

INTERNATIONAL STANDARD

ISO 10442

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Petroleum, chemical and gas service industries — Packaged, integrally geared centrifugal air compressors

*Industries du pétrole, de la chimie et du gaz naturel — Compresseurs d'air
centrifuges assemblés à multiplicateur intégré*



Reference number
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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 10442 was prepared by Technical Committee ISO/TC 118, *Compressors, pneumatic tools and pneumatic machines*, in collaboration with Technical Committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*, Subcommittee SC 6, *Processing equipment and systems*.

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

Introduction

This International Standard is based on the American Petroleum Institute's API Std 672, second edition, April 1988.

Some of the content of this International Standard is identical or similar to ISO 10439, which covers centrifugal compressors for the petroleum, chemical and gas service industries.

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.

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Petroleum, chemical and gas service industries — Packaged, integrally geared centrifugal air compressors

1 Scope

This International Standard specifies requirements and gives recommendations for the design, materials, fabrication, inspection, testing and preparation for shipment of constant-speed, packaged, integrally geared centrifugal air compressors, including their accessories, for use in the petroleum, chemical and gas service industries. It is also applicable to gas services other than air that are non-hazardous and non-toxic. It is not applicable to machines that develop a pressure rise of less than 35 kPa above atmospheric pressure, which are classed as fans or blowers.

NOTE In this International Standard, where practical, US customary units have been included in brackets for information.

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 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 724, *ISO general-purpose metric screw threads — Basic dimensions*

ISO 965 (all parts), *ISO general purpose metric screw threads — Tolerances*

ISO 3511-1, *Process measurement control functions and instrumentation — Symbolic representation — Part 1: Basic requirements*

ISO 3744, *Acoustics — Determination of sound power levels of noise sources using sound pressure — Engineering method in an essentially free field over a reflecting plane*

ISO 5389, *Turbocompressors — Performance test code*

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

ISO 9614 (both parts), *Acoustics — Determination of sound power levels of noise sources using sound intensity*

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

ISO 10438, (all parts), *Petroleum and natural gas industries — Lubrication, shaft-sealing and control-oil systems and auxiliaries*

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

IEC 60079-10, *Electrical apparatus for explosive gas atmospheres — Part 10, Classification of hazardous areas*

ABMA¹⁾ Std 7, *Shaft and housing fits for metric radial ball and roller bearings (except tapered roller bearings) conforming to basic boundary plan*

ABMA Std 20, *Radial bearings of ball, cylindrical roller and spherical roller types — Metric design*

AGMA²⁾ 2000, *Gear classification and inspection handbook*

AGMA 6011, *Specification for High Speed Helical Gear Units*

API Std 670, *Vibration, axial position, and bearing temperature monitoring systems*

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

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

ASME³⁾ PTC 10, *Performance test code on compressors and exhausters*

ASTM⁴⁾ A275, *Standard test method for magnetic particle examination of steel forgings*

DIN⁵⁾ 3990, *Load calculations for gearings*

NEMA⁶⁾ SM 23, *Steam turbines for mechanical drive service*

TEMA⁷⁾ *Standards of the Tubular Exchanger Manufacturers Association, eight edition*

3 Terms and definitions

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

3.1

bull gear

low-speed rotor of the integral gear

3.2

inlet volume flow

volume flow rate determined at the conditions of pressure, temperature, compressibility and gas composition, including moisture, at the compressor inlet flange

[ISO 10439:2002, definition 3.5]

1) American Bearing Manufacturers Association, 2025 M Street, NW. Suite 800, Washington, DC 20036, USA.

2) American Gear Manufacturers Association, 1500 King St, Suite 201, Alexandria VA 22314, USA.

3) American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017-2392, USA.

4) American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103-11887, USA.

5) Deutsches Institut für Normung E.V., Beuth Verlag GmbH, Burggrafenstrasse 6, D10787, Berlin, Germany.

6) US National Electrical Manufacturers Association, 1300 North 17th Street, Suite 1847, Rosslyn, Virginia 22209, USA.

7) US Tubular Exchanger Manufacturers Association, 25 N Broadway, Tarrytown, New York, NY 10007, USA.

3.3**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

[ISO 10439:2002, definition 3.6]

3.4**maximum allowable working pressure**

maximum continuous pressure for which the manufacturer has designed the equipment (or any part to which the term is referred) when operating at the maximum allowable temperature

[ISO 10439:2002, definition 3.7]

3.5**normal operating point**

point at which usual operation is expected and optimum efficiency is desired

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

[ISO 10439:2002, definition 3.11]

3.6**pinion**

high-speed rotor, or rotors, of the integral gear

3.7**piping design code**

recognized piping standard specified or agreed by the purchaser

EXAMPLE ASME B31.3.

3.8**pressure casing**

composite of all the stationary pressure-containing parts of the unit

3.9**pressure design code**

recognized pressure vessel standard specified or agreed by the purchaser

EXAMPLE ASME Boiler and Pressure Vessel Code, Section VIII.

[ISO 10439:2002, definition 3.14]

3.10**rated discharge pressure**

highest pressure required to meet the specified operating conditions

3.11**rated operating point**

operating point at which the rated volume flow and the rated discharge pressure are attained

3.12**rated operating speed**

speed required to meet the conditions specified by the purchaser for the intended service

NOTE This speed is equal to the maximum continuous speed for constant speed compressor units.

3.13

rated volume flow

inlet volume flow required by the specified operating conditions

3.14

standby service

service condition in which a normally idle or idling piece of equipment is capable of immediate automatic or manual start-up and continuous operation

3.15

trip speed

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

NOTE For constant speed motor drivers, this is the speed corresponding to the synchronous speed of the motor at the maximum frequency of the electrical supply.

[ISO 10439:2002, definition 3.19]

4 Basic design

4.1 General

4.1.1 Purchaser decision or information

A bullet (●) at the beginning of a clause indicates that the purchaser is required to make a decision or provide information. This information should be indicated on the data sheets (see annex A).

4.1.2 Packaged equipment

The vendor shall provide, as a minimum, the following equipment (referred to herein as a package), packaged to meet the specified operating conditions:

- a) centrifugal compressor with integral speed-increasing gear unit;
- b) intercoolers, moisture separators and V-notched gate drain valves;
- c) inlet throttle device (valve or variable-inlet guide vanes);
- d) driver (motor or turbine as specified);
- e) couplings and guards;
- f) "lube"-oil system;
- g) vibration monitoring system;
- h) controls and instrumentation;
- i) instrument and control panel;
- j) common baseplate.

If requested by the purchaser, the layout of the package shall be agreed by the purchaser.

4.1.3 Shipped loose equipment

The vendor shall provide the following accessory equipment, either packaged or included within the scope of supply and shipped loose, to meet the specified operating conditions:

- a) aftercooler with moisture separator and V-notched gate drain valve;
- b) discharge check valve;
- c) discharge blowoff or by-pass valve;
- d) air inlet filter-silencer;
- e) blowoff or by-pass silencer.

4.1.4 Other equipment

- Any other equipment required shall be specified by the purchaser and included in the vendor's proposal.

4.1.5 Standby service

If standby service is specified, the vendor shall provide all necessary controls and protective systems to allow automatic or manual start-up.

4.1.6 Turbine-driven equipment

All turbine-driven equipment shall be designed to run without damage to the trip speed of the driver.

4.1.7 Normal operating point

- The purchaser shall specify the normal operating point on the data sheets.

4.1.8 Environmental conditions

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

4.1.9 Engineering coordination

The vendor shall assume responsibility for the engineering coordination of the package and all accessories included in the scope of the order.

4.1.10 Package arrangement

The arrangement of the package, including piping, coolers, pumps and controls, shall provide adequate clearance areas and safe access for operation and maintenance.

4.1.11 Oil reservoirs and housings

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

4.1.12 Motors and electrical components

- Motors and all other electrical components and installations shall be suitable for the area classification (zone) specified by the purchaser on the data sheets (see annex A), shall meet the requirements of IEC 60079-10 and shall comply with applicable local codes and regulations specified by the purchaser.

4.1.13 External parts

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

4.1.14 Service life

The equipment (including auxiliaries) covered by this International Standard shall be designed and constructed for a minimum service life of twenty years and at least three years of uninterrupted operation.

4.1.15 Performance criteria

The package shall perform on the test stand and on its permanent foundation within the specified acceptance criteria. After installation, the performance of the package shall be the joint responsibility of the purchaser and the vendor having package responsibility.

4.1.16 Sound pressure level

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

4.1.17 Pressure design code

- The pressure design code shall be specified or agreed by the purchaser.

Pressure components shall comply with the pressure design code as well as the requirements of this International Standard.

4.1.18 Heat exchangers

4.1.18.1 Cooling water systems, if required, shall be designed for the conditions specified in Table 1 unless otherwise specified. Provision shall be made for complete venting and draining of the system.

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

4.1.18.2 The coolers shall be of a water-cooled, shell-and-tube type, or a suitable air-cooled type, as specified. A removable-bundle design is required for coolers with more than 0,50 m² of surface, unless otherwise specified. Removable-bundle coolers shall be in accordance with TEMA Class C unless otherwise specified, and shall be constructed with a removable channel cover. Tubes shall not have an outside diameter of less than 16 mm (5/8 in), and the tube wall shall not have a thickness of less than 1,25 mm (0,05 in). Unless otherwise specified, cooler shells, channels and covers shall be of steel, tube sheets shall be of brass, and tubes shall be of inhibited admiralty. U-bend tubes are not permitted. Each cooler shall be sized to accommodate the total cooling load.

Table 1 — Cooling water systems — Design requirements

Velocity over heat exchange surfaces	1,5 m/s to 2,5 m/s (5 ft/s to 8 ft/s)
Maximum allowable gauge working pressure	≥ 500 kPa (75 psi)
Test gauge pressure	≥ 750 kPa (110 psi)
Maximum inlet temperature	30 °C (90 °F)
Maximum temperature rise	20 K (35 °F)
Fouling factor on water side	0,35 m ² ·K/kW (0,002 h·ft ² ·°F/Btu)
Maximum pressure drop	100 kPa (15 psi)
Maximum outlet temperature	50 °C (120 °F)
Minimum temperature rise	10 K (20 °F)
Shell corrosion allowance	3,0 mm (1/8 in)

4.1.18.3 The package shall provide complete venting and draining of the cooling system. This shall include vent and drain connections on both the air/oil and water sides.

4.1.18.4 The vendor shall include in the proposal complete details of any proposed air-cooled cooler.

4.1.19 Special tools and fixtures

4.1.19.1 If special tools and fixtures are required to disassemble, assemble or maintain the unit, they shall be included in the quotation and furnished as part of the initial supply of the package. For multi-unit installations, the requirements for quantities of special tools and fixtures shall be mutually agreed upon by the purchaser and the vendor. These or similar special tools shall be used during shop assembly and post-test disassembly of the equipment.

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

4.1.20 Preliminary review

Many factors (such as piping loads, alignment at operating conditions, supporting structure, handling during shipment, and handling and assembly at the site) may adversely affect site performance. To minimize the influence of these factors, the vendor shall review and comment on the purchaser's piping and foundation drawings, and the vendor's representative shall observe a check of the piping performed by parting the flanges. If specified, the vendor's representative shall be present during the initial alignment check and shall check alignment at the operating temperature.

4.1.21 Spare parts

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

4.1.22 Regulations

- The purchaser and the vendor shall agree on the measures to be taken for compliance with governmental regulations, ordinances or rules that are applicable to the equipment.

4.2 Package

4.2.1 Lubrication — General

4.2.1.1 Unless otherwise specified, bearings and bearing housings shall be arranged for hydrocarbon oil lubrication.

4.2.1.2 A pressurized oil system shall be furnished to supply oil at a suitable pressure or pressures, as applicable, to the following:

- a) the bearings of the integrally geared compressor;
- b) the spray nozzles for the gear teeth;
- c) the bearings of the driver, if specified.

4.2.1.3 If oil is supplied from a common system to two or more machines (such as a compressor, a gear and a motor), the oil's characteristics shall be specified on the data sheets (see annex A) by the purchaser on the basis of mutual agreement with all vendors supplying equipment served by the common oil system.

Unless otherwise specified, pressurized oil systems shall conform to the requirement of ISO 10438.

4.2.2 Pressure lubrication systems

4.2.2.1 The pressure lubrication system shall consist of main and standby positive displacement oil pumps, a supply-and-return system, oil cooler twin full-flow filters and instruments (see Figure 1). The filter assembly shall include a continuous-flow two-way switch valve(s). The requirements of 4.2.2.2 to 4.2.2.10 shall apply.

Unless otherwise specified, oil-containing pressure components shall be steel.

4.2.2.2 The main oil pump shall be driven in accordance with the data sheets (see annex A). The standby pump shall be separately driven and automatically controlled. Both pumps shall be full capacity. The required pump shaft power shall not exceed the driver nameplate rating, with the pump delivering lubricating oil at the relief valve set pressure and with the oil at the maximum viscosity expected at the vendor's minimum allowable oil temperature. This temperature shall be stated in the vendor's proposal. Oil pumps shall be sized so that they can each deliver the required capacity when pumping lubricating oil at the highest temperature and corresponding minimum viscosity.

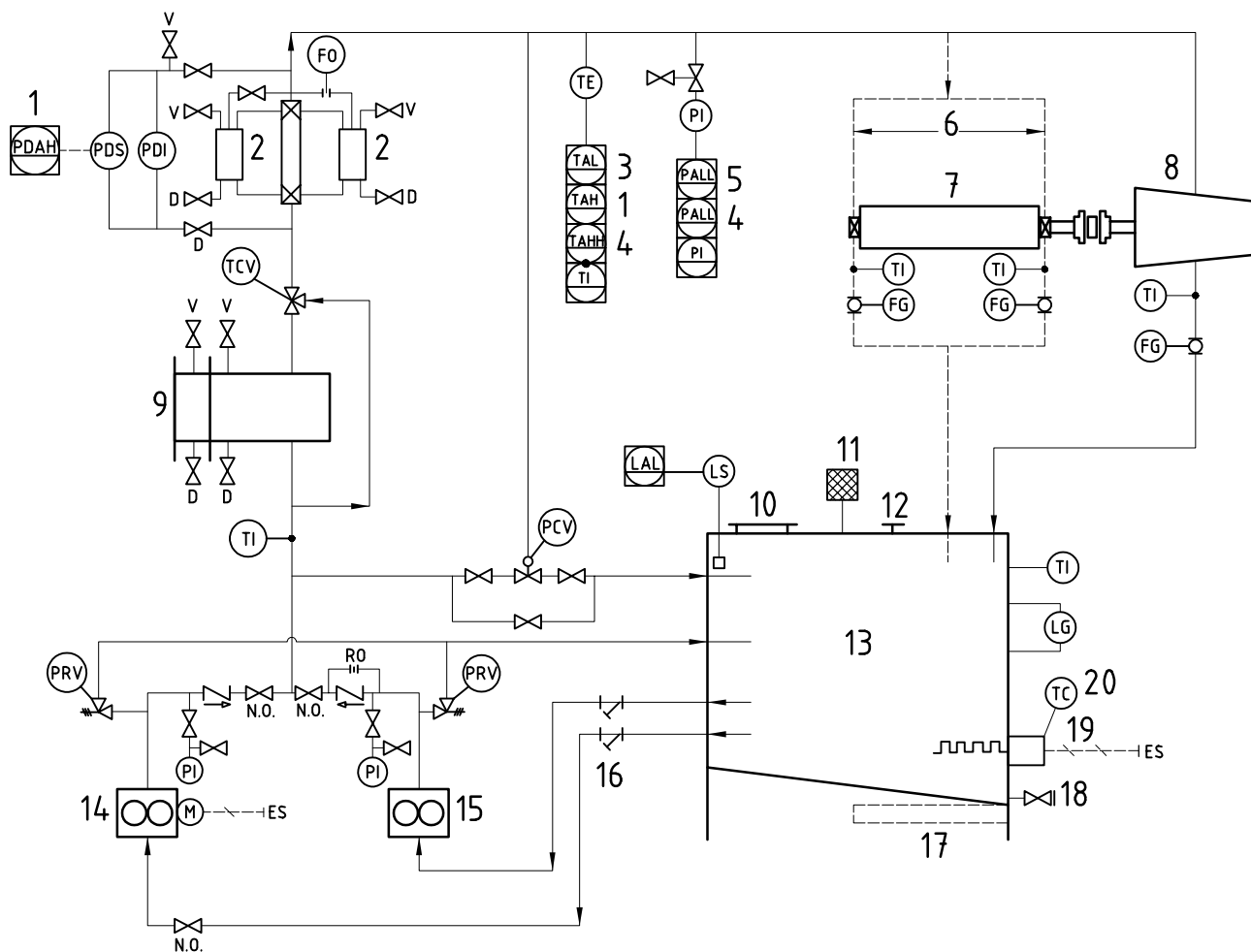
4.2.2.3 Individual external relief valves shall be provided for each positive displacement pump. These valves shall function only to protect the pumps from over pressure. Relief valves for all operating equipment shall meet the limiting relief valve requirements defined in API RP 520, Parts I and II, or local regulation. Relief valves shall be set to operate at not more than the maximum allowable working pressure, but not less than 110 % of the rated pressure or the rated pressure plus 170 kPa (25 psi), whichever is the greater. The vendor shall determine the sizes and set pressures of all relief valves related to the equipment.

4.2.2.4 A separate, direct-acting back-pressure control valve with manual bypass shall be provided and sized to maintain system pressure even when both pumps are operating.

- **4.2.2.5** An oil cooler shall be provided to maintain the oil supply temperature at or below 50 °C (120 °F). A removable-bundle design is required for coolers with more than 0,50 m² of surface, unless otherwise specified. Removable-bundle coolers shall be in accordance with TEMA Class C, unless otherwise specified and shall be constructed with a removable channel cover. To prevent the oil from being contaminated if the cooler fails, the oil-side operating pressure shall be higher than the water-side operating pressure. Coolers shall be equipped with vent and drain connections on their oil and water sides. Internal oil coolers are not permitted. Each cooler may require to be equipped with an automatic oil-side bypass for regulation of the oil temperature.
- **4.2.2.6** Full-flow filters with replaceable elements and filtration of 10 µm (400 micro-inch) nominal or finer shall be supplied. The filters shall be located downstream of the coolers. The filter cases and heads shall be suitable for operation at a pressure of not less than the relief valve setting. Filters that have covers with a mass of more than 16 kg (35 lb) shall have cover lifters (see 4.1.22). Filters shall not be equipped with a relief valve or an automatic bypass. Filter cartridge materials shall be corrosion-resistant. Metal-mesh or sintered-metal filter elements are not permissible. Stacked filter cartridge designs are not permitted. The pressure drop for clean filter elements shall not exceed 15 % of the total allowable dirty pressure drop, or 34 kPa (5 psi) at an operating temperature of 38 °C (100 °F) and normal flow. Cartridges shall have a minimum collapsing differential pressure of 500 kPa (75 psi). The filters shall be equipped with a vent and clean-and-dirty drain connections.

If a specific filter element is desired, the purchaser shall specify the make and model number of the element.

NOTE Particle size implies the diameter of a spherical bead: thus, a 10 μm (400 micro-inch) particle is a sphere with a diameter of 10 μm . Within the element recommended maximum pressure drop, 10 μm (400 micro-inch) nominal implies that the efficiency of the filter on particles that are 10 μm or larger in diameter will be no less than 90 % for the life of the element. Absolute particle ratings are different. An absolute filter rating implies that no particle of the rating size or larger will pass; for example, a filter rating may be 10 μm (400 micro-inch) nominal and 15 μm (600 micro-inch) absolute.



A common suction line may be used, but shall then be sized for the capability of two pumps.

Key

- | | |
|--------------------|---|
| 1 Alarm | 11 Mist eliminator |
| 2 Filter | 12 Fill connection |
| 3 Interlock | 13 Oil reservoir, stainless steel |
| 4 Shutdown | 14 Auxiliary pump, motor driven |
| 5 Alarm/pump start | 15 Main oil pump, motor driven |
| 6 Optional | 16 See the above provisions for suction lines |
| 7 Driver | 17 Steam coil, optional |
| 8 Compressor | 18 Drain valve |
| 9 Oil cooler | 19 Electric heater |
| 10 Manhole | 20 On/off |

Figure 1 — Sketch of minimum requirements for pressure lubrication system

	Flow indicator	D	Drain	PI	Pressure indicator
	Check valve	ES	Electronic supply	PT	Pressure transmitter
	Six-way valve	FG	Flow glass	PAL	Pressure alarm-low
	Block valve	F0	Flow restriction orifice	PALL	Pressure alarm-low, low
	Three way valve	LG	Level gauge	R0	Restriction orifice
	Pressure relief valve	LS	Level switch	TE	Temperature element
	Pressure control valve	LAL	Level alarm-low	TAL	Temperature alarm-low
	Local mount	N.O.	Normally open	TAH	Temperature alarm-high
	Panel mount	PCV	Pressure control valve	TI	Temperature indicator
	Shared display	PRV	Pressure relief valve	TC	Temperature controller
	Strainer	PDI	Pressure differential indicator	TCV	Temperature control valve
		PDS	Pressure differential switch	V	Vent
		PDAH	Pressure differential alarm-high		

NOTE For abbreviations, see ISO 3511-1.

Figure 1 (continued)

- **4.2.2.7** If specified, a removable steam-heating element, external to the oil reservoir, or a thermostatically controlled electric immersion heater with a sheath of austenitic stainless steel shall be provided for heating the charge capacity of oil before start-up in cold weather. The heating device shall have sufficient capacity to heat the oil in the reservoir from the specified minimum site ambient temperature to the manufacturer's required start-up temperature within 12 h. If an electric immersion heater is used, it shall have a maximum watt density of 2,4 W/cm².

4.2.2.8 Unless otherwise specified, an austenitic stainless steel oil reservoir shall be supplied, having the following characteristics and appendages:

- the capacity to avoid frequent refilling, to provide adequate allowance for system rundown, and to settle moisture and foreign matter adequately;
- provisions to eliminate air and to minimize flotation of foreign matter to pump suction;
- separate fill and vent connections, a level indicator with an armoured gauge glass and a breather suitable for outdoor use;
- a sloped bottom and connections for complete drainage;
- cleanout openings large enough to provide access for thorough cleaning;
- an interior that has been descaled and protected from rust by the manufacturer's standard procedure, subject to the purchaser's approval (permanent surface coatings shall not be applied without the purchaser's specific approval);
- a retention time of at least 3 min, based on normal flow and total volume below the normal operating level.

4.2.2.9 The vendor shall state in the instruction manual the required amount, specifications and supply temperature, and the pressure ranges for the lubrication oil.

4.2.2.10 The oil system drain lines (as well as the reservoir vent or mist eliminator, or both) shall be large enough to prevent emission of visible oil vapours above the vent. They shall also be large enough to provide adequate drainage with the airflow from the sealing system into the oil system, with seal clearances that are at least twice the design clearance.

4.2.3 Piping

4.2.3.1 General

- **4.2.3.1.1** Piping design and joint fabrication, examination and inspection shall be in accordance with the piping design code.

4.2.3.1.2 Auxiliary systems in the following services shall be considered as piping systems:

- a) instrument and control air;
- b) lubricating oil;
- c) cooling water;
- d) sealing fluid;
- e) drains;
- f) interstage piping.

NOTE For casing connections, see 4.3.5.

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

4.2.3.1.4 The vendor shall furnish all piping systems, including mounted appurtenances, located within the confines of the package. Each piping system requiring external connections shall terminate with flanged single-supply and single-return connections at the edge of the package. It is not necessary to provide flanged connections for instrument tubing systems. The purchaser shall furnish only interconnecting piping between equipment groupings and off-base facilities.

4.2.3.1.5 The design of piping systems shall achieve the following:

- a) proper support and protection to prevent damage due to vibration from shipment, operation or maintenance;
- b) proper flexibility and normal accessibility for operation, maintenance and thorough cleaning;
- c) installation in a neat and orderly arrangement adapted to the contour of the package without obstruction of access openings;
- d) elimination of air pockets;
- e) complete drainage through low points without disassembly of piping.

4.2.3.1.6 Piping should be fabricated by bending and welding to minimize the use of flanges and fittings. Welded flanges are permitted only at equipment connections, at the edge of any base, and for ease of maintenance. Threaded connections shall be kept to a minimum. Pipe bushing shall not be used.

4.2.3.1.7 Pipe threads shall be taper threads in accordance with the piping design code. Flanges shall be in accordance with the piping design code. Slip-on flanges are permitted only with the purchaser's specific approval. For socket-welded construction, a 1,5 mm (1/8 in) gap shall be left between the pipe end and the bottom of the socket.

4.2.3.1.8 Threaded connections for oil service shall be seal-welded; however, seal welding is not permitted on cast iron equipment, on instruments, or where disassembly is required for maintenance. Seal-welded joints shall be made in accordance with the piping design code.

4.2.3.1.9 Connections, pipe, valves and fittings of nominal pipe size DN 32 (NPS 1¼), DN 65 (NPS 2½), DN 90 (NPS 3½) or DN 125 (NPS 5) shall not be used.

4.2.3.1.10 Seamless carbon steel piping shall be in accordance with the piping design code. Stainless steel piping shall be seamless or electric-fusion welded in accordance with the piping design code. The schedules shall be in accordance with Table 2.

4.2.3.1.11 Where space does not permit the use of nominal pipe sizes DN 15 (NPS $\frac{1}{2}$), DN 20 (NPS $\frac{3}{4}$) and DN 25 (NPS 1), seamless carbon steel or stainless steel tubing may be furnished. Except for the lube oil system, steel fittings may be furnished with stainless steel tubing. Tubing thickness shall meet the requirements of Table 3. Equivalent materials and the make and model of fittings shall be subject to the purchaser's approval.

4.2.3.1.12 The minimum size of any connection shall be DN 6 (NPS $\frac{1}{4}$).

4.2.3.1.13 Piping systems furnished by the vendor shall be fabricated, installed in the shop, and properly supported. Bolt holes for flanged connections shall straddle lines parallel to the main horizontal or vertical centreline of the equipment.

Table 2 — Minimum piping schedules

Material	Nominal pipe size mm	Minimum schedule
Carbon steel	DN 20 and smaller	160
Carbon steel	DN 25 and DN 40	80
Carbon steel	DN 50 and larger	40
Stainless steel	DN 40 and smaller	40S
Stainless steel	DN 50 and larger	10S

Table 3 — Minimum tubing wall thickness

Nominal tubing size mm	Minimum wall thickness mm
12,5	1,65
20	2,41
25	2,76

4.2.3.2 Oil piping

4.2.3.2.1 Oil-supply piping, tubing and fittings (excluding slip-on flanges) shall be of stainless steel.

4.2.3.2.2 Oil drains shall be sized to run no more than half full when flowing at a velocity of 0,3 m/s and shall be arranged to ensure good drainage (recognizing the possibility of foaming conditions). Horizontal runs shall slope continuously at least 40 mm/m toward the reservoir. If possible, laterals (not more than one in any transverse plane) should enter drain headers at 45° angles in the direction of the flow.

4.2.3.2.3 Non-consumable backup rings and sleeve-type joints shall not be used. Pressure piping down-stream of oil filters shall be free from internal obstructions that could accumulate dirt. Pipe joints downstream of the oil filter (filter to bearing housing) shall be butt-welded. Piping joints in return lines and upstream of the filter (reservoir to filter) may be socket-welded. Threaded connections shall be used for instrument connections and where tubing is used.

4.2.3.3 Instrument piping

Unless otherwise specified, instrument and control-air tubing shall be of austenitic stainless steel. Tubing thickness shall meet the requirements of Table 4. For instrument piping and valving details, see 4.2.5.4.

4.2.4 Baseplate

4.2.4.1 The equipment feet and mating baseplate shall have machined surfaces. The baseplate mating surfaces shall be machined after completion of welding.

4.2.4.2 Machinery supports shall be designed to limit a change of alignment caused by worst combination of pressure, torque, and allowable piping stress to 50 µm (0,002 in) at the coupling flange (see 4.3.4.2 and 4.3.6).

4.2.4.3 The baseplate shall not be drilled for equipment to be mounted by others. A baseplate intended for installation on concrete shall be supplied with levelling screws. The pads on the bottom of the baseplate, which are to be grouted, shall have 50 mm (2 in) radiused outside corners (in the plan view).

4.2.4.4 Anchor bolt holes shall be drilled perpendicular to the mounting surfaces and spot-faced appropriately in relation to the hole.

4.2.4.5 If specified, anchor bolts shall be furnished by the purchaser instead of the vendor.

4.2.4.6 Anchor bolts shall not be used to fasten machinery to the baseplate.

4.2.4.7 All fasteners and shims for attaching and levelling equipment on the baseplate shall be supplied by the vendor. Shim packs shall be of austenitic stainless steel and between 3 mm to 6 mm (1/8 in to 1/4 in) thick between the equipment feet and the mounting plates. All shim packs shall straddle hold-down bolts and jack screws.

Table 4 — Minimum tubing wall thickness (instrument and control air)

Nominal tubing size mm	Minimum wall thickness mm
6	0,89
10	0,89
12	1,65

4.2.4.8 The compressor shall be doweled, and the feet of the driver shall be drilled with pilot holes that are accessible for use in final doweling.

4.2.4.9 The baseplate shall be furnished with horizontal and vertical jackscrews for driver alignment. Horizontal jackscrews shall be the same size as, or larger than, vertical jackscrews.

- **4.2.4.10** If specified, the baseplate shall be suitable for column mounting (i.e., of sufficient rigidity to be supported at specified points) without continuous grouting under structural members. The baseplate design shall be mutually agreed upon by the purchaser and the vendor.

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

- **4.2.4.12** The bottom of the baseplate between structural members shall be open. If the baseplate is installed on a concrete foundation, accessibility shall be provided for grouting under all load-carrying structural members. The mounting pads on the bottom of the baseplate shall be in one plane, in order to permit use of a single-level foundation. If specified, sub-sole plates shall be provided by the vendor.

4.2.5 Controls and instrumentation

4.2.5.1 General

4.2.5.1.1 The purchaser shall outline in the inquiry the control philosophy to be followed.

4.2.5.1.2 Unless otherwise specified, a microprocessor or a programmable logical controller-(PLC-) based control and instrumentation system, suitable for outdoor installation, shall be provided.

4.2.5.1.3 Signals shall be generated from transmitters, transducers or switches, referred to in this International Standard as devices.

4.2.5.2 Control system

- 4.2.5.2.1 The purchaser shall specify which of the following compressor capacity control modes shall be furnished.

- a) Capacity modulation (inlet throttle device or variable-inlet guide vanes or variable diffuser). This mode is used when constant discharge pressure to surge is required and system air demand is relatively constant.
- b) Two-step (load-unload or intermittent) operation. This mode is used when large variations in system air demand are expected and constant pressure is not mandatory.
- c) Automatic dual control-capacity modulation plus intermittent mode control for smaller air demands.
- d) Automatic start and automatic stop control.
- e) Constant-discharge pressure base mode (blowoff to atmosphere or by-pass without inlet throttling).

4.2.5.2.2 When more than one mode is specified, a change to any mode shall be accomplished by a suitable device. If two compressors are to be operated in parallel, the control system shall include the necessary controls to permit operation of both compressors on the same control mode, or one on a separate control mode.

4.2.5.2.3 A surge-recognition and protection system shall be furnished to control the discharge blowoff or by-pass valve.

4.2.5.2.4 An automatic driver-overload control system shall be included to permit continuous operation at minimum ambient air and water temperatures without exceeding the nameplate rating (excluding the service factor, if any).

- 4.2.5.2.5 If specified, a manual override shall be provided to allow manual operation of the inlet capacity control device and discharge blowoff or by-pass valve.

4.2.5.2.6 To facilitate start-up of a motor-driven package, automatic unloading of the compressor by closing the inlet capacity control device and opening the discharge blowoff or by-pass valve shall be provided by the vendor. An auxiliary source of control air or nitrogen may be required for initial start-up.

4.2.5.2.7 The vendor's proposal shall fully describe the design and operation of the control system, including surge recognition and protection and the electric power and operating air requirements.

4.2.5.3 Instrument and control panel

4.2.5.3.1 A panel from which start-up can be accomplished shall be provided, which shall include the following unless otherwise specified:

- a) components for control systems (4.2.5.2.1), exclusive of the inlet capacity control device or variable-inlet guide valve and discharge blowoff or bypass valve;

- b) control mode device;
- c) manual override valve device;
- d) instrument air gauges;
- e) solenoid valves if applicable;
- f) annunciator display unit;
- g) switches, transmitters and control devices;
- h) alarms and shutdowns;
- i) lamp test push-button;
- j) permissible start contact with separate pilot-light indication;
- k) pilot light on the incoming side of each supply circuit;
- l) switches for starting and stopping the package from the control panel;
- m) vibration monitor and readout instrument.

The instruments on the exterior of the panel shall be clearly visible and legible from the driver control point.

- **4.2.5.3.2** The panel shall be fully enclosed. The purchaser shall specify the area classification and the type of enclosure required on the data sheets as well as the location of the panel (on the base or remote) and the necessity of weather hood and lighting etc. If purge connections are used, they shall be provided with a rotameter-type flow indicator.

4.2.5.3.3 If the panel is installed on the compressor baseplate, the panel shall be completely piped and wired to other components of the package as applicable, requiring only connection to the purchaser's external piping and wiring circuits. Wiring external to the panel shall be installed in metal conduits or armoured cabling. Attention shall be paid to segregation and routing of cables to avoid electrical signal interference. All leads and posts on terminal strips, switches and instruments shall be tagged for identification. For off-base mounted panels, wiring shall be to rack-mounted junction boxes.

4.2.5.4 Instrumentation

4.2.5.4.1 Thermometers and temperature gauges

4.2.5.4.1.1 Dial-type temperature gauges shall be heavy duty and corrosion-resistant. They shall be at least 100 mm in diameter and bimetallic or liquid-filled.

NOTE Black printing on a white background is standard for gauges.

4.2.5.4.1.2 The sensing elements of thermometers and temperature gauges shall be in the flowing fluid.

4.2.5.4.1.3 Thermometers and temperature gauges shall be furnished with austenitic stainless steel separable-flange-type, standard-threaded thermowells at least 19 mm ($\frac{3}{4}$ in) in diameter. Thermometers and temperature gauges that are in contact with flammable or toxic fluids or that are located in pressurized or flooded lines shall be furnished with austenitic stainless steel separable-flange-type solid-bar thermowells.

4.2.5.4.2 Pressure gauges

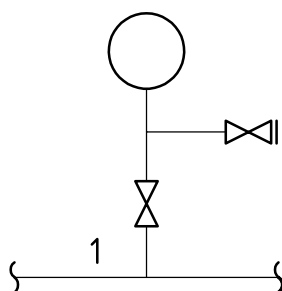
- Pressure gauges (not including built-in instrument air gauges), unless otherwise specified, shall be furnished with stainless steel bourdon tubes and stainless steel movements, 100 mm ($4\frac{1}{2}$ in) dials [160 mm dials for the range

over 5 500 kPa (800 psi)] and DN 16 (NPS 5/8) pipe thread male alloy steel connections. If specified, oil filled gauges shall be furnished in locations subject to vibration. Gauges ranges should be selected so that the normal operating pressure is at the middle of the gauge's range. In no case, however, shall the maximum reading on the dial be less than the applicable relief valve setting plus 10 %. Each pressure gauge shall be provided with a device, such as a disk insert or blow-out back, designed to relieve excess case pressure.

NOTE 1 Black printing on a white background is standard for gauges.

If approved by the purchaser, a combination block-and-bleed gauge valve may be substituted for individual block and vent-bleed valves (see Figure 2). Block and vent-bleed valves shall be omitted for all instruments in shutdown service.

NOTE 2 See Figure 1 for identification of symbols.



Key

1 Service line

Figure 2 — Instrument piping and valving details

4.2.5.4.3 Solenoid valves

4.2.5.4.3.1 Direct solenoid-operated valves shall be used only in clean, dry, instrument-air service, shall have Class F insulation or better, and shall have a continuous service rating.

4.2.5.4.3.2 All instruments and controls other than shutdown sensing devices shall be installed with sufficient valving to permit their replacement while the system is in operation.

4.2.5.4.3.3 Bleeder valves are required between instruments and their isolating valves, except in instrument-air service, where combinations of isolating and bleeder valves may be used.

4.2.5.5 Alarms and shutdowns

4.2.5.5.1 General

4.2.5.5.1.1 Control devices and a first-out annunciator shall be furnished in accordance with Table 5. Alarm and shutdown settings shall be indicated in the vendor's data. In case of use of sealing devices for gasses other than air, other control devices shall be considered.

Table 5 — Conditions requiring alarms and shutdowns

Condition	Alarm	Shutdown
High vibration-compressor	X	X
High last-stage inlet air temperature	X	X
Low lube oil pressure	X	X
High oil supply temperature	X	X
High oil cooler/oil filter differential pressure	X	
Low sealing system pressure	X	d
Operation of standby oil pump	X	
Low lube oil level in reservoir ^a	X	
High inlet-air filter differential pressure	X	
High vibration of driver ^b	X	X
Panel purge ^c	X	X
Surge recognition	X	
Permissive start contact ^b		
^a With oil-heater cut-out. ^b If specified. ^c If required. ^d Separate pilot-light indication.		

- **4.2.5.5.1.2** The sequence of alarm and shutdown annunciation shall be as follows, unless otherwise specified by the purchaser.

- The alarm level shall always precede shutdown level.
- The alarm and shutdown indications shall consist of flashing lights and the sounding of a horn or buzzer.
- Acknowledgement of the alarm or shutdown condition, or both, shall be accomplished by operating a common silencing push-button suitably located on the instrument and control panel.
- When the annunciation is acknowledged, the horn or buzzer shall be silenced and the light shall remain lit. The horn or buzzer that has been silenced shall still be capable of being sounded by a subsequent alarm from another station.
- When field contacts return to normal, the annunciation lights and system shall return to the normal conditions after being reset.
- One abnormal condition may cause a sequence of events resulting in several annunciation signals at almost the same time. With the first-out annunciator, the initiating abnormal condition shall be indicated by a flashing light, and subsequent abnormal conditions shall be indicated by flashing lights until the upset is acknowledged.

4.2.5.5.1.3 Connections shall be provided for a common remote alarm and a common remote shutdown indication when any of the switches or locally displayed compressor alarms or shutdowns operate.

4.2.5.5.1.4 Alarm and trip devices shall be arranged to permit testing of the control circuit, including, when possible, the actuating element, without interfering with normal operation of the equipment. The vendor shall provide a clearly visible light on the panel to indicate when trip circuits are in a test bypass mode. Unless otherwise

specified, shutdown systems shall be provided with switches or another suitable means to permit testing without shutting down the unit.

4.2.5.5.1.5 Low-pressure alarms shall be equipped with a valved bleed or vent connection to allow controlled depressurizing so that the operator can note the alarm set pressure on the associated pressure gauge. High-pressure alarms shall be equipped with valved test connections so that a portable test pump can be used to raise the pressure.

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

4.2.5.5.2 Alarm and shutdown devices

- **4.2.5.5.2.1** Each alarm device and each shutdown device shall be furnished in a separate housing located to facilitate inspection and maintenance, unless otherwise specified. Hermetically sealed, single-pole, double-throw switches with a minimum capacity of 5 A at 120 V AC shall be used. Mercury switches shall not be used. For shutdown functions, separate sensors and transmitters/transducers may be used. For control and alarm functions, combined sensors and transmitters/transducers may be used.

4.2.5.5.2.2 Unless otherwise specified, electric device that open (de-energize) to alarm and to trip shall be furnished by the vendor.

4.2.5.5.2.3 Alarm and shutdown device settings shall not be adjustable from outside the housing.

4.2.5.5.2.4 Pressure-sensing elements shall be of austenitic stainless steel.

4.2.5.5.2.5 Particular attention is called to the requirements of 4.1.12 concerning the characteristics of housings for arcing-type switches outlined in the applicable codes.

4.2.5.6 Electrical systems

- **4.2.5.6.1** The characteristics of electrical power supplies for motors, heaters and instrumentation shall be specified by the purchaser. A pilot light shall be provided on the incoming side of each supply circuit to indicate that the circuit is energized. The pilot light shall be installed on the control panels.

4.2.5.6.2 Power and control wiring within the confines of the baseplate shall be resistant to heat, moisture and abrasion. Stranded conductors shall be used within the confines of the baseplate and in other areas subject to vibration. Measurement and remote control panel wiring may be solid-conductor. Where rubber insulation is used, a neoprene (or equivalent) or high-temperature thermoplastic sheath shall be provided for insulation protection. Wiring shall be suitable for environmental temperatures.

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

4.2.5.6.4 To facilitate maintenance, liberal clearances shall be provided for all energized parts (such as terminal blocks and relays) on equipment. The clearances required for 600 V service shall also be provided for lower voltages. To guard against accidental contact, enclosures shall be provided for all energized parts.

- **4.2.5.6.5** Electrical materials, including insulation, shall be corrosion-resistant and non-hydroscopic as far as possible. If specified for a tropical location, materials shall be given the following treatments:

- parts (such as coils and windings) shall be protected from fungus attack;
- unpainted surfaces shall be protected from corrosion by plating or another suitable coating.

4.2.5.6.6 Control, instrumentation and power wiring (including thermocouple leads) within the limits of the baseplate shall be installed, properly bracketed to minimize vibration and isolated or shielded to prevent