INTERNATIONAL STANDARD

ISO 10442

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

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

Reference number
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.

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*

ABMA[1] 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*

AGMA[2] 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*

ASME[3] PTC 10, *Performance test code on compressors and exhausters*

ASTM[4] A275, *Standard test method for magnetic particle examination of steel forgings*

DIN[5] 3990, *Load calculations for gearings*

NEMA[6] SM 23, *Steam turbines for mechanical drive service*

TEMA[7] *Standards of the Tubular Exchanger Manufacturers Association, eight edition*

3 Terms and definitions

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

3.1
bull gear
low-speed rotor of the integral gear

3.2
inlet volume flow
volume flow rate determined at the conditions of pressure, temperature, compressibility and gas composition, including moisture, at the compressor inlet flange

[ISO 10439:2002, definition 3.5]

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

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

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

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

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

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

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

3.3
maximum allowable temperature
maximum continuous temperature for which the manufacturer has designed the equipment (or any part to which the term is referred) when handling the specified fluid at the specified pressure

[ISO 10439:2002, definition 3.6]

3.4
maximum allowable working pressure
maximum continuous pressure for which the manufacturer has designed the equipment (or any part to which the term is referred) when operating at the maximum allowable temperature

[ISO 10439:2002, definition 3.7]

3.5
normal operating point
point at which usual operation is expected and optimum efficiency is desired

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

[ISO 10439:2002, definition 3.11]

3.6
pinion
high-speed rotor, or rotors, of the integral gear

3.7
piping design code
recognized piping standard specified or agreed by the purchaser

EXAMPLE ASME B31.3.

3.8
pressure casing
composite of all the stationary pressure-containing parts of the unit

3.9
pressure design code
recognized pressure vessel standard specified or agreed by the purchaser

EXAMPLE ASME Boiler and Pressure Vessel Code, Section VIII.

[ISO 10439:2002, definition 3.14]

3.10
rated discharge pressure
highest pressure required to meet the specified operating conditions

3.11
rated operating point
operating point at which the rated volume flow and the rated discharge pressure are attained

3.12
rated operating speed
speed required to meet the conditions specified by the purchaser for the intended service

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

3.13
rated volume flow
inlet volume flow required by the specified operating conditions

3.14
standby service
service condition in which a normally idle or idling piece of equipment is capable of immediate automatic or manual start-up and continuous operation

3.15
trip speed
speed at which the independent emergency overspeed device operates to shut down a prime mover

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

[ISO 10439:2002, definition 3.19]

4 Basic design

4.1 General

4.1.1 Purchaser decision or information

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

4.1.2 Packaged equipment

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

a) centrifugal compressor with integral speed-increasing gear unit;

b) intercoolers, moisture separators and V-notched gate drain valves;

c) inlet throttle device (valve or variable-inlet guide vanes);

d) driver (motor or turbine as specified);

e) couplings and guards;

f) “lube”-oil system;

g) vibration monitoring system;

h) controls and instrumentation;

i) instrument and control panel;

j) common baseplate.

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

4.1.3 Shipped loose equipment

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

a) aftercooler with moisture separator and V-notched gate drain valve;

b) discharge check valve;

c) discharge blowoff or by-pass valve;

d) air inlet filter-silencer;

e) blowoff or by-pass silencer.

4.1.4 Other equipment

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

4.1.5 Standby service

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

4.1.6 Turbine-driven equipment

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

4.1.7 Normal operating point

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

4.1.8 Environmental conditions

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

4.1.9 Engineering coordination

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

4.1.10 Package arrangement

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

4.1.11 Oil reservoirs and housings

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

4.1.12 Motors and electrical components

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

4.1.13 External parts

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

4.1.14 Service life

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

4.1.15 Performance criteria

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

4.1.16 Sound pressure level

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

4.1.17 Pressure design code

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

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

4.1.18 Heat exchangers

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

The vendor shall notify the purchaser if the criteria for minimum temperature rise and velocity over heat exchange surfaces result in a conflict. The criterion for velocity overheat 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 m^2 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 (⅛ 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.

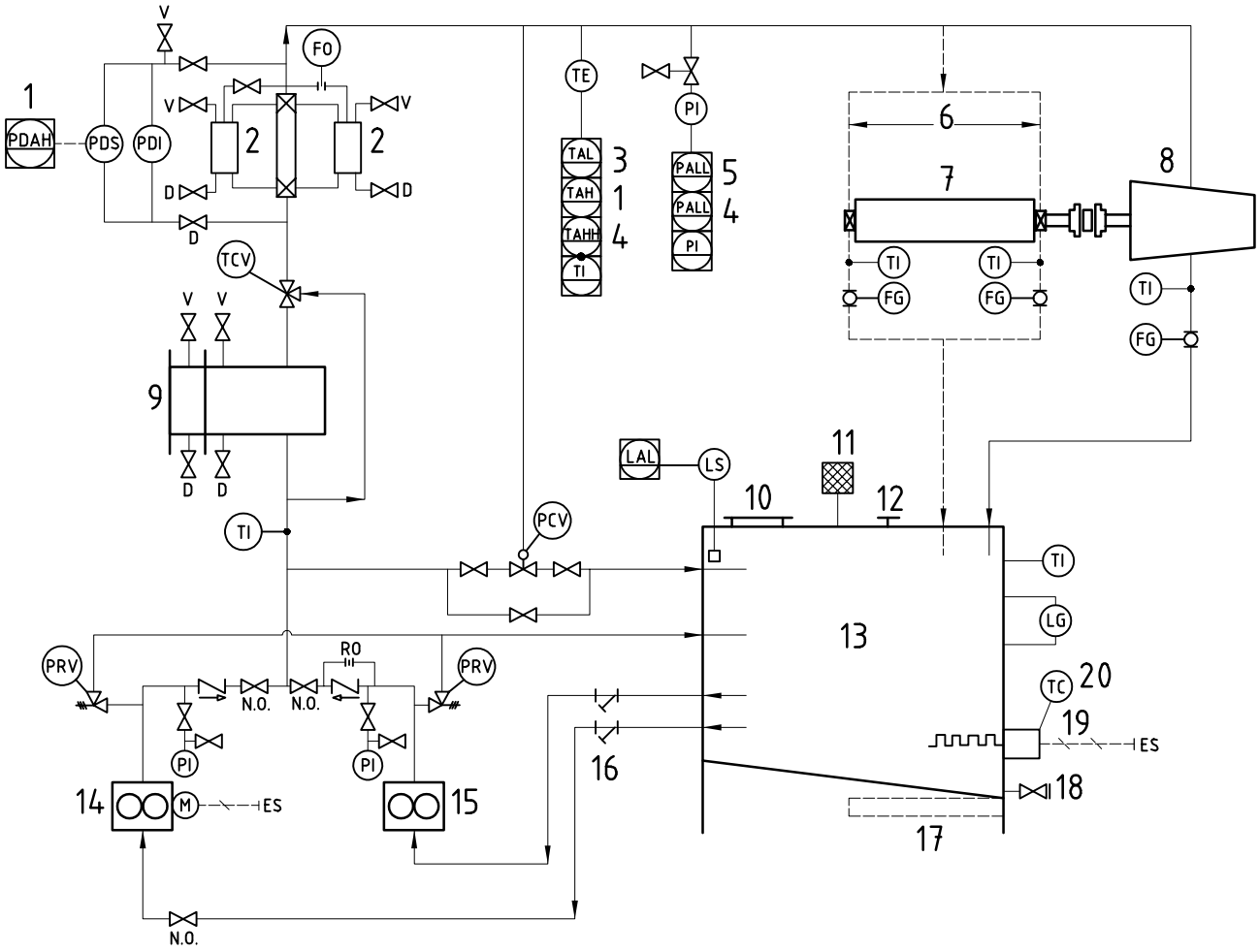
4.2.2.4 A separate, direct-acting back-pressure control valve with manual bypass shall be provided and sized to maintain system pressure even when both pumps are operating.

- **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 m^2 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.

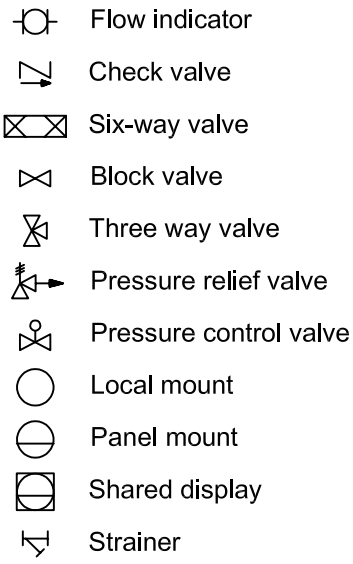


A common suction line may be used, but shall then be sized for the capability of two pumps.

Key

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

Figure 1 — Sketch of minimum requirements for pressure lubrication system



D	Drain
ES	Electronic supply
FG	Flow glass
FO	Flow restriction orifice
LG	Level gauge
LS	Level switch
LAL	Level alarm-low
N.O.	Normally open
PCV	Pressure control valve
PRV	Pressure relief valve
PDI	Pressure differential indicator
PDS	Pressure differential switch
PDAH	Pressure differential alarm-high

PI	Pressure indicator
PT	Pressure transmitter
PAL	Pressure alarm-low
PALL	Pressure alarm-low, low
RO	Restriction orifice
TE	Temperature element
TAL	Temperature alarm-low
TAH	Temperature alarm-high
TI	Temperature indicator
TC	Temperature controller
TCV	Temperature control valve
V	Vent

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/cm^2.

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

a) the capacity to avoid frequent refilling, to provide adequate allowance for system rundown, and to settle moisture and foreign matter adequately;

b) provisions to eliminate air and to minimize flotation of foreign matter to pump suctions;

c) separate fill and vent connections, a level indicator with an armoured gauge glass and a breather suitable for outdoor use;

d) a sloped bottom and connections for complete drainage;

e) cleanout openings large enough to provide access for thorough cleaning;

f) 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);

g) 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 ½), DN 20 (NPS ¾) 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 ¼).

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 ¼ 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 (¾ 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

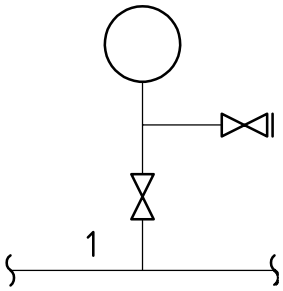
- Pressure gauges (not including built-in instrument air gauges), unless otherwise specified, shall be furnished with stainless steel bourdon tubes and stainless steel movements, 100 mm (4½ in) dials [160 mm dials for the range

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.

  a) The alarm level shall always precede shutdown level.

  b) The alarm and shutdown indications shall consist of flashing lights and the sounding of a horn or buzzer.

  c) 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.

  d) 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.

  e) When field contacts return to normal, the annunciation lights and system shall return to the normal conditions after being reset.

  f) 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 $1^1/_2$ times the major diameter of the stud; the first $1^1/_2$ 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 µm to 0,8 µm (16 micro-inches to 32 micro-inches) Ra, 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 µm, 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, babbitted 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:

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

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 Shafts 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

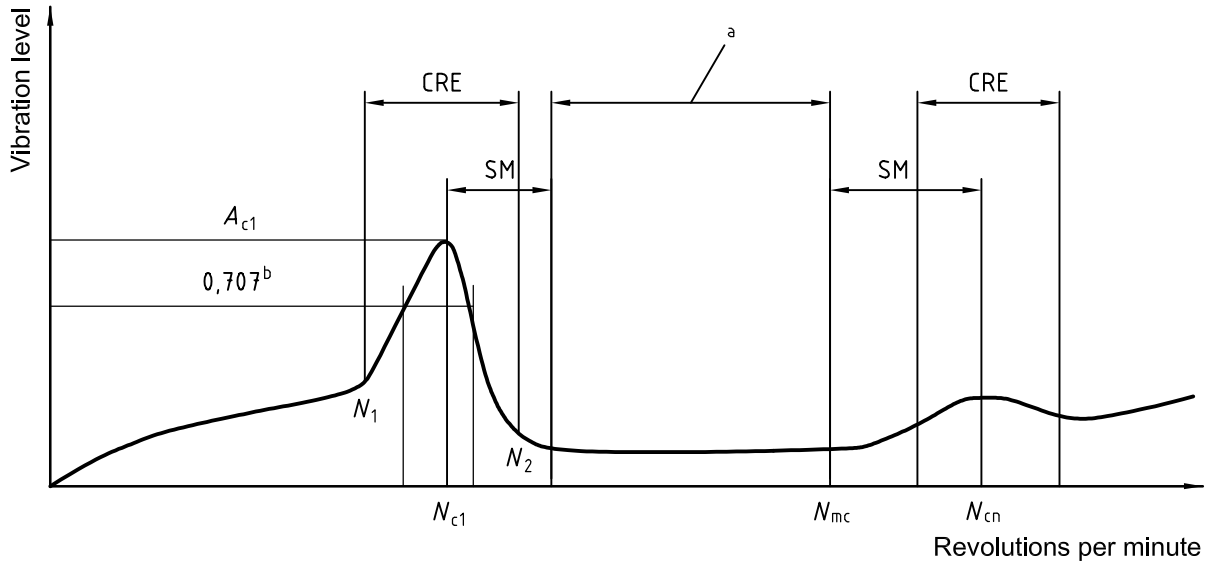
4.3.10.1 Critical speed

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 ....nth) 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	μ	amplification factor $\mu = \frac{N_{c1}}{N_2 - N_1}$
N_{cn}	critical speed, nth	SM	separation margin
N_{mc}	maximum continuous speed, 105 %	CRE	critical response envelope
N_1	initial (lesser) speed at 0,707 times peak amplitude (critical)	A_{c1}	amplitude at N_{c1}
N_2	final (greater) speed at 0,707 times peak amplitude (critical)	A_{cn}	amplitude at N_{cn}
$N_2 - N_1$	peak width at the half-power point		

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:

a) each rotor's operating speed;

b) 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/m^3, 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 torsional 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:

$$U = \frac{6\ 350 \times W}{N} \quad \text{for } N \leqslant 25\,000 \tag{5}$$

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

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:

$$A = 25{,}4\sqrt{12\,000/N} \tag{7}$$

Or, in U.S. customary units:

$$A = \sqrt{12\ 000/N} \tag{8}$$

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 Materials[8)]

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.

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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 gades 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 °C (− 20 °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 studded 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 reproducibles 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.

Annex A
(informative)

Data sheets

INTEGRALLY GEARED CENTRIFUGAL COMPRESSOR DATA SHEET ISO 10442

ENQUIRY/ORDER NO. _____

JOB NO. _____ ITEM NO. _____

REVISION	BY	DATE	CHKD.	DATE	APPD.	DATE

APPLICABLE TO: O PROPOSAL O PURCHASE O AS BUILT (7.2.1.2)

FOR _____ UNIT _____

SITE _____ SERIAL No._____

SERVICE _____ NO. REQUIRED _____

NOTE: INFORMATION TO BE COMPLETED: O BY PURCHASER ☐ BY MANUFACTURER

GENERAL

COMPRESSOR MFR._____MODEL SIZE AND TYPE _____

DRIVER MFR _____ DRIVER TYPE _____ RATED kW _____r/min _____

DRIVER SYSTEM ❍ DIRECT COUPLED ❍ OTHER _____

Pressure design code (4.1.17) _____ Piping design code (4.2.3.1.1) _____ Applicable regulations (4.1.22) _____

OPERATING CONDITIONS	NORMAL	RATED	LOW AMBIENT	OTHER
(ALL DATA ON PER UNIT BASIS)	(4.1.7)	(3.13)	(4.4.4)	
O GAS HANDLED (ALSO SEE PAGE 2)				
O DELIVERED VOL.FLOW, AT 1.013 MPa & 0 ºC, Z =1, DRY (m^3/h)				
O MASS FLOW, [WET/DRY] (kg/h)				
INLET CONDITIONS				
O PRESSURE (MPa)				
O TEMPERATURE (ºC)				
O RELATIVE HUMIDITY (%)				
O MOLAR MASS (%)				
O ISENTROPIC EXPONENT (K_1)				
☐ COMPRESSIBILITY (Z_1)				
☐ INLET VOLUME FLOW, [WET/DRY] (m^3/h)				
DISCHARGE CONDITIONS				
☐ PRESSURE (MPa)				
☐ TEMPERATURE (ºC)				
☐ ISENTROPIC EXPONENT (K_2)				
☐ COMPRESSIBILITY (Z_2)				
PERFORMANCE				
☐ POWER REQUIRED, AT DRIVER COUPLING, (kW)				
☐ MECHANICAL LOSSES, (kW)				
☐ SPEED (r/min)				
☐ ESTIMATED SURGE AT ABOVE SPEED (m^3/h)				
☐ POLYTROPIC HEAD, SPECIFIC COMPRESSION WORK FLANGE TO FLANGE (kJ/kg)				
☐ POLYTROPIC EFFICIENCY FLANGE TO FLANGE (%)				
O GUARANTEE POINT FLANGE TO FLANGE				
☐ MAX. Δ P ACROSS INLET FILTER (MPa)				
☐ MAX. Δ P ACROSS AFTER COOLER (MPa)				
INCLUDED IN CALCULATION YES/NO				
❍ AFTERCOOLER OUTLET TEMP (°C)				
❍ COOLING WATER INLET TEMP. (°C)				
☐ PERFORMANCE CURVE NO.				

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

_____

_____

PROCESS CONTROL METHOD (4.2.5.2.1)

❍ INLET THROTTLE DEVICE (CONSTANT DISCHARGE PRESSURE) [4.2.5.2.1a)]

❍ VARIABLE INLET GUIDE VANES

❍TWO STEP CONTROL: _____ MPa TO _____ MPa DISCHARGE PRESSURE

❍ AUTOMATIC DUAL CONTROL (INLET THROTTLING AND TWO STEP)

❍ AUTOMATIC START AND STOP

❍ CONSTANT DISCHARGE PRESSURE BASE MODE (BLOWOFF) [4.2.5.2.1, e)]

❍ STANDBY SERVICE AUTOMATIC START-UP

THE CONTROL SYSTEM SHALL BE SUITABLE FOR PARALLEL OPERATION:

_____ CENTRIFUGAL COMPRESSORS _____ RECIPROCATING COMPRESSORS _____BOTH

CENTRIFUGAL COMPRESSOR
DATA SHEET ISO 10442

PAGE 2 of 12

REVISION	BY	DATE	CHKD.	DATE	APPD.	DATE

OPERATING CONDITIONS (Continued)

GAS ANALYSIS:		NORMAL	RATED	OTHER CONDITIONS				REMARKS:
O MOL% O				A	B	C	D	
	M kg/kmol							
AIR	28.966							
OXYGEN	32.000							
NITROGEN	28.016							
WATER VAPOUR	18.016							
CARBON MONOXIDE	28.010							
CARBON DIOXIDE	44.010							
TOTAL								
AVG. MOL. MASS								

REMARKS:

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LOCATION, SITE DATA

O INDOOR O HEATED O UNDER ROOF

O OUTDOOR O UNHEATED O PARTIAL SIDES

O GRADE O MEZZANINE O _____

O WINTERISATION REQ. O TROPICALISATION REQD.

SITE DATA:

O ELEVATION _____m BAROMETER _____ MPa

O RANGE OF AMBIENT TEMPS:

	°C	RELATIVE HUMIDITY
SITE RATED	_____	_____
NORMAL	_____	_____
MAXIMUM	_____	_____
MINIMUM	_____	_____

LOCATION: AUXILIARY EQUIPMENT

O CONTROL PANEL _____

O LUBE/SEAL OIL CONSOLE _____

O NITROGEN GENERATOR _____

O _____

UNUSUAL CONDITIONS: O DUST O FUMES

O OTHER (4.1.8)

O **AREA CLASSIFICATION (4.1.12)**

	ZONE	GAS GROUP
COMPRESSOR SKID	_____	_____
LUBE/SEAL OIL CONSOLE	_____	_____
CONTROL PANEL	_____	_____
NITROGEN GENERATOR	_____	_____
	_____	_____

O **UTILITY CONDITIONS:**

STEAM:	DRIVERS		HEATING	
INLET MIN _____ MPa	_____ °C		_____ MPa	_____°C
NORM _____ MPa	_____ °C		_____ MPa	_____°C
MAX _____ MPa	_____ °C		_____ MPa	_____°C
EXHAUST. MIN_____ MPa	_____ °C		_____ MPa	_____°C
NORM _____ MPa	_____ °C		_____ MPa	_____°C
MAX _____ MPa	_____ °C		_____ MPa	_____°C

O **ELECTRICAL SUPPLY (4.1.12)**

	DRIVERS	HEATING	CONTROL	SHUTDOWN
VOLTAGE	_____	_____	_____	_____
HERTZ	_____	_____	_____	_____
PHASE	_____	_____	_____	_____

O **COOLING WATER:**

TEMP. INLET _____ °C MAX RETURN _____ °C

PRESS NORM _____ MPa DESIGN _____MPa

MIN RETURN MAX ALLOW ΔP _____ MPa

_____MPa

WATER SOURCE _____

O **AIR / GAS (FOR MOTORS)**

MAX PRESS _____ MPa MIN PRESS _____ MPa

O GAS COMPOSITION _____

O CORROSIVES PRESENT _____

_____

SPECIFICATIONS

NOISE SPECIFICATIONS / (4.1.16)

O dba

_____

O APPLICABLE TO MACHINE

SEE SPECIFICATION

_____

O APPLICABLE TO NEIGHBOURHOOD

SEE SPECIFICATION

_____

ACOUSTIC HOUSING: O YES O NO

APPLICABLE SPECIFICATIONS:

O ISO 10442 _____

_____

_____

PAINTING:

O MANUFACTURERS STANDARD

O OTHER _____

_____

UTILITY CONSUMPTION

ELECTRIC	kW	LOCKED ROTOR AMPS	FULL LOAD AMPS
MAIN DRIVER	_____	_____	_____
MAIN LUBE OIL PUMP	_____	_____	_____
AUX. LUBE OIL PUMP	_____	_____	_____
_____	_____	_____	_____

OIL HEATER _____W _____

SPACE HEATER_____W_____

STEAM	Kg/h	INLET MPa	EXHAUST MPa
MAIN DRIVER	_____	_____	_____
_____	_____	_____	_____

COOLING WATER

	LO. COOLER	INTER COOLER	AFTER COOLER	OTHER	
QUANTITY m^3/h	_____	_____	_____	_____	___
INLET TEMP. °C	_____	_____	_____	_____	___
OUTLET TEMP. °C	_____	_____	_____	_____	___
INLET PRESSURE. MPa	_____	_____	_____	_____	___
OUTLET PRESSURE MPa	_____	_____	_____	_____	___
MAX. WORKING PRESS. MPa	_____	_____	_____	_____	___
TOTAL C.W. m^3/h	_____	_____	_____	_____	___
_____	_____	_____	_____	_____	___
AIR _____	_____	_____	_____	_____	___

SHIPMENT: (6.4.1)

O DOMESTIC O EXPORT O EXPORT BOXING REQUIRED

O OUTDOOR STORAGE OVER 6 MONTHS

_____

_____

_____

_____

_____

_____

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CONSTRUCTION FEATURES

☐ **COMPRESSOR SPEEDS:**
MAX. CONT._____ r/min TRIP_____r/min
GEAR CRITICALS 1ST_____ r/min 2ND _____r/min
PINION CRITICALS:
1st PINION-1ST _____r/min 2ND _____r/min
2nd PINION-1ST_____r/min 2ND _____r/min
3rd PINION-1ST_____r/min 2ND _____r/min

PINION SPEEDS	MAX. TRIP SPEEDS @ TRIP SPEED
1ST PINION _____r/min	1ST/2ND STAGE_____ m/sec
2ND PINION _____r/min	3RD/4TH STAGE_____ m/sec
3RD PINION _____r/min	5TH/6TH STAGE_____ m/sec

COMPRESSOR SUITABLE FOR:
SLOW ROLL YES NO

☐ **ROTATION, VIEWED FROM INPUT SHAFT END:**
(CW) (CCW)

☐ **COMPRESSOR CASING:**
MODEL _____ CASING SPLIT _____
MATERIAL _____
SPECIAL LOW TEMP MATL. (4.3.11.4) _____
MAX. ALLOWABLE WORK. PRESSURE MPa _____
MAX. DESIGN PRESSURE MPa _____
HYDRO TEST PRESSURE MPa _____
MAX. OPER. TEMP. _____ °C MIN OPER. TEMP. _____°C

☐ **IMPELLERS:**
NO. OF IMPELLERS _____
DIAMETERS (mm) 1ST STAGE _____ 2ND STAGE _____
3RD STAGE _____ 4 TH. STAGE _____
5TH STAGE _____ 6TH STAGE _____
TYPE (OPEN, RADIAL, BACKWARD LEANING, ETC.)_____
FABRICATION TYPE _____
MATERIAL _____ COATING TYPE _____

☐ **COMPRESSOR BEARINGS & BEARING HOUSINGS:**
☐ BEARING HOUSINGS: MATERIAL _____
☐ PINIONS WITH THRUST COLLAR ☐ YES ☐ NO
☐ RADIAL BEARINGS: ☐ COMBINED RADIAL THRUST BEARINGS
TYPE: RADIAL _____THRUST_____ NO. EACH_____TOTAL _____
LOADING Mpa ACT. _____ _____ _____ MAX. ALLOW _____
THRUST Mpa ACT. _____ _____ _____ MAX. ALLOW _____
MFR._____ AREA mm^2_____
☐ BULL GEAR:_____RADIAL BEARING (DRIVER SIDE)
_____COMBINED DOUBLE ACTING RADIAL THRUST BEARING
MANUFACTURER_____ TYPE_____SPAN _____mm
LOADING RADIAL Mpa ACT. _____ ALLOW _____
LOADING THRUST Mpa ACT. _____ ALLOW _____
AREA mm^2 _____
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: O TAPERED O 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)**

	SIZE	RATING	FACING	POSITION
INLET				
DISCHARGE				
ATM. BLOWOFF				
INLET FILTER				

☐ **OTHER CONNECTIONS:**

SERVICE	NO.	SIZE	TYPE
LUBE OIL INLET			
LUBE OIL OUTLET			
COOLING WATER INLET			
COOLING WATER OUTLET			
PRESSURE GAUGE			
TEMPERATURE GAUGE			
CONDENSATE DRAINS			

☐ **ALLOWABLE PIPING FORCES & MOMENTS:**

	INLET		DISCHARGE			
	FORCE	MOMT.	FORCE	MOMT.	FORCE	MOMT.
	N	Nm	N	Nm	N	Nm
AXIAL						
VERTICAL						
HORIZ. 90°						

REMARKS: _____

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CONSTRUCTION FEATURES

VIBRATION DETECTORS:

O TYPE _____ ☐MODEL _____
O MFR _____
O No. AT EACH PINION BEARING _____ TOTAL No. _____
O No. AT EACH DRIVER BEARING _____ TOTAL No. _____
O OSCILLATOR-DEMODULATOR SUPPLIED BY _____
O MFR_____ ☐ MODEL_____
O MONITOR SUPPLIED BY _____
O LOCATION _____ ENCLOSURE _____
O MFR_____ ☐ MODEL_____
☐ SCALE RANGE_____ O ALARM ☐SET AT _____ mm
O SHUTDOWN ♦ SET AT _____ mm O TIME DELAY _____ s.
O PER API Std 670 (4.2.5.7.2)

AXIAL MOVEMENT DETECTOR:

O TYPE _____ MODEL _____
O MFR._____ O No. REQUIRED _____
O OSCILLATOR-DEMODULATOR SUPPLIED BY_____
O MFR_____ ☐ MODEL_____
O MONITOR SUPPLIED BY _____
O LOCATION _____ ENCLOSURE _____
O MFR_____ MODEL_____
☐ SCALE RANGE_____ O ALARM ☐ SET AT _____mm
O SHUTDOWN ♦ SET AT _____ mm O TIME DELAY _____ s.
O PER API Std 670 (4.2.5.7.1) (4.2.5.7.2)

COUPLINGS: **DRIVER-COMPRESSOR**

O MAKE _____
☐ MODEL _____
☐ CPLG. RATING (kW/100 r/min) _____
O LUBRICATION _____
O MOUNT COUPLING HALVES _____
O LIMITED END FLOAT REQUIRED _____
O SPACER LENGTH _____mm
O COUPLING PER ISO 10441
O DRIVER HUB CYLINDRICAL KEYED
O COMPRESSOR HUB CYLINDRICAL KEYED
O COMPRESSOR HUB TAPERED KEYED (4.5.8)
O DRIVER HUB TAPERED KEYED (4.5.8)
O SPARK RESISTANT SAFETY GUARD (4.5.4)

☐ **MASS kg:**

COMPRESSOR _____ DRIVER_____ BASE _____
ROTORS. COMP._____ DRIVER_____ GEAR _____
GEAR UPPER CASE
caseCASE_____
INTER COOLER(s) _____ COOLER BUNDLES_____
AFTERCOOLER(s) _____ COOLER BUNDLES_____
CONTROL PANEL _____
MAX. FOR MAINTENANCE (IDENTIFY)_____
TOTAL SHIPPING WEIGHT _____

REMARKS

_____
_____
_____
_____

SHOP INSPECTION AND TEST	OBSERVE	WITNESS
O SHOP INSPECTION	_____	_____
O HYDROSTATIC (INCL. INTER AFTER COOLERS)	_____	_____
O PERFORMANCE TEST (ISO 5389/ ASME PTC 10)	_____	_____
O CONTROL PANEL FUNCTIONAL TEST	_____	_____
O PERFORMANCE TEST AIR SINGLE POINT	_____	_____
O PERFORMANCE TEST AIR 5 POINTS	_____	_____
O COMPRESSOR WITH SHOP DRIVER	_____	_____
O COMPRESSOR WITH JOB DRIVER	_____	_____
O USE SHOP LUBE SYSTEM	_____	_____
O USE JOB LUBE SYSTEM	_____	_____
O USE SHOP VIBRATION PROBES	_____	_____
O USE JOB VIBRATION SYSTEM (COMPLETE)	_____	_____
O DISASSEMBLE- REASSEMBLE COMP. AFTER TEST	_____	_____
O CHECK BEARINGS AND SEALS AFTER TEST	_____	_____
O NOISE LEVEL TEST (6.3.5.4)	_____	_____
O FUNCTIONAL JOB LUBE SYSTEM TEST	_____	_____
O NONDESTRUCTIVE EXAMINATION (6.2.2.4) (6.2.2.5)	_____	_____
O RESIDUAL UNBALANCE CHECK (4.3.10.5.3)	_____	_____
O MAINTENANCE & RUNNING CLEARANCE (6.2.1.1c)	_____	_____
O ACCESS TO VENDOR'S QC PROGRAM	_____	_____
O MECHANICAL RUN USING SPARE ELEMENTS (6.3.5.5)	_____	_____
O LOW AMBIENT TEMPERATURE IMPACT STRENGTH TEST	_____	_____
	_____	_____
	_____	_____

☐ **SPACE REQUIREMENTS:**

COMPLETE UNIT L _____ W _____ H _____
CONTROL PANEL L _____ W _____ H _____

MISCELLANEOUS:

☐ RECOMMENDED STRAIGHT RUN OF PIPE TO SUCTION _____
O VENDOR'S REVIEW & COMMENTS ON CONTRACTOR'S PIPING & FOUNDATION
O TORSIONAL ANALYSIS REPORT REQUIRED (4.3.10.4.5)
O VENDOR REP TO WITNESS INITIAL & HOT ALIGNMENT (4.1.20)
O BASE DESIGNED FOR COLUMN MOUNTING (4.2.4.10)
O SUBSOLE PLATES PROVIDED BY VENDOR (4.2.4.12)
O QUANTITY OF DRAWINGS REQUIRED (7.2.3.1)
O PRINTS _____ O REPRODUCIBLES _____
TIME REQUIRED _____
O CERTIFIED COPIES OF TEST DATA (7.2.4.2c) _____
O OTHER TEST DATA (7.2.4.2c) _____
O PROGRESS REPORT FREQUENCY (7.2.5) _____

DYNAMICS (4.3.10)

O CRITICAL LATERAL SPEEDS DETERMINED (4.3.10.1.4)
O CRITICAL TORSIONAL SPEEDS DETERMINED (4.3.10.4.2)
O DAMPED UNBALANCED RESPONSE ANALYSIS (4.3.10.2.1)
O STIFFNESS MAP OF UNDAMPED ROTOR RESPONSE (4.3.10.2.4 e)
O TEST STAND CRITICAL SPEED RESPONSE (4.3.10.1.4)
O PACKAGE TORSIONAL VIBRATION ANALYSIS (4.3.10.4.5)
O TRANSIENT TORSIONAL VIBRATION ANALYSIS (4.3.10.4.6)
O RESIDUAL UNBALANCE CHECK (4.3.10.5.3)

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LUBE OIL SYSTEM

	PIPING MATERIALS: (4.2.3.2.1)	CARBON STEEL	STAINLESS STEEL
	O OIL SUPPLY PIPING		_____X_____
	O RETURN PIPING	_____	_____
	_____	_____	_____
	O CARBON STEEL SLIP-ON FLANGES ON STAINLESS STL PIPE		

	SYSTEM COMPONENT SUPPLIERS:	MFR	MODEL
	O MAIN PUMP	_____	_____
	O STANDBY PUMP	_____	_____
	O ELECTRIC MOTOR(S)	_____	_____
	O STEAM TURBINE(S)	_____	_____
	O OIL COOLER(S)	_____	_____
	O OIL FILTER(S) (4.2.2.6)	_____	_____
	O ACCUMULATOR(S)	_____	_____
	O SUCT. STRAINER(S)	_____	_____
	O CHECK VALVE(S)	_____	_____
	O SWITCH VALVE(S)	_____	_____
	O PUMP COUPLING(S)	_____	_____
	O RELIEF VALVES	_____	_____

OIL SYSTEM PRESSURES:

☐ DESIGN _____ MPa HYDROTEST _____ MPa

☐ PUMP RELIEF VALVE(S) SETTINGS _____ MPa

BASIC SYSTEM REQUIREMENTS (NORMAL OIL FLOW) (4.2.1.3)

	☐ LUBE OIL	m^3/h	MPa	viscosity @ 48 °C
	COMPRESSOR	_____	_____	_____
	O DRIVER (4.2.1.2C)	_____	_____	_____

	PUMP: (4.2.2.2)	MAIN	STANDBY
	O HORIZONTAL	_____	_____
	O VERTICAL	_____	_____
	O SUBMERGED	_____	_____
	O MOTOR-DRIVEN	_____	_____
	O TURBINE-DRIVEN	_____	_____
	O SHAFT-DRIVEN	_____	_____
	O CENTRIFUGAL	_____	_____
	O GEAR/SCREW	_____	_____
	O FLANGE CONNECTED	_____	_____
	☐ m^3/h (RATED)	_____	_____
	☐ @ MPa	_____	_____
	☐ kW MAX @ cst	_____	_____
	☐ DRIVER kW	_____	_____
	O CASING MATERIAL	_____	_____
	☐ SPEED		
	O COUPLING		
	☐ GUARD		
	O MECHANICAL SEAL		

EMERGENCY LUBE OIL PUMP:

O AIR MOTOR DRIVEN OTHER _____

O SAFETY GUARD REQUIRED

STANDBY PUMP CONTROL RESET;

O MANUAL O AUTOMATIC

O "ON-OFF-AUTO" SELECTOR SWITCH

RESERVOIR;

O MATERIALS _____

RETENTION TIME _____MIN. CAPACITY _____ m^3

O BAFFLE REQUIRED O INTERIOR COATING _____

FREE SURFACE AREA _____ m^2

O HEATER(S) (4.2.2.7) O ELECTRIC O STEAM

O MIN. SITE _____° C/OILcst @ MIN TEMP _____

O FILTER/BREATHER O FLANGED VENT

O PRESS RELIEF VENT O INSULATION SUPPORTS

O SPRING LOADED FILL CAP WITH S.S. STRAINER

COOLERS (4.2.2.5)

O HEATING STEAM TO WATERSIDE _____ MPa @ _____°C

O FOULING FACTOR: SHELL SIDE _____ TUBE SIDE _____

☐ MAKE _____ ☐ TYPE _____

☐ DUTY _____kJ/h ☐ SURFACE_____m^2

☐ CODE (S)_____

☐ DESIGN PRESS.MPa :SHELL SIDE _____ TUBE SIDE _____

☐ TUBES: O.D. _____ mm

WALL THICKNESS (AVE.) (MIN.) _____mm

LENGTH _____ THICKNESS _____

☐ MATERIALS:

TUBES:_____

TUBE SHEETS:_____

SHELL _____

TUBE SUPPORT:_____

SHELL COVER/FLANGE_____

ACCUMULATORS;

O SINGLE O MULTI

O CODE DESIGN O CODE STAMP

O MATERIAL

☐ CORROSION ALLOWANCE (mm) _____

☐ CAPACITY (TOTAL) m^3 _____

☐ PRE-CHARGE PRESS (BARG) _____

O DIRECT CONTACT TYPE O BLADDER TYPE

☐ BLADDER MATERIAL

O WITH SUPPLY REGULATOR O MANUAL CHARGE VALVE

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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:

PRESSURE GAUGES:	MFR. _____	SIZE AND TYPE _____
TEMPERATURE GAUGES:	MFR. _____	SIZE AND TYPE _____
LEVEL GAUGES:	MFR. _____	SIZE AND TYPE _____
DIFFERENTIAL PRESSURE GAUGES:	MFR. _____	SIZE AND TYPE _____
PRESSURE DEVICES:	MFR. _____	SIZE AND TYPE _____
DIFFERENTIAL PRESSURE DEVICES:	MFR. _____	SIZE AND TYPE _____
TEMPERATURE DEVICES:	MFR. _____	SIZE AND TYPE _____
LEVEL DEVICES:	MFR. _____	SIZE AND TYPE _____
CONTROL VALVES:	MFR. _____	SIZE AND TYPE _____
PRESSURE RELIEF VALVES:	MFR. _____	SIZE AND TYPE _____
THERMAL RELIEF VALVES	MFR. _____	SIZE AND TYPE _____
SIGHT FLOW INDICATORS:	MFR. _____	SIZE AND TYPE _____
GAS FLOW INDICATORS:	MFR. _____	SIZE AND TYPE _____
VIBRATION EQUIPMENT:	MFR. _____	SIZE AND TYPE _____
TACHOMETER:	MFR. _____	SIZE AND TYPE _____
SOLENOID VALVES:	MFR. _____	SIZE AND TYPE _____
ANNUNCIATOR:	MFR. _____	MODEL & No. POINTS_____
_____	MFR. _____	_____

PRESSURE GAUGE REQUIREMENTS O SUPPLIED BY PURCHASER ☐ SUPPLIED BY VENDOR

FUNCTION	LOCALLY MOUNTED	LOCAL PANEL	FUNCTION	LOCALLY MOUNTED	LOCAL PANEL
LUBE OIL DISCHARGE _____	O ☐	O ☐	COMPRESSOR SUCTION EACH STAGE___	O ☐	O ☐
LUBE OIL FILTER Δ P _____	O ☐	O ☐	COMPRESSOR DISCHARGE EACH STAGE	O ☐	O ☐
LUBE OIL SUPPLY_____	O ☐	O ☐	_____	O ☐	O ☐
AIR FILTER/SILENCER Δ P _____	O ☐	O ☐	_____	O ☐	O ☐
_____	O ☐	O ☐	_____	O ☐	O ☐

TEMPERATURE GAUGE REQUIREMENTS:

FUNCTION LUBE OIL PUMP DISCHARGE FROM EACH	LOCALLY MOUNTED	LOCAL PANEL	FUNCTION	LOCALLY MOUNTED	LOCAL PANEL
PINION JOURNAL BEARING _____	O ☐	O ☐	OIL COOLER INLET AND OUTLET _____	O ☐	O ☐
DRIVER JOURNAL BEARINGS _____	O ☐	O ☐	COMPRESSOR SUCTION EACH STAGE __	O ☐	O ☐
BULL GEAR JOURNAL BEARINGS _____	O ☐	O ☐	COMPRESSOR DISCHARGE EACH STAGE	O ☐	O ☐
COMPRESSOR THRUST BEARINGS _____	O ☐	O ☐	_____	O ☐	O ☐
DRIVER THRUST BEARINGS _____	O ☐	O ☐	_____	O ☐	O ☐
GEAR THRUST BEARINGS _____	O ☐	O ☐	_____	O ☐	O ☐
_____	O ☐	O ☐	_____	O ☐	O ☐

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INSTRUMENTATION

SWITCH CLOSURES: (4.2.5.5.1)

ALARM CONTACTS SHALL: O OPEN O CLOSE TO SOUND ALARM AND BE NORMALLY O ENERGIZED O DE-ENERGIZED

SHUTDOWN CONTACTS SHALL: O OPEN O CLOSE TO TRIP AND BE NORMALLY O ENERGIZED O DE-ENERGIZED

NOTE: NORMAL CONDITION IS WHEN COMPRESSOR IS IN OPERATION.

REMARKS: _____

MISCELLANEOUS:

PRE-ALARM AND SHUTDOWN DEVICES SHALL BE SEPARATE.

CONTRACTOR ELECTRICAL AND INSTRUMENT CONNECTIONS WITHIN THE CONFINES OF THE COMPRESSOR BASE SHALL BE BROUGHT OUT TO TERMINAL BOXES.

COMMENTS REGARDING INSTRUMENTATION; _____

_____

_____

ALARM & SHUTDOWN DEVICES: (4.2.5.5) (TABLE 5)

O SUPPLIED BY PURCHASER ☐ SUPPLIED BY VENDOR

FUNCTION	PRE-ALARM	SHUTDOWN	OPTIONAL FUNCTION	PRE-ALARM	SHUTDOWN
☐ O HI COMPRESSOR DISCHARGE TEMP.	_____	_____	☒ O HI LAST STG INLET TEMP	____X____	_____X___
☐ O HI COMPRESSOR THRUST BRG. TEMP.	_____	_____	☒ O LOW LUBE OIL PRESSURE	____X____	_____X___
☐ O COMPRESSOR AXIAL POSITION	_____	_____	☒ O HI OIL SUPPLY TEMP __	____X____	_____X___
☐ O DRIVER AXIAL POSITION	_____	_____	☒ O HI OIL FILTER Δ P	____X____	_____X___
☐ O HI DRIVER THRUST BRG. TEMP	_____	_____	☒ O HI OIL COOLER Δ P	____X____	_____X___
☐ O HI VIBRATION DRIVER	_____	_____	☐O LOW SEAL SYSTEM PRESS.	_____	_____
☒ O HI VIBRATION COMPRESSOR	_____	_____	☒ O STAND BY OIL PUMP RUNNING	____X____	_____
☒ O LOW LUBE OIL RESERVOIR	_____	_____	☐ O _____	_____	_____
☒ O HI INLET AIR FILTER Δ P	_____	_____	☐ O _____	_____	_____
☒ O PANEL PURGE FAILURE	_____	_____	☐ O _____	_____	_____
☒ O SURGE RECOGNITION	_____	_____	☐ O _____	_____	_____
☐ O _____	_____	_____	☐ O _____	_____	_____
☐ O _____	_____	_____	☐ O _____	_____	_____

MISCELLANEOUS INSTRUMENTATION:

☐ O SIGHT FLOW INDICATORS: EACH JOURNAL & THRUST BEARING OIL RETURN LINE

☐ O LEVEL GAUGES, LUBE OIL RESERVOIR, SEPARATOR, CONDENSATE TRAPS

☒ O VIBRATION AND SHAFT POSITION PROBES & OSCILLATOR-DEMODULATORS

☐ O VIBRATION AND SHAFT POSITION READOUT EQUIPMENT

VIBRATION READOUT LOCATED ON: LOCAL PANEL ☐ SEPARATE PANEL ☐ MAIN BOARD

☐ O DRIVER SPEED PICK-UP DEVICES

☐ O DRIVER SPEED INDICATORS

DRIVER SPEED INDICATORS LOCATED ON: ☐ LOCAL PANEL ☐ SEPARATE PANEL ☐ MAIN BOARD

☐ O REMOTE HAND SPEED CHANGE MOUNTED ON LOCAL PANEL

☒ O ALARM HORN & ACKNOWLEDGEMENT DEVICE

☒ O TEST LAMP PUSH BUTTON (4.2.5.3.1i)

☒ O PERMISSIVE START WITH PILOT LIGHT (4.2.5.3.1j)

☒ O PILOT LIGHT INCOMING CIRCUITS (4.2.5.3.1k)

☒ O START STOP DEVICE (4.2.5.3.1l)

☒ O CONTROL MODE SELECTOR DEVICE (4.2.5.2.2)

☐ O MANUAL OVERRIDE DEVICE (4.2.5.2.5)

REMARKS:

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INTEGRALLY GEARED
CENTRIFUGAL COMPRESSOR
DATA SHEET ISO 10442

ENQUIRY/ORDER NO._____
JOB NO._____ ITEM NO. _____

REVISION	BY	DATE	CHKD.	DATE	APPD.	DATE

(INTER) (AFTER) COOLER (S)

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

OPERATING CONDITIONS

	SHELL SIDE	TUBE SIDE
O FLUID		
☐ TOTAL FLOW kg/h		
☐ SPECIFIC GRAVITY	@ °C	@ °C
☐ THERMAL COND. w/(m^{3}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		
O PRESSURE DROP MPa	ALLOW. CALC.	ALLOW. CALC.
☐ DESIGN TEMPERATURE C		
PRESSURE MPa	MIN. TEST	MIN. TEST
FOULING RESISTANCE m^{2}k/w		
O MIN. CORROSION ALLOWANCE mm		
☐ NUMBER OF PASSES PER SHELL		

CONSTRUCTION DETAILS

☐ TOTAL AREA (1), m^2 _____
☐ LMTD _____
CORRECTED MTD _____
☐ TRANSFER RATE, CLEAN _____
☐ TRANSFER RATE, SERVICE _____
CROSS BAFFLES, TYPE _____
O CODE REQUIREMENTS (2)_____ TEMA _____
☐ MASSES _____EACH BUNDLE _____kg

☐ SHELL, No. X ID. _____X _____
☐ TUBES, No. PER SHELL _____
☐ OUTSIDE DIAMETER X LENGTH _____
☐ GAUGE, BWG _____AVG., MIN. WALL
☐ TUBE PITCH _____ mm Δ ☐ O
☐ REMOVABLE TUBE BUNDLE ☐ YES O NO
O CODE STAMP ☐ YES O NO
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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APPLICABLE TO ❍ PROPOSAL ❍ PURCHASE ❍ AS BUILT
FOR _____
SITE _____
SERVICE_____
MANUFACTURER _____ MODEL _____
NOTE: ❍ INDICATES INFORMATION TO BE COMPLETED BY PURCHASER

FURNISHED BY (5.1.1) _____
UNIT _____
DRIVER EQUIPMENT_____
NO. REQUIRED _____
SERIAL NO._____
☐ BY MANUFACTURER_____

MOTOR DESIGN DATA

APPLICABLE SPECIFICATIONS
❍ NEMA _____
❍ _____
❍ _____

SITE DATA
AREA: ❍ ZONE _____ TEMP. CLASS _____
❍ ALTITUDE _____m AMBIENT TEMP. MAX °C _____MIN ____°C
UNUSUAL CONDITIONS ❍ DUST ❍ FUMES
❍ OTHER _____

DRIVE SYSTEM
❍ DIRECT CONNECTED
❍ GEAR
❍ OTHER _____

TYPE OF MOTOR (4.4.2.5)
❍ SQUIRREL CAGE INDUCTION ❍ NEMA DESIGN
❍ SYNCHRONOUS
❍ POWER FACTOR REQUIRED _____
EXCITATION: ❍ BRUSHLESS ❍ SLIP RING
❍ FIELD DISCHARGE RESISTOR BY MOTOR MANUFACTURER
❍ WOUND ROTOR INDUCTION
❍ _____

ENCLOSURE
❍ ZONE _____GROUP _____ TEMP._____
❍ TEFC SEVERE DUTY ❍ EXPLOSION PROOF
❍ WEATHER PROTECTED? TYPE _____
❍ TEWAC ❍ TEIGF, USING _____GAS
❍ DOUBLE WALL CARBON STEEL TUBES
❍ WATER SUPPLY PRESSURE _____MPa TEMP _____°C
☐❍ WATER ALLOW: Δ P _____MPa & TEMP. RISE _____°C
☐❍ WATER SIDE MIN. CORROSION ALLOWANCE _____mm
AND FUEL FACTOR _____
❍ (AIR) (GAS) SUPPLY PRESSURE _____MPa
❍ FORCED VENTILATED
❍ OPEN DRIP PROOF
❍ OPEN
❍ _____
❍ _____

BASIC DATA (4.4.2.5)
❍ _____VOLT _____ PHASE _____HERTZ
☐ NAMEPLATE kW _____SERVICE FACTOR _____
❍ INSULATION CLASS _____ TYPE _____
❍ TEMPERATURE RISE _____°C ABOVE _____°C BY _____

MOTOR DESIGN DATA (CONTINUED)

STARTING (4.4.1.3) (4.4.2.5)
❍ FULL VOLTAGE ❍ REDUCED VOLTAGE _____%
❍ LOADED ❍ UNLOADED
❍ VOLTAGE DIP _____%

VIBRATION
❍ STANDARD ❍ _____

NOISE
❍ ISO 9614 STANDARD ❍ _____ dba
_____
_____

ACCESSORY EQUIPMENT

❍ BASEPLATE ❍ SOLE PLATE ❍ STATOR SHIFT
❍ MANUFACTURERS STANDARD FANS ❍ NON SPARKING FANS
❍ DC EXCITATION
☐ kW REQUIRED _____ VOLT _____
BY ❍ PURCHASER ❍ MANUFACTURER
DESCRIPTION _____
❍ ENCLOSED COLLECTOR RINGS
❍ PURGED : MEDIUM _____PRESSURE _____ MPa
❍ EXPLOSION RESISTANT NON PURGED
❍ FORCED VENTILATION
☐ m^3/h _____ PRESSURE DROP _____mbar
❍ BEARING TEMPERATURE DEVICES:
☐ LOCATION _____
☐ DESCRIPTION _____
☐ SET @ _____°C FOR ALARM _____°C FOR SHUTDOWN
❍ SPACE HEATERS
☐ _____kW ❍ _____ VOLT _____PHASE _____ HERTZ
❍ MAX. SHEATH TEMPERATURE _____%

WINDING TEMPERATURE DETECTOR
❍ THERMISTORS : NO/PHASE _____
TYPE: ❍ POS. TEMPERATURE COEFF. ❍ NEGATIVE TEMP. COEFF.
TEMPERATURE DEVICE ❍ YES ❍ NO
❍ RESISTANCE TEMPERATURE DETECTORS: NO/PHASE _____
❍ RESISTANCE MATERIAL _____❍ _____OHM
SELECTOR SWITCH & INDICATOR BY: ❍ PURCHASER ❍ MANUFACTURER
☐ MAX. STATOR WINDING TEMPERATURES.
_____°C FOR ALARM _____°C FOR SHUTDOWN

WINDING TEMPERATURE & DETECTOR & SPACE HEATER LEADS:
❍ IN SAME CONDUIT BOX
❍ IN SEPERATE CONDUIT BOXES

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ACCESSORY EQUIPMENT (Continued)

❍ **MOTOR ARRANGED FOR DIFFERENTIAL PROTECTION:**
❍ SELF-BALANCE PRIMARY-CURRENT METHOD
❍ C.T. DESCRIPTION _____
❍ EXTENDED LEADS ☐ LENGTH _____ m
❍ **SURGE CAPACITORS:**
❍ **LIGHTNING ARRESTERS**
❍ **C.T. FOR AMMETER**
❍ DESCRIPTION _____

MAIN CONDUIT BOX SIZED FOR:
❍ MAIN MOTOR LEADS ❍ TYPE: _____
❍ INSULATED ❍ NON-INSULATED
❍ C.T.'s FOR DIFF. PROTECTION (MOUNTED BY): _____
❍ SURGE CAPACITORS (MOUNTED BY): _____
❍ LIGHTINING ARRESTERS (MOUNTED BY): _____
❍ C.T. FOR AMMETER (MOUNTED BY): _____
❍ SPACE FOR STRESS CONES
❍ **AIR FILTERS:**
☐ MFR. _____ ☐ TYPE _____

MANUFACTURER'S DATA

MANUFACTURER _____
FRAME N°. _____ FULL LOAD RPM (IND.) _____
EFFICIENCY: F.L. _____ 3/4L _____ 1/2L _____
POWER FACTOR (IND.) : F.L. 3/4L _____ 1/2L _____
CURR. (RATED VOLT.): FULL LOAD _____ LOCKED ROTOR _____
LOCKED ROTOR POWER FACTOR _____
LOCKED ROTOR W/STAND TIME (COLD START) _____
LOCKED ROTOR W/STAND TIME (HOT START) _____
TORQUE (N-m): FULL LOAD _____
LOCKED ROTOR _____ STARTING (SYN) _____
PULL-UP (IND.) _____ PULL-IN (SYN) _____
BREAKDOWN (IND.) _____ PULL-OUT (SYN) _____
_____
OPEN CIRCUIT TIME CONSTANT (s) _____
SYMMETRICAL CONTRIBUTION TO 3 PHASE TERMINAL FAULT:
AT 1/2 CYCLES _____ AT 3 CYCLES _____
REACTANCES: SUB-TRANSIENT (X"D) _____
TRANSIENT (X'D) _____ SYNCHRONOUS (XD) _____
AC. STATOR RESISTANCE _____ OHM @ _____ °C
RATED KVA _____
KVA INRUSH @ FULL VOLT & LOCKED ROTOR (SYN/) _____ %
KVA @ FULL VOLTAGE & 95 % SPEED _____ %
MAX. LINE CURR. IN STATOR ON 1ST SLIP CYC. & PULL-OUT (SYN) _____
_____
ACCELERATION TIME (MTS ONLY & RATED VOLT.) _____ s
ACCEL. TIME (MTR & LOAD & 85 % RATED VOLT.) _____ s
ROTOR INERTIA WK^2 & MTR SHAFT (N-m^2) _____
N° OF STARTS PER HOUR _____

MANUFACTURER'S DATA (Continued)

BEARING: TYPE _____ LUBR. _____
LUBE OIL REQUIRED: _____ m^3/h: & _____ MPa
TOTAL SHAFT END FLOAT _____
LIMIT END FLOAT TO _____
CURVES REQD. BASED ON MTR SATURATION & RATED VOLT:
❍ SPEED VS. TORQUE @ 100 %, 90 % & 80 % RATED VOLTAGE
❍ SPEED VS. CURRENT @ 100 %, 90 % & 80 % RATED VOLTAGE

MASSES (kg):
NET MASS _____ SHIPPING MASS _____
ROTOR MASS _____ MAX. ERECTION MASS _____
MAX. MAINT. MASS. (IDENTIFY) _____
_____
_____

DIMENSIONS (m & mm)
L _____ W _____ H _____
_____
_____

SHOP INSPECTION AND TESTS

	REQD.	WITNESS
SHOP INSPECTION	❍	❍
TESTING PER NEMA	❍	❍
MFR. STD. SHOP TESTS	❍	❍
IMMERSION TEST	❍	❍
SPECIAL TESTS (LIST BELOW)	❍	❍
_____	❍	❍
_____	❍	❍
_____	❍	❍

PAINTING:
❍ MANUFACTURER 'S STANDARD
❍ _____
❍ _____

SHIPMENT:
❍ DOMESTIC ❍ EXPORT ❍ EXPORT BOXING REQ.D
❍ OUTDOOR STORAGE OVER 3 MONTHS
❍ _____
❍ _____

REMARKS: _____

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ADDITIONAL DATA.

Annex B
(informative)

Material specifications for major component parts

Table B.1 — Typical specifications for major component parts

Part	Material [a]	Specification	Form	Temperature limits [c]	
				Minimum °C	Maximum °C
Compressor casings, scrolls (volutes), diaphragms					
	Cast Iron	ASTM A 278, Class 40	Cast	– 29	260
		ASTM A 48	Cast	– 29	260
	Ductile Iron	ASTM A 395	Cast	– 29	260
		ASTM A 536 Grade 60-40-18	Cast	– 29	260
	Cast Steel	ASTM A 27	Cast	– 29	345
		ASTM A 216 Grade WCA	Cast	– 29	345
		ASTM A 216 Grade WCC	Cast	– 29	345
		ASTM A 352 Grade LCC	Cast	– 29	345
		ASTM A 757 Grade D1Q1	Cast	– 29	345
		ASTM A 487 Grade CA-6NM	Cast	– 29	345
		ASTM A 743 Grade CF-8	Cast	– 29	345
		ASTM A 743 Grade CF-8M	Cast	– 29	345
Diffuser	Ductile iron	ASTM A 395	Cast	– 29	345
		ASTM A 536 Grade 60-40-18	Cast	– 29	345
	Carbon steel	ASTM A 516 Grade 60	Plate	– 29	345
	Steel	ASTM A 283 Grade B	Plate	– 29	345
		ASTM A 516 Grade 65	Plate	– 29	345
		ASTM A 516 Grade 70	Plate	– 29	345
		ASTM A 662 Grade C	Plate	– 29	345
		ASTM A 757 Grade D1Q1	Cast	– 29	345
		Lead bearing, free machining	Plate	– 29	260
	Stainless steel	ASTM A 487 Grade CA-6NM	Cast	– 29	260
		ASTM A 743 Grade CF-8	Cast	– 29	260
		ASTM A 749 Grade CF-8M	Strip	– 29	260
	Aluminium	ASTM B 26 Alloy 355.0	Cast	– 195	205
	Aluminium	ASTM B 209 Alloy 6061-T6	Plate	– 195	205
	Aluminium	ASTM B 26 Alloy 443.0	Cast	– 195	205

Table B.1 (*continued*)

Part	Material [a]	Specification	Form	Temperature limits [c]	
				Minimum °C	Maximum °C
Stage inlet adaptor	Cast iron	ASTM A 48 Class 30	Cast	– 29	260
	Cast iron	Meehanite GA	Cast	– 29	260
	Steel	ASTM A 53 Grade B Type S	Wrought	– 29	345
	Steel	ASTM A 106	Wrought	– 29	400
	Steel	ASTM A 355 Grade B Type S	Wrought	– 29	400
Interstage Piping	Cast Iron	ASTM A 278 Class 30	Cast	– 29	400
	Cast Iron	ASTM A 278 Class 40	Cast	– 29	260
	Steel	ASTM A 53 Grade B Type S	Wrought	– 29	345
	Steel	ASTM A 106	Wrought	– 29	400
Impellers	Stainless steel	ASTM A 564 Type 630	Bar or shape	– 29	400
	Stainless steel	ASTM A 743 Grade CA-6NM	Cast	– 45	345
	Stainless steel	ASTM A 182 Grade F6NM	Forged	– 45	345
	Stainless steel	ASTM A 522 Type 1	Forged	– 45	345
	Stainless steel	AISI Type 410 [b]	Cast	– 45	400
	Stainless steel	AISI Type 403 [b]	Forged	– 45	400
	Stainless steel	SAE AMS 5353C	Cast	– 45	315
	Ni alloys	N05500	Forged	– 45	315
	Ti alloys	ASTM B 381 Grade F5	Forged	– 45	315
Pinion gears	Steel	AISI Type 4340 [b]	Bar	– 45	400
	Steel	AISI Type 8620 [b]	Forged	– 45	400
	Steel	AISI Type 9310 [b]	Forged	– 45	400
	Steel	AISI Type 4140 [b]	Forged	– 45	400
	Steel	AISI Type 4340 [b]	Forged	– 45	400
	Steel	ASTM A 322 Grade 4320	Bar	– 45	400
	Stainless steel	ASTM A 564 Type 630	Bar or shape	– 45	400
	Steel	ASTM A 522 Type 1	Forged	– 45	400
Bull gear shaft	Steel	AISI Type 4140 [b]	Forged	– 45	400
	Steel	AISI Type 4340 [b]	Forged	– 45	400
	Steel	ASTM A 322 Grade 4137	Bar	– 45	400

Table B.1 (*continued*)

Part	Material [a]	Specification	Form	Temperature limits [c]	
				Minimum °C	Maximum °C
Bull gear rim	Steel	AISI Type 4140 [b]	Forged	– 45	400
	Steel	AISI Type 4340 [b]	Forged	– 45	400
	Steel	AISI Type 4320 [b]	Forged	– 45	400
Gear casing	Cast iron	ASTM A 498 Class 40	Cast	– 29	260
	Cast iron	ASTM A 48 Class 30	Cast	– 29	260
	Cast iron	ASTM A 278 Class 40	Cast	– 29	260
	Steel	AISI Type 1010 or 1020 [b]	Bar	– 29	345
Backplate	Steel	ASTM A 516 Grade 60	Plate	– 29	345
Baseplate	Cast iron	ASTM A 278 Class 40	Cast	– 29	260
	Steel	AISI Type 1010 or 1020 [b]	Plate	– 29	345
	Steel	ASTM A 283 Grade D	Plate	– 29	345
Bolts	Steel	ASTM A 193 Grade B7	Bar or forged	– 29	345
	Steel	ASTM A 449 Grade 5	Forged	– 29	345
	Steel	ASTM A 307 Grade B	Forged	– 29	260
	Steel	ASTM A 307 Grade B	Bar	– 29	260
	Steel	ASTM A 574	Bar	– 29	260
	Steel	AISI Type 4140 [b]	Bar	– 29	260
	Steel	SAE J429 Grade 8	Forged	– 29	230
Nuts	Steel	ASTM A 108	Forged	– 29	260
	Steel	ASTM A 194 Grade 2H	Bar or forged	– 29	260
	Steel	ASTM A 307 Grade B	Forged	– 29	260

[a] The materials shown on this table are those commonly used by compressor manufacturers, but the list is not all inclusive. Other suitable materials may exist and may be used by compressor manufacturers as indicated by specific design considerations (4.3.11.1.1).

[b] Descriptions of AISI types can be found in publication ASTM DS 56E. AISI designations are only a description of chemical analyses of types of steel, they are not procurement specifications. All materials should be purchased to a specification which adequately defines the required properties and controls.

[c] The temperature limits shown in this table are those commonly observed by compressor manufacturers and are not necessarily the same as any temperature limits specified in the applicable material specifications.

Annex C
(informative)

Rotor dynamic logic diagrams (see ISO 10439)

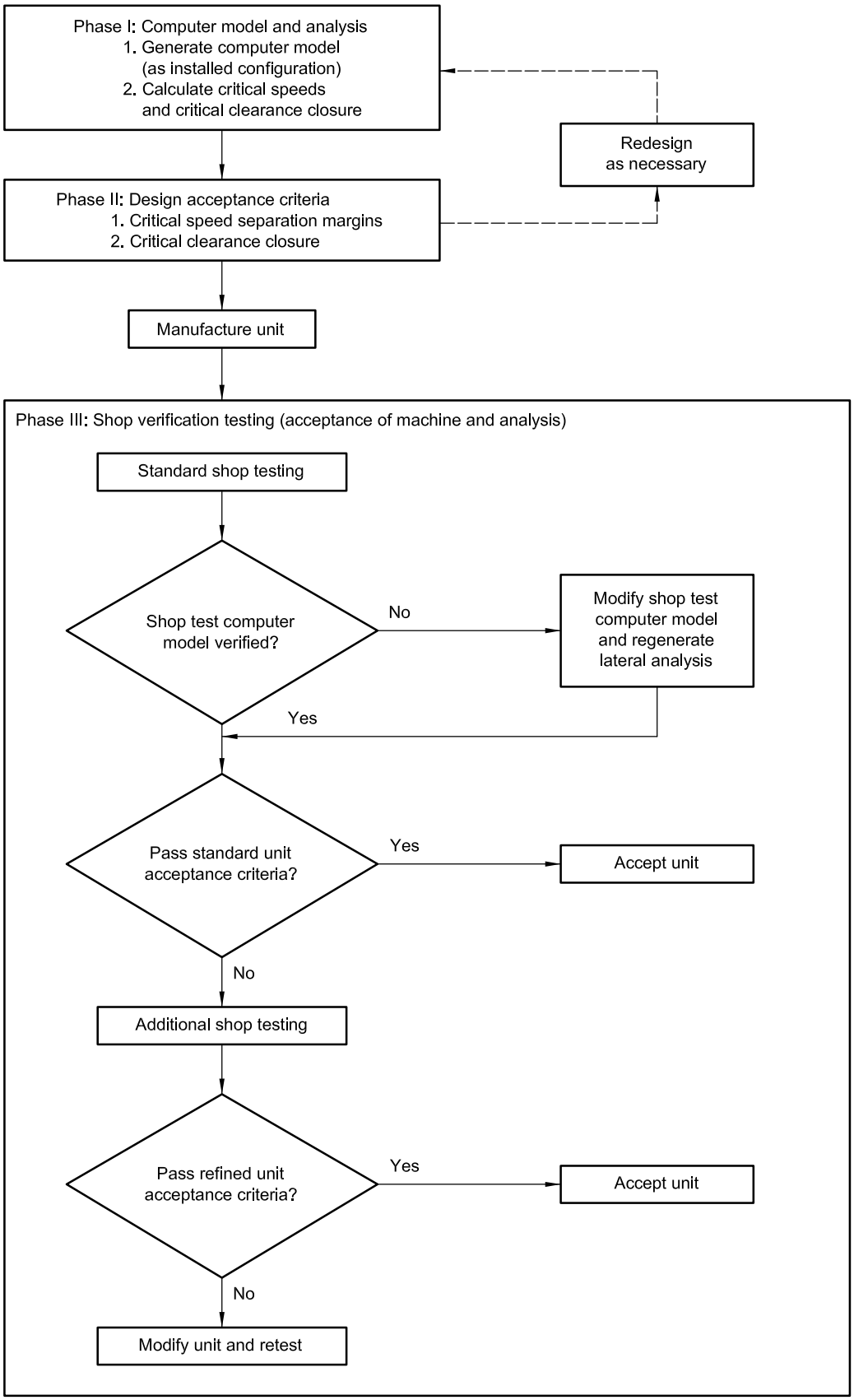


Figure C.1 — Three-phase vibration acceptance program

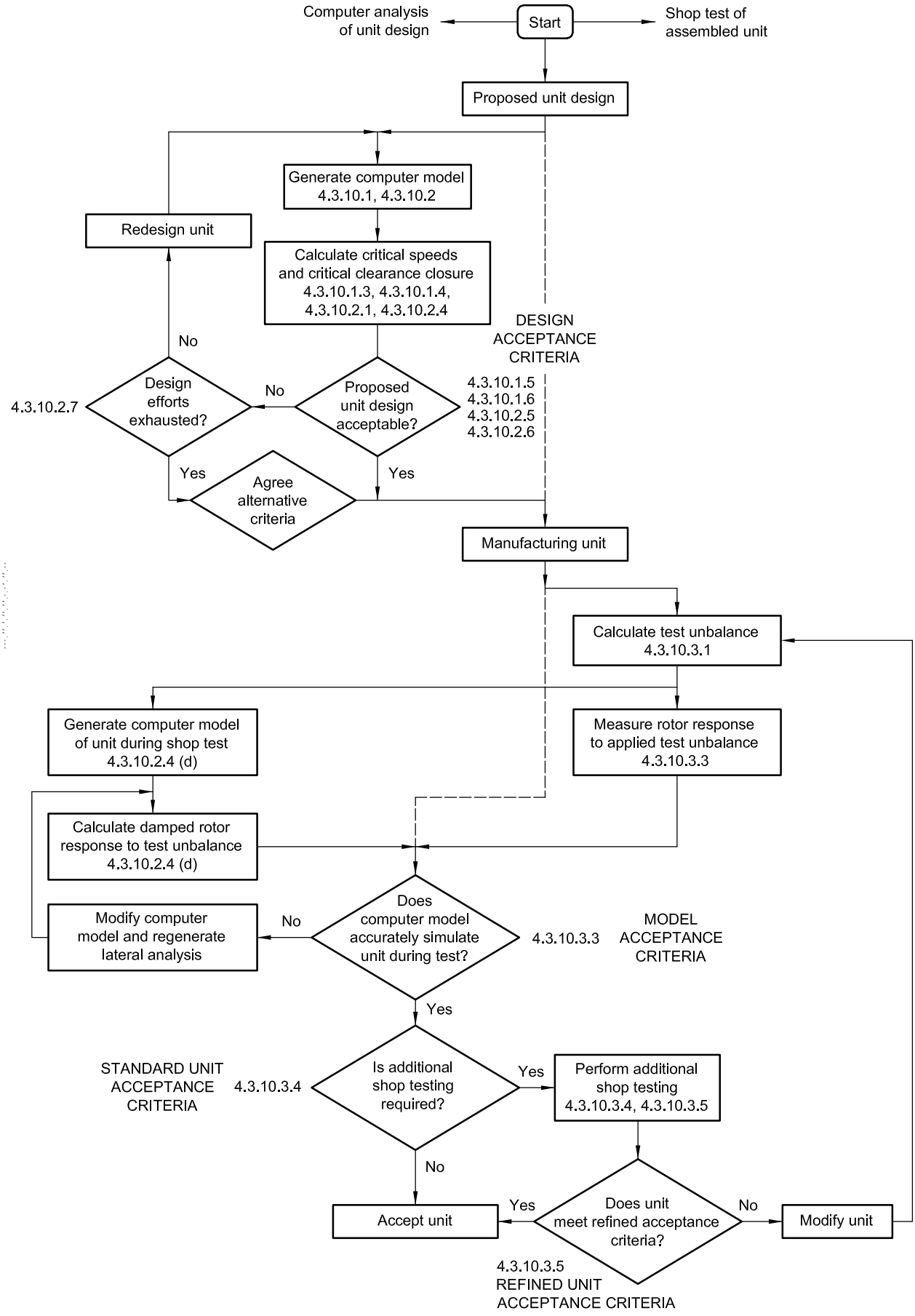


Figure C.2 — Detailed flow chart of vibration acceptance program

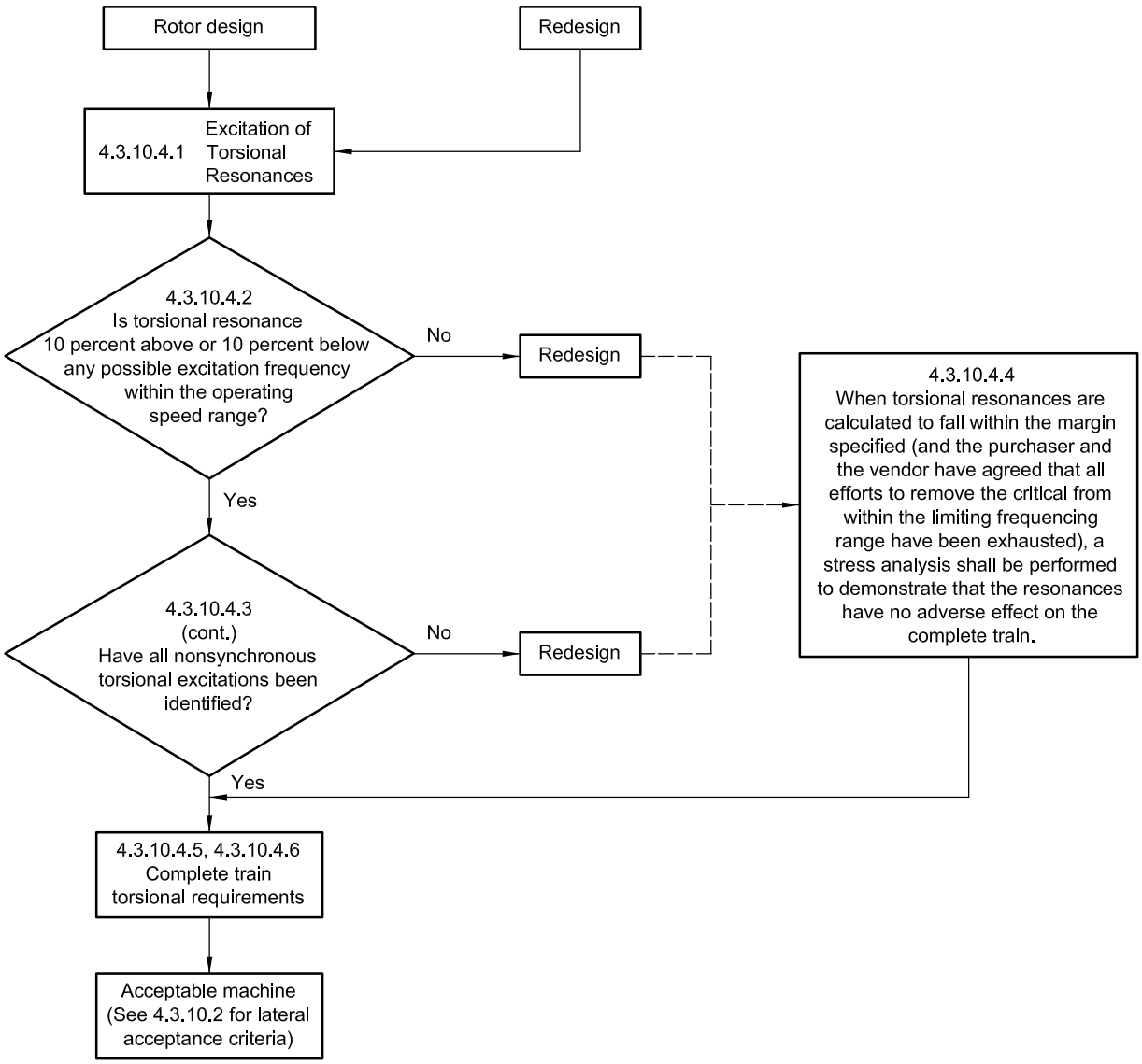


Figure C.3 — Rotor dynamics logic diagram (torsional analysis)

Annex D
(normative)

Forces and moments

D.1 General

The following equations have been adapted for compressors from those in NEMA SM 23 by identifying all the constants, and clarifying that the equivalent of the exhaust nozzle in the NEMA calculation is the largest compressor nozzle. This is usually, but not necessarily, the inlet nozzle.

D.2 Equations

D.2.1 The design of each compressor body shall allow for limited piping loads on the various casing nozzles. For maximum system reliability, nozzle loads imposed by piping should be as low as possible, regardless of the compressor's load carrying capacity. The forces and moments acting on compressors due to the inlet, side stream and discharge connections are to be limited by the following.

D.2.2 The total resultant force, F_r, and the moment, M_r, should not exceed those calculated in the following equations:

$$F_r + 1{,}09\, M_r \leqslant 54{,}1\, D_e$$

Or, in US customary units:

$$3F_r + M_r \leqslant 927\, D_e$$

where

F_r = Resultant force, in Newtons (pound force) (see Figure D.1)

$$F_r = \sqrt{F_x^2 + F_y^2 + F_z^2}$$

M_r = Resultant moment, in Newton metres (foot pound force) (see Figure D.1)

$$M_r = \sqrt{M_x^2 + M_y^2 + M_z^2}$$

For sizes up to 200 mm (8 in) in diameter:

$$D_e = D_{nom}$$

For sizes greater than 200 mm (8 in), use a value of

$$D_e = \frac{(400 + D_{nom})}{3}$$

in millimetres

Or, in US customary units:

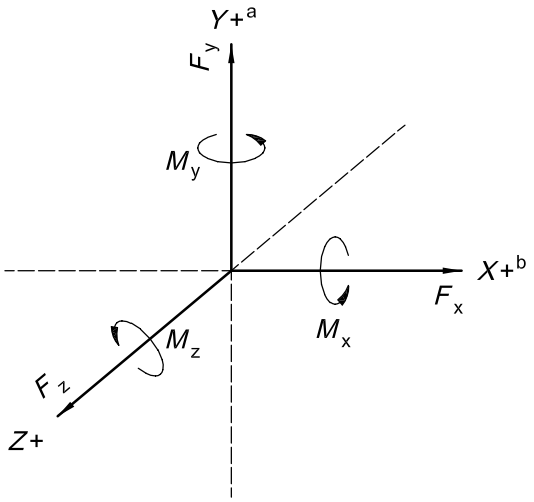
$$D_e = \frac{(16 + D_{nom})}{3}$$

in inches

where

D_e is the equivalent pipe diameter of the connection, in millimetres (inches)

D_{nom} is the nominal pipe diameter, in millimetres (inches).



Key

F_x is the horizontal component of F_c parallel to the compressor shaft, in Newtons (pound force)

F_y is the vertical component of F_c at right angles to the compressor shaft, in Newtons (pound force)

F_z is the horizontal component of F_c at right angles to the compressor shaft, in Newtons (pound force)

M_x is the component of M_c around the horizontal axis, in Newton metres (foot pound force)

M_y is the component of M_c around the vertical axis, in Newton metres (foot pound force)

M_z is the component of M_c around the horizontal axis at right angles to the compressor shaft, in Newton metres (foot pound force).

a Vertical

b Parallel to compressor shaft

Figure D.1 — Combined resultants of the forces and moments

D.2.3 The combined resultants of the forces and moments of the inlet, side stream and discharge connections shall be designed to withstand resultant force and moments as calculated using:

$$F_c + 1{,}64\ M_c \leqslant 40{,}4\ D_e$$

Or, in US customary units:

$$2F_c + M_c \leqslant 462\ D_e$$

where

F_c is the combined resultant of inlet, sidestream, and discharge forces, in Newtons (pound force)

M_c is the combined resultant of inlet, sidestream, and discharge moments, and moments resulting from forces, in Newton metres (foot pound force)

D.2.4 These values of allowable forces and moments pertain to the compressor structure only. They do not pertain to the forces and moments in the connecting piping, flanges or flange bolting, which should not exceed the allowable stress as defined by the applicable codes and regulatory bodies.

Loads may be increased by mutual agreement between the purchaser and vendor. However, it is recommended that expected operating loads be minimized.

Bibliography

[1] ISO 10439:2002, *Petroleum, chemical and gas service industries — Centrifugal compressors*

[2] ISO 10442, *Petroleum, chemical and gas service industries — Packaged, integrally geared centrifugal air compressors*

[3] ABMA Std 9, *Load ratings and fatigue life for ball bearings*

[4] API Std 672, *Packaged, integrally geared centrifugal air compressors for petroleum, chemical, and gas industry services,* second edition, April 1988

[5] ASME B31.3, *Process piping*

[6] ASME B36.10M, *Welded and seamless wrought steel pipe*

[7] ASME VIII, ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, *Design and Fabrication of Pressure Vessels*

[8] ASTM A 27, *Standard specification for steel castings, carbon, for general application*

[9] ASTM A 48, *Standard specification for grey iron castings*

[10] ASTM A 53, *Standard specification for pipe, steel, black and hot-dipped, zinc-coated, welded and seamless*

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

[12] ASTM A 108, *Standard specification for steel bars, carbon, cold-finished, standard quality*

[13] ASTM A 182, *Standard specification for forged or rolled alloy-steel pipe flanges, forged fittings, and valves and parts for high-temperature service*

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

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

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

[17] ASTM A 278, *Standard specification for gray iron castings for pressure-containing parts for temperatures up to 650 °F (350 °C)*

[18] ASTM A 283, *Standard specification for low and intermediate tensile strength carbon steel plates*

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

[20] ASTM A 322, *Standard specification for steel bars, alloy, standard grades*

[21] ASTM A 352, *Standard specification for steel castings, ferritic and martensitic, for pressure-containing parts, suitable for low-temperature service*

[22] ASTM A 355, *Standard specification for steel bars, alloys, for nitriding*

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

[24] ASTM A 449, *Standard specification for quenched and tempered steel bolts and studs*

[25] ASTM A 487, *Standard specification for steel castings suitable for pressure service*

[26] ASTM A 498, *Standard specification for seamless and welded carbon, ferritic, and austenitic alloy steel heat-exchanger tubes with integral fins*

[27] ASTM A 515, *Standard specification for pressure vessel plates, carbon steel, for intermediate- and higher-temperature service*

[28] ASTM A 516, *Standard specification for pressure vessel plates, carbon steel, for moderate- and lower-temperature service*

[29] ASTM A 522, *Standard specification for forged or rolled 8 and 9 % nickel alloy steel flanges, fittings, valves, and parts for low-temperature service*

[30] ASTM A 536, *Standard specification for ductile iron castings*

[31] ASTM A 564, *Standard specification for hot-rolled and cold-finished age-hardening stainless steel bars and shapes*

[32] ASTM A 574, *Standard specification for alloy steel socket-head cap screws*

[33] ASTM A 662, *Standard specification for pressure vessel plates, carbon-manganese-silicon steel, for moderate and lower temperature service*

[34] ASTM A 743, *Standard specification for castings, iron-chromium, iron-chromium-nickel, corrosion resistant, for general application*

[35] ASTM A 749, *Standard specification for steel, strip, carbon and high-strength, low-alloy, hot-rolled, general requirements for*

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