INTERNATIONAL STANDARD

ISO 13631

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Petroleum and natural gas industries — Packaged reciprocating gas compressors

Industries du pétrole et du gaz naturel — Unités de compresseurs alternatifs à gaz

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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.

The main task of technical committees is to prepare International Standards. 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.

ISO 13631 was prepared by Technical Committee ISO/TC 118, *Compressors, pneumatic tools and pneumatic machines*.

Annex B forms a normative part of this International Standard. Annexes A, C, D and E are for information only.

Introduction

This International Standard is based on API specification 11P second edition, November 1989.

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.

A bullet (•) at the beginning of a subclause or paragraph indicates that either a decision is required or further information is to be provided by the purchaser. This information should be indicated on the data sheets (see annex A).

Petroleum and natural gas industries — Packaged reciprocating gas compressors

1 Scope

This International Standard gives requirements and recommendations for the design, materials, fabrication, inspection, testing and preparation for shipment of packaged skid-mounted, reciprocating, separable or integral compressors with lubricated cylinders and their prime movers, for use in the petroleum and natural gas industries for the compression of hydrocarbon gas.

It is also applicable to all necessary auxiliary equipment, such as water and gas coolers, silencers, emission control equipment, filters, separators, control panel, piping, etc., required to install an operable unit in compliance with the purchase specifications and with the intent of minimizing field construction and field-purchased equipment.

This International Standard is not applicable to the following:

— reciprocating compressors for petroleum and natural gas industries covered by ISO 13707;

— column-mounted compressors;

— non-lubricated compressors;

— compressors having trunk-type (automotive-type) pistons that also serve as crossheads;

— utility or instrument air compressors with a discharge gauge pressure of 0,9 MPa (9 bar) or less;

— compressors driven by diesel engine, gas turbine and steam turbine prime movers.

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 68-2:1998, *ISO general-purpose screw threads — Basic profile — Part 2: Inch screw threads*

ISO 185, *Grey cast iron — Classification*

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 263:1973, *ISO inch screw threads — General plan and selection for screws, bolts and nuts — Diameter range 0.06 to 6 in*

ISO 281, *Rolling bearings — Dynamic load ratings and rating life*

ISO 1813, *Belt drives — V-ribbed belts, joined V-belts and V-belts including wide section belts and hexagonal belts — Electrical conductivity of antistatic belts: Characteristics and methods of test*

ISO 4126-1:1991, *Safety valves — Part 1: General requirements*

ISO 4986:1992, *Steel castings — Magnetic particle inspection*

ISO 5864:1993, *ISO inch screw threads — Allowances and tolerances*

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

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

ISO 8504-2, *Preparation of steel substrates before application of paints and related products — Surface preparation methods — Part 2: Abrasive blast-cleaning*

ISO 9934-2, *Non-destructive testing — Magnetic particle testing — Part 2 Detection media*

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

ISO 13707, *Petroleum and natural gas industries — Reciprocating compressors*

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

ISO 15649, *Petroleum and natural gas industries — Piping*

IEC 60034, *Rotating electrical machines*

IEC 60079, *Electrical apparatus for explosive gas atmospheres*

IEC 60364-5, *Electrical installation of buildings — Part 5: Selection and erection of electrical equipment — Common rules*

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

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

API Std 1B[1)], *Specification for oil-field V-belt*

API RP 520 Part I, *Sizing, selection and installation of pressure relieving devices in refineries. Part I — Sizing and selection*

API RP 520 Part II, *Sizing, selection and installation of pressure relieving devices in refineries. Part II — Installation*

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

ASME[2] B 1.1 *Unified inch screw threads (UN and UNR thread form)*

ASME B 1.20.1, *Pipe threads, general purpose (inch)*

ASME VIII, ASME Boiler and pressure vessel code: 1998, Section VIII, *Rules for construction of pressure vessels*

ASTM A 320/A 320M, *Standard specification for alloy/steel bolting materials for low-temperature service*

ASTM A 503, *Standard specification for ultrasonic examination of forged crankshafts*

ASTM A 536, *Standard specification for ductile iron castings*

ASTM A 668/A 668M, *Standard specification for steel forgings, carbon and alloy, for general industrial use*

ASTM A 781/A 781M, *Standard specification for castings, steel and alloy, common requirements, for general industrial use*

EN 1561:1997 *Founding — Grey cast irons*

EN 1563:1997 *Founding — Spheroidal graphite cast irons*

EN 10213-1:1995, *Technical delivery conditions for steel castings for pressure purposes — Part 1: General*

EN 10213-2:1995, *Technical delivery conditions for steel castings for pressure purposes — Part 2: Steel grades for use at room temperature and elevated temperatures*

EN 10213-3:1995, *Technical delivery conditions for steel castings for pressure purposes — Part 3: Steel grades for use at low temperatures*

EN 10213-4:1995, *Technical delivery conditions for steel castings for pressure purposes — Part 4: Austenitic and austenitic-ferritic steel grades*

EN 10269, *Steels and nickel alloys for fasteners with specified elevated and/or low temperature properties*

NACE MR 0175[3], *Standard material requirements, Sulfide stress cracking resistant metallic materials for oilfield equipment*

NEMA Standards Publication 250-1997, *Enclosures for Electrical Equipment (10 000 Volts Maximum)*

3 Terms and definitions

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

3.1
capacity
quantity of gas taken into the compressor at the specified inlet conditions, compressed and delivered at the specified discharge pressure

NOTE 1 It is expressed in units of mass flow or standard volume flow.

NOTE 2 The capacity of a compressor 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.

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

3) National Association of Corrosion Engineers, P.O. Box 218340, Houston, TX 77218-8340, USA.

3.2
combined rod load
algebraic sum of gas load and inertia force on the crosshead pin

3.2.1
gas load
force resulting from differential gas pressure acting on the piston differential area

3.2.2
inertia force
force resulting from the acceleration of reciprocating mass

NOTE 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 accelerations.

3.3
manufacturer's rated capacity
capacity of the compressor used by the manufacturer to assign its size

3.4
maximum allowable continuous combined rod load
highest combined rod load at which none of the forces in the running gear and the compressor frame exceeds the values that the compressor manufacturer's design permits for any component for continuous operation

NOTE Running gear includes the piston, piston rod, crosshead assembly, connecting rod, crankshaft, bearings, etc.

3.5
maximum allowable speed
highest speed at which the manufacturer's design permits continuous operation

3.6
maximum allowable 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

3.7
maximum allowable working pressure
MAWP
maximum continuous gauge pressure for which the compressor manufacturer has designed the equipment (or relevant part thereof) when handling the specified fluid at the specified temperature

3.8
minimum allowable speed
lowest speed at which the manufacturer's design permits continuous operation

3.9
normal operating point
point at which usual operation is expected and optimum efficiency is desired

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

3.10
rated discharge pressure
highest pressure required to meet the conditions specified by the purchaser for the intended service

3.11
rated power
〈of the compressor〉 maximum power required of the compressor plus any shaft-driven appurtenances for any of the specified operating conditions

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

3.12
rated speed
highest speed required to meet any of the specified operating conditions

3.13
required capacity
capacity specified by the purchaser to meet process conditions, with no negative tolerance (NNT) permitted

3.14
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

3.15
standard flow
flowrate at an absolute pressure of 0,101 3 MPa (1,013 bar) and a temperature of 0 °C

NOTE It is expressed in units of volume flow.

4 Statutory requirements

The purchaser shall specify any applicable regulations. The purchaser and the vendor shall mutually determine the measures to be taken to comply with those regulations that are applicable to the equipment.

Use of the word “design” in the purchaser's specifications should be avoided.

5 General package requirements

5.1 Compressor package performance curves

- If specified, the compressor package performance curves shall cover the range of operating conditions indicated by the purchaser. Any limitations such as rod load, available driver power, additional clearance required to meet the range of operating conditions, etc., shall be marked on the performance curves.

5.2 Package arrangement

The arrangement of the package components shall be developed by the vendor to provide reasonable access for operation and maintenance.

5.3 Drawings

- The vendor shall furnish plan and elevation drawings. Pre-fabrication approval or additional drawings may be specified by the purchaser.

5.4 Sound pressure level

- Control of the sound pressure level of all equipment furnished shall be the joint effort of the purchaser and the vendor. If specified, the equipment furnished by the vendor shall not exceed the maximum sound pressure level required by the purchaser.

5.5 Electrical area classification

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

5.6 Package installation

- The purchaser shall specify the site conditions (altitude, ambient temperature, etc.), and whether the installation is indoors (heated or unheated) or outdoors (with or without a roof) and the weather or environmental conditions in which the equipment must operate (including maximum and minimum temperatures, unusual humidity or dust problems). The unit and its auxiliaries shall be suitable for operation in these specified conditions. The purchaser shall specify dimensional limitations, if any.

5.7 Torsional analysis

- The vendor shall provide a torsionally sound system and perform an analysis to demonstrate this. When specified, a torsional analysis report shall be provided, and the vendor shall be responsible to coordinate with the compressor and prime-mover manufacturers to produce such a report.

6 Compressor

6.1 General

6.1.1 Manufacturer's rated capacity

The compressor shall be sized to handle not less than the required capacity with the gas composition, suction pressures, suction temperatures, discharge pressures and site conditions specified by the purchaser. The number of stages of compression shall accommodate pressure limitations and gas additions or withdrawals as specified. The package design shall also allow for all pressure drops through the separators, pulsation suppression devices (if any), coolers and piping from the inlet flange to the outlet flange of the package.

6.1.2 Performance calculations

The vendor shall use the specified values of mass flowrate, 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 flowrate. The compressor vendor shall indicate his values on the data sheets with the proposal and use them to calculate performance data.

6.1.3 Compressor size

- If specified, the compressor shall be furnished with cylinders which, when operating at the specified operating condition(s), shall as far as practical, load the gas engine to the limit specified in 8.2.1 or electric motor to the limit specified in 8.3.2.

Compressors driven by induction motors shall be sized at the motor operating speed.

6.1.4 Forces and couples

The vendor shall furnish values for the unbalanced primary and secondary forces and couples in the horizontal and vertical planes for the package.

6.2 Allowable speeds

- The maximum acceptable average piston speed (in metres per second) and the maximum acceptable speed (in revolutions per minute) may be specified by the purchaser where experience indicates that specified limits should not be exceeded for a given service.

6.3 Allowable discharge temperature

- Unless otherwise specified and agreed, the maximum predicted discharge temperature shall not exceed 135 °C. This limit applies to all specified operating and load conditions. If specified, the vendor shall provide the purchaser with both the predicted and adiabatic discharge temperatures.

NOTE The actual discharge temperature will vary from the adiabatic depending on such factors as the power input to a cylinder, the ratio of compression, the size of the cylinder, the surface area of the cooling passages and the velocity of the coolant.

6.4 Rod loads

6.4.1 Allowable rod loads

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

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

6.4.2 Rod load reversal

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

6.5 Compressor cylinders

6.5.1 General

6.5.1.1 The maximum allowable working pressure of the cylinder shall exceed the rated discharge pressure by at least 10 % or 0,17 MPa (1,7 bar), whichever is greater. The maximum allowable working pressure shall be at least equal to the specified relief valve set pressure including accumulation.

6.5.1.2 Horizontal cylinders shall have bottom discharge connections except where side or top discharge connections are accepted by the purchaser.

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

6.5.2 Cylinder/crankcase appurtenances

6.5.2.1 The cylinder support shall be designed to avoid misalignment or excessive rod run-out during the warm-up period and at actual operating temperature. The cylinder support shall, where practical, not be attached to the outboard cylinder head. When impractical, then the crankcase through to cylinder assembly shall be capable of supporting the weight of the cylinder during maintenance. The pulsation suppression device, if furnished, shall not be used to support the compressor cylinder, unless approved by the purchaser.

Most cylinder supports are attached at the end of the distance piece. Some pulsation analyses require both a distance piece support and a cylinder end support. A cylinder end support should not be used unless required due to a pulsation requirement, as incorrect support types or their adjustment result in operation difficulties. Additionally a cylinder end support should not be used in place of the distance piece support.

6.5.2.2 Cylinders may be non-liquid-cooled (no provision for coolant jackets) or liquid-cooled (coolant jacket around the cylinder bore and cylinder head).

6.5.2.3 Bolting shall be furnished as specified in 6.5.2.3.1 through 6.5.2.3.4.

6.5.2.3.1 Details of threading shall conform to ASME B1.1 or ISO 68-2, ISO 261, ISO 262, ISO 263 and ISO 5864. The use of fine-pitch threads shall not be used in cast irons and in external fasteners subject to routine maintenance, including pressure-containing parts.

Fine-pitch threads should be avoided in all cases, as being subject to self-unfastening.

6.5.2.3.2 Studs are preferred to cap screws.

6.5.2.3.3 Stud material shall be in accordance with EN 10269 for steel and ductile iron cylinders. EN 10269 or ASTM A 307 Grade B may be used for cast iron cylinders. ASTM A 320 shall be used for temperatures of −20°C and below. Stud markings shall be located on the exposed end of the stud. With high-temperature studs, use nuts in accordance with EN 10269. Nuts in accordance with EN 10269 are acceptable for use with EN 10269 or ASTM A 307 studs.

NOTE For the purposes of this subclause, ASTM A 193 Grade B7 for studs and ASTM 194 Grade 4, Grade 7 or Grade 2H, as appropriate, for nuts, are equivalent to EN 10269.

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

6.5.3 Cylinder connections

6.5.3.1 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 working pressure of the cylinder as specified in 6.5.1.1. The facing and bolting of the main inlet and outlet flanges and auxiliary connections shall conform to the dimensional requirements of ISO 7005-1 or ISO 7005-2 as applicable. Alternative standards are acceptable by mutual agreement. The details of any special connections, such as a lens joint, shall be submitted to the purchaser for review.

- **6.5.3.2** If specified, each cylinder shall be provided with a DN 12 (1/2 in) indicator tap at each end.

6.6 Valves

6.6.1 Average valve gas velocity

The vendor shall state the average valve gas velocity for each specified operating condition. The average valve gas velocity shall be computed as follows:

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

where

v is the average gas velocity, in metres per second;

F is the effective piston area of the cylinder end or ends concerned, in square centimetres;

f is the product of the actual lift, the valve opening periphery and number of inlet or discharge valves, in square centimetres;

c_m is the average piston speed, in metres per second.

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.

NOTE 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 or disc/plate impact.

6.6.2 Valve design

6.6.2.1 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.

6.6.2.2 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.

6.6.2.3 Valve discs or plates shall be suitable for installation with either-side sealing.

6.6.2.4 Valves shall be suitable for operation with any specified gas.

6.7 Pistons, piston rods and piston rings

6.7.1 Piston attachment

Pistons that are removable from the rod shall be attached to the rod by a shoulder-and-nut design or by a multi-through-bolt design. All nuts shall be positively locked in place. Nuts attaching the piston rod to the piston and to the crosshead shall be tightened in accordance with the manufacturer's regulations. The rod shall be positively locked to the crosshead to prevent rotation. Hydraulic or thermal methods are preferred for tightening piston-rod nuts.

6.7.2 Hollow pistons

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

6.7.3 Piston wear bands

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

6.7.4 Piston rod hardness

A minimum surface hardness of HRC 50 is required on piston rods in the area that passes through the packing. For piston rods in corrosive gas service, see clause 20.

6.7.5 Piston rod threads

Piston rods shall be furnished with rolled threads.

6.7.6 Coated piston rods

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. If coatings are used, piston rods shall be continuously coated from the piston rod packing through the oil-wiper travel areas. The coating material shall 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.

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 raisers left in the surface. Use of sub-coating under the main coating is not recommended.

6.8 Crankcases, crankshafts, connecting rods, bearings and crossheads

6.8.1 Crankshafts

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

6.8.2 Bearings

Main bearings shall be replaceable sleeve type or of the tapered or spherical roller type. Roller bearing selection shall be based on an L10 rating equivalent to 44 000 h or greater as defined in ISO 281 at rated compressor speed and maximum allowable continuous combined rod load. Cylindrical roller or ball-type bearings are unacceptable. Crank pin bearings shall be replaceable sleeve type.

6.8.3 Connecting rods

Connecting rods shall be of the compressor manufacturer's standard material with removable cap. They shall be free of any sharp corners. Forced-lubrication passages shall be drilled.

6.8.4 Crossheads

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

6.8.5 Crankcases

- 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.

The total throat area of these devices should be not less than 70 mm^2 for each cubic decimetre of crankcase free volume.

6.9 Distance pieces

6.9.1 Design

- **6.9.1.1** Distance pieces shall conform to Type 1, 2 or 3 as specified by the purchaser. Type 1 (short, close-coupled, without compartment) is used where it is desired to keep overall width of the compressor to a minimum. Type 2 (single compartment) is used when physical separation of the pressure and wiper packing is desired. Type 3 provides double compartments for varying degrees of purging when required.

- **6.9.1.2** If specified, slinger rings shall be provided to Type 2 or 3 distance pieces to prevent migration and mixing of oil between the crankcase and the compressor cylinders, in which case the respective compartment will be of the long type.

6.9.2 Openings

Openings of adequate size to permit servicing of the pressure packing case shall be provided and shall have bolted access covers, a bottom drain connection, and a top vent connection. See 11.17.1 for drain and vent specifications.

6.9.3 Pressure-relief devices

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

6.10 Packing cases and pressure packings

6.10.1 Type

All oil-wiper, intermediate-seal and gas-cylinder pressure packings shall be segmental rings with corrosion-resistant garter springs.

6.10.2 Construction

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

6.10.3 Services

For flammable, hazardous, toxic or wet gas service, the pressure packing case shall be provided with a common vent and drain below the piston rod piped to the outside of the distance piece. See 11.17.1 for drain and vent specifications and clause 20 for corrosive gas applications.

6.10.4 Oil-wiper packing

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

6.11 Compressor crankcase lubrication system

6.11.1 Crankcase lubrication

The crankcase lubrication system shall be pressurized and shall have sufficient capacity to provide adequate lubrication at all speeds required to meet the specified operating conditions. Splash systems may be used on horizontal compressors with rolling element bearings when the compressor's nominal frame rating is 150 kW or less.

NOTE Information on lubricants is provided in ISO 3448.

6.11.2 Level indication

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

6.11.3 Lubrication oil pumps

6.11.3.1 The main oil pump shall be crankshaft-driven either directly, or through gears or a chain.

6.11.3.2 For each unit having a nominal rating of more than 225 kW, the vendor shall provide a separate, independently driven auxiliary oil pump.

6.11.4 Oil filtration

Full-flow filters with replaceable elements shall be supplied with filtration of 10 µm (nominal) or finer. For babbitt bearings, filtration may be 25 µm (nominal) or finer. The filters shall be located downstream of the cooler. Filters shall not be equipped with a relief valve or automatic by-pass. Filter cartridge materials shall be corrosion-resistant. Metal-mesh or sintered-metal filter elements shall not be used. The design of the filter-cartridge assembly shall assure that internal by-passing cannot occur due to filter-to-cartridge or cartridge-to-cartridge misalignment, inadequate end cover sealing design, or other sealing deficiencies. Additionally, the cartridge collapse differential pressure shall be at least 0,35 MPa (3,5 bar) and the clean differential pressure shall not exceed 0,03 MPa (0,3 bar) at design temperature and flow.

6.11.5 Materials

All parts in the crankcase and lubricating oil system shall be of materials suitable for the site environment. For corrosive gas services, see clause 20 for material requirements.

6.11.6 Oil level control

- If cylinder lubrication oil is taken from the crankcase, then a compressor crankcase oil-level control device shall be furnished (see 6.12.2). If specified by the purchaser, the vendor shall furnish a storage tank with level gauge and compressor crankcase oil-level control device.

6.11.7 Lubricating oil heater

- If specified by the purchaser, a lubricating oil heater shall be furnished by the vendor. When an internal heater is used, it shall be fully immersed even at minimum oil level and its surface heat flux shall not exceed 2 W/cm^2.

6.12 Compressor cylinder lubrication

6.12.1 Cylinder lubrication

Either block-distribution lubrication systems or pump-to-point lubrication systems shall be furnished for lubrication of compressor cylinder ring travel bore and piston rod packing. The force-feed lubricator shall be suited for variable flow and of weather-proof construction and shall be equipped with a reservoir level indicator. Unless otherwise specified, lubricators shall be crankcase-mounted and crankshaft-driven. Block-distribution lubrication systems shall be complete with no-flow shutdown, rupture relief discs, check valves and carbon steel or austenitic stainless steel tubing. Line filters, flow meter and fault indicators may be specified by the purchaser for block-distribution lubrication systems. For pump-to-point lubrication systems, a sight indicator for each point, check valves and carbon steel or austenitic stainless steel tubing shall be furnished.

6.12.2 Oil supply

- The force-feed lubrication system shall be complete with automatic oil replacement. The oil supply should be from a separate reservoir in preference to filtered oil from the compressor crankcase. A storage tank with level gauge shall be furnished if specified by the purchaser.

6.13 Materials

6.13.1 General

6.13.1.1 Materials of construction of the compressor and auxiliaries shall be the compressor manufacturer's standard for the specified operating conditions, unless otherwise required in the data sheets.

6.13.1.2 Steel compressor cylinders shall be equipped with steel heads.

6.13.1.3 Unless otherwise specified, materials for pressure-containing parts shall be used with the limitation of the MAWP indicated in Table 1.

Table 1 — Gauge MAWPs for cylinder materials

Material	MAWP MPa (bar)	
	Internal cylinder diameter	
	$\leqslant$ 200 mm	$>$ 200 mm
Grey cast iron	11,0 (110)	7,0 (70)
Nodular iron	17,0 (170)	10,0 (100)
Cast steel	18,0 (180)	18,0 (180)
Fabricated steel	10,0 (100)	8,5 (85)
Forged steel	No limitation	

6.13.1.4 ISO/TS 16528 should be used as a guideline for material and the quality of all welding of parts other than pressure vessels. The applicable standards shall be agreed between purchaser and vendor. For pressure vessels, see clause 10.

6.13.2 Castings and forgings

6.13.2.1 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 another standard method. All mould-parting fins and remains of gates and risers shall be chipped, filed or ground flush.

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

6.13.2.3 Unless otherwise specified by the purchaser, grey iron castings shall be produced in accordance with ISO 185 for pressure-containing castings. Grade shall be specified by the compressor manufacturer.

6.13.2.4 Unless otherwise specified by the purchaser, nodular iron castings shall be produced in accordance with EN 1563 or ASTM A 536 for pressure-containing castings. Grade shall be specified by the compressor manufacturer.

NOTE For the purposes of this provision, ASTM A 395 is equivalent to EN 1563.

6.13.2.5 The minimum quality standard allowed for steel castings shall be the appropriate part of EN 10213 and ASTM A 781. Grade shall be specified by the compressor manufacturer.

NOTE For the purposes of this provision, ASTM A 216, ASTM A 487 and ASTM A 703 are equivalent to EN 10213.

6.13.2.6 Forgings for pressure-containing parts shall as a minimum meet quality in accordance with ASTM A 668. Grade shall be specified by the compressor manufacturer.

6.13.2.7 Chemical analysis of an as-cast sample from each ladle is not required, unless otherwise specified or for use in corrosive services as identified in clause 20.

6.13.3 Casting repair

6.13.3.1 Major repairs to pressure-containing-parts and all repairs to moving parts subject to load reversals and crankshafts shall not be undertaken without notifying the purchaser. Pressure-containing castings shall not be repaired by peening, burning-in or impregnating. Pressure-containing castings and forgings shall not be repaired except as specified in 6.13.3.2 and 6.13.3.3.

6.13.3.2 Weldable grades of steel castings and forgings may be repaired by welding using qualified welding procedures based on the requirements of applicable recognized standards. 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.

6.13.3.3 Cast grey iron or nodular iron may be repaired by plugging. Repairs by plugging shall be within the limits specified in EN 1561 or EN 1563.

NOTE 1 For the purposes of this provision, ASTM A 278 is equivalent to EN 1561, and ASTM A 395 is equivalent to EN 1563.

Cast grey iron or nodular iron shall not be repaired by welding. However, unless otherwise agreed 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 2 Some acceptable repair techniques are described in annex E.

6.14 Power transmission

6.14.1 Gears

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

6.14.2 Couplings

Flexible shaft couplings shall be non-lubricated, steel disc type, except when torsional analysis requires a torsionally soft coupling or for low-speed applications. Couplings shall be selected for the maximum continuous power rating of the prime mover plus the coupling manufacturer's standard service factor for reciprocating compressor applications. The material shall be suitable for the ambient conditions specified in 5.6. Flexible couplings shall comply with ISO 10441 or ISO 14691.

6.14.3 V-belt drives

V-belt drives for compressor applications shall be in accordance with ISO 1813 or API Std 1B.

6.14.4 Clutches

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

6.14.5 Guards

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 for barring-over the machine and

provide for 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, corrosion-resistant, 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.

Guards over belt drives shall be corrosion-resistant and properly ventilated to prevent excessive heat build-up.

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

7 Capacity control

7.1 General

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

7.2 Method of capacity control

- Capacity control can be obtained by speed variation, clearance variation, bypass, single-acting or double-acting compressor cylinders, valve unloaders, or any combination thereof. Control operation shall be either automatic with manual over-ride or manual as specified by the purchaser on the data sheets. Some of these methods may require unit shutdown and depressurizing to effect a change. The purchaser shall specify if such unit shutdowns are acceptable. If any of these methods are implemented by other than the compressor manufacturer, then they shall be approved by the compressor manufacturer.

7.3 Speed variation

- If specified by the purchaser, capacity control can be achieved by prime-mover speed variation.

7.4 Clearance variation

7.4.1 Methods

Clearance variation may be achieved by one of the methods described in 7.4.2 through 7.4.6. These methods may be used alone or in combination. In all cases where clearance volume is added to a compressor cylinder end, the volumetric efficiency shall not be reduced to less than 15 %.

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

7.4.2 Clearance pockets

- Clearance pockets may be specified by the purchaser and be either of the fixed type (pocket clearance is fixed and the pocket is either open or closed) or the variable type (pocket clearance is variable over the range from fully open to closed). Variable-volume clearance pockets shall have a non-restricted vent line provided to vent the back side of the variable pocket piston to the suction port of the compressor cylinder, to the suction piping or to the vent system.

7.4.3 Valve spacers

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

7.4.4 Clearance bottles

- If specified, clearance bottles for capacity control may be added to the compressor cylinder. They shall be designed for the maximum allowable working pressure of the compressor cylinder and according to the specified applicable pressure vessel code.

7.4.5 Cylinder head spacer(s)

Spacer(s) may be placed between the compressor cylinder body and cylinder head to add clearance volume.

7.4.6 Clearance plugs

The compressor cylinder head may be furnished with clearance plugs.

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

7.5 Bypass systems

7.5.1 General

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

7.5.2 Start-up bypass

- If specified by the purchaser, a manually operated hot-gas bypass (from the discharge of the final stage to the inlet side of the compressor with no cooling of the gas) shall be provided for start-up purposes. A hot-gas bypass shall not be used for capacity control.

7.5.3 Capacity control bypass

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

A cold-gas bypass may be used for both start-up and capacity control purposes.

7.6 Valve removal or unloading

7.6.1 Valve removal

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

7.6.2 Valve unloaders

Compressor cylinder capacity control can be accomplished with valve depressors or plug-type unloaders. Valve depressors, when used, shall be installed on all suction valves of the cylinder end involved.

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

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

7.6.3 Automatic valve unloading

- If specified, the vendor shall provide a system of properly sequenced unloader operation. Otherwise, a definition of acceptable operating configurations and sequences shall be supplied by the vendor. Pneumatically operated unloaders with no manual overrides shall be piped by the vendor in such a manner that inadvertent non-sequenced operation shall not occur.

7.6.4 Unloader operator

Pneumatically operated unloaders shall be suitable for operation with any specified gas. If air-operated, they shall be designed so that the air used for unloading cannot mix with the gas being compressed, even in the event of failure of the diaphragm or another part.

7.7 Suction pressure limitation

- If specified by the purchaser, a suction pressure-reducing valve shall be used to limit the suction pressure to a set value in order to limit the load on the unit.

8 Prime mover

8.1 General

- The type of prime mover (gas engine or electric motor) shall be specified by the purchaser.

8.2 Spark-ignited gas engines

8.2.1 Engine rated power

Unless otherwise specified by the purchaser, the gas engine shall be sized for the compressor rated power plus transmission losses and plus engine accessories for the specific location, without exceeding the engine manufacturer's standard published rating criteria for continuous duty service. The engine manufacturer's continuous duty service is defined as the load and speed which can be applied without interruption after taking into consideration site conditions of altitude, temperature and fuel gas composition as listed on the data sheets.

NOTE A margin of 10 % on the engine rated power has been demonstrated to result in better operating reliability.

8.2.2 Operating speed

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

8.2.3 Starting systems

8.2.3.1 General

Electric, air or gas starting systems for the engine driver should be specified by the purchaser.

NOTE Engine shutdowns are addressed in clause 14.

8.2.3.2 Air or gas starting systems

Unless otherwise specified, air or gas starting systems shall include the items listed below:

a) manual block valve to isolate the following system;

- b) if required, a regulator to provide proper starter pressure. The purchaser shall specify source and minimum/ maximum pressure of air or gas available for the starting system;

c) safety relief valve (see 11.18 for sizing, setting criteria and venting);

d) spring-loaded (spring to close) quick-opening valve;

e) air or gas starter with lubricator and strainer;

f) The starter vent piping (sized for at least the same diameter as the starter exhaust connection) shall be piped to skid edge unless otherwise specified by the purchaser. The safe disposition of the starter vent gas shall be considered in the installation and is the responsibility of the purchaser.

8.2.3.3 Electric starting systems

Electric starting systems, when provided, shall be suitable for the electrical area classification (5.5) and shall include the following items:

a) electric starting motor with starting control;

- b) if specified, a battery set with sufficient capacity to start the engine at the lowest specified ambient temperature;

- c) if specified, a charging alternator of sufficient capacity to charge the battery set furnished.

8.2.4 Air intake system

8.2.4.1 Air shall not be taken from inside enclosed buildings.

8.2.4.2 Unless otherwise specified, the engine manufacturer's standard dry-type air intake filter, suitable for outdoor service, shall be provided. If alternative filters are specified by the purchaser, their design shall conform to the following minimum criteria.

a) The micrometre particle rating shall be that recommended by the engine manufacturer.

b) Site environmental conditions (blowing sand, ice, snow, etc.) shall be taken into consideration.

NOTE For low temperature applications, the inlet air may need to be heated (with exhaust heat for example) to avoid frost build-up on the filter.

c) The filter shall be oriented to allow in-service maintenance.

8.2.4.3 In addition to the above, the following features shall be considered for air filters that are mounted remote from the engine.

a) Piping and supports shall be furnished by the purchaser, unless otherwise specified.

b) Inlet piping to the engine shall have internal-surface corrosion protection.

c) Air filters shall be placed so that ground dust or snow will not clog the filter.

8.2.4.4 All ducting, including air cleaner-to-manifold connections, shall be air-tight to avoid the intake of unfiltered air.

8.2.4.5 Restricted inlets, sharp or numerous bends, and undersized piping shall be avoided. Maximum pressure drop shall not exceed engine manufacturer's recommendation.

- **8.2.4.6** A pressure drop indicator shall be provided if specified by the purchaser.

8.2.5 Exhaust system

8.2.5.1 The exhaust system shall be properly anchored and supported, include all interconnecting piping, and direct the expansion of the piping involved away from the engine. If an expansion joint is required, it shall be stainless steel.

NOTE Bellow-type expansion joints are preferred to flanged ones.

8.2.5.2 The muffler/silencer shall be painted with high-temperature-resistant aluminium paint or equivalent protection.

8.2.5.3 Exhaust piping shall be designed such that the back-pressure limitations of the engine are not exceeded.

8.2.5.4 Provision shall be made to prevent rainwater from entering the system and to eliminate water from exhaust gases or condensation.

8.2.5.5 Unless otherwise specified, an industrial-type exhaust silencer shall be provided. If an alternative exhaust silencer is specified by the purchaser, its design shall conform to the minimum criteria as specified on the data sheets, such as

— sound attenuation,

— personnel protection,

— spark-arresting capability.

8.2.5.6 Insulation and/ or guarding of hot metal surfaces shall not be provided, unless otherwise specified by the purchaser. However, adequate clearance shall be provided for insulation and/ or guarding by others.

8.2.6 Engine ignition system

The engine ignition system shall be suitable for the electrical area classification specified by the purchaser. The engine shall be equipped with a complete ignition system of the manufacturer's standard design, unless otherwise specified by the purchaser.

- For outdoor installation or if specified by the purchaser, all components shall be of weather-protected design or fitted with weather covers to prevent rain from directly contacting or accumulating in system components.

8.2.7 Engine emissions

8.2.7.1 General

- Compliance with any imposed exhaust gas emission regulations is the responsibility of the purchaser. To assist the purchaser in the selection of equipment as well as to supply the applicable regulatory body with accurate emission data, the vendor shall provide either engine manufacturer's performance data or actual stack test data, if specified by the purchaser. The purchaser shall furnish the fuel gas composition, the known emission level limits and their units for the installation on the data sheets when requesting emission data.

8.2.7.2 Emission data

- If specified by the purchaser, emission data shall be supplied by the vendor for the following compounds at specified engine load conditions:

  — nitrous oxides;

  — carbon monoxide;

  — non-methane hydrocarbons;

  — sulfur dioxide.

  The basis for obtaining the amounts of these compounds is as follows.

- a) The engine shall be loaded to either its rated power shown on the data sheets, or the engine manufacturer's nameplate rating, as specified by the purchaser.

  b) The fuel gas composition used for the test shall be shown and differences, if any, related to differences in the test gas and specified fuel gas shall be noted.

  c) The air/fuel ratio shall be within the engine manufacturer's recommended range.

8.2.7.3 Emission control device

If a catalytic converter or other external device is provided by the vendor to meet the air emission requirements specified by the purchaser, the engine rated power shall reflect the effects, if any, of the additional back-pressure or heat loads placed on the engine by the device. Any special operational considerations, fuel gas composition, air/fuel ratio or lubrication specifications shall be clearly stated in the vendor's proposal.

8.2.8 Engine lubrication system

Engines shall be equipped with the engine manufacturer's standard lubricating oil system, unless otherwise specified.

8.2.9 Oil level control

- A crankcase oil level control device shall be furnished by the vendor. A storage tank with level gauge shall be furnished by the vendor if specified by the purchaser.

8.2.10 Fuel gas system

Unless otherwise specified, the fuel gas system shall include the following items:

a) pressure-reducing regulator with downstream pressure gauge and isolating valve;

b) relief valve sized for maximum output capacity of pressure-reducing regulator based on maximum supply pressure and orifice installed in regulator. See 11.18 for sizing, setting and venting criteria;

c) fuel gas system manual block valve;

d) automatic valve in fuel gas system to shut off fuel gas to the engine and vent engine side of fuel gas system when engine is shut down;

- e) fuel gas filter/separator, if specified, installed downstream of the high-pressure regulator.

8.2.11 Fuel gas composition

- The fuel gas composition and pressure, if different than the compressed gas, shall be shown in the data sheets. Any contaminants shall be listed by the purchaser, and the engine manufacturer shall be consulted for fuel gas treatment requirements and special precautions.

If several fuel gas sources can be used (e.g. start-up case, emergency, etc.), it should be so mentioned in the data sheet, with indication of the changeover time.

WARNING — Use of an alternative gas with low methane index can result in detonation and possibly engine destruction.

8.2.12 Crankcase relief devices

Crankcase relief devices shall be furnished on the engine crankcase, unless otherwise specified by the purchaser. 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.

The total throat area of these devices should be not less than 70 mm^2 for each cubic decimetre of crankcase free volume.

8.3 Electric motors

8.3.1 Motor type

- The purchaser shall specify the motor type on the data sheets, including electrical data, starting conditions, type of enclosure, area classification, type of insulation, service factor, ambient temperature, elevation, and accessories such as temperature detectors, vibration sensors, heaters and instrumentation.

8.3.2 Rated power

The motor power rating, including service factor if any, shall be a minimum of 110 % of the compressor rated power. Unless otherwise specified, the design of the motor shall conform to IEC 60034, IEC 60079 and IEC 60529.

8.3.3 Motor current variation limits

The combined inertia of rotating parts of 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) for all specified loading conditions, including unloaded operation with cylinders pressurized to their normal suction pressures.

- The purchaser shall provide the vendor with the electrical system data necessary for proper design.

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

9 Cooling system

9.1 General

This International Standard is not applicable to shell-and-tube type and plate-type coolers.

9.2 Gas engine

An engine cooling system shall include the following features as appropriate:

a) engine coolant section(s) as required by the engine manufacturer for engine lubricating oil, engine turbocharger, air aftercooler (if required) and engine jacket cooling;

b) elevated de-aerating-type reservoir with gauge glass, vent line, coolant level switch, overflow, filling connection and drain. Gauge glasses are not required on engine radiators;

c) thermostatic coolant temperature control in accordance with the engine manufacturer's recommendation;

d) plugged manual drain connection(s) to completely drain equipment and system;

e) plugged manual vents to completely vent equipment and system.

9.3 Compressor

9.3.1 Circulated coolant

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

NOTE For low-temperature operation, temperature controls may be necessary for heating the coolant and keeping the cylinders at an appropriate temperature.

9.3.1.2 If furnished, the cylinder jacket system shall be designed to positively prevent leakage of gas into the coolant.

The purchaser is cautioned regarding the following.

a) Coolant inlet temperatures less than 5 K greater than gas inlet temperatures may cause gas constituent condensation.

b) Insufficient coolant flow or low coolant velocity may cause fouling of the cylinder jacket system.

c) Coolant exit temperature more than 17 K above gas inlet temperature may cause capacity reduction.

● **9.3.1.3** Sight flow and temperature indicators shall be furnished if specified by the purchaser.

9.3.2 Thermo-syphon and static cooling

If applicable, the compressor-cylinder jacket cooling system may be either static or thermo-syphon type where the compressor discharge temperatures are within the temperature limits recommended by the compressor manufacturer for the compression duties.

9.3.3 Rod-packing cooling

Unless otherwise specified on the data sheets, the pressure packing case cooling shall be in accordance with the following.

a) The compressor manufacturer's standard design may be used for packing gauge pressures up to 17,0 MPa (170 bar) on piston rods 65 mm (2 1/2 in) in diameter or less.

b) Cooled packing cases with totally enclosed cooled cups are required for packing gauge pressures above 17,0 MPa (170 bar). Internal tubing of austenitic stainless steel and forged fittings shall be furnished by the compressor manufacturer.

c) If packing cooling is required, the compressor manufacturer is responsible for advising the vendor of minimum requirements such as flowrate and pressure, pressure drop, temperature, filtration, corrosion protection and type of coolant.

9.3.4 Crankcase lubricating oil

A compressor oil cooling system, if required by the compressor manufacturer, shall be provided either separate (with thermostat) or integral with the engine cooling system to provide coolant to the compressor shell-and-tube lubricating oil cooler.

9.3.5 Gas cooling

- Gas intercooling shall be provided as required, and gas aftercooling shall be provided as specified by the purchaser.

9.4 Types of coolers

9.4.1 Air-cooled heat exchangers

Units which require air cooling of several streams should be equipped with finned-tube exchangers mounted in one compact cooler assembly.

NOTE Information on air-cooled heat exchangers is provided in ISO 13706 and in API 661.

9.4.2 Radiator

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

9.5 Air-cooled heat exchangers

9.5.1 Properties

Physical and thermal properties of the fluids to be cooled shall be obtained from recognized sources.

9.5.2 Glycol/water

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

9.5.3 Cooler maximum allowable working gauge pressure

The maximum allowable working gauge pressure of the gas sections shall exceed the rated discharge pressure by at least 10 % or 170 kPa (1,7 bar), whichever is greater, at a temperature of 180 °C. The maximum allowable working gauge pressure of the oil or water sections shall be at least 700 kPa (7 bar).

9.5.4 Pressure design code

- The cooler shall be designed and constructed in accordance with the pressure design code specified or agreed by the purchaser.

EXAMPLE ISO/TS 16528 or ASME VIII.

9.5.5 Heat load and flowrate

Heat transfer equipment for packaged compressor units shall have the following design flowrates and heat loads.

— Gas cooler: Intercoolers and aftercoolers (when supplied) shall be designed for the rated capacity of the compressor plus the latent heat of any condensables with a minimum fouling factor of 0,35 $m^2 \cdot K/kW$.

— Engine jacket coolant, oil and auxiliary coolers: These shall be designed for equipment manufacturer's excess capacity but not less than 110 % of the equipment manufacturer's calculated heat load and a minimum fouling factor of 0,09 $m^2 \cdot K/kW$ for coolant and 0,18 $m^2 \cdot K/kW$ for oil.

9.5.6 Pressure drop

Unless otherwise specified, the allowable pressure drop for gas coolers shall be in accordance with Table 2.

Table 2 — Allowable pressure drop for gas coolers

Absolute operating pressure MPa	**Allowable pressure drop** MPa
$\leqslant$ 0,25	5 % up to maximum 0,007 5
$>$ 0,25 and $\leqslant$ 1,7	3 % up to maximum 0,035
$>$ 1,7 and $\leqslant$ 7,0	2 % up to maximum 0,07
$>$ 7,0	1 %
NOTE 1 bar = 0,1 MPa = 10^5 Pa.	

9.6 Arrangement and construction

9.6.1 Cooler air flow

Unless otherwise agreed, air-cooled heat exchangers shall be arranged so that air is not drawn from or directed toward the prime mover.

9.6.2 Fan tip speed

Fan tip speed shall not exceed 70 m/s, unless otherwise specified by the purchaser.

9.6.3 Draft

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

9.6.4 Fins

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

9.6.5 Tube material — Steel

Steel tubes shall be used, unless specified otherwise by the purchaser, and shall conform to the appropriate recognized standards. For all size steel tubes, the wall thickness shall be not less than 1,5 mm.

9.6.6 Tube material — Marine brass

If marine brass tubes are specified, they shall comply with the appropriate recognized standard and with wall thickness in accordance with Table 3.

9.6.7 Clean-out facilities

Air-cooled exchangers, other than radiator type, shall have header plugs to facilitate clean-out and replacement of each tube.

Table 3 — Minimum wall thickness for marine brass tubing

Metric sizes		US Customary sizes	
Nominal tubing size OD mm	Minimum wall thickness mm	Nominal tubing size OD in	Minimum wall thickness in
< 20	1	$< 3/4$	0,042
$\geqslant 20$	1,2	$\geqslant 3/4$	0,049

9.6.8 Air flow control

- If specified by the purchaser, air-cooled heat exchangers shall have automatic temperature control. This control may be accomplished by means of louvres, variable-speed fans, variable-pitch fans, bypass valves or any combination of these. Manual louvres shall be adjustable from ground level. Louvres that cannot be seen from ground level shall have position indicators clearly visible from ground level.

9.6.9 Screens and guards

- If specified by the purchaser, insect screens and hail guards shall be furnished. They shall be sufficiently large to minimize any pressure drop into the cooler and be easily removable for cleaning. Unless otherwise specified, insect screens shall be 3,25 mm (#10 swg) galvanized steel mesh and hail guards shall be 12 mm (1/2 in) to 20 mm (3/4 in) expanded metal.

For other guards, see 6.14.5.

9.6.10 Fan support

Fans for air-cooled heat exchangers, other than standard engine radiators, shall be supported by a tripod or equivalent structure.

For V-belts see 6.14.3.

9.6.11 Lubrication

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

9.6.12 Piping supports

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

10 Pressure vessels

10.1 General

10.1.1 Code

- Pressure vessels shall be designed and constructed in accordance with the pressure design code specified or agreed by the purchaser.

EXAMPLE ISO/TS 16528 or ASME VIII.

10.1.2 Material

All materials in contact with the process gases shall be compatible with the gases handled. Materials and the quality of welding shall be in accordance with the specified pressure design code.

10.1.3 Corrosion allowance

Unless otherwise specified, the corrosion allowance for carbon steel vessels shall be a minimum of 3 mm.

10.1.4 Flanges

Unless otherwise specified, flanges shall be in accordance with ISO 7005-1, except that lap-joint and slip-on flanges shall not be used. Ring-type joints or spiral-wound metallic gaskets with a centring ring shall be employed for Class 900 flanges or higher.

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

10.1.5 Threaded connections

- Use of threaded connections shall be held to a minimum and not be used for gas piping, except for thermowell and directly plugged applications. If used, threaded connections shall not exceed DN 50 (2 in). Only manufactured threadolets shall be employed. Pipe threads shall be tapered in accordance with ISO 7-1 or ASME B 1.20.1, as specified, and be minimum Class 3000. Threaded connections shall not be used in toxic gas service.

10.1.6 Flanged connections

Connections DN 50 (2 in) and larger shall be flanged. Machined and studded connections are not permitted. Connections DN 40 (1 1/2 in) or smaller shall be designed in accordance with 11.4.

10.1.7 Baffles and partitions

Regardless of materials, all baffles and partitions shall have a minimum thickness of 9 mm.

10.2 Separators

10.2.1 Internal separators

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

10.2.2 Arrangement

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

10.2.3 Liquid-level control devices

Any liquid-level control device shall be positioned outside turbulent areas.

10.2.4 Mist extractor

Unless otherwise specified, vane- or mesh-type mist extractors shall be furnished. They shall be constructed from austenitic stainless steel or other materials of a superior corrosion resistance. Mesh-type mist extractors, when furnished, shall be supported both above and below the mesh material.

10.2.5 Equipment

The minimum equipment furnished on separators shall be as follows:

— manual drain;

— automatic drain valve with liquid level controller;

— high-level shutdown device.

- If an external liquid-level gauge is specified, it shall be equipped with isolating, vent and drain valves. If a pressure gauge is specified, it shall be equipped with isolating and vent valves.

10.2.6 Diameter

- The purchaser shall specify the separator service class required. The diameter of a vertical separator shall be based on the separator class specified, using the following procedure, unless otherwise specified by the purchaser.

  a) k factors for determining maximum allowable superficial velocity for vertical compressor separators are listed for each separator service class described as follows:

     1) separator service class A, $k = 0{,}35$;

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

     2) separator service class B, $k = 0{,}25$;

        Separating for design conditions plus moderate additional separating capacity. Generally used only for interstage separators without sidestreams.

     3) separator service class C, $k = 0{,}18$;

Separating for design conditions plus substantial additional separating capacity. Generally used only for suction separators.

b) Maximum allowable superficial velocity, the actual gas volume flowrate, and the minimum separator diameter required shall be calculated using the following equations:

$$v = 0{,}3048 \quad k \left(\frac{\rho_l - \rho_g}{\rho_g} \right)^{0{,}5}$$

$$D = \left(\frac{4 q_V}{\pi \cdot v} \right)^{0{,}5}$$

where

k is a constant depending on the separator service class;

v is the maximum allowable superficial velocity through the separator, in metres per second;

ρ_l is the liquid density at operating conditions, in kilograms per cubic metre;

ρ_g is the gas density at operating conditions, in kilograms per cubic metre;

q_V is the gas volume flowrate at operating conditions, in cubic metres per second;

D is the minimum internal diameter of the separator, in metres.

10.3 Pulsation suppression devices

10.3.1 Pulsation control

- Pulsation control and pulsation studies shall be specified by the purchaser and shall be quoted separately by the vendor. Mechanical natural frequencies and acoustic (organ-pipe) frequencies should not be coincident with pulsation frequencies generated by the compressor.

Caution should be exercised in applying air-cooled heat exchangers because of their susceptibility to pulsation-induced vibration in systems and structures.

10.3.2 Size

- If volume bottles are specified by the purchaser and a special pulsation dampening design is not specified, then volume bottles shall be furnished on the suction and discharge of each stage. The bottle volume shall be determined by the sum of all the cylinder-swept volumes connected to it, multiplied by the factor specified in Annex B.

NOTE If the cylinder is double-acting, then the swept volume is the sum of both ends of the cylinder.

10.3.3 Drains

Easily accessible plugged drains, DN 20 (3/4 in) minimum size, shall be provided. If baffle plates are utilized, a drain shall be provided in each chamber. 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.

10.3.4 Internal risers

Internal nozzle risers on suction and discharge bottles, if used, shall be slotted or have weep holes (sufficiently sized to avoid plugging) to prevent an accumulation of liquids in the pulsation bottle.

10.3.5 Inlet and discharge connections

Regardless of the use of pulsation suppression devices, the diameter of the piping to or from the compressor cylinders shall be at least equal to the diameter of the compressor cylinder nozzles. If pulsation suppression devices are used, the inlet piping to the suction bottle shall be at least equal to the diameter of the compressor cylinder suction nozzle.

10.3.6 Reinforced connections

All flanged branch connections shall be reinforced in accordance with the specified pressure design code. Additional reinforcement and/or local stress analysis may be required to take into account stress concentration and fatigue loads resulting from pulsations and vibrations.

11 Piping and appurtenances

11.1 General

11.1.1 Code

Piping design and joint fabrication, examination and inspection shall be in accordance with ISO 15649, unless otherwise specified.

NOTE For the purposes of this provision, ANSI/ASME B 31.3 is equivalent to ISO 15649.

11.1.2 System

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

11.1.3 Scope

The vendor shall furnish all piping systems, including mounted appurtenances, for all equipment mounted on the skid. Piping for connection to the purchaser's system shall terminate with flanged connections at the edge of the skid or at another readily accessible location.

11.1.4 Gas piping and appurtenances

- The extent of gas piping to be supplied by the vendor shall be specified by the purchaser. If specified by the purchaser, or required by the vendor, the piping and appurtenances shall be designed and arranged to allow heat tracing and insulation.

11.1.5 Drawings

- If specified, the purchaser shall review the arrangement drawings of all piping and appurtenances (pulsation suppression devices, inter-coolers, after-coolers, separators, knockouts, air intake filters, expansion joints, vessels, etc.) immediately upstream or downstream of the compressor prior to fabrication.

11.2 Design

Design of piping systems shall achieve the following:

— proper support and protection to prevent damage from vibration or from shipment, operation and maintenance;

— minimize loads on the nozzles of cylinders and pulsation suppression devices;

— avoidance of pipework bending forces and/or introduction of adequate flexibility to minimize stress;

— good accessibility for operation, maintenance and cleaning;

— installation in a neat and orderly arrangement adapted to the contour of the machine and not obstructing access openings;

— elimination of air pockets;

— complete drainage through low points without piping disassembly;

— elimination of low points in the inlet process piping including recycle/by-pass piping that could trap liquid;

— use of pipe clamps on all gas piping and on all piping DN 50 (2 in) and larger;

— supports shall not be welded directly to gas piping.

11.3 Assembly

All pipework should be assembled at the vendor's/sub-vendor's facilities to demonstrate correct assembly.

11.4 Connections

Connections DN 40 (1 1/2 in) or smaller shall be designed to minimize overhung mass and shall be reinforced to avoid breakage due to vibration. This reinforcement should preferably be by the use of integrally reinforced forged nozzles or by bracing back to the main pipe in at least two planes. Bracing shall be arranged to occupy minimum space.

11.5 Fabrication

Welding fittings, flanges and threaded connections shall be held to a minimum. Pipe bushings shall not be used to change diameter in a piping run. Break-out flanges or unions shall be included when packages need disassembly for transportation.

For flanged joints see 10.1.4.

11.6 Seal welding

Where threaded joints are permitted, they shall not be seal welded, unless so specified by the purchaser, in which case the seal welding shall be carried out in accordance with ISO 15649. Seal welding is not permitted on cast iron equipment, on instruments, or where disassembly is required for maintenance.

NOTE For the purposes of this provision, ANSI/ASME B 31.3 is equivalent to ISO 15649.

11.7 Sizes

Connections, pipe, valves and fittings that are DN 32 (1 1/4 in), DN 65 (2 in1/2), DN 90 (3 1/2 in), DN 125 (5 in), DN 175 (6 7/8 in) or DN 225 (8 7/8 in) in size shall not be used. If the use of proprietary equipment makes this impractical, the vendor shall ensure that all the purchaser's connections are adapted to standard sizes.

11.8 Pipe material and sizes

- 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 or ASTM A 312, or as specified by the purchaser. Pipe wall thickness shall be in accordance with Table 4.

Table 4 — Minimum pipe wall thickness

Material	Nominal pipe size		Minimum schedule
	DN	NPS	ANSI
Carbon steel	⩽ 25	⩽ 1	160
Carbon steel	> 25	> 1	80
Carbon steel	⩾ 80	⩾ 3	40
Carbon steel	⩾ 250	⩾ 10	STD
Stainless steel	⩽ 40	⩽ 1,5	40
Stainless steel	⩾ 50	⩾ 2	10

11.9 Tubing material and sizes

All tubing shall be seamless stainless steel and shall conform to appropriate recognized standards, such as ASME A 269. With the exception of cylinder lubrication, tubing wall thickness shall be in accordance with Table 5. Cylinder lubrication tubing shall be at least 6 mm (1/4 in) outside diameter with a minimum wall thickness of 1,5 mm (0,065 in).

Table 5 — Minimum tubing wall thickness

Metric sizes		US Customary sizes	
Nominal tubing size OD mm	Minimum wall thickness mm	Nominal tubing size OD in	Minimum wall thickness in
6 [a]	1	1/4 [a]	0,035
8 [a]	1		
10 [a]	1	3/8 [a]	0,049
12	1,5	2	0,065
20	2	3/4	0,095
25	3	1	0,109

[a] These sizes are permitted for instrument and control air and inert gas purge only.

11.10 Valves

- Valves in flammable or toxic service shall be steel and, when specified, shall have bolted or welded bonnets, bolted glands.

11.11 Flange orientation

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

11.12 Plugs

Tapped openings shall be plugged with solid steel, long-shank or hexagonal-head plugs. Pipe threads shall be coated with a non-locking pipe thread sealant. Polytetrafluoroethylene (PTFE) tape is not acceptable.

11.13 Start-up screens

If 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 by both the purchaser and the vendor prior to manufacture or purchase.

- If specified, the vendor shall supply 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.

11.14 Lubricating oil piping requirements

11.14.1 Lubricating oil piping system

The vendor shall supply a complete compressor-lubricating oil piping system with its mounted appurtenances when applicable.

11.14.2 Material

- If specified, pressurized lubricating oil lines downstream of the filter (with the exception of cast-in-frame lines or passages) shall be made of austenitic stainless steel. For either tubing or piping, bends shall be used to minimize the number of fittings wherever possible. Steel fittings shall be furnished with stainless steel tubing. Pressure piping downstream of oil filters shall be free of internal obstructions or pockets (such as those created by socket weld fittings) that could accumulate dirt at pipe joints. Non-consumable back-up rings and sleeve-type joints shall not be used. Other piping fittings shall be of the socket-weld or butt-weld type. When butt welds are necessary, such precautions as internal grinding of joints and use of gas tungsten-arc welding for the first weld pass shall be taken to prevent weld splatter inside the lines. After fabrication, oil lines shall be thoroughly cleaned and preserved. In addition, carbon steel piping shall be pickled and passivated.

11.15 Coolant piping requirements

11.15.1 Coolant piping

- If coolant piping is specified to be furnished by the vendor, the vendor shall supply a piping system for all equipment mounted on the skid, including radiators and coolers. The piping shall be arranged to provide a single inlet connection on the bottom and a single outlet connection on the top for each coolant circuit operating at different inlet temperature levels, and shall include a coolant control valve.

11.15.2 Coolant vents and drains

Coolant piping shall be arranged so that air cannot be trapped. Where air traps cannot be avoided, venting equipment shall be provided. All low points shall have drains. All liquid-cooled compressor cylinders shall be equipped with valved coolant drains.

11.16 Instrument piping requirements

The vendor shall supply all necessary tubing, valves and fittings for all instruments and instrument panels. A common connection for remotely mounted instruments measuring the same pressure may be used where convenient.

11.17 Drain and vent piping

11.17.1 Drains and vents

Unless otherwise specified, external drain and vent piping shall be schedule 80 carbon steel not less than DN 20 (3/4 in) nominal size. However, vent connections in the packing case and interconnecting tubing within or from the distance piece shall be in accordance with 11.9.

11.17.2 Common distance piece vent header

- If specified by the purchaser, a common distance piece vent header terminating at the edge of the skid shall be furnished by the vendor.

11.17.3 Common distance piece drain header

- If specified by the purchaser, a common distance piece drain header terminating at the edge of the skid shall be furnished by the vendor.

11.17.4 Common packing vent header

- If specified by the purchaser, a common packing vent header terminating at the edge of the skid shall be furnished by the vendor.

11.18 Relief valves

11.18.1 Relief valve location

Relief valves shall be located in each continuous system, including but not limited to, the compressor suction system, each interstage system and final discharge system. When gas coolers are present in any system, relief valves shall be located upstream of the cooler.

11.18.2 Relief valve design

Relief valves shall be of a conventional design. Pilot-operated relief valves may be used with the purchaser's approval.

11.18.3 Relief valve sizing

- If specified, the vendor shall furnish relief valves that are to be installed on equipment or in piping that the vendor supplies. The purchaser shall specify if additional suction relief valve capacity is required to protect the package for conditions other than rated. Other relief valves shall 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 given in ISO 4126-1 and in API RP 520, parts I and II, provided 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, mal-operation and the protection of piping systems.

NOTE For the purposes of this provision, API 526 is equivalent to ISO 4126-1.

11.18.4 Relief valve material

Unless otherwise specified, relief valves shall have steel bodies.

11.18.5 Relief valve setting

Relief valves shall be set to operate at not more than the maximum allowable working pressure, but not less than the values listed in Table 6.

Table 6 — Relief valve settings

Rated discharge gauge pressure (each stage) MPa (bar)	Minimum relief valve set pressure margin above rated discharge pressure
$\leqslant$ 17,0 (170)	10 % [a]
$>$ 17,0 (170) to $\leqslant$ 24,0 (240)	8 %
$>$ 24,0 (240) to $\leqslant$ 34,5 (345)	6 %
$>$ 34,5 (345) [b]	[b]

[a] Not less than 0,1 MPa (1 bar).

[b] Shall be agreed by the purchaser and vendor.

11.18.6 Relief-valve venting

- Each relief valve shall be connected to a vent pipe. The vent pipe shall vent released gas either upward at a safe location into the atmosphere or into a common vent header terminating at the edge of the skid, as specified by the purchaser.
- If specified, atmospheric vents shall have weep holes at the lowest point near the relief valve.

The effect of back-pressure should be considered when selecting and sizing relief valves and vent systems, because back-pressure can prevent relief valves from relieving at their set pressure.

11.19 Blowdown valve

- If specified by the purchaser, a package blowdown valve shall be furnished by the vendor. The vent pipe shall vent released gas either upward at a safe location into the atmosphere or into a common vent header terminating at the edge of the skid or elsewhere, as specified by the purchaser.

11.20 Thermowells

Thermowells shall be in accordance with 13.3.2 and 13.3.3.

11.21 Insulation and/or guarding

Insulation and/or guarding shall be in accordance with 8.2.5.6.

12 Electrical systems

12.1 Codes

Motors, electrical components and electrical installations shall comply with all applicable local codes and regulations.

12.2 Power supply

- If electrical equipment is to be supplied by the vendor, electrical power supply characteristics for motors, heaters and instrumentation shall be specified by the purchaser.

12.3 Wiring

All power and control wiring within the confines of the main unit base area, any console base area, or any auxiliary skid area shall be resistant to oil, heat, moisture and abrasion. Stranded conductors shall be used within the confines of the skid and other areas subject to vibration. If rubber insulation is used, high-temperature thermoplastic sheath shall be provided for insulation protection. All wiring shall be suitable for operating temperatures.

12.4 Maintenance

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

12.5 Insulation

All electrical materials including insulation shall be corrosion-resistant and non-hygroscopic insofar as possible.

- If specified for tropical locations, all materials shall be treated as follows.

  a) All parts (such as coils and windings) shall be protected against fungus attack.

  b) Materials subject to corrosion shall be suitably protected.

12.6 Conduits and cable runs

All wiring, including that for power and instrumentation, within the limits of any skid 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. Flexible metallic conduits, if used, shall be liquid-tight and suitable for the specified area classification.

12.7 Power installations

Unless otherwise specified by the purchaser, electrical power installations with nominal voltages up to 1 000 V shall be in accordance with IEC 60364-5.

12.8 Earthing

Earthing connections shall be provided on each skid and on off-skid-located panels and equipment. Equipotential bonding conductors shall be provided between the skid and the skid-mounted control panel as well as for all equipment parts without a direct metallic contact to the skid or to the compressor.

12.9 Terminations

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.

13 Instruments and controls

13.1 General

13.1.1 Compressor control systems

- 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 (purpose or function), the type of control system (manual, automatic or programmable) and control range. The purchaser shall specify which process sensing lines handling flammable, 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 shutdowns) in his scope of supply by means of logic diagrams in accordance with IEC 60848.

  If 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, shutdowns, etc.).

  Examples of typical logic diagrams are given in annex C.

  For corrosive gases see clause 20.

13.1.2 Location

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

13.1.3 Codes and standards

Instruments and controls shall meet the requirements of IEC 60079 and other standards specified by the purchaser and shall comply with all applicable local codes and regulations.

13.1.4 Visibility and accessibility

All controls and instruments shall be located and arranged for good visibility and easy access by operators and for accessibility for tests and maintenance.

13.1.5 Instrumentation mounting

All instrumentation shall be securely supported to eliminate vibration and undue forces on instrument piping and to prevent damage during shipment, storage, operation and maintenance.

13.1.6 Pneumatic supply

Filtered and regulated sweet dry natural gas or dry oil-free air shall be used to operate pneumatic instruments and controls, unless otherwise specified by the purchaser. The vendor shall state the consumption and the pressure level if the pressure is not specified by the purchaser. If natural gas is used, all vents shall be tubed to a common header terminating with a vent-pipe connection at skid edge or provided with a vent pipe to release the gas at a safe location. Gas-operated pneumatic instruments that vent shall have vent connections.

13.2 Instrument and control panel

13.2.1 General

A panel shall be provided for the compressor package. Unless otherwise specified, the panel shall include all panel-mounted instruments for the equipment to be supplied by the vendor. The panel shall be designed and fabricated in accordance with the purchaser's description. The instruments on the panel shall be clearly visible to

the operator from the driver control point. Panels shall be completely assembled, requiring only connection to the purchaser's external piping and wiring circuits.

13.2.2 Panel construction

Unless otherwise specified by the purchaser, panels shall be made of steel plate at least 3 mm (1/8 in) thick, reinforced, self-supporting, and closed on the top and sides.

- If specified, the backs of panels shall be enclosed to minimize electrical hazards, to protect equipment from tampering, or to allow purging and venting for safety or corrosion prevention. All flush-mounted instruments shall be mounted on the front of the panel and all fasteners shall be of corrosion-resistant material. Each panel-mounted instrument shall be identified by an engraved name plate.

13.2.3 Panel mounting

- Control and instrument panels shall be free-standing, skid-mounted or off-skid, as specified by the purchaser. Any skid-mounted instrument panel shall be securely supported to minimize vibration, to prevent undue forces on piping, and to prevent damage during shipment, storage, operation and maintenance. The mounting location shall not block access doors or covers that must be removed for inspection or maintenance. Lifting rings shall be provided on panels weighing in excess of 50 kg.

13.2.4 Panel wiring

If 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 outside enclosed panels and terminal boxes shall be run in metal conduit or be in the form of armoured cable supported in cable tray 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.

13.2.5 Remote panel wiring

If off-skid-mounted control panels are used, all connections shall be brought to one point on the skid with provision for ease of access. All leads and posts on terminal strips, switches and instruments shall be tagged for identification. Splicing of wiring inside conduits shall not be allowed.

- Wiring shall be installed in metal conduit or be in the form of armoured cable supported in cable tray, as specified by the purchaser.

13.2.6 Panel instrument tubing

Panel instrument tubing shall be austenitic stainless steel, unless otherwise specified by the purchaser.

13.2.7 Maximum operating limits

All instruments and controls shall be designed to withstand 125 % of the maximum anticipated operating temperature and pressure.

13.3 Instrumentation

13.3.1 Tachometers

- A tachometer shall be provided in the panel if specified. The type and range shall be stated by the purchaser on the data sheets. Digital-readout tachometers with continuous readout may be used. The minimum tachometer speed range shall be from the lowest speed control point to 115 % of maximum continuous speed. When a variable-speed driver is used, the driver vendor shall furnish the speed sensor and indicator(s).

13.3.2 Temperature measurement

- Temperature indicators shall be furnished and mounted locally or on a panel, as specified on the data sheets. Locally mounted dial-type temperature gauges shall be heavy duty, corrosion-resistant and mounted in stainless steel thermowells. Heat-transfer compound shall be used between thermowells and sensing elements.

- If specified by the purchaser, liquid-filled gauges shall be furnished by the vendor. Black printing on a white background is standard for gauges. Metal-case, glass-front, stem-type mercury or bi-metallic thermometers shall be furnished in locations subject to vibration.

  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.

13.3.3 Thermowells

Temperature-sensing elements that are in contact with flammable 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 (0,748 in) in diameter. The temperature-sensing elements shall be in the flowing fluid. This is particularly important for lines that may run partially full.

13.3.4 Pressure measurement

- Pressure indicators shall be furnished and mounted locally or on a panel, as specified on the data sheets.

  When pressure indication in services other than pneumatic control signals is by means of gauges (direct-acting devices), these shall be furnished with austenitic stainless steel bourdon tubes and stainless steel movements. Black printing on a white background is standard for gauges.

- If specified, liquid-filled gauges shall be furnished in locations subject to vibrations. Gauge ranges should be selected so that the normal operating pressure is at the middle of the gauge's range. The maximum reading on the dial shall not 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.

13.3.5 Fuel gas metering

- If specified, a fuel gas meter shall be furnished by the vendor.

13.3.6 Valving

Unless otherwise specified, all instruments and controls, other than shutdown sensing devices, shall be installed with sufficient valving to permit replacement while the system is in operation.

- If shut-off valves are specified for shutdown sensing devices, the vendor shall provide a means of locking the valves in the open position. All pressure gauges shall be furnished with isolation and bleed valves.

13.3.7 Minimum requirements for indication

13.3.7.1 Temperature indicators are required at the

— engine coolant outlet,

— gas discharge of each compressor cylinder.

Other temperatures may also be indicated.

13.3.7.2 Pressure indicators are required at the

— engine lubricating oil inlet,

— compressor lubricating oil inlet,

— gas suction of compressor first stage,

— gas discharge of each compressor stage.

Other pressures may also be indicated.

14 Shutdowns, alarms and annunciators

14.1 General

An alarm/shutdown system shall be provided which initiates an alarm if any one of the conditions specified by the purchaser as alarm conditions reaches an agreed alarm level. This system shall also initiate shutdown of the compressor when any of the conditions specified or recommended as shutdown conditions reaches an agreed shutdown level. Shutdown and alarm systems shall be designed to operate in a fail-safe mode.

- The systems may function hydraulically, pneumatically, electrically or in any combination, as specified by the purchaser.

- Unless otherwise agreed, for every shutdown function an alarm function shall be provided and set at a value which represents a deviation from the normal condition and less than the setting of the shutdown. Additional alarms, not associated with shutdowns, shall be provided as specified.

14.2 Minimum required shutdowns

The conditions at which shutdown is required, as a minimum, are specified in Table 7.

14.3 Additional alarms and shutdowns

- The extent to which the alarm and shutdown systems shall be supplied by the vendor shall be specified by the purchaser on the data sheets.

Low oil-level alarms in the engine and compressor crankcases are recommended.

NOTE Information on vibration and temperature monitoring is provided in API 670.

Table 7 — Minimum shutdown requirements

Alarm-level condition	Shutdown
Engine:	
Low fuel-gas pressure	X
High fuel-gas pressure	X
High cooling-water temperature	X
Low lubricating-oil pressure	X
Overspeed	X
High vibration	X
Motor:	
High stator-winding temperature	X
High vibration	X
Compressor:	
Low suction-gas pressure	X
High discharge-gas pressure (each stage)	X
Cylinder lubricator failure	X
Low lubricating-oil pressure	X
High discharge-gas temperature (each cylinder)	X
High vibration	X
Other:	
High cooler vibration	X
High liquid level in inlet and interstage separators	X
Low cooling-water level	X

14.4 Annunciators

Each component which actuates an alarm or a shutdown shall also actuate an annunciating device which indicates first-out cause of alarm or shutdown. Annunciators shall be bypassed only for the purpose of a preset-time lock-out for use on certain shutdown devices during start-up and manual testing. The vendor shall specify the type and size of annunciator, the shutdowns and alarms to be annunciated, the number of spare points on the annunciator panel and the type of warning (audible or flashing light or both) for alarms and shutdowns.

14.5 Switches

14.5.1 Installation

Alarm, shutdown and automatic-start switches (except vibration switches) shall be installed so that the normal vibration of the equipment does not cause the switch to falsely trip.

14.5.2 Compressor temperature

High-temperature shutdown sensors shall be installed as close to each compressor cylinder discharge connection as practical.

14.5.3 Compressor oil pressure

The pressure-sensing element of the lubricating oil low-pressure switch in contact with the lubricating oil shall be resistant to corrosion attack by the compressed gas which may enter the compressor crankcase and dissolve in the oil, and shall be located to sense the oil pressure at the end of the bearing oil header.

14.5.4 Vibration

The prime mover and compressor high-vibration shutdown sensor and switch shall be located at crankshaft level. The cooler high-vibration sensor shall be mounted at the centreline of the fan shaft.

14.6 Emergency shutdown systems

14.6.1 Engine

The emergency shutdown shall close the fuel valves and open the vent valve between the fuel valve and the engine in addition to earthing the high-voltage side of the ignition.

14.6.2 Motor

The emergency shutdown system shall provide a volt-free contact for the purchaser to shut off the power supply.

14.6.3 Compressor

- If specified by the purchaser, the blowdown valve shall open automatically on shutdown.

14.6.4 Additional requirements

14.6.4.1 Start-up bypass device

A timed lock-out device to bypass certain shutdown devices, thus permitting starting of the prime mover, shall be provided.

14.6.4.2 Manual test feature

For those shutdown devices which can only be tested while the compressor unit is in operation, a manual feature shall be provided to enable testing of the individual shutdown functions without causing a stop.

The bypass device for each shutdown test shall be automatically removed by a 0 min to 5 min timer and the mode “test” shall be indicated on the annunciator panel.

For safety reasons, this test should only be performed by authorized persons.

14.7 Shutdown and alarm settings

Shutdown and alarm settings shall be mutually agreed upon by the purchaser and vendor.

15 Skids

15.1 General

Structural steel, pre- or post-stressed concrete or concrete-filled structural steel skids shall be of sufficient strength for transportation and installation, and to transmit equipment-generated forces and couples to the purchaser's foundation.

15.2 Design

15.2.1 Lifting

Skid shall have provisions for winching and/or lifting.

15.2.2 Members

On structural steel skids, load-bearing components shall be full depth members and of sufficient strength to prevent excess deflections that would damage installed equipment when the skid is moved or installed.

15.2.3 Mechanical equipment support

The compressor and prime mover shall be mounted on full-depth, load-bearing structural members and secured by bolting.

15.2.4 Mechanical equipment alignment

15.2.4.1 Two jackscrews shall be provided for the horizontal alignment of the prime mover. All bolts and nuts shall be accessible for maintenance using standard tooling.

15.2.4.2 Mounting surfaces shall be machined flat and parallel to all other mounting surfaces within 0,15 mm/m (0,002 in/ft). Provision for shims or other adjustable supports shall be made for vertical alignment. These shall be capable of being adjusted in the field to within ± 3 mm (± 1/8 in) and shall be made of stainless steel.

15.2.5 Size

Skid shall be of sufficient width and length for installation of equipment and ease of maintenance.

15.2.6 Screws and bolts

On non-concrete-filled structural steel skids, a minimum of three levelling screws and three anchor bolt holes per side shall be provided, with a sufficient number of levelling screws to support the total mass of the skid and installed equipment.

15.2.7 Floor plate

Open areas on structural steel skids shall be covered with solid chequered floor plate of minimum thickness 5 mm (0,2 in), welded or bolted in place. Provisions shall be made to facilitate grout placement. Floor plate is not required on concrete or concrete-filled structural steel skids.

15.2.8 Drip pans

Drip pans shall be provided where oil leakage or spillage can be expected and shall be attached to the base of the skid.

15.2.9 Braces

Supports and braces shall not be attached to unsupported floor plate.

15.2.10 Vessels

On structural steel skids, separators and other vessels shall be supported by full-depth structural skid members and not the floor plate. They shall be bolted to the members.

15.3 Construction

Structural steel skids shall be of welded construction. Abutting beams shall be welded on both sides. Flanges of load-bearing members shall not be spliced. Contact between webs at perpendicular joints shall be a minimum of one-third of the depth of the smallest member. Welding requirements shall be in accordance with 6.13.1.4.

15.4 Walkways, stairs and platforms

- Walkways, stairs and platforms, if specified by the purchaser, shall be provided with handrails on all sides except those bounded by equipment not presenting a safety hazard. Handrails shall be complete with midrail and toeplate. The surface areas of walkways, stairs and platforms shall be of a non-slip design and open construction such as expanded grating.

16 Paint and painting

16.1 General

Unless otherwise specified by the purchaser, the surface preparation, paint and application shall be in accordance with the manufacturer's specification. The manufacturer's painting specification shall be submitted in the proposal for the purchaser's review.

16.2 Surface preparation

- If specified by the purchaser in the data sheets, surfaces should be prepared for painting in accordance with Table 8.

Table 8 — Surface preparation

Method of surface preparation		
Component	**Normal environment**	**Severely corrosive environment**
Engine, compressor, radiator and exhaust silencer	Manufacturer's specification	Manufacturer's specification
Gas and jacket water cooling unit	Manufacturer's specification	Manufacturer's specification
Skids, separators, bottles, piping and valves	ISO 8504-3	ISO 8504-2

16.3 Application

Paint should always be applied by spray to obtain a minimum dry film thickness of 40 µm per coat. Paint shall be applied in accordance with the paint manufacturer's specifications. The total dry film thickness of the primer and a finish coat should be 80 µm with the exception that aluminium paints may require a thinner coat. This should be checked with the paint manufacturer.

16.4 Items not to be painted

Hoses, ignition wire, nameplates, finish-painted instruments, non-metallic products, rotating parts of machinery, finned tubes surfaces, V-belts, machined surfaces, threads, sheave grooves and temporary closures shall not be painted. All other external surfaces shall be given at least one coat of paint in addition to the primer.

16.5 Paints

Paints shall not contain lead or chromates, and shall be suitable for the environmental conditions and the maximum expected equipment-surface temperatures. Any paint exposed to lubricants shall be oil-resistant. When synthetic lubricants are used, special precautions shall be taken to assure compatibility with the paint.

16.6 Air-cooled heat exchanger

For a severely corrosive environment, ducting and structure of the air-cooled heat exchanger may be hot-dipped galvanized in lieu of painted. Headers may be galvanized or painted as specified by the purchaser.

17 Inspection and testing

17.1 General

17.1.1 Right of entry

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

17.1.2 Notice to vendors

The vendor shall be responsible for notifying all sub-vendors of the purchaser's inspection and testing requirements. 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.

17.1.3 Purchaser participation

The purchaser shall specify in the vendor's quality plan or in any other applicable documents whether the inspection and testing programme will be

— witnessed, in which case a hold point shall be applied to the production schedule and the inspection or test shall be carried out with the purchaser or his representative in attendance. For mechanical running or performance tests, this requires, with or after the advance notification, confirmation of successful preliminary tests carried out by the vendor;

or

— observed, in which case the purchaser shall be notified of the timing of the inspection or test; however, the inspection or test shall be performed as scheduled, and if the purchaser or his representative is not present, the vendor shall proceed to the next step.

17.1.4 Required equipment

Equipment required for specified inspections or tests shall be provided by the vendor.

17.1.5 Data retention

The vendor shall keep the following data available for at least 10 years from date of shipment for examination by the purchaser or his representative upon request:

a) all necessary certification of material, such as mill test reports when required;

b) purchase orders for serial-numbered items on the bill of materials;

c) results of quality-control tests, hydrostatic tests, mechanical run tests and other tests, as specified by the purchaser;

d) weld procedures and welder qualifications.

17.1.6 Advance notification period

- The purchaser shall specify the required advance notification period prior to any witnessed or observed inspection points.

17.1.7 Quality control

The purchaser's representative shall have access to the vendor's and sub-vendor's quality assurance programmes for review prior to the start of fabrication.

17.1.8 Cleaning

During fabrication and assembly of the system, each component and all piping and appurtenances shall be cleaned to remove foreign materials, corrosion products and mill scale. After cleaning, open ends of piping and vessels shall be suitably covered to prevent contamination.

17.2 Material inspection

17.2.1 Inspection codes

- If radiographic, ultrasonic, magnetic-particle or liquid-penetrant inspection is required or specified, radiography shall be in accordance with ASME Section VIII, Division 1, UW-52 ; ultrasonic inspection shall be in accordance with ASME Section VIII, Division 1, Appendix 12 ; magnetic-particle inspection shall be in accordance with ASME Section VIII, Division 1, Appendix 6 ; and liquid-penetrant inspection shall be in accordance with ASME Section VIII, Division 1, Appendix 8. If specified, forged parts shall be ultrasonically inspected in accordance with ASTM A 503.

17.2.2 Magnetic-particle inspection

If magnetic-particle inspection as described in ISO 9934-2 is required, acceptability of defects shall be based on a comparison with the photographs in ISO 4986. For each type of defect, the degree of severity shall not exceed the limits specified in Table 9.

NOTE For the purposes of this provision, ASTM E 709 is equivalent to ISO 9934-2 and ASTM E 125 is equivalent to ISO 4986.

Table 9 — Maximum severity of defects in castings

Type	Defect	Max. severity level
I	Linear discontinuities	1
II	Shrinkage	2
III	Inclusions	2
IV	Chills and chaplets	1
V	Porosity	1
VI	Welds	1

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

17.2.3 Material samples

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

17.3 Testing

17.3.1 General

Equipment shall be tested in accordance with 17.3.3, 17.3.4 and 17.4. At least six weeks before the first scheduled test, the vendor shall submit, for the purchaser's review and comments, detailed procedures for all running tests, including acceptance criteria for all monitored parameters.

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.

17.3.2 Hydrostatic and gas leak tests

Tests shall be in accordance with the applicable code. In the event that a discrepancy exists between the code test pressure and the pressure in this International Standard, the higher pressure shall govern. Test gaskets shall be identical to those required for the service conditions.

17.3.3 Hydrostatic tests

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

a) Cylinder gas passages and bore: 1,5 times maximum allowable working gauge pressure, but not less than gauge pressure of 0,15 MPa (1,5 bar).

b) Cylinder cooling jackets and packing cases: 1,5 times maximum allowable working gauge pressure.

c) Piping, pressure vessels, filters and other pressure-containing components: 1,5 times maximum allowable working gauge pressure or in accordance with applicable code, but not less than gauge pressure of 0,15 MPa (1,5 bar).

The tests a) and b) shall be performed prior to the installation of the cylinder liner using job fasteners.

NOTE For gas pressure-containing parts, the hydrostatic test is not considered to be an acceptable or valid gas leak test.

17.3.3.2 If the part tested is to operate at a temperature at which the strength of the material is below the strength of that material at room temperature, the hydrostatic test pressure shall be multiplied by a factor obtained by dividing the allowable working stress for the material at room temperature by that at operating temperature. The 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.

17.3.3.3 The chloride content of liquids used to test austenitic stainless steel materials shall not exceed 50 ml/l. 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.

17.3.4 Gas leak tests

17.3.4.1 Basic requirements

The leak tests shall be conducted with the components thoroughly dried and unpainted. Compressor cylinders shall be leak-tested without liners, but with heads, valve covers, fasteners, clearance pockets and using the intended service type of gaskets.

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 0,001 mole fraction hydrogen sulfide, shall have performed, in addition to the hydrostatic test specified in 17.3.3, a pressure test with helium at the maximum allowable working gauge pressure or 15,0 MPa (150 bar), whichever is the lesser.

   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 allowable working gauge pressure. Zero leakage is required (see 17.3.5). In the case of testing by helium probe, the procedure, the sensitivity of the instrument and the acceptance criteria shall be agreed.

b) Cylinders handling gases other than those described in a) above shall have a gas leak test performed as described in a), except the test gas may be air or nitrogen.

- **17.3.4.2 Assembled package**

If specified by the purchaser, the assembled package shall be tested for piping leaks. Details of this test shall be mutually agreed by the purchaser and vendor.

17.3.5 Test period

Test conditions shall be maintained for a sufficient period of time to permit complete examination of parts under pressure. The hydrostatic and gas leak 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 mutually agreed by the purchaser and vendor.

17.4 Mechanical running tests

17.4.1 Main components

All compressors, drivers and gear units shall be shop-tested in accordance with the vendor's specification.

17.4.2 Packaged unit

Unless otherwise specified, the packaged unit, including all auxiliaries, shall undergo the vendor’s/sub-vendor’s usual shop running test prior to shipment. The test shall prove mechanical operation of the compressor, driver, mechanical accessory equipment, instruments, control system and skid-mounted cooler as a complete unit. The compressor does not have to be pressure-loaded for this test.

17.4.3 Testing of modified units

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 shall not be acceptable and the final shop tests shall be run after these replacements or corrections are made.

17.4.4 Inspection

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

18 Marking

18.1 Rotation arrows

Rotation arrows shall be cast in or permanently attached to each major item of rotating equipment.

18.2 Material

Nameplates and rotation arrows shall be stainless steel or Monel and attached with corrosion-resistant fasteners.

18.3 Nameplates

18.3.1 Package nameplate

Package nameplates shall include packager's name, date of fabrication and serial number, and be securely affixed in a conspicuous place on the packaged compressor unit.

18.3.2 Manufacturer's nameplates

A manufacturer's nameplate shall be securely attached at an easily accessible point on the compressor frame, to each compressor cylinder, the prime mover, the air-cooled exchanger, pressure vessels and to any other piece of major auxiliary equipment.

18.3.3 Compressor frame

The frame nameplate shall give the compressor manufacturer's name, serial number, frame size/model and type, stroke, minimum and maximum speeds and maximum allowable rod load.

18.3.4 Compressor cylinder

Nameplates on each compressor cylinder shall give the bore, stroke, maximum allowable working gauge pressure (MAWP), serial number, class/type and minimum clearances for each end as a percentage of the displacement of that end.

18.3.5 Engine

Nameplates on engine drivers shall give the engine manufacturer's name, serial number, model, rated power, rated speed, displacement, power cylinder diameter and stroke.

18.3.6 Motor

Nameplates on motor drivers shall give the motor manufacturer's name, serial number, model, rated power, rated speed, service factor (if any), temperature rise of coils, voltage and full-load amperage.

18.3.7 Cooler

Nameplates on coolers shall give the cooler manufacturer's name, serial number and model. In addition, each gas-, oil- or water-cooling section shall have a nameplate that gives the maximum allowable working gauge pressure, hydrostatic test pressure, serial number and number of passes.

19 Preparation for shipment

19.1 General

19.1.1 Notice to vendors

The vendor shall be responsible for notifying all sub-vendors of the purchaser's requirements for preparation for shipment.

19.1.2 Release for preparation

The equipment shall be prepared for shipment after all testing and inspection have been completed and the equipment has been released by the purchaser.

19.2 Protection

19.2.1 Drainage

All equipment (including compressor, engine, cooler, etc.) shall be completely free of coolant and oil prior to any shipment preparation, unless otherwise specified by the purchaser.

19.2.2 External machined surfaces

External machined surfaces shall be coated with a suitable rust preventive.

19.2.3 Internal surfaces

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

19.2.4 Flanged openings

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 metal closure of 5 mm (0,2 in) minimum thickness 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.

19.2.5 Threaded openings

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.

19.2.6 Bevelled openings

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.

19.2.7 Dismantled and spare parts

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.

19.2.8 Exposed shafts

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

19.2.9 Pressure vessels and piping

External surfaces of pulsation suppressors, piping and vessels shall be cleaned free of pipe scale, welding spatter and other foreign objects.

19.2.10 Bearing assemblies

Bearing assemblies shall be fully protected from the entry of moisture and dirt. If VCI 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 the bag location shall be indicated by corrosion-resistant tags attached with stainless steel wire.

19.3 Shipment and storage

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

  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.

  It is recognized that failure to follow these instructions can jeopardize the successful operation of the equipment.

19.4 Crating

19.4.1 Crating and handling

- 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. If special lifting devices, such as spreader bars, are required, the supply of these shall be subject to agreement. Upright position, lifting points, mass and dimensions shall be clearly marked on each package.

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

19.4.2 Identification

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.

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.

19.4.3 Loose parts

Components' parts, loose parts, and spare parts associated with a specific major item of equipment shall be separately crated for shipment, and shall not be mixed with similar parts associated with another major item of equipment. For example, parts for the compressor shall not be mixed in the same crate with similar parts for the prime mover.

19.5 Manuals

One copy of the Installation Manual, one copy of the Operating Manual and one copy of the Maintenance Manual shall be shipped with the package.

20 Corrosive gases

20.1 General

If hydrogen sulfide or carbon dioxide gases are specified on the data sheets, the items covered in this clause are required as a minimum.

20.2 Hydrogen sulfide

All materials exposed to hydrogen sulfide gas service as defined in 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.

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

NOTE In many applications, small amounts of hydrogen sulfide are sufficient to require NACE MR 0175 materials.

If 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 MR 0175 materials are required.

The use of copper and copper alloys is cautioned for parts of compressors or auxiliaries in contact with corrosive gases.

Components to which NACE MR 0175 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). For further information see annex D.

On multistage machines where NACE MR 0175 is applicable to any stage, then its requirements shall apply to all cylinders handling gas containing hydrogen sulfide, regardless of its partial pressure.

Exceptions to NACE MR 0175 requirements for hardness are acceptable in the following cases:

a) valve seats when used with metallic valve plates;

b) piston rods when the requirements of NACE MR 0175 result in insufficient surface hardness. For wear resistance, a proven surface coating shall be proposed for purchaser's approval.

Mutual agreement shall be reached between compressor manufacturer and purchaser on alternative alloys or special heat treatment, as required.

20.3 Carbon dioxide

The presence of CO_2 in the process gas can cause corrosion when the process gas is wet. To avoid or minimize corrosion, the following shall apply.

a) All metal gaskets shall be soft iron.

b) Piston rods shall be precipitation hardened stainless steel or high-alloy steel annealed to HR C22 with hardening in the packing area by a suitable coating. Other proprietary corrosion-resistant steels may be used only with the purchaser's approval.

c) Compressor valve seats and guards shall be stainless steel or ductile iron. Metallic plates shall be stainless steel.

For all other parts, the compressor manufacturer's standard material shall be used, unless otherwise specified by the purchaser.

NOTE Corrosion can be severe when oxygen and/or chlorine are present.

21 Offshore and marine environments

21.1 General

21.1.1 External parts

External parts subject to rotary or sliding motions shall be of corrosion-resistant materials suitable for site environment.

EXAMPLES Control linkage joints and adjusting mechanisms.

21.1.2 Minor parts

Minor parts not identified shall have corrosion resistance equal to that of specified parts in the same environment.

EXAMPLES Nuts, springs, washers, gaskets.

21.1.3 Corrosive agents

- The purchaser shall specify the presence of corrosive agents in the environment on the data sheets.

21.1.4 Intergranular corrosion

Parts exposed to conditions which promote intergranular corrosion shall be made of low-carbon or stabilized grades of austenitic stainless steels.

21.1.5 Electrical installations

All electrical components and installations shall be in compliance with IEC 60034, IEC 60079, IEC 60529 and IEC 60848.

21.2 Air-cooled heat exchangers

- The cooler structure shall be hot-dipped galvanized. The cooler header shall be galvanized or painted as specified by the purchaser.

21.3 Skid

21.3.1 Drip lip

Unless specified otherwise by the purchaser, the skid shall be furnished with a drip pan of minimum side wall height 75 mm (3 in) and shall be furnished with a DN 40 (1 1/2 in) drain connection in each corner.

21.3.2 Seal welding

All steel skids shall be seal-welded throughout. Concrete-filled steel skids shall be seal-welded except in concrete-filled areas.

21.3.3 Lifting lugs

Lifting lugs with a 50 mm (2 in) minimum eye, each designed to support the entire mass of the package, shall be furnished at each corner of the skid.

21.4 Control and shutdown systems

All gas-pressure-sensing instruments used to initiate shutdowns shall have individual block and bleed valves. All sensing devices shall be mounted on the skid.

21.5 Instrumentation

All components shall be suitable for an offshore or marine environment.

21.6 Panel

21.6.1 Panel construction

Unless otherwise specified, the panel shall be stainless steel and weatherproof in accordance with IEC 60079, IEC 60529 and/or NEMA 250-1997, type 4.

21.6.2 Panel components

The panel shall include a stop/run valve, class B time delay, explosion-proof ignition grounding switch and class C lockout. The panel shall be equipped with a platform emergency shutdown (ESD) annunciator with signal furnished by others, and a signal for remote run/stop indication.

21.7 Gas piping, tubing and appurtenances

21.7.1 Gas piping

Gas piping of size DN 50 (2 in) and larger shall be butt-welded and flanged, except for threaded connections furnished by the engine and starter manufacturers.

21.7.2 Tubing and fittings

Tubing and fittings in panel and piping systems shall be austenitic stainless steel. Fittings shall be Class 3000 as a minimum.

21.7.3 Gaskets

Regardless of flange rating, gaskets for raised-face flanges shall be spiral-wound metallic with centring ring.

21.7.4 Separator level shutdowns

Unless otherwise specified by the purchaser, separator level shutdowns (high and low) shall be external type, bridle-mounted with DN 25 (1 in) flanged isolation valves and with DN 12 (1/2 in) plugged vent and drain valves.

21.8 Painting

21.8.1 Surface preparation

In addition to the requirements for severely corrosive environment given in Table 8, the exhaust system and control panel, if other than stainless steel, shall be prepared in accordance with ISO 8504-2, unless otherwise specified.

21.8.2 Proprietary components

Components which are mechanically cleaned and have the manufacturer's standard primer coating shall, unless otherwise agreed, receive an intermediate coat of vinyl alkyd having a minimum dry film thickness of 50 µm and a finish coat of aliphatic acrylic polyurethane having a minimum dry film thickness of 40 µm.

21.8.3 Bare metal mechanically cleaned parts

These parts shall, unless otherwise agreed, receive a coat of self-priming aluminium epoxy mastic having a minimum dry film thickness of 125 µm and a finish coat of aliphatic acrylic polyurethane having a minimum dry film thickness of 40 µm.

21.8.4 Sandblasted parts

Except for the exhaust silencer and exhaust piping, all parts shall, unless otherwise agreed, receive a prime coat of inorganic zinc silicate having a minimum dry film thickness of 50 µm, an intermediate coat of 100 µm of epoxy polyamide and a finish coat of 40 µm of aliphatic acrylic polyurethane.

21.8.5 Engine exhaust system

The engine exhaust system shall, unless otherwise agreed, have a finish coat of aluminium silicone having a minimum dry film thickness of 30 µm and rated at 550 °C.

21.8.6 Painting repairs

Repairs to any finished painting, other than to the exhaust system, shall be made with self-priming aluminium epoxy mastic and top coat.

21.8.7 Concrete-filled skids

Exposed concrete shall receive a prime coat only.

21.9 Valves in gas service

21.9.1 Fire protection

Isolating, bleed, control and safety valves in the gas path and in the lubrication system shall be fire-safe.

21.9.2 Valve material

Valves of size DN 40 (1 1/2 in) and smaller in gas service shall have stainless steel stem and trim.

21.9.3 Block valves

- If specified by the purchaser, the vendor shall furnish the suction and discharge block valves. The purchaser shall also specify type and whether manual or pilot-operated.

Annex A
(informative)

Data sheets and check list

A.1 Data sheets

A.1.1 Service conditions

	Ref. subclause	ISO 13631 — Packaged reciprocating compressor — Data sheet **Service conditions** (to be completed by purchaser)					Rev. No.
1		**GENERAL INFORMATION**					
2 3 4		Company: Address: Contact: Tel: Fax: E-mail:					
5		Project: No.: Service: No. required:					
6		Issued for: Inquiry [ ] No.: Date: Purchase order: [ ] No.: Date:					
7		**PROPOSAL REQUIREMENTS**					
8		Furnish No. of copies indicated: Proposal: Reports: Drawings Data books: Curves: Misc:					
9	5.1/5.7	Performance curves: YES [ ] NO [ ] Indicate range: Torsional report: YES [ ] NO [ ]					
10	5.3	Drawings: Approval YES [ ] NO [ ] As-built: YES [ ] NO [ ] Misc.: YES [ ] NO [ ] Type:					
11							
12							
13							
14		**OPERATING CONDITIONS**					
15	6.1.1	CASE No.:	Normal	Alternative 1	Alternative 2	Alternative 3	
16		Service					
17		GAS COMPOSITION, mole fraction					
18		Methane — CH_4					
19		Ethylene — C_2H_4					
20		Ethane — C_2H_6					
21		Propylene — C_3H_6					
22		Propane — C_3H_8					
23		Isobutane — C_4H_{10}					
24		n-butane — C_4H_{10}					
25		Isopentane — C_5H_{12}					
26		n-pentane — C_5H_{12}					
27		Hexane — C_6H_{14}					
28		Heptane +					
29							
30							
31		Ammonia — NH_3					
32		Air					
33		Water vapour — H_2O					
34		Oxygen — O_2					
35		Nitrogen — N_2					
36		Hydrogen — H_2					
37		Hydrogen sulfide — H_2S					
38		Carbon monoxide — CO					
39		Carbon dioxide — CO_2					
40							
41							
42							
43		Mixture MW or SG					
44		$c_p/c_V\,(k)$ at 65 °C					
45		Relative humidity %					
46		Number of stages					
47		Suction temperature °C					
48		Suction pressure (abs) MPa (bar)					
49		Discharge pressure (abs) MPa (bar)					
50		Req'd capacity, standard m^3/h					
51		**SIDESTREAMS**					
52		Service					
53		Number of stages					
54		Suction temperature °C					
55		Suction pressure (abs) MPa (bar)					
56		Discharge pressure (abs) MPa (bar)					
57		Req'd capacity, standard m^3/h					
58		Max. allowable cylinder discharge temperature: C Max. allowable aftercooler discharge temperature: °C					
59							
60							

61		**SITE INFORMATION**	Rev.
62		Location (address):	
63	5.4	Maximum allowable sound pressure level: dB(A)	
64	5.5	Electric power available: YES [ ] NO [ ] Voltage: Phases: Frequency Hertz. Hazardous: YES [ ] NO [ ] Electrical area classification:	
65	5.6	Ambient temperature: Max.: °C: Min.: °C: Design: °C.	
66		Elevation: m Barometric pressure: hPa (mbar). Relative humidity: %	
67		Tropical [ ] Arctic [ ] Desert [ ] Inland [ ] Coastal [ ] Offshore [ ] Inland water [ ] Sand [ ] Dust [ ]	
68		Attended [ ] Partially attended [ ] Unattended [ ]	
69		Size limitation (if any): Length: m Width: m. Height: m	
70			
71		**MATERIAL REQUIREMENTS — COMPRESSOR**	
72	6.1.3	Prime mover loading:	
73	6.2	Maximum allowable average piston speed: m/s Maximum allowable prime mover speed r/min	
74	6.3	Furnish predicted actual [ ] and/or calculated adiabatic [ ] compressor cylinder discharge temperatures.	
75	6.5.3.2	Furnish plugged indicator taps: YES [ ] NO [ ]	
76	6.7.3	Furnish non-metallic piston wear bands YES [ ] NO [ ]	
77	6.8.5	Crankcase relief devices required: YES [ ] NO [ ]	
78	6.9.1.1	Furnish Type 1 [ ], Type 2 [ ] or Type 3 [ ] distance pieces	
79	6.9.1.2	Furnish slinger rings	
80	6.11.6	Furnish oil storage tank: YES [ ] NO [ ] Capacity litres	
81	6.11.7	Furnish lubricating oil heater: YES [ ] NO [ ]	
82	6.12.1	For block cyl lube system Furnish: Line filters YES[ ] NO[ ], lube meter YES[ ] NO[ ] Fault indicators YES[ ] NO[ ]	
83	6.12.2	Furnish lubricator oil storage tank: YES [ ] NO [ ] Capacity litres	
84	6.14.2	Coupling material: Steel [ ] or stainless steel [ ]	
85	6.14.5	Aluminium guards prohibited: YES [ ] NO [ ]	
86		**CAPACITY CONTROL**	
87	7.1	Capacity control to be furnished: YES [ ] NO [ ]	
88		Controlled parameter: Suction pressure [ ], Discharge pressure [ ] Flow rate [ ]	
89		Controlled range: from MPa (bar) to MPa (bar) Or capacity variation from: % to %	
90		Control system to be: Mechanical [ ], Pneumatic [ ], Hydraulic [ ], Electrical [ ]	
91		Control signal by Vendor [ ] or Purchaser [ ]. Source: Range: Sensitivity:	
92	7.2	Control operation: Automatic with manual over-ride [ ], Manual [ ]. Unit shutdowns acceptable YES [ ] NO[ ]	
93	7.3	Control by prime mover speed variation: YES [ ] NO [ ]	
94	7.4.2	Clearance pockets: YES[ ] NO [ ] Fixed [[Variable [ ]	
95	7.4.3/7.4.4	Valve spacers (if required to meet operating condition): YES [ ] NO [ ] Clearance bottles YES [ ] NO [ ]	
96	7.5.2/7.5.3	Start-up bypass: YES [ ] NO [ ] Capacity control bypass: YES [ ] NO[ ] Manual [ ] Automatic [ ]	
97	7.6.3	Automatic valve unloading: YES [ ] NO [ ]	
98	7.7	Suction pressure-reducing valve: YES [ ] NO [ ] by Purchaser [ ] or Vendor [ ] Max. suction pressure: MPa (bar)	
99		**PRIME MOVER**	
100	8.1	Type of prime mover: Gas engine [ ] Electric motor [ ]	
101	8.2.3.1/ 8.2.3.2	Gas engine starting by: Electric [ ], Air [ ] or Gas [ ] Air/Gas from: Max./Min. gauge pressure: / MPa (bar)	
102	8.2.3.3	Battery for electric start: YES [ ] NO [ ] Capacity: ampere-hour Charging alternator: YES [ ] NO [ ]	
103	8.2.4.2/ 8.2.4.6	Engine air filter: Vendor's st'd [ ] Other [ ] Details: Press. drop indicator: YES [ ] NO [ ]	
104	8.2.5.5	Exhaust silencer: Vendor's st'd [ ] Other[ ] Details: Spark-arresting: YES [ ] NO [ ]	
105		Sound attenuation requ'ts: Personnel protection requ'ts:	
106	8.2.6	Ignition weather protection required: YES [ ] NO [ ]	
107	8.2.7	Exhaust gas emission levels required: YES [ ] NO [ ]. Based on: Manufacturer's perf. data [ ] Actual stack tests [ ] Based on: Quotation rated power [ ] or Manufacturer's nameplate rating [ ]	
108		Site emission level limits: NO_X CO SO_2 Non-methane hydrocarbons	
109	8.2.9	Crankcase oil storage tank required: YES[ ] NO [ ] Capacity: litre	
110	8.2.10	Fuel gas filter/separator required: YES [ ] NO [ ]	
111	8.2.11	Fuel gas: Sweet [ ], Sour [ ], Dry [ ], Rich [ ]. LHV kJ/kg Supplied at gauge pressure of: MPa (bar)	
112	8.3.1	Electric motor prime mover. Type Volts Phases: Hertz Service factor:	
113		Area classification: Enclosure type: Insulation type: Starting conditions:	
114		Motor starter by: Vendor [ ] or Purchaser [ ] Starting at full [ ] or reduced voltage [ ]:	
115		Space heater: YES [ ] NO[ ] by Vendor [ ] or Purchaser [ ]	
116		Instrumentation required: Temperature detectors [ ], Vibration switches [ ] Other instrumentation:	
117		**COOLING SYSTEM**	
118	9.3.1.3	Cylinder jacket cooling: Sight flow indicators required: YES [ ] NO [ ] Temperature indicators: YES [ ] NO [ ]	
119	9.3.5	Gas aftercooling required to °C Gas cooler design code:	
120	9.6.8	Auto control of coolers by: Louvres [ ], Variable-pitch fan [ ],Variable-speed fan [ ], Recirculation [ ] Other [ ] Details:	
121	9.6.9	Insect screens required: YES [ ] NO [ ]. Hailguards required: YES [ ] NO [ ]	

122		**PRESSURE VESSELS**					Rev.
123	10.1.1	Pressure vessel design code: Pipe threads to: ISO 7-1 [ ] or ANSI B1.20.1 [ ]					
124	10.2.5	Separators ; Furnish: external level gauge with cocks and check valves[ ], press. indicator with valve [ ]					
125	10.2.6	Suction separator required: YES [ ] NO [ ]. Diameter based on service class A [ ], B [ ] or C [ ] Interstage separator(s) required: YES [ ] NO [ ]. Diameter based on service class A [ ], B [ ] or C [ ] Discharge separator required: YES [ ] NO [ ]. Diameter based on service class A [ ], B [ ] or C [ ]					
126	10.3.1	Pulsation control and studies required: YES [ ] NO [ ] Type: Scope:					
127	10.3.2	Suction and discharge volume bottles required: YES [ ] NO [ ]					
128		**PIPING AND APPURTENANCES**					
129	11.1.4	Vendor to supply complete piping from package suction flange to package discharge flange: YES [ ] NO [ ]					
130		Vendor to supply suction piping from: Suct. separator [ ]; Suct. pulsation suppressor [ ]: Compressor nozzle [ ]; Other [ ] Details:					
131		Vendor to supply sidestream piping from: Interstage sep't'r [ ]; Pulsation suppressor [ ]; Compressor nozzle[ ] Other: [ ] Details ;					
132		Vendor to supply discharge piping from: Aftercooler [ ] Pulsation suppressor [ ]; Compressor nozzle[ ] Other: [ ] Details ;					
133		Vendor to supply complete interstage piping system: YES [ ] NO [ ]					
134		Piping, vessels and thermowells designed and arranged for: Lagging [ ] and/or Heat tracing [ ]					
135	11.1.5	Purchaser to review/approve arrangement drawing prior to fabrication: YES [ ] NO [ ]					
136	11.8	Piping design code: ASTM A106 [..] ASTM A312 [..] Other [..]					
137	11.10	Valves to be furnished: Suction block valve [ ]; Discharge block valve [ ];Check valve [ ]; Blowdown valve [ ]					
138		Valves to have: Bolted or welded bonnets [ ]; Bolted glands [ ]; and be “fire-safe” (metal-to-metal seated) [ ]					
139	11.13	Temporary start-up screens required: YES [ ] NO [ ] Removable spool piece required: YES [ ] NO [ ]					
140	11.14.2	Oil pipework downstream of filter to be stainless steel: YES [ ] NO [ ]					
141	11.15.1	Complete on-skid coolant system to be furnished: YES [ ] NO [ ]					
142	11.17.2	Common distance-piece vent header, terminating at the edge of the skid required: YES [ ] NO [ ]					
143	11.17.3	Common distance-piece drain header, terminating at the edge of the skid required: YES [ ] NO [ ]					
144	11.17.4	Common packing vent header, terminating at the edge of the skid required: YES [ ] NO [ ]					
145	11.18.3	Vendor to furnish relief valves: YES [ ] NO [ ] Additional suction RV capacity req'd: YES [ ] NO [ ] Sm^3/h					
146	11.18.6	RV vent pipes to discharge to atmosphere [ ] or to a common header terminating at skid edge [ ] or elsewhere [ ]					
147		Atmospheric vents with weep holes at lowest point near relief valves: YES [..] NO [..]					
148	11.19	Package blowdown valve to discharge to atmosphere [ ] or to a common header terminating at skid edge [ ] or elsewhere{] Details:					
149							
150							
151							
152		**ELECTRICAL SYSTEMS**					
153	8.3.3/12.2	ELECTRICAL POWER	AC volts	AC phases	AC frequency	DC volts	
154		Main prime mover					
155		Auxiliary motors					
156		Heaters					
157		Instrumentation					
158		Alarms and shutdowns					
159							
160							
161							
162		**INSTRUMENTS AND CONTROLS**					
163	13.1.1	Following control systems are req'd in addition to the instr. and control panel (9.2) and any capacity control (3)					
164		Purpose or function	Control signal source	Control signal range	Control signal sensitivity	Manual, automatic or programmable	
165							
166							
167							
168							
169							
170	5.5	Instrument and control panel to be in accordance with Purchaser's specification: YES [ ] NO [ ]					
171	13.2.2/ 13.2.3	Panels to have enclosed backs: YES [ ] NO [ ], to be free-standing on-skid [ ] or off-skid [ ]					
172	13.2.5	Wiring: outside panels to be in conduits [ ] or cable trays [ ] Wiring to remote panels in conduits [ ], cable trays [ ]					
173	13.3.1	Tachometer in panel required: YES [ ] NO [ ] Range to r/min					
174	13.3.2/ 13.3.4	Liquid-filled dial temperature gauges: YES [ ] NO [ ] Liquid-filled pressure gauges: YES [ ] NO [ ]					
175	13.3.5/ 13.3.6	Fuel gas meter: YES [ ] NO [ ] Fuel shut-off valve: YES [ ] NO [ ]					
176							
177							
178							
179							

180		SHUTDOWNS, ALARMS AND ANNUNCIATORS										Rev.
181	14.1	Shutdowns, alarms and annunciators shall be hydraulic [ ] pneumatic [ ] or electric [ ] and supplied as follows:										
182	13.3.2/ 13.3.4/ 14.1/14.3		Desired action			Type and location of annunciation				Sensor location		
183		Note: X indicates the desired action type and location of annunciation and location of the sensor. Mark each box for multiple requirements	Shutdown	Alarm	Indicator	Visual	Audible	Panel	Remote	Panel	local	
184		**COMPRESSOR**										
185		Suction gas pressure — first stage										
186		Low	X									
187		High										
188		Suction gas pressure — interstage										
189		Low										
190		High										
191		Discharge gas pressure — interstage										
192		Low										
193		High	X									
194		Discharge gas pressure — final stage										
195		Low										
196		High	X									
197		Lubricating oil pressure										
198		In-filter										
199		Out-filter										
200		Low	X									
201		Lubricating oil temperature										
202		In										
203		Out										
204		High										
205		Gas temperature — each stage										
206		Suction										
207		Discharge — each cylinder	X									
208		High — each cylinder										
209		Lubricating oil level										
210		Low — frame										
211		Low — lubricator										
212		Lubricator — no flow	X									
213		Vibration — high	X									
214		Cylinder coolant temperature										
215		In										
216		Out — each cylinder										
217		High										
218												
219		**GAS ENGINE —** IF FURNISHED										
220		Manifold pressure/vacuum — High/low										
221		Coolant temperature										
222		In										
223		Out										
224		High	X									
225		Lubricating oil temperature										
226		In										
227		Out										
228		High										
229		Lubricating oil pressure										
230		In — filter										
231		Out — filter										
232		Low	X									
233		Coolant pressure										
234		In										
235		Out										
236		Low										

237		**SHUTDOWNS, ALARMS AND ANNUNCIATORS CONTINUED**										Rev.
238			Desired action			Type and location of annunciation				Sensor location		
239			Shutdown	Alarm	Indicator	Visual	Audible	Panel	Remote	Panel	local	
240		Fuel gas pressure										
241		High	X									
242		Low	X									
243		Starting air/gas pressure										
244		Vibration — High	X									
245		Lubricating oil level										
246		Low										
247		Overspeed	X									
248												
249												
250												
251		**ELECTRIC MOTOR** — IF FURNISHED										
252		Stator winding temperature										
253		High	X									
254		Vibration — High	X									
255												
256												
257		OTHER										
258		Cooler vibration — high	X									
259		Cooler coolant level										
260		Low	X									
261		Inlet separator liquid level — each stage										
262		High	X									
263		Low										
264												
265												
266	14.6.3	Blowdown valve to open automatically on shutdown YES [ ] NO [ ]										
267		**SKID**										
268	15.4	Skid to be provided with walkways, stairs and platforms YES [ ] NO [ ]										
269		**PAINT AND PAINTING**										
270	16.2	The environment is: Normal [ ] or severely corrosive [ ]										
271		Compressor: Vendor's/Manufacturer's standard [ ] or special [ ] Details:										
272		Prime mover: Vendor's/Manufacturer's standard [ ] or special [ ] Details:										
273		Package: Vendor's/Packager's standard [ ] or special [ ] Details:										
274		Air-cooled heat exchanger: Ducting/structure: Vendor's/Manufacturer's standard [ ], Hot-dipped galvanizing [ ] or special [ ] Details:										
275		Air-cooled heat exchanger: Headers: Vendor's/Manufacturer's standard [ ], Hot-dipped galvanizing [ ] or special [ ] Details:										
276		**INSPECTION AND TESTING**										
277	17.1.3	Purchaser will participate YES [ ] NO [ ] Hold and witness points as vendor's standard quality plan YES [ ] NO [ ]										
278	17.1.6	Advanced notification period: working days										
279	17.2.1/ 17.3.4.2	Ultrasonic inspection of forgings YES [ ] NO [ ] Assembled package leakage test YES [ ] NO [ ]										
280	17.4.4	Dismantle for expansion YES [ ] NO [ ]										
281		**PREPARATION FOR SHIPMENT**										
282	19.3	Type of shipment and expected duration of storage:										
283	19.4.1	Equipment to be packed for domestic [ ] or export [ ]										
284		**OFFSHORE AND MARINE ENVIRONMENT**										
285	21.1.3	Corrosive environment: YES [ ] NO [ ] Details:										
286	21.2	Cooler headers: Vendor's/Manufacturer's standard paint [ ], Hot-dipped galvanizing [ ] or special paint [ ] Details:										
287	21.9.3	Furnish manual [ ] or pilot-operated [ ] suction[ ] and/or discharge [ ] block valves YES [ ] NO [ ]										
288		**OTHER REQUIREMENTS**										
289												
290												
291												
292												

A.1.2 Vendor's design

	Ref. subclause	ISO 13631 — Packaged reciprocating compressor — Data sheet Vendor's design					Rev. No.
1			**Vendor**		**Purchaser**		
2		Company					
3		Address					
4							
5							
6							
7							
8		Telephone					
9		E mail					
10		Fax					
11		Contact 1					
12		Contact 2					
13		Cost estimate only [ ] For purchase [ ]					
14		Project name: No.: Service:					
15		Inquiry No.: Proposal No.: Date: No. of units: Delivery quoted:					
16							
17		**MISCELLANEOUS**					
18		Copies furnished of: Proposal Reports Drawings Data books Curves Miscellaneous:					
19	5.1	Performance curves: YES [ ] NO [ ] Range:					
20	5.3	Drawings: Approval [ ], As-built [ ]. Miscellaneous [ ] Details:					
21	5.4	Noise emission: Actual sound pressure level: dB(A)					
22	5.7	Torsional report: YES [ ] NO [ ]					
23		**COMPRESSOR**					
24		Manufacturer: Model: Rated speed: r/min. Rated power: kW					
25		Stroke: mm Av. piston speed: m/s. Piston rod diam. mm					
26		Max allowable continuous combined rod load: compression/tension / kN					
27	6.1.4	Unbalanced forces and moments		Primary		Secondary	
28		Horizontal force: kN					
29		Vertical force: kN					
30		Horizontal moment: kN·m					
31		Vertical moment: kN·m					
32	6.9.1.1/6.9.3	Distance pieces: Type: 1 / 2 / 3 Pressure-relief devices: YES [ ] NO [ ]					
33	6.11.6/6.11.7	Crankcase lube system: I. storage tank; with Level gauge: YES [ ] NO [ ] Oil heater: YES [ ] NO [ ]					
34	6.12.1	Cylinder lube system: Block / Pump to point type. With: line filters [ ], flow meter [ ], fault indicators [ ]					
35	6.12.2	Cylinder lubricator I. storage tank. With level gauge: YES [ ] NO [ ]					
36	6.13.1.4	Proposed welding code:					
37	6.14.2	Coupling: Type: Manufacturer: Model: Disc pack: Steel / Stainless steel					
38		**COMPRESSOR CONSTRUCTION FEATURES**					
39	6	Service					
40		Stage					
41		Cylinder bore — mm					
42	6.5.2.2	Cooled / non-cooled cylinder					
43		**Materials**					
44		Cylinder					
45		Cylinder liner (if furnished)					
46		Piston					
47		Piston rings					
48		Wear bands					
49		Piston rod					
50		Piston rod base metal hardness — HRC					
51		Piston rod coating					
52		Coating hardness — HRC					
53		Valve seats					
54		Valve guards					
55		Valve plates					
56		Valve springs					
57		Rod packing case					
58		Rod pressure packing rings					
59		Rod wiper packing rings					
60		Crankshaft					
61		Crankshaft main journal bearings					
62		Connecting rod					
63		Connecting rod bearings					
64		Crosshead					

65		**COMPRESSOR CONSTRUCTION FEATURES** (CONTINUED)					Rev.
66		Crosshead pin					
67		Crosshead pin bushing					
68		Crosshead shoes (if furnished)					
69		Cylinder indicator connections					
70		**COMPRESSOR PERFORMANCE**					
71		Case					
72		Service					
73		Stage					
74		No. of cylinders					
75		Cylinder bore mm					
76		Rated discharge gauge pressure MPa (bar)					
77		Max allowable working temp. °C					
78		Cylinder action (DA/SACE/SAHE)					
79		Flange size/rating/facing type					
80		Piston displacement/cylinder m^3/s					
81		Molar mass kg/kmol					
82		c_p/c_V (k) value					
83		Critical pressure MPa (bar)					
84		Critical temperature K					
85		Compressibility (z) at suction					
86		Compressibility (z) at discharge					
87		Suction pressure MPa (bar)					
88		Discharge pressure MPa (bar)					
89		Suction temperature °C					
90		Discharge temperature adiabatic °C					
91		Discharge temp estimate actual °C					
92		Required capacity m^3/h					
93		Quoted capacity m^3/h					
94		Compression power/stage kW					
95		Compression power total kW					
96		Accessories power kW					
97		Compressor rated power kW					
98		$\left(\frac{\text{Compressor rated power}}{\text{Engine site rated power}}\right) \times 100\ \%$					
99		Rated speed r/min					
100		Average piston speed m/s					
101		Cylinder clearance HE %					
102		Cylinder clearance CE %					
103		Total cylinder clearance %					
104		Volumetric efficiency HE %					
105		Volumetric efficiency CE %					
106		Total volumetric efficiency %					
107		Rod load (gas) — compression kN					
108		Rod load (gas) — tension kN					
109		Combined rod load — compression kN					
110		Combined rod load — tension kN					
111		Clearance pocket position % open					
112		Valve spacers installed quantity/cyl					
113		Valve velocity — average m/s					
114		Valves/cyl end — suction/discharge					
115		Valve type and size mm					
116		Valve lift mm					
117		Valve area mm^2					
118							
119		**COMPRESSOR CAPACITY CONTROL**					
120		**PARTIAL LOAD OPERATION**					
121		Case					
122		Service					
123		Stage					
124		Cylinder action — (DA/SACE/SAHE)					
125		c_p/c_V (k) value					
126		Critical pressure MPa (bar)					
127		Critical temperature K					
128		Compressibility (z) at suction					
129		Compressibility (z) at discharge					

130		**PARTIAL LOAD OPERATION** (CONTINUED)					Rev.
131		Suction pressure MPa (bar)					
132		Discharge pressure MPa (bar)					
133		Suction temperature °C					
134		Discharge temperature adiabatic °C					
135		Discharge temp estimate actual °C					
136		Required capacity m^3/h					
137		Quoted capacity m^3/h					
138		Compression power/stage kW					
139		Compression power total kW					
140		Accessories power kW					
141		Compressor rated power kW					
142		$\left(\frac{\text{Compressor rated power}}{\text{Engine site rated power}}\right) \times 100\ \%$					
143		Actual speed					
144		Cylinder clearance HE %					
145		Cylinder clearance CE %					
146		Clearance pocket position % open					
147		Valve spacers installed quantity/cyl					
148		Clearance plug: Yes/No					
149		Clearance bottle: Yes/No					
150		Valve unloaders: Yes/No					
151		Capacity control bypass: Yes/No					
152							
153	7.3	Speed variation: YES [ ] NO [ ]: Range to r/min. Manual [ ] Automatic [ ]					
154	7.4.2	Clearance pockets Fixed (open/closed) [ ] Variable [ ] None [ ] Manual/Automatic Cylinders 1 / 2 / 3 / 4					
155	7.4.3	Valve spacers: Head end: No Cyl 1 / 2 / 3 / 4 Crank end: No Cyl 1 / 2 / 3 / 4					
156	7.4.4	Clearance bottles: YES [ ] NO [ ] Cylinders: 1 / 2 / 3 / 4					
157	7.4.6	Clearance plugs: YES [ ] NO [ ] Cylinders: 1 / 2 / 3 / 4					
158	7.6.2/7.6.3	By-pass system: Start-up [ ], Capacity control [ ]; Manual [ ] Auto [ ]; Hot [ ] Cold [ ]					
159	7.6.2	Valve unloaders: YES [ ] NO [ ]; Plate depressors [ ], Plug [ ]; Manual [ ] Auto [ ] Cyl: 1 / 2 / 3 / 4					
160	7.7	Suction pressure-reducing valve: YES [ ] NO [ ]					
161							
162		**PRIME MOVER — GAS ENGINE**					
163		Manufacturer: Model:					
164		Site rated power: kW; Max. allowable speed r/min Min. allowable speed r/min					
165		No. of power cylinders: Bore: mm. Stroke: mm. Displacement: m^3					
166		Turbo-charged [ ], Naturally aspirated [ ]; Compression ratio: Fuel consumption: kJ/kW·h					
167	8.2.3	Starting system: electric / air / gas; ampere-hour battery [ ] Charging generator YES [ ] NO [ ]					
168	8.2.4.2	Air filter manufacturer's standard dry type [ ]; Other [ ] Details:					
169	8.2.4.6	Air filter pressure-drop indicator: YES [ ] NO [ ]					
170	8.2.5	Exhaust silencer: manufacturer's standard [ ] Other [ ] Spark-arresting YES [ ] NO [ ]					
171	8.2.7.1	Sound attenuation: Personnel protection [ ] Details:					
172	8.2.7	Exhaust gas emissions: from manufacturer's performance test [ ] or from actual stack test data [ ]					
173	8.2.7.3	NO_X: Non-methane hydrocarbons: CO_2: SO_2: At rated power [ ], nameplate rating [ ]					
174	8.2.9	Crankcase oil storage tank: YES [ ] NO [ ] Capacity: litre					
175	8.2.10/8.2.12	Fuel gas filter/separator: YES [ ] NO [ ] Crankcase pressure relief devices: YES [ ] NO [ ]					
176							
177		**PRIME MOVER — ELECTRIC MOTOR**					
178	8.3.1	Manufacturer: Model: IEC rating kW					
179		Synchronous / Induction Rated power: kW; Rated speed: r/min. Service factor					
180		Frame type: Enclosure type:: Volts: Phase: Frequency: Hz					
181		Electrical area classification: Insulation: Temperature rise: °C above °C					
182		Space heater YES [ ] NO [ ] Volts: Phase: Frequency: Hz.					
183		Starter YES [ ] NO [ ]; IEC rating: Manufacturer: Full voltage [ ] reduced voltage [ ]					
184		Variable speed: YES [ ] NO [ ]					
185		Accessories: Temperature detectors [ ], Vibration sensing [ ] Other:					
186							
187		**COOLING SYSTEM**					
188		Manufacturer: Model: On compressor skid [ ] separate skid [ ]					
189		Vertical [ ] Horizontal [ ] Electric driven [ ] Vee-belt driven [ ] Fans: No.: diam. mm. Tip speed m/s					
190	9.3.1.3	Sight-flow [ ] and/or temperature indicators [ ] Gas after cooler to °C: YES [ ] NO [ ]					
191		MAWP MPa (bar): Water side: Gas side:1st stage: 2nd stage: 3rd stage: 4th stage: After cooler:					
192	9.6.8	Control: Automatic [ ] Manual [ ] on interstage gas [ ] and/or final discharge gas [ ]					
193		Control by: Louvres [ ], variable pitch fans [ ], variable speed fans [ ], recirculation [ ], Other [ ]					
194	9.6.9	Cooler insect screens: YES [ ] NO [ ], Hail guards: YES [ ] NO [ ]					

195	10	**PRESSURE VESSELS**					Rev.
196	10.3.1	Pulsation study: YES [ ] NO [ ] Details:					
197		**Separators**	Stage 1	Stage 2	Stage 3	Discharge	
198		Pressure vessel design code					
199		Inside diameter mm					
200		Seam-to-seam length mm					
201		Design gauge pressure MPa (bar)					
202		Design temperature °C					
203		Mesh pad/vane mist extractor					
204		Mist extractor material					
205		Manual drain YES/NO					
206		Type automatic drain control					
207		Type automatic drain valve					
208		Level gauge glass YES/NO					
209		Pressure indicator YES/NO					
210		Inlet flange size/rating/facing/type					
211		Outlet flange size/rating/facing/type					
212		Corrosion allowance mm					
213		Weld pads/saddles YES/NO					
214							
215		**Suction pulsation/volume bottles**	Stage 1	Stage 2	Stage 3		
216		Pressure vessel design code					
217		Volume m^3					
218		Swept volume factor (Annex B)					
219		Inside diameter mm					
220		Seam-to-seam length mm					
221		Design gauge pressure MPa (bar)					
222		Design temperature °C					
223		Inlet flange size/rating/facing/type					
224		Outlet flange size/rating/facing/type					
225		Corrosion allowance mm					
226		Type drain opening					
227		Weld pads/saddles YES/NO					
228							
229		**Discharge pulsation/volume bottles**	Stage 1	Stage 2	Stage 3		
230		Pressure vessel design code					
231		Volume m^3					
232		Swept volume factor (Annex B)					
233		Inside diameter mm					
234		Seam-to-seam length mm					
235		Design gauge pressure MPa (bar)					
236		Design temperature °C					
237		Inlet flange size/rating/facing/type					
238		Outlet flange size/rating/facing/type					
239		Corrosion allowance mm					
240		Type drain opening					
241		Weld pads/saddles YES/NO					
242							
243		**PIPING AND APPURTENANCES**					
244	11.1.4	Vendor will supply all piping from package suction to package discharge: YES [ ] NO [ ]					
245		Or piping supply shall be as follows:					
246		**Suction**: from separator [ ], pulsation-suppression device [ ], compressor nozzle [ ], other[ ]					
247		Details:					
248		**Interstage**: from separator [ ], pulsation-suppression device [ ], compressor nozzle [ ], sidestream connection [ ], complete interstage piping system [ ], other [ ]					
249		Details:					
250		**Discharge**: to cooler discharge [ ], pulsation-suppression device [ ], compressor nozzle [ ], spool piece from final discharge cooler to discharge separator [ ], other [ ]					
251		Details:					
252		Piping, vessels and thermowells arranged for heat tracing and/or insulation YES [ ] NO [ ]					
253	11.10	Valves in flammable or toxic service to have bolted or welded bonnets [ ], bolted glands [ ], be fire-safe [ ]					
254	11.13	Temporary start-up screens YES [ ] NO [ ]; Removable spool-piece YES [ ] NO [ ]					
255	11.14.2	Oil piping downstream of filters: steel [ ] or austenitic stainless steel [ ]					
256	11.15.1	Complete on-skid coolant piping system YES [ ] NO [ ]					
257	11.17.2	Common distance piece vent header YES [ ] NO [ ]					

258		**PIPING AND APPURTENANCES** (CONTINUED)						Rev.
259	11.17.3	Common distance piece drain header: YES [ ] NO [ ]						
260	11.17.4	Common packing vent header: YES [ ] NO [ ]						
261	11.18.6	Relief and blowdown valves vent to atmosphere [ ], common header [ ] or other [ ]						
262		Details:						
263	11.1-11.8	Process piping	Suction	1st interstage	2nd interstage	3rd interstage	Discharge	
264		Piping ID mm						
265		Design gauge pressure MPa (bar)						
266		Design temperature °C						
267								
268		Relief valve size mm						
269		Relief valve rating MPa (bar)						
270		Relief valve setting MPa (bar)						
271		Relief valve orifice mm						
272		Block valve size mm						
273		Block valve rating MPa (bar)						
274		Check valve size mm						
275		Check valve rating MPa (bar)						
276								
277								
278		**ELECTRICAL SYSTEMS**						
279	12.2	**Electric motors**						
280		Service						
281		Manufacturer						
282		Model						
283		Speed						
284		IEC rating						
285		Volts						
286		DC/AC phase/frequency						
287		Enclosure type						
288		Service factor						
289		Motor control manufacturer						
290		IEC rating						
291								
292	12.5	Electrical material suitable for tropical location: YES [ ] NO [ ]						
293								
294		**INSTRUMENTS AND CONTROLS**						
295	13.1.1	In addition to any capacity control, the following control systems are included:						
296		Function						
297		Manual/Auto						
298	13.1.6	Pneumatic instrument supply: gas [ ] or instrument air [ ]						
399	13.2.2/13.2.3	Panel: free-standing [ ], skid-mounted [ ], off-skid [ ]. With enclosed back: YES [ ] NO [ ]						
300	13.2.5	Wiring to remote panels: in conduit [ ], armoured cable [ ] on cable trays [ ]						
301	13.3.1	Panel-mounted digital [ ] or analog [ ] tachometer						
302	13.3.2-13.3.5	Liquid-filled temp. indicators [ ], liquid-filled pressure indicators [ ], fuel gas meter [ ], shut-off valves [ ]						
303								
304								
305								
306		**NOTES**						
307								
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321		SHUTDOWNS, ALARMS AND ANNUNCIATORS										Rev.
322	14.1	Shutdowns, alarms and annunciators: pneumatic [ ], hydraulic [ ] or electric [ ]										
323	14.3	Note: X indicates the desired action type and location of annunciation and location of the sensor. Mark each box for multiple requirements	Desired action			Type and location of annunciation				Sensor location		
			Shutdown	Alarm	Indicator	Visual	Audible	Panel	Remote	Panel	Local	
324		**COMPRESSOR**										
325		Suction gas pressure — first stage										
326		Low	X									
327		High										
328		Suction gas pressure — interstage										
329		Low										
330		High										
331		Discharge gas pressure — interstage										
332		Low										
333		High	X									
334		Discharge gas pressure — final stage										
335		Low										
336		High	X									
337		Lubricating oil pressure										
338		In-filter										
339		Out-filter										
340		Low	X									
341		Lubricating oil temperature										
342		In										
343		Out										
344		High										
345		Gas temperature — each stage										
346		Suction										
347		Discharge — each cylinder	X									
348		High — each cylinder										
349		Lubricating oil level										
350		Low — frame										
351		Low — lubricator										
352		Lubricator — no flow	X									
353		Vibration — high	X									
354		Cylinder coolant temperature										
355		In										
356		Out — each cylinder										
357		High										
358												
359												
360		**GAS ENGINE** (if furnished)										
361		Manifold press./vacuum — High/low										
362		Coolant temperature										
363		In										
364		Out										
365		High	X									
366		Lubricating oil temperature										
367		In										
368		Out										
369		High										
370		Lubricating oil pressure										
371		In — filter										
372		Out — filter										
373		Low	X									
374		Coolant pressure										
375		In										
376		Out										
377		Low										

378		**SHUTDOWNS, ALARMS AND ANNUNCIATORS** (CONTINUED)										Rev.
379		Note: X indicates the desired action type and location of annunciation and location of the sensor. Mark each box for multiple requirements	Desired action			Type and location of annunciation				Sensor location		
			Shutdown	Alarm	Indicator	Visual	Audible	Panel	Remote	Panel	Local	
380		**GAS ENGINE** (continued)										
381		Fuel gas pressure										
382		High	X									
383		Low	X									
384		Starting air/gas pressure										
385		Vibration — High	X									
386		Lubricating oil level										
387		Low										
388		Overspeed	X									
389												
390												
391		**ELECTRIC MOTOR** (if furnished)										
392		Stator winding temperature										
393		High	X									
394		Vibration — High	X									
395												
396												
397		**OTHER**										
398		Cooler vibration — high	X									
399		Cooler coolant level										
400		Low	X									
401		Separator liquid level										
402		High	X									
403		Low										
404												
405												
406												
407	14.6.3	Furnish blowdown valve: YES [ ] NO [ ] To open automatically on shutdown: YES [ ] NO [ ]										
408												
409		**SKID**										
410	15.1	Structural steel [ ], Pre/post stressed concrete [ ], Concrete filled structural steel [ ],										
411		Other [ ] Details:										
412	15.2.6	Number of foundation bolts per side:										
413	15.4	Beam: Flange mm Mass kg Floor plate: YES [ ] NO [ ] Walkways: YES [ ] NO [ ] Stairs: YES [ ] NO [ ]										
414			Main skid									
415		Height: mm										
416		Width: mm										
417		Length: mm										
418		Mass: kg										
419												
420		**PAINT AND PAINTING**										
421	16.1	Package: Vendor's/Packager's standard [ ] Special [ ] Details:										
422	16.1	Compressor: Vendor's/Manufacturer's standard [ ] Special [ ] Details:										
423	16.1	Prime mover: Vendor's/Manufacturer's standard [ ] Special [ ] Details:										
424	16.6	Air cooler ducting/structure: Vendor's/Manufacturer's standard [ ] Special [ ] Details:										
425		Heat exchanger: Hot-dipped galvanizing [ ] Special [ ] Details:										
426		Headers: Vendor's/Manufacturer's Standard [ ], Hot-dipped galvanizing [ ], Special [ ] Details:										
427												
428		**INSPECTION AND TESTING**										
429	17.1.3/17.3	Tests performed: Review of quality control [ ], Hydrostatic [ ], Mechanical run [ ], Package leak test [ ]										
430		Other [ ] Details:										
431												
432												
433		**PREPARATION FOR SHIPMENT**										
434	19.4.1	Export crated: YES [ ] NO [ ], Vendor storage: YES [ ] NO [ ] Special shipment preparation: YES [ ] NO [ ]										
435		Details:										
436												
437												

438		**CORROSIVE GASES**				Rev.
439	20.1	Corrosive gases compressed: YES [ ] NO [ ]				
440		Piston rod: precip. hardened stainless steel [ ] or 4140 annealed to HRC22 [ ] with hardening in packing area by chrome plating [ ] or tungsten carbide coating [ ] or NACE MR 0175 equivalent material [ ]				
441		Purged packing case: YES [ ] NO [ ] with sweet natural gas [ ] or inert gas [ ] Type:				
442		Distance piece: Type 1 / 2 / 3 Evacuated [ ] or purged [ ] with sweet gas [ ] or inert gas [ ] Type:				
443						
444		**Materials:**				
445		Process piping:		Valves:		
446		Cold side		Suction block valve		
447		Hot side		Discharge block valve		
448		Bypass		Bypass valve		
449		Vent lines		Blowdown valve		
450		Drain lines		Check valve		
451		Pulsation suppressors:		Utility process valves		
452		Suction		Relief valves		
453		Discharge		Instrumentation:		
454		Separators:		Separator controls		
455		Suction		Pressure switches		
456		Interstage		Temperature switches		
457		Discharge		Tubing		
458		Gas cooler:		Fittings		
459		Header				
460		Tubes				
461						
462		**OFFSHORE AND/OR MARINE ENVIRONMENT**				
463	21.1.3	Corrosive environment YES [ ] NO [ ]				
464	21.2	Cooler headers: Vendor's/Manufacturer's standard paint [ ] or hot-dipped galvanizing [ ] or special [ ]				
465		Details:				
466	21.9.3	Block valves furnished: YES [ ] NO [ ] Suction [ ] and/or discharge [ ], Manual [ ] or pilot operated [ ]				
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A.2 Purchaser's check list

This checklist 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.

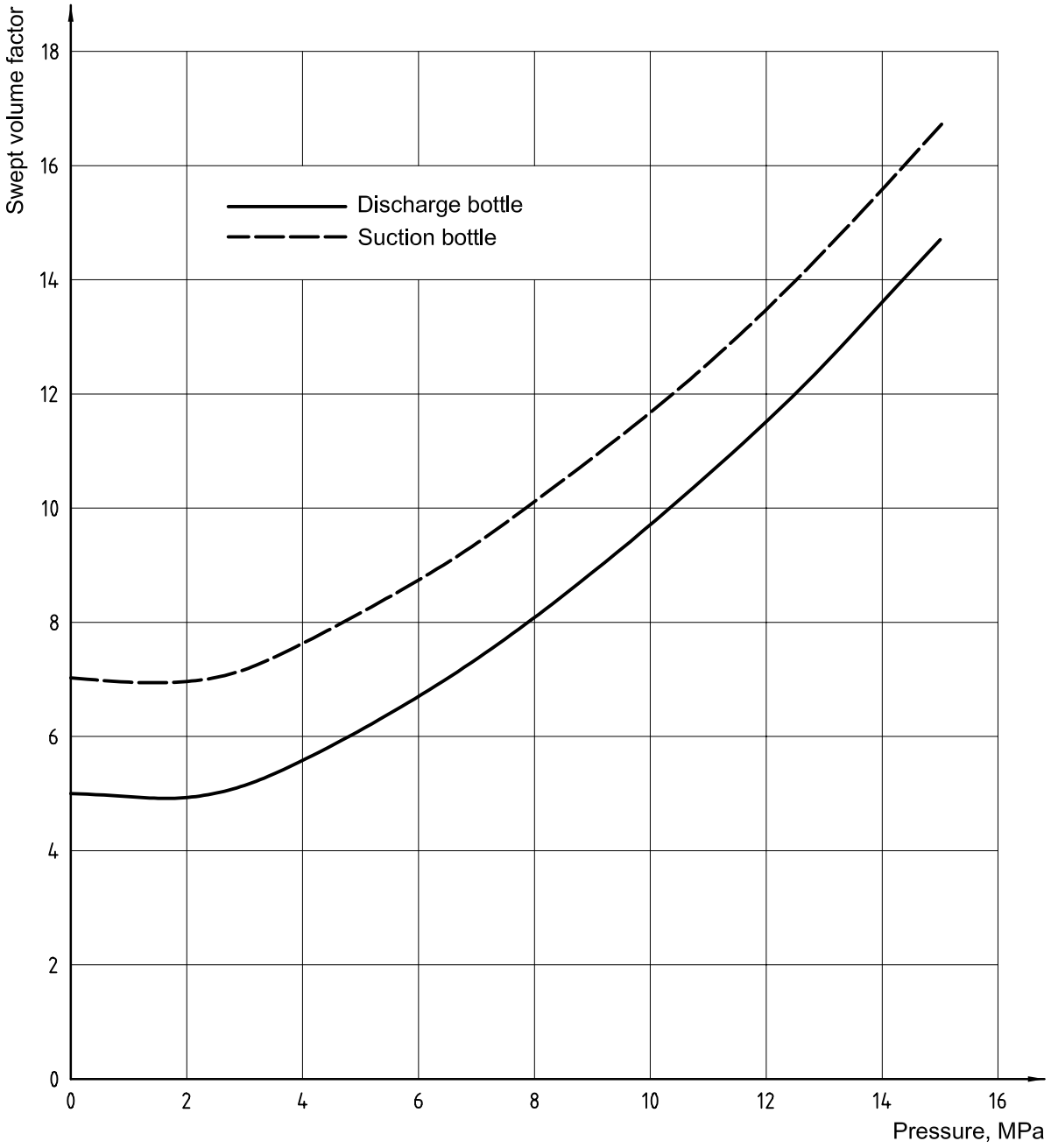
The check list should be used in conjunction with the data sheets (A.1).

Subclause	Question	Answer YES or NO
5.1	Compressor package performance curves required?	
5.3	Pre-fabrication approval or additional drawings specified ?	
5.4	Maximum sound pressure level specified?	
5.5	Electrical Area Classification specified?	
5.6	Site conditions specified?	
	Size limitations?	
5.7	Torsional analysis report required?	
6.1.1	Gas composition, suction and discharge conditions specified?	
6.1.3	Load compressor to gas engine limit?	
6.2	Piston speed/ rotating speed limit?	
6.3	Maximum predicted discharge temperature allowed other than 135 °C?	
6.5.3.2	Cylinder indicator taps required?	
6.7.3	Non-metallic wear bands required?	
6.8.5	Crankcase relief devices required?	
6.9.1.1	Distance pieces types specified?	
6.9.1.2	Distance piece slinger required?	
6.11.6	Crankcase lubricating oil storage tank required?	
6.11.7	Crankcase lubricating oil heater required?	
6.12.1	Special lubricator drive/mounting required?	
6.12.2	Cylinder lubrication oil storage tank required?	
6.14.5	Guard supply by purchaser?	
	Aluminium guard unacceptable?	
7.1	Capacity control variation specified?	
	Capacity control parameter/sensitivity/range specified?	
7.2	Capacity control auto/manual operation specified?	
	Shutdown/depressurization for capacity control allowed?	
7.3	Capacity control by speed variation required?	
7.4.2	Clearance pockets required?	
7.4.3	Valve spacers required?	
7.4.4	Clearance bottles required?	
7.5.2	Start-up bypass required?	
7.5.3	Capacity control bypass required?	
7.6.3	Automatic valve unloading required?	
7.7	Suction pressure reducing control valve required?	
8.1	Type of prime mover specified?	
8.2.3	Alternative to standard ignition system required?	
	Alternative to weather-protected design required?	
8.2.3	Source and minimum/maximum pressure of air or gas available for the starting system specified?	
8.2.3	Start-up battery set required and lowest ambient temperature specified?	
	Charging alternator required?	
8.2.4.6	Air intake pressure drop indicator required?	
8.2.11	Fuel gas composition specified?	
	Known emission level limits specified?	
8.2.11	Engine emissions data required?	
	Engine emission load points specified?	
	Engine emission loading specified?	
8.2.9	Crankcase oil storage tank with level gauge specified?	
8.2.10	Fuel gas filter/ separator required?	
8.2.11	Fuel gas contaminants specified?	
8.3.1	Motor type specified?	
8.3.3	Electrical data specified?	
	Type of enclosure specified?	
	Area classification specified?	
	Type of insulation specified?	
	Service factor specified?	
	Ambient temperature specified?	
	Elevation specified?	

Subclause	Question	Answer YES or NO
	Accessories specified?	
9.3	Sight flow and temperature indicators required?	
9.3.5	Gas aftercooling required?	
9.5.4	Gas cooler design code specified?	
9.6.8	Air flow control type specified?	
9.6.9	Screens and guards required?	
10.1.1	Pressure vessel design code specified?	
10.1.5	ISO or ANSI threaded screen and guards required? connections specified?	
10.2.5	Separator liquid-level gauge required?	
	Separator pressure gauge required?	
10.2.6	Separator class specified?	
	Special separator sizing criteria specified?	
10.3.1	Pulsation control study required?	
10.3.2	Volume bottle required?	
11.1.4	Gas piping and appurtenances required?	
	Gas piping design to allow heat tracing/insulation?	
11.1.5	Review of drawings prior to fabrication required?	
11.9	Pipe material and sizes applicable standard specified?	
11.10	Bolted or welded bonnet valves required?	
	Bolted glands required?	
	Fire safe valves required?	
11.13	Start-up screen removable spool pieces required?	
11.14.2	Stainless steel lubricating oil piping required?	
11.15.1	Coolant piping required?	
11.17.2	Common distance piece vent header required?	
11.17.3	Common distance piece drain header required?	
11.17.4	Common packing vent header required?	
11.18.3	Relief valves required?	
	Additional suction capacity specified?	
11.19.6	Relief valves to venting termination specified?	
	Atmospheric vent with weep holes at lowest point near relief valves required?	
11.19	Blowdown valve required?	
12.2	Power supply characteristics specified?	
12.5	Tropical installation specified?	
13.1.1	Compressor control system signal specified?	
13.2.2	Panels backs required enclosed?	
13.2.3	Panel mounting location specified?	
13.2.4	Panel wiring in conduit or cable tray specified?	
13.2.5	Remote panel wiring in conduit or cable tray specified?	
13.3.1	Tachometer required?	
13.3.2	Temperature indicators required?	
	Temperature indicators mounting specified?	
	Liquid-filled gauges required?	
13.3.4	Pressure indicators required?	
	Pressure indicators mounting specified?	
	Liquid-filled gauges required?	
13.3.5	Fuel gas metre required?	
13.3.6	Shutoff valves required?	
14.1	Shutdown and alarm system function specified?	
14.3	Additional alarms required?	
14.6.3	Automatic blowdown valve operation required?	
15.4	Walkways, stairs and platforms required?	
16.2	Environment for surface preparation specified?	
	Standard or special painting specified?	
16.6	Air-cooled heat exchanger header protection specified?	
17.1.3	Purchaser participation in inspection and testing required?	
17.1.6	Advance notification period specified?	
17.2.1	Type of NDE specified?	
17.3.4.2	Assembled package leak test required?	
17.4.4	Dismantling for inspection after testing required?	
19.3	Shipment and storage requirements specified?	
19.4.1	Type of packing specified?	
21.1.3	Corrosive agents specified?	
21.2.1	Cooler header protection specified?	
21.9.3	Block valves required?	

Annex B
(normative)

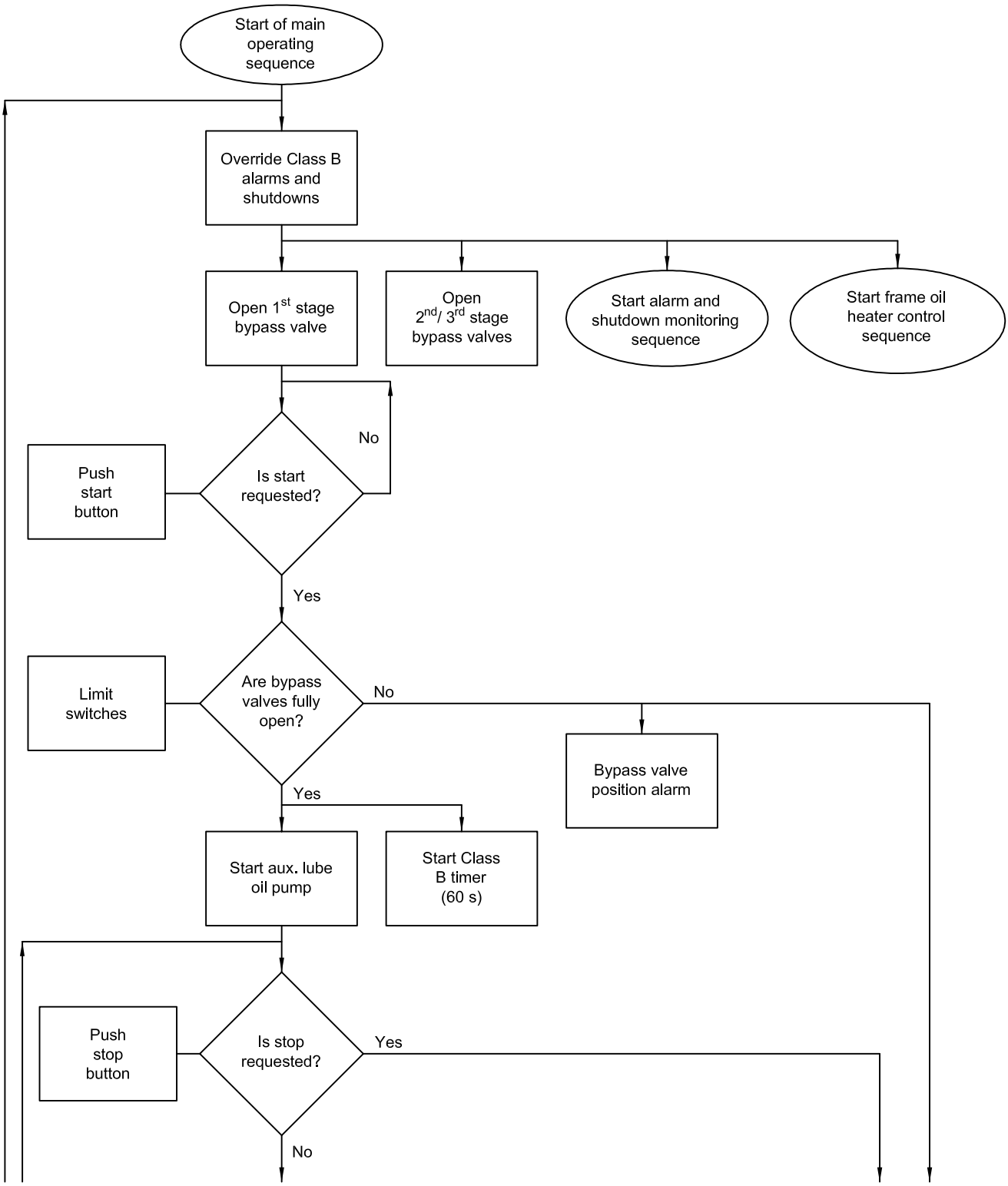
Volume bottle sizing

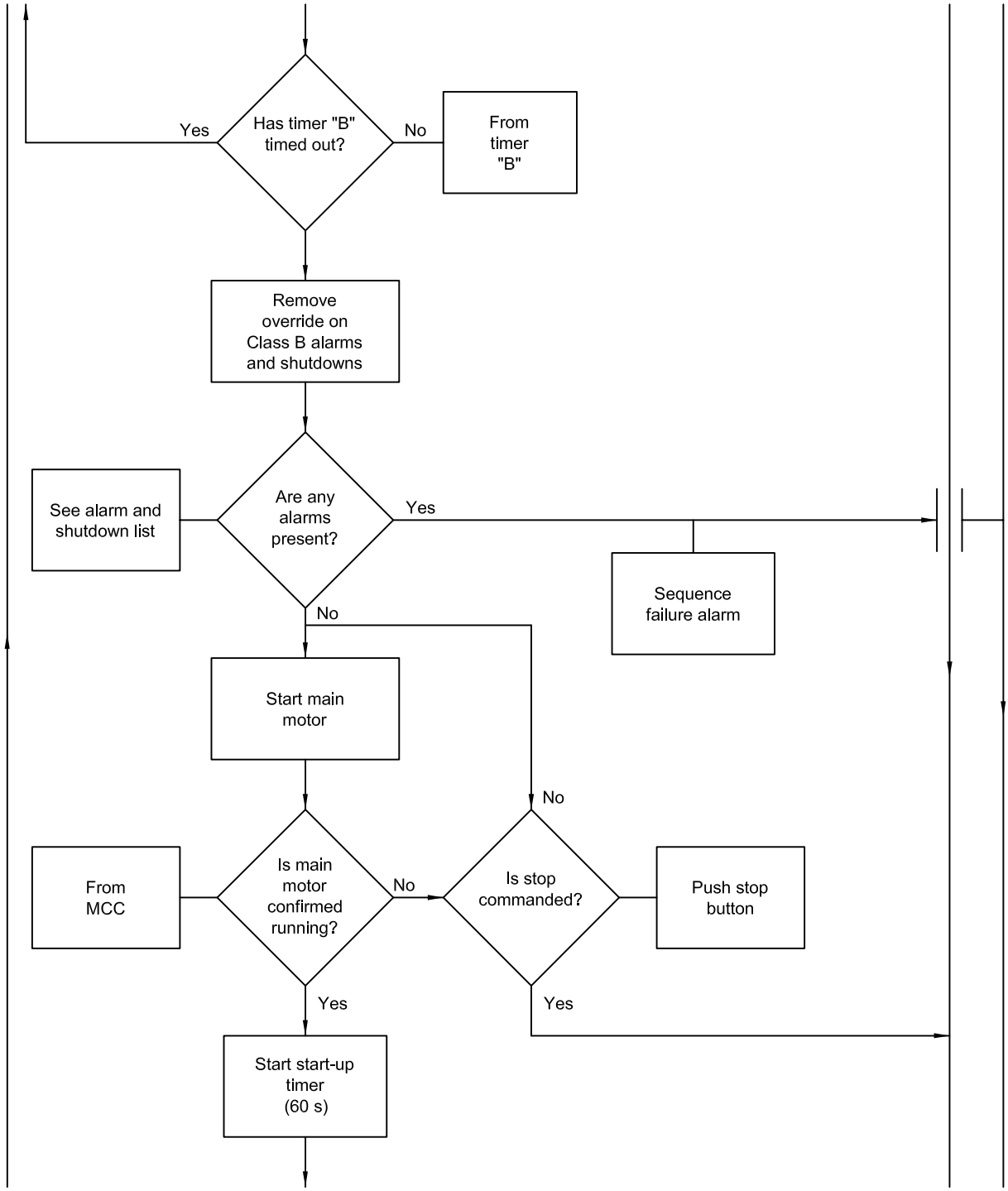


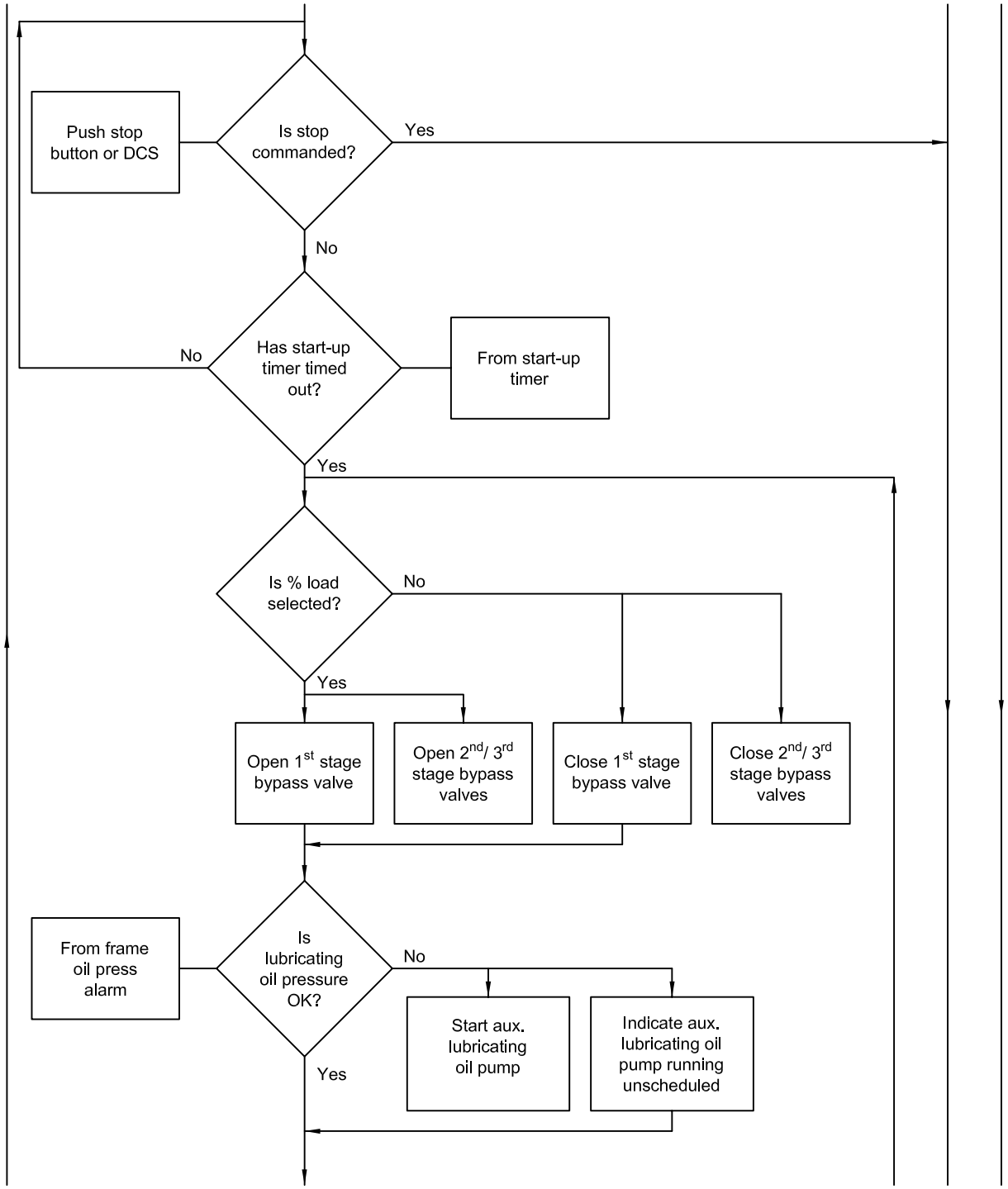
Annex C
(informative)

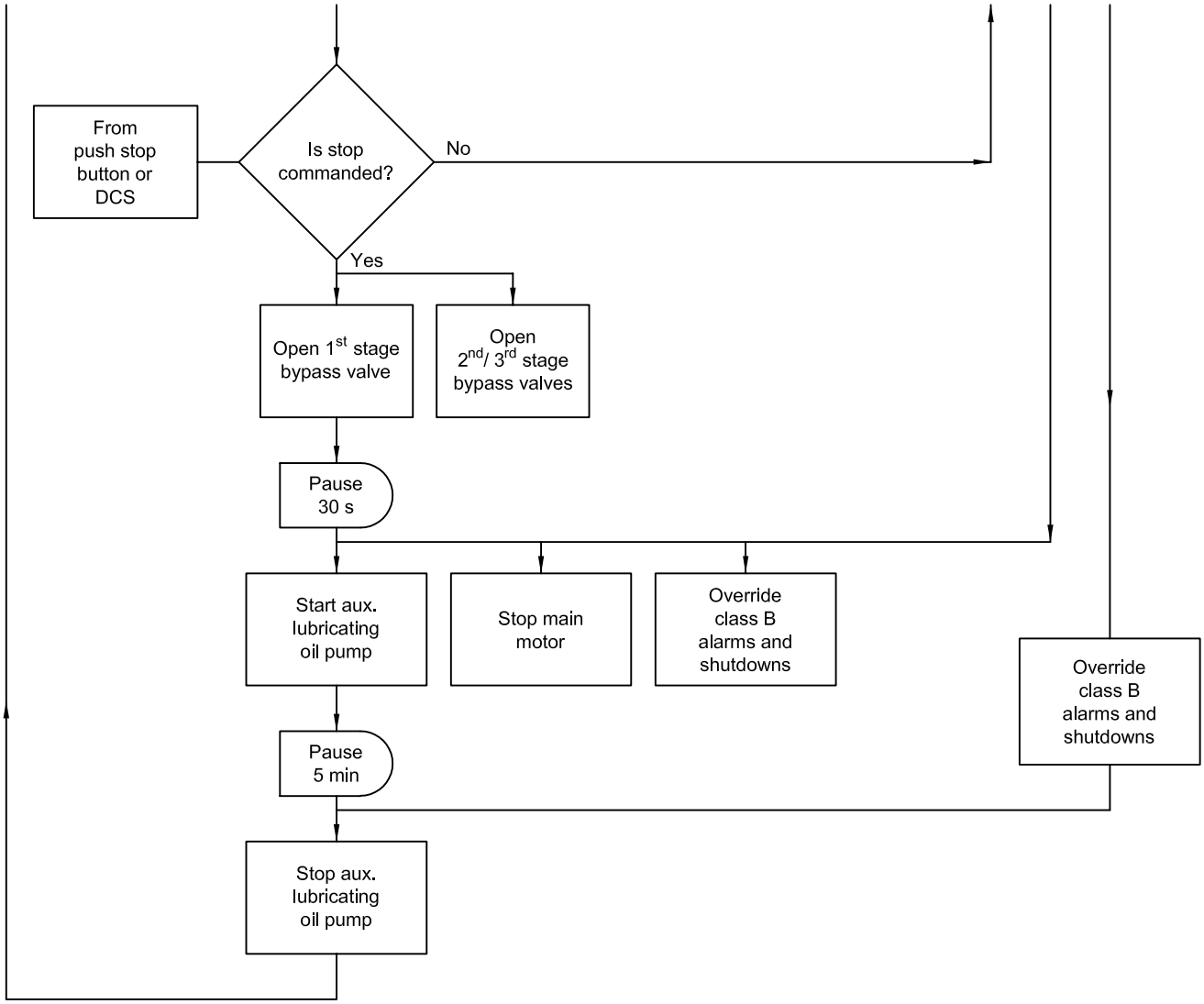
Typical sequence logic diagrams

C.1 Typical start-up flow logic

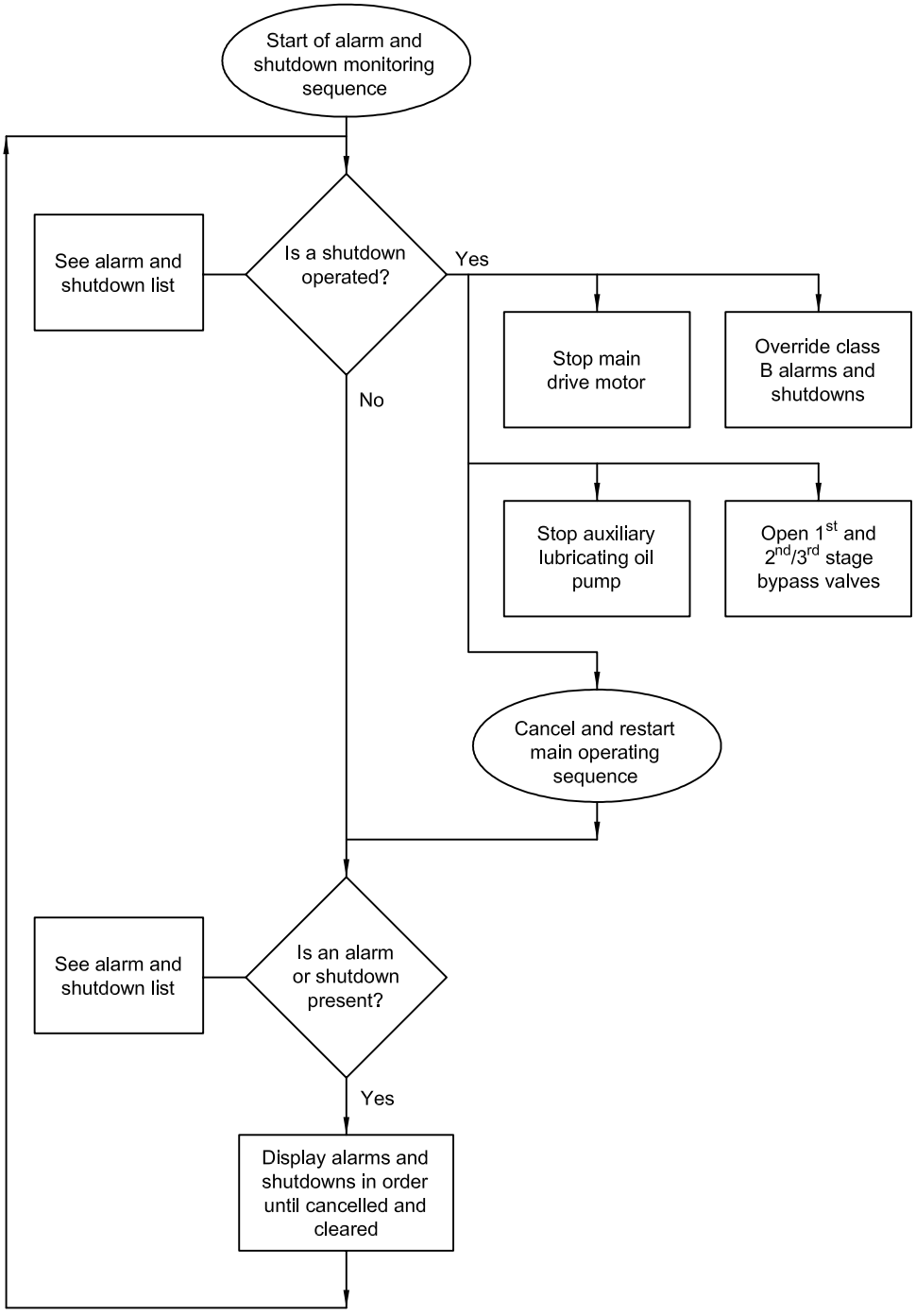








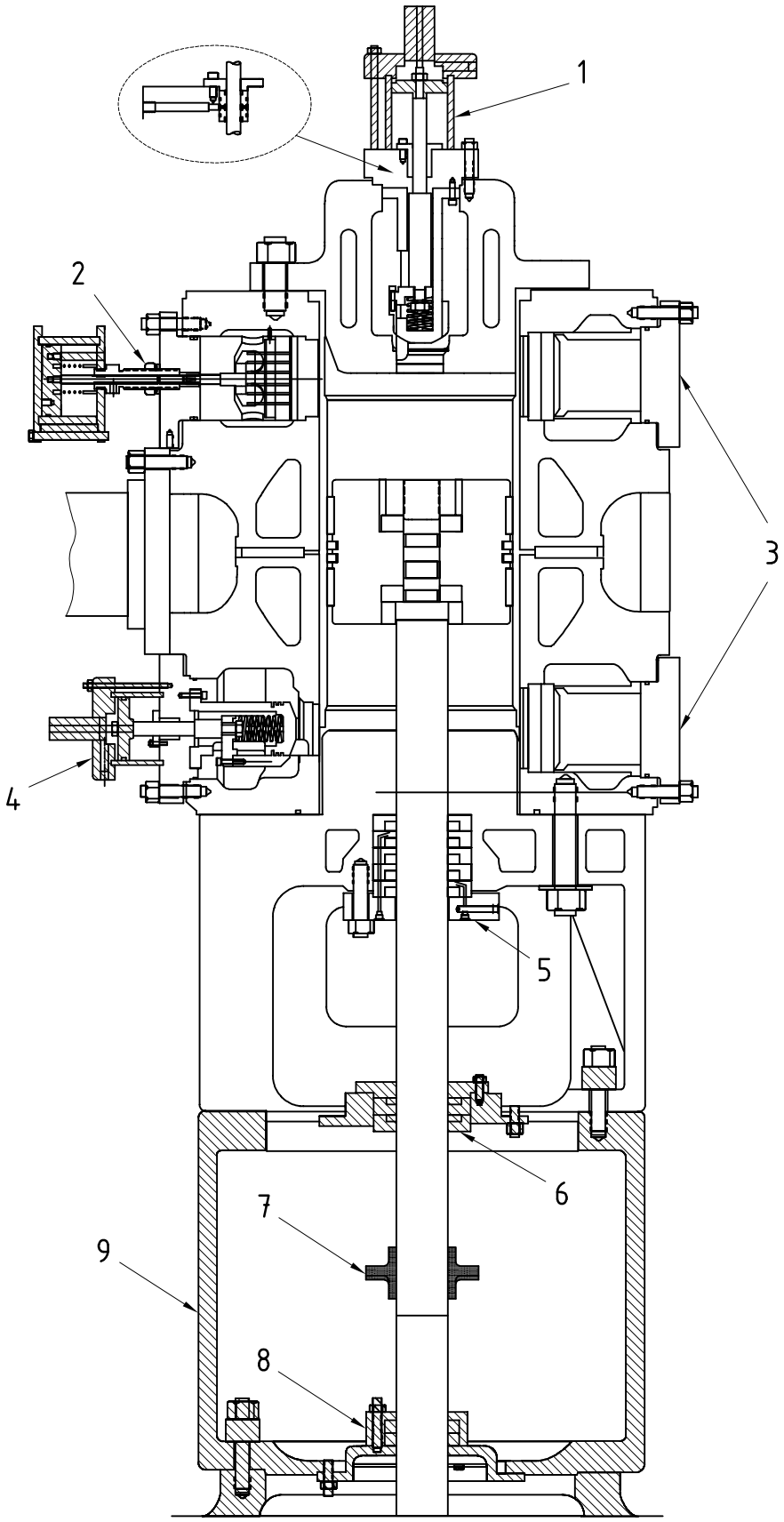
C.2 Typical shutdown flow logic



Annex D
(informative)

Compliance of compressor components with NACE MR 0175

Figure D.1 distinguishes those compressor components which should comply with NACE MR 0175.



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 seal
7 Oil slinger
8 Oil wiper packing
9 Distance piece

NOTE Hatched items are not required to be in accordance with NACE MR 0175.

Figure D.1 — Identification of parts that do not need to be in accordance with NACE MR 0175

Annex E
(informative)

Repairs to grey or nodular iron castings

E.1 General

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 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.

E.2 Repair methods and limitations

E.2.1 In cylinders designed to handle gases having a mean molar mass below 12, no repairs of any type should 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 E.2.2 through E.2.4 may be used for compressor cylinders designed to compress gases with a mean molar mass of 12 or greater.

E.2.2 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 EN 1561 or EN 1563 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 17.3.3.1).

NOTE For the purposes of this provision, ASTM A 278M is equivalent to EN 1561 and ASTM A 395 is equivalent to EN 1563.

E.2.3 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 6.13.2.

E.2.4 Damaged threaded holes in castings may be mechanically repaired by use of thread inserts or bushings.

Bibliography

[1] ISO 3448, *Industrial liquid lubricants — ISO viscosity classification*

[2] ISO 13706, *Petroleum and natural gas industries — Air-cooled heat exchangers*

[3] ISO 8504-3, *Preparation of steel substrates before application of paints and related products — Surface preparation methods — Part 3: Hand- and power-tool cleaning*

[4] ISO/TS 16528, *Boilers and pressure vessels — Registration of Codes and Standards to promote international recognition*

[5] API Std 526, *Flanged steel pressure relief valves*

[6] API 661, *Air cooled heat exchangers*

[7] API Std 670, *Machinery protection systems*

[8] ASME B 31.3, *Process piping*

[9] ASTM A 106, *Standard specification for steamless carbon steel pipe for high-temperature service*

[10] ASTM A 193/A 193M, *Standard specification for alloy-steel and stainless steel bolting materials for high-temperature service*

[11] ASTM A 194/A 194M, *Standard specification for carbon and alloy steel nuts for bolts for high pressure or high temperature service*

[12] ASTM A 216/A 216M, *Standard specification for steel castings, carbon, suitable for fusion welding, for high-temperature service*

[13] ASTM A 269, *Standard specification for seamless and welded austenitic stainless steel tubing for general service*

[14] ASTM A 278/A 278M, *Standard specification for gray iron castings for pressure-containing parts for temperatures up to 350 °C*

[15] ASTM A 307, *Standard specification for carbon steel bolts and studs, 60 000 psi tensile strength*

[16] ASTM A 312/A 312M, *Standard specification for seamless and welded austenitic stainless steel pipes*

[17] ASTM A 395/A 395M, *Standard specification for ferritic ductile iron pressure-retaining castings for use at elevated temperatures*

[18] ASTM A 487/A 487M, *Standard specification for steel castings suitable for pressure service*

[19] ASTM A 703/A 703M, *Standard specification for steel castings, general requirements, for pressure-containing parts*

[20] ASTM E 125, *Standard reference photographs for magnetic particle indications on ferrous castings*

[21] ASTM E 709, *Standard guide for magnetic particle examination*

ICS 75.180.20

Price based on 80 pages