

INTERNATIONAL STANDARD

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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
ISO 10442:2002(E)

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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**pipng 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.

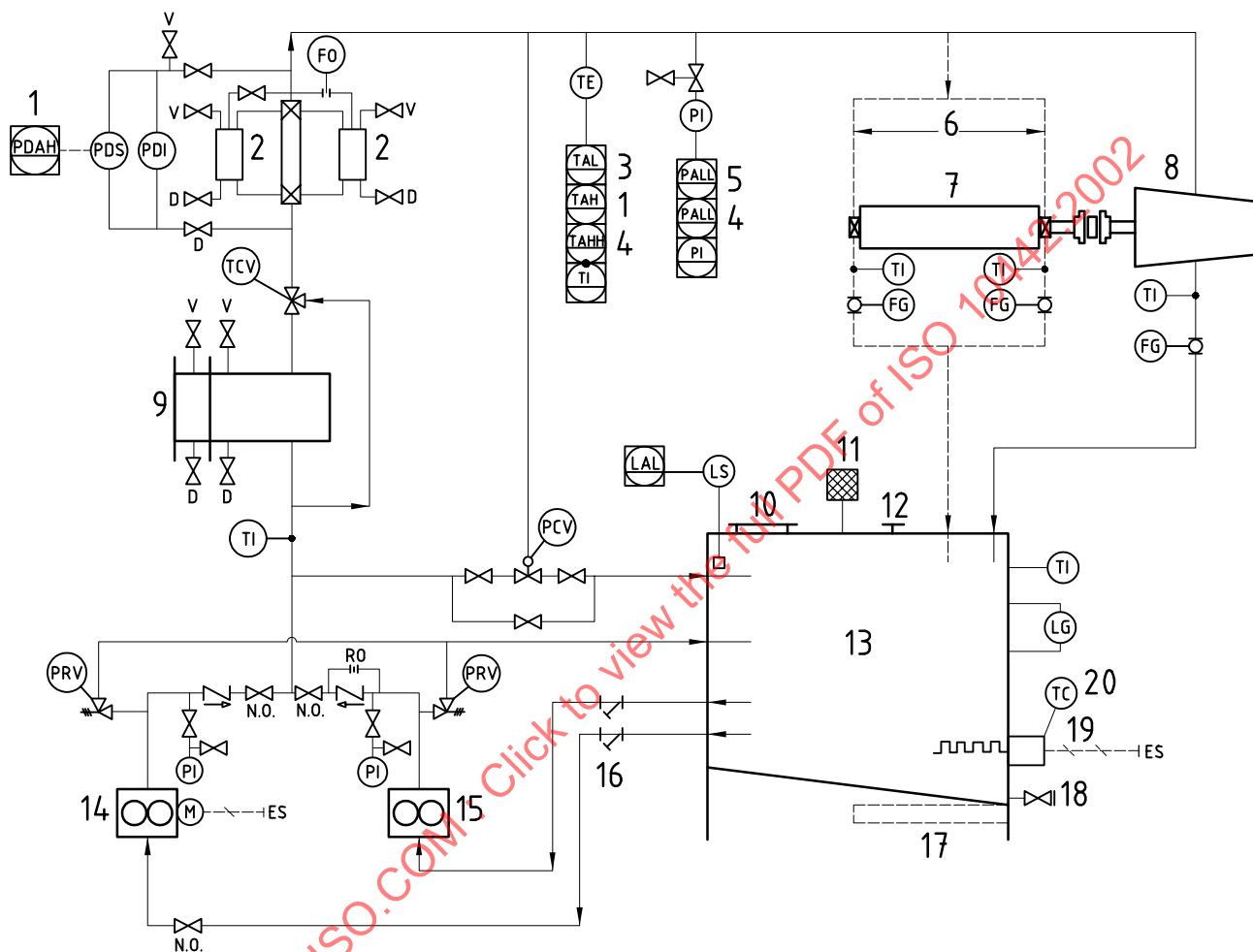
4.2.2.3 Individual external relief valves shall be provided for each positive displacement pump. These valves shall function only to protect the pumps from over pressure. Relief valves for all operating equipment shall meet the limiting relief valve requirements defined in API RP 520, Parts I and II, 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

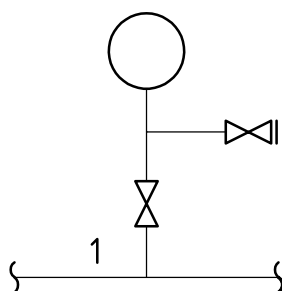
- Pressure gauges (not including built-in instrument air gauges), unless otherwise specified, shall be furnished with stainless steel bourdon tubes and stainless steel movements, 100 mm ($4\frac{1}{2}$ in) dials [160 mm dials for the range

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-constructor. 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

interference between voltage levels. If thermocouple heads are to be exposed to temperatures above 60 °C (140 °F), they shall be installed with suitable heat protection.

4.2.5.7 Vibration and position detectors

- **4.2.5.7.1** Unless otherwise specified, a vibration-monitoring system consisting of a single, radially oriented, non-contacting shaft vibration-sensing probe, an oscillator-demodulator and a readout instrument shall be provided for each high-speed rotor and, if specified, for driver bearings. For single-impeller rotors, the probe shall be located at the bearings adjacent to the impeller.

4.2.5.7.2 Unless otherwise specified, vibration and axial position transducers shall be supplied, installed and calibrated in accordance with API Std 670.

4.3 Integrally geared compressor

4.3.1 General

4.3.1.1 All equipment shall be designed to permit rapid and economical maintenance. Major parts such as casing components and bearing housings shall be designed and manufactured to ensure accurate alignment on reassembly. This may be accomplished by the use of shouldering, cylindrical dowels or keys. Shaft seals and bearings shall be accessible for inspection and replacement with minimum disassembly.

4.3.1.2 The compressor's aerodynamic performance shall be such that a continuously rising compressor total head curve is developed. The compressor total head curve shall be developed from the differential pressure measurement between the compressor inlet flange and the final-stage discharge flange.

4.3.1.3 The specified capacity shall be met on the understanding that the discharge pressure shall be within + 5 % and – 0 % of that specified. The power required shall not exceed predicted power by more than 4 %, including all tolerances.

4.3.1.4 The combined performance (impellers, diffusers, intercoolers and so forth) shall provide a minimum 10 % pressure rise from rated capacity to surge while the compressor is operating at rated speed and the highest specified ambient operating temperature. However, when the normal and rated points are not identical, the pressure rise from the normal point to the surge point may not be 10 %.

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

4.3.1.6 Studded connections shall be furnished with studs and nuts installed. Blind stud holes should only be drilled deep enough to allow a preferred tap depth of $1\frac{1}{2}$ times the major diameter of the stud; the first $1\frac{1}{2}$ threads at both ends of each stud shall be removed.

4.3.2 Bolting

4.3.2.1 The details of threading shall conform to ISO 261, ISO 262, ISO 724 or ISO 965. For external bolting, the purchaser's agreement shall be obtained.

4.3.2.2 Studs are preferred to cap screws.

4.3.2.3 Adequate clearance shall be provided at bolting locations to permit the use of socket or box wrenches.

4.3.2.4 Slotted-nut or spanner bolting shall not be used, unless specifically approved by the purchaser.

4.3.3 Other assembly requirements

4.3.3.1 Jackscrews, guide rods and cylindrical casing-alignment dowels shall be provided to facilitate disassembly and reassembly. When jackscrews are used as a means of parting contacting faces, one of the faces

shall be relieved (counter-bored or recessed) to prevent a leaking joint or improper fit caused by marring of the face. Guide rods shall be of sufficient length to prevent damage to the internals or casing studs caused by the casing during disassembly or reassembly. Lifting lugs or eyebolts shall be provided for lifting only the top half of the casing. Methods of lifting the assembled machine shall be specified by the vendor.

4.3.3.2 The sealing of stud clearance holes to prevent leakage is not permitted.

4.3.3.3 The upper and lower surfaces of mounting plates shall be machined parallel.

4.3.4 Pressure casings

4.3.4.1 The thickness of the casing shall be suitable for the maximum allowable working and test pressures and shall include at least a 3 mm (1/8 in) corrosion allowance. The thickness of the casing shall not be less than that calculated in accordance with the pressure design code.

4.3.4.2 Casings and supports, including the baseplate, shall be designed to have sufficient strength and rigidity to limit any change of shaft alignment at the coupling flange caused by the worst combination of allowable pressure, torque and piping forces and moments, to 50 µm (0,002 in). Higher values may be used if supporting calculations are approved by the purchaser. Supports and alignment bolts shall be rigid enough to permit the driver to be moved by the use of its horizontal and vertical jackscrews.

4.3.5 Casing connections

4.3.5.1 General

- **4.3.5.1.1** The first-stage inlet and final-stage outlet connections shall be flanged or machined and studded, and oriented as specified on the data sheets (see annex A). Pipe couplings are also permissible for straight pipe inlet air connections. All interstage and final-stage outlet connections shall be suitable for the maximum allowable working pressure of the casing.

4.3.5.1.2 Flanges shall be in accordance with the pressure design code. If specified, the vendor shall supply all mating flanges, including studs and nuts.

4.3.5.1.3 Connections welded to the casing shall meet the material requirements of the casing, including impact values, rather than the requirements of the connected piping.

4.3.5.2 Casing openings for pipe connections

4.3.5.2.1 Casing openings for pipe connections shall be at least DN 18 (NPS ¾) and shall be flanged or machined and studded. Where flanged or machined and studded openings are impractical, threaded openings in sizes DN 18 (NPS ¾) to DN 38 (NPS 1½) are permissible. These threaded openings shall be installed as specified in 4.3.5.2.2 to 4.3.5.2.7.

4.3.5.2.2 A pipe nipple, which should not be more than 150 mm (6 in) long, shall be screwed into the threaded opening.

4.3.5.2.3 Pipe nipples shall be a minimum of Schedule 160 seamless for sizes DN 25 (NPS 1) and smaller and a minimum of Schedule 80 for DN 38 (NPS 1½) (see 4.2.3.1.10).

NOTE See ASME B36.10M for schedules.

4.3.5.2.4 The pipe nipple shall be provided with a welding-neck or socket-weld flange.

4.3.5.2.5 The nipple and flange materials shall meet the requirements of 4.3.5.1.3.

4.3.5.2.6 The metal thickness and boss diameter of tapped openings and bosses for pipe threads shall conform to the piping design code.

4.3.5.2.7 Pipe threads shall be taper threads and shall comply with the piping design code.

4.3.5.3 Restricted sizes

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.

4.3.5.4 Plugs

Tapped openings not connected to piping shall be plugged with solid steel plugs. As a minimum, these plugs shall meet the material requirements of the casing. Plugs that could later require removal shall be of corrosion-resistant material. Threads shall be lubricated. Tape shall not be applied to the threads of plugs inserted into oil passages. Plastic plugs shall not be used.

4.3.5.5 Flanges

4.3.5.5.1 Flanges shall be in accordance with the pressure design code.

4.3.5.5.2 Cast iron flanges shall be flat-faced and conform to the dimensional requirements of ISO 7005-2. Class 125 flanges shall have a minimum thickness equal to class 250 for sizes DN 200 and smaller.

4.3.5.5.3 Flat-faced flanges of full raised-face thickness may be used on casings other than cast iron.

4.3.5.5.4 Flanges that are thicker or have a larger outside diameter than required by the pressure design code may be used, but should be identified as such on drawings.

4.3.5.6 Studs

Machined and studded connections shall conform to the facing and drilling requirements as specified in 4.3.5.5. Studs and nuts shall be furnished installed. The first 1½ threads at both ends of each stud shall be removed.

4.3.5.7 Accessibility

All of the purchaser's connections shall be accessible for disassembly without moving either the integrally geared compressor or the driver.

4.3.6 External forces and moments

The compressor shall be designed to withstand external forces and moments at least equal to values calculated in accordance with annex D, and shall meet the requirement 4.2.4.2. For these calculations, constants in the formulas shall be increased by a factor of 1,85. Whenever possible, these allowable forces and moments should be increased after such factors as location and degree of compressor support, nozzle length and degree of reinforcement, and casing configuration and thickness have been considered. The allowable forces and moments shall be shown on the outline drawing.

If the vendor's standard compressor design cannot accept the allowable piping forces and moments specified above, then the maximum acceptable forces and moments without the use of expansion joints shall be stated in the proposal and shown on the outline drawings.

4.3.7 Rotating elements

4.3.7.1 Shafts

4.3.7.1.1 Shafts shall be of forged or of hot-rolled alloy steel.

4.3.7.1.2 Shafts shall be machined throughout their entire length. They shall have a surface finish of 0,8 µm *Ra* or better at bearing surfaces.

4.3.7.1.3 The rotor shaft sensing areas to be observed by radial vibration probes shall be concentric with the bearing journals. All shaft sensing areas (both radial vibration and axial position) shall be free from stencil and scribe marks or any other surface discontinuity (e.g. oil hole or keyway). These areas shall not be metallized, sleeved or plated. The final surface finish shall be $0,4\text{ }\mu\text{m}$ to $0,8\text{ }\mu\text{m}$ (16 micro-inches to 32 micro-inches) R_a , preferably obtained by honing or burnishing. The radial areas shall be properly demagnetized or otherwise treated so that the combined total electrical and mechanical runout does not exceed 25 % of the maximum allowed peak-to-peak vibration amplitude, or $6,5\text{ }\mu\text{m}$, whichever is the greater.

4.3.7.1.4 Chrome plating of the shaft at the journal area is not permissible.

4.3.7.2 Impellers

4.3.7.2.1 Impellers may be closed, consisting of disk, vanes and cover, or they may be semi-open, consisting of disk and vanes. Impellers shall be of welded, brazed, milled or cast construction. Other manufacturing methods, such as electroerosion and riveting, may be used if approved by the purchaser. Each impeller shall be marked with an unique identification number.

4.3.7.2.2 Impellers may consist of forged and cast components. Welds in the gas passageway shall be smooth and free from weld spatter. Impellers shall be heat-treated and stress-relieved after welding or brazing.

4.3.7.2.3 The vendor's proposal shall describe in detail the type of impeller construction and the method of attachment to the shaft.

4.3.7.3 Gears

4.3.7.3.1 As a minimum, gears shall be manufactured to the tolerances specified in AGMA 2000 for quality number 13 or DIN 3990 for quality number 4.

4.3.7.3.2 The gear unit shall be rated in accordance with AGMA 6011, using minimum service factors of 1,4 for constant speed motor-driven units and 1,6 for steam-turbine-driven units. The rating shall be based on the driver nameplate rating, including any service factor.

4.3.7.3.3 Bull-gear and pinion hardness combinations shall be in accordance with the values recommended in AGMA 6011. Brinell hardness numbers of 275 and 320 or greater for bull gear and pinion, respectively, are preferred. The calculated values of gear rated power, based on both tooth surface durability and tooth-bending strength, shall be included in vendor's proposal.

4.3.7.3.4 The tooth portion of the pinion shall be integrally forged with its shaft.

4.3.7.3.5 The bull gear may be integrally forged with or separate from its shaft. A separate gear shall be a forging or of fabricated construction using a forged steel rim, and shall be assembled on the shaft with an interference fit.

4.3.7.3.6 Gears shall not require a break-in period in the field to attain continuous satisfactory operation at rated conditions.

4.3.8 Bearings and bearing housings

4.3.8.1 General

4.3.8.1.1 Hydrodynamic radial and thrust bearings shall be required for any of the following conditions.

- a) Where the shaft transmits more than 335 kW or operates above 3 600 r/min, unless otherwise approved by the purchaser.
- b) Where antifriction-bearing dN factors are 300 000 or more.

NOTE A dN factor is the product of bearing size (bore) in millimetres and rated speed in revolutions per minute.

- c) When standard anti friction bearings fail to meet an L10 rating life (see ABMA Std 9) of either 25 000 h with continuous operation at rated conditions or 16 000 h at maximum axial and radial loads and rated speed.

NOTE The rating life is the number of hours at rated bearing load and speed that 90 % of a group of identical bearings will complete or exceed before the first evidence of failure.

4.3.8.1.2 Hydrodynamic radial bearings shall be designed for easy replacement by having either a split design or an axial removable arrangement. They shall be precision bored and of the sleeve or pad type. These bearings shall be equipped with anti-rotation pins and shall be positively secured in the axial direction. The bearing design shall suppress hydrodynamic instabilities and provide sufficient damping to limit rotor vibration to the maximum specified amplitudes (see 4.3.10.5.5) while the equipment is operating loaded or unloaded at the specified operating speed.

4.3.8.1.3 Hydrodynamic thrust bearings shall be steel-backed, babitted and arranged for continuous pressurized lubrication. Integral thrust collars are preferred. If replaceable collars are furnished (for assembly and maintenance purposes), they shall be positively locked to the shaft to prevent fretting. The faces of the collar shall have a surface finish of not more than 0,4 µm *Ra*, and the axial total indicated runout of either face shall not exceed 12,7 µm.

4.3.8.2 Thrust bearings

4.3.8.2.1 General

4.3.8.2.1.1 Thrust bearings shall be sized for continuous operation under the most adverse specified operating conditions, including maximum differential pressure. Loads shall be determined at design internal clearances and also at two times design internal clearances. As a guide, hydrodynamic thrust bearings should be selected at no more than 50 % of the bearing manufacturer's rating to accommodate the larger of these two loads. In addition to thrust from the rotor and any internal gear reactions due to the most adverse operating conditions, the axial force transmitted through the flexible coupling shall be considered a part of the duty of any thrust bearing.

4.3.8.2.1.2 For gear-type couplings, the external force shall be calculated from the following formula:

$$F = \frac{(0,25) \times (19\,100) \times P}{N_r \times D}$$

where

F = external force, in kilonewtons;

P_r = rated power, in kilowatts;

N_r = rated speed, in revolutions per minutes;

D = pitch diameter of the coupling, in millimetres.

4.3.8.2.1.3 Thrust forces for flexible-element couplings shall be calculated on the basis of the maximum allowable deflection permitted by the coupling manufacturer.

4.3.8.2.1.4 If two or more rotor thrust forces are to be carried by one thrust bearing (such as in a gearbox), the resultant of the forces shall be used, provided the directions of the forces make them numerically additive; otherwise, the largest of the forces shall be used.

4.3.8.2.2 Arrangement for axial positioning

Thrust bearings shall be arranged to allow axial positioning of each rotor relative to the casing and setting of the thrust bearings' clearance.

4.3.8.2.3 Bearing housings

Bearing housings for pressure-lubricated hydrodynamic bearings shall be arranged to minimize foaming. The drain system shall be adequate to maintain the oil and foam level below shaft end seals. The rise in oil temperature through the bearing and housings shall not exceed 30 °C (50 °F) under the most adverse specified operating conditions. When the inlet oil temperature exceeds 50 °C (120 °F), special consideration shall be given to bearing design, oil flow and allowable temperature rise. Oil outlets from thrust bearings shall be tangential and in the upper half of the control ring or, if control rings are not used, in the thrust-bearing cartridge.

4.3.8.2.4 Fitting

Antifriction bearings shall be retained on the shaft and fitted into housings in accordance with the requirements of ABMA Std 7 however, the device used to lock ball thrust bearings to the shaft shall be restricted by a nut with a tongue-type lock washer, for example, series W.

4.3.8.2.5 Internal clearance

Except for the angular contact-type, antifriction bearings shall have a loose internal clearance fit equivalent to ABMA Symbol 3, as defined in ABMA Std 20. Single or double-row bearings shall be of the Conrad type (no filling slots).

4.3.9 Seals and sealing system

4.3.9.1 Shaft seals shall be provided such that they

- a) contain compressed air inside the compressor castings,
- b) prevent oil from entering the compressor casings and contaminating the compressed air,
- c) prevent oil from leaking out of the gear casing into the atmosphere, and
- d) prevent atmospheric air from entering any gear or compressor casing that could allow contamination of the oil system or compressed air by dirt or moisture.

An atmospheric space between air and oil seals is preferred.

4.3.9.2 If a sealing system is required, it shall be furnished complete with piping, differential pressure control valve, control instrumentation, filters and necessary start-up interlocks. This system, including seal fluid consumption, shall be fully described in the proposal.

4.3.9.3 Seal operation shall be suitable for all specified operating conditions, including suction throttling, start-up, shutdown, standby and momentary surge. The type of standby operation shall be agreed upon by the purchaser and the vendor.

4.3.9.4 Shaft seals shall be of the labyrinth, carbon-ring, mechanical face or self-acting gas seal types, or a combination of these types.

4.3.10 Dynamics

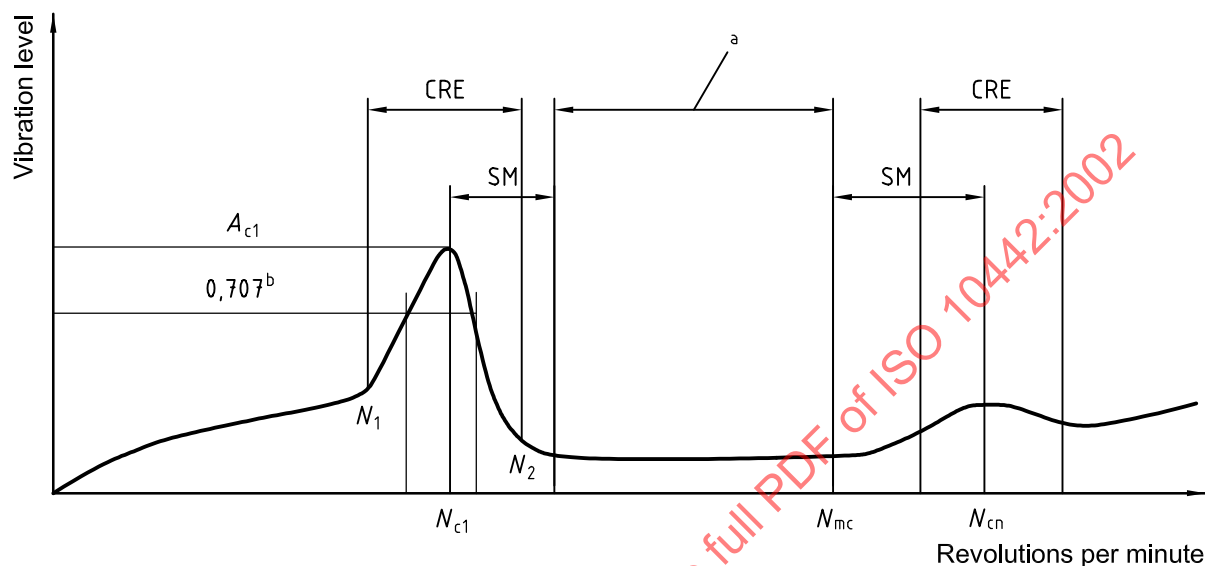
4.3.10.1 Critical speed

4.3.10.1.1 When the frequency of a periodic forcing phenomenon (exciting frequency) applied to a rotor-bearing support system corresponds to a natural frequency of that system, the system can be in a state of resonance.

4.3.10.1.2 A rotor-bearing support system in resonance will have its normal vibration displacement amplified. The magnitude of the amplification and the rate of the phase angle are related to the amount of damping in the system and the mode shape taken by the rotor.

NOTE The mode shapes are commonly referred to as the first rigid (translatory or bouncing) mode, the second rigid (conical or rocking) mode and the (first, second, third*n*th) bending mode.

4.3.10.1.3 When the rotor amplification factor (see Figure 3), as measured on the test stand at the vibration probe, is greater than or equal to 2,5, that frequency is called critical and the corresponding shaft rotational frequency is called a “critical speed”. For the purposes of this International Standard, a critically damped system is one in which the amplification factor is less than 2,5.



Key

N_{c1}	rotor first critical, centre frequency, cycles per minute
N_{cn}	critical speed, <i>n</i> th
N_{mc}	maximum continuous speed, 105 %
N_1	initial (lesser) speed at 0,707 times peak amplitude (critical)
N_2	final (greater) speed at 0,707 times peak amplitude (critical)
$N_2 - N_1$	peak width at the half-power point

μ	amplification factor $\mu = \frac{N_{c1}}{N_2 - N_1}$
SM	separation margin
CRE	critical response envelope
A_{c1}	amplitude at N_{c1}
A_{cn}	amplitude at N_{cn}

NOTE The curve shape is for illustration only and does not necessarily represent any actual rotor response plot.

a Operating speeds.

b Peak.

Figure 3 — Rotor response plot

4.3.10.1.4 Critical speeds shall be determined analytically by means of a damped unbalanced rotor response analysis and shall be confirmed by test stand data. With the purchaser's approval, those of the vendor's standard critical speed values which have been analytically derived and proven by testing of previously manufactured compressors of the same frame size are permissible.

4.3.10.1.5 An exciting frequency may be less than, equal to or greater than the rotational speed of the rotor. Potential forced and self-exciting frequencies considered in system design shall include, but are not limited to, the following sources:

- each rotor's operating speed;
- unbalance in the rotor system;

- c) oil film instabilities (whirl);
- d) internal rubs;
- e) blade, vane, nozzle and diffuser passing frequencies;
- f) gear tooth meshing and side bands;
- g) coupling misalignment;
- h) loose rotor system components;
- i) hysteretic and friction whirl;
- j) boundary layer flow separation;
- k) acoustic and aerodynamic cross coupling forces;
- l) asynchronous whirl.

4.3.10.1.6 Resonances of support systems within the vendor's scope of supply shall not occur within the specified operating speed range or the specified separation margins, unless the resonances are critically damped.

- **4.3.10.1.7** The vendor having unit responsibility shall ensure that the drive-train critical speeds (rotor lateral, system torsional, blading modes and the like) are compatible with the critical speeds of the machinery being supplied and that the combination is suitable for the specified operating speed range, including any starting speed detent (hold point) requirements of the train. A list of all undesirable speeds from zero to trip shall be submitted to the purchaser for review and included for guidance in the instruction manual (see annex C).

4.3.10.2 Lateral analysis

- **4.3.10.2.1** If specified, the vendor shall provide a damped unbalanced response analysis for each machine in order to ensure acceptable amplitudes of vibration at any speed from zero to trip. For a logic diagram of the lateral analysis and test procedures, see annex C.

4.3.10.2.2 The damped unbalanced response analysis shall include, but shall not be limited to, the following considerations:

- a) support (base, frame and bearing housing) stiffness, mass and damping characteristics, including effects of rotational speed variation (the vendor shall state the assumed support system values);
 - b) bearing lubricant film stiffness and damping changes due to speed, load, preload, oil temperatures, accumulated assembly tolerances and maximum to minimum clearances;
 - c) rotational speed, including the various starting speed detents, operating speed and load ranges (including agreed-upon test conditions if different from those specified), trip speed and coast-down conditions;
 - d) rotor masses, including the mass moment of coupling halves, stiffness and damping effects (e.g., accumulated fit tolerances, and frame and casing effects);
 - e) asymmetrical loading (e.g., partial arc admission, gear forces, side streams and casing effects).
- **4.3.10.2.3** If specified, the effects of other equipment in the train shall be included in the damped unbalanced response analysis (i.e., a train lateral analysis shall be performed) — for example, a train lateral analysis should be specified for trains with a rigid coupling.

4.3.10.2.4 As a minimum, the damped unbalanced response analysis shall include the following.

- a) A plot and identification of the mode shape at each resonant speed (critically damped or not) from zero to trip, as well as the next mode occurring above the trip speed.
- b) Frequency, phase and response amplitude data at the vibration probe locations through the range of each critical speed, using the following arrangement of unbalance for the particular mode. This unbalance shall be sufficient to raise the displacement of the rotor at the probe locations to the vibration limit defined by the following equation:

$$L_V = 25,4\sqrt{12\,000/N} \quad (1)$$

or in US customary units:

$$L_V = \sqrt{12\,000/N} \quad (2)$$

where

L_V is the vibration limit (amplitude of unfiltered vibration), μm peak-to-peak;

N is the operating speed nearest the critical of concern, in revolutions per minute.

The unbalance shall be no less than two times and no more than eight times the unbalance limit specified in 4.3.10.5.2. The unbalance mass or masses shall be placed at the location or locations within the bearing span that have been analytically determined as affecting the particular mode most adversely (e.g. at mid span for translatory modes or near both ends and 180° out of phase for conical modes). For bending modes with maximum deflections at the shaft's ends, the amount of unbalance shall be based on the overhung mass rather than the static bearing loading.

- c) Modal diagrams for each response in b), indicating the phase and major axis amplitude at each coupling engagement plane, the centrelines of the bearings and the locations of the vibration probes, at each seal area throughout the machine. The minimum design diametrical running clearance of the seals shall also be indicated.
- d) For the purposes of the verification test (see 4.3.10.3) an additional plot of a test unbalance, as specified in b) (based on static bearing loading for rigid modes or based on overhung mass for bending modes). This test mass shall be at least two times the unbalance limit specified in 4.3.10.5.2 and shall be placed at a location determined by the vendor.
- e) If specified, the generation of a stiffness map of the undamped rotor response from which the damped unbalanced response analysis specified in c) was derived. This plot shall show frequency versus support system stiffness with the calculated support system stiffness curves superimposed.

4.3.10.2.5 The damped unbalance response analysis shall confirm that the machine in the unbalanced condition 4.3.10.2.4, b) meets the following acceptance criteria (see Figure 3).

- a) If the amplification factor is less than 2,5, the response is considered critically damped and no separation margin is required.
- b) If the amplification factor is 2,5 to 3,55, a separation margin of 15 % above the maximum continuous speed and 5 % below the minimum operating speed is required.
- c) If the amplification factor, μ , is greater than 3,55 and the critical response peak is below the minimum operating speed, the required separation margin (a percentage of minimum speed) is equal to the following:

$$SM = 100 - \left(84 + \frac{6}{\mu - 3} \right) \quad (3)$$

- d) If the amplification factor is greater than 3,55 and the critical response peak is above the trip speed, the required separation margin (a percentage of maximum continuous speed) is equal to the following:

$$SM = \left(126 - \frac{6}{\mu - 3} \right) - 100 \quad (4)$$

4.3.10.2.6 The calculated unbalanced peak-to-peak rotor amplitudes (see 4.3.10.5.5) at any speed from zero to trip shall not exceed 75 % of the minimum design diametrical running clearances throughout the machine (with the exception of floating ring and abradable seal locations).

4.3.10.2.7 If, after the purchaser and the vendor have agreed that all practical design efforts have been exhausted, the analysis indicates that the separation margins still cannot be met or that a critical response peak falls within the operating speed range, acceptable amplitudes shall be mutually agreed upon by the purchaser and the vendor, subject to the requirement of 4.3.10.2.6.

- **4.3.10.2.8** When specified or when the average gas density exceeds 60 kg/m³, the vendor shall carry out a rotor stability analysis. This should be made at rated speed for constant speed machines and over the speed range from minimum to maximum continuous speed for variable speed compressors. The analysis shall be performed without and then with destabilising aerodynamic effects, taking into account the highest gas density. The results are to be provided as plots showing the damped critical speeds and the log decrement as a function of speed. The vendor should demonstrate the acceptability of the calculated value of log decrement by reference to similar machines in satisfactory operation of over the speed range from minimum to maximum continuous speed. This stability analysis should also take into account a) to e), in 4.3.10.2.2.

4.3.10.3 Shop verification of unbalanced response analysis

- **4.3.10.3.1** If specified, the vendor shall demonstrate the accuracy of the vendor's unbalance response calculation by performing an unbalanced response test in accordance with 4.3.10.

4.3.10.3.2 The actual critical speed responses, as revealed on the test stand with a rotor unbalance magnitude in accordance with 4.3.10.2.4, d), and placed at a location (usually the coupling) determined by the vendor, shall be the criteria for confirming the validity of the damped unbalanced response analysis.

NOTE The dynamic response of the machine on the test stand will be a function of the agreed-upon test conditions. Unless the test stand results are obtained at the conditions of pressure, temperature, speed, and load expected in the field, they may not be the same as the results expected in the field.

4.3.10.3.3 The parameters to be measured during the test shall be speed and shaft vibration amplitudes with corresponding phase. The vibration amplitudes and phase from each pair of *x-y* vibration probes shall be vectorially summed at each response peak to determine the maximum amplitude of vibration. The major axis amplitude of each response peak shall not exceed the limits specified in 4.3.10.5.5. The gain of the recording instrumentation used shall be predetermined and pre-set before the test so that the highest response peak is within 60 % to 100 % of the recorder's full scale on the test unit coast-down (deceleration).

NOTE 1 Vectorial subtraction of slow roll (300 r/min to 600 r/min) total electrical and mechanical runout is always necessary for this verification and vectorial subtraction of bearing housing motion is normally necessary.

NOTE 2 The phase on each vibration signal, *x* or *y*, is the angular measure, in degrees, of the phase difference (lag) between a phase reference signal (from a phase transducer sensing a once per revolution mark on the rotor, as described in API Std 670) and the next positive peak, in time, of the synchronous (*1x*) vibration signal. When proximity probes are used, this is the lag angle between the vibration probe and the high spot on the rotor.

NOTE 3 The major axis amplitude is properly determined from a Lissajous (orbit) display on an oscilloscope, oscillograph or equivalent. When the phase angle between the *x* and *y* signals is not 90°, the major axis amplitude can be approximated by $(x^2 + y^2)^{1/2}$. When the phase angle between the *x* and *y* signals is 90°, the major axis value is the greater of the two vibration signals.

4.3.10.3.4 Additional testing and correction of the original damped unbalanced rotor response analysis shall be required if, from the test data described above or from a phase or amplitude indication in the damped unbalanced

response analysis (based on the unbalanced conditions described in 4.3.10.2.4 b), or both, it appears that either of the following conditions exists:

- a) any critical response fails to meet the separation margin requirements (4.3.10.5.5) or falls within the operating speed range;
- b) the requirement of 4.3.10.2.6 has not been met.

4.3.10.3.5 Unbalance masses shall be determined and placed as mutually agreed upon by the purchaser and the vendor [4.3.10.2.4, b) and d)]. Unbalance magnitudes shall be achieved by adjusting the residual unbalance that exists in the rotor from the initial run to raise the displacement of the rotor at the probe locations to the vibration limit defined by Equation 1 at the maximum continuous speed. The measurements from this test, taken in accordance with 4.3.10.3.3, shall indicate the following acceptance criteria for the machine:

- a) at no speed shall the shaft deflections exceed 90 % of the minimum design running clearances;
- b) at no speed within the operating speed range shall the shaft deflections exceed 55 % of the minimum design running clearances or 150 % of the allowable vibration limit at the probes [see 4.3.10.2.4 b)].

The internal deflection limits specified in items a) and b) shall be based on the calculated displacement ratios between the probe locations and the areas of concern identified in 4.3.10.2.4 c). Actual internal displacements for these tests shall be calculated by multiplying these ratios by the major axis amplitudes (see 4.3.10.3.3). Acceptance shall be based on these calculated displacements, not on inspection of seals after testing, however, damage to any portion of the machine as a result of this testing shall constitute failure of the test. Minor internal seal rubs that do not cause clearance changes outside the vendor's new part tolerance do not constitute damage.

4.3.10.4 Torsional analysis

4.3.10.4.1 Excitations of torsional natural frequencies may come from many sources, which should be considered in the analysis. These sources may include, but are not limited to, the following:

- a) gear problems such as unbalance and pitch line runout;
- b) start-up conditions such as speed detents (under inertial impedances) and other torsional oscillations;
- c) torsional transients such as switch-on and terminal short circuit of all kinds of electric motors, start-up, operation and worst-case transient of variable speed electric motors, as well as start-up of synchronous electric motors.

4.3.10.4.2 The torsional natural frequencies of the complete train shall be at least 10 % above or below any possible excitation frequency within the specified operating speed range (from minimum to maximum continuous speed).

4.3.10.4.3 Torsional criticals at two times running speeds as well as one and two times the supply frequency for motor-driven systems should be avoided or, in systems in which corresponding excitation frequencies occur, shall be shown to have no adverse effect. In addition to multiples of running speeds, torsional excitations that are not a function of operating speeds or non-synchronous in nature shall be considered in the torsional analysis as applicable. Identification of these frequencies shall be the mutual responsibility of the purchaser and the vendor.

- a) Torsional criticals at two or more times running speed of all shafts shall be avoided, except where, on variable speed motor driven compressors, corresponding excitation frequencies are unavoidable, in which case they shall be shown to have no adverse effect.
- b) For the torsional analysis of variable speed motor-driven compressors, the vendor together with the variable speed motor supplier shall identify all excitation frequencies and their consequences on the train. These frequencies shall include but not be limited to
 - 1) non speed-dependant excitations, such as ripple,

- 2) integer harmonics,
- 3) non-integer harmonics,
- 4) carrier frequency harmonics, and
- 5) switching harmonics between speed control windows.

4.3.10.4.4 When torsional resonances are calculated to fall within the margin specified above (and the purchaser and the vendor have agreed that all efforts to remove the critical from within the limiting frequency range have been exhausted), the vendor shall demonstrate that the resonances have no adverse effect on the complete train.

4.3.10.4.5 A torsional vibration analysis of the complete train shall be performed, and the vendor shall be responsible for directing the modifications necessary to meet the requirements of 4.3.10.4.1 to 4.3.10.4.4.

4.3.10.4.6 In addition to the torsional analyses required in 4.3.10.4.2 to 4.3.10.4.5, the vendor shall perform a transient torsional vibration analysis for motor-driven units. The acceptance criteria for this analysis shall be mutually agreed upon by the purchaser and the vendor.

4.3.10.5 Vibration and balancing

4.3.10.5.1 Major parts of the rotating element, such as the shaft and impellers, shall be dynamically balanced. When a bare shaft with a single keyway is dynamically balanced, the keyway shall be filled with a fully crowned half-key. The initial balance correction to the bare shaft shall be recorded. A shaft with keyways 180° apart but not in the same transverse plane shall also be filled as described above.

4.3.10.5.2 The pinions, bull gear and impellers shall be multiplane dynamically balanced during assembly. This shall be accomplished after the addition of each major component. Balancing correction shall only be applied to the elements added. Balancing of impellers by welding is prohibited. Minor correction of other components may be required during the final trim balancing of the completely assembled element. On rotors with single keyways, the keyway shall be filled with a fully crowned half-key. The weight of all half-keys used during final balancing of the assembled element shall be recorded on a residual unbalance work sheet. The maximum allowable residual unbalance per plane (journal) shall be calculated as follows:

$$U = \frac{6 \ 350 \times W}{N} \text{ for } N \leq 25 \ 000 \quad (5)$$

$$U = \frac{6 \ 350 \times W}{25 \ 000} \text{ for } N > 25 \ 000 \quad (6)$$

where

U is the residual unbalance, in gram millimetres (ounce inches)

W is the journal static weight load, in newtons (pound force)

N is the maximum continuous speed, in revolutions per minute.

NOTE The balance tolerances above 25 000 r/min are based on an eccentricity of 0,635 µm for each journal static mass load. Unbalance readings shall be measured at each journal bearing position with no compensation to actual balance planes.

If spare rotating elements are supplied, they shall be dynamically balanced to the same tolerances as the main rotating elements.

- **4.3.10.5.3** If specified, after the final balancing of each assembled rotating element has been completed, a residual unbalance check shall be performed and recorded on a residual unbalance work sheet.

4.3.10.5.4 High-speed balancing may be done (balancing in a high-speed balancing machine at the operating speed). The acceptance criteria for this balancing shall be mutually agreed upon by the purchaser and the vendor.

4.3.10.5.5 During the shop test of the compressor, for each rotating element operating at its maximum continuous speed or at any other speed within the specified operating range, the peak-to-peak amplitude of unfiltered vibration in any plane, measured on the shaft adjacent and relative to each radial bearing, shall not exceed the value calculated as follows, or 50 µm, whichever is the lesser:

$$A = 25,4\sqrt{12\,000/N} \quad (7)$$

Or, in U.S. customary units:

$$A = \sqrt{12\,000/N} \quad (8)$$

where

A is the amplitude of unfiltered vibration, in micrometres peak-to-peak;

N is the maximum continuous speed, in revolutions per minute.

At any speed greater than the rated operating speed, up to and including the trip speed of the driver, the vibration shall not exceed 150 % of the maximum value recorded at the rated operating speed unless the unbalance response analysis indicates a stepper rise of vibration levels; then the limit shall be that given by calculation, or 150 % of the result given by Equation 7, whichever is lower. (For motor-driven compressors, trip speed and rated operating speed are synonymous.)

NOTE These limits are not to be confused with the limits specified in 4.3.10.3 for shop verification of unbalanced response.

4.3.10.5.6 Electrical and mechanical runout shall be determined and recorded.

4.3.10.5.7 If the vendor can demonstrate that electrical or mechanical runout is present, a maximum of 25 % of the test level calculated from Equation 7 or 6,4 µm (250 micro-inches), whichever is the greater, may be vectorially subtracted from the vibration signal measured during the factory test.

4.3.11 Materials⁸⁾

4.3.11.1 General

4.3.11.1.1 Construction materials shall be the manufacturer's standard for the specified operating conditions, except as required or prohibited by the data sheets or by this International Standard. Table B.1 lists material specifications that, if used with appropriate heat treatment or impact testing requirements or both, are generally considered acceptable for major component parts. Other international material specifications are, by agreement between the purchaser and vendor, acceptable for major component parts. The metallurgy of all major components shall be clearly stated in the vendor's proposal. See 4.2.3 for requirements for auxiliary piping materials.

4.3.11.1.2 Materials and the material grade shall be identified in the proposal using established international, national or industry designations. If no such designation is available, the vendor's material specification, giving physical properties, chemical composition and test requirements, shall be included in the proposal.

4.3.11.1.3 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.

4.3.11.1.4 Material that is notch-sensitive and prone to brittle fracture at ambient temperatures (e.g. ASTM A 515) shall not be used.

8) Also applicable to package components other than the compressor.

4.3.11.2 Castings

4.3.11.2.1 General

4.3.11.2.1.1 Castings shall be sound and free from porosity, hot tears, shrink holes, blow holes, cracks, scale, blisters and similar injurious defects. Surfaces of castings shall be cleaned by sandblasting, shot blasting, chemical cleaning or any other standard method. Mold-parting fins and remains of gates and risers shall be chipped, filed or ground flush.

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

4.3.11.2.2 Casting repairs

4.3.11.2.2.1 Cast grey iron or nodular iron castings shall not be repaired by welding, peening, plugging, burning in, or impregnating, except as specified in 4.3.11.2.2.2 and 4.3.11.2.2.3.

4.3.11.2.2.2 Weldable grades of steel castings may be repaired by welding, using a qualified welding procedure in accordance with the pressure design code.

4.3.11.2.2.3 Cast grey iron or nodular iron may be repaired by plugging within the limits specified in the selected material specification. The holes drilled for plugs shall be carefully examined, using liquid penetrant, to ensure that all defective material has been removed. All repairs that are not covered by the specifications shall be subject to the purchaser's approval.

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

4.3.11.3 Welding

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

4.3.11.4 Low temperature

- For operating temperatures below $-30\text{ }^{\circ}\text{C}$ ($-20\text{ }^{\circ}\text{F}$), or if specified for other low ambient temperatures, steels shall have, at the lowest specified temperature, an impact strength sufficient to qualify under the minimum Charpy V-notch impact energy requirements of the pressure design code. For materials and thickness not covered by the code, the purchaser shall specify the requirements on the data sheets.

4.3.12 Nameplates and rotation arrows

4.3.12.1 The compressor nameplate shall be securely attached at an easily accessible point on the package. Nameplates shall also be provided for all other major pieces of equipment.

4.3.12.2 As a minimum, the following data shall be clearly stamped on the compressor nameplate:

- a) vendor's name;
- b) serial number;
- c) size and type;
- d) rated capacity;
- e) rated discharge pressure;
- f) maximum allowable working pressure;

- g) rated input speed;
- h) maximum allowable discharge temperature;
- i) purchaser's item number;
- j) critical speeds (if the unit is variable-speed).

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

4.4 Driver

4.4.1 General

- **4.4.1.1** The type of driver shall be specified by the purchaser. The driver shall be sized to meet the maximum specified operating conditions, including gear or coupling losses or both, and shall be in accordance with applicable specifications, as stated in the inquiry and order. The driver shall be suitable for satisfactory operation under the utility and site conditions specified by the purchaser.
- **4.4.1.2** Anticipated process variations that can affect the sizing of the driver (such as changes in the pressure, temperature or relative humidity of the air, the cooling-water temperature, or the properties of the fluid handled, as well as special plant start-up conditions) shall be specified by the purchaser.
- **4.4.1.3** The starting conditions for the driven equipment shall be specified by the purchaser, and the starting method shall be mutually agreed upon by the purchaser and the vendor. The driver's starting-torque capabilities shall exceed the speed-torque requirements of the integrally geared compressor.

4.4.2 Electric motor driver

4.4.2.1 Electric motor drivers shall be sized in accordance with the more restrictive of the criteria given in 4.4.2.2 and 4.4.2.3.

- **4.4.2.2** The product of the motor nameplate rating and the service factor shall not be less than the power required (including losses from the shaft-driven oil pump, coupling and gear) when the compressor is operated unthrottled (with the inlet throttle device wide open) at the specified low ambient operating conditions. The purchaser shall specify on the data sheets the minimum inlet air temperature and the minimum inlet water temperature to be used by the vendor in calculating the maximum unthrottled power.

4.4.2.3 The motor nameplate rating (exclusive of the service factor) shall be at least 110 % of the power required (including losses from the shaft-driven oil pump, coupling and gear) at the rated operating point, or 104 % of any other specified operating point, whichever is greater.

- **4.4.2.4** The motor shall be capable of overcoming the inertia of the integrally geared compressor on starting and accelerating the load to rated speed at rated and reduced system voltage without exceeding the rated motor-winding temperature rise. The reduced system voltage shall be specified by the purchaser.
- **4.4.2.5** The purchaser shall specify the type of motor and its characteristics and accessories, including the following:
 - a) electrical characteristics;
 - b) starting conditions (including the expected voltage drop on starting);
 - c) the type of enclosure;
 - d) the sound pressure level;

- e) the area classification;
- f) the type of insulation;
- g) the required service factor;
- h) the ambient temperature and elevation above sea level;
- i) transmission losses;
- j) temperature detectors, vibration sensors, and heaters, if these are required.

4.4.3 Trip speed

The trip speed of drivers shall be in accordance with Table 6.

Table 6 — Trip speed values

Driver type	Trip speed (Percent of maximum continuous speed)
Steam turbine	110
Gas turbine	105
Constant-speed motor	100
Reciprocating engine	110

4.4.4 Steam-turbine drivers

- Unless otherwise specified by the purchaser, steam-turbine drivers shall be in accordance with ISO 10436. The turbine nameplate rating shall not be less than the power required (including losses from the shaft-driven oil pump, coupling and gear) when the compressor is operated unthrottled (with the inlet throttle device wide open) at the specified low ambient operating conditions. The purchaser shall specify on the data sheets (see annex A) the minimum inlet air temperature and minimum inlet water temperature to be used by the vendor in calculating the maximum unthrottled power. Steam-turbine drivers shall be equipped with a Class D constant-speed governor as specified in NEMA SM 23. The purchaser shall specify whether the governor is to be hydraulic or electronic.

4.4.5 Other driver types

Driver rating for other types of driver and the system of control shall be agreed between vendor and purchaser.

4.5 Driver-to-compressor coupling and guard

4.5.1 Unless otherwise specified, the coupling and guard shall be in accordance with ISO 10441.

4.5.2 The coupling shall be of the forged steel, flexible spacer type. The purchaser and the vendor shall agree upon the make, model, type and mounting arrangement of the coupling.

4.5.3 The coupling spacer shall be of sufficient length to permit removal of the coupling hubs without removal of the rotating elements.

- 4.5.4 The removable guard shall be of a sufficiently heavy and rigid design to avoid contact with the coupling or the shaft as a result of bodily contact. The guard shall be designed to prevent drawing oil out of adjacent bearing housings. The coupling guard shall comply with the specified national code. If specified by the purchaser, the guard shall be fabricated from spark-resistant materials.

4.5.5 A limited-end-float coupling shall be provided for a sleeve-bearing motor to prevent the motor rotor from rubbing either bearing shoulder.

4.5.6 For a flexible-disk-retained spacer-type coupling, the shaft thermal movements for all operating conditions shall be compatible with the optimum deflection positions of the coupling. The shaft end clearances for assembly shall be specified by the vendor. The flexible disks shall be stainless steel or other material suitably protected against corrosion.

4.5.7 Where necessary, the driver half of the coupling shall be furnished with an idling adapter to permit uncoupled operation.

- **4.5.8** Coupling hubs shall be mounted on the shafts with either a taper or a cylindrical fit. The choice of non-keyed (tapered bore, hydraulically fitted) or keyed (tapered or straight bore) hubs shall be specified by the purchaser. Fits shall be in accordance with ISO 10441.

4.5.9 Coupling hubs with cylindrical fit shall be provided with tapped puller holes to aid removal.

- **4.5.10** The maximum coupling operating torque load shall be 80 % of the manufacturer's published rating or conform to ISO 10441 if specified by the purchaser. Couplings bored larger than the manufacturer's nominal rating shall be subject to the purchaser's approval.

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

4.6 Intercoolers

4.6.1 The vendor shall furnish a cooler between each compression stage. Intercoolers shall be designed and constructed in accordance with the purchaser-specified pressure design code. Some plant locations may require consideration of alternative materials to combat atmospheric corrosion.

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

4.6.3 Intercoolers shall have continuous-bleed V-notched gate valves to permit removal of liquid.

5 Accessories

5.1 Aftercooler

- **5.1.1** Unless otherwise specified, the vendor shall furnish a water-cooled shell-and-tube aftercooler and separator after the final compression stage. The aftercooler shall be designed and constructed in accordance with the pressure design code. Some plant locations may require consideration of alternative materials to combat atmospheric corrosion.

5.1.2 Unless otherwise approved by the purchaser, the aftercooler shall be constructed and arranged to allow removal of tube bundles without dismantling piping or compressor components.

5.1.3 The aftercooler shall have a continuous-bleed valve or condensate traps to permit removal of liquid.

5.2 Air intake filter-silencer

- The vendor shall furnish a dry-type, multistage, high-efficiency air-intake filter-silencer suitable for outdoor mounting. This filter-silencer shall be provided with the following:
 - a) a differential pressure device;
 - b) a filter portion designed so that the first-stage (prefilter) elements may be changed while the unit is operating;
 - c) a weather hood or louvres;
 - d) a maximum allowable clean gauge pressure drop across the filter elements of not more than 5 hPa (5,0 millibars);
 - e) removal of a minimum of 97 % of particles 25 μm (1 mil) or larger over the inlet capacity range.

Many filter-silencer configurations and arrangements are available. The purchaser shall specify any required specific features, such as special coatings or construction to avoid corrosion.

For plant locations subject to unusual conditions such as sand storms, the filter-silencer may be elevated some distance above the compressor. Inlet piping between the filter-silencer and the compressor shall be of corrosion-resistant material.

5.3 Discharge blowoff silencer

5.3.1 The vendor shall furnish a flanged discharge blowoff or bypass silencer.

5.3.2 The silencer shall be suitable for service in an unprotected location. The silencer should preferably be located immediately downstream of the discharge blowoff valve and piped to minimize pressure drop.

NOTE Refer to the data sheets (annex A) for maximum allowable noise levels.

6 Inspection, testing and preparation for shipment

6.1 General

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

6.1.2 The vendor shall notify subvendors of the purchasers' inspection and testing requirements.

6.1.3 The purchaser and the vendor shall meet to coordinate manufacturing hold points and inspector's visits.

6.1.4 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 [see 6.1.5 a) and b)].

- **6.1.5** The purchaser shall specify the extent of purchaser participation in the inspection and testing.
 - a) "Witnessed" means that a hold shall be applied to the production schedule and that the inspection or test shall be carried out with the purchaser or purchaser's representative in attendance. For mechanical running or performance tests, this requires written notification of a successful preliminary test.
 - b) "Observed" means that the purchaser shall be notified of the timing of the inspection or test. However, the inspection or test shall be performed as scheduled, and if the purchaser or purchaser's representative is not present, the vendor shall proceed to the next step. (The purchaser should expect to be in the factory longer than for a witnessed test).

6.1.6 Equipment for the specified inspection and tests shall be provided by the vendor.

6.2 Inspection

6.2.1 General

6.2.1.1 The vendor shall keep the following data available for at least 5 a (five years) years for examination by the purchaser or his representative upon request:

- a) certification of materials, such as mill test reports;
- b) test data for verifying that the requirements of the specification have been met;
- c) if specified, final-assembly maintenance and running clearances.

6.2.1.2 Pressure-containing parts shall not be painted until the specified inspection of the parts is completed.

- **6.2.1.3** If specified, the purchaser's representative shall have access to the vendor's quality control program for review.

6.2.2 Material inspection

- **6.2.2.1** Casting surfaces shall be examined visually and shall be free from adhering sand, scale, cracks and hot tears. Other surface discontinuities shall meet the visual acceptance standards specified by the purchaser.

6.2.2.2 All accessible areas of welds on built-up impellers shall receive magnetic particle or liquid penetrant inspection.

6.2.2.3 All bull-gear and pinion teeth shall receive 100 % magnetic particle inspection in accordance with ASTM A 275 or equivalent. Cracks are not permissible. Linear indications due to non-metallic inclusions larger than 1,5 mm in the tooth flanks or roots shall be reported to the purchaser for disposition. Linear indications are defined as indications whose length is at least three times their width. Acceptance or rejection shall be decided on a case-by-case basis and shall be mutually agreed upon by the purchaser and the vendor.

- **6.2.2.4** The purchaser shall specify any parts or welds that shall be subjected to surface and subsurface inspection and the type of inspection required, such as magnetic particle or liquid penetrant.
- **6.2.2.5** If magnetic particle or liquid penetrant inspection of welds or materials is specified, the magnetic particle inspection and liquid penetrant inspection shall be in accordance with the pressure design code.

6.2.3 Mechanical inspection

6.2.3.1 During assembly of the package and before testing, each component (including cast-in passages of these components) and all piping and appurtenances shall be cleaned chemically or by another appropriate method to remove foreign materials, corrosion products and mill scale.

6.2.3.2 The oil system furnished shall meet the cleanliness requirements given in ISO 10438.

6.3 Testing

6.3.1 General

6.3.1.1 The package shall be tested in accordance with 6.3.2 to 6.3.4. Other tests that may be specified by the purchaser are given in 6.3.5.

6.3.1.2 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.

6.3.2 Hydrostatic tests

6.3.2.1 Pressure-containing parts (including auxiliaries) shall be tested hydrostatically with liquid at a minimum of 1,5 times the maximum allowable working pressure but at a gauge pressure of not less than 140 kPa (20 psi).

6.3.2.2 Tests shall be maintained for a sufficient period of time to permit complete examination of parts under pressure. The hydrostatic test shall be considered satisfactory when neither leaks nor seepage through the casing or casing joint is observed for a minimum period of 30 min. Large, heavy castings may require a longer testing period, agreed upon by purchaser and vendor. Seepage past internal closures required for testing of segmented cases and operation of a test pump to maintain pressure are acceptable.

6.3.2.3 The chloride content of liquids used to test austenitic stainless steel materials shall not exceed 50 µg/g by mass. 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.

6.3.2.4 If the part tested is to operate at a temperature at which the strength of a material is below the strength of the same 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 stress values used shall comply with the pressure design code. The pressure thus obtained shall then be the minimum pressure at which the hydrostatic test is performed. The data sheets shall list actual hydrostatic test pressures.

6.3.3 Impeller overspeed test

Each impeller shall be subject to an overspeed of at least 115 % of rated operating speed for at least 1 min. After the overspeed test, each impeller shall receive magnetic particle or liquid penetrant inspection. Impeller dimensions identified by the manufacturer as critical (such as bore, eye seal and outside dimension) shall be measured before and after each overspeed test. Any permanent deformation of the bore or other critical dimensions outside drawing tolerances might be cause for rejection, and shall be resolved to the satisfaction of the vendor and the purchaser.

6.3.4 Combined mechanical and performance test

6.3.4.1 General

A combined mechanical and performance test of the package shall be conducted at rated operating speed, for a continuous period of 4 h after bearing and "lube-oil" temperatures have stabilized. A minimum of five test points shall be taken, including surge, rated and maximum capacity. Performance at the normal operating point shall be calculated from test data, in accordance with the vendor's standard procedures or as otherwise agreed upon. The power required at the normal operating point shall not exceed the expected power requirement at normal conditions by more than 4 %.

6.3.4.2 Prior to the combined mechanical and performance testing

6.3.4.2.1 The contract shaft seals and bearings shall be used for the test.

6.3.4.2.2 All oil pressures, viscosities, and temperatures shall be within the range of operating values recommended in the vendor's operating instructions for the particular package being tested.

6.3.4.2.3 The package oil system shall be used, unless otherwise agreed upon. Oil system components downstream of the filters shall meet the cleanliness requirements of 6.2.3.2 before any test is started.

6.3.4.2.4 All joints and connections shall be checked for tightness, and any leaks shall be corrected.

6.3.4.2.5 All warning, protective and control devices shall be checked, and adjustments made as required.

6.3.4.2.6 The vibration monitoring system shall be used as specified in the data sheets (see annex A).

6.3.4.3 During the combined mechanical and performance testing

6.3.4.3.1 The performance of the package shall satisfy the requirements of 6.3.4.1. Performance shall be calculated from test data (accounting for all blowdown losses, using actual or simulated equipment) in accordance with the vendor's standard procedures or as otherwise agreed upon.

- **6.3.4.3.2** Compressor vibration shall meet the criteria of 4.3.10.5.5 and 4.3.10.5.7. The purchaser shall specify any other requirements on the data sheets (see annex A).

6.3.4.3.3 Driver vibration shall meet the criteria of 4.3.10.5.5 and 4.3.10.5.7 or the vendor's criteria, whichever are more stringent.

6.3.4.3.4 The difference between inlet and drain oil temperature shall not exceed 30 °C (90 °F).

6.3.4.3.5 The control panel shall be functionally tested. All control and safety functions shall be verified.

6.3.4.3.6 The compressor sealing system shall be in operation throughout the test to prevent the entrance of oil into the compressor.

6.3.4.3.7 Dismantling of the package to replace or modify parts in order to correct or improve the mechanical or aerodynamic performance of the package shall result in retesting after these modifications are made.

6.3.4.4 After the combined mechanical and performance testing

6.3.4.4.1 The bearings, seals and gearing shall be inspected. Bearings shall not exhibit any indication of distress. Retesting is required if any bearing needs replacement or repair.

- **6.3.4.4.2** If the design of the integrally geared compressor necessitates disassembly of any pinion rotor to inspect the bearings and seals, the purchaser shall specify either

- a) inspecting the bearings once and retesting in accordance with 6.3.4, or
- b) foregoing inspection of the bearings and seals based on analysis of the test data.

6.3.4.4.3 The gear contact pattern shall be checked (e.g. by the two-colour method with all pinions in place).

The preferred method of preserving the results of the contact check is to lift the colour from a representative tooth on the bull gear and each pinion shaft by applying and peeling off a strip of clear adhesive tape and then sticking the tape to an annotated sheet of paper.

The gear contact pattern after full load test shall be within the vendor's criteria, or shall exceed 60 % of the effective width of the gear mesh, whichever is the more stringent, and shall be centralized on the mesh.

6.3.5 Optional tests

6.3.5.1 Shop tests — General

- The purchaser shall specify in the inquiry or in the order whether any of the following shop tests shall be performed. Test details shall be mutually agreed upon by the purchaser and the vendor.

6.3.5.2 Performance test

The package shall be performance-tested in accordance with ISO 5389 or ASME PTC 10 as mutually agreed between the purchaser and vendor before ordering.

6.3.5.3 Guide-vane test

The package shall be performance-tested at five points, including surge, normal, rated and overload, by varying the position of the guide vanes.

6.3.5.4 Sound-level test

The sound-level test shall be performed in accordance with ISO 3744 or ISO 9614.

6.3.5.5 Spare rotating elements test

Spare rotating elements shall be given a combined mechanical and performance test in accordance with 6.3.4.

6.4 Preparation for shipment

- **6.4.1** The package shall be suitably prepared for the type of shipment specified, including blocking of the rotating elements when necessary. The preparation shall make the equipment suitable for six months of outdoor storage from the time of shipment, with no disassembly required before operation, except for inspection of bearings and seals. If storage for a longer period is contemplated, the purchaser shall consult with the vendor regarding the recommended procedures to be followed.
- 6.4.2** The vendor shall provide the purchaser with the instructions necessary to preserve the integrity of the storage preparation after the equipment arrives at the job site and before start-up.
- 6.4.3** The package shall be prepared for shipment after all testing and inspection have been completed and the equipment has been approved by the purchaser. The preparation shall include that specified in 6.4.4 to 6.4.16.
- 6.4.4** Exterior surfaces, except for machined surfaces, shall be given at least one coat of the manufacturer's standard paint. The paint shall not contain lead or chromates.
- 6.4.5** Exterior machined surfaces shall be coated with a suitable rust preventive.
- 6.4.6** The interior of the integrally geared compressor (and the driver, if turbine-driven) shall be clean, free from scale, welding spatter and foreign objects, and spayed or flushed with an oil-soluble rust preventive that can be removed with solvent. The rust preventive shall be applied through all openings while the unit is slow-rolled.
- 6.4.7** Internal steel areas of bearing housings and carbon steel oil systems components such as reservoirs, vessels and piping shall be coated with a suitable oil-soluble rust preventive.
- 6.4.8** Exposed shafts and shaft couplings shall be protected against rust and damage.
- 6.4.9** Bearing assemblies shall be fully protected from the entry of moisture and dirt. If vapour-phase-inhibitor crystals in bags are installed in large cavities to absorb moisture, the bags shall be attached in an accessible area for ease of removal. Where applicable, bags shall be installed in wire cages attached to flanged covers, and bag locations shall be indicated by corrosion-resistant tags attached with stainless steel wire.
- 6.4.10** Flanged openings shall be provided with metal closures at least 5 mm (3/16 in) thick, with rubber gaskets and at least four full-diameter bolts. For studed openings, all nuts needed for the intended service shall be used to secure closures.
- 6.4.11** Threaded openings shall be provided with steel caps or round-head steel plugs. In no case shall non-metallic (e.g. plastic) plugs or caps be used.
- 6.4.12** Openings that have been bevelled for welding shall be provided with closures designed to prevent the entrance of foreign materials and damage to the bevel.
- 6.4.13** Lifting points and lifting lugs shall be clearly identified on the equipment or equipment package. The recommended lifting arrangement shall be identified on boxed equipment.
- 6.4.14** The package 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, crated equipment shall be shipped with duplicate packing lists — one inside and one on the outside of the shipping container.

- **6.4.15** If spare rotating elements are purchased, they shall be prepared for unheated indoor storage for a period of at least three years. The rotating elements shall be treated with a rust preventive and shall be housed in a vapour-barrier envelope with a slow-release vapour-phase inhibitor. They shall be suitably crated for domestic or export shipment. Lead sheeting, at least 3 mm (1/8 in) thick, shall be used between the rotating elements and the cradle at the support areas. The rotating elements shall not be supported at journals.

6.4.16 The purchaser's piping connections shall be impression-stamped or permanently tagged to agree with the vendor's connection table or general arrangement drawing.

6.4.17 One copy of the vendor's standard installation instructions shall be packed and shipped with the package.

7 Vendor data

7.1 Proposals

The vendor's proposal shall include the following information.

- a) A statement of the vendor's promised times, after placement of the order, for transmittal of the contract data (see 7.2). This information shall be presented in the form of an explicit schedule.
- b) A specific statement that the package and accessories are in accordance with this International Standard. If this is not the case, the vendor shall include a specific list that details and explains each deviation.
- c) Copies of the purchaser's data sheets with complete vendor information entered thereon.
- d) Complete performance curves to fully define the operating envelope and the operating point at which the vendor has rated the equipment.
- e) Utility requirements such as steam, water, electricity, air and lubricating oil, including the quantity of such oil required at the supply pressure, the heat load to be removed by the oil, and the nameplate power rating and operating power requirements of auxiliary drivers. (Approximate data shall be defined and clearly identified as such.) This information shall be entered on the data sheets (see annex A).
- f) Net and maximum operating weights, maximum shipping and erection weights with identification of the item, and the maximum normal maintenance weight with identification of the item. These data shall be stated individually where separate shipments, packages or assemblies are involved. These data shall be entered on the data sheets (see annex A) where applicable.
- g) Preliminary outline and arrangement drawings and schematic diagrams.
- h) Typical cross-sectional drawings and literature fully describing the details of the offerings.
- i) A list of spare parts recommended for start-up and normal maintenance purposes.
- j) An itemized list of the special tools included in the offering. The vendor shall list any non-metric items included in the offering.
- k) An outline of all necessary special weather and winterizing protection required by the package and its accessories for start-up, operation and idleness. The vendor shall list separately the protective items he proposes to furnish.
- l) Any start-up, shutdown or operating restrictions required to protect the integrity of the equipment.
- m) A list of all relief valves, specifying those furnished by the vendor.
- n) Allowable forces and moments (see 4.3.6).

- o) Impeller construction and attachment details (see 4.3.7.2.3).
- p) Details of any air coolers provided (see 4.1.18.4).
- q) Identification of materials for all major components (see 4.3.11.1.2).
- r) A description of other equipment provided with the package (see 4.1.4).
- s) A description of the sealing system, including air consumption (see 4.3.9.2).
- t) A description of the design and operation of the control system (see 4.2.5.2.7).
- u) A description of the alarm and shutdown functions (see 4.2.5.5.1.6).
- v) A statement of the number of radial vibration probes that can be mounted adjacent to each impeller (see 4.2.5.7.1).
- w) The calculated values of gear-rated power, based on both tooth surface durability and tooth bending strength (see 4.3.7.3.3).
- x) The vendor's minimum allowable oil temperature (see 4.2.2.2).

7.2 Contract data

7.2.1 General

7.2.1.1 The vendor shall forward to the address or addresses noted on the order a statement detailing the schedule for transmission of drawings, curves and data as agreed to at the time of the order, as well as the number and type of copies required by the purchaser.

7.2.1.2 The data shall be identified on transmittal (cover) letters and in title blocks or pages with the following information:

- a) purchaser/user's corporate name;
- b) job/project number;
- c) package name and item number;
- d) purchase order number;
- e) any other identification specified in the purchase order;
- f) vendor's identifying shop order number, serial number or other reference required to identify return correspondence completely.

7.2.2 Coordination meeting

Unless otherwise specified, a coordination meeting shall be held, preferably at the vendor's plant, within three weeks of the purchase commitment being made. An agenda shall be prepared and distributed prior to this meeting and, as a minimum, should include the following items:

- a) purchase order, scope of supply, and subvendor items;
- b) data sheets;
- c) schedules for transmittal of drawings, production and testing;

- d) inspection, expediting and testing;
- e) physical orientation of the package components;
- f) schematics of the pressure lubrication, cooling and sealing systems;
- g) review of applicable specifications and previously agreed-upon exceptions to specifications;
- h) assignment of all purchaser-required item numbers.

7.2.3 Drawings

- **7.2.3.1** The purchaser shall state in the inquiry and in the order the number of prints or reproduces or both required, and the times within which they are to be submitted by the vendor [(see 7.1, a)].

7.2.3.2 The purchaser shall promptly review the vendor data when he receives them. However, this review shall not constitute permission to deviate from any requirements in the order unless specifically agreed upon in writing. After the data has been reviewed, the vendor shall furnish certified copies in the quantity specified.

7.2.3.3 The following information shall be provided on the drawings (typical drawings are not permissible):

- a) purchaser's order number (on every drawing);
- b) purchaser's equipment item number (on every drawing);
- c) vendor's shop order and/or serial number (on every drawing);
- d) weight of the package, of the heaviest piece of equipment that must be handled for erection, and of significant items to be handled for maintenance;
- e) principal dimensions, including those required for the piping design, maintenance clearances, and the maximum loading limit on the flanges (both forces and moments);
- f) direction and magnitude of all unbalanced forces and couples, and the location of the centre of gravity;
- g) direction of rotation;
- h) size, type, rating and identification of all purchaser's connections, including vents, drains, lubricating oil, conduits and instruments;
- i) make, size, and type of the couplings, and style of coupling guards;
- j) complete bills of materials covering the vendor's entire scope of supply;
- k) list of reference drawings;
- l) list of any special weather-protection and climatization features;
- m) cold-alignment setting data for equipment furnished by the vendor (data on expected thermal growth, including transient effects, shall be included);
- n) complete information to permit adequate foundation design by the purchaser, which shall include, but shall not be limited to
 - 1) grouting details,
 - 2) size and location of foundation bolts,
 - 3) weight distribution for each bolt location,

- 4) any unbalanced forces and moments generated by the unit in the operating speed range,
- 5) any peak forces and moments due to possible failure scenarios (e.g. phase short-circuit of electric motor drive), and
- o) location of the centre of gravity and rigging provisions to permit removal of the top half of the casing, the rotating elements, and any subassemblies having a mass of more than 135 kg.

7.2.3.4 The vendor shall supply schematic diagrams of each system in the vendor's scope of supply, as well as outline drawings and specifications for the components.

7.2.3.5 The vendor shall supply cross-sectional or assembly-type drawings for all equipment furnished, showing all parts, running fits, clearances and balancing data required for erection and maintenance. (Typical drawings are not permissible.)

7.2.4 Data sheets (see annex A)

7.2.4.1 Completion of the data sheets is the joint responsibility of the purchaser and vendor. The purchaser is responsible for the process data on the datasheets. The vendor shall provide full information to enable completion of the data sheets for the train and auxiliary equipment, first for "as purchased", and then for "as built".

7.2.4.2 The vendor shall make the following information available to the purchasers.

- a) Certified shop logs of the combined mechanical and performance test.
- b) Record of shop test data, which the vendor shall maintain for at least five years after the date of shipment. If specified, the vendor shall submit certified copies on the test data to the purchaser before shipment.
- c) Other test data and reports specified by the purchaser.

7.2.4.3 Instruction manuals shall be furnished no later than the date of shipment. A preliminary general instruction manual without test data shall be provided in advance. The manuals shall describe the installation, operation and maintenance procedures, and shall cover all drivers, accessories and instruments for items furnished by the vendor. For each package, the manual shall be organized and indexed by principal equipment items and systems and shall include, as a minimum, the following information.

- a) Written instructions covering start-up, normal shutdown, emergency shutdown, operating limits and routine operational procedures.
- b) A written sequence of installation and final tests and checks for equipment furnished by the vendor. Reference may be made to installation and testing details covered in this International Standard.
- c) A description of compressor construction features and of functioning component parts or systems. The recommended clearances and maximum and minimum design clearances shall be clearly stated.
- d) All outline and sectional drawings (schematic and illustrative sketches in sufficient detail to identify all parts), clearly showing the operation of all equipment and components and the method of their inspection and repair. All running fits, clearances and balancing data required for erection and maintenance shall be clearly stated.
- e) Instructions for preparing the package and accessory equipment for use and for erecting, piping and aligning, including the expected hot centreline shift between the position at ambient temperature 15 °C (60 °F) and that at normal operating temperature.
- f) Rigging procedures and methods of disassembly, repair, adjustment, inspection and reassembly, including any required torque values for nut tightening.
- g) Completed as-built data sheets and performance curves.
- h) All subvendor data and instructions.

7.2.4.4 The vendor shall submit a complete list of spare parts, including those shown in the original proposal. The list shall include spare parts for all equipment and accessories supplied, with cross-sectional or assembly-type drawings for identification, part numbers and delivery times. Part numbers shall identify each part for purposes of interchangeability. Standard purchased items shall be identified by the original manufacturer's numbers. The vendor shall forward the list to the purchaser promptly after receipt of the reviewed drawings and in time to permit order and delivery of the parts before field start-up. The transmittal letter shall be identified with the data specified.

7.2.4.5 At least 6 weeks before shipment, the vendor shall submit his preservation, packaging, and shipping procedures to the purchaser for his review.

7.2.5 Progress reports

- The vendor shall submit progress reports to the purchaser at the intervals specified. The reports shall include engineering, purchasing and manufacturing schedules for all major components. Planned and actual dates and the percentage completed shall be indicated for each "milestone" in the schedule.

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Annex A
(informative)

Data sheets

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INTEGRALLY GEARED CENTRIFUGAL COMPRESSOR DATA SHEET ISO 10442

Page 1 of 12

ENQUIRY/ORDER NO. _____						
JOB NO. _____			ITEM NO. _____			
REVISION	BY	DATE	CHKD.	DATE	APPD.	DATE

1	APPLICABLE TO: ☐ PROPOSAL ☐ PURCHASE ☐ AS BUILT (7.2.1.2)			
2	FOR _____ UNIT _____			
3	SITE _____ SERIAL No. _____			
4	SERVICE _____ NO. REQUIRED _____			
5	NOTE: INFORMATION TO BE COMPLETED: ☐ BY PURCHASER ☐ BY MANUFACTURER			
6	GENERAL			
7	COMPRESSOR MFR. _____ MODEL SIZE AND TYPE _____			
8	DRIVER MFR. _____ DRIVER TYPE _____ RATED kW _____ r/min _____			
9	DRIVER SYSTEM ☐ DIRECT COUPLED ☐ OTHER _____			
10	Pressure design code (4.1.17) _____ Piping design code (4.2.3.1.1) _____ Applicable regulations (4.1.22) _____			
11	OPERATING CONDITIONS			
12	(ALL DATA ON PER UNIT BASIS)	NORMAL (4.1.7)	RATED (3.13)	LOW AMBIENT (4.4.4)
13	☐ GAS HANDLED (ALSO SEE PAGE 2)			
14	☐ DELIVERED VOL.FLOW, AT 1.013 MPa & 0 °C, Z =1, DRY (m³/h)			
15	☐ MASS FLOW, [WET/DRY] (kg/h)			
16	INLET CONDITIONS			
17	☐ PRESSURE (MPa)			
18	☐ TEMPERATURE (°C)			
19	☐ RELATIVE HUMIDITY (%)			
20	☐ MOLAR MASS (%)			
21	☐ ISENTROPIC EXPONENT (K_1)			
22	☐ COMPRESSIBILITY (Z_1)			
23	☐ INLET VOLUME FLOW, [WET/DRY] (m³/h)			
24	DISCHARGE CONDITIONS			
25	☐ PRESSURE (MPa)			
26	☐ TEMPERATURE (°C)			
27	☐ ISENTROPIC EXPONENT (K_2)			
28	☐ COMPRESSIBILITY (Z_2)			
29	PERFORMANCE			
30	☐ POWER REQUIRED, AT DRIVER COUPLING, (kW)			
31	☐ MECHANICAL LOSSES, (kW)			
32	☐ SPEED (r/min)			
33	☐ ESTIMATED SURGE AT ABOVE SPEED (m³/h)			
34	☐ POLYTROPIC HEAD, SPECIFIC COMPRESSION WORK FLANGE TO FLANGE (kJ/kg)			
35	☐ POLYTROPIC EFFICIENCY FLANGE TO FLANGE (%)			
36	☐ GUARANTEE POINT FLANGE TO FLANGE			
37	☐ MAX. ΔP ACROSS INLET FILTER (MPa)			
38	☐ MAX. ΔP ACROSS AFTER COOLER (MPa)			
39	INCLUDED IN CALCULATION YES/NO			
40	☐ AFTERCOOLER OUTLET TEMP (°C)			
41	☐ COOLING WATER INLET TEMP. (°C)			
42	☐ PERFORMANCE CURVE NO.			
43	PROCESS CONTROL METHOD (4.2.5.2.1)			
44	☐ INLET THROTTLE DEVICE (CONSTANT DISCHARGE PRESSURE) [4.2.5.2.1a]			
45	☐ VARIABLE INLET GUIDE VANES			
46	☐ TWO STEP CONTROL: _____ MPa TO _____ MPa DISCHARGE PRESSURE			
47	☐ AUTOMATIC DUAL CONTROL (INLET THROTTLING AND TWO STEP)			
48	☐ AUTOMATIC START AND STOP			
49	☐ CONSTANT DISCHARGE PRESSURE BASE MODE (BLOWOFF) [4.2.5.2.1, e]			
50	☐ STANDBY SERVICE AUTOMATIC START-UP			
51	THE CONTROL SYSTEM SHALL BE SUITABLE FOR PARALLEL OPERATION:			
52	_____ CENTRIFUGAL COMPRESSORS _____ RECIPROCATING COMPRESSORS _____ BOTH			

DRIVER (4.4)
☐ INDUCTION ☐ SYNCHRON
 REFER TO ATTACHED DATA SHEETS _____
☐ STEAM TURBINE
☐ ISO 10436 DATA SHEET ATTACHED
☐ TYPE OF GOVERNOR (4.4.4) _____
ACCESSORIES
☐ INLET AIR FILTER/SILENCER
☐ AFTER COOLER
☐ INLET EXPANSION JOINT
☐ BLOWOFF SILENCER
 dBA _____
INLET PIPING
☐ STAINLESS STEEL
☐ PVC
☐ CS INTERNALLY COATED
COOLING WATER SYSTEM
☐ EXTERNAL SUPPLY
☐ CLOSED SYSTEM BY ____
☐ DISCHARGE CHECK VALVE
☐ COUPLING AND GUARDS
 PER ISO 10441

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1	OPERATING CONDITIONS (Continued)							
2	GAS ANALYSIS:	NORMAL	RATED	OTHER CONDITIONS				REMARKS:
3	O MOL% O			A	B	C	D	
4		M kg/kmol						
5	AIR	28.966						
6	OXYGEN	32.000						
7	NITROGEN	28.016						
8	WATER VAPOUR	18.016						
9	CARBON MONOXIDE	28.010						
10	CARBON DIOXIDE	44.010						
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
21								
22								
23								
24								
25	TOTAL							
26	AVG. MOL. MASS							
27	REMARKS:							
28								
29								
30								
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LOCATION, SITE DATA				SPECIFICATIONS			
1	☐ INDOOR	☐ HEATED	☐ UNDER ROOF	NOISE SPECIFICATIONS / (4.1.16)			
2	☐ OUTDOOR	☐ UNHEATED	☐ PARTIAL SIDES	☐ dba			
3	☐ GRADE	☐ MEZZANINE	☐ _____	☐ APPLICABLE TO MACHINE			
4	☐ WINTERISATION REQ.	☐ TROPICALISATION REQD.		SEE SPECIFICATION			
5	SITE DATA:			☐ APPLICABLE TO NEIGHBOURHOOD			
6	☐ ELEVATION _____ m	BAROMETER _____ MPa		SEE SPECIFICATION			
7	☐ RANGE OF AMBIENT TEMPS:			ACOUSTIC HOUSING: ☐ YES ☐ NO			
8		°C	RELATIVE HUMIDITY	APPLICABLE SPECIFICATIONS:			
9	SITE RATED	_____	_____	☐ ISO 10442			
10	NORMAL	_____	_____				
11	MAXIMUM	_____	_____				
12	MINIMUM	_____	_____	PAINTING:			
13	LOCATION: AUXILIARY EQUIPMENT			☐ MANUFACTURERS STANDARD			
14	☐ CONTROL PANEL _____			☐ OTHER _____			
15	☐ LUBE/SEAL OIL CONSOLE _____						
16	☐ NITROGEN GENERATOR _____						
17	☐ _____						
18	UNUSUAL CONDITIONS: ☐ DUST ☐ FUMES			UTILITY CONSUMPTION			
19	☐ OTHER (4.1.8)						
20							
21	☐ AREA CLASSIFICATION (4.1.12)			ELECTRIC kW LOCKED FULL LOAD			
22		ZONE	GAS GROUP	ROTOR AMPS AMPS			
23	COMPRESSOR SKID	_____	_____	MAIN DRIVER _____			
24	LUBE/SEAL OIL CONSOLE	_____	_____	MAIN LUBE OIL PUMP _____			
25	CONTROL PANEL	_____	_____	AUX. LUBE OIL PUMP _____			
26	NITROGEN GENERATOR	_____	_____	OIL HEATER _____ W			
27		_____	_____	SPACE HEATER _____ W			
28	☐ UTILITY CONDITIONS:			STEAM Kg/h INLET EXHAUST			
29	OSTEAM: DRIVERS HEATING			MPa MPa			
30	INLET MIN _____ MPa	_____ °C	_____ MPa _____ °C	MAIN DRIVER _____			
31	NORM _____ MPa	_____ °C	_____ MPa _____ °C	COOLING WATER			
32	MAX _____ MPa	_____ °C	_____ MPa _____ °C	LO. INTER AFTER OTHER			
33	EXHAUST. MIN _____ MPa	_____ °C	_____ MPa _____ °C	COOLER COOLER COOLER			
34	NORM _____ MPa	_____ °C	_____ MPa _____ °C	QUANTITY m ³ /h _____			
35	MAX _____ MPa	_____ °C	_____ MPa _____ °C	INLET TEMP. °C _____			
36	☐ ELECTRICAL SUPPLY (4.1.12)			OUTLET TEMP. °C _____			
37	DRIVERS HEATING CONTROL SHUTDOWN			INLET PRESSURE. MPa _____			
38	VOLTAGE _____	_____	_____	OUTLET PRESSURE MPa _____			
39	HERTZ _____	_____	_____	MAX. WORKING PRESS. MPa _____			
40	PHASE _____	_____	_____	TOTAL C.W. m ³ /h _____			
41	☐ COOLING WATER:			AIR _____			
42	TEMP. INLET _____ °C	MAX RETURN _____ °C		SHIPMENT: (6.4.1)			
43	PRESS NORM _____ MPa	DESIGN _____ MPa		☐ DOMESTIC ☐ EXPORT ☐ EXPORT BOXING REQUIRED			
44	MIN _____ MPa	RETURN MAX ALLOW ΔP _____ MPa		☐ OUTDOOR STORAGE OVER 6 MONTHS			
45	WATER SOURCE _____						
46	☐ AIR / GAS (FOR MOTORS)						
47	MAX PRESS _____ MPa	MIN PRESS _____ MPa					
48	☐ GAS COMPOSITION _____						
49	☐ CORROSIVES PRESENT _____						
50							

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CONSTRUCTION FEATURES

1 ☐ COMPRESSOR SPEEDS: 2 MAX. CONT. _____ r/min TRIP _____ r/min 3 GEAR CRITICALS 1ST _____ r/min 2ND _____ r/min 4 PINION CRITICALS: 5 1st PINION-1ST _____ r/min 2ND _____ r/min 6 2nd PINION-1ST _____ r/min 2ND _____ r/min 7 3rd PINION-1ST _____ r/min 2ND _____ r/min 8 PINION SPEEDS MAX. TRIP SPEEDS @ TRIP SPEED 9 1ST PINION _____ r/min 1ST/2ND STAGE _____ m/sec 10 2ND PINION _____ r/min 3RD/4TH STAGE _____ m/sec 11 3RD PINION _____ r/min 5TH/6TH STAGE _____ m/sec 12 COMPRESSOR SUITABLE FOR: 13 SLOW ROLL YES NO 14 ☐ ROTATION, VIEWED FROM INPUT SHAFT END: 15 (CW) (CCW) 16 ☐ COMPRESSOR CASING: 17 MODEL _____ CASING SPLIT _____ 18 MATERIAL _____ 19 SPECIAL LOW TEMP MATL. (4.3.11.4) _____ 20 MAX. ALLOWABLE WORK. PRESSURE MPa _____ 21 MAX. DESIGN PRESSURE MPa _____ 22 HYDRO TEST PRESSURE MPa _____ 23 MAX. OPER. TEMP. _____ °C MIN OPER. TEMP. _____ °C 24 ☐ IMPELLERS: 25 NO. OF IMPELLERS _____ 26 DIAMETERS (mm) 1ST STAGE _____ 2ND STAGE _____ 27 3RD STAGE _____ 4 TH. STAGE _____ 28 5TH STAGE _____ 6TH STAGE _____ 29 TYPE (OPEN, RADIAL, BACKWARD LEANING, ETC.) _____ 30 FABRICATION TYPE _____ 31 MATERIAL _____ COATING TYPE _____ 32 ☐ COMPRESSOR BEARINGS & BEARING HOUSINGS: 33 ☐ BEARING HOUSINGS: MATERIAL _____ 34 ☐ PINIONS WITH THRUST COLLAR ☐ YES ☐ NO 35 ☐ RADIAL BEARINGS: ☐ COMBINED RADIAL THRUST BEARINGS 36 TYPE: RADIAL _____ THRUST _____ NO. EACH _____ TOTAL _____ 37 LOADING Mpa ACT. _____ MAX. ALLOW _____ 38 THRUST Mpa ACT. _____ MAX. ALLOW _____ 39 MFR. _____ AREA mm² _____ 40 ☐ BULL GEAR: _____ RADIAL BEARING (DRIVER SIDE) 41 _____ COMBINED DOUBLE ACTING RADIAL THRUST 42 BEARING _____ 43 MANUFACTURER _____ TYPE _____ SPAN _____ mm 44 LOADING RADIAL Mpa ACT. _____ ALLOW _____ 45 LOADING THRUST Mpa ACT. _____ ALLOW _____ 46 AREA mm² _____ 47 GAS LOADING Mpa _____ CPLG. SLIP LOAD Mpa _____	SEALS: GEAR: ☐ TYPE _____ ☐ MATERIAL _____ COMPRESSOR SHAFT SEALS: ☐ TYPE _____ ☐ MATERIAL _____ BULL GEAR SHAFT: MATERIAL _____ DIA. @ GEAR mm _____ DIA. @ COUPLING mm _____ SHAFT END: ☐ TAPERED ☐ CYLINDRICAL SHAFT SLEEVES: AT SHAFT SEALS _____ MATERIAL _____ BULL GEAR: MIN. AGMA SERVICE FACTOR _____ ☐ ACTUAL S.F. _____ ☐ GEAR RIM MATERIAL _____ HARDNESS _____ ☐ GEAR FACE WIDTH _____ mm GEAR CENTRE MATL. _____ ☐ MECHANICAL EFFICIENCY _____ % ☐ AGMA QUALITY _____ ☐ PITCH DIA. _____ ☐ PITCH LINE VELOCITY _____ m/s PINIONS: NO. _____ SERVICE FACTORS _____ MATERIAL _____ HARDNESS _____ ☐ MAIN CONNECTIONS: (4.3.5.1.1) <table border="1"> <thead> <tr> <th></th> <th>SIZE</th> <th>RATING</th> <th>FACING</th> <th>POSITION</th> </tr> </thead> <tbody> <tr> <td>INLET</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>DISCHARGE</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>ATM. BLOWOFF</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>INLET FILTER</td> <td></td> <td></td> <td></td> <td></td> </tr> </tbody> </table> ☐ OTHER CONNECTIONS: <table border="1"> <thead> <tr> <th>SERVICE</th> <th>NO.</th> <th>SIZE</th> <th>TYPE</th> </tr> </thead> <tbody> <tr> <td>LUBE OIL INLET</td> <td></td> <td></td> <td></td> </tr> <tr> <td>LUBE OIL OUTLET</td> <td></td> <td></td> <td></td> </tr> <tr> <td>COOLING WATER INLET</td> <td></td> <td></td> <td></td> </tr> <tr> <td>COOLING WATER OUTLET</td> <td></td> <td></td> <td></td> </tr> <tr> <td>PRESSURE GAUGE</td> <td></td> <td></td> <td></td> </tr> <tr> <td>TEMPERATURE GAUGE</td> <td></td> <td></td> <td></td> </tr> <tr> <td>CONDENSATE DRAINS</td> <td></td> <td></td> <td></td> </tr> </tbody> </table> ☐ ALLOWABLE PIPING FORCES & MOMENTS: <table border="1"> <thead> <tr> <th rowspan="3"></th> <th colspan="2">INLET</th> <th colspan="4">DISCHARGE</th> </tr> <tr> <th>FORCE</th> <th>MOMT.</th> <th>FORCE</th> <th>MOMT.</th> <th>FORCE</th> <th>MOMT.</th> </tr> <tr> <th>N</th> <th>Nm</th> <th>N</th> <th>Nm</th> <th>N</th> <th>Nm</th> </tr> </thead> <tbody> <tr> <td>AXIAL</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>VERTICAL</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>HORIZ. 90°</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> </tbody> </table>		SIZE	RATING	FACING	POSITION	INLET					DISCHARGE					ATM. BLOWOFF					INLET FILTER					SERVICE	NO.	SIZE	TYPE	LUBE OIL INLET				LUBE OIL OUTLET				COOLING WATER INLET				COOLING WATER OUTLET				PRESSURE GAUGE				TEMPERATURE GAUGE				CONDENSATE DRAINS					INLET		DISCHARGE				FORCE	MOMT.	FORCE	MOMT.	FORCE	MOMT.	N	Nm	N	Nm	N	Nm	AXIAL							VERTICAL							HORIZ. 90°						
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CONSTRUCTION FEATURES

		SHOP INSPECTION AND TEST	OBSERVE	WITNESS
1	VIBRATION DETECTORS:			
2	O TYPE _____ ☐ MODEL _____	O SHOP INSPECTION	_____	_____
3	O MFR _____	O HYDROSTATIC (INCL. INTER AFTER COOLERS)	_____	_____
4	O No. AT EACH PINION BEARING _____ TOTAL No. _____	O PERFORMANCE TEST (ISO 5389/ ASME PTC 10)	_____	_____
5	O No. AT EACH DRIVER BEARING _____ TOTAL No. _____	O CONTROL PANEL FUNCTIONAL TEST	_____	_____
6	O OSCILLATOR-DEMULATOR SUPPLIED BY _____	O PERFORMANCE TEST AIR SINGLE POINT	_____	_____
7	O MFR _____ ☐ MODEL _____	O PERFORMANCE TEST AIR 5 POINTS	_____	_____
8	O MONITOR SUPPLIED BY _____	O COMPRESSOR WITH SHOP DRIVER	_____	_____
9	O LOCATION _____ ENCLOSURE _____	O COMPRESSOR WITH JOB DRIVER	_____	_____
10	O MFR _____ ☐ MODEL _____	O USE SHOP LUBE SYSTEM	_____	_____
11	☐ SCALE RANGE _____ O ALARM ☐ SET AT _____ mm	O USE JOB LUBE SYSTEM	_____	_____
12	O SHUTDOWN ♦ SET AT _____ mm O TIME DELAY _____ s.	O USE SHOP VIBRATION PROBES	_____	_____
13	O PER API Std 670 (4.2.5.7.2)	O USE JOB VIBRATION SYSTEM (COMPLETE)	_____	_____
14	AXIAL MOVEMENT DETECTOR:	O DISASSEMBLE- REASSEMBLE COMP. AFTER TEST	_____	_____
15	O TYPE _____ MODEL _____	O CHECK BEARINGS AND SEALS AFTER TEST	_____	_____
16	O MFR. _____ O No. REQUIRED _____	O NOISE LEVEL TEST (6.3.5.4)	_____	_____
17	O OSCILLATOR-DEMULATOR SUPPLIED BY _____	O FUNCTIONAL JOB LUBE SYSTEM TEST	_____	_____
18	O MFR _____ ☐ MODEL _____	O NONDESTRUCTIVE EXAMINATION (6.2.2.4) (6.2.2.5)	_____	_____
19	O MONITOR SUPPLIED BY _____	O RESIDUAL UNBALANCE CHECK (4.3.10.5.3)	_____	_____
20	O LOCATION _____ ENCLOSURE _____	O MAINTENANCE & RUNNING CLEARANCE (6.2.1.1c)	_____	_____
21	O MFR _____ MODEL _____	O ACCESS TO VENDOR'S QC PROGRAM	_____	_____
22	☐ SCALE RANGE _____ O ALARM ☐ SET AT _____ mm	O MECHANICAL RUN USING SPARE ELEMENTS (6.3.5.5)	_____	_____
23	O SHUTDOWN ♦ SET AT _____ mm O TIME DELAY _____ s.	O LOW AMBIENT TEMPERATURE IMPACT STRENGTH TEST	_____	_____
24	O PER API Std 670 (4.2.5.7.1) (4.2.5.7.2)		_____	_____
25	COUPLINGS: DRIVER-COMPRESSOR	☐ SPACE REQUIREMENTS:		
26	O MAKE _____	COMPLETE UNIT L _____ W _____ H _____		
27	☐ MODEL _____	CONTROL PANEL L _____ W _____ H _____		
28	☐ CPLG. RATING (kW/100 r/min) _____	MISCELLANEOUS:		
29	O LUBRICATION _____	☐ RECOMMENDED STRAIGHT RUN OF PIPE TO SUCTION _____		
30	O MOUNT COUPLING HALVES _____	O VENDOR'S REVIEW & COMMENTS ON CONTRACTOR'S PIPING & FOUNDATION		
31	O LIMITED END FLOAT REQUIRED _____	O TORSIONAL ANALYSIS REPORT REQUIRED (4.3.10.4.5)		
32	O SPACER LENGTH _____ mm	O VENDOR REP TO WITNESS INITIAL & HOT ALIGNMENT (4.1.20)		
33	O COUPLING PER ISO 10441	O BASE DESIGNED FOR COLUMN MOUNTING (4.2.4.10)		
34	O DRIVER HUB CYLINDRICAL KEYED	O SUBSOLE PLATES PROVIDED BY VENDOR (4.2.4.12)		
35	O COMPRESSOR HUB CYLINDRICAL KEYED	O QUANTITY OF DRAWINGS REQUIRED (7.2.3.1)		
36	O COMPRESSOR HUB TAPERED KEYED (4.5.8)	O PRINTS _____ O REPRODUCIBLES _____		
37	O DRIVER HUB TAPERED KEYED (4.5.8)	TIME REQUIRED _____		
38	O SPARK RESISTANT SAFETY GUARD (4.5.4)	O CERTIFIED COPIES OF TEST DATA (7.2.4.2c) _____		
39	☐ MASS kg:	O OTHER TEST DATA (7.2.4.2c) _____		
40	COMPRESSOR _____ DRIVER _____ BASE _____	O PROGRESS REPORT FREQUENCY (7.2.5) _____		
41	ROTORS. COMP. _____ DRIVER _____ GEAR _____	DYNAMICS (4.3.10)		
42	GEAR UPPER CASE caseCASE _____	O CRITICAL LATERAL SPEEDS DETERMINED (4.3.10.1.4)		
43	INTER COOLER(s) _____ COOLER BUNDLES _____	O CRITICAL TORSIONAL SPEEDS DETERMINED (4.3.10.4.2)		
44	AFTERCOOLER(s) _____ COOLER BUNDLES _____	O DAMPED UNBALANCED RESPONSE ANALYSIS (4.3.10.2.1)		
45	CONTROL PANEL _____	O STIFFNESS MAP OF UNDAMPED ROTOR RESPONSE (4.3.10.2.4 e)		
46	MAX. FOR MAINTENANCE (IDENTIFY) _____	O TEST STAND CRITICAL SPEED RESPONSE (4.3.10.1.4)		
47	TOTAL SHIPPING WEIGHT _____	O PACKAGE TORSIONAL VIBRATION ANALYSIS (4.3.10.4.5)		
48	REMARKS			
49	_____	O TRANSIENT TORSIONAL VIBRATION ANALYSIS (4.3.10.4.6)		
50	_____	O RESIDUAL UNBALANCE CHECK (4.3.10.5.3)		

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LUBE OIL SYSTEM					
1	PIPING MATERIALS: (4.2.3.2.1)		CARBON	STAINLESS	EMERGENCY LUBE OIL PUMP:
2			STEEL	STEEL	O AIR MOTOR DRIVEN OTHER _____
3	O OIL SUPPLY PIPING		_____	X	O SAFETY GUARD REQUIRED
4	O RETURN PIPING		_____	_____	STANDBY PUMP CONTROL RESET;
5			_____	_____	O MANUAL O AUTOMATIC
6	O CARBON STEEL SLIP-ON FLANGES ON		STAINLESS STL PIPE		O "ON-OFF-AUTO" SELECTOR SWITCH
7	SYSTEM COMPONENT SUPPLIERS:		MFR	MODEL	RESERVOIR;
8	O MAIN PUMP		_____	_____	O MATERIALS _____
9	O STANDBY PUMP		_____	_____	RETENTION TIME _____ MIN. CAPACITY _____ m ³
10	O ELECTRIC MOTOR(S)		_____	_____	O BAFFLE REQUIRED O INTERIOR COATING _____
11	O STEAM TURBINE(S)		_____	_____	FREE SURFACE AREA _____ m ²
12	O OIL COOLER(S)		_____	_____	O HEATER(S) (4.2.2.7) O ELECTRIC O STEAM
13	O OIL FILTER(S) (4.2.2.6)		_____	_____	O MIN. SITE _____ ° C/Oilcst @ MIN TEMP _____
14	O ACCUMULATOR(S)		_____	_____	O FILTER/BREATHES O FLANGED VENT
15	O SUCT. STRAINER(S)		_____	_____	O PRESS RELIEF VENT O INSULATION SUPPORTS
16	O CHECK VALVE(S)		_____	_____	O SPRING LOADED FILL CAP WITH S.S. STRAINER
17	O SWITCH VALVE(S)		_____	_____	COOLERS (4.2.2.5)
18	O PUMP COUPLING(S)		_____	_____	O HEATING STEAM TO WATERSIDE _____ MPa @ _____ °C
19	O RELIEF VALVES		_____	_____	O FOULING FACTOR: SHELL SIDE _____ TUBE SIDE _____
20	OIL SYSTEM PRESSURES:				O MAKE _____ O TYPE _____
21	O DESIGN _____ MPa		HYDROTEST _____ MPa		O DUTY _____ kJ/h O SURFACE _____ m ²
22	O PUMP RELIEF VALVE(S) SETTINGS _____ MPa				O CODE (S) _____
23	BASIC SYSTEM REQUIREMENTS (NORMAL OIL FLOW) (4.2.1.3)				O DESIGN PRESS. MPa : SHELL SIDE _____ TUBE SIDE _____
24	O LUBE OIL		m ³ /h	MPa	viscosity @ 48 °C
25	COMPRESSOR		_____	_____	O TUBES: O.D. _____ mm
26	O DRIVER (4.2.1.2C)		_____	_____	WALL THICKNESS (AVE.) (MIN.) _____ mm
27	PUMP: (4.2.2.2)		MAIN	STANDBY	LENGTH _____ THICKNESS _____
28	O HORIZONTAL		_____	_____	O MATERIALS:
29	O VERTICAL		_____	_____	TUBES: _____
30	O SUBMERGED		_____	_____	TUBE SHEETS: _____
31	O MOTOR-DRIVEN		_____	_____	SHELL _____
32	O TURBINE-DRIVEN		_____	_____	TUBE SUPPORT: _____
33	O SHAFT-DRIVEN		_____	_____	SHELL COVER/FLANGE _____
34	O CENTRIFUGAL		_____	_____	ACCUMULATORS;
35	O GEAR/SCREW		_____	_____	O SINGLE O MULTI
36	O FLANGE CONNECTED		_____	_____	O CODE DESIGN O CODE STAMP
37	O m ³ /h (RATED)		_____	_____	O MATERIAL
38	O @ MPa		_____	_____	O CORROSION ALLOWANCE (mm) _____
39	O kW MAX @ cst		_____	_____	O CAPACITY (TOTAL) m ³ _____
40	O DRIVER kW		_____	_____	O PRE-CHARGE PRESS (BARG) _____
41	O CASING MATERIAL		_____	_____	O DIRECT CONTACT TYPE O BLADDER TYPE
42	O SPEED		_____	_____	O BLADDER MATERIAL
43	O COUPLING		_____	_____	O WITH SUPPLY REGULATOR O MANUAL CHARGE VALVE
44	O GUARD		_____	_____	
45	O MECHANICAL SEAL		_____	_____	
46					
47					
48					
49					
50					

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LUBE OIL SYSTEM

FILTERS:

☐ O FILTER REQUIREMENT (4.2.2.6) MAKE _____ MODEL _____ ☐ Δ P COLLAPSE MPa _____
☐ FILTER MEDIUM _____ ☐ CASING MATERIAL _____
☐ DESIGN PRESSURE MPa _____ ☐ CARTRIDGE INDENT No. MAKE, MODEL _____
☐ Δ P CLEAN MPa _____ ☐ O FURNISH SET OF SPARE CARTRIDGE WITH FILTERS
☐ O SPECIAL COATING

INSTRUMENTATION

LOCAL CONTROL PANEL:

☐ O CONTROLS AND INSTRUMENTATION PER (4.2.5) ☐ LOCATION LOCAL/REMOTE (4.2.5.3.2)
☐ O STAND-BY SERVICE (4.1.5) (4.2.5.2.1,d)
☐ VIBRATION ISOLATORS ☐ STRIP HEATERS ☐ PURGE CONNECTIONS
☐ O METAL CASE, GLASS FRONT, STEM-TYPE MERCURY THERMOMETERS FURNISHED (4.2.5.4.1.3)
☐ O LIQUID FILLED PRESSURE GAUGES FURNISHED (4.2.5.4.2)
☐ O HIGH VIBRATION DRIVER ALARM AND SHUTDOWN (4.2.5.5.2.1)

INSTRUMENT SUPPLIERS:

16	PRESSURE GAUGES:	MFR. _____	SIZE AND TYPE _____
17	TEMPERATURE GAUGES:	MFR. _____	SIZE AND TYPE _____
18	LEVEL GAUGES:	MFR. _____	SIZE AND TYPE _____
19	DIFFERENTIAL PRESSURE GAUGES:	MFR. _____	SIZE AND TYPE _____
20	PRESSURE DEVICES:	MFR. _____	SIZE AND TYPE _____
21	DIFFERENTIAL PRESSURE DEVICES:	MFR. _____	SIZE AND TYPE _____
22	TEMPERATURE DEVICES:	MFR. _____	SIZE AND TYPE _____
23	LEVEL DEVICES:	MFR. _____	SIZE AND TYPE _____
24	CONTROL VALVES:	MFR. _____	SIZE AND TYPE _____
25	PRESSURE RELIEF VALVES:	MFR. _____	SIZE AND TYPE _____
26	THERMAL RELIEF VALVES	MFR. _____	SIZE AND TYPE _____
27	SIGHT FLOW INDICATORS:	MFR. _____	SIZE AND TYPE _____
28	GAS FLOW INDICATORS:	MFR. _____	SIZE AND TYPE _____
29	VIBRATION EQUIPMENT:	MFR. _____	SIZE AND TYPE _____
30	TACHOMETER:	MFR. _____	SIZE AND TYPE _____
31	SOLENOID VALVES:	MFR. _____	SIZE AND TYPE _____
32	ANNUNCIATOR:	MFR. _____	MODEL & No. POINTS _____
33	_____	MFR. _____	_____

PRESSURE GAUGE REQUIREMENTS

O SUPPLIED BY PURCHASER

□ SUPPLIED BY VENDOR

FUNCTION	LOCALLY MOUNTED	LOCAL PANEL	FUNCTION	LOCALLY MOUNTED	LOCAL PANEL
37 LUBE OIL DISCHARGE _____	☐ ☐	☐ ☐	COMPRESSOR SUCTION EACH STAGE _____	☐ ☐	☐ ☐
38 LUBE OIL FILTER Δ P _____	☐ ☐	☐ ☐	COMPRESSOR DISCHARGE EACH STAGE _____	☐ ☐	☐ ☐
39 LUBE OIL SUPPLY _____	☐ ☐	☐ ☐	_____	☐ ☐	☐ ☐
40 AIR FILTER/SILENCER Δ P _____	☐ ☐	☐ ☐	_____	☐ ☐	☐ ☐
41 _____	☐ ☐	☐ ☐	_____	☐ ☐	☐ ☐

TEMPERATURE GAUGE REQUIREMENTS:

FUNCTION	LOCALLY MOUNTED	LOCAL PANEL	FUNCTION	LOCALLY MOUNTED	LOCAL PANEL
44 LUBE OIL PUMP DISCHARGE FROM EACH _____	☐ ☐	☐ ☐	OIL COOLER INLET AND OUTLET _____	☐ ☐	☐ ☐
45 PINION JOURNAL BEARING _____	☐ ☐	☐ ☐	COMPRESSOR SUCTION EACH STAGE _____	☐ ☐	☐ ☐
46 DRIVER JOURNAL BEARINGS _____	☐ ☐	☐ ☐	COMPRESSOR DISCHARGE EACH STAGE _____	☐ ☐	☐ ☐
47 BULL GEAR JOURNAL BEARINGS _____	☐ ☐	☐ ☐	_____	☐ ☐	☐ ☐
48 COMPRESSOR THRUST BEARINGS _____	☐ ☐	☐ ☐	_____	☐ ☐	☐ ☐
49 DRIVER THRUST BEARINGS _____	☐ ☐	☐ ☐	_____	☐ ☐	☐ ☐
50 GEAR THRUST BEARINGS _____	☐ ☐	☐ ☐	_____	☐ ☐	☐ ☐
51 _____	☐ ☐	☐ ☐	_____	☐ ☐	☐ ☐

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INSTRUMENTATION

1	SWITCH CLOSURES: (4.2.5.5.1)					
2	ALARM CONTACTS SHALL:	☐ OPEN	☐ CLOSE TO SOUND ALARM AND BE NORMALLY	☐ ENERGIZED	☐ DE-ENERGIZED	
3	SHUTDOWN CONTACTS SHALL:	☐ OPEN	☐ CLOSE TO TRIP AND BE NORMALLY	☐ ENERGIZED	☐ DE-ENERGIZED	
4	NOTE: NORMAL CONDITION IS WHEN COMPRESSOR IS IN OPERATION.					
5	REMARKS: _____					
6	MISCELLANEOUS:					
7	PRE-ALARM AND SHUTDOWN DEVICES SHALL BE SEPARATE.					
8	CONTRACTOR ELECTRICAL AND INSTRUMENT CONNECTIONS WITHIN THE CONFINES OF THE COMPRESSOR BASE SHALL BE BROUGHT OUT TO TERMINAL BOXES.					
9	COMMENTS REGARDING INSTRUMENTATION; _____					
10	_____					
11	_____					
12	ALARM & SHUTDOWN DEVICES: (4.2.5.5) (TABLE 5)			☐ SUPPLIED BY PURCHASER ☐ SUPPLIED BY VENDOR		
13	FUNCTION	PRE-ALARM	SHUTDOWN	OPTIONAL FUNCTION	PRE-ALARM	SHUTDOWN
14	☐ O HI COMPRESSOR DISCHARGE TEMP.	_____	_____	☒ O HI LAST STG INLET TEMP	_____X_____	_____X_____
15	☐ O HI COMPRESSOR THRUST BRG. TEMP.	_____	_____	☒ O LOW LUBE OIL PRESSURE	_____X_____	_____X_____
16	☐ O COMPRESSOR AXIAL POSITION	_____	_____	☒ O HI OIL SUPPLY TEMP	_____X_____	_____X_____
17	☐ O DRIVER AXIAL POSITION	_____	_____	☒ O HI OIL FILTER Δ P	_____X_____	_____X_____
18	☐ O HI DRIVER THRUST BRG. TEMP	_____	_____	☒ O HI OIL COOLER Δ P	_____X_____	_____X_____
19	☐ O HI VIBRATION DRIVER	_____	_____	☐ O LOW SEAL SYSTEM PRESS.	_____	_____
20	☒ O HI VIBRATION COMPRESSOR	_____	_____	☒ O STAND BY OIL PUMP RUNNING	_____X_____	_____
21	☒ O LOW LUBE OIL RESERVOIR	_____	_____	☐ O _____	_____	_____
22	☒ O HI INLET AIR FILTER Δ P	_____	_____	☐ O _____	_____	_____
23	☒ O PANEL PURGE FAILURE	_____	_____	☐ O _____	_____	_____
24	☒ O SURGE RECOGNITION	_____	_____	☐ O _____	_____	_____
25	☐ O _____	_____	_____	☐ O _____	_____	_____
26	☐ O _____	_____	_____	☐ O _____	_____	_____
27	MISCELLANEOUS INSTRUMENTATION:					
28	☐ O SIGHT FLOW INDICATORS: EACH JOURNAL & THRUST BEARING OIL RETURN LINE					
29	☐ O LEVEL GAUGES, LUBE OIL RESERVOIR, SEPARATOR, CONDENSATE TRAPS					
30	☒ O VIBRATION AND SHAFT POSITION PROBES & OSCILLATOR-DEMODULATORS					
31	☐ O VIBRATION AND SHAFT POSITION READOUT EQUIPMENT					
32	VIBRATION READOUT LOCATED ON: LOCAL PANEL ☐ SEPARATE PANEL ☐ MAIN BOARD					
33	☐ O DRIVER SPEED PICK-UP DEVICES					
34	☐ O DRIVER SPEED INDICATORS					
35	DRIVER SPEED INDICATORS LOCATED ON: ☐ LOCAL PANEL ☐ SEPARATE PANEL ☐ MAIN BOARD					
36	☐ O REMOTE HAND SPEED CHANGE MOUNTED ON LOCAL PANEL					
37	☒ O ALARM HORN & ACKNOWLEDGEMENT DEVICE					
38	☒ O TEST LAMP PUSH BUTTON (4.2.5.3.1i)					
39	☒ O PERMISSIVE START WITH PILOT LIGHT (4.2.5.3.1j)					
40	☒ O PILOT LIGHT INCOMING CIRCUITS (4.2.5.3.1k)					
41	☒ O START STOP DEVICE (4.2.5.3.1l)					
42	☒ O CONTROL MODE SELECTOR DEVICE (4.2.5.2.2)					
43	☐ O MANUAL OVERRIDE DEVICE (4.2.5.2.5)					
44	REMARKS: _____					
45	_____					
46	_____					
47	_____					
48	_____					
49	_____					
50	_____					

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(INTER) (AFTER) COOLER (S)

DUTY _____	COOLER ITEM No. _____
SUPPLIER _____	No. UNITS REQUIRED _____
MODEL No. _____	TYPE _____

OPERATING CONDITIONS

	SHELL SIDE		TUBE SIDE	
☐ FLUID				
☐ TOTAL FLOW kg/h	@	°C	@	°C
☐ SPECIFIC GRAVITY	@	°C	@	°C
☐ THERMAL COND. w/(m ² C/m)	@	°C	@	°C
☐ SPECIFIC HEAT KJ/(kg-K)	@	°C	@	°C
☐ VISCOSITY cst	@	°C	@	°C
☐ OPERATING TEMPERATURE C	IN	OUT	IN	OUT
INLET PRESSURE MPa				
INLET VELOCITY m/s				
☐ PRESSURE DROP MPa	ALLOW.	CALC.	ALLOW.	CALC.
☐ DESIGN TEMPERATURE C				
PRESSURE MPa	MIN.	TEST	MIN.	TEST
FOULING RESISTANCE m ² k/w				
☐ MIN. CORROSION ALLOWANCE mm				
☐ NUMBER OF PASSES PER SHELL				

CONSTRUCTION DETAILS

☐ TOTAL AREA (1), m ² _____	☐ SHELL, No. X ID. _____ X _____
☐ LMTD _____	☐ TUBES, No. PER SHELL _____
CORRECTED MTD _____	☐ OUTSIDE DIAMETER X LENGTH _____
☐ TRANSFER RATE, CLEAN _____	☐ GAUGE, BWG _____ AVG., MIN. WALL
☐ TRANSFER RATE, SERVICE _____	☐ TUBE PITCH _____ mm Δ ☐ O
CROSS BAFFLES, TYPE _____	☐ REMOVABLE TUBE BUNDLE ☐ YES ☐ NO
☐ CODE REQUIREMENTS (2) _____ TEMA	☐ CODE STAMP ☐ YES ☐ NO
☐ MASSES _____ EACH BUNDLE _____ kg	FULL OF WATER _____ kg

NOZZLE SIZES

	SHELL SIDE			TUBE SIDE		
	NO.	SIZE	RATING & FACING	NO.	SIZE	RATING & FACING
INLET						
OUTLET						
DRAIN						
VENT						

O MATERIALS

TUBES _____	BAFFLES _____
TUBE SHEETS _____	CHANNEL _____
SHELL _____	CHANNEL FLANGES _____
SHELL FLANGES _____	CHANNEL NOZZEL FLANGES _____

(1) OUTSIDE TUBE AREA EXCLUDING AREA IN TUBE SHEETS.

(2) UNITS EXEMPT FROM CODE STAMP SHELL HAVE LONGITUDINAL WELD SEAMS SPOT EXAMINED PER REFERENCED PRESSURE VESSEL SPECIFICATION.

(3) FOR GAS COOLED BY AIR SEE SEPARATE APPLICABLE DATA SHEETS.

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1	APPLICABLE TO ☐ PROPOSAL ☐ PURCHASE ☐ AS BUILT	FURNISHED BY (5.1.1) _____
2	FOR _____	UNIT _____
3	SITE _____	DRIVER EQUIPMENT _____
4	SERVICE _____	NO. REQUIRED _____
5	MANUFACTURER _____ MODEL _____	SERIAL NO. _____
6	NOTE: ☐ INDICATES INFORMATION TO BE COMPLETED BY PURCHASER	☐ BY MANUFACTURER
7	MOTOR DESIGN DATA	MOTOR DESIGN DATA (CONTINUED)
8	APPLICABLE SPECIFICATIONS	STARTING (4.4.1.3) (4.4.2.5)
9	☐ NEMA _____	☐ FULL VOLTAGE ☐ REDUCED VOLTAGE _____ %
10	☐ _____	☐ LOADED ☐ UNLOADED
11	☐ _____	☐ VOLTAGE DIP _____ %
12	SITE DATA	VIBRATION
13	AREA: ☐ ZONE _____ TEMP. CLASS _____	☐ STANDARD ☐ _____
14	☐ ALTITUDE _____ m AMBIENT TEMP. MAX °C _____ MIN °C _____	NOISE
15	UNUSUAL CONDITIONS ☐ DUST ☐ FUMES	☐ ISO 9614 STANDARD ☐ _____ dba
16	☐ OTHER _____	_____
17	DRIVE SYSTEM	_____
18	☐ DIRECT CONNECTED	ACCESSORY EQUIPMENT
19	☐ GEAR	☐ BASEPLATE ☐ SOLE PLATE ☐ STATOR SHIFT
20	☐ OTHER _____	☐ MANUFACTURERS STANDARD FANS ☐ NON SPARKING FANS
21	TYPE OF MOTOR (4.4.2.5)	☐ DC EXCITATION
22	☐ SQUIRREL CAGE INDUCTION ☐ NEMA DESIGN	☐ kW REQUIRED _____ VOLT _____
23	☐ SYNCHRONOUS	BY ☐ PURCHASER ☐ MANUFACTURER
24	☐ POWER FACTOR REQUIRED _____	DESCRIPTION _____
25	EXCITATION: ☐ BRUSHLESS ☐ SLIP RING	☐ ENCLOSED COLLECTOR RINGS
26	☐ FIELD DISCHARGE RESISTOR BY MOTOR MANUFACTURER	☐ PURGED : MEDIUM _____ PRESSURE _____ MPa
27	☐ WOUND ROTOR INDUCTION	☐ EXPLOSION RESISTANT NON PURGED
28	☐ _____	☐ FORCED VENTILATION
29	ENCLOSURE	☐ m ³ /h _____ PRESSURE DROP _____ mbar
30	☐ ZONE _____ GROUP _____ TEMP. _____	☐ BEARING TEMPERATURE DEVICES:
31	☐ TEFC SEVERE DUTY ☐ EXPLOSION PROOF	☐ LOCATION _____
32	☐ WEATHER PROTECTED? TYPE _____	☐ DESCRIPTION _____
33	☐ TEWAC ☐ TEIGF, USING _____ GAS	☐ SET @ _____ °C FOR ALARM _____ °C FOR SHUTDOWN
34	☐ DOUBLE WALL CARBON STEEL TUBES	☐ SPACE HEATERS
35	☐ WATER SUPPLY PRESSURE _____ MPa TEMP _____ °C	☐ _____ kW ☐ _____ VOLT _____ PHASE _____ HERTZ
36	☐ WATER ALLOW: Δ P _____ MPa & TEMP. RISE _____ °C	☐ MAX. SHEATH TEMPERATURE _____ %
37	☐ WATER SIDE MIN. CORROSION ALLOWANCE _____ mm	WINDING TEMPERATURE DETECTOR
38	AND FUEL FACTOR _____	☐ THERMISTORS : NO/PHASE _____
39	☐ (AIR) (GAS) SUPPLY PRESSURE _____ MPa	TYPE: ☐ POS. TEMPERATURE COEFF. ☐ NEGATIVE TEMP. COEFF.
40	☐ FORCED VENTILATED	TEMPERATURE DEVICE ☐ YES ☐ NO
41	☐ OPEN DRIP PROOF	☐ RESISTANCE TEMPERATURE DETECTORS: NO/PHASE _____
42	☐ OPEN	☐ RESISTANCE MATERIAL _____ ☐ _____ OHM
43	☐ _____	SELECTOR SWITCH & INDICATOR BY: ☐ PURCHASER ☐ MANUFACTURER
44	☐ _____	☐ MAX. STATOR WINDING TEMPERATURES.
45	BASIC DATA (4.4.2.5)	_____ °C FOR ALARM _____ °C FOR SHUTDOWN
46	☐ _____ VOLT _____ PHASE _____ HERTZ	WINDING TEMPERATURE & DETECTOR & SPACE HEATER LEADS:
47	☐ NAMEPLATE kW _____ SERVICE FACTOR _____	☐ IN SAME CONDUIT BOX
48	☐ INSULATION CLASS _____ TYPE _____	☐ IN SEPERATE CONDUIT BOXES
49	☐ TEMPERATURE RISE _____ °C ABOVE _____ °C BY _____	
50		