INTERNATIONAL STANDARD

ISO 10440-1

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Petroleum and natural gas industries — Rotary-type positive-displacement compressors —

Part 1: Process compressors (oil-free)

Industries du pétrole et du gaz naturel — Compresseurs volumétriques de type rotatif —

Partie 1: Compresseurs de procédé (sans huile)

Reference number
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Foreword

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

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

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

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

International Standard ISO 10440-1 was prepared by Technical Committee ISO/TC 118, Compressors, pneumatic tools and pneumatic machines, and Technical Commitee ISO/TC 67, *Materials, equipment and offshore structures for petroleum and natural gas industries*, Subcommittee SC 6, *Processing equipment and systems*.

ISO 10440 consists of the following parts, under the general title *Petroleum and natural gas industries — Rotary-type positive-displacement compressors*:

— *Part 1: Process compressors (oil-free)*

— *Part 2: Packaged air compressors (oil-free)*

Annex A forms a normative part of this part of ISO 10440.

Introduction

This part of ISO 10440 is based on the 2nd edition of API 619. This part of ISO 10440 is not intended to obviate the need for sound engineering judgement as to when and where this standard should be utilized, and users should be aware that further or differing requirements may be needed for individual applications.

This part of ISO 10440 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 part of ISO 10440 and provide details.

Standards referenced herein may be replaced by other international or national standards that can be shown to meet or exceed the requirements of the referenced standards.

Petroleum and natural gas industries — Rotary-type positive-displacement compressors —

Part 1: Process compressors (oil-free)

1 Scope

This part of ISO 10440 specifies requirements and gives recommendations for helical, spiral and straight lobe rotary compressors used for vacuum or pressure, or both, for use in the petroleum and natural gas industries. This part of ISO 10440 is applicable to compressors that are in continuous duty and are unspared. This part of ISO 10440 does not apply to standard air compressors, liquid ring compressors, vane-type compressors, or compressors in oxygen-bearing gas service using flammable liquid for injection or flooding.

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

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 10440. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 10440 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

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

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

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

ISO 1217, *Displacement compressors — Acceptance tests.*

ISO 1328-1:1995, *Cylindrical gears — ISO system of accuracy — Part 1: Definitions and allowable values of deviations relevant to corresponding flanks of gear teeth.*

ISO 1940-1:1986, *Mechanical vibration — Balance quality requirements of rigid rotors — Part 1: Determination of permissible residual unbalance.*

ISO 5167-1, *Measurement of fluid flow by means of pressure differential devices — Part 1: Orifice plates, nozzles and Venturi tubes inserted in circular cross-section conduits running full.*

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

ISO 9329-2, *Seamless steel tubes for pressure purposes — Technical delivery conditions — Part 2: Unalloyed and alloyed steels with specified elevated temperature properties.*

ISO 9329-4, *Seamless steel tubes for pressure purposes — Technical delivery conditions — Part 4: Austenitic stainless steels.*

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

ISO 10816-1, *Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts — Part 1: General guidelines.*

ISO 10816-3, *Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts — Part 3: Industrial machines with nominal power above 15 kW and nominal speeds between 120 r/min and 15 000 r/min when measured in situ.*

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

EFC 17, *Corrosion resistant alloys for oil and gas production: guidance on general requirements and test methods for H_2S service* (ISBN 1 86125 001 0 P).[1)]

ASTM E 125, *Reference photographs for magnetic particle indications on ferrous castings.*

ASTM E 709, *Standard guide for magnetic particle examination.*

ANSI/API 614, *Lubrication, shaft-sealing, and control-oil systems for special-purpose application.*

ANSI/API 670, *Vibration, axial-position, and bearing-temperature monitoring systems.*

NACE MR0175, *Sulfide stress cracking resistant metallic materials for oilfield equipment.*

NACE TM0177, *Standard test method for laboratory testing of metals for resistance to sulfide stress cracking and stress corrosion cracking in H_2S environments.*

NACE TM0198, *Slow strain rate test method for screening corrosion resistant alloys (CRAs) for stress corrosion cracking in sour oilfield service.*

NEMA SM23, *Steam turbines for mechanical drive service.*

3 Terms and definitions

For the purposes of this part of ISO 10440, the following terms and definitions apply.

3.1
axially [horizontally] split
〈casing joints〉 parallel to the shaft centreline

3.2
maximum allowable differential pressure
highest differential pressure that can be permitted in the casing under the most severe operating conditions of minimum suction pressure and discharge pressure equal to the relief valve setting

3. 3
maximum allowable discharge temperature
maximum continuous discharge temperature for which the manufacturer has designed the equipment

1) Issued by: European Federation of Corrosion, The Institute of Materials, 1 Carlton House Terrace, London SW1Y 5DB, GB.

3.4
maximum allowable speed
highest speed of the power input rotor at which the manufacturer's design will permit continuous operation

NOTE It is expressed in revolutions per minute.

3.5
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 handling the specified fluid at the specified temperature

3.6
maximum sealing pressure
highest pressure expected at the seals during any specified static or operating conditions and during startup or shutdown

3.7
minimum allowable speed
lowest speed of the power input rotor at which the manufacturer's design will permit continuous operation for the lowest rated conditions

NOTE It is expressed in revolutions per minute.

3.8
pressure casing
composite of all stationary pressure-containing parts of the unit, including all nozzles and other attached parts

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

EXAMPLE ASME VIII.

3.10
radially [vertically] split
⟨casing joints⟩ transverse to the shaft centreline

3.11
rated capacity
capacity, in cubic metres per hour, required by the rated conditions

3.12
rated conditions
specified conditions at which operation is expected and/or optimum efficiency is expected

3.13
rated discharge pressure
highest pressure required to meet the conditions the purchaser specifies for the intended service

3.14
rated discharge temperature
predicted actual operating temperature resulting from rated conditions

3.15
rated power
maximum power the compressor and any shaft-driven appurtenances require for any of the rated conditions, including the effect of any equipment (such as pulsation suppression devices, process piping, intercoolers, aftercoolers, and separators) furnished by the compressor vendor

3.16
rated speed
speed of the power input rotor corresponding to the requirements of the compressor rated capacity

NOTE It is expressed in revolutions per minute.

3.17
rotor
complete rotor body and the shaft and shrunk-on sleeves (when furnished)

3.18
rotor assembly
all rotating elements mounted on the rotor, excluding couplings

3.19
rotor body
profile section on or integral with the shaft

3.20
trip speed
speed at which independent emergency overspeed devices operate to shut down a prime mover

NOTE It is expressed in revolutions per minute.

4 Basic design

4.1 General

4.1.1 The pressure design code shall be specified on the data sheet (annex A). Pressure components shall comply with the pressure design code and the supplemental requirements in this part of ISO 10440.

4.1.2 The equipment (including auxiliaries) covered by this part of ISO 10440 shall be suitable for the specified operating conditions and shall be designed and constructed for a minimum service life of 20 years and at least 3 years of uninterrupted operation.

NOTE It is recognized that this is a design criterion.

4.1.3 Equipment shall be capable of running safely to the trip speed at 110 % relief valve setting and specified maximum differential pressure.

NOTE To run safely involves factors other than differential pressure, such as maximum discharge temperature or limiting driver power.

4.1.4 Cooling water systems shall be designed for the following conditions unless otherwise specified:

— velocity in exchanger tubes	1,5 m/s to 2,5 m/s
— maximum allowable working pressure	>5 bar
— test pressure	>7,7 bar
— maximum pressure drop	1 bar
— maximum inlet temperature	32 °C
— maximum outlet temperature	49 °C

— maximum temperature rise 17 °C

— minimum temperature rise 11 °C

— fouling factor on water side 0,35 $m^2 \cdot K/kW$

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

4.1.5 The arrangement of the equipment, including piping and auxiliaries, shall be developed jointly by the purchaser and the package vendor. The arrangement shall provide clearance areas and safe access for operation and maintenance.

4.1.6 All equipment shall be designed to permit rapid and economical maintenance. Major parts such as casing components and bearing housings, including shoulders and dowels, shall be designed and manufactured to ensure accurate alignment on reassembly.

4.1.7 Unless otherwise specified by the purchaser, spare parts for compressors and their auxiliaries shall meet all the requirements of the original equipment supplied.

4.1.8 Oil reservoirs and housings that enclose moving lubricated parts, including bearings, shaft seals, highly polished parts, instruments and control elements, shall be designed to prevent contamination by moisture, dust and other foreign matter during periods of operation or idleness.

4.1.9 When special tools and fixtures are required to disassemble, assemble or maintain the unit, they shall be included in the quotation and furnished as part of the initial supply of the compressor. For multi-unit installations, the requirements for quantities of special tools and fixtures shall be agreed between by the purchaser and the vendor.

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

4.1.11 The performance of the machine after installation shall be the responsibility of the package vendor providing that the utilities and the process conditions are as specified in the data sheets.

● **4.1.12** The vendor shall review and comment on the purchaser's piping and foundation drawings. The vendor shall observe a check on the piping made by parting the flanges. The vendor shall check alignment at operating temperatures and, when specified, shall be present during the initial alignment check.

NOTE Many factors, such as pipe loadings, nozzle loadings, alignment at operating conditions, piping and foundation vibrations from other equipment installed locally, supporting structure, handling during shipment, and handling and assembly at site, may adversely affect site performance.

● **4.1.13** All electrical components and installations shall be suitable for the area classification and grouping specified by the purchaser on the data sheets and shall be in accordance with the local codes specified.

● **4.1.14** Control of the sound level of all equipment furnished shall be a joint effort of the purchaser and the vendor. The equipment furnished shall comply with the requirements and local codes as specified by the purchaser as detailed on the data sheets.

● **4.1.15** Specifications for any liquid separation equipment required in the discharge gas stream shall be developed jointly by the purchaser and the vendor.

● **4.1.16** The purchaser shall specify in the data sheets (annex A) whether the installation is indoors (heated or unheated) or outdoors (with or without a roof) and the weather or environmental conditions in which the equipment shall operate, including maximum and minimum temperatures and unusual humidity or dusty environments. For the purchaser's guidance, the vendor shall list in the proposal any special protection that the purchaser is required to supply.

4.2 Pressure casing

4.2.1 The hoop stress values used in the design of the casings shall not exceed the maximum allowable stress values in tension specified in the pressure design code at the maximum and minimum operating temperature of the materials used.

4.2.2 The maximum allowable working pressure of the casing shall be not less than or equal to the specified relief valve setting.

4.2.3 Casings shall be made of steel if

a) the rated discharge gauge pressure is above 27,5 bar, or

b) the discharge temperature is over 260 °C, or

c) the gas is flammable or toxic.

4.2.4 Split pressure level casings should be avoided. If the casing is split into two or more pressure levels, the vendor shall define the physical limits and the maximum allowable working pressure of each part of the casing. See 7.1 item h).

4.2.5 Each axially split casing shall allow removal and replacement of its upper half without disturbing rotor-to-casing running clearances.

4.2.6 Casings and supports shall be designed to limit a change of shaft alignment to 50 μm at the coupling flange caused by the worst combination of pressure, torque, allowable piping forces and moments. Supports and alignment bolts shall permit the machine to be moved by the use of its lateral, axial and vertical jackscrews.

4.2.7 Axially split casings shall use a metal-to-metal joint that is tightly maintained by bolting. Jointing compound may be used. Gaskets, including string type, shall not be used on the axial joint. Gaskets, when used between the end covers and the cylinder of radially split casings, shall be confined.

4.2.8 Jacket cooling systems shall be designed to prevent leakage of the process stream into the coolant. Coolant passages shall not open into casing joints.

4.2.9 Jackscrews, guide rods and 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. Guide rods shall be of sufficient length to prevent damage to the internals or casing studs by the casing during disassembly and reassembly. Lifting lugs or eyebolts shall be provided for lifting only the top half of the casing. Methods for lifting the assembled machine shall be specified by the vendor.

4.2.10 For corrosion resistance, wear resistance and running in, overlay cladding or plating may be applied to the casing wall. The end wall may be lined similarly or have compatible end plates provided. The vendor shall provide details of his procedures to the purchaser.

NOTE This procedure may require an overbore of the casing during manufacture prior to final machining.

4.2.11 Details of threading shall conform to ISO 262.

4.2.12 Studs are preferred to cap screws.

4.2.13 A clearance shall be provided at bolting locations to permit the use of socket or box wrenches. The vendor shall supply any special tools and fixtures.

4.2.14 Socket, slotted nut or spanner bolting shall not be used unless specifically approved by the purchaser.

4.2.15 Tapped holes in pressure parts shall be kept to a minimum. Metal in addition to the metal allowance for corrosion shall be left around and below the bottom of drilled and tapped holes in pressure sections of casings to prevent leakage.

4.2.16 Studded connections shall be furnished with studs installed. Blind stud holes should only be drilled to allow a preferred tap depth of 1,5 times the major diameter of the stud; the first 1,5 threads at both ends of all studs shall be removed.

4.3 Casing connections

4.3.1 Inlet and outlet connections shall be flanged or machined and studded, oriented as specified in the data sheets, and suitable for the maximum allowable working pressure of the casing.

4.3.2 All the purchaser's connections shall be accessible for disassembly without moving the machine.

4.3.3 Connections welded to the casing shall comply with the material requirements, including impact values, of the casing rather than the requirements of the connected piping (see 4.11.4.5).

4.3.4 When the following items are required or specified, flanged or studded boss connections of a size not less than DN 20 shall be provided. Smaller connections, as follows, shall be used only with the purchaser's approval:

a) vents;

b) pressure and temperature gauge connections;

c) liquid injection;

d) water cooling;

e) lube and seal oil;

f) flushing;

g) buffer gas;

h) casing drains;

i) pressure-equalizing pipes.

4.3.5 All casing openings for pipe connections shall be of a size not less than DN 20 and shall be flanged or machined and studded. Where flanged or machined and studded openings are impractical, threaded openings are permissible in sizes DN 20 and DN 25. These threaded openings shall be installed as specified in 4.3.5.1 to 4.3.5.5.

4.3.5.1 A pipe nipple, preferably not more than 150 mm long, shall be screwed into the threaded openings.

4.3.5.2 Pipe nipples shall be made from seamless tube capable of handling the pressure requirements of the data sheets and withstanding a mechanical load of 1 000 N in any direction.

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

4.3.5.4 The nipple and flange material shall meet the requirements of 4.3.3.

4.3.5.5 The threaded connections shall not be seal welded.

4.3.6 Industry non-standard openings shall not be used.

4.3.7 Flanges shall conform to the pressure design code. Alternatives shall be in accordance with 4.3.7.1 and 4.3.7.2.

4.3.7.1 Cast iron flanges shall be flat faced.

4.3.7.2 Flat-faced flanges with raised-face thickness are acceptable for materials except cast iron.

4.3.8 Machined and studded connections shall conform to ISO 7005-1 for facing and drilling requirements. Studs and nuts shall be furnished and installed.

4.3.9 Tapped openings and bosses for pipe threads shall conform to ISO 7-1. Pipe threads shall be taper threads conforming to ISO 7-1.

4.3.10 Tapped openings not connected to piping shall be plugged with solid steel plugs. Plugs that may later require removal shall be of corrosion-resistant material. Threads shall be lubricated. Tape shall not be applied to threads. Plastic plugs shall not be used.

4.4 External forces and moments

Compressors shall be designed to withstand external forces and moments of at least 1,85 times the values calculated in accordance with NEMA SM23. The allowable forces and moments shall be shown on the outline drawing. Expansion joints should not be used in flammable or toxic service.

Wherever possible, these allowable forces and moments should be increased after considering such factors as the location and degree of compressor supports, nozzle length and degree of reinforcement, and casing configuration and thickness. Care should be exercised in the selection and location of expansion joints to prevent possible early fatigue due to either pulsation or expansion strain or both.

4.5 Rotating elements

4.5.1 Rotors

4.5.1.1 Rotor stiffness shall prevent contact between the rotor bodies and the casing and between gear-timed rotor bodies at the most unfavourable specified conditions, including 110 % of the relief valve set pressure. Rotor bodies not integral with the shaft shall be permanently attached to the shaft to prevent relative motion under any condition. Keyways shall have 1,6 mm fillet radii. Structural welds on rotors shall be continuous and shall be stress relieved through a minimum of two heating and cooling cycles.

4.5.1.2 Shafts shall be forged steel unless otherwise approved by the purchaser.

4.5.1.3 When required by 6.3.3.5, the rotor shaft sensing areas to be observed by vibration probes shall be concentric with the bearing journals and free from stencil and scribe marks or any other surface discontinuity such as an oil hole or keyway. These areas shall be neither metallized, sleeved nor plated. The final surface finish shall be 0,4 μm to 0,8 μm root mean square, obtained by honing or burnishing. These areas shall be demagnetized or otherwise treated so that the combined total electrical and mechanical runout shall not exceed 25 % of the maximum allowed peak-to-peak vibration amplitude or 6 μm, whichever is the greater.

4.5.1.4 Chromium-plated shafts or removable shaft sleeves shall be provided in the seal spaces. These sleeves shall be of a corrosion-resistant material hardened to resist wear and sealed to prevent leakage between the shaft and the sleeve.

4.5.2 Timing gears

4.5.2.1 Timing gears shall be made of forged steel or rolled steel and shall be a minimum of Quality 6 conforming to ISO 1328-1:1995. Timing gears shall be of the helical type.

4.5.2.2 The meshing relationship between gear-timed rotors shall be adjustable and the adjustment shall be arranged for locking. The adjustment and locking provisions shall be accessible with the rotors in their bearings.

4.5.2.3 The gear enclosing chamber shall not be subject to contact with the gas being compressed.

4.5.2.4 If timing gears have to be removed for seal replacement, it shall be possible to be able to retime the rotors without further disassembly of the casing.

4.5.2.5 Timing gears for helical and spiral compressors shall have the same helix hand (right or left) as the rotors.

NOTE This is so that axial rotor position has a minimal effect on rotor timing.

4.6 Seals

4.6.1 Application

4.6.1.1 Shaft seals shall be provided to prevent leakage from or into the compressor over the range of specified conditions including periods of idleness. Seal operation shall be suitable for all conditions that may prevail during startup, shutdown, and any other special operation specified in the data sheets by the purchaser.

Attention should be drawn to the dangers involved in mixing gases.

4.6.1.2 For low-temperature services, seal systems shall have provision for maintaining the seal oil above its pour-point temperature at the inner-seal drain.

- **4.6.1.3** Shaft seals may be one of or a combination of the types described in 4.6.2 through 4.6.5, as specified by the purchaser. Materials of component parts shall be suitable for the service.

- **4.6.1.4** Where an ejector system is used, it shall be provided with automatic control to maintain the desired seal chamber pressure. The motive fluid shall be inert gas or compressor discharge gas, as specified.

- **4.6.1.5** The purchaser or the vendor shall specify if buffer gas injection is required for the specified operating condition.

4.6.1.6 Piping for continuous buffer gas injection shall include a 150 µm strainer, automatic differential pressure controller, low-pressure alarm, and buffer gas pressure gauge. Any alternative arrangement shall be specified by the purchaser.

4.6.2 Labyrinth type

Labyrinth type seals shall be furnished with eductors or injection systems, where required. Seal systems shall be complete with piping, regulating and control valves, pressure gauges and strainers. Each item shall be piped and valved to permit its removal during operation of the compressor. Where gas from the compressor discharge is the motivating power for the eductor, provision shall be made for sealing during startup and shutdown.

4.6.3 Restrictive-ring type

Restrictive-ring type seals shall include segmental rings of carbon or other suitable material mounted in retainers or spacers. The seals may be operated dry, as in the labyrinth type, or with a sealing liquid, as in the mechanical type of seal.

4.6.4 Mechanical (contact type)

4.6.4.1 Mechanical-type seals shall be provided with labyrinths and slingers to minimize oil leakage to the atmosphere or into the compressor. Oil or other suitable liquid furnished under pressure to the rotating faces may be supplied from the lube oil system or from an independent oil system in accordance with 4.10.

4.6.4.2 Mechanical-type seals shall incorporate a self-closing feature to prevent gas leakage from the compressor on shutdown and loss of seal oil pressure.