERS
37 ○ MANIFOLD PIPING; ○ DRAINS ○ VENTS ○ RELIEF VALVES ○ AIR/GAS SUPPLY **FLANGE FINISH**
38 ○ RELIEF VALVE(S) (□ ○ ⬡): ○ INITIAL INLET ○ INTERSTAGE ○ FINAL DISCHARGE ○ ISO 13707 FLANGE FINISH
39 ○ RUPTURE DISC(S) (□ ○ ⬡) ○ THRU STUDS IN PIPING FLANGES REF 6.1.4.4 > 3.2 < 6.4
40 ○ CRANKCASE RAPID PRESSURE RELIEF DEVICE(S) (□ ○ ⬡) ○ FLANGE FINISH PER ANSI 16.5
41 ○ SPECIAL PIPING REQUIREMENTS PER 11.1.12.23. (DEFINE IN REMARKS SECTION NEXT PAGE) ○ SPECIAL FINISH ______
42 ○ INITIAL INLET, ○ INTERSTAGE SUCTION PIPING ARR'D FOR: ○ INSULATION (□ ○ ⬡) ○ HEAT TRACING (□ ○ ⬡)
43 ○ FOR ATMOSPHERIC INLET AIR COMPR. ONLY: ○ INLET AIR FILTER (□ ○ ⬡) ○ INLET FILTER -SILENCER (□ ○ ⬡)
44 ○ PREFERRED TYPE OF CYLINDER COOLING (□ ○ ⬡): ○ FORCED ○ THERMOSYPHON ______ STAGE CYL'(S)
45 ○ STATIC (STAND-PIPE) ______ STAGE CYL'(S)
46 ○ CYL. COOLING WATER PIPING (□ ○ ⬡) ○ MATCH M'RKED
47 ○ SINGLE INLET/OUTLET MANIFOLD & VALVES ○ SIGHT GL'SS(S)
48 ○ INDIVIDUAL INLET/ OUTLET PER CYL. ○ VALVE(S)
49 ○ CLOSED SYS. WITH WATER PUMP, C00LER, SURGE TANK, & PIPING
50 ○ SHOP RUN ○ ARR'D FOR HEATING JACKET AS WELL AS COOLING

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○ **SCOPE OF BASIC SUPPLY (Con't)**

○ SEPARATE COOLING CONSOLE (□ ○ ⬡): ○ ONE FOR EA. UNIT ○ ONE COMN TO ALL UNITS ○ DUAL PUMPS (AUX .& MAIN)
○ ARRANGED FOR HEATING JACKET WATER AS WELL AS COOLING

FRAME LUBE OIL SYSTEM (□ ○ ⬡): ○ AUX. PUMP ○ DUAL FILTERS WITH TRANSFER VALVE ○ SHOP RUN
○ CONTINUOUS FLOW IN SENSING LINE TO PRESSURE SWITCHES
○ EXTENDED TO MOTOR OUTBOARD BEARING

○ SEPARATE LUBE OIL CONSOLE (□ ○ ⬡): ○ SHOP RUN
ISO 13438 APPLIES (REFER TO NOTE OF 8.1.2.) ○ NO ○ YES

NOTE: PIPING BETWEEN ALL CONSOLES AND COMPRESSOR UNIT BY PURCHASER

○ CAPACITY CONTROL (□ ○ ⬡): ○ SEE DATA SHEET PAGE 3 FOR DETAILS ○ IN INSTRUMENT & CONTROL PANEL
○ SEPARATE MACHINE MOUNTED PANEL ○ SEPARATE FREE STANDING PANEL
○ PNEUMATIC ○ ELECTRIC ○ ELECTRONIC ○ HYDRAULIC
○ PROGRAMMABLE CONTROLLER

○ INSTRUMENT & CONTROL PANEL (□ ○ ⬡): ○ ONE FOR EACH UNIT ○ ONE COMMON TO ALL UNITS
○ MACHINE MOUNTED ○ FREE STANDING (OFF UNIT)

SEE INSTRUMENTATION DATA SHEETS FOR DETAILS OF PANEL, ADDITIONAL REMARKS, AND INSTRUMENTATION.

NOTE: ALL TUBING, WIRING, & CONNECTIONS BETWEEN OFF-UNIT FREE STANDING PANELS AND COMPRESSOR UNIT BY PURCHASER.

○ HEATERS (□ ○ ⬡): ○ FRAME LUBE OIL ○ CYL. LUBRICATORS ○ COOLING WATER ○ DRIVER(S) ○ GEAR OIL
○ ELECTRIC ○ STEAM

○ BARRING DEVICE (□ ○ ⬡): ○ MANUAL ○ PNEUMATIC ○ ELECTRIC ○ FLYWHEEL LOCKING DEVICE (□ ○ ⬡)
○ ROD PRESSURE PACKING COOLING SYSTEM (□ ○ ⬡): ○ SEPARATE CONSOLE ○ FILTERS
○ SPECIAL CORROSION PROTECTION: ○ NO ○ YES ○ MFR'S STANDARD ○ OTHER ____
○ HYDRAULIC TENSIONING TOOLS ○ NO ○ YES ○ IF YES, STATE FOR WHICH BOLTING ____
○ MECHANICAL RUN TEST: ○ NO ○ YES ○ MANUFACTURER'S STANDARD ○ OTHER ____
○ COMPLETE SHOP RUN TEST OF ALL MACHINE MOUNTED EQUIPMENT, PIPING & APPURT.'(S)

PAINTING: ○ MANUFACTURER'S STANDARD ○ SPECIAL ____
NAMEPLATES: ○ SI UNITS ○ OTHER UNITS
SHIPMENT: ○ DOMESTIC ○ EXPORT ○ EXPORT BOXING REQUIRED (□ ○ ⬡)
○ STANDARD 6 MONTH STORAGE PREPARATION (□ ○ ⬡), PER SPECIFICATION ____
○ OUTDOOR STORAGE FOR OVER 6 MONTHS (□ ○ ⬡), PER SPECIFICATION ____

○ INITIAL INSTALLATION AND OPERATING TEMP ALIGNMENT CHECK AT JOBSITE BY VENDOR REPRESENTATIVE
○ COMPRESSOR MANUFACTURER'S USER'S/INSTALLATION LIST REQUIRED ○ FOR SIMILAR SERVICE ONLY
○ PERFORMANCE DATA REQUIRED PER 15.3.3.1.: ○ POWER vs SUCTION PRESSURE CURVES
○ ROD LOAD/GAS LOAD CHARTS
○ VALVE FAILURE DATA CHARTED
○ SPEED/TORQUE CURVE DATA
○ POWER vs CAPACITY PERFORMANCE CURVES OR TABLES REQUIRED FOR UNLOADING STEPS
AND / OR VARIABLE SUCTION / DISCHARGE PRESSURES: ○ YES ○ NO
○ REPORT - VALVES DYNAMIC (6.2.9.)

APPLICABLE SPECIFICATIONS: ____

REMARKS: ____

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UTILITY CONDITIONS

ELECTRICAL POWER: AC VOLTS / PHASE / HERTZ / DC VOLTS

	AC VOLTS	PHASE	HERTZ	DC VOLTS
○ MAIN DRIVER	____	____	____	____
○ AUXILIARY MOTORS	____	____	____	____
○ HEATERS	____	____	____	____
○ INSTRUMENT	____	____	____	____
○ ALARM & SHUTDOWN	____	____	____	____
○ ____	____	____	____	____

INSTRUMENT AIR: NORMAL GAUGE PRESSURE ____ bar MAX/MIN GAUGE PRESSURE ____ / ____ bar

STEAM FOR: DRIVERS | HEATERS

DRIVERS			HEATERS		
PRESSURES ARE GAUGE PRESSURES			PRESSURES ARE GAUGE PRESSURES		
INLET: PRESS ____ bar	MAX/MIN	____ / ____ bar	INLET: PRESS ____	MAX/MIN	____ / ____
(NORM.) TEMP ____ °C	MAX/MIN	____ / ____ °C	(NORM.) TEMP ____ °C	MAX/MIN	____ / ____ °C
EXH'ST: PRESS ____ bar	MAX/MIN	____ / ____ bar	EXH'ST:PRESS ____	MAX/MIN	____ / ____
(NORM.) TEMP ____ °C	MAX/MIN	____ / ____ °C	(NORM.) TEMP ____ °C	MAX/MIN	____ / ____ °C

COOLING WATER FOR: **COMPRESSOR CYLINDERS** | **COOLERS**

COMPRESSOR CYLINDERS			COOLERS		
TYPE WATER ____			TYPE WATER ____		
PRESSURES ARE GAUGE PRESSURES			PRESSURES ARE GAUGE PRESSURES		
SUPP.: PRESS ____	MAX/MIN	____ / ____	SUPP.: PRESS ____	MAX/MIN	____ / ____
(NORM.) TEMP ____ °C	MAX/MIN	____ / ____ °C	(NORM.) TEMP ____ °C	MAX/MIN	____ / ____ °C
R'T'RN: PRESS ____	MAX/MIN	____ / ____	R'T'RN: PRESS ____	MAX/MIN	____ / ____
(NORM.) TEMP ____ °C	MAX/MIN	____ / ____ °C	(NORM.) TEMP ____ °C	MAX/MIN	____ / ____ °C

COOLING FOR ROD PACKING:
TYPE FLUID ____ SUPPLY GAUGE PRESSURE: ____ bar @ ____ °C RETURN ____ bar @ ____ °C

FUEL GAS: NORMAL GAUGE PRESSURE ____ bar MAX/MIN GAUGE PRESSURES ____ / ____ bar
LHV ____ MJ/m³
COMPOSITION ____

REMARKS/SPECIAL REQUIREMENTS:

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1	○ CYLINDER DATA AT FULL LOAD CONDITION							
2	SERVICE/ITEM NO.							
3	STAGE							
4	INLET ABSOLUTE PRESSURE, bar } @ CYLINDER							
5	DISCHARGE ABSOLUTE PRESSURE, bar } FLANGES							
6	CYLINDERS PER STAGE							
7	SINGLE OR DOUBLE ACTING (SA OR DA)							
8	BORE, mm							
9	STROKE, mm							
10	RPM: RATED / MAX ALLOW	/						
11	PISTON SPEED, m/s: RATED / MAX ALLOW	/						
12	CYLINDER LINER, YES/NO							
13	LINER NOMINAL THICKNESS, mm							
14	PISTON DISPLACEMENT, m³							
15	CYLINDER DESIGN CLEARANCE, % AVERAGE							
16	VOLUMETRIC EFFICIENCY, % AVERAGE							
17	VALVES, INLET/DISCHARGE, QTY PER CYL.	/	/	/	/	/	/	
18	TYPE OF VALVES							
19	VALVE LIFT, INLET/DISCHARGE, mm	/	/	/	/	/	/	
20	VALVE VELOCITY (6.2.1.) m/s							
21	SUCTION VALVE(S)							
22	DISCHARGE VALVE(S)							
23	ROD DIAMETER, mm							
24	MAX ALLOWABLE COMBINED ROD LOADING. C * kN							
25	MAX ALLOWABLE COMBINED ROD LOADING. T ** kN							
26	CALCULATED GAS ROD LOAD. C * kN							
27	CALCULATED GAS ROD LOAD. T ** kN							
28	COMBINED ROD LOAD (GAS + INERTIA). C * kN							
29	COMBINED ROD LOAD (GAS + INERTIA). T ** Kn							
30	ROD REVERSAL, DEGREES MIN @ X-HD PIN***							
31	RECIPROCATING MASS. (PISTON, ROD, X-HD & NUTS), kg							
32	MAX ALLOWABLE WORKING GAUGE PRESSURE, bar							
33	MAX ALLOWABLE WORKING TEMPERATURE, °C							
34	HYDROSTATIC TEST GAUGE PRESSURE, bar							
35	HELIUM TEST GAUGE PRESSURE, bar							
36	INLET FLANGE SIZE/RATING	/	/	/	/	/	/	
37	FACING							
38	DISCHARGE FLANGE SIZE/RATING	/	/	/	/	/	/	
39	FACING							
40	DISCHARGE RELIEF VALVE SETTING DATA AT INLET PRESSURES GIVEN ABOVE:							
41	RECOMMENDED SETTING, bar							
42	GAS ROD LOAD, C * kN							
43	GAS ROD LOAD, T ** kN							
44	COMBINED ROD LOAD, C * kN							
45	COMBINED ROD LOAD, T ** kN							
46	ROD REVERSAL, °MIN @ X-HD PIN**							
47	NOTE: CALCULATED AT INLET PRESSURES							
48	GIVEN ABOVE & RECOMMENDED SETTING.							
49	○ SETTLE-OUT GAS PRESSURE							
50	(DATA REQUIRED FOR STARTING), bar							
51	* C = COMPRESSION ** T = TENSION	***X-HD = CROSSHEAD						
52	**NOTES/REMARKS:**							

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CONSTRUCTION FEATURES

1	SERVICE ITEM NO.						
2	STAGE						
3	CYLINDER SIZE (BORE DIAMETER), mm						
4	ROD RUN-OUT: NORMAL COLD VERTICAL (annex C)						
5	○ FABRICATED CYLINDER, HEADS & CONNECTION SKETCHES FOR DESIGN REVIEW BY PURCHASER (SEE 7.5.2.8.)						
6	**MATERIALS OF CONSTRUCTION**						
7	CYLINDER(S)						
8	CYLINDER LINER(S)						
9	PISTON(S)						
10	PISTON RINGS						
11	WEAR BANDS ○ REQUIRED						
12	PISTON ROD(S): MATERIAL/YIELD, N/mm²	/	/	/	/	/	/
13	THREAD ROOT STRESS @ MACCRL * @ X-HD END						
14	PISTON ROD HARDNESS, BASE MATERIAL, HRc						
15	PISTON ROD COATING ○ REQUIRED						
16	COATING HARDNESS, HRc						
17	VALVE SEATS / SEAT PLATE						
18	VALVE SEAT MIN HARDNESS, HRc						
19	VALVE GUARDS (STOPS)						
20	VALVE DISCS						
21	VALVE SPRINGS						
22	ROD PRESSURE PACKING RINGS						
23	ROD PRESSURE PACKING CASE						
24	ROD PRESSURE PACKING SPRINGS						
25	SEAL / BUFFER PACKING, DISTANCE PIECE						
26	SEAL / BUFFER PACKING, INTERMEDIATE						
27	WIPER PACKING RINGS						
28	MAIN JOURNAL BEARINGS, CRANKSHAFT						
29	CONNECTING ROD BEARING, CRANKPIN						
30	CONNECTING ROD BUSHING, X-HD END						
31	CROSSHEAD (X-HD) PIN BUSHING						
32	CROSSHEAD PIN						
33	CROSSHEAD						
34	CROSSHEAD SHOES						
35	CYLINDER INDICATOR VALVES (**X**)						
36	INDICATOR CONNECTIONS ABOVE 300 bar						
37	FLUOROCARBON SPRAYED CYLINDER BORE (**X**)						
38	INSTRUMENTATION IN (**X**) COLD SIDE						
39	CONTACT W/PROCESS GAS (**X**) HOT SIDE						
40	* MAXIMUM ALLOWABLE CONTINUOUS COMBINED ROD LOAD	USE (**X**) IN APPROPRIATE COLUMN WHERE APPLICABLE					

41	○ COMPRESSOR CYLINDER ROD PACKING	DISTANCE PIECE(S): ○ TYPE A ○ TYPE B ○ TYPE C ○ TYPE D Ref: Annex I
42	○ FULL FLOATING PACKING WITH STAINLESS STEEL SPRINGS	COVERS: ○ SOLID METAL ○ SCREEN ○ LOUVERED
43	○ VENTED TO: ○ FLARE @ ____ ○ ATMOS.	GAUGE PRESSURES CYLINDER COMPARTMENT: (Outboard Distance Piece) FRAME COMPARTMENT: (Inboard Distance Piece)
44	○ SUCTION GAUGE PRESSURE @ ____ bar	○ VENTED TO ____ bar ____ bar
45	○ FORCED LUBRICATED ○ NON-LUBE ○ TFE	○ PURGED AT ____ bar ____ bar
46	○ WATER COOLED, ____ STAGE(S), ____ m³/h REQ'D	○ PRESSURIZED TO ____ bar ____ bar
47	○ OIL COOLED, ____ STAGE(S), ____ m³/h REQ'D	○ W/ RELIEF VLVE VENTED TO ____ bar ____ bar
48	○ WATER FILTER PROV.FUTURE WATER/OIL COOLING	○ SEAL/BUFFER GAS PACKING ARRAGEMENT (Annex I)
49	○ VENT/BUFFER GAS SEAL PACKING ARRANGEMENT (Annex I)	○ FRAME END (ADJACENT TO WIPER PACKING)
50	○ CONSTANT OR ○ VARIABLE DISPOSAL SYSTEM	○ INTERMEDIATE SEAL PACKING, BUFFER/PURGE GAS ○ NITROGEN ○ OTHER
51	○ BUFFER GAS GAUGE PRESSURE ____ bar	○ VENT, DRAIN, PURGE PIPING BY MFR ○ NO ○ YES
52	○ SPLASH GUARDS FOR WIPER PACKING	☐ DISTANCE PIECE MAWP ____ bar W/ RELIEF VALVE

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CONSTRUCTION FEATURES (CONTINUED)

COUPLING(S) ○ LOW-SPEED Between Compressor & Driver or Gear ○ HI-SPEED Between Driver & Gear

◇ BY MANUFACTURER ______ ______

◇ MODEL ______ ______

◇ TYPE ______ ______

ISO 10441 APPLIES ○ YES ○ NO

INSPECTION AND SHOP TESTS (REF. 13.1.3)

	REQ'D	WITN.	OBSER.
*SHOP INSPECTION	○	○	○
ACTUAL RUNNING CLEARANCES AND RECORDS	○	○	○
MFG STANDARD SHOP TESTS	○	○	○
CYLINDER HYDROSTATIC TEST	○	○	○
CYLINDER PNEUMATIC TEST	○	○	○
CYLINDER HELIUM LEAK TEST	○	○	○
CYL. JACKET WATER HYDRO TEST	○	○	○
*MECHANICAL RUN TEST (4 HR)	○	○	○
BAR-OVER TO CHECK ROD RUNOUT	○	○	○
*LUBE OIL CONSOLE RUN/TEST (4 HR)	○	○	○
*COOLING WATER CONSOLE RUN/TEST	○	○	○
RADIOGRAPHY BUTT WELDS	○	○	○
○ GAS ○ OIL ○ FABRICATED CYLINDERS			
MAG PARTICLE/LIQUID PENETRANT OF WELDS	○	○	○
SPECIFY ADDITIONAL REQUIREMENTS (13.2.1.3)			
______	○	○	○
QC OF INACCESSIBLE WELDS (7.5.2.4)	○		
SHOP FIT-UP OF PULSATION SUPPL. DEVICES & ALL ASSOCIATED GAS PIPING	○	○	○
*CLEANLINESS OF EQUIP., PIPING, & APPURTENANCES	○	○	○
*HARDNESS OF PARTS, WELDS & HEAT AFFECTED ZONES	○	○	○
*NOTIFICATION TO PURCHASER OF ANY REPAIRS TO MAJOR COMPONENTS	○		
______	○	○	○
______	○	○	○
______	○	○	○

APPENDIX K COMPLIANCE: ○ VENDOR ○ PURCHASER

*NOTE
SPECIFIC REQUIREMENTS TO BE DEFINED, FOR EXAMPLE, DISMANTLING, AUX EQUIPMENT OPERATIONAL & RUN TESTS.

V-BELT DRIVE

	DRIVEN SHEAVE (Compressor Shaft)	DRIVE SHEAVE (Driver Shaft)
RPM (EXPECTED)	______	______
PITCH DIAMETER	______ mm	______ mm
◇ QTY & GROOVE X-SEC.	______	______
POWER TRANSMITT'D	______ Kw	______ Kw Incl. Belt Losses

DRIVER NAMEPLATE RATING ______ Kw

◇ CENTER DISTANCE ______ mm

◇ QTY, TYPE, X-SEC., & LENGTH BELTS ______

◇ BELT SERVICE FACTOR (RELATIVE TO DRIVER NAMEPLATE RATING) ______

CYLINDER LUBRICATION

○ NON-LUBE ______ STAGE(S)/SERVICE

○ LUBRICATED ______ STAGE(S)/SERVICE

TYPE OF LUBE OIL: ○ SYNTHETIC ______ ○ HYDROCARBON ______

LUBRICATOR DRIVE BY: ☐ COMP. CRANKSHAFT, DIRECT ☐ CHAIN, FROM CRANKSHAFT ○ ELECTRIC MOTOR ○ OTHER ______

◇ LUBRICATOR MFR ______

◇ MODEL ______

TYPE LUBRICATOR: (8.2.1.1.) ○ SINGLE PLUNGER PER POINT ○ DIVIDER BLOCKS ______

◇ COMPARTM'T, TOTAL QTY. ______

◇ PLUNGERS (PUMPS), TOTAL QTY. ______

◇ SPARE PLUNGERS, QTY. ______

◇ SPARE COMPARTM'T W/OUT PLUNGERS, QTY ______

○ HEATERS: ○ ELECTRIC W/THERMOSTAT ○ STEAM

☐ **ESTIMATED WEIGHTS AND NOMINAL DIMENSIONS**

☐ TOTAL COMPRESSOR, LESS DRIVER & GEAR ______ kg

◇ COMPLETE UNIT, (LESS CONSOLES) ______ kg

◇ MAXIMUM FOR ERECTION ______ kg

◇ MAXIMUM FOR MAINTENANCE ______ kg

◇ DRIVER/GEAR ______ / ______ kg

◇ LUBE OIL/COOLING WATER CONS. ______ / ______ kg

◇ FREE STANDING PANEL ______

SPACE REQUIREMENTS-m	LENGTH	WIDTH	HEIGHT
◇ COMPLETE UNIT	______	______	______
◇ LUBE OIL CONSOLE	______	______	______
◇ COOLING WATER CONSOLE	______	______	______
◇ FREE STANDING PANEL	______	______	______

☐ PISTON ROD REMOVAL DIST. ______

OTHER EQUIPMENT SHIPPED LOOSE (DEFINE)

◇ PULSATION SUPP., WEIGHT ______ kg

◇ PIPING ______ kg

◇ INTERSTAGE EQUIPMENT ______ kg

______ ______ kg

______ ______ kg

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CONSTRUCTION FEATURES (CONTINUED)

UTILITY CONSUMPTION

ELECTRIC MOTORS

	RATING (kW)	LOCKED ROTOR CURRENT (A)	FULL LOAD STEADY STATE CURRENT (A)
MAIN DRIVER			
MAIN LUBE OIL PUMP			
AUX LUBE OIL PUMP			
MAIN COOLING WATER PUMP			
AUX COOLING WATER PUMP			
ROD PACKING COOLING PUMP			
CYLINDER LUBRICATOR			

MAIN DRIVER NON-STEADY STATE AMPS AT COMPRESSOR RATED HORSEPOWER (Induction Motors Only)

@ COMPRESSOR RATED POWER OF ______ Kw @ CURRENT PULSATIONS OF ______ %

Note: for induction motors see note of 6.7.5. and motor data sheet

ELECTRIC HEATERS

	POWER (Kw)	VOLTAGE (V)	FREQUENCY (Hz)
FRAME OIL HEATER(S)			
COOLING WATER HEATER(S)			
CYL. LUBRICATOR HEATER(S)			

STEAM

	FLOW		PRESSURE		TEMPERATURE		BACK PRESSURE	
MAIN DRIVER		kg/h @		(bar)		°C TO		(bar)
FRAME OIL HEATER(S)		kg/h @		(bar)		°C TO		(bar)
CYL. LUB. HEATER(S)		kg/h @		(bar)		°C TO		(bar)
		kg/h @		(bar)		°C TO		(bar)
		kg/h @		(bar)		°C TO		(bar)

COOLING WATER REQUIREMENTS

	FLOW m³/h	INLET TEMP °C	OUTLET TEMP °C	INLET PRESS (bar)	OUTLET PRESS (bar)	MAX PRESS (bar)
CYLINDER JACKETS						
INTERCOOLER(S)						
AFTERCOOLER						
FRAME LUBE OIL COOLER						
ROD PRESSURE PACKING*						
TOTAL QUANTITY, m³/h						

*ROD PACKING COOLANT MAY BE OTHER THAN WATER

REMARKS/SPECIAL REQUIREMENTS:

NOTE: Except where specifically stated otherwise, all pressures shown are GAUGE PRESSURES

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FRAME LUBE OIL SYSTEM

1 **BASIC LUBE OIL SYSTEM FOR FRAME:** SPLASH PRESSURE (FORCED) HEATERS REQUIRED: STEAM
2 TYPE MAIN BEARINGS: TAPERED ROLLER PRECISION SLEAVE OTHER ______ ELEC. W/THERMOSTAT(S)
3 **PRESSURE SYSTEM:** MAIN OIL PUMP DRIVEN BY: COMP. CRANKSHAFT ELEC. MOTOR OTHER ______
4 PSV FOR MAIN PUMP EXTERNAL TO CRANKCASE ______
5 AUXILIARY OIL PUMP DRIVEN BY: ELEC. MOTOR OTHER ______
6 HAND OPERATED PRE-LUBE PUMP FOR STARTING OPERATIONAL TEST & 4 HOUR MECH RUN TEST
7 ISO 10438 LUBE SYSTEM: NO YES (See Note of 8.1.2.) CHECK VALVE ON MAIN PUMP (FIG G-4)
8 CONTINUOUS FLOW THROUGH OIL (8.1.3.3.)
9 **SEP. CONSOLE FOR PRESS. LUBE SYS:** ONE CONSOLE PER COMPR'R ONE CONSOLE FOR ______ COMPRESSORS
10 Note: Instrumentation to be listed on CONSOLE TO BE OF DECK PLATE TYPE CONSTRUCTION SUITABLE FOR
11 Instrumentation Data Sheets. MULTI-POINT SUPPORT AND GROUTING WITH GROUT & VENT HOLES.
12 ELECTRICAL CLASSIFICATION : ZONE ______ , GAS GROUP ______ , TEMP. CLASS ______ NON-HAZARDOUS

13 **BASIC SYSTEM REQUIREMENTS (NORMAL OIL FLOWS & VOLUMES):**

	FLOW m^3/h	PRESSURE (bar)	VISCOSITY ISO 3448	VISCOSITY OTHER	SUMP VOLUME m^3
14–15 LUBE OIL					
16 COMPRESSOR FRAME					
17 DRIVER					
18 GEAR					

19 SYSTEM PRESSURES: DESIGN ______ (bar) HYDROTEST ______ (bar)
20 PRESSURE CONTROL VALVE SETTING @ ______ (bar) PUMP RELIEF VALVE(S) SET ______ (bar)

21–22 **PIPING MATERIALS:**

	CARBON STEEL	STAINLESS STEEL WITH SS FLANGES	STAINLESS STEEL WITH CARBON STEEL FLANGES
23 UPSTREAM OF PUMPS & FILTERS	O	O	O
24 DOWNSTREAM OF FILTERS	O	O	O
25 ______	O	O	O
26 ______	O	O	O

27–28 **PUMPS** (Gear or Screw Type Only)

	RATED FLOW m^3/h	PRESSURE (bar)	COLD START REQ'D (Kw)	DRIVER RATING (Kw)	SPEED RPM	COUPLING REQ'D	MECH. SEAL REQ'D
29 MAIN						O	O
30 AUXILIARY						O	O

31 PUMP CASING MATERIAL (Ref. 2.12.3.1): MAIN PUMP ______ AUX PUMP ______
32 GUARD(S) REQ. FOR COUPLING(S): MAIN PUMP AUX PUMP GUARD TYPE OR CODE ______
33 AUXILIARY PUMP CONTROL: MANUAL AUTOMATIC ON-OFF-AUTO SEL. SWITCH: BY PURCH. BY MFR.
34 WIRING TO TERMINAL BOX: BY PURCH. BY MFR.
35 SWITCHES RTD'S/THERMOCOUPLES

36 **COOLERS:** SHELL & TUBE SINGLE DUAL W/TRANSFER VALVE MFG'S STD. ASME VIII OTHER
37 REMOVABLE BUNDLE WATER COOLED AIR COOLED W/AUTO TEMP CONTROL PLATE TYPE
38 W/BYPASS & TEMP CONTROL VALVE: MANUAL AUTO (SELF ACTUATED)
39 Note: See separate heat exchanger data sheet for details. Specify % glycoil on coling water side. AUTO (PNEUMATICALLY ACTUATED)

40 **FILTER(S)** SINGLE DUAL W/TRANSFER VALVE MFR'S STANDARD ASME VIII OTHER ______
41 CODE STAMP REQUIRED
42 DESIGN PRESSURE, ______ bar ΔP CLEAN, ______ bar ΔP COLLAPSE, ______ bar
43 NOMINAL RATING, ______ µm CARTRIDGE MATERIAL, ______ CARTRIDGE PART N° ______
44 BONNET MATERIAL, ______ CASING MATERIAL, ______ FURN.SPARE CARTR.,QTY ______

45 **SYS. COMPONENT SUPP.**

	MANUFACTURER	MODEL		MANUFACTURER	MODEL
46 MAIN PUMP			OIL COOLER(S)		
47 AUXILIARY PUMP			TRANSFER VALVE(S)		
48 MECHANICAL SEALS			PUMP COUPLING(S)		
49 ELECTRIC MOTORS			SUCTION STRAINER(S)		
50 STEAM TURBINES			CHECK VALVE(S)		
51 OIL FILTER(S)			______		

52 NOTE: Except where specifically stated otherwise, all pressures shown are GAUGE PRESSURES

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COOLING WATER SYSTEM

1 ○ **COOLING SYS. REQ'D FOR:** ○ COMPRESSOR CYL.(S) ○ INTERCOOLER(S) ○ AFTERCOOLER ○ OIL COOLER(S) ○ ROD PACKINGS

2 ○ HEATERS REQ.'D FOR PRE-HEATING: ○ ELEC.,W/ THERMOSTAT(S) ○ STEAM

3 ○ **PRESSURE FORCED CIRCULATING SYS:** ○ OPEN PIPING BY: ○ PURCH. ○ MFR ○ CLOSED, PIPING BY MFR.

4 MAIN WATER PUMP DRIVEN BY: ○ ELEC. MOTOR ○ STEAM TURBINE ○ OTHER ______

5 AUX WATER PUMP DRIVEN BY: ○ ELEC. MOTOR ○ STEAM TURBINE ○ OTHER ______

6 ○ **SEP. CONSOLE FOR COOLING WATER SYS.:** ○ ONE CONSOLE PER COMP. ○ ONE CONSOLE FOR ______ COMP'RS

7 NOTE: Instrumentation to be Listed on Instrumentation Data Sheets ○ CONSOLE TO BE OF DECK PLATE TYPE CONSTRUCTION SUITABLE FOR

8 MULTI-POINT SUPPORT AND GROUTING WITH GROUT & VENT HOLES.

9 ○ ELECTRICAL CLASSIFICATION : ○ ZONE ______, GAS GROUP ______, TEMPERATURE CLASS ______ ○ NON-HAZARDOUS

10 ○ **BASIC SYS. REQ'MTS (NORM. COOLING WATER FLOW DATA)** ○ COOL'G WATER TO BE ______ % ETHYL'NE GLYC'L

Line		FORCED COOLING	THERMO SYPHON	STAND PIPE	FLOW m³/h	PRESSURE (bar)	INLET TEMP °C	OUTLET TEMP °C	FLOW GLASS
13	CYLINDER(S), ___ STAGE	○	○	○	___	___	___	___	○
14	CYLINDER(S), ___ STAGE	○	○	○	___	___	___	___	○
15	CYLINDER(S), ___ STAGE	○	○	○	___	___	___	___	○
16	CYLINDER(S), ___ STAGE	○	○	○	___	___	___	___	○
17	CYLINDER(S), ___ STAGE	○	○	○	___	___	___	___	○
18	CYLINDER(S), ___ STAGE	○	○	○	___	___	___	___	○
19	PRESSURE PACKING TOTAL	○			___	___	___	___	○
20	INTERCOOLER(S) TOTAL	○			___	___	___	___	○
21	AFTERCOOLER	○			___	___	___	___	○
22	OIL COOLER(S)	○			___	___	___	___	○
23	___	○			___	___	___	___	○
24	TOTAL FLOW				___				

25 □ **SYS. PRESSURES:** □ DESIGN, ______ bar □ HYDROTEST, ______ bar ○ RELIEF VALVE(S), SETTING ______ bar

26 ○ **WATER RESERVOIR:** ◇ SIZE, ______ mm DIA X ______ mm HT. ◇ CAPACITY ______ m³ @ Normal Operating Level

27 ◇ RESERVOIR MATERIAL ______ ◇ INTERNAL COATING, TYPE ______

28 RESERVOIR LOCATION ○ ABOVE COMPRESSOR ○ BELOW COMPRESSOR

29 ○ LEVEL GAUGE ○ LEVEL SWITCH ○ DRAIN VALVE ○ INSPECTION & CLEAN-OUT OPENINGS

Line	□ **PUMPS: (Centrifugal Only)**	◇ RAT'D FL'W m³/h	◇ PRESS. (bar)	◇ SHAFT PWR kW	◇ DRIVER RTG kW	◇ SPEED RPM	COUPLING REQ'D	MECH.SEAL REQ'D
32	MAIN	___	___	___	___	___	○	○
33	AUXILIARY	___	___	___	___	___	○	○

34 □ PUMP CASING MATERIAL MAIN PUMP ______ AUX PUMP ______

35 ○ GUARD(S) REQ.'D FOR COUP'G(S) ○ MAIN PUMP ○ AUX PUMP ○ GUARD TYPE OR CODE ______

36 ○ AUX.PUMP CONTROL: ○ MANUAL ○ AUTO ○ ON-OFF-AUTO SEL. SWITCH: ○ BY PURCH. ○ BY MANUFACTURER

37 ○ WIRING TO TERMINAL BOX: ○ BY PURCH. ○ BY MANUFACTURER

38 ○ **COOLING WATER HEAT EXCH.:** ○ SHELL & TUBE ○ SINGLE ○ DUAL W/TRANSFER VALVE ○ TEMA C ○ TEMA R

39 ○ AIR COOLED EXCHANGER WITH TEMPERATURE CONTROL VALVE ○ PLATE TYPE

40 ○ W/BYPASS & TEM. CONTROL VALVE ○ MANUAL ○ AUTO ○ LOUVERS FOR AIR EXCH.

41 NOTE: See separate cooler data sheet for details, specify % Glycol on both shell and tube sides

Line	**SYS. COMPONENT SUPP.**	MANUFACTURER	MODEL		MANUFACTURER	MODEL
43	◇ MAIN PUMP	___	___	◇ TEMP CONTROL VALVE(S)	___	___
44	◇ AUXILIARY PUMP	___	___	◇ TRANSFER VALVE(S)	___	___
45	◇ MECHANICAL SEALS	___	___	◇ PUMP COUPLING(S)	___	___
46	◇ ELECTRIC MOTORS	___	___	◇ ___	___	___
47	◇ STEAM TURBINES	___	___	◇ ___	___	___
48	◇ HEAT EXCHANGER(S)	___	___	◇ ___	___	___
49	◇ ___	___	___	◇ ___	___	___
50	◇ ___	___	___	◇ ___	___	___

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PULSATION SUPPRESSION DEVICES FOR RECIPROCATING COMPRESSORS

THESE SHEETS TO BE FILLED OUT FOR EACH SERVICE AND/OR STAGE OF COMPRESSION

1 APPLICABLE TO: ○ PROPOSALS ○ PURCHASE ○ AS BUILT
2 FOR/USER
3 SITE/LOCATION ____ AMBIENT TEMPERATURE MIN/MAX ____ / ____ °C
4 COMPRESSOR SERVICE ____ MINIMUM DESIGN TEMPERATURE ____
5 COMPRESSOR MANUFACTURER. ____ NUMBER OF COMPRESSORS ____
6 SUPPRESSOR MANUFACTURER. ____ MODEL/TYPE
7 **GENERAL INFORMATION APPLICABLE TO ALL SUPPRESSORS**
8 TOTAL NUMBER OF SERVICES AND/OR STAGES ____
9 TOTAL NUMBER OF COMPRESSOR CYL. ____ TOTAL NUMBER OF CRANKTHROWS ____ STROKE ____ mm RPM ____
10 ○ PRESSURE VESSEL CODE ____ ○ CODE STAMP REQUIRED
11 ○ OTHER APPLICABLE PRESSURE VESSEL SPEC. OR CODE ____
12 ○ THIRD PARTY APPROVAL OF: ○DESIGN ○CONSTRUCTION BY: APPOINTED BY: ○PURCHASOR ○ VENDOR
13 RADIOGRAPHY OF WELDS: ○ NONE ○ SPOT ○ 100% ○ IMPACT TEST ○ SPECIAL WELDING REQUIREMENTS
14 ○ SHOP INSPECTION ○ WITNESS HYDROTEST ○ OUTDOOR STORAGE OVER 6 MONTHS ○ SPECIAL PAINT SPEC ____
15 ○ LUBE SERVICE ○ NON-LUBE SERV. ○ NO OIL ALLOWED INTERNALLY DRY TYPE INTER.CORROSION COATING ○ YES ○ NO
16 ACOUSTIC SIMULATION STDY, DESIGN APPROCH: ○1. ○1. W/SIMPLIFIED MANUAL ANALYSIS OF PIPING SYSTEMS
17 ○2. ACOUSTIC SIMULATION STUDY ○3. ACOUSTIC SIMULATION AND MECHANICAL RESPONSE
18 **CYLINDER, GAS, OPERATING, AND SUPPRESSOR DESIGN DATA**
19 SERVICE ____ STAGE NO. ____

20	○ COMPRESSOR CYLINDER DATA (THIS SERVICE ONLY)	No OF CYLINDERS ON CRANKSHAFT THROW(S) No:
21	☐ CLEARANCE VOLUME %: HE ____ CE ____	CRANK ANGLE(S) BETWEEN MANIFOLDED CYLINDER(S)
22	NOTES: ____	CYLINDER BORE DIAM: mm STROKE mm RPM
23		ROD DIAM: mm PISTON DISPLACEMENT m^3
24		UNLOADERS FOR ○START-UP ONLY ○CAP. CONTROL ○ NONE
25		OPERATING MODE ○DOUBLE ACTING ○SINGLE ACTING ○ BOTH
26	○ GAS HANDLED-SEE DATA SHEET P 1 FOR NORMAL:ALTERNATIVE	NORMAL OPERATING GAS
27	AND/OR START-UP CONDITION AND GAS	○ CORROSIVE PRESENT (DESCRIBE):
28		MOLAR MASS ____ Cp/Cv (K) ____ @65°C OR ____ °C
29	SEE GAS ANALISYS P 2 FOR COMPLETE GAS COMPOSITION AND	Z AT INLET ____ Z AT OUTLET ____
30	COMPRESSIBILITY FACTORS.	○OPERATION IN PARALLEL WITH: ____
31	☐ COMPRESSOR MANUFACTURER'S RATED CAPACITY ____ Kg/h	STANDARD VOLUME FLOW ____ m^3/h

32	○ LINE SIDE OPERATING ABSOLUTE PRESSURE	INLET, ____ (bar)	DISCHARGE, ____ (bar)
33	○ OPERATING TEMPERATURE WITHIN SUPPRESSORS	INLET, ____ °C	DISCHARGE, ____ °C
34	○ ALLOWABLE PRESSURE DROP THROUGH SUPPRESSORS	Δ P ____ bar / ____ %	Δ P ____ bar / ____ %
35		INLET SUPPRESSOR	DISCHARGE SUPPRESSOR
36	○ SUPRESSOR TAG NUMBER		
37	○ COMBINATION INLET SUPP SEPARATOR/INTERNALS	○ YES ○ NO / ○ YES ○ NO	/ ○ YES ○ NO
37	○ NO. (QTY) OF INLET & DISCH. SUPP. PER STAGE		
38	○ ALLOWABLE PEAK-PEAK PULSE @ LINE SIDE NOZZLE	bar / %	bar / %
39	○ ALLOWABLE PEAK-PEAK PULSE @ CYL FLANGE NOZZLE	bar / %	bar / %
40	○ DESIGN FOR FULL VACUUM CAPABILITY	○ YES ○ NO	○ YES ○ NO
41	○ MAWGP AND MINIMUM REQUIRED TEMPERATURE*	bar @ °C	bar @ °C
42	○ INITIAL SIZING VOL. PER FORMULA OF 12.2.2.2**	m^3	m^3

43 *NOTE: After design, the actual Mawgp & temp are to be determined based on the weakest component and stamped on the vessel. The actual Mawp
44 is to be shown on pg.14 line 9
45 **NOTE: This is a reference voloume only, final design volume to be shown on P 14 line 7
46 NOTE: Except where specifically stated otherwise, all pressures shown are GAUGE PRESSURES

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PULSATION SUPPRESSION DEVICES FOR RECIPROCATING COMPRESSORS (CONT'D) SERVICE ______

THESE SHEETS TO BE FILLED OUT FOR EACH SERVICE AND/OR STAGE OF COMPRESSION STAGE NO. ______

		INLET SUPPRESSOR	DISCHARGE SUPPRESSOR
1	**CONSTRUCTION REQUIREMENTS & DATA**		
2	○ SUPRESSOR TAG NUMBER		
3	○ BASIC MATERIAL REQUIRED, CS, SS, ETC.		
4	◇ ACTUAL MATERIAL DESIGNATION SHELL/HEAD	/	/
5	○ SPECIAL HARDNESS LIMITATIONS, HRC ○ YES ○ NO	○ SHELL & HEADS ○ WELDS	○ SHELL & HEADS ○ WELDS
6	▢ CORROSION ALLOWANCE., mm ○ REQUIRED	mm	mm
7	◇ WALL THICKNESS SHELL/HEAD	mm / mm	mm / mm
8	□ NOM. SHELL DIA X OVERALL LGTH.	x mm / m³	x mm / mm³
9	□ PIPE OR ROLLED PLATE CONSTRUCTION	□ PIPE □ ROLLED PLATE	□ PIPE □ ROLLED PLATE
10	◇ ACTUAL MAWGP AND TEMPERATURE	bar @ °C	bar @ °C
11	○ MINIMUM DESIGN METAL TEMP (7.8)	°C	°C
12	○ INLET SUPRESS. TO BE SAME MAWGP AS DISCH'RGE SUPPRESS.	○ YES ○ NO	
13	◇ MAX EXPECTED PRESSURE DROP(Δ P, %) LINE PRESS	Δ P bar / %	Δ P bar / %
14	◇ MASS (EACH)	kg	kg
15	○ INSUL NUTS & ALLOW. FOR INSULATION REQUIRED (**X**)		
16	◇ EXPECTED P-P PULSATION @ LINE SIDE/CYL FLANGE	% /	% /
17	◇ % LINE PRESS BASED ON FINAL SUPPRESSOR DESIGN	%	%
18	▢ SUPPORTS, TYPE/QUANTITY		
19	**CONNECTION REQUIREMENTS & DATA**		
20	○ LINE SIDE FLANGE. SIZE/RATING/FACING/TYPE		
21	○ COMP CYL FLANGE(S), QTY/SIZE/RATING/FACING/TYPE		
22	○ FLANGE FINISH, ○ PER 12.3.15 ○ SPECIAL (SPECIFY)		
23	○ INSPECTION OPENINGS REQUIRED (12.3.13.)	○ YES ○ NO ○ BLINDED	○ YES ○ NO ○ BLINDED
24	○ SPECIAL-QTY. SIZE, /FLG TYPE & RATING		
25	◇ * QTY. SIZE, /FLG TYPE & RATING		
26	○ VENT CONNECTIONS REQUIRED	○ YES ○ NO	○ YES ○ NO
27	○ SPECIAL-QTY. SIZE, /FLG TYPE & RATING		
28	◇ * QTY. SIZE, /FLG TYPE & RATING		
29	○ DRAIN CONNECTIONS REQUIRED	○ YES ○ NO	○ YES ○ NO
30	○ SPECIAL-QTY. SIZE, /FLG TYPE & RATING		
31	◇ * QTY. SIZE, /FLG TYPE & RATING		
32	○ PRESSURE CONNECTIONS REQUIRED	○ YES ○ NO	○ YES ○ NO
33	○ SPECIAL-QTY. SIZE, /FLG TYPE & RATING		
34	◇ * QTY. SIZE, /FLG TYPE & RATING		
35	○ ADDITIONAL TEMPERATURE CONNECTIONS REQUIRED (12.3.11.)	○ YES ○ NO	○ YES ○ NO
36	○ SPECIAL-QTY. SIZE, /FLG TYPE & RATING		
37	○ CYL NOZZLE ○ MAIN BODY		
38	◇ * QTY. SIZE, /FLG TYPE & RATING		
39	○ ADDITIONAL PRESSURE CONNECTIONS REQUIRED (12.3.11.)	○ YES ○ NO	○ YES ○ NO
40	**OTHER DATA AND NOTES**		
41	◇ COMPRESSOR MFG'S SUPP. OUTLINE OR DRAWING NO.		
42	◇ SUPP. MFG'S OUTLINE OR DRAWING NO.		
43			
44			
45			
46			
47			
48	NOTE: * INDICATES AS BUILT CONDITION		
49	REMARKS:		

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SHELL AND TUBE HEAT EXCHANGERS FOR RECIPROCATING COMPRESSORS

THESE SHEETS TO BE FILLED OUT FOR EACH EXCHANGER

1 APPLICABLE TO: ○ PROPOSALS ○ PURCHASE ○ AS BUILT
2 FOR/USER
3 SITE/LOCATION ____ AMBIENT TEMPERATURE MIN/MAX ____ / ____ °C
4 COMPRESSOR SERVICE ____ NUMBER OF COMPRESSORS ____
5 COMPRESSOR MANUFACTURER. ____ MODEL/TYPE ____
6 EXCHANGER MANUFACTURER.

7 **GENERAL INFORMATION APPLICABLE TO ALL EXCHANGERS**

8 TOTAL NUMBER OF SERVICES AND/OR STAGES ____
9 ○ PRESSURE VESSEL CODE ____ ○ CODE STAMP REQUIRED ○TEMA C ○TEMA R
10 ○ OTHER APPLICABLE PRESSURE VESSEL SPECIFICATIONS ____
11 ○ THIRD PARTY APPROVAL OF: ○DESIGN ○ CONSTRUCTION BY: ____ APPOINTED BY: ○ PURCHASOR ○ VENDOR
12 RADIOGRAPHY OF WELDS: ○NONE ○ SPOT ○ 100% ○ IMPACT TEST ○ SPECIAL WELDING REQUIREMENTS
13 ○ SHOP INSPECTION ○ WITNESS HYDROTEST ○ OUTDOOR STORAGE OVER 6 MONTHS ○ SPECIAL PAINT SPEC ____
14 ○ LUBE SERVICE ○ NON-LUBE SERV. ○ NO OIL ALLOWED INTERNALLY DRY TYPE INTER.CORROSION COATING ○ YES ○ NO
15 NOTES: USE THIS DATA SHEET FOR ALL PROCESS GAS EXCHANGERS AND SPECIAL OIL AND COOLING WATER COOLERS
16 USE STANDARD TEMA HEAT EXCHANGER SPECIFICATION FOR STANDARD OIL AND COOLING WATER COOLERS

18 **PERFORMANCE OF ONE EXCHANGER**

19 ○ THIS EXCHANGER IS FOR: ○INTERCOOLING BETWEEN & STAGE ○AFTERCOOLER DOUBLE PIPE: ○ YES ○NO
20 ○SPECIAL OIL COOLER ○ SPECIAL COOLING WATER COOLER
21 ○ COOLANT SIDE TO BE PER 5.1.3. ○YES ○NO ○TOTAL NUMBER OF IDENTICAL EXCHANGERS PER THIS DATA SHEET
22 ☐ DESIGN DUTY ____ Kw SIZE (HORIZONTAL/VERICAL)
23 ☐ TRANSFER RATE: SERVICE ____ W/m²K CLEAN ____ W/m²K MTD (EFF) ____ K
24 ☐ TOTAL SURFACE (EFF) ____ m² SHELL/UNIT ____ SURFACE PER SHELL (EFF) ____ m²

			SHELL SIDE		TUBE SIDE	
25			SHELL SIDE		TUBE SIDE	
26	○ FLUID					
27	○ TOTAL FLOW	kg/h				
28			INLET	OUTLET	INLET	OUTLET
29	○ LIQUID	kg/h				
30	○ DENSITY	kg/m³				
31	○ THERMAL CONDUCTIVITY	W/mK				
32	○ SPECIFIC HEAT	kJ/kg K				
33	○ KINEMATIC VISCOSITY	mm²/s				
34	○ ____ % GLYCOL IN WATER					
35						
36	○ VAPOUR	kg/h				
37	○ MOLAR MASS	kg/kmol				
38	○ DENSITY	kg/m³				
39	○ THERMAL CONDUCTIVITY	W/mK				
40	○ SPECIFIC HEAT	kJ/kg K				
41	○ KINEMATIC VISCOSITY	mm²/s				
42	○ LATENT HEAT	kJ/kg K				
43	○ DEW POINT AT OPERATING PRESSURE	°C				
44	○ NON CONDENSABLES	kg/h				
45	○ MOLAR MASS	kg/kmol				
46	○ STEAM LEFT IN GAS	kg/h				
47	○ WATER CONDENSED;	kg/h				

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SHELL AND TUBE HEAT EXCHANGERS FOR RECIPROCATING COMPRESSORS (CONT'D)

THESE SHEETS TO BE FILLED OUT FOR EACH EXCHANGER

			Shell side inlet	Shell side outlet	Tube side inlet	Tube side outlet
1	○ I/COOLING BETWEEN & STAGE ○ AFTERCOOLER		SHELL SIDE		TUBE SIDE	
2			INLET	OUTLET	INLET	OUTLET
3	☐ TEMPERATURE	°C				
4	☐ PRESSURE CONNECTIONS REQUIRED	bar				
5	◙ PRESSURE DROP	bar				
6	◙ VELOCITY	m/s				
7	◙ FOULING FACTOR	m²K/kW				
8	◙ DESIGN PRESSURE	bar				
9	☐ HYDROSTATIC TEST PRESSURE	bar				
10	☐ DESIGN TEMPERATURE	°C				
11	☐ CORROSION ALLOWANCE	mm				
12	☐ NUMBER OF PASSES					
13	☐ DIFFERENTIAL DESIGN PRESSURE	bar				
14	☐ FLOW ARRANGEMENT		PARALLEL	COUNTERFLOW	CROSSFLOW	

CONSTRUCTION (15)

16	☐ SHELL DIAMETER (OD/ID) mm / mm	☐ BAFFLE TYPE	☐ MASS OF BUNDLE & SHELL kg
17	☐ NUMBER OF TUBES	☐ No x SPACING x mm	◇ MASS BUNDLE kg
18	◙ TUBE OD x LENGTH	☐ SEGMENTAL CUT %	◇ MASS FULL OF WATER kg
19	◙ TUBE WALL THICKNESS mm x mm	◙ IMPIGEMENT BAFFLE (YES/NO)	◇ ρV INLET NOZZLE kg/m³s
20	☐ TUBE PITCH mm	☐ EXPANSION JOINT (YES/NO)	◇ ρV BUNDLE ENTRY kg/m³s
21	○ TEMA CLASS mm 30 60 90 45	☐ EXP.JOINT DESIGN TEMP. °C	◇ ρV BUNDLE EXIT kg/m³s
22	◙ VESSEL DESIGN CODE	◙ SURFACE PREPARATION	◙ TEMA TYPE
23	◙ CODE STAMP YES/NO	◙ PAINT	◙ FLOAT TUBE SHT ○ YES ○ NO
24	REMOVABLE TUBE BUNDLE YES/NO	○ INSULATION (YES/NO)	
25	TUBES ○ U-BEND ○ STRAIT	◙ BYPASS SEALS ARGEMNT (Y/NO)	SEAL TYPE LONG BAFFLE
26	SHELL COVER ○ INTEGRAL ○ REMOVABLE	◙ TUBE TO TUBESHEET JOINT: ○ ROLLED ○ WELDED ○ OTHER	

MATERIAL/ (Mark SR for stress-relieved, XR for radiographed (27)

28	◙ TUBES	◙ SHELL
29	◙ TUBE SHEET	◙ SHELL COVER
30	◙ BAFFLES/TUBE SUPPORTS	◙ SHELL FLANGE
31	◙ TIE RODS AND SPACERS	◙ CHANNEL/BONNET
32	◙ LONGITUDINAL BAFFLE	◙ CHANNEL COVER
33	◙ GASKET (SHELL SIDE)	◙ CHANNEL FLANGE
34	◙ GASKET (TUBE SIDE)	◙ FLOATING HEAD COVER
35	◙ BOLTING	◙ EXPANSION NO
36	◙ FLOATING HEAD GASKET	◙ FLOATING HEAD SEAL
37	◙	

38	NOZZLES	SHELL SIDE			TUBE SIDE		
39		No	SIZE	RATING & FACING	No	SIZE	RATING/FACING
40	◙ INLET		mm			mm	
41	◙ OUTLET		mm			mm	
42	◙ VENT		mm			mm	
43	◙ DRAIN		mm			mm	
44	◙ PRESSURE GAUGE (EA. NOZZLE)		mm			mm	
45	◙ THERMOWELL CONN. (EACH NOZZLE)		mm			mm	
46	◙ INTERCONNECTING CONNECTION		mm			mm	
47	◙ SPECIFY GAS SIDE FLANGE FINISH		mm			mm	

48 REMARKS: ALL PRESSURES ARE GAUGE PRESSURES. USE SEPARATE SKETCH FOR NOZZLE ORIENTATION

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INSTRUMENTATION

PURCHASER TO FILL IN (□ ○ ⬡) AFTER COMMODITY TO INDICATE: □ BY COMP. MFR. ○ BY PURCH. ⬡ BY OTHERS

INSTRUMENT & CONTROL PANEL (□ ○ ⬡): ○ ONE FOR EA. UNIT ○ ONE COMMON TO ALL UNITS
○ MACHINE MOUNTED ○ FREE STANDING (OFF UNIT) ○ LOCAL ○ REMOTE ○ OUTDOORS
○ PNEUMATIC ○ ELEC. ○ ELECTRONIC ○ HYDRAULIC ○ PROGRAMMABLE CONTL'R
○ ZONE ______ ,GAS GROUP ______ , TEMPERATURE CLASS ______ ○ INTRINSICALLY SAFE
○ Ex(d) ○ Ex(e) ○ Ex(p) ○ Ex(i) ○ I/S BARRIERS BY (□ ○ ⬡)
○ DEGREE OF PROTECTION (IEC 529): ______
○ OTHER ______
○ VIBRATION ISOLATORS ○ STRIP HEATERS ○ PURGE CONNECTION ○ EXTRA CUTOUTS
○ ANNUNCIATOR WITH FIRST-OUT INDICATION LOCATED ON CONTROL PANEL
○ PURCHASER'S CONNECTIONS BROUGHT OUT TO TERMINAL BOX BY VENDOR

ADDITIONAL PANEL REMARKS:

○ INSTRUMENTATION SUITABLE FOR: ○ INDOORS ○ OUTDOORS ○ OTHER ______

○ PREFERRED INSTRUMENT SUPPLIERS, (TO BE COMPLETED BY PURCHASER), OTHERWISE MANUFACTURER'S STANDARD APPLIES

PRESSURE GAUGES	MFR		SIZE & TYPE		MTL	
TEMPERATURE GAUGES	MFR		SIZE & TYPE		MTL	
LIQUID LEVEL GAUGES	MFR		TYPE		MTL	
DIFFERENTIAL PRESSURE GAUGES	MFR		SIZE & TYPE		MTL	
PRESSURE TRANSMITTERS	MFR		TYPE		MTL	
LIQUID LEVEL TRANSMITTERS	MFR		TYPE		MTL	
PRESSURE SWITCHES	MFR		TYPE		MTL	
TEMPERATURE SWITCHES	MFR		TYPE		MTL	
LIQUID LEVEL SWITCHES	MFR		TYPE		MTL	
DIFFERENTIAL PRESSURE SWITCHES	MFR		TYPE		MTL	
CONTROL VALVES	MFR		TYPE		MTL	
PRESSURE RELIEF VALVES	MFR		TYPE		MTL	
SIGHT FLOW INDICATORS	MFR		TYPE		MTL	
VIBRATION MONITORS & EQUIPEMENT	MFR		TYPE		MTL	
THERMOCOUPLES	MFR		TYPE		MTL	
RTD'S	MFR		TYPE		MTL	
SOLENOID VALVES	MFR		TYPE		MTL	
ANNUNCIATOR	MFR		MODEL & (QTY SPARE POINTS)	( )		
PROGRAMMABLE CONTROLLER	MFR		TYPE		MTL	
______	MFR		TYPE		MTL	
______	MFR		TYPE		MTL	

○ PRESSURE GAUGE REQUIREMENTS ○ LIQUID FILLED PRESSURE GAUGES: ○ YES ○ NO

FUNCTION	LOCALLY MOUNTED	PANEL MOUNTED	TRANSM.*	PROCESS GAS:	LOCALLY MOUNTED	PANEL MOUNTED
LUBE OIL MAIN PUMP DISCHARGE	(□ ○ ⬡)	(□ ○ ⬡)	○	INLET PRESS.	(□ ○ ⬡)	(□ ○ ⬡)
LUBE OIL AUX. PUMP DISCHARGE	(□ ○ ⬡)	(□ ○ ⬡)	○	@ EA. STAGE	(□ ○ ⬡)	(□ ○ ⬡)
LUBE OIL PRESS. AT FRAME HEADER	(□ ○ ⬡)	(□ ○ ⬡)	○	DISCH. PRESS.	(□ ○ ⬡)	(□ ○ ⬡)
LUBE OIL FILTER Δ P	(□ ○ ⬡)	(□ ○ ⬡)	○	@ EA. STAGE	(□ ○ ⬡)	(□ ○ ⬡)
COOLING WATER INLET HEADER	(□ ○ ⬡)	(□ ○ ⬡)	○	______	(□ ○ ⬡)	(□ ○ ⬡)
______	(□ ○ ⬡)	(□ ○ ⬡)	○	______	(□ ○ ⬡)	(□ ○ ⬡)
______	(□ ○ ⬡)	(□ ○ ⬡)	○	______	(□ ○ ⬡)	(□ ○ ⬡)

REMARKS:

NOTE: *PNEUMATIC/ELECTRONIC TRANSMITTERS ARE REQUIRED FOR PANEL MOUNTED READINGS WHERE CHECKED ( ) ✓

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INSTRUMENTATION (CONT'D)

TEMPERATURE MEASUREMENT REQUIREMENTS	LOCALLY MOUNTED	PANEL MOUNTED	GAUGE W/ CAPIL'RY	THERMO CPL SYS	RTD SYS	I/S SYS
FUNCTION						
LUBE OIL O INLET TO O OUT OF FRAME	(□ O ⬡)	(□ O ⬡)	O	O	O	O
LUBE OIL O INLET TO O OUT OF COOLER	(□ O ⬡)	(□ O ⬡)	O	O	O	O
MAIN JOURNAL BEARINGS (THERMOCOUPLES OR RTD'S ONLY)	(□ O ⬡)	(□ O ⬡)	O	O	O	O
MOTOR BEARING(S) (THERMOCOUPLES OR RTD'S ONLY)	(□ O ⬡)	(□ O ⬡)	O	O	O	O
COOLING WATER HEADER: O INLET O OUTLET	(□ O ⬡)	(□ O ⬡)	O	O	O	O
CYL. COOLING WATER: O INLET O OUTLET O EA. CYL	(□ O ⬡)	(□ O ⬡)	O	O	O	O
PROCESS GAS: O INLET O DISCH. O EACH CYL	(□ O ⬡)	(□ O ⬡)	O	O	O	O
INTERCOOLER(S) O INLET O GAS O WATER	(□ O ⬡)	(□ O ⬡)	O	O	O	O
O DISCH. O GAS O WATER	(□ O ⬡)	(□ O ⬡)	O	O	O	O
AFTERCOOLER: O INLET O GAS O WATER	(□ O ⬡)	(□ O ⬡)	O	O	O	O
O DISCH. O GAS O WATER	(□ O ⬡)	(□ O ⬡)	O	O	O	O
COOLING WATER O INLET O OUTLET/COOLED PKG CASE(S)	(□ O ⬡)	(□ O ⬡)	O	O	O	O
PRESS. PGK CASE, CYL PIST ROD (THRM'CPLS OR RTD'S ONLY)	(□ O ⬡)	(□ O ⬡)		O	O	O
COMPRESSOR VALVES O SUCT. O DISCH. TC'S OR RTD'S ONLY	(□ O ⬡)	(□ O ⬡)	O	O	O	O
____	(□ O ⬡)	(□ O ⬡)	O	O	O	O
____	(□ O ⬡)	(□ O ⬡)	O	O	O	O

ALARM & SHUTDOWN SWITCH REQ'MTS NOTE: ALARM & SHUTDOWN SWITCHES SHALL EACH BE INDEPENDANT TO THE OTHER

			ANNUNCIATION POINTS				
			ALARM		SHUTDOWN		
FUNCTION	ALARM	SHUT DOWN	IN PNL BY MFR	IN CTL ROOM PANEL OTH'RS	IN PNL BY MFR	IN CTL ROOM PANEL OTH'RS	TOTAL NO. OF POINTS
LOW LUBE OIL PRESS. @ BEARING HEADER	(□ O ⬡)	(□ O ⬡)	O	O	O	O	____
HIGH LUBE OIL Δ P ACROSS FILTER	(□ O ⬡)	(□ O ⬡)	O	O	O	O	____
LOW LUBE OIL LEVEL, FRAME	(□ O ⬡)	(□ O ⬡)	O	O	O	O	____
AUX LUBE OIL PUMP, FAIL TO START	(□ O ⬡)	(□ O ⬡)	O	O	O	O	____
CYL LUBE SYSTEM PROTECTION	(□ O ⬡)	(□ O ⬡)	O	O	O	O	____
COMPR. VIBRATION, SHUTDOWN ONLY		(□ O ⬡)	O	O	O	O	____
VIBRATION, W/ CONTINUOUS MONITORING	(□ O ⬡)	(□ O ⬡)	O	O	O	O	____
ROD DROP DETECTOR, CONTACT TYPE(1/CYL)	(□ O ⬡)	(□ O ⬡)	O	O	O	O	____
ROD DROP PROXIMITY PROBE (1/CYL)	(□ O ⬡)	(□ O ⬡)	O	O	O	O	____
OIL TEMP OUT OF FRAME	(□ O ⬡)	(□ O ⬡)	O	O	O	O	____
HIGH GAS DISCH. TEMP EACH CYLINDER	(□ O ⬡)	(□ O ⬡)	O	O	O	O	____
HIGH JACKET WATER TEMP., EA. CYL	(□ O ⬡)	(□ O ⬡)	O	O	O	O	____
LOW SUCTION PRESS., FIRST STG INLET	(□ O ⬡)	(□ O ⬡)	O	O	O	O	____
HI DISCH. PRESS. O FINAL O EA STG	(□ O ⬡)	(□ O ⬡)	O	O	O	O	____
HI CYL. GAS Δ P, EACH STAGE	(□ O ⬡)	(□ O ⬡)	O	O	O	O	____
HI LIQ. LEV., EA. MOISTURE SEPARATOR	(□ O ⬡)	(□ O ⬡)	O	O	O	O	____
LOW PURGE GAS PRESS, DISTANCE PIECE(S)	(□ O ⬡)	(□ O ⬡)	O	O	O	O	____
HI X-HD PIN TEMP	(□ O ⬡)	(□ O ⬡)	O	O	O	O	____
PRESS PKG CASE (PISTON ROD TEMP)	(□ O ⬡)	(□ O ⬡)	O	O	O	O	____
____	(□ O ⬡)	(□ O ⬡)	O	O	O	O	____
TOTAL NUMBER OF ANNUNCIATION POINTS							____

O SWITCH CONTACT OPERATION — NOTE: EACH SWITCH SHALL BE MINIMUM SPDT ARRANGEMENT

O ALARM CONTACTS SHALL:
- O OPEN (DE-ENERGISE) TO SOUND ALARM & BE ENERGIZED WHEN COMPR. IS IN OPERATION
- O CLOSE (ENERGIZE) TO SOUND ALARM & BE DE-ENERGIZED WHEN COMPR. IS IN OPERATION

O SHUTDOWN CONTACTS SHALL:
- O OPEN (DE-ENERGIZED) TO SHUTDOWN & BE ENERGIZE WHEN COMPR. IS IN OPERATION
- O CLOSE (ENERGIZE) TO SHUTDOWN & BE DE-ENERGIZE WHEN COMPR. IS IN OPERATION

NOTES: WHERE SWITCHES ARE NORMALLY DE-ENERGISED (OPEN) ALTERNATIVE ARRANGEMENTS SHALL BE MADE TO ACHEIVE A FAIL SAFE SYSTEM

FOR MINIMUM RECOMMENDED PROTECTION REQUIREMENTS SEE 10.5.1

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○ INSTRUMENTATION (CONT'D)

○ MISCELLANEOUS INSTRUMENTATION — ○ INTERCLR(S) ○ AFTERCLR ○ OIL CLR ○ WATER CLR

SIGHT FLOW IND. (COOLING WATER ONLY)	(☐ ○ ⬡)	FOR: ○ CYL JACKET WATER ○ ROD PRESS. PKG CASES
PNEUMATIC PRESSURE TRANSMITTERS	(☐ ○ ⬡)	FOR:
PRESSURE TRANSMITTERS (ELEC. OUTPUT)	(☐ ○ ⬡)	FOR:
PNEUMATIC LEVEL TRANSMITTERS	(☐ ○ ⬡)	
ALARM HORNS & ACKN'LMT TEST BUTTON	(☐ ○ ⬡)	
CONDUIT & WIRING W/JUNCT. BOXES	(☐ ○ ⬡)	
TEST VALVES	(☐ ○ ⬡)	FOR:
DRAIN VALVES	(☐ ○ ⬡)	FOR:
LEVEL GAUGES	(☐ ○ ⬡)	FOR:
TACHOMETER	(☐ ○ ⬡)	SPEED RANGE ____ TO ____ RPM
CRANKSHAFT KEY PHASER AND TRANSDUCER	(☐ ○ ⬡)	FOR:
	(☐ ○ ⬡)	
	(☐ ○ ⬡)	

○ SEPARATE LUBE OIL CONSOLE INSTRUMENTATION: — PURCH. TO LIST REQ'MTS IN ADDITION TO ANY ABOVE REQ'MTS

	(☐ ○ ⬡)	
	(☐ ○ ⬡)	
	(☐ ○ ⬡)	
	(☐ ○ ⬡)	
	(☐ ○ ⬡)	
	(☐ ○ ⬡)	

○ SEPARATE COOLING WATER CONSOLE INSTRUMENTATION: — PURCH. TO LIST REQ'MTS IN ADDITION TO ANY ABOVE REQ'MTS

RESERVOIR LEVEL GAUGE	(☐ ○ ⬡)	
RESERVOIR LEVEL SWITCH	(☐ ○ ⬡)	
	(☐ ○ ⬡)	
	(☐ ○ ⬡)	
	(☐ ○ ⬡)	
	(☐ ○ ⬡)	

○ RELIEF VALVES

LOCATION	BY	MANUFACTURER	TYPE	◇ SIZE	◇ SETTING
	(☐ ○ ⬡)				
	(☐ ○ ⬡)				
	(☐ ○ ⬡)				
	(☐ ○ ⬡)				
	(☐ ○ ⬡)				
	(☐ ○ ⬡)				
	(☐ ○ ⬡)				
	(☐ ○ ⬡)				
	(☐ ○ ⬡)				
	(☐ ○ ⬡)				

NOTES: SEE MOTOR DATA SHEET FOR ADDITIONAL MOTOR INSTRUMENTATION REQUIREMENTS
FOR TURBINE DRIVERS USE APPLICABLE DATA SHEETS
FOR GEAR REDUCERS USE APPLICABLE DATA SHEETS
PURCHASER'S ELECTRICAL & INSTRUMENTATION CONNECTIONS SHALL BE MADE DIRECTLY BY THE PURCHASER

ADDITIONAL INSTRUMENTATION REMARKS/SPECIAL REQUIREMENTS:

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	ELECTRIC MOTOR DRIVERS FOR RECIPROCATING COMPRESSORS	
1	APPLICABLE TO: ○ PROPOSALS ○ PURCHASE ○ AS BUILT	
2	FOR/USER	
3	SITE/LOCATION	No COMPRESSORS: MODEL/TYPE /
4	COMPRESSOR SERVICE	RATED POWER OF DRIVEN EQPMENT (INCL. LOSSES) Kw
5	COMPRESSOR MANUFACTURER.	
6	MOTOR MANUFACTURER.	No OF IDENTICAL DRIVERS: DRIVER RTG Kw
7	**MOTOR DESIGN DATA**	
8	APPLICABLE SPECIFICATIONS: ____	BASIC DATA (CONTINUED)
9	____	☐ RATED MOTOR POWER ____ Kw
10	____	○ SYNCHRONOUS RPM ____ ☐ OPERATING RPM ____
11	○ SITE DATA	○ INSULATION CLASS
12	ZONE: ____ GAS GROUP: ____ TEMP. CLASS ____	○ TEMPERATURE CLASS ____
13	ALTITUDE: ____ m AMBIANT TEMP.: MAX ____ °C, MIN ____ °C	STARTING (9.1.2.3.)
14	USUAL CONDITIONS: ○ DUST ○ FUMES	○ FULL VOLTAGE ○ REDUCED VOLTAGE %
15	○ OTHERS	○ INSTANTANEOUS VOLTAGE DIP AT STARTING ____ %
16	○ DRIVE SYSTEM	VIBRATION:
17	○ V-BELT (Radial 1 vibratory load data review req'd by motor manufacturer)	○ STANDARD ○ ____
18	○ TYPE MOTOR	NOISE
19	○ SQUIRREL CAGE INDUCTION OTHER DESIGN	○ STANDARD ○ ____
20	○ SYNCHRONOUS	REMARKS: ____
21	○ POWER FACTOR REQUIRED	____
22	○ EXITATION: ○ BRUSHLESS ○ SLIP RING	____
23	○ FIELD DISCHARGE RESISTOR BY MOTOR MANUFACTURER	
24	○ WOUND ROTOR INDUCTION	**ACCESSORY EQUIPMENT**
25	○ CONSTRUCTION (See 9.1.2.2.)	○ BASEPLATE ○ SOLEPLATE ○ STATOR SHIFT
26	○ CANTILEVERED ○ WITH BEARINGS ○ SINGLE ○ TWO	○ MANUFACTURER'S STANDARD FANS NON-SPARKING FANS
27	○ INTEGRAL ○ PEDESTAL	○ DC EXITATION
28	IEC TYPE: ____	◇ POWER REQUIRED ____ Kw ____ V
29	ENCLOSURE:	BY: ○ PURCHASOR ○ MANUFACTURER
30	○ Ex(d) ○ Ex(e) ○ Ex(p) ○ OTHER	DESCRIPTION ____
31	METHOD OF COOLING ____	○ ENCLOSED COLLECTOR RINGS:
32	○ DOUBLE WALL CARBON STEEL TUBES	○ PURGED: MEDIUM ____ PRESSURE ____ bar
33	○ WATER SUPPLY: PRESSURE ____ bar TEMPERATURE °C	○ EXPLOSION RESISTANT, NON-PURGED
34	○ WATER ALLOWED P & TEMPERATURE RISE ____ bar / K	○ FORCED VENTILATION
35	○ WATER SIDE MINIMUM CORROSION ALLOWANCE ____ mm	◇ m³/h ____ PRESSURE DROP ____ mm WATER
36	○ FOULING FACTOR ____ m²K/kW	○ BEARING TEMPERATURE DEVICES:
37	○ (AIR) (GAS) SUPPLY PRESSURE ____ bar	◇ LOCATION ____
38	○ DEGREE OF PROTECTION IEC 529 IP ____	◇ DESCRIPTION ____
39	OTHER ____	◇ SET @ ____ °C FOR ALARM, ____ °C FOR SHUTDOWN
40	○ BASIC DATA	○ SPACE HEATERS:
41	○ ____ V PHASE ____ Hz	◇ ____ Kw ____ V PHASE ____ Hz
42	○ STD EFFICIENCY ○ PREMIUM EFFICIENCY ○ HIGH EFFICEINCY	○ MAX. SHEATH TEMPERATURE ____ °C
43	NOTE: high efficiency motors require special inertia and current pulsation study for reciprocating compressors	
44	NOTE: All pressures are GAUGE PRESSURES	

RECIPROCATING COMPRESSOR **DATA SHEET** **ISO 13707 Appendix A**	JOB NO. ______ ITEM NO. ______ REVISION NO. ______ DATE ______ PAGE 21 OF 22 BY ______

Revision

ELECTRIC MOTOR DRIVERS FOR RECIPROCATING COMPRESSORS (CONT'D) SERVICE ______

	ACCESSORY EQUIPMENT	MANUFACTURER'S DATA
1	WINDING TEMPERATURE DETECTORS	TORQUES (Nm): FULL LOAD
2	○ RESISTANCE TEMPERATUIRE DETECTORS: No/PHASE ___ / ___	◇ LOCKED ROTOR ______ ◇ STARTING (SYM) ______
3	SELECTOR SWITCHAND INDICATOR BY: ○ PURCHASOR ○ MFR	◇ PULL UP (IND) ______ ◇ PULL IN (IND) ______
4	◇ MAXIMUM STATOR WINDING TEMPERATURES:	◇ BREAKDOWN (IND) ______ ◇ PULL OUT (SYN) ______
5	______ °C FOR ALARM, ______ °C FOR SHUTDOWN	◇ OPEN CIRCUIT TIME CONSTANT ______ %
6	○ OTHER ______	◇ SYMETRICAL CONTRIBUTION TO SCTERMINAL FAULT:
8	WINDING TEMPERATURE DETECTOR & SPACE HEATER LEADS:	@ 1/2 CYCLE ______ @ 5 CYCLES ______
9	○ IN SAME CONDUIT BOX	◇ REACTANCES: SUB TRANSIENT (X"d) ______
10	○ IN SEPARATE CONDUIT BOXES	TRANSIENT (X'd) ______ SYNC. (Xd) ______
11	○ MOTOR ARRANGED FOR DIFFERENTIAL PROTECTIONS:	◇ AC STATOR RESISTANCE ______ ohm @ ______ °C
12	○ SELF BALANCE PRIMARY CURRENT METHOD	◇ RATED kVA ______
13	○ C.T. DESCRIPTION ______	◇ kVA INRUSH @ FULL V & LOCKED ROTOR (SYN) ______ %
14	○ EXTENDED LEADS LENGTH ______ m	◇ kVA @ FULL VOLTAGE & 95% SPEED ______ %
15	○ SURGE CAPACITORS	◇ MAX. LINE CURRENT IN STATOR ON 1st SLIP CYCLE
16	○ LIGHTNING ARRESTORS	@ PULL OUT (SYN) ______ A
17	○ C.T. FOR AMP METERS	◇ ACCELERATION TIME (MOTOR ONLY @ RATED V) ______ %
18	○ DESCRIPTION ______	◇ ACCELERATION TIME (MOTOR & LOAD @85% RT V) ______ %
19	MAIN CONDUIT BOX SIZED FOR:	◇ MOMENT OF INERTIA (INCL. MOTOR SHAFT) ______ kgm²
20	○ MAIN MOTOR LEADS ○ TYPE	◇ ROTATION FACING COUPLING END ______
21	○ INSULATED ○ NON INSULATED	◇ No OF STARTS PER HOUR: COLD ______ HOT ______
22	○ C.T.'s FOR DIFFERENTIAL PROTECTION: (MOUNTED BY: ______)	◇ FIELD DISCHARGE RESISTOR ______ ohm
23	○ LIGHTNING ARRESTORS: (MOUNTED BY: ______)	◇ RATED EXITATION FIELD VOLTAGE ______ V DC
24	○ C.T. FOR AMP METER (MOUNTED BY: ______)	◇ RESISTANCE OF EXITATION FIELD @ 25°C ______ ohm
25	○ SPACE FOR STRESS CONES	◇ EXITATION FIELD CURRENT @ FL & RATED PF ______ A
26	○ AIR FILTERS	◇ EXITATION FIELD CURRENT: MAX ______ A, MIN ______ A
27	◇ MANUFACTURER ______ ◇ TYPE ______	◇ EXITATION FIELD ☐ RHEOSTAT ☐ FIXED RESISTOR REQUIRED
28	**REMARKS:** ______	SUPPLIED BY ______
29	______	○ BEARING TYPE ______ LUBR. ______
30	______	LUBE OIL REQUIRED ______ m³/h @ ______ bar
31	______	◇ TOTAL SHAFT END FLOAT ______
32	☐ **MANUFACTURER'S DATA**	◇ LIMIT END FLOAT TO ______
33	MANUFACTURER ______	MOTOR ROTOR: ☐ SOLID ☐ KEYED ☐ KEYLESS
34	FRAME No: ______ FULL LOAD RPM (IND) ______	MOTOR HUB: ☐ SOLID ☐ KEYED ☐ KEYLESS
35	CURRENT @ STEADY LOAD: FULL LOAD: ______ A, 1/2 L ______ A	FOR WATER COOLED AND GAS FILLEDE MOTORS:
36	◇ CURRENT @ NON STEADY LOAD @ COMP. RATED POWER OF	◇ COOLING WATER REQUIRED ______
37	______ kW BASED ON EXPECTED CURRENT PULSATION OF: ___ %	○ CW TEMPERATURE RISE ______ K PRESSURE DROP ______ bar
38	IS EXPECTED TO BE ______ A	◇ (AIR) (GAS) REQUIRED ______ m³/h PRES. MAINT. ______ mbar
38	EFFICIENCY @ STEADY LOAD: FULL LOAD: ______ A, 1/2 L ______ A	○ CURVES REQUIRED BASED ON mtr SAT. @ RATED VOLTAGE
39	EFFICIENCY STATED IS: ☐ STANDARD ☐ PREMIUM ☐ HIGH	○ SPEED vs TORQUE (ALSO @ ______ % RATED VOLTAGE)
40	POWER FACTOR (IND): FULL LOAD ___ 3/4 L ______ 1/2 L ______	○ SPEED vs POWER FACTOR
41	◇ LOCKED ROTOR POWER FACTOR ______	○ SPEED vs CURRENT
42	◇ LOCKED ROTOR WITHSTAND TIME (COLD START)	○ AVAILABLE COOLING WATER TEMPERATURE °C

43 **REMARKS:** ______

44 ______

45 ______

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ELECTRIC MOTOR DRIVERS FOR RECIPROCATING COMPRESSORS (CONT'D) SERVICE ________

☐ MANUFACTURER'S DATA (CONT'D)

MASSES (kg):
NET MASS ________ kg SHIPPING MASS ________ kg
ROTOR MASS ________ kg MAX. ERECTION MASS ________ kg
MAX. MAINTENANCE MASS (IDENTIFY) ________ kg/ ________

DIMENTIONS (m):
L ________ m W ________ m H ________ m

REMARKS: ________

SHOP INSPECTION AND TESTS (CONT'D)

PAINTING:
○ MANUFACTURER'S STANDARD
○ SOLEPLATES EPOXY PRIMED
○ ________

SHIPMENT
○ DOMESTIC ○ EXPORT ○ EXPORT BOXING REQUIRED
○ OUTDOOR STORAGE MORE THAN 6 MONTHS
○ ________

○ SHOP INSPECTION AND TESTS

REF: 13.1.4.

	REQ'D	WITNESS	OBSERVED
SHOP INSPECTION*	○	○	○
TESTING PER	○	○	○
MFR STD SHOP TESTS	○	○	○
IMMERSION TEST	○	○	○
SPECIFY TEST (LIST BELOW)			
________	○	○	○
________	○	○	○
________	○	○	○
________	○	○	○

* SPECIFIC REQUIREMENTS TO BE DEFINED

ADDITIONAL REFERENCE DATA

COUPLING:
○ SUPPLIED BY ________
○ MFR ________ ☐ MODEL ________
MOTOR HALF COUPLING TO BE MOUNTED ON MOTOR SHAFT BY:
○ MOTOR MANUFACTURER
○ COMPRESSOR MANUFACTURER
○ PURCHASER

REMARKS / SPECIAL REQUIREMENTS ________

A.2 Purchaser's check-list

This check-list may be used to indicate the purchaser's specific requirements when this International Standard indicates, with a bullet (•), that a decision or information is required from the purchaser.

The check-list should be used in conjunction with the data sheets (A.1). Below, the purchaser should circle yes or no, or mark the appropriate space with an X, or fill in the requirements.

NOTE The use of this check-list is optional where these items are covered by a narrative specification.

Item

Clause	Question	Answer	
5.1.2	Requirements and maximum permissible sound pressure level?		
	Requirement:______________________________		
	Maximum permissible sound pressure level:____________________dB (A)		
5.1.7	Area classification for electrical components?		
	Applicable standards: ______________________________		
	Are local codes and regulations applicable?	Yes	No
5.1.11	Which details of an initial installation check shall be agreed upon by vendor and purchaser?		
	______________________________		
	______________________________		
	Operating temperature alignment check?	Yes	No
5.1.12	Equipment's normal operating point specified in the data sheet page 1, line 18?	Yes	No
5.1.14	Location and environmental conditions (see data sheet page 2).		
5.2	Values specified by the purchaser, based on his experience?		
	for: maximum average piston speed: ____________________ m/s		
	for: maximum speed: ____________________s^{-1} (rpm)		
5.3.2	Is 100 % unloading necessary?	Yes	No
6.1.2.6	Is coating of the running bore of the cylinder required?	Yes	No
6.1.3.5	Self-contained, forced circulation, closed jacket cooling system to be furnished by the vendor:	Yes	No
6.1.4.6	DN 12 indicator tap at each end of each cylinder?	Yes	No
6.2.9	Shall the vendor submit a written valve dynamics report?	Yes	No
6.2.11	Minimum hardness of valve seats for use with metallic valve plates HRC 32?	Yes	No
6.2.12	Is unloading to be specified (data sheet page 3)?	Yes	No
6.3.3	Purchaser requires wear bands?	Yes	No
6.4.7	Are relief devices for crankcases required?	Yes	No
6.5.1	Type of distance piece, specified in data sheet page 8?	Yes	No
6.5.1.4	Provison for intermediate packing sealing gas required?	Yes	No
6.5.2	Type of distance piece covers required: Mesh screens / Louvered / Solid metal / Other		
6.6.1	Are shields in the crosshead housing over the oil return drains required?	Yes	No
6.6.5	Closed liquid cooling system for packing to be supplied?	Yes	No
6.6.8	Venting and buffer gas cups for cylinder pressure packing required?	Yes	No
7.1.1	Have materials of construction been specified?	Yes	No
7.1.6	Has the presence and maximum amounts of corrosive, reactive or hazardous agents or components in the process fluid been specified on the data sheet page 2?	Yes	No

Clause	Question	Answer	
7.1.10	Has the amount of hydrogen sulfide been specified on the data sheet page 2, line 13?	Yes	No
7.5.2.4	Is an agreement of the quality control of welds which are inaccessible required?	Yes	No
7.5.2.8	Shall the proposed welding designs of fabricated cylinders be available for purchaser's review?	Yes	No
7.6.1	Is notice of repairs to other major components required?	Yes	No
7.6.2.1	Welding code for repairs to forgings and castings?	Yes	No
7.7.5.1	Is 100 % radiography of butt welds or magnetic particle inspection or liquid inspection of welds required?	Yes	No
7.7.5.3	Shall proposed connection sketches be submitted to the purchaser before fabrication?	Yes	No
7.8	Has the minimum design metal temperature related to the expected operating conditions been specified?	Yes	No
8.1.3.2	Has the type of driver for the auxiliary lubricating oil pump been specified on the data sheet page 11?	Yes	No
8.1.3.3	Shall the relief valve for crankcase driven pump be mounted outside the crankcase?	Yes	No
8.1.4	Has the type of oil cooler been specified on the data sheet page 15?	Yes	No
8.1.6	Are dual lubricating-oil filters with separate or integral continuous-flow transfer valve required?	Yes	No
8.1.7	Has the heating device for the oil reservoir been specified on the data sheet page 9?	Yes	No
8.2.1.1	Has the type of lubricator for compressor cylinders and for the pressure packing lubrication been specified on the data sheet (pages 9 and 8)?	Yes	No
8.2.1.2	Lubricator to be driven: from crankshaft / independently		
8.2.1.4	Is a heating device with thermostatic control for the lubricator reservoir required?	Yes	No
8.2.1.6	Which alarm functions for cylinder and pressure packing lubrication are required? for cylinder: ____________________ for pressure packing: ____________________ (see also data sheet page 18)		
8.2.1.9	Are synthetic lubricants of compressor cylinder lubrication required and specified in data sheet page 9?	Yes	No
8.2.3	Is an agreement of the method of pre-lubrication for divider block lubrication required?	Yes	No
	Is an agreement for protection device for divider block lubrication required?	Yes	No
9.1.1.1	Has the type of driver been specified on the data sheet page 1, line 10?	Yes	No
9.1.1.2	Are there process-variation or start-up conditions that affect driver selection?	Yes	No
9.1.1.3	Are the driver starting conditions specified on the data sheet?	Yes	No
9.1.2.2	Is the type of motor required specified on the data sheets (e.g. sheet 20, line 25)?	Yes	No
	Shall single bearing motors be provided with a temporary inboard support device?	Yes	No
9.1.2.3	Are the type of motor electrical characteristics, starting conditions, type of enclosure, specified on the data sheet page 20?	Yes	No
9.1.2.4	Has the reduced voltage for starting-torque requirements been specified on the data sheet page 20?	Yes	No
9.1.2.12	Shall hydrodynamic motor bearings be supplied with oil from compressor frame lubrication system? (Data sheet page 11)	Yes	No
9.1.3.1	Has the standard for turbine drivers been specified?	Yes	No
9.1.3.2	Is a separate lubricating oil system for turbine drive train in accordance with ISO 10438-2 (or API Std 614) required?	Yes	No

Clause	Question	Answer	
9.2.1.2	Is a spacer coupling required? (data sheet page 9)	Yes	No
9.2.1.6	Are auxiliary couplings required to comply with ISO 14691?	Yes	No
9.2.2.1	Has the standard for guards been specified on data sheet page 4?	Yes	No
	Is aluminium an acceptable non-sparking material for guards?	Yes	No
9.3.1	Has the standard for gear units been specified on data sheet page 4?	Yes	No
9.5.1.1	Has the type of mounting plate been specified on the data sheet page 4?	Yes	No
9.5.1.11	Have chock blocks been specified on the data sheet page 4?	Yes	No
9.5.1.15	Has epoxy grout been specified on the data sheet page 4?	Yes	No
9.5.1.16	Have levelling plates been specified on data sheet page 4?	Yes	No
9.5.2.3	Has the major equipment to be mounted on a base plate been indicated on the data sheet page 4?	Yes	No
9.5.2.9	Has a base plate suitable for column mounting been specified on the data sheet page 4?	Yes	No
9.5.2.12	Has nonskid decking covering been specified on the data sheet page 4?	Yes	No
9.5.3.3	Have soleplates or rails been specified on the data sheet page 4?	Yes	No
9.6.1	Has the type of intercooler to be furnished by the vendor been specified on the data sheet page 15?	Yes	No
9.6.2	Has the type of aftercooler to be furnished by the vendor been specified on the data sheet page 15?	Yes	No
9.6.3	Has the TEMA Class C or R for shell-and-tube intercoolers and aftercoolers been specified on data sheet page 15?	Yes	No
9.6.7	Are air coolers required?	Yes	No
9.6.11	Have the materials of construction for intercoolers and aftercoolers been specified on the data sheet page 16?	Yes	No
9.6.13	Has piping between compressor stages and the intercoolers and aftercoolers furnished by the vendor been specified on data sheet page 4?	Yes	No
9.7	Special design details for air intake filters? ____________________	Yes	No
9.8.2	Shall hydraulic tensioning tools be included in special tools?	Yes	No
9.8.4	Shall the compressor be fitted with a device to lock the shaft in position during maintenance?	Yes	No
10.1.1	Which sensing lines handling hazardous fluids require transduced signals? ____________________ ____________________ ____________________		
	Source of the control signal and its sensitivity and range? ____________________ ____________________ ____________________		
10.1.5	Is all auxiliary system instrumentation to be provided by the vendor, specified?	Yes	No
10.1.8	Are shutoff valves for shut-down sensing devices specified?	Yes	No
10.2.1	Is an automatic loading-delay interlock required?	Yes	No
10.3.1	Have panels been specified on data sheet page 17?	Yes	No
10.3.2	Are enclosed backs of panels required?	Yes	No
10.3.3	Shall wiring not inside enclosed panels be:		
	— in armoured cable?	Yes	No
	— run in metal conduits?	Yes	No
10.4.1	Has a tachometer to indicate compressor speed been specified on the data sheet page 19?	Yes	No

Clause	Question	Answer	
10.4.2.1	Have temperature indicators and mounted position been specified on the data sheet page 18?	Yes	No
10.4.2.6	Has the means for temperature indication been specified on the data sheet page 18?	Yes	No
10.4.2.8	Have temperature detectors for main bearings and valves been specified on data sheet page 18?	Yes	No
10.4.3.1	Have pressure indicators and mounted position been specified on the data sheet page 17?	Yes	No
10.4.3.2	Have oil-filled pressure gauges been specified on the data sheet page 17?	Yes	No
10.4.5.1	Have the relief valves to be furnished by the vendor been specified on data sheet page 19?	Yes	No
10.5.2	Has the extent of the alarm/shut-down system to be supplied by the vendor been specified on data sheet page 18?	Yes	No
10.5.3.2	Has an audible warning or a flashing light or both, to be initiated for alarms, been specified on data sheet page 18?	Yes	No
10.5.3.3	Has an audible warning or a flashing light or both, to be initiated for shut-downs, been specified on data sheet page 18?	Yes	No
10.5.6	Has the sequence of operation for an annunciator system been specified on data sheet page 18?	Yes	No
10.5.8	Have high-temperature alarms for crosshead pins been specified on data sheet page 18?	Yes	No
10.6.2	Have electrical power supply characteristics for motors, heaters and instrumentation, when panels are supplied by the vendor, been specified?	Yes	No
10.6.6	For tropical location, shall all electrical materials be given the treatments specified in 10.6.6.1 and 10.6.6.2?	Yes	No
10.7.1	Shall the vendor furnish and mount vibration detection and transducing devices?	Yes	No
10.7.2	Shall a non-contacting proximity device to measure vertical movement of each piston rod be installed?	Yes	No
10.7.3	Shall a one-event-per-revolution mark be provided on the crankshaft?	Yes	No
10.7.4	Shall the vendor provide piston rod drop detectors?	Yes	No
11.1.5	Shall piping, pulsation suppression devices and knockout vessels be arranged for heat tracing and insulation?	Yes	No
11.1.6	Has the extent of piping system to be supplied by the vendor been specified on data sheet page 4?	Yes	No
11.1.7	Shall the vendor review the drawings of all upstream and downstream piping, appurtenances, vessels and supports?	Yes	No
11.1.12.1	Which standard for pipe taper threads shall be used? Standard:______________________________		
11.1.12.19	Piping standard to apply:______________________________		
11.1.12.23	Special requirements for piping, flanges, valves and other appurtenances for hydrogen, hydrogen sulfide or toxic services? ______________________________ ______________________________		
11.1.14	Shall each utility supply and return lines and other lines be manifolded to a common connection?	Yes	No
11.2.7	Is a continuous through-flow for instrument sensing lines to safety switches required?	Yes	No
11.4.3	Shall coolant piping on the compressor be furnished by the vendor?	Yes	No
11.5.3	Shall a test valve adjacent to all instruments be supplied?	Yes	No

Clause	Question	Answer	
11.6.1	Extent of process piping to be furnished by the vendor? ______________________________		
11.6.3	Shall removable spool pieces for start-up screens be supplied?	Yes	No
12.2.1	Has the design approach for pulsaton and vibration been specified on data sheet page 4?	Yes	No
12.2.8	Is an interactive simulation study of the whole system required?	Yes	No
12.3.1	Standards for design and construction of pulsation suppression devices? ______________________________		
12.3.4	Shall butt welds of pulsation suppression devices be 100 % radiographed?	Yes	No
12.3.6	Shall a final moisture removal section be included in the suction suppression device?	Yes	No
12.3.10	Shall a pressure test connection of DN 20 be provided at each pulsation suppressor compressor connection nozzle?	Yes	No
12.3.11	Shall a thermowell connection for the cylinder nozzle of each suction pulsation suppressor be provided?	Yes	No
12.3.16	Has provision for insulation at pulsation suppression devices been specified on the data sheet page 14?	Yes	No
12.4	Shall the vendor supply supports for the pulsation suppression devices and for vendor-supplied piping?	Yes	No
13.1.4	Has the extent of purchaser’s participation in the inspection and testing and amount of advance notification been specified on the data sheet page 13?	Yes	No
13.1.6	Is purchaser’s inspector to submit completed inspection check-list before shipment?	Yes	No
13.2.1.1	Shall the vendor keep available for at least 20 years final-assembly, maintenance and running clearances?	Yes	No
13.2.1.3	Which parts shall be subjected to surface and subsurface examination? ______________________________ and which type of examination is required? ______________________________		
13.2.2.1	Required radiographic, ultrasonic, magnetic particle or liquid penetrant inspection of welds or materials:		
	— radiographic?	Yes	No
	— ultrasonic?	Yes	No
	— magnetic particle?	Yes	No
	— liquid penetrant?	Yes	No
13.2.3.2	Shall the oil system be run in the manufacturer’s shop?	Yes	No
13.2.3.3	Has inspection for cleanlines of the equipment and all piping and appurtenances by the purchaser been specified on the data sheet page 9?	Yes	No
13.2.3.4	Shall the hardness of parts, welds and heat-affected zones be tested?	Yes	No
13.3.3.1	Has a 4 h running test of the compressor been specified on the data sheet page 9?	Yes	No
13.3.3.5	Is an operational test and a 4 h mechanical running test prior to shipment for auxiliary system consoles required?	Yes	No
13.3.3.6	Is dismantling for inspection required?	Yes	No
13.3.4.2	Shall all machine-mounted equipment, prefabricated piping and appurtenances furnished by the vendor be fitted and assembled in the vendor’s shop?	Yes	No
13.3.4.4	Shall the compressor be performance tested in accordance with ISO 1217?	Yes	No

Clause	Question	Answer	
14.1	Time for storage for a longer period than 6 months? ____________________		
14.3.10	Shall the equipment be packed for domestic or export shipment?		
	Domestic	Yes	No
	Export	Yes	No
15.2.2	Are additional drawings required with the proposal?	Yes	No
	Which ____________________		
	____________________		
15.2.3. m)	Special requirements for long term storage of spare parts: ____________________		
	____________________		
15.2.3. s)	Is a list of similar machines installed to be attached to the proposal required?	Yes	No
15.3.3.1	Shall the vendor submit performance curves or tables etc.?	Yes	No
15.3.3.2	Shall the vendor furnish data required for independent rod-load, gas-load and rod-load reversal calculations?	Yes	No
15.3.3.3	Shall the effect of valve failure on rod loads and reversals be calculated and furnished?	Yes	No
15.3.5	Shall progress reports be submitted by the vendor to the purchaser?	Yes	No

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Annex B
(informative)

Required capacity, manufacturer's rated capacity and no negative tolerance

(See 3.5, 3.14, 3.36, 5.1.12 and 5.1.13)

This annex discusses capacity sizing of reciprocating compressors and the intent of the term "no negative tolerance (NNT)" as used in this International Standard to apply to the "required capacity" of reciprocating process compressors.

The term "required capacity", is the minimum capacity required to meet the process conditions with no negative tolerance permitted. The purchaser completes the data sheets (page 1 line 36) with a required capacity if the required capacity must never be less than that specified. In such a case the sizing of the compressor takes into account the manufacturer's standard tolerances so that the resulting capacity will never be less than the required capacity.

The compressor "manufacturer's rated capacity" is that capacity to which the compressor is sized. The acceptable standard reciprocating compressor industry tolerance of ± 3 % is applicable to both the capacity and power at the compressor shaft. Because of this tolerance on capacity, the manufacturer can increase the required capacity by 3 % prior to sizing the compressor. (The required capacity divided by 0,97 equals the manufacturer's rated capacity). If NNT is not a purchaser's requirement, the purchaser should complete only the manufacturer's rated capacity (page 1 line 40) on the data sheet.

As used in the data sheets (page 1 of 22) under the manufacturer's rated capacity, "Total power at the compressor shaft" (line 46) is intended to mean the power required at the compressor input shaft as it would be measured by a brake. "Total power including V-belt and gear losses" (line 47) is the total power at the compressor shaft plus all losses in the drive system and is used for selecting the driver.

The concept of no positive tolerance on power is omitted from this International Standard on the basis of the following conditions:

a) The tolerance on the manufacturer's certified shaft power is ± 3 % and is calculated on the basis of manufacturer's rated capacity.

b) Using the manufacturer's rated capacity and corresponding power, the proper relationship of power to unit capacity (for example kW/100 m^3/h (of inlet volume flow)) exists and will agree with calculations.

c) The driver nameplate power should be selected to be a minimum of 110 % (for electric motors) or 120 % (for turbines) of the greatest total power required, including losses, for any of the given operating conditions. (See 9.1.2.1 and 9.1.3.1).

Annex C
(informative)

Piston rod and runout

C.1 General

Incorrect alignment of cylinders and crossheads, and thermal expansion effects and distortion of the rod itself can result in piston rod runout which may cause excessive wear of the pressure packing and the piston rod.

It is generally desirable to align the machine so that the rod runout at the pressure packing, in the operating (hot) condition, over the working life of the machine is minimized.

In horizontal compressors, the rod runout in the operating (hot) condition will be different from that in the cold condition and will vary as some components wear.

The manufacturer should estimate the magnitude of this difference and variation and calculate the rod runout in the cold condition to achieve the optimum runout in the operating (hot) condition considering such factors as:

— thermal expansion of cylinders, supports and other static components;

— differential expansion of piston and cylinder;

— differential expansion of crosshead and guide;

— sag of piston rod;

— wear of crosshead shoes and guides;

— wear of piston rider-bands and cylinder liners;

— lift of the crosshead due to angularity of the connecting rod;

— lubricant film effects.

C.2 Discussion of piston rod runout and the causes thereof

Piston rod runout can be defined as the variation, during one complete rotation of the crankshaft, of the reading of a dial indicator, or other instrument, arranged to measure the position of the adjacent surface of the piston rod.

In horizontal compressors, the piston rod runout is measured in both vertical and horizontal directions.

Horizontal runout is normally the result of manufacturing inaccuracies; e.g., the mating faces of the crosshead guide, distance piece or cylinder not being precisely square to the centre line. However, it should be noted that external loads imposed on the compressor by thermal expansion of the connected pipework or vessels, can cause distortion of the compressor resulting in horizontal runout. A particular case is where two or more cylinders are closely connected to a single pulsation suppressor.

The causes of vertical runout are various but can be grouped into two types:

Type A Effects which result in the line of motion of the two ends of the rod not being in the same straight line.

Type B Effects which result in bending of the rod itself.

Type A effects can be further sub-divided thus:

A1 Effects due to inaccurate machining or incorrect assembly as described for horizontal runout.

A2 Effects due to the piston and the crosshead running at the extremes of their respective working clearances.

A3 Thermal expansion effects, particularly on the piston and cylinder.

A4 Wear of components during the life of the compressor, particularly the piston rider-bands.

A5 Lift of the crosshead to the top of its working clearance on one side of the compressor due to the thrust and angularity of the connecting rod.

NOTE In most cases the crosshead will drop at each end of the stroke.

Type B effects can also be sub-divided:

B1 Sagging of the rod under it’s own weight.

B2 Bending of the rod caused by “out of squareness” of threads or other mating surfaces at the connections between the rod and the crosshead and piston.

Effect types A1, A2, B1 and B2 will normally be the same in the “cold” condition in the manufacturer’s shop as in the “hot” operating condition in the field. The objective is to achieve the minimum operating runout at the pressure packing over the life of the machine. Provided that the runout is measured as close to the packing as possible, only effect types A3, A4 and A5 need to be considered in determining the extent to which the cold runout during the shop bar-over test will be different from the hot runout in the field.

Effects A3 and A4 result in the true line of motion of the two ends of the rod being parallel but not co-linear. The vertical displacement can be related to the measured runout by simple geometry (see Figure C.1).

Analysis of effect A5 requires a detailed knowledge of the geometry of the machine, the masses of various components and the loads imposed. It will obviously depend on the actual operating conditions at any one time. Allowance for this effect therefore requires careful consideration.

Calculation of the effect of sagging of the rod under its own weight (B1) is difficult because the end conditions are indeterminate and in any case will be independent of the actual loading conditions.

If necessary, some indication of the extent of rod sag can be obtained by measuring the runout at two positions, one close to the pressure packing and the other close to the crosshead. Whilst the effect of a parallel relative displacement of the line of motion of the two ends of the rod will be the same at both measurement positions, the effect of rod sag will be different and generally of opposite sign.

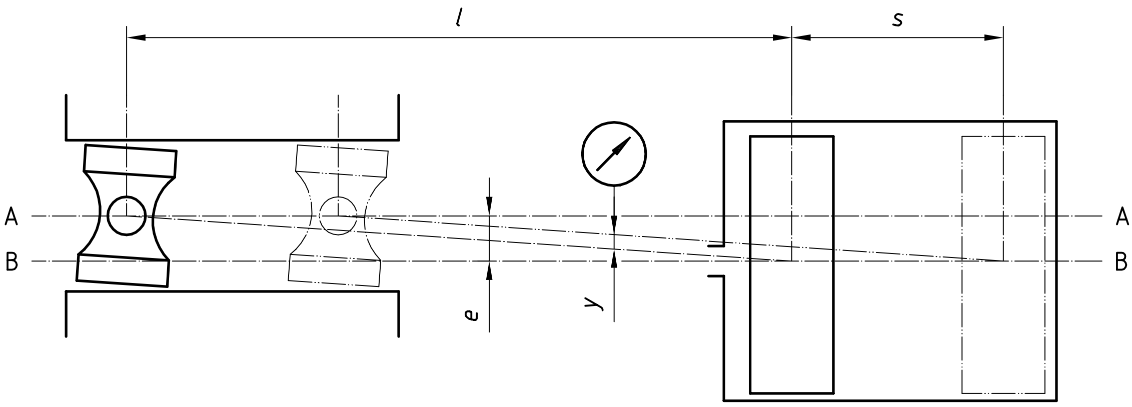


Figure C.1 — Piston rod runout — Types A3 and A4 effect.

Key

A-A is the line of motion of crank end of piston rod

B-B is the line of motion of piston end of piston rod

$$y = e\frac{s}{l}$$

where:

l is the effective length of piston rod

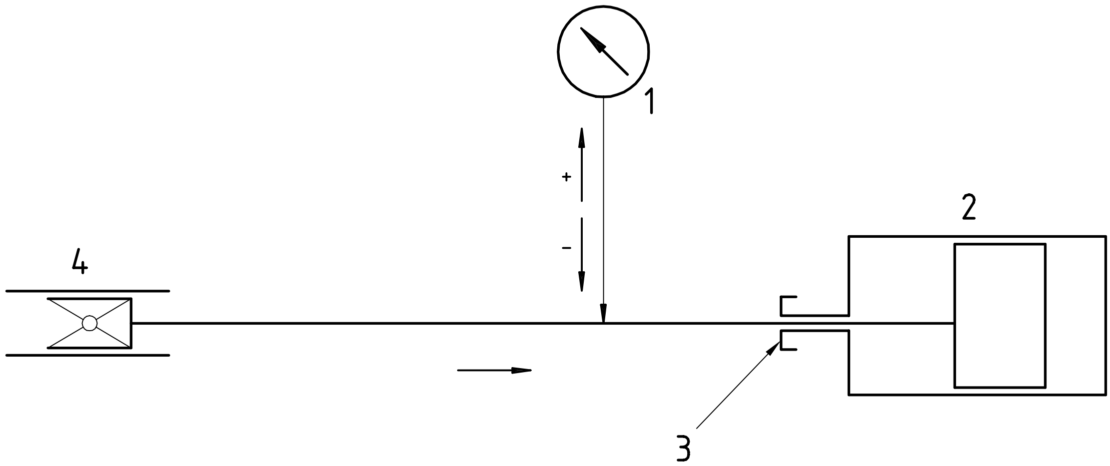
s is the stroke

e is the vertical displacement between A-A and B-B

y is the piston rod runout

C.3 Shop runout test worksheet

Figure C.2 is a typical worksheet that may be used for recording the results of the shop rod runout test.



Key

1 Dial indicator

2 Piston

3 Pressure packing case

4 Crosshead

Figure C.2 — Typical piston rod runout worksheet

NOTE 1 The values recorded are the changes in indicator readings when the piston is moved from crank-end towards head-end by rotation of the crankshaft in the normal direction.

NOTE 2 The precise position of the dial indicator is recorded in the table.

Dimensions in millimetres

Cylinder	Runout					
	Permissible (calculated)		Actual measured			
	Vertical	Horizontal	Vertical	Horizontal	Date	Inspector (Vendor)
1.						
2.						
3.						
4.						
5.						
6.						

Annex D
(informative)

Repairs to grey or nodular iron castings

D.1 Scope

This annex covers repair procedures that have been successfully applied to grey and nodular iron castings for compressor cylinders and related parts in various services. These procedures are only briefly described for the purpose of reference by the purchaser and the vendor; detailed descriptions of the procedures are beyond the scope of this International Standard. Limitations on the use of the procedures are included. These procedures should be applied only after careful evaluation of the situation by the purchaser and the vendor. When the service conditions of the casting involve toxic or hazardous gases, an even more exhaustive evaluation should be made.

D.2 Repair methods and limitations

In cylinders designed to handle gases having a mean molar mass < 12, no repairs of any type shall be made to defects that result in leakage between the cylinder bore and the water jacket during hydrostatic testing. With the purchaser's written approval, the repair methods specified in D.2.1 to D.2.3 may be used for compressor cylinders designed to compress gases with a mean molar mass $\geqslant 12$.

D.2.1 Areas in which hydrostatic testing shows leaks between the water jacket and the atmosphere or between the gas passage and the atmosphere or between the water jacket and the gas passage may be repaired by plugging within the limits of ASTM A 278 or ASTM A 395 or by approved procedures for vacuum-plus-pressure impregnating. Impregnating may be considered only for limited porosity-type leakage and only after hydrostatic testing of both the water jacket and the gas passage has proved the mechanical integrity of the casting. (See 7.6.2.2)

D.2.2 Defects that show up on machined surfaces or in other areas where no leak is involved, may be repaired by plating. Such defects could include porosity in valve seats or head and cylinder end faces or out-of-tolerance of cylinder bores requiring a liner. Plating repairs are not acceptable in critical areas such as "o"-ring seating areas or surfaces swept by the compressor piston. If repair plating is used no sharp corners shall be formed or left which could damage "o"-rings, etc. See 7.6.

D.2.3 Damaged threaded holes in castings may be mechanically repaired by use of thread inserts or bushings.

Annex E
(informative)

Examples of typical logic diagram showing critical functions

A system logic diagram is very useful during system design, check-out and operation. It is a language readily understood by electrical, instrument and machinery engineers and by operations personnel. It becomes, in effect, the definitive specification from which the circuit designer works. The diagram is particularly helpful in pre-startup functional check-out of the system as well as in system troubleshooting. Once the diagram has been completed to describe the requirements of the equipment and process designers, the preparation of the instrument and electrical schematics becomes quite simple and positive.

See Figures E.1 to E.6.

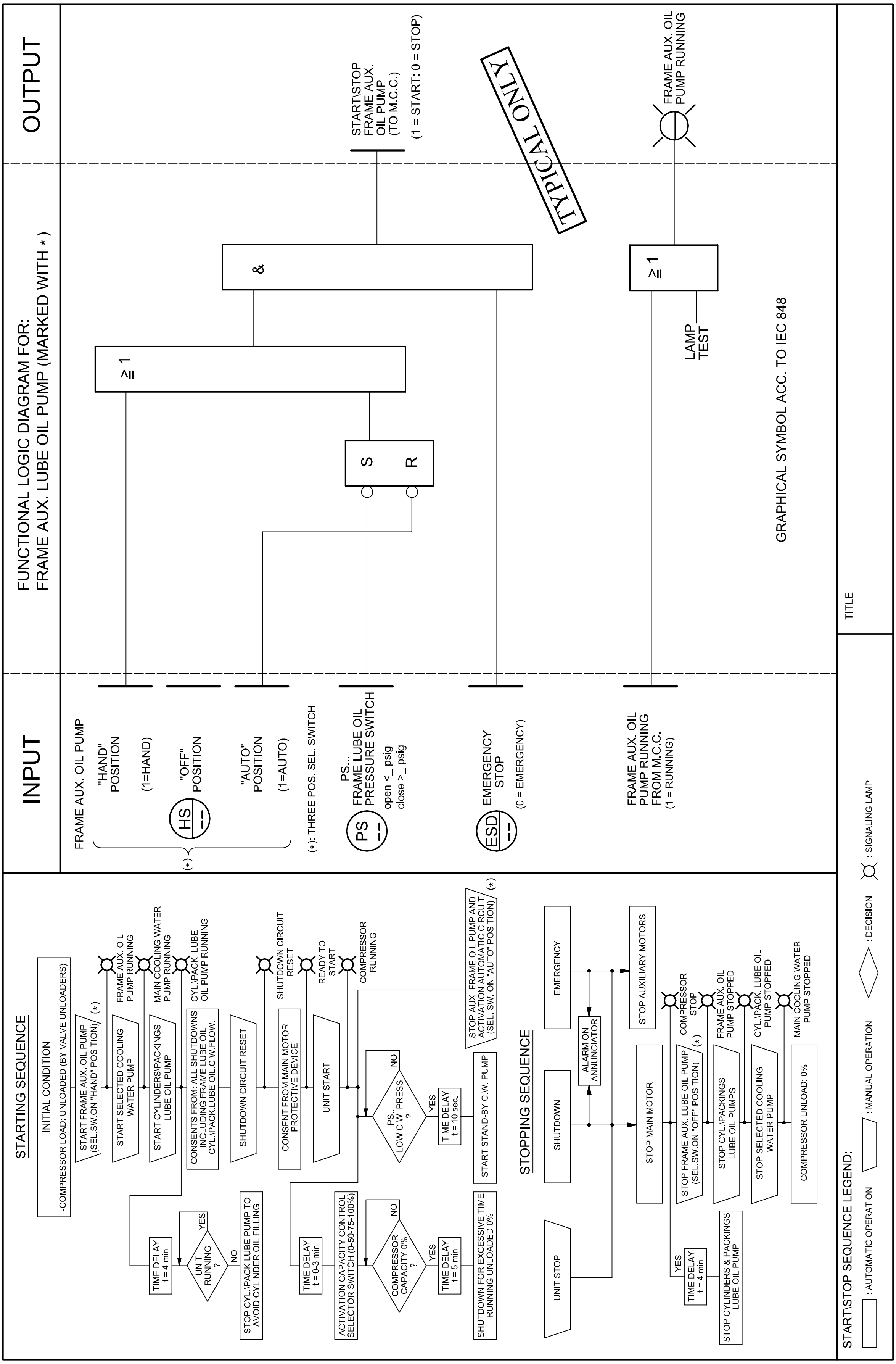


Figure E.1 — Typical manual control logic for frame auxiliary oil pump

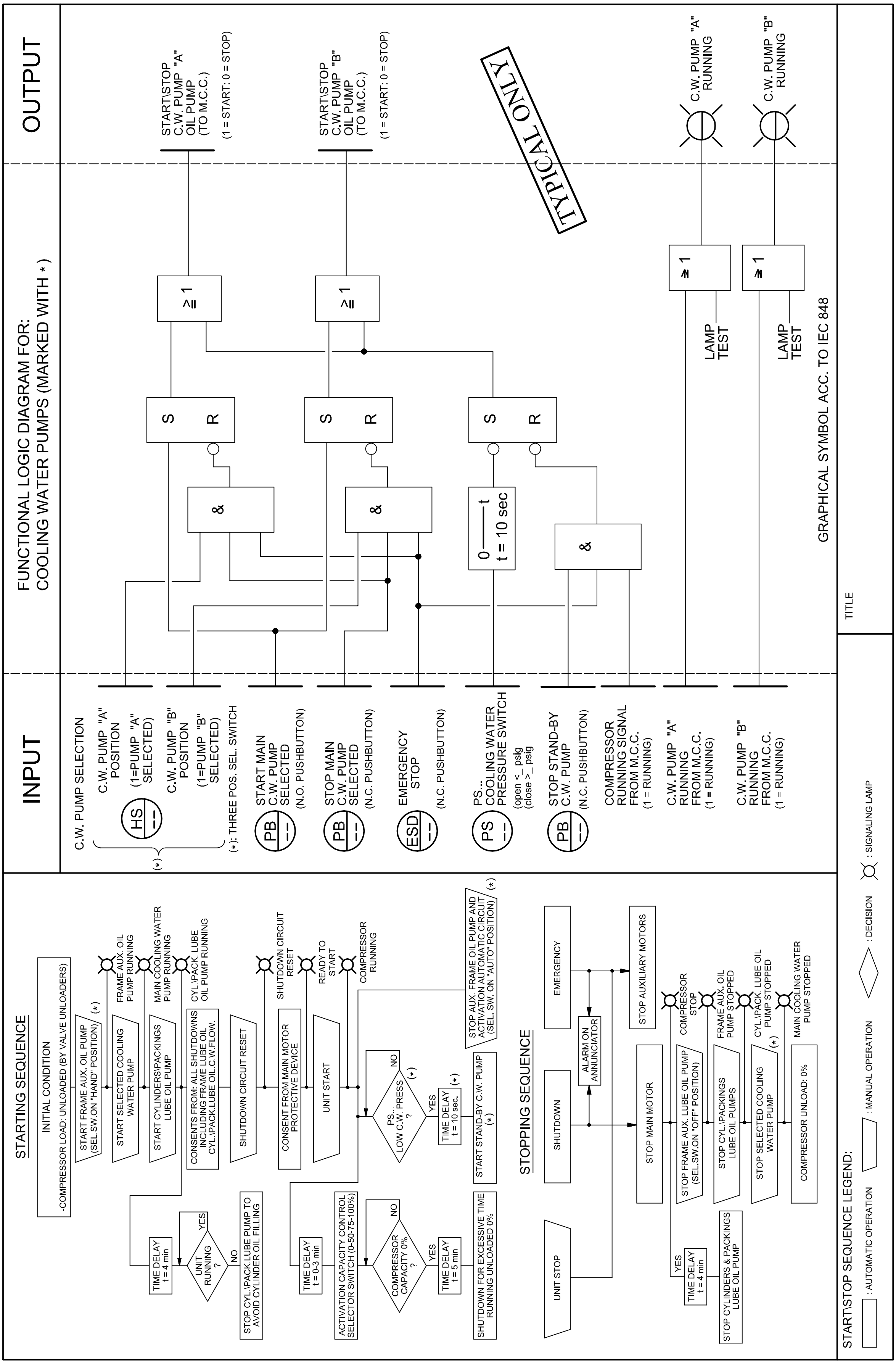


Figure E.2 — Typical manual control logic for cooling water pump

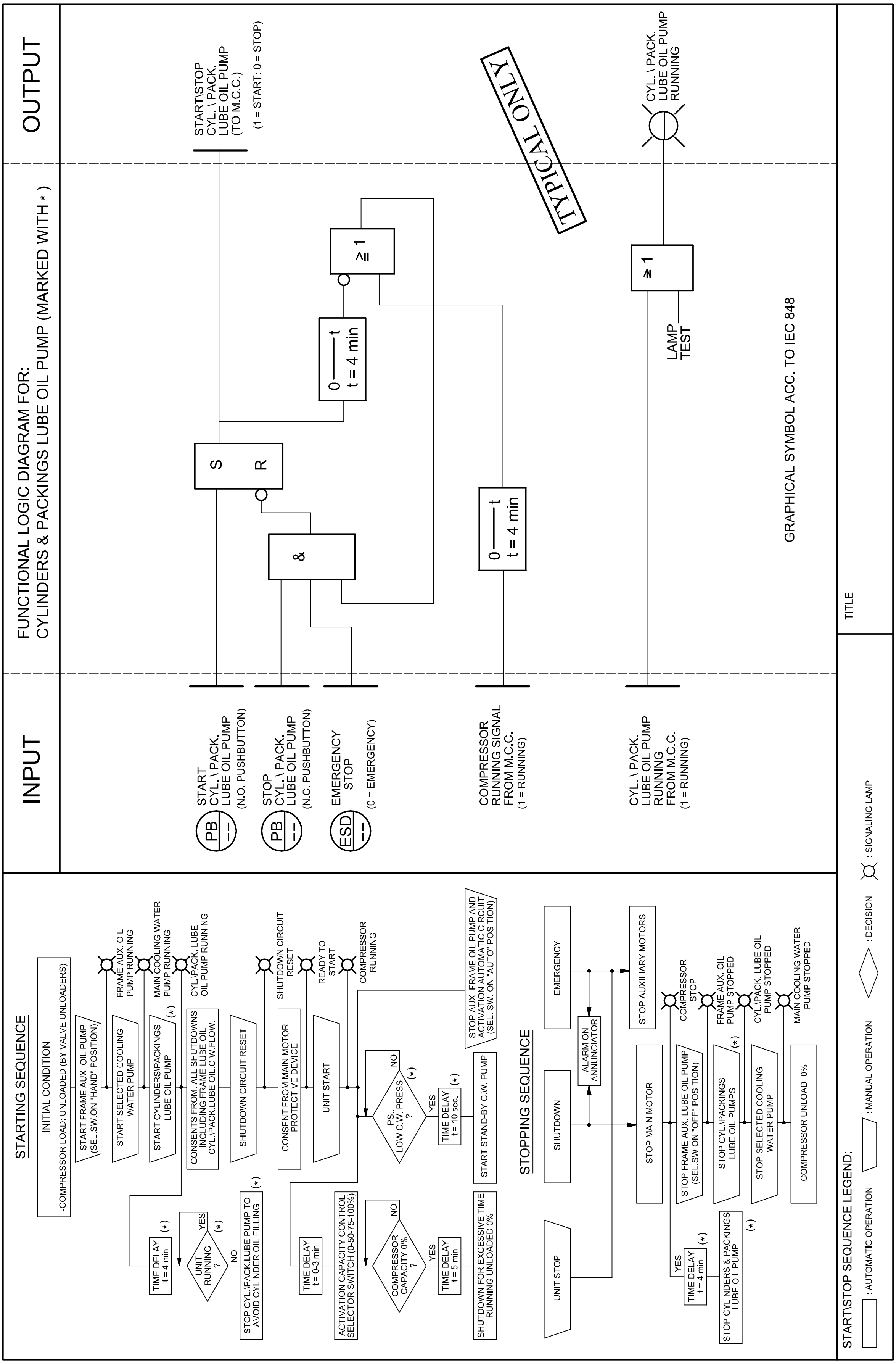


Figure E.3 — Typical manual control logic for cylinder/packing lubricating oil pump

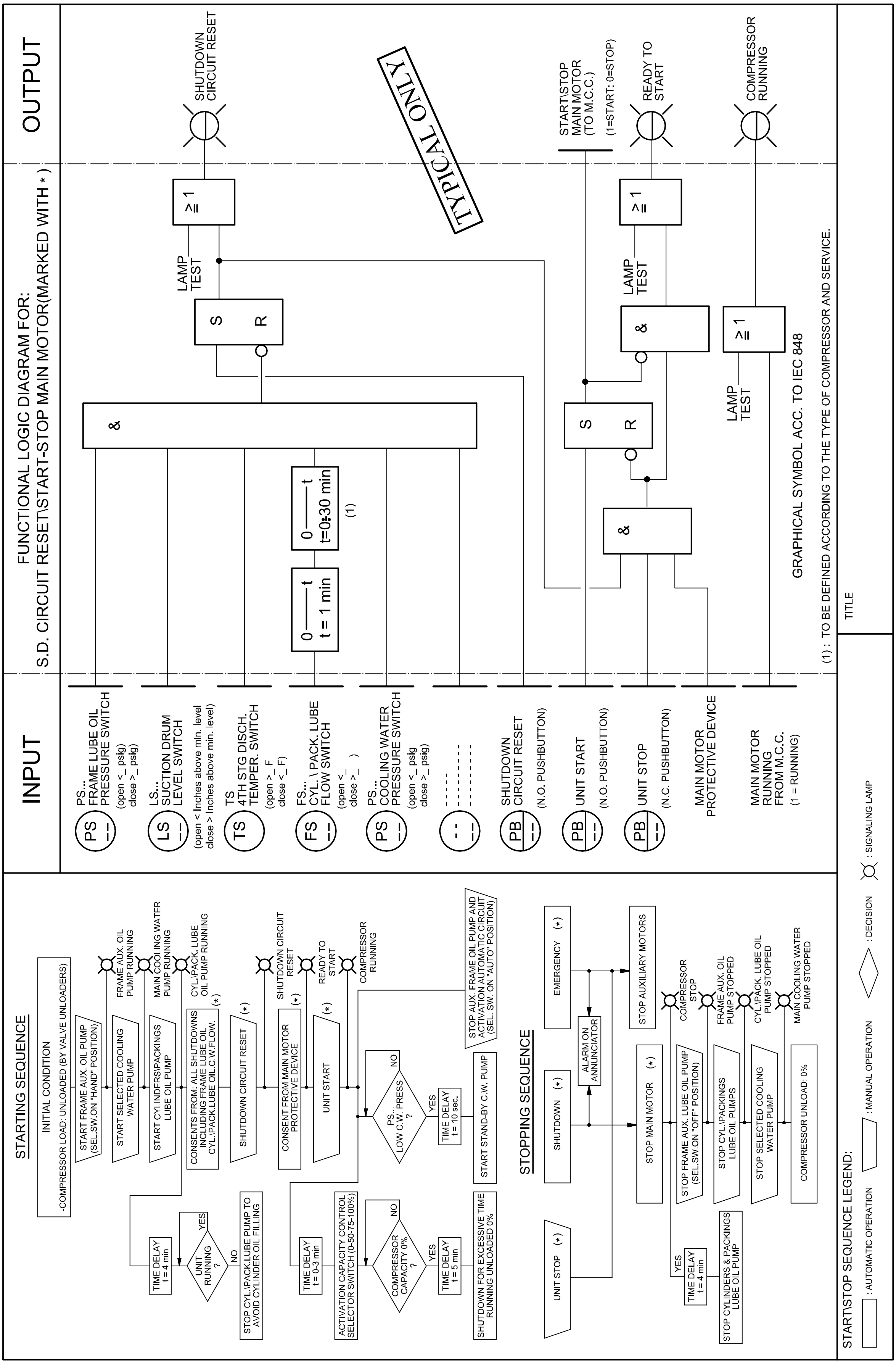


Figure E.4 — Typical control logic for compressor start/stop

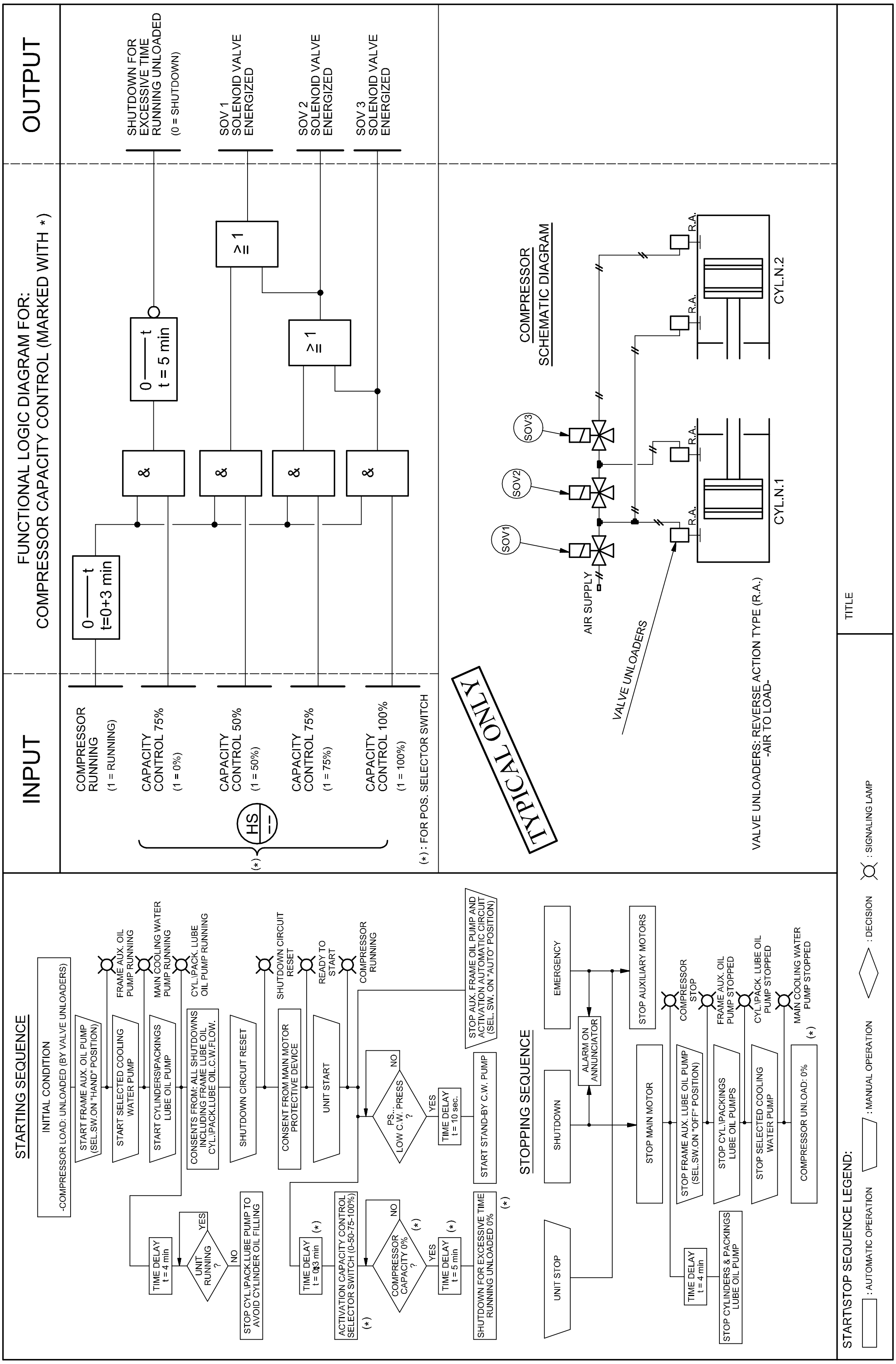


Figure E.5 — Typical control logic for manual capacity control

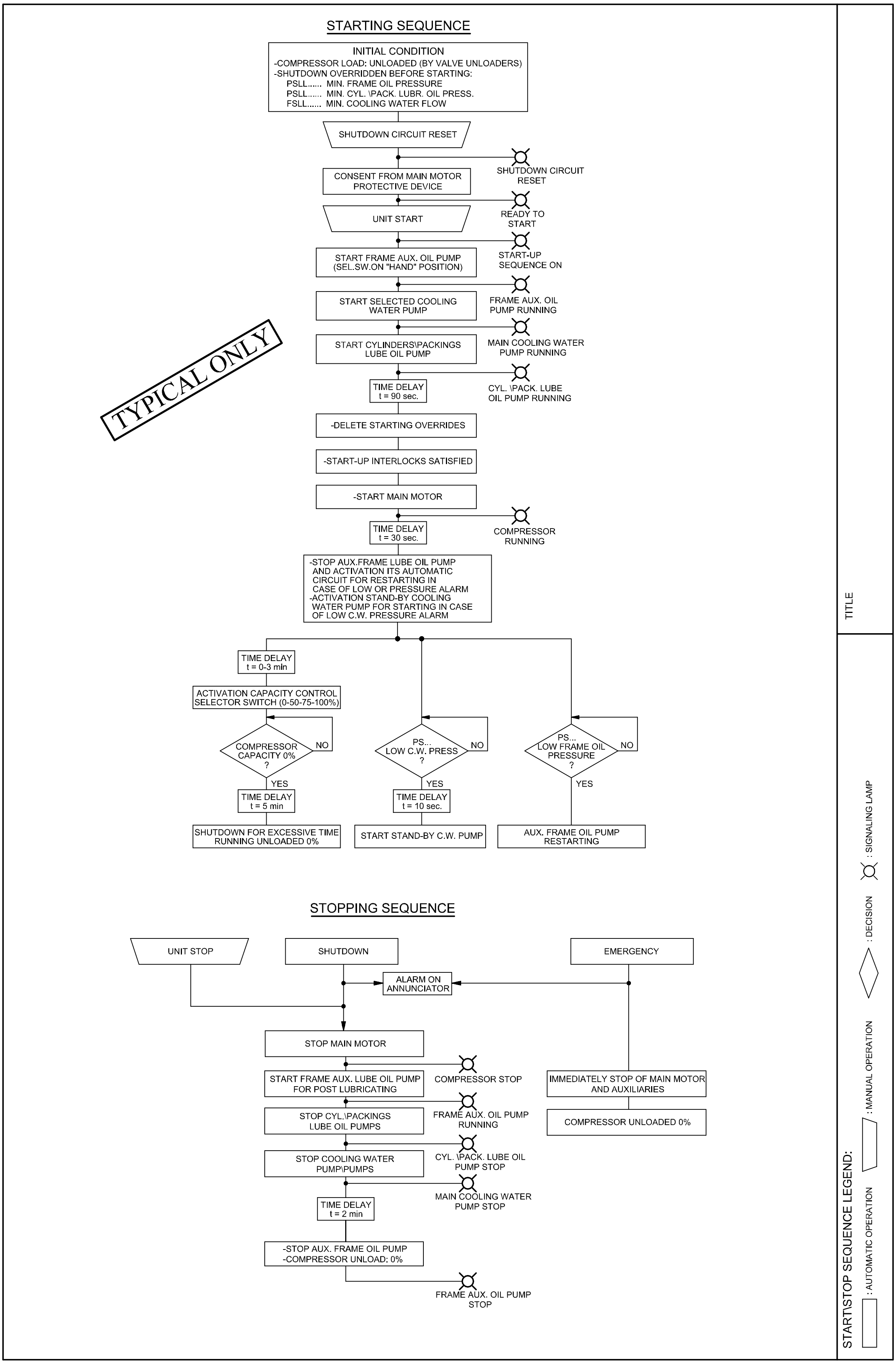


Figure E.6 — Typical automatic start/stop sequence

Annex F
(informative)

Vendor drawing and data requirements

This annex consists of a sample vendor drawing and data requirements form (VDDR), followed by a list of possible items that may be included on the form and representative descriptions of those items. Since different manufacturers will use different names for the same drawing, the items in the description column of the VDDR should be modified in the early stages of the order using the drawing names supplied by the manufacturer.

F.1 VDDR 1

TYPICAL
VENDOR DRAWING AND
DATA REQUIREMENTS

JOB No. ____________ ITEM No. ____________
PURCHASE ORDER No. ____________ DATE ________
REQUISITION No. ____________ DATE ________
INQUIRY No. ____________ DATE ________
PAGE 1 OF 2 BY ____________
FOR ____________
REVISION ____________
SITE ____________
UNIT ____________
SERVICE ____________
No. REQUIRED ____________

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

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

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

DISTRIBUTION RECORD

Proposal [a]	Review [b]	Final [c]	DESCRIPTION	Review-Due from vendor [c]	Review-Received from vendor	Review-Returned to vendor	Final-Due from vendor [c]	Final-Received from vendor

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

F.2 VDDR 2

TYPICAL
VENDOR DRAWING AND
DATA REQUIREMENTS

JOB No. ______________ ITEM No. ______________
PAGE 2 OF 2 BY ______________
DATE ______________ REVISION ______________

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

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

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

DISTRIBUTION RECORD

Proposal[a]	Review[b]	Final[c]	DESCRIPTION	Review-Due from vendor[c]	Review-Received from vendor	Review-Returned to vendor	Final-Due from vendor[c]	Final-Received from vendor

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

Notes:

1. Send all drawings and data to ____

____

2. All drawings and data must show project, appropriation, purchase order and item numbers in addition to the plant location and unit. In addition to the copies specified above, one set of the drawings/instructions necessary for field installation must be forwarded with the shipment.

Nomenclature:

______ S: number of weeks prior to shipment.
______ F: number of weeks after firm order.
______ D: number of weeks after receipt of approved drawings.

Vendor ____

Date ________________ Vendor reference ______________________

Signature ____

(Signature acknowledges receipt of all instructions)

F.3 Items for VDDR Form

Items to be entered on the VDDR should be selected from the following list as appropriate. However, this list is not necessarily exclusive.

1) Certified dimensional outline drawing (general arrangement) and list of connections.

2) Foundation plan showing anchor bolt location.

3) Permissible flange loading (either cylinder or pulsation suppression device) and coordinates. See 6.1.2.2.

4) Driver outline.

5) Drive arrangement drawing.

6) Dimensional outline for all vendor-supplied major accessory equipment.

7) Performance data. See 15.3.3.1

8) Pressure packing drawing.

9) Gas load, rod load and crosshead load reversal and duration charts. See 15.3.3.2.

10) Starting torque versus speed curves (for driver and compressor).

11) Motor driver performance characteristics.

12) Tabulation of utility requirements.

13) List of unsafe or undesirable speeds. See 5.1.4.

14) Gear data.

15) Other driver data.

16) Shaft coupling assembly drawing and bill of materials.

17) Weld procedures for pulsation suppression devices. See 12.3.3.

18) Intercooler and aftercooler data.

19) Parts list with sectional drawings.

20) “Start-up” spares list. See 15.2.3 i).

21) Recommended normal maintenance spare parts. See 15.3.6.

22) Process schematic.

23) Frame and cylinder lubricating oil schematics and bills of materials.

24) Lubricating oil system assembly drawings and list of connections.

25) Lubricating oil system component drawings and data.

26) Cooling system schematics and bills of materials.

27) Cooling system assembly drawings and list of connections.

28) Cooling system component drawings and data.

29) Distance piece vent, drain and buffer schematics and list of connections.

30) Capacity control schematics and bill of materials.

31) Instrumentation and electrical schematics and bills of materials.

32) Instrumentation and electrical arrangement drawing and list of connections.

33) Instrumentation and electrical wiring diagrams.

34) Instrumentation set-point list.

35) Instrumentation data sheets.

36) Pulsation suppression device detail drawings and final pressure vessel code calculations.

37) Special tools list. See 9.8.1.

38) Fabrication, testing and delivery schedule.

39) Drawing list.

40) Weather protection and climatization required.

41) Comments on purchaser's piping and foundation drawings. See 5.1.11 and 11.1.7.

42) Progress reports. See 15.3.5.

43) Torsional analysis report. See 5.5.1 and 9.1.2.6.

44) Data for an independent torsional analysis.

45) Lateral analysis report. See 5.5.1.

46) Acoustic and mechanical analysis report.

47) Data required for 3rd party acoustic and mechanical analysis.

48) Engineering analysis for fabricated cylinders. See 7.5.1.

49) Balancing data tabulation.

50) Valve dynamics report. See 6.2.8.

51) Data for an independent valve dynamic analysis.

52) Connection sketches. See 7.7.5.3.

53) Coupling alignment diagram.

54) As-built dimensions and data.

55) Hydrostatic test certificates. See 13.3.2.1.

56) Certified mechanical run test data (if test ordered).

57) Certified performance test data (if test ordered).

58) Non-destructive test procedures for fabricated cylinders.

59) Procedures for special or optional tests (if tests ordered).

60) Certified data from special or optional tests (if tests ordered). See 13.3.4.1.

61) Certified mill test reports.

62) Crankshaft ultrasonic test certificate. See 13.2.2.3.3.

63) Gas leak test certificates. See 13.3.2.2.

64) Valve leak test certificate.

65) As-built data sheets.

66) Installation manual. See 15.3.7.2.

67) Operation and maintenance manual. See 15.3.7.3.

68) Technical data manual. See 15.3.7.4.

69) Procedures for preservation, packing and shipping.

70) Shipping list.

71) Material safety data sheets.

72) Deviation / exception list.

73) Quality plan.

74) Control logic diagrams.

F.4 Description of VDDR Items

1) Certified dimensional outline drawings (general arrangement) and tables include, but are not limited to, the following:

   i) Size, type, rating, location and identification of all customer connections; including vents, drains, lubricating oil, conduits, conduit boxes, electrical and pneumatic junction boxes and instruments. The vendor's plugged connections shall be identified. Details of special connections are required. See 6.1.4.3.

   ii) The mass of each assembly, of the heaviest piece of equipment which must be handled for erection and of significant items to be handled for maintenance.

   iii) All principal dimensions, including those required for piping design, maintenance clearances and dismantling clearances. Including valve maintenance clearance if pulsation suppression devices are not supplied.

   iv) Shaft centreline.

   v) Shaft end separation.

   vi) Centre of mass, vertical and plan location.

vii) Direction of rotation.

viii) When applicable, the make, size and type of couplings and the location of guards and their coverage.

2) Foundation plan including:

i) Dimensions of mounting plates for the complete train and auxiliary systems complete with diameter, number and location of both holes and thickness of metal through which bolts must pass.

ii) Speed, critical speed (if any), location and direction in the x, y, z-coordinate system of static and the first and 2nd order dynamic forces and moments and the location of the centre of mass.

iii) Levelling jack screw location.

3) Permissible flange loading (either cylinder or pulsation suppression device) and coordinates. See 6.1.2.2.

Permissible flange loading(s) for all cylinder (or pulsation bottle) connections, including anticipated thermal movements referenced to a defined point and x, y, z-coordinate system.

4) Driver outline.

Certified dimensional outline drawing for the driver and all its auxiliary equipment including:

i) Size, location, orientation and purpose of all customer connections, including conduit boxes, conduit, instrumentation and any piping or ducting.

ii) Type, rating and facing for any flanged connections.

iii) Size and location of anchor bolt holes and levelling jack screws and thickness of sections through which bolts must pass.

iv) Total mass of each item of equipment (driver and auxiliary equipment).

v) Overall dimensions and all horizontal and vertical clearances necessary for dismantling and the approximate location of lifting lugs.

vi) Shaft centreline height.

vii) Shaft end dimensions, plus tolerances for the coupling.

viii) Direction of rotation.

5) Drive arrangement drawing including, but not limited to, the following:

i) Flywheel data.

ii) Driver and mechanical transmission weights.

iii) Moment of inertia.

iv) Stator shift.

v) Air gap.

6) Dimensional outline for all vendor-supplied major accessory equipment.

7) Performance data. See 15.3.3.1.

8) Pressure packing drawing.

9) Gas load, rod load and crosshead load reversal and duration charts. See 15.3.3.2.

10) Starting torque versus speed curves. (For driver and compressor — on the same chart). Acceleration time. See 15.3.3.4.

11) Motor driver performance characteristics and performance data including:

    i) For induction motors 150 kW and smaller:

        I) efficiency and power factor at one-half, three-quarter and full load;

        II) torque-speed curves.

    ii) For induction motors larger than 150 kW, certified test reports for all tests run and performance curves as follows:

        I) time–current heating curve;

        II) torque–speed curves at 70 %, 80 %, 90 % and 100 % of rated voltage;

        III) efficiency and power factor curves from 0 to rated service factor;

        IV) current versus load curves from 0 to rated service factor;

        V) current versus speed curves from 0 % to 100 % of rated speed;

        VI) permissible safe stall time and repeated start capability (hot and cold).

    iii) For synchronous motors.

        I) torque–speed, current–speed and power factor–speed curves at 70 %, 80 %, 90 % and 100 % of rated voltage;

        II) pull-in and pull-out torque;

        III) permissible safe stall time and repeated start capability (hot and cold);

        IV) efficiency and power factor curves from 0 to rated service factor;

        V) current pulsation–speed curve during normal acceleration.

12) Tabulation of utility requirements (may be on data sheets).

13) List of unsafe or undesirable speeds. See 5.1.4.

14) Gear Data.

    i) Certified dimensional outline drawings and list of connections including:

        I) size, rating, location and identification of all customer connections including vents, drains, lubricating oil, conduit boxes, junction boxes and instruments;

        II) all principal dimensions, including those required for the purchaser's foundation, piping design, maintenance clearances and dismantling clearances;

        III) overall and handling masses;

        IV) shaft centre line heights;

V) shaft end dimensions and tolerances for the couplings;

VI) direction of rotation;

VII) location of the centre of mass of the gear unit;

VIII) size and location of anchor bolt holes and thickness of sections through which bolts must pass;

IX) thermal and mechanical movements of casings and shafts.

ii) Cross-sectional drawing and bill of materials including axial gear and pinion float.

iii) As-built data sheets including:

I) data for torsional analysis;

II) lateral critical speed reports when specified.

iv) Certified mechanical running test data;

v) Certified gear manufacturer's standard test data including gear contact test data;

vi) Optional test data and reports agreed by the purchaser and the gear manufacturer;

vii) Spare parts recommendations.

15) Other driver data, including:

i) Cross-sectional drawing and bill of materials, including the axial rotor float.

ii) As-built data sheets.

iii) Certified drawings of driver auxiliary systems including wiring diagrams for each auxiliary system supplied. The drawings should clearly indicate the extent of the system to be supplied by the manufacturer and the extent to be supplied by others.

iv) Spare parts recommendations.

v) Other driver data per driver VDDR.

16) Shaft coupling assembly drawing and bill of materials including:

i) Permissible misalignment.

ii) Hydraulic mounting procedure.

iii) Shaft end gap and tolerance.

iv) Coupling guards.

17) Weld procedures for fabrication and/or repair, including those in 12.3.3.

18) Intercooler and aftercooler data, including, but not limited to:

i) Dimensional outline drawings.

ii) Data sheets (e.g. TEMA).

iii) Final calculation in accordance with the specified pressure vessel code.

19) Parts list with sectional drawings.

The parts list includes pattern number, stock or production drawing numbers and the materials of construction. The list completely identifies each part so that the purchaser may determine interchangeability of parts with other equipment furnished by the same manufacturer. Standard purchased items are identified by the original manufacturer's name and part number. Materials are identified as specified in 7.1.2.

20) "Start-up" spares list. See 15.2.3 i).

21) Recommended normal maintenance spare parts. See 15.3.6.

22) Schematic diagram of the process fluids flowing through the machine, including:

    i) Steady-state and transient gas flow rates, temperatures and pressures.

    ii) Cooler heat loads.

    iii) Pipe, tubing and valve sizes of equipment provided by the vendor.

    iv) Instrumentation, safety devices and control schemes.

    v) Bill of materials.

23) Frame and cylinder lubricating oil schematics, including the following:

    i) Steady-state and transient oil flows and pressures at each point.

    ii) Control, alarm and trip settings (pressure and recommended temperatures).

    iii) Total heat loads.

    iv) Utility requirements, including electrical, water and air.

    v) Pipe, tubing and valve sizes.

    vi) Instrumentation, safety devices and control schemes.

    vii) Bill of materials.

24) Lubricating-oil system assembly and arrangement drawing(s), including size, rating and location of all customer connections.

25) Lubricating-oil system component drawings and data including:

    i) Outline and sectional drawings and data sheets for auxiliary pumps and drivers.

    ii) Outline and sectional drawings and data sheets for coolers, filters and reservoir.

    iii) Instrumentation.

    iv) Spare parts lists and recommendations.

26) Cooling system schematics and bill of materials.

    i) Cooling (including packing cooling) or heating schematic and bill of materials including cooling or heating fluid, fluid flows, pressure, pipe and valve sizes, instrumentation and orifice sizes.

27) Cooling system assembly drawings and list of connections.

    i) Cooling (including packing cooling) or heating system assembly and arrangement drawing(s), including size, rating and location of all customer connections.

28) Cooling system component drawings and data.

    i) Outline and sectional drawings and data sheets for pumps and coolers.

    ii) Outline and sectional drawings and data sheets for coolers, filters and reservoir.

    iii) Instrumentation.

    iv) Spare parts lists and recommendations.

29) Distance piece vent, drain and purge schematic and bill of materials including fluid, fluid flows, pressure, pipe, tube and valve sizes and instrumentation, and list of connections.

30) Capacity control schematics and bill of materials.

31) Instrumentation and electrical schematics and bills of materials for all systems, including pneumatic and hydraulic systems (including bar over device limit switch).

32) Instrumentation and electrical arrangement drawing and list of connections, including pneumatic and hydraulic systems and including but not limited to:

    i) Control panel general arrangement.

    ii) Control panel certified outline.

    iii) Control panel bill of materials.

33) Instrumentation and electrical wiring diagrams for all systems.

34) Instrumentation set-point list.

35) Instrument data sheets.

36) Pulsation suppression device detail drawings and final pressure vessel code calculations.

37) List of special tools furnished for maintenance. See 9.8.1.

38) Fabrication, testing and delivery schedule. See 42).

    i) Milestone fabrication, testing and delivery schedule, including vendor buyouts.

39) Drawing list.

    i) Drawing list, including latest revision numbers and dates.

40) Weather protection and climatization required.

41) Comments on purchaser's piping and foundation drawings. See 5.1.11 and 11.1.7.

42) Progress reports. See 15.3.5. and 38), including:

    i) Planned and actual milestone dates.

    ii) Engineering and manufacturing information on all major components.

    iii) Details of causes of delays.

43) Torsional analysis report, (see 5.5.1 and 9.1.2.6) including, but not limited to, the following:

    i) Complete description of method used.

    ii) Graphic display of mass elastic system.

    iii) Tabulation identifying the mass moment and torsional stiffness for each component identified in the mass elastic system.

    iv) Graphic display of exciting forces versus speed and frequency.

    v) Graphic display of torsional critical speeds and deflections (mode shape diagram).

    vi) Effects of proposed changes on analysis.

    vii) Current pulsation analysis.

44) Data for an independent torsional analysis.

45) Lateral analysis report, (see 5.5.1) including, but not limited to, the following:

    i) Method used (complete description).

    ii) Graphic display of critical speeds versus operating speeds.

    iii) Graphic display of bearing and support stiffness and its effect on critical speeds.

    iv) Journal static loads.

    v) Stiffness and damping coefficients.

46) Acoustic and mechanical analysis report, (see 12 and annex M) including, but not limited to the following:

    i) Design approach (see 12.2) and method used (complete description), including description of design techniques used.

    ii) Findings and comparison with permitted values.

    iii) Effects of required modifications, and marked-up drawings showing changes.

    iv) Other information as required by annex M.

47) Data required for 3rd party acoustic and mechanical analysis.

    i) Information described in annex N, Section 4.

48) Engineering analysis for fabricated cylinders. See 7.5.1.

49) Balancing data tabulation.

    i) Listing of mass balance data for each throw, including piston, rod, crosshead, nuts, bushings, bearings and balance masses and including both design target masses and actual assembly masses. The list includes permissible mass tolerance per throw.

50) Valve dynamics report. See 6.2.9.

51) Data for an independent valve dynamic analysis.

52) Connection sketches. See 7.7.5.3.

53) Coupling alignment diagram.

  i) Shaft alignment diagrams (vertical and horizontal), including recommended coupling limits during operation. Note all shaft-end position changes and support growths from 15 °C ambient reference temperature or other reference temperature specified by the purchaser. Include the recommended alignment method and cold setting targets.

54) As-built dimensions and data, including:

  i) Fits, clearances and runouts measured during final assembly.

  ii) Nameplate data for each cylinder.

  iii) Cylinder minimum and design clearances for each end of each cylinder.

  iv) Volume of all clearance pockets, plugs or bottles installed on each cylinder.

  v) Crank angle phasing.

55) Hydrostatic test certificates. See 13.3.2.1.

56) Certified mechanical run test data (if test ordered).

57) Certified performance test data (if test ordered).

58) Non-destructive test procedures for fabricated cylinders.

59) Procedures for any special or optional tests (if tests ordered).

60) Certified data from special or optional tests (if test ordered). See 13.3.4.1.

61) Certified mill test reports of items as agreed in the pre-commitment or pre-inspection meeting(s). Physical and chemical data.

62) Crankshaft ultrasonic test certificate. See 13.2.2.3.3.

63) Gas leak test certificates. See 13.3.2.2.

64) Valve leak test certificate.

65) As-built data sheets for compressor, gear, driver and auxiliary equipment, including gas data. See 5.1.15.

66) Installation manual (see 15.3.7.2) describing the installation requirements for the complete train, including the drawings necessary for assembly of the equipment and location of field connections and including, but not limited to, the following:

  i) Section 1 — Compressor

    I) items 1, 2, 3, 40, 53;

    II) grouting (see 9.5.1.15);

    III) setting equipment, rigging procedures, component masses and lifting diagram;

    IV) dismantling clearances;

    V) preservation and storage requirements (see 14.2);

    VI) field assembly procedures, including frame and cylinder alignment requirements.

ii) Section 2 — Driver

I) storage and preservation;

II) setting gear, rigging procedures, component masses and lifting diagram;

III) piping recommendations;

IV) composite outline drawing for driver including anchor bolt hole locations;

V) dismantling clearances;

VI) thermal and mechanical movements of frame and shaft;

VII) motor air gap data (see 9.1.2.10).

iii) Section 3 — Gear

I) storage and preservation;

II) setting gear, rigging procedures, component masses and lifting diagram;

III) piping recommendations;

IV) composite outline drawing for gear including anchor bolt hole locations;

V) dismantling clearances;

VI) thermal and mechanical movements of casing and shaft.

iv) Section 4 — Auxiliary equipment

I) storage and preservation;

II) setting equipment, rigging procedures, component masses and lifting diagram;

III) piping recommendation.

67) Operation and maintenance manual, (see 15.3.7.3) describing the operating and maintenance procedures, requirements and limitations for the complete train and auxiliary equipment including, but not limited to, the following:

i) Section 1 — Operation

I) initial commissioning and start-up, including final test and checks;

II) normal start-up;

III) normal shut-down;

IV) emergency shut-down;

V) operating limits, including 13;

VI) lubricating-oil recommendations, including injection rates and specifications;

VII) routine operational procedures;

VIII) 22), 30), 34) and 74).

ii) Section 2 — Maintenance, disassembly, repair and reassembly instructions for the complete train and auxiliary and accessory equipment including, but not limited to, the following:

I) valve overhaul data;

II) cylinder overhaul data;

III) table of bolt torques; the required torque values or elongations for tensioning the valve cover, valve hold down bolts, connecting rod and main bearing bolts and any other bolts that the vendor feels are critical. Data should be included for fasteners in both the lubricated and non-lubricated condition;

IV) fits and clearances for wearing parts, recommended, maximum and minimum;

V) 4), 8), 19), 21), 37), 49), 53), 54) and 65);

VI) routine maintenance requirements;

VII) maximum permissible crankshaft web deflection.

iii) Section 3 — Performance data
7), 9) and 10).

iv) Section 4 — As-built data
54) and 65).

v) Section 5 — Drawing and data
Drawings in the manual should be for the specific equipment supplied. Typical drawings are unacceptable.

1), 5), 6), 8), 11), 15), 16), 19), 23), 24), 25), 26), 27), 28), 29), 30), 31), 32), 33), 36) and 39).

68) Technical data manual. See 15.3.7.4.

Technical and quality control data for technical support personnel for the complete train and auxiliary equipment including, but not limited to, the following:

1), 2), 3), 4), 5), 6), 7), 8), 9), 10), 11), 12), 13), 14), 15), 16), 18), 19), 20), 23), 26), 29), 30), 31), 33), 34), 35), 36), 37), 39), 40), 43), 45), 46), 47), 48), 49), 50), 53), 55), 56), 57), 58), 59), 60), 61), 62), 63), 64), and 65).

69) Procedures for preservation, packing and shipping.

70) Shipping list, including all major components that will ship separately.

71) Material safety data sheets, containing a description of the hazardous and potentially hazardous materials included in the scope of supply.

72) Deviation / exception list (see 15.2.1).

73) Quality plan in accordance with ISO 9000 series.

74) Control logic diagram.
See 10.1.1 and annex E.

Annex G
(informative)

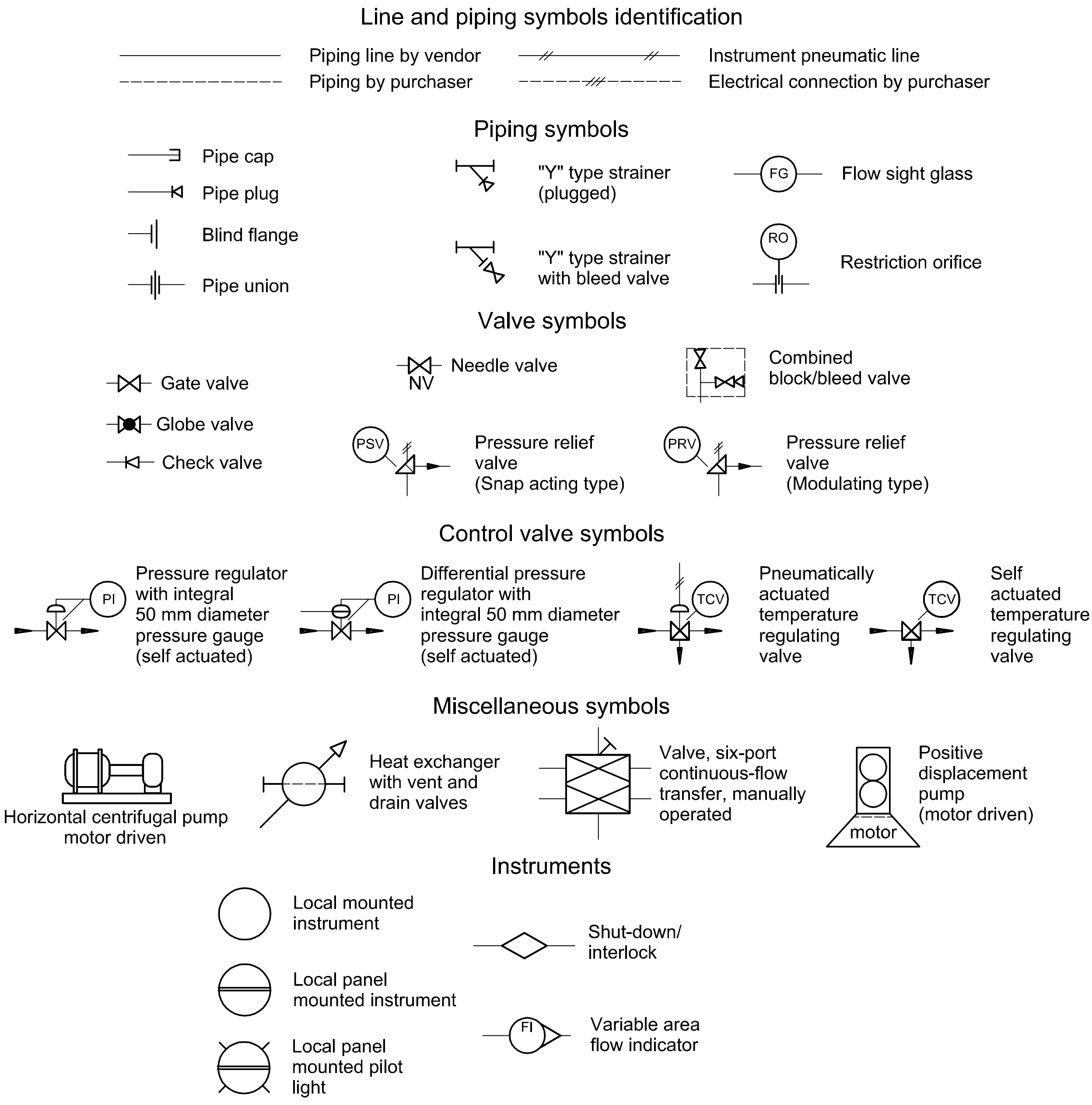
Figures and schematics

The schematics presented in this annex illustrate the general philosophy and requirements of this International Standard and are typical of commonly used systems. They are not intended to include all details such as vent and drain details and minor piping connections to permit disassembly. The systems may be modified as necessary with the agreement of the purchaser and vendor.

Instrument piping and valving details are not shown on typical schematics. Such requirements, including on-line testing requirements, shall be agreed by the purchaser and vendor.

Requirements for all of the systems illustrated are covered in the main text, as indicated by the cross references in the notes accompanying each figure. Further elaboration on the details of pressure packing to minimize process gas emissions is given in annex I.

See Figures G.1 to G.5.



Abbreviations

FO	= Fail open	NC	= Normally closed
FC	= Fail closed	NO	= Normally open
LO	= Locked open	OWS	= Oily water sewer

Key

FG	= Flow sight glass	PSL	= Low pressure switch
FI	= Variable flow area meter	PSLL	= Low low pressure switch
LG	= Level gauge	PSV	= Pressure relief valve (snap acting type)
PAL	= Low pressure alarm	RO	= Restricting orifice
PDSH	= High differential pressure shut-down	TE	= Temperature element
PI	= Pressure indicator	TI	= Temperature indicator
PRV	= Pressure relief valve (modulating type)		

NOTE Legend and symbology shown applies to schematics in annexes G & I.
Other symbology may be used in execution of contracts as agreed between purchaser and vendor.

Figure G.1 — Legend and symbols

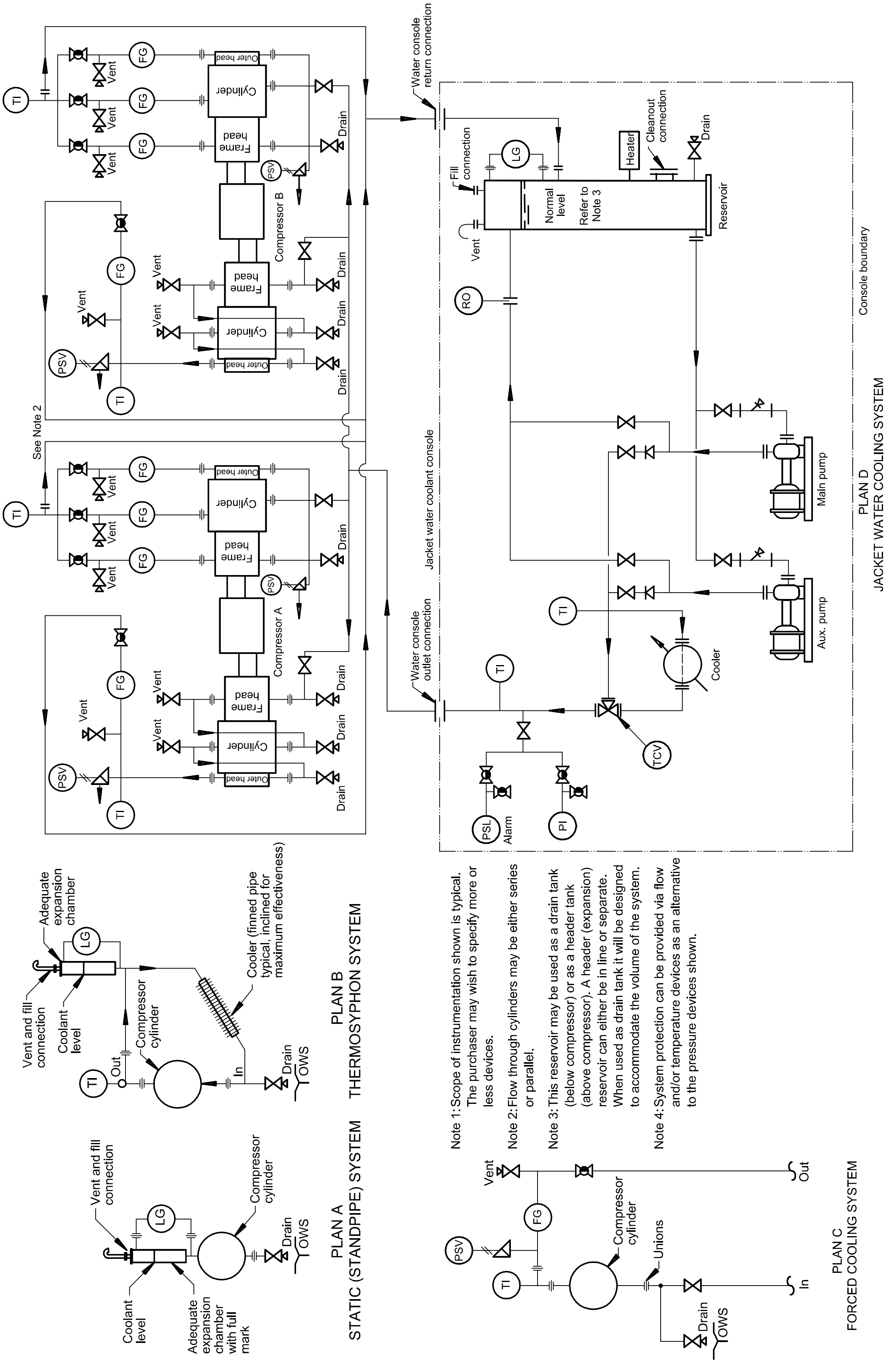
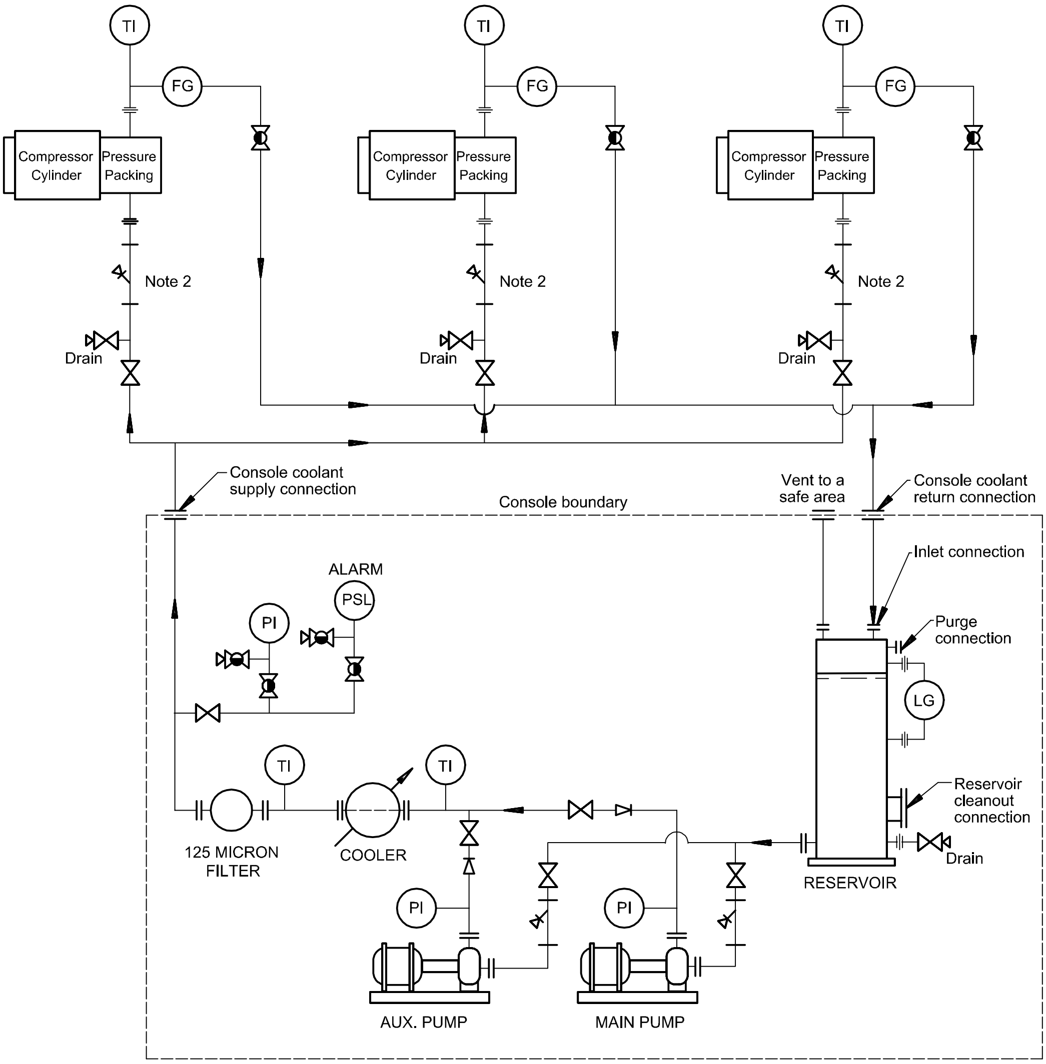


Figure G.2 — Cylinder cooling system schematic



NOTES

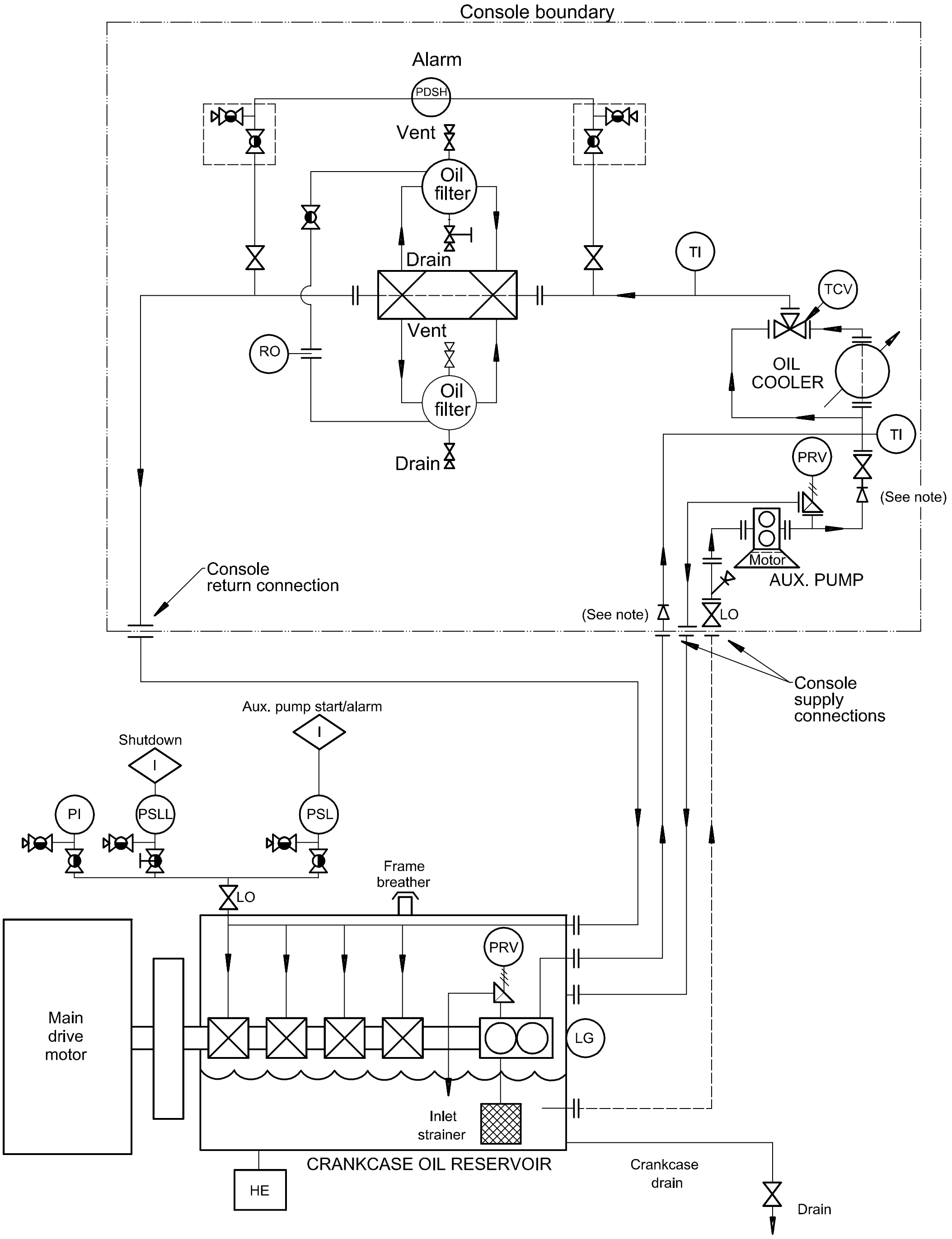
1 The system shown is typical: more or less euipment may be furnished.

2 If a packing cooling console is not supplied, individual 125 µm strainers are required.

3 For cooling media other than water, system design shall be mutually agreed upon between purchaser and the vendor.

4 System protection can be provided via flow and/or temperature devices as an alternative to the devices shown.

Figure G.3 — Pressure packing cooling schematic

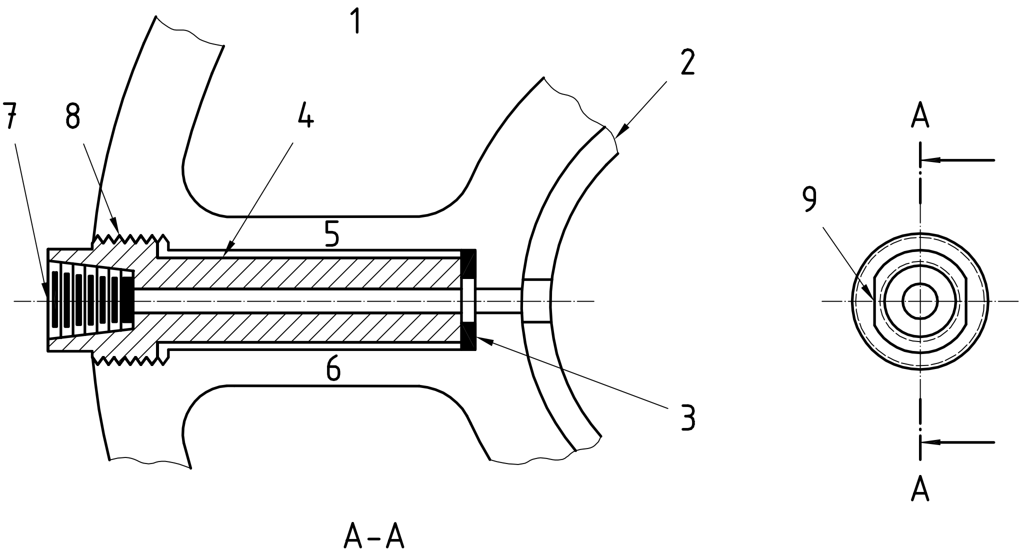


NOTES

1 Check valve type and location should be selected to ensure that, where the main oil pump is located above the normal oil level in the frame, operation of the auxiliary pump will automatically prime the main oil pump.

2 Pressure instrumentation shown local to the frame may be located on console when agreed by purchaser and manufacturer.

Figure G.4 — Frame lubricating oil system schematic



NOTES

1 See 2.6.4.6.

2 This typical arrangement utilizes a 17-4 stainless steel sleeve as a standard compressor cylinder design. the sleeve is installed during manufacture of the cylinder, providing a high-strengh, corrosion-resistant passage through a minor boss area. The design installation arrangement of the 17-4 stainless steel sleeve may vary among manufacturers.

Key

1 Cylinder water jacket

2 Liner

3 Soft steel gasket

4 17-4 PH stainless steel valve

5 Boss

6 Cylinder body casting

7 ½ in NPT

8 Straight threads

9 Wrench flats

Figure G.5 — Typical cylinder indicator tap connection

Annex H
(informative)

Materials for major component parts

Table H.1 — Materials for reciprocating compressor parts

Part	Material	Form
Frame	Cast iron	Cast
Crankshafts	Steel	Forged
Connecting rods	Steel	Bar stock, forged or cast
	Ductile iron	Cast
Crosshead pins	Steel	Forged or bar stock
Distance pieces	Cast iron	Cast
Cylinders	Steel	Cast, forged or fabricated
	Stainless steel	Cast or fabricated
	Nodular iron	Cast
	Grey iron	Cast
Cylinder liners	Steel	Tubing
	Stainless steel	Cast
	Ni-resist	Cast
	Nodular iron	Cast
	Grey iron	Cast
Cylinder heads	Steel	Cast, forged or fabricated
	Stainless steel	Plate
	Nodular iron	Cast
	Grey iron	Cast
Pistons	Steel	Forged, cast, bar stock or fabricated
	Cast iron	Cast
	Aluminium	Forged or cast
Piston rods and tailrods	Steel	Forged or bar stock
	Stainless steel	Bar stock
Piston rod nuts	Steel	Forged or bar stock
	Stainless steel	Forged or bar stock
Valve seats and guards	Steel	Plate or bar stock
	Stainless steel	Plate, bar stock or cast
	Nodular iron	Cast or bar stock
	Cast iron	Cast
Valve plates	Stainless steel	Plate
	Non-metallic	Molded
Valve springs	Steel	Drawn
	Stainless steel	Formed
Packing cases	Steel	Bar stock
	Stainless steel	Bar stock
	Cast iron	Cast
Packing case flange	Steel	Forged, bar stock or plate
Piston rings, wear bands and packing rings	Metallic	Cast or bar stock
	Non-metallic	Molded or sintered

Annex I
(informative)

Distance piece vent, drain and buffer systems to minimize process gas leakage

I.1 General

This annex contains a general philosophy for the design of reciprocating compressor distance piece vent and drain systems, which are typical of systems commonly used in conjunction with means to minimize process gas leakage. This annex is not intended to cover all possible situations, rather it focuses on providing an approach which can be used to design successful systems.

NOTE The piping, tubing and components external to the distance piece may be supplied by either the purchaser or vendor. It is good practice for the vendor and purchaser to discuss the vent and drain system and agree on its design. See 6.5.4 and 6.5.5.

Instrument piping and valving details are not shown on typical schematics. Such requirements, including on-line testing requirements, should be agreed by the purchaser and vendor.

I.2 Abbreviations and symbols

The abbreviations and symbols used in the schematics in this annex are shown on Figure G.1.

I.3 The purpose of distance piece vent, drain and buffer systems

A distance piece vent and drain system working in conjunction with packing, buffer system and partitions, accomplishes several functions, including:

a) confining and collecting the normal leakage from compressor rod pressure packing and carrying the leakage to a safe location;

b) preventing toxic or hazardous gas leakage into the area around the machine;

c) preventing contamination of the crankcase lubricating oil;

d) atmospheric fugitive emission control;

e) confining and collecting large leakage in the event of compressor pressure packing failure and directing the leakage to a safe location;

f) helping to prevent an explosive atmosphere from developing in the crankcase;

g) preventing excessive liquid accumulation in the distance piece;

h) avoiding gas leakage to sewer systems;

i) allowing the operator to monitor and determine the condition of compressor pressure packing.

I.4 Minimizing process gas leakage

Figures I.2 and I.3 illustrate the arrangement of two typical distance piece types that may be used when it is necessary to reduce the leakage of process gas to a minimum. Figure I.1 show the arrangement of the packing rings and the direction of flow and typical pressures of the buffer gas.

Side-loaded packing rings provide constant mechanical axial loading towards the sealing face of the cup. This mechanical axial loading, added to a nitrogen buffer pressure of at least 1 bar higher than the disposal pressure, hold the rings positively against their sealing faces thus minimizing buffer gas leakage and, at the same time, assures that all the process gas that leaks past the cylinder pressure packing cups will be forced out into the disposal system (e.g. flare) through the vent plate.

When proper differential buffer gas pressures are maintained, process gas leakage into the distance pieces is minimal; process gas is prevented from entering the compressor frame.

To minimize gas emissions, special packing and long distance pieces should be specified. See 6.6.8.

I.5 Design consideration

In addition to meeting the purposes described in I.3 the following factors should be considered in designing a distance piece vent, drain and buffer system.

a) Small diameter vent and drain piping will tend to foul and corrode over time, inhibiting their function. Consider using large (e.g. DN 50) vent and drain headers and corrosion-resistant materials.

b) On two-compartment distance piece systems, external cross connections between the inner and outer compartment vents and drains shall be avoided.

c) On multiple machine systems, it should be possible to isolate each machine for maintenance.

d) Effective control of gas leakage requires the specification of gasketed solid metal covers on distance pieces. See 6.5.2.

e) Where vents, drains, liquid collection pots and distance pieces are connected to disposal systems, such as a flare or closed drain system, they should be designed to withstand the maximum disposal system pressure (e.g. flare back pressure under relieving conditions). See 6.5.4.

   NOTE Distance pieces are typically designed for a maximum gauge pressure of 2 bar. Special designs are required for higher pressures.

f) Typically, the common vent and drain from the pressure packing (connection G in Figures I.2 and I.3) will be carrying a mixture of liquid and gas. The system shall be designed to separate these phases in order to avoid liquid blockage of the vent system.

g) Leaks from the stems of valve unloaders and clearance pockets may also need to be collected and controlled. These can be integrated with the distance piece vent and drain system.

h) There is concern about the reliability of check valves in safety situations, particularly in low pressure systems such as distance piece vent and drain systems where there is any mixture of gas and liquids. Check valve use should be avoided, where possible.

i) Except for the pressure packing combined vent and drain, which is a pressure driven flow, separate vent and drain lines are necessary between the distance piece and liquid collection pot to pressure balance the system and allow free drainage. Sloped headers, without pockets, assist draining.

j) Large diameter tubing (20 mm OD minimum) can be used between the individual distance pieces and the vent and drain headers. This usually results in a neat, easily maintained installation compared to a piping system.

k) Manifolding and cross-connections with drains and blowoffs from other equipment should be avoided.

l) The inert gas purge pressure shall be limited to the maximum permissible pressure for the distance piece components. See 6.5.4. Some inert gas will flow into the compressor frame. Frame venting shall allow an outlet for this flow. (See Figure G.4).

m) Pneumatic trip systems internal to the frame (e.g. crosshead pin temperature) should be energized with nitrogen rather than air to assist in maintaining an inert atmosphere in the crankcase.

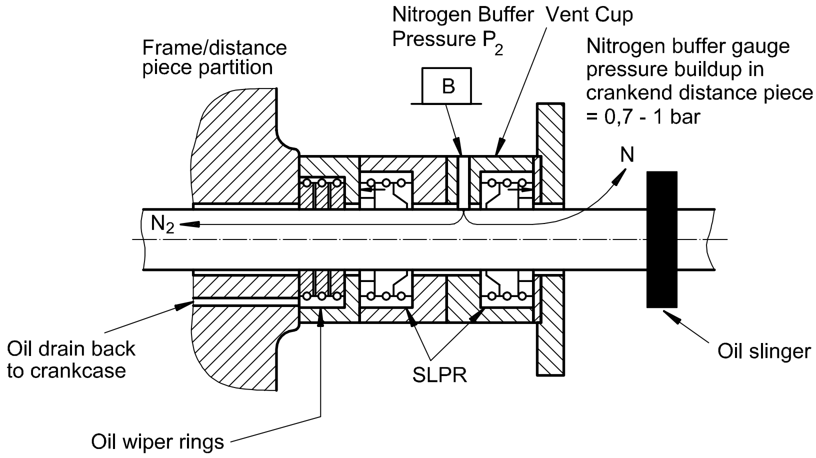
n) Effective establishment of an inert atmosphere in the crankcase will necessitate special maintenance safety procedures.

o) Where climatic conditions require, drains should be heat-traced and insulated.

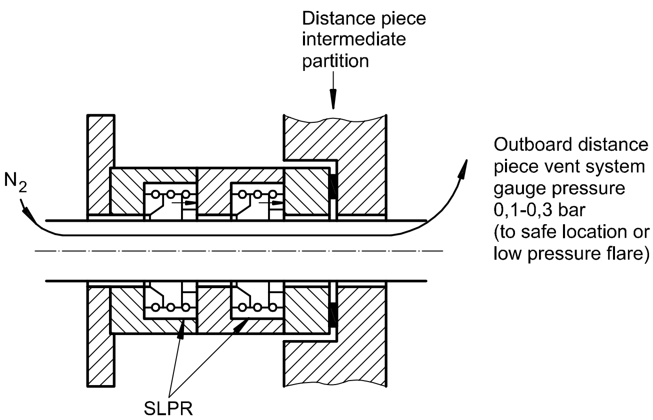
p) Under total packing failure, it should not be possible to over-pressure the distance piece. (See 6.5.4 and 6.5.5). If the vent area is not sufficient, additional venting to a safe location by way of emergency pressure relief valves or spring loaded pressure relief doors may be required.

q) Nitrogen purge rates are typically sized for a flow rate of 0,03 m^3/h per packing set (may reach 0,2 m^3/h per packing set on startup) and are fitted with flow indicators.

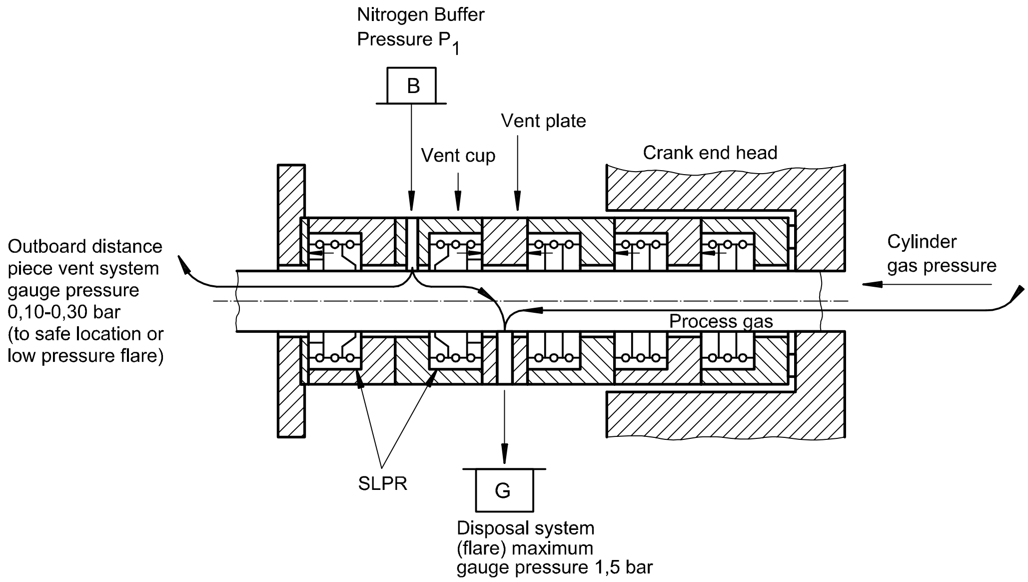
See Figures I.1 to I.3.



Oil wiper packing (with N_2 buffer)



Intermediate seal packing (with N_2 purge)
(Not used with Type A & B distance pieces)



Pressure packing

SLPR   Side-loaded packing rings

→   Indicates sealing face of packing rings

NOTES

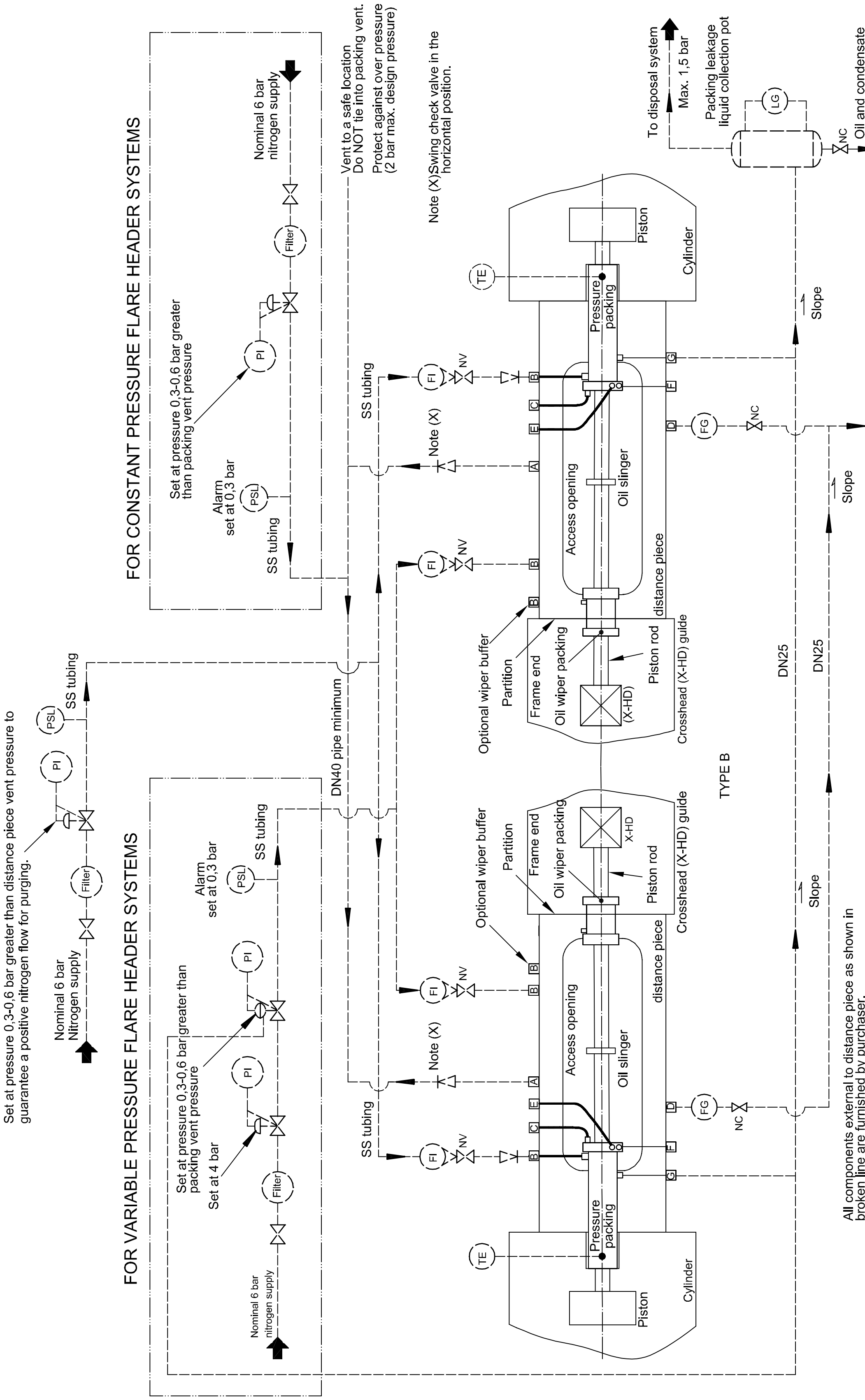
1   See 2.10.6 and 2.11.8.

2   Nitrogen buffer gauge pressure P_1 should be at least 1 bar higher than the disposal system at connection A or G (Figure I.2, I.3). Buffer gauge pressure P_2 should be at least 0,6 bar higher than the disposal system at connection A (Figures I.2, I.3).

3   The oil wiper packing may be on the distance piece side of the partition and integral with buffer seal packing.

4   The intermediate seal packing may be buffered in addition to the inboard oil wiper packing or the intermediate seal packing alone may be buffered with the inboard distance piece vented to atmosphere.

Figure I.1 — Typical purged and buffered packing arrangment



Key

A Vent, distance piece
B Purge, buffer or pressure, packing or distance piece
C Lubricating, pressure packing
D Drain, distance piece
E Coolant out, pressure packing
F Coolant in, pressure packing
G Common vent and drain, pressure packing

NOTES
1. This is a typical system and may require modification based on specific user requirements. (See I 1)
2. As an alternative to separate distance piece purging system shown, the wiper packing may be buffered.
3. All pressure values given are typical.

Figure I.2 — Single compartiment distance piece — Typical buffer gas vent and drain schematic

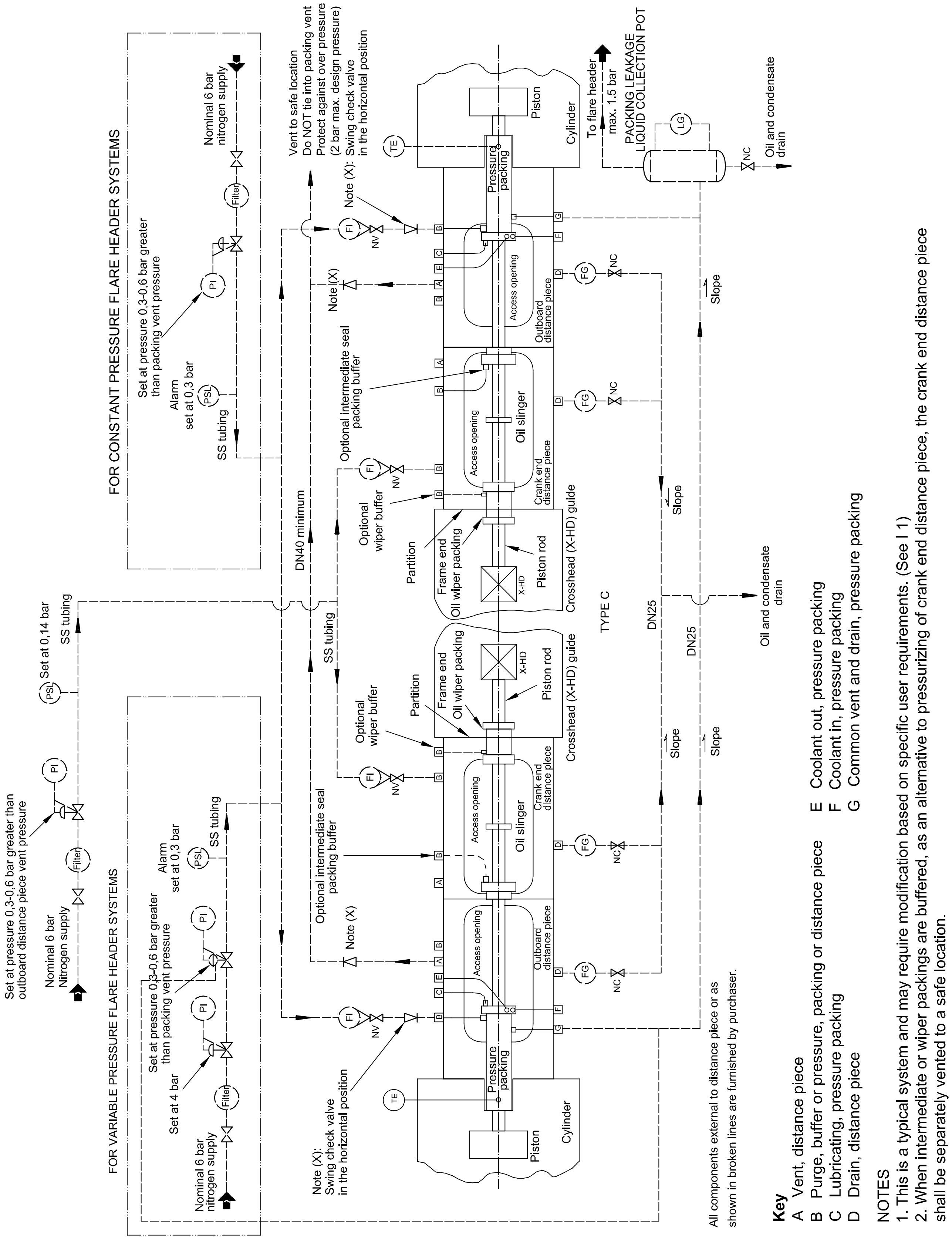
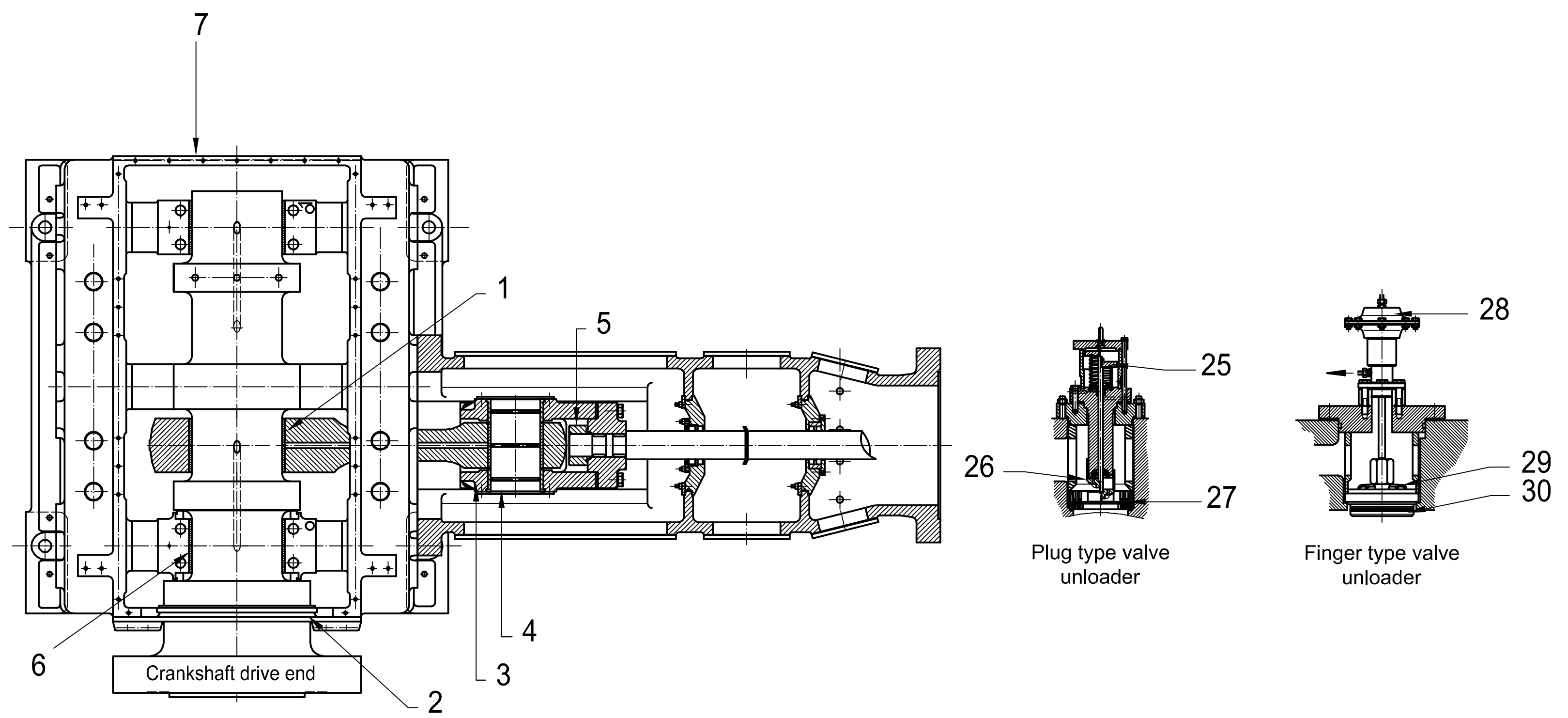


Figure I.3 — Two-compartiment distance piece — Typical buffer gas vent and drain schematic
(cranked compartment pressurized — outboard compartment vented)

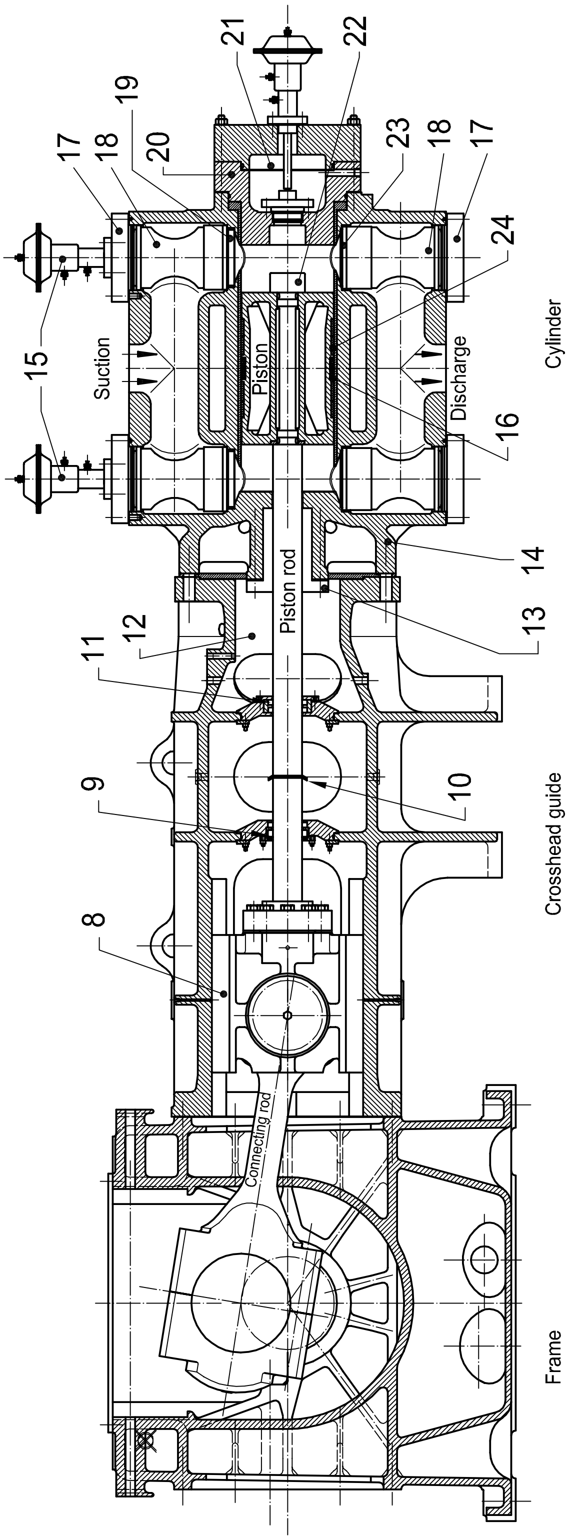
Annex J
(informative)

Reciprocating compressor nomenclature



Key

1 CRANK PIN BEARING
2 CRANKSHAFT SEAL
3 CROSS HEAD
4 CROSS HEAD PIN
5 PISTON ROD LOCK NUT
6 MAIN BEARING
7 OIL PUMP END, AUXILIARY END
8 CROSS HEAD SHOE
9 OIL WIPER PACKING
10 OIL SLINGER
11 INTERMEDIATE SEAL PACKING
12 DISTANCE PIECE
13 PISTON ROD PRESSURE PACKING
14 CYLINDER HEAD CRANK END
15 SUCTION VALVE UNLOADERS
16 PISTON RINGS
17 VALVE COVER
18 VALVE CAGE
19 SUCTION VALVE
20 CYLINDER HEAD, HEAD END
21 CLEARANCE POCKET
22 PISTON NUT
23 DISCHARGE VALVE
24 RIDER RINGS
25 PISTON TYPE ACTUATOR
26 PLUG UNLOADER
27 RING-TYPE SUCTION VALVE
28 MEMBRANE-TYPE ACTUATOR
29 FINGER-TYPE UNLOADER
30 PLATE-TYPE SUCTION VALVE


17
18
19
20
21
22
23
18
17
24
15
Suction
Piston
Discharge
16
Cylinder
14
Piston rod
13
12
11
9
10
Crosshead guide
8
Connecting rod
Frame

Annex K
(informative)

Inspector's check-list

This inspector's check-list represents a summary of the potential inspection points mentioned in the main text.

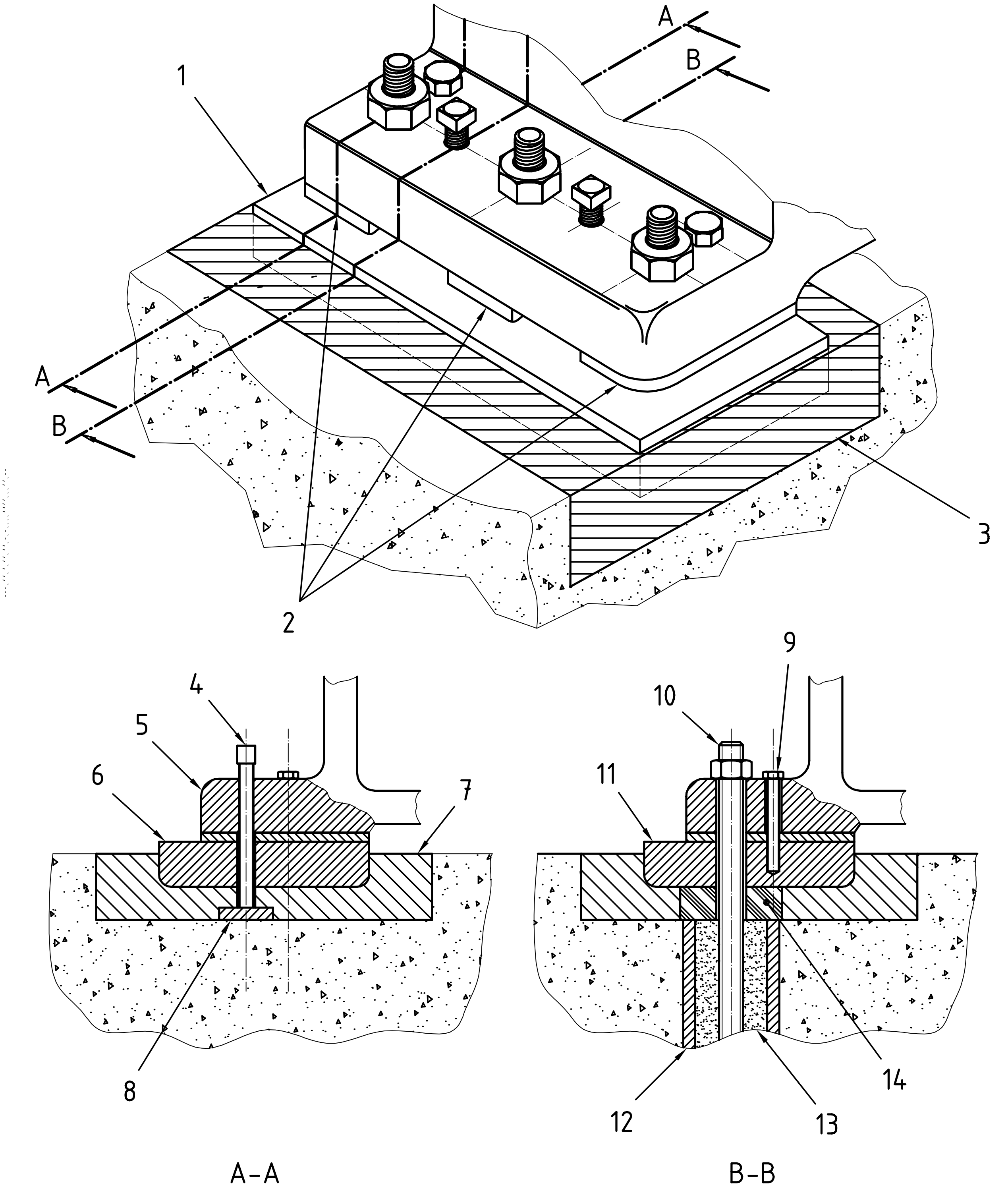
The final inspection plan shall be agreed between purchaser and vendor and reflected in the quality plan.

Item	Reference	Date inspected	Inspected by	Status
Material inspection	13.2.2			
Crankshaft ultrasonic inspection	13.2.2.3.3			
Piping fabrication and installation	11.1.10 11.1.11 11.1.12			
Hydrostatic test–cylinder	13.3.2.1			
Hydrostatic test–piping and vessels	13.3.2.1			
Gas leakage test	13.3.2.2			
Shop test	13.3.3.1			
Bar-over test Piston rod runout per Rod Runout worksheet in annex C	13.3.4.1			
Cylinder valve leak test	13.3.4.3			
Additional tests–as specified				
Crankshaft web deflection				
Examination of internals for cleanliness: piping crankcase pulsation suppressors coolers filters other				
Rotation arrow	6.7.2			
Overall dimensions and finish[a]				
Anchor bolt layout and size[a]				
Painting	14.3.2			
Corrosion protection exterior	14.3.3 14.3.13			
Corrosion protection interior	14.3.4			

Item	Reference	Date inspected	Inspected by	Status
Corrosion protection lubricated surfaces	14.3.5			
Closures of all openings	14.3.6 14.3.7 14.3.8			
Equipment nameplate data	6.7.3			
Packing for shipment	14.3.10			
Equipment identification	14.3.11			
Piping connections identification (tagging)	14.4			
Additional inspections – as specified				
NOTE [a]Check against certified drawings.				

Annex L
(informative)

Typical mounting plate arrangement



A–A B–B

Key

1 Mounting plate (sole-plate/rail)
2 Chock block locations
3 Epoxy grout
4 Levelling jackscrew
5 Frame
6 Rail or sole-plate
7 Epoxy grout
8 Levelling plate
9 Capscrew
10 Anchor bolt
11 Chock block
12 Anchor bolt sleeve
13 Non-bonding fill
14 Anchor bolt sleeve grout seal

NOTE Epoxy grout not to contact anchor bolt.

Annex M
(informative)

Pulsation and vibration control studies

M.1 General

This annex describes a number of specific procedures (Items A to H) associated with the three design approaches (refer 12.2) and optional additional procedures (Items I to K).

The procedures which may be considered to be associated with each design approach are as follows:

Design Approach 1	Item A
Design Approach 2	Items B, C and D
Design Approach 3	Items B, C, D, E, F, G and H
Optional	Items I, J and K

M.2 Item A — Analytical study

a) Design of compressor pulsation suppression devices using proprietary and/or empirical analytical techniques (acoustic simulation is not required) to meet pulsation levels specified in 12.2.5.

NOTE Without an acoustic simulation, it is not possible to know whether or not the specified levels will be met.

b) A simplified analysis of the purchaser’s piping system to determine critical piping lengths that may be in resonance with acoustic excitation frequencies.

M.3 Item B — Acoustic analysis (acoustic simulation study)

Consists of using modelling techniques which account for the acoustic interaction between the compressor and piping. The modelling method shall account for the dynamic interaction of flow through the valves and the dynamic pressure variation in the cylinder and in the cylinder passages immediately outside of the valves. Variations in specified operating conditions shall be analysed by extending the analysis above and below the specified operating conditions. This is normally accomplished by simulating speeds above and below the specified speed(s). This step may include a passive piping analysis to determine the acoustic response of the piping. The piping system shall be modelled to a point where piping changes will have insignificant effects on the parts of the system under study (usually a large vessel upstream and downstream of the units to be studied). The pulsation analysis study shall produce the following information.

a) Prediction of pulsation levels

Operating conditions and compressor loading steps are chosen to yield the highest expected pulsation amplitudes throughout the piping systems. Pulsation amplitudes are then compared to the levels identified in 12.2.7 and 12.2.2.3.

b) Calculation of pulsation-induced shaking forces (unbalanced forces)

Predict the maximum pulsation-induced shaking forces and unbalanced pressure acting on the critical elements of the piping system such as pulsation suppression devices, pulsation suppression device internals, vessels, closed-end headers etc.

c) Development of piping modifications

If the pulsation analysis indicates that pulsation levels and/or shaking forces are too high, modifications to the pulsation suppression devices and/or piping systems will be made and the analysis continued until the system meets the guidelines defined in 12.2.7 and 12.2.2.3.

M.4 Item C — Performance analysis (pulsation and pressure drop effects)

a) Pressure drops are calculated through each pulsation suppression device and compared to the levels identified in 12.2.2.4.

b) The effects of dynamic interaction between compressor cylinders, pulsation suppression devices and attached piping on cylinder performance are evaluated and pulsation-induced power and capacity deviations are determined for the recommended design. This analysis should optimize pulsation related compressor performance.

M.5 Item D — Mechanical piping system analysis

This study calculates the mechanical natural frequencies of the individual piping spans using published frequency factors, nomograms etc. to ensure that the piping span natural frequencies are detuned from significant pulsation excitation harmonics. From this analysis the piping supports, clamp type, planes of restraint and their locations are recommended. Thermal flexibility effect should be considered in the clamp designs and anchoring systems. Generally the clamp and support stiffness should be at least twice the basic piping span stiffness in order to ensure a vibratory node at the clamp.

M.6 Item E — Mechanical compressor manifold system analysis

Calculation of mechanical natural frequencies and mode shapes of the cylinder manifold system.

This analysis involves modelling the properties of the crosshead guide(s), distance piece(s), cylinder(s), flange(s), compressor nozzle(s), branch connection(s), pulsation suppression devices and inlet and outlet piping. For accurate results, the modelling process should consider the significant mechanical component properties (such as gasket flexibility, clamp stiffness, shell deflections of the pulsation suppression device etc.) that influence the response.

M.7 Item F — Compressor manifold system vibration and dynamic stress analysis

The significant pulsation-induced forces are implied to the mechanical model of the compressor manifold system. The vibration and dynamic stresses at the critical points in the system are compared to the levels identified in 12.2.2.1. The cylinder gas load as determined by 5.4.3 should be considered in the evaluation of dynamic stresses. The analysis shall be carried out to the extent required to obtain meaningful information for a given design and then justified in the report.

M.8 Item G — Piping system dynamic stress analysis

A piping system dynamic stress analysis calculates the mechanical system responses and associated mode shapes. The significant predicted pulsation forces are imposed on the piping to the extent necessary in order to calculate the expected vibration and stress amplitudes at the critical points in the system. These stresses are compared to the levels identified in 12.2.2.1.

M.9 Item H — Calculation of dynamic and static stresses on pulsation suppressor internals

This study applies pulsation-induced shaking forces and pressure induced static forces to the shell and vessel internals and computes stress levels to satisfy 12.2.2.1.

M.10 Item I — Compressor valve dynamic response study

This study calculates dynamic response of the valve spring and sealing element including interaction with the piping and compressor cylinder gas passage induced pulsations. It evaluates the pulsation related effects on compressor performance and valve efficiency, reliability and life. The valve dynamic model shall include all items as required in 6.2.

M.11 Item J — Pulsation suppression device low cycle fatigue analysis

This analysis is used to predict the stresses from thermal gradients, thermal transients and pressure cycles on the pulsation suppression devices and internal components. These stresses are compared with the values acceptable in accordance with the pressure vessel code.

M.12 Item K — Piping system flexibility

This analysis predicts the forces and stresses resulting from thermal gradients and thermal transients, pipe and fitting masses, static pressure and bolt-up strains. These stresses are compared to the levels identified in the applicable standard code. Modelling includes frame growths and component properties listed in Item F.

Annex N
(informative)

Guideline for compressor gas piping design and preparation for an acoustic simulation analysis

N.1 General

N.1.1 Any reciprocating compressor in conjunction with a piping system forms an interactive dynamic system that cannot be accurately analysed as two separate systems. Therefore, it is virtually impossible for the pulsation system designer and the piping system designer to arrive at proposed designs on an independent basis that can be guaranteed to work in the final analysis and be cost effective.

N.1.2 Clause 12 of this International Standard defines the technical requirements placed on the pulsation control system designer. This annex gives guidelines for the piping system designer which will help to minimize problems that can occur at the time of the acoustic simulation and outlines the information that must be available at the time of this interactive analysis. Communication between the piping system designer, the compressor vendor and the pulsation control system designer during the course of a project is important in order to minimize problems and develop the best overall compressor system installation. The key times of interaction are at the post order co-ordination meeting (see 15.1.3) early in the project and during the interactive acoustic simulation/mechanical analysis.

N.1.3 The purchaser may elect to perform an in-house acoustic simulation, use equipment vendor services or services of a third party.

N.2 Acoustic consideration in piping designs

N.2.1 The interaction of the compressor, pulsation devices and piping system produces potentially harmful pulsations when there is resonant interaction between the various elements in the system. The system designer can help to minimize this interaction by avoiding resonant lengths of pipe. When resonant lengths of pipe are used and the resonant frequency matches compressing frequency, one can expect major changes to the system as a result of the acoustic simulation analysis. The resonant length of various piping configurations is given in equation N.1. It is recommended that lengths of these configurations be avoided in a ± 10 % band for the first four harmonics of compressor speed. The piping areas where this is most important are the sections of piping between the first major volume on the suction side and the first major volume on the discharge side. Once the outside major volumes are far enough away from the compressor(s) the potential for harmful pulsation buildup is considerably reduced.

N.2.2 For piping sections open at both ends or closed at both ends the length to be avoided can be calculated from the following:

$$L_{\mathrm{H}} = 30 \frac{c}{z \times n} \tag{N.1}$$

where

L_{H} is the pipe length to be avoided in metres;

c is the velocity of sound in gas in metres per second;.

z is the harmonic number (1, 2, 3, 4)

n is the compressor speed in revolutions per minute.

Examples of this are lengths between major volumes, length of headers, etc.

N.2.3 For pipe sections open at one end and closed at the other end, the length, L_Q, to be avoided can be calculated from the following:

$$L_Q = 15 \frac{c}{z \times N} \qquad \text{(N.2)}$$

Examples of this are relief valve lines and bypass lines.

NOTE Pipe diameter changing from a small to a larger size can be considered an open end when the diameter change is 2 to 1 or more. Similarly, pipe diameter changes from a large to a small diameter can be considered a closed end when the diameter change is 2 to 1 or more.

N.2.4 The acoustic simulation should be carried out after a piping stress analysis has demonstrated that the location and design of the piping restraints result in acceptable piping stresses.

N.2.5 For variable speed compressors and/or those with varying gas composition and/or varying pressures and temperatures, the separation of resonances are more difficult to calculate and can only be handled properly with an acoustic simulation study.

N.3 Acoustic simulation study

N.3.1 The extent of the piping system to be analysed by acoustic simulation techniques is usually defined as all associated piping systems to a point where piping changes will have only insignificant effects on the parts of the system under study and in determining the acoustic characteristics of the design. Typically, these requirements are satisfied by beginning the simulation with the inlet of a major process vessel or volume on the suction side of the compressor unit(s), continuing through all interstage systems (if any) and terminating the study at the outlet of a major process vessel or volume on the discharge side of the unit(s). Included are side branches to or from this system, such as relief valve lines and bypass lines.

N.3.2 When major volumes do not exist or are very remote from the compressor, suitable piping lengths are included such that the pulsation levels are sufficiently low so as to minimize the potential of pulsation-driven vibration problems.

N.4 Information required

N.4.1 The acoustic simulation requires a considerable amount of information in order to be properly performed. The purchaser and the vendor should agree as to who is responsible for the co-ordination of the necessary information. In any case, the purchaser should be given the opportunity to review the data.

N.4.2 Information from the system designer

N.4.2.1 Data sheet showing all compressor operating conditions, analysis of all gases to be compressed and steps of unloading.

N.4.2.2 Isometric drawings showing all lengths (between bends, valves, diameter changes, etc.) and line sizes and schedules for the complete piping systems, including all branch lines. If a mechanical study is included, the distance between the supports and the type of support and clamp used at each location must be shown on the isometrics. A detailed drawing of each type of support and clamp is required.

N.4.2.3 Piping and instrument diagrams (P&IDs) are required to ensure that all piping and equipment that may effect the study is included.

N.4.2.4 Layout drawings are required to help determine the practicality of any proposed modifications. Reproducible drawings are useful since they can be marked up and copies included in the report.

N.4.2.5 Complete information must be supplied in section N.3 on all of the piping up to and including the first large volume in the suction, the interstage and the discharge piping. Every branch must be included up to a shutoff valve or a large volume.

N.4.2.6 Any orifice or other flow resistive device must be shown and complete details provided.

N.4.2.7 Detailed drawings of each vessel, showing the location of all nozzles, the internal diameter and the length, as well as details of any vessel internals are required. Normal liquid levels and design pressure drops in these vessels must be shown.

N.4.2.8 TEMA data sheets, or their equivalent, must be provided for all heat exchangers. The data sheet must show whether gas is through the tubes or in the shell, the number, length and gauge of tubes, whether the tubes are plain or finned, the number of passes, the I.D. of the shell, the gas temperature in and out, the gas pressure drop and the dimensions of the header. A dimensional drawing is preferred.

N.4.2.9 If there are different gas routings, a complete description must be included to show the relative positions of all the valves for each routing. If different gases are involved, the description must show which routings apply to which gases. Flow from/to any sidestream must be shown including gas analysis, flow rate and direction.

N.4.2.10 If there are gas filters used, the type of filter, internal diameter, length and element pressure drop must be supplied. A dimensional drawing is desirable.

N.4.2.11 When two or more compressors are connected to the same piping system, a clear description is required explaining how they will operate (e.g. loading steps, speed differences, etc.).

N.4.3 Information from the pulsation suppressor vendor

Detailed dimensional drawings on each suppressor showing the location of all nozzles, length, internal diameters and details on suppressor internals, if any.

N.4.4 Information from the compressor vendor

Compressor data	Design Approach 2	Design Approach 3
Compressor data		
Head end fixed clearance volume	X	X
Head end unloader volume(s)	X	X
Crank end fixed clearance volume	X	X
Crank end unloader volume(s)	X	X
Compressor cylinder (internal passage)	X	X
Distance piece (inertia and stiffness)		X
Crosshead guide (inertia and stiffness)		X
Assembled cylinder weight		X
Support drawings		
Cylinder support drawings		X
Crosshead guide support drawings		X
Distance piece support drawings		X
Pulsation suppressor support drawings		X
Compressor Valve Data		
Number of valve assemblies		X
Type of valves		X
Number of valve elements per assembly		X
Valve lift		X
Weight per element		X
Spring pre-load per element		X
Full projected lift area per element		X
Effective full list flow area per assembly		X
Crank angle between manifolded cylinders		X

N.4.5 A system design representative who is familiar with the piping system should be present at the acoustical simulation analysis so that piping changes can be made if necessary.

Annex O
(informative)

Guidelines for sizing low pass acoustic filters

O.1 General

The general configuration for an acoustic filter is shown in Figure O.1.

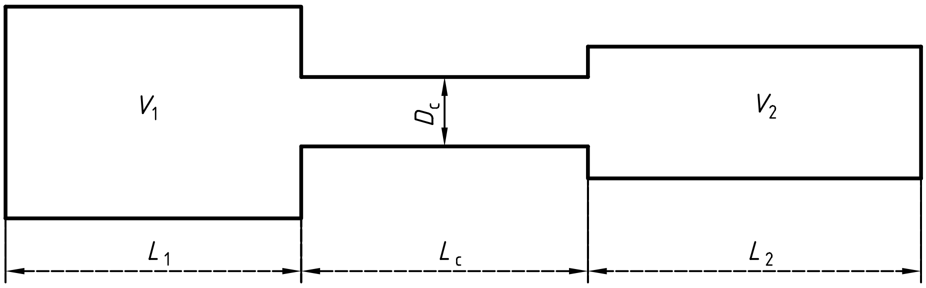


Figure O.1 — Nonsymmetrical filter

The lowest acoustic resonant frequency of the filter system is referred to as the Helmholtz frequency. An accepted generalized equation for Helmholtz frequency, f_H, is:

$$f_H = \frac{c}{2\pi}\left(\frac{\mu}{V_1} + \frac{\mu}{V_2}\right)^{1/2} \quad \text{in Hz} \tag{O.1}$$

where

c is the velocity of sound in gas in metres per second;

V_1 is the volume in cylinder bottle (chamber) in cubic metres;

V_2 is the volume in filter bottle (chamber) in cubic metres;

μ is the acoustic conductivity.

and

$$\mu = \frac{A}{L_c + 1{,}2\ D_c} = \frac{A}{L}$$

A is the internal cross-sectional area of choke in square metres;

L_c is the actual length of choke in metres;

L is the acoustic length of choke in metres;

D_c is the diameter of choke in metres.

The filter cut-off frequency, f_{00}, which is the frequency above which pulsation attenuation is achieved, is usually defined as follows:

$$f_{00} = \sqrt{2}\, f_H$$

The acoustic filter can be either symmetrical or non-symmetrical. As shown in Figure O.1 and Equation O.1, the non-symmetrical filter can have different volumes (lengths and diameters) and a different length of choke.

For a symmetrical filter, the volumes are equal and the acoustic length of the choke L is equal to the length of each volume. This also means that the diameter of each volume is equal.

Substituting into Equation O.1 for symmetry, the Helmholtz frequency for a symmetrical filter becomes:

$$f_H = \frac{2}{\sqrt{2}} \frac{c}{\pi} \frac{D_c}{L D_B} \quad \text{in Hertz} \tag{O.2}$$

where D_B is the diameter of bottles in metres.

O.2 Guidelines

Unless otherwise specified and agreed upon, the following guidelines are to be used for the preliminary sizing of acoustic filters.

O.2.1 Selection of Helmholtz frequency (f_H)

The preferred Helmholtz frequency is:

$$f_H = \frac{n}{85} \quad \text{in Hertz}$$

where

n is the compressor speed in revolution per minute.

Only when conditions are such that it is uneconomical, or physically impractical, should a higher Helmholtz frequency be considered, i.e., only when pressure drop is very critical–as in the case of low suction pressure, or when space is limited by the compressor system layout. In that instance, a higher Helmholtz frequency may be chosen. Generally, the Helmholtz frequency should not be higher than:

$$f_H = \frac{n}{45} \quad \text{in Hertz}$$

unless the acoustic simulation proves otherwise. For compressor speeds above 8,333 s^{-1} (500 r.p.m.), the Helmholtz frequency should not exceed:

$$f_H = \frac{n}{85} \quad \text{in Hertz}$$

O.2.2 Relationships of filter element diameters

The diameter of the cylinder bottle (chamber) V_1 should be equal to, or greater than, 2 × the diameter of the cylinder connection (flange).

The diameter of the filter bottle (chamber) V_2 should be equal to, or greater than, 3 × the diameter of the line piping.

O.2.3 Relationship of Filter Element Length

The preferred filter system has equal lengths of cylinder bottle (chamber), choke tube and filter bottle (chamber). In cases where the physical restraints (piping layout) and the required sizes do not permit equal lengths, the next best alternative is with equal length of choke and filter (chamber).

O.2.4 Sizing of the diameter of the choke tube (D_C)

Unless otherwise specified, calculate the maximum permissible pressure drop per the applicable equation in 12.2.2.4. Using maximum permissible pressure drop and appropriate pressure drop relationship, calculate the minimum diameter choke tube which can be used considering all operating conditions expected.

Annex P
(informative)

Compressor components — compliance with NACE MR0175

Key

1 Clearance pocket valve

2 Finger type valve unloader

3 O-ring cover type inlet and discharge valve

4 Plug/port unloader

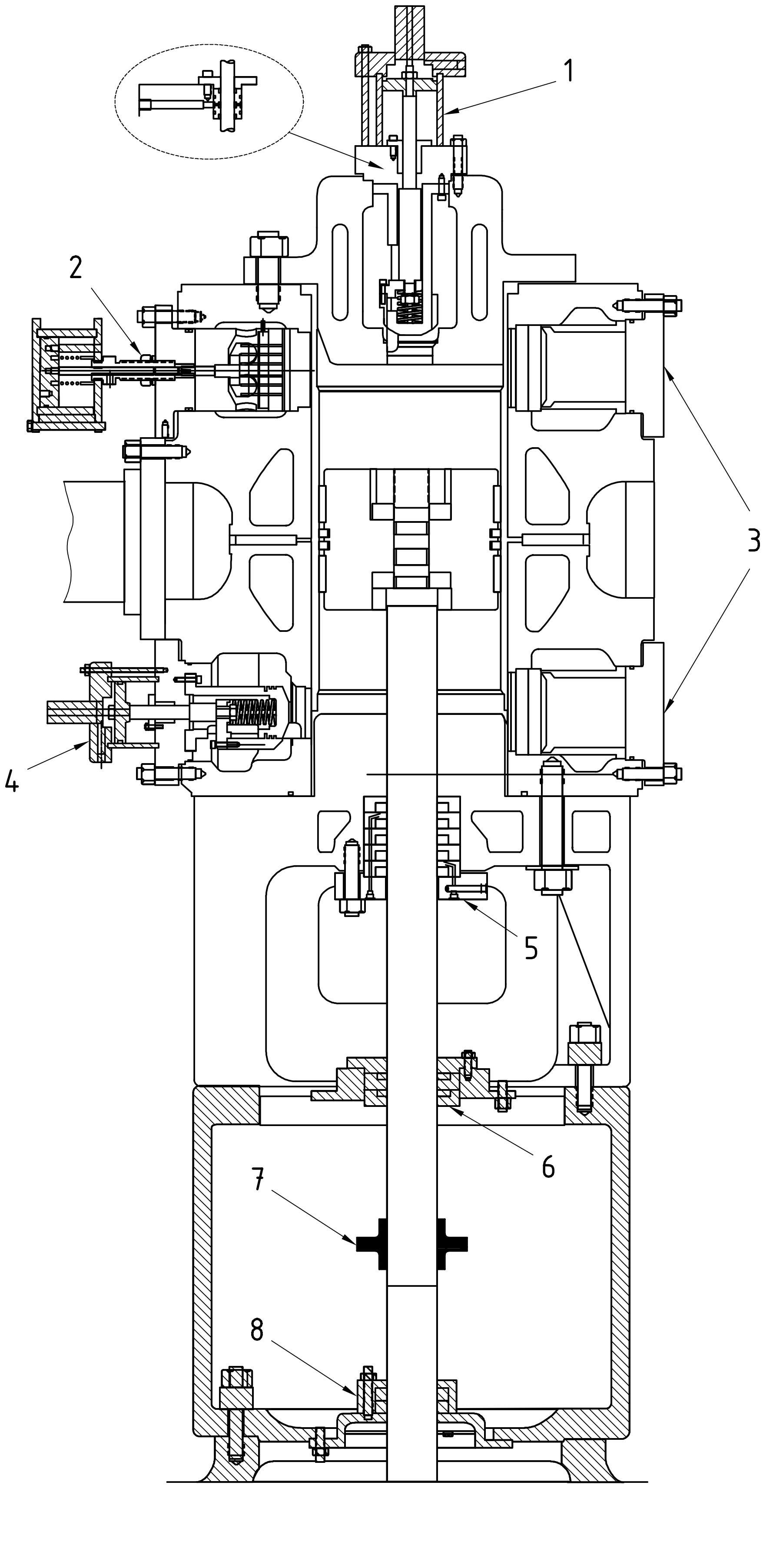
5 Pressure packing

6 Intermediate partition packing

7 Oil slinger

8 Oil wiper packing

NOTE Components shown in section area are not required to be supplied in materials compliant with MR 0175.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Annex Q
(informative)

Alarm and shut-down systems

Q.1 General

For the guidance of purchaser and vendor three arrangements are described below which meet the intent of 10.5.3.

Q.2 Arrangement 1

Q.2.1 Alarms and shut-downs are initiated by conventional, locally mounted, direct-acting switches.

Q.2.2 Alarm and trip switches are completely independent of each other.

Q.2.3 Each alarm and each shut-down switch is furnished in a separate housing, located to facilitate inspection and maintenance. Switch settings are not adjustable from outside the housing.

Q.2.4 Both shut-down and alarm switches are connected through normally energised, fail-safe circuits. The shut-down circuit wiring is completely independent from the alarm circuit wiring and is run in separate conduit or armoured cable.

Q.3 Arrangement 2

Q.3.1 Shut-down functions are initiated by local direct-acting switches connected in a normally-energized, fail-safe circuit as described in Arrangement 1.

Q.3.2 Alarm functions comprise locally-mounted transmitters (electronic or pneumatic) connected to either separate panel-mounted switches or to a multi-point scanning-type instrument.

Q.3.3 Where multi-point, scanning-type instruments are used, the alarm setting for each function is separately and independently adjustable.

Q.4 Arrangement 3

Q.4.1 Each function for which both an alarm and a shut-down are specified, is provided with three separate and independent electronic transmitters.

Q.4.2 Each transmitter is independently connected to one of three multi-point, electronic, scanning-type instruments. Connections are made through separate cables.

Q.4.3 Each multi-point instrument provides both alarm and shut-down settings, separately and independently adjustable, for each transmitted input.

Q.4.4 The shut-down and alarm function outputs from the three multi-point instruments are connected through “two-out-of-three” voting logic. The arrangement is such that operation of any one alarm or shut-down function will initiate an alarm; operation of two shut-down functions monitoring the same parameter will initiate a separate alarm and cause the compressor to shut-down.

Q.3.5 Alarm functions which are not associated with a shut-down function, are provided with one single transmitter. These alarm transmitters may be connected to one of three alarm/shut-down multi-point instruments or to a separate multi-point instrument.

Q.3.6 This arrangement (Arrangement 3) has the following advantages.

— Any shut-down or alarm function can be tested at any time with the equipment in service without the need to disarm any part of the system.

— Failure of any one component will initiate an alarm but will not result in equipment shut-down.

— The use of modern, digital instrument technology is facilitated.

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[7] ASTM A 182M, *Standard Specification for Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service.*

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