BS EN ISO 10439-2:2015

BSI Standards Publication

Petroleum, petrochemical and natural gas industries — Axial and centrifugal compressors and expander-compressors

Part 2: Non-integrally geared centrifugal and axial compressors

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National foreword

This British Standard is the UK implementation of EN ISO 10439-2:2015. Together with BS EN ISO 10439-1:2015, BS EN ISO 10439-3:2015 and BS EN ISO 10439-4:2015, it supersedes BS EN ISO 10439:2002, which will be withdrawn upon publication of all parts of the series.

The UK participation in its preparation was entrusted to Technical Committee MCE/8/-/1, Compressors - Safety.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Industries du pétrole, de la pétrochimie et du gaz naturel - Compresseurs axiaux et centrifuges et compresseurs-détenteurs - Partie 2: Compresseurs centrifuges et axiaux sans multiplicateur intégré (ISO 10439-2:2015)

Erdöl-, petrochemische und Erdgasindustrie - Axial- und Radialkompressoren und Expanderkompressoren - Teil 2: Radial- und Axialkompressoren ohne integrierte Getriebeeinheit (ISO 10439-2:2015)

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Foreword

This document (EN ISO 10439-2:2015) has been prepared by Technical Committee ISO/TC 118 "Compressors and pneumatic tools, machines and equipment" in collaboration with Technical Committee CEN/TC 12 “Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries” the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by August 2015, and conflicting national standards shall be withdrawn at the latest by August 2015.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

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Endorsement notice

The text of ISO 10439-2:2015 has been approved by CEN as EN ISO 10439-2:2015 without any modification.

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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The committee responsible for this document is ISO/TC 118, *Compressors and pneumatic tools, machines and equipment*, Subcommittee SC 1, *Process compressors*.

This first edition, together with ISO 10439-1, ISO 10439-3, and ISO 10439-4, cancels and replaces ISO 10439:2002.

ISO 10439 consists of the following parts, under the general title *Petroleum, petrochemical and natural gas industries — Axial and centrifugal compressors and expander-compressors*:

— *Part 1: General requirements*

— *Part 2: Non-integrally geared centrifugal and axial compressors*

— *Part 3: Integrally geared centrifugal compressors*

— *Part 4: Expander-compressors*

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Introduction

This International Standard is based on the 7th edition of the American Petroleum Institute standard API 617.

Further or differing requirements might be needed for individual applications. This International Standard is not intended to inhibit a supplier from offering, or the purchaser from accepting, alternative equipment or engineering solutions for the individual application. This can be particularly appropriate where there is innovative or developing technology. Where an alternative is offered, the supplier should identify any variations from this part of ISO 10439 and provide details.

An asterisk (*) at the beginning of the paragraph of a clause or subclause indicates that either a decision is required or further information is to be provided by the purchaser. This information is indicated on data sheets or stated in the enquiry or purchase order (see examples in Annex A in this part of ISO 10439, ISO 10439-3:2015, Annex A, and ISO 10439-4:2015, Annex A).

This International Standard includes the following annexes:

— Annex A: Datasheets;

— Annex B: Vendor (Supplier) data and drawing requirements (VDDR);

— Annex C: Centrifugal compressor nomenclature;

— Annex D: Typical materials;

— Annex E: Inspector's checklist;

— Annex F: Nozzle forces and moments;

— Annex G: Full load, full pressure, full speed testing;

Annex A forms a normative part of this part of ISO 10439. Annex B to Annex G are for information only.

In this International Standard, where practical, US Customary units are included in parentheses for information.

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Petroleum, petrochemical and natural gas industries — Axial and centrifugal compressors and expander-compressors —

Part 2: Non-integrally geared centrifugal and axial compressors

1 Scope

This part of ISO 10439 specifies minimum requirements and gives recommendations for axial compressors, single-shaft, and integrally geared process centrifugal compressors and expander-compressors for special purpose applications that handle gas or process air in the petroleum, petrochemical, and natural gas industries. This part of ISO 10439 specifies requirements for non-integrally geared centrifugal and axial compressors, in addition to the general requirements specified in ISO 10439-1. These machines do not have gears integral with their casing but can have external gears.

NOTE See ISO 10439-3 for integrally geared process compressors, or API 672 for packaged plant instrument air compressors.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 10439-1:2015, *Petroleum, petrochemical and natural gas industries — Axial and centrifugal compressors and expander-compressors — Part 1: General requirements*

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

ISO 5389, *Turbocompressors — Performance test code*

API 670, *Machinery protection systems*

ASME PTC 10-1997, *Performance test code on compressors and exhausters*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 10439-1 and the following apply.

NOTE Certain terms are depicted graphically in Figures 1 to 3.

4 General

4.1 Dimensions and units

The dimensional and unit requirements shall be in accordance with ISO 10439-1.

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4.2 Statutory requirements

The statutory requirements shall be in accordance with ISO 10439-1.

4.3 Unit responsibility

The unit responsibilities shall be in accordance with ISO 10439-1.

4.4 Basic design

4.4.1 Performance

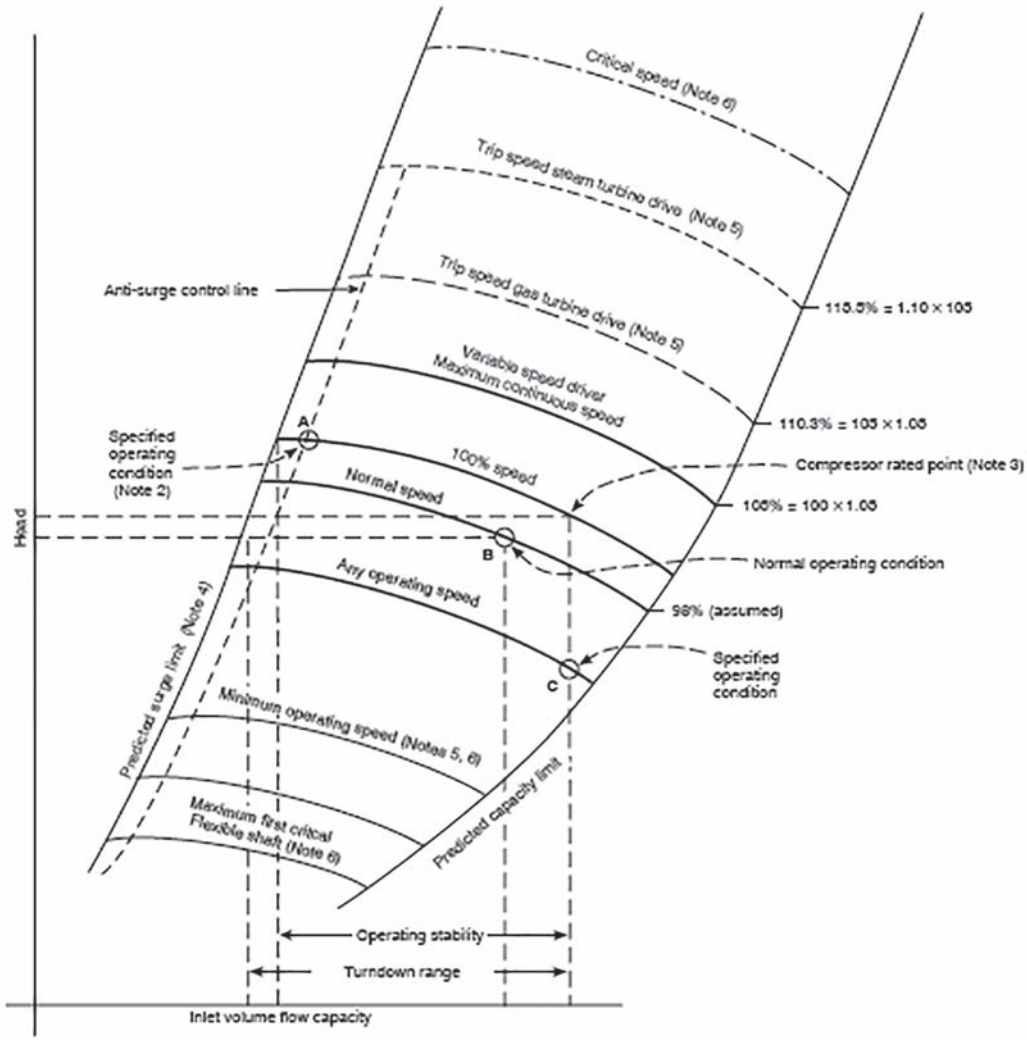

Figure 1 — Centrifugal compressor performance map — Illustration of terms

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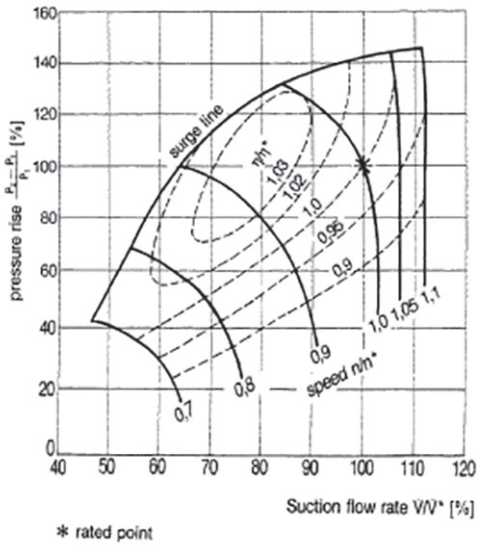

Figure 2 — Axial compressor performance map — variable speed

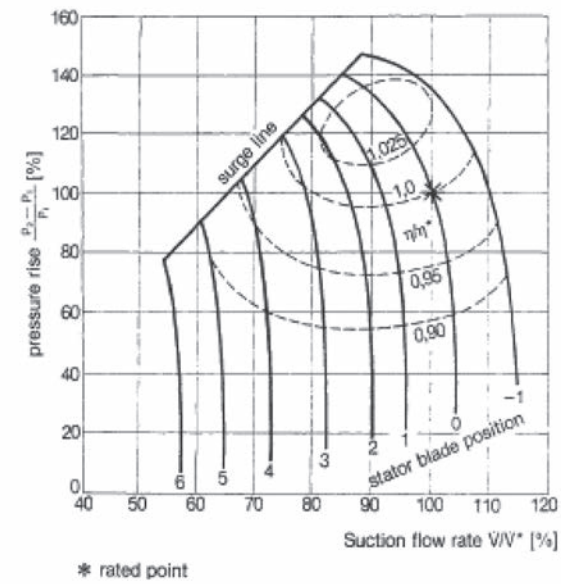

Figure 3 — Axial compressor performance map — variable stator vanes

NOTE Figure 1 is a typical operating map for a centrifugal compressor. Figures 2 and 3 are typical operating maps for an axial compressor.

4.4.1.1 The sectional head-capacity characteristic curve shall rise continuously from the rated point to predicted surge. The compressor, without the use of a bypass, shall be suitable for continuous operation at any capacity at least 10 % greater than the predicted surge capacity shown in the proposal.

4.4.1.2 The supplier shall provide an overload limit for axial compressors to avoid damaging blade stresses.

4.5 Materials

Materials shall be in accordance with ISO 10439-1:2015, 4.5.

NOTE Refer to Annex D for typical materials.

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4.6 Casings

Casings shall be in accordance with ISO 10439-1:2015, 4.6 and 4.6.1 to 4.6.6 of this part of ISO 10439.

4.6.1 Pressure-containing casings

4.6.1.1 The purchaser should specify the relief valve set pressure. The maximum allowable working pressure of the casing shall be at least equal to the specified relief valve set pressure.

When a relief valve set pressure is not specified, the maximum allowable working pressure shall be at least 125 % of the maximum specified discharge pressure (gauge). System protection shall be furnished by the purchaser.

4.6.1.2 Casings designed for more than one maximum allowable pressure level (split pressure-level casings) are permitted only in process air service with an atmospheric pressure inlet. Split pressure-level casings are not permitted in other services unless specifically approved by the purchaser. If approved, the supplier shall define the physical limits and the maximum allowable working pressure of each section of the casing.

4.6.1.3 Unless otherwise specified, casings shall be radially split when the partial pressure of hydrogen (at maximum allowable working pressure) exceeds 1 380 kPa gauge (200 psi gauge). The partial pressure of hydrogen shall be calculated by multiplying the highest specified mole (volume) per cent of hydrogen by the maximum allowable working pressure.

4.6.1.4 Each axially split casing shall be sufficiently rigid to allow removal and replacement of its upper half without disturbing rotor-to-casing running clearances and bearing alignment.

4.6.1.5 Axially split casings shall use a metal-to-metal joint (with a suitable joint compound compatible with the process gas) that is tightly maintained by suitable bolting. Gaskets (including string type) shall not be used on the axial joint. “O” rings retained in grooves machined into the flange facing of an axially split casing joint can be used with purchaser’s approval.

4.6.1.6 Radially split casings normally use “O” rings, gaskets, or other sealing devices between the end head(s) and cylinder. These devices shall be confined in machined grooves, and they shall be made of materials suitable for all specified service conditions.

4.6.1.7 Socket-head or spanner-type bolting shall not be used externally unless specifically approved by the purchaser.

4.6.2 Casing repair

Casings repairs shall be in accordance with ISO 10439-1:2015, 4.6.2.

4.6.3 Material inspection of pressure containing parts

Casings material inspection of pressure containing parts shall be in accordance with ISO 10439-1:2015, 4.6.3.

4.6.4 Pressure casing connections

Pressure casing connections shall be in accordance with ISO 10439-1:2015, 4.6.4 and 4.6.4.1 to 4.6.4.4 of this part of ISO 10439.

4.6.4.1 Main inlet and outlet connections for radially split machines shall be located in the outer casing, not in the end heads. On radially split overhung design machines, the process inlet connection can be in the end head.

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4.6.4.2 Auxiliary connections shall be at least DN 20 (3/4-in nominal pipe size).

NOTE See ISO 10439-1:2015, 4.6.4.1.3 for allowable connection sizes.

4.6.4.3 Threaded connections for pipe sizes DN 20 (NPS 3/4-in) to DN 40 (NPS 1-1/2-in) sizes are permissible with the approval of the purchaser.

NOTE See ISO 10439-1:2015, 4.6.4.1.3 for allowable connection sizes.

4.6.4.4 * If specified, connections for borescopic examination shall be supplied in agreed locations.

4.6.5 Casing support structures

The casing support structures shall be in accordance with ISO 10439-1:2015, 4.6.5.

4.6.6 External forces and moments

4.6.6.1 The compressor shall be designed to withstand external forces and moments on each nozzle calculated per Annex F. The supplier shall furnish the allowable forces and moments for each nozzle in tabular form.

4.6.6.2 Casing and supports shall be designed to have sufficient strength and rigidity to limit coupling movement caused by imposing allowable forces and moments to 50 µm (0.002 in).

4.6.7 Guide vanes, stators, and stationary internals

4.6.7.1 * If specified or required to meet specified operating conditions, adjustable inlet guide vanes (AIGVs) on centrifugal compressors shall be supplied.

4.6.7.2 * If specified or required to meet specified operating conditions, variable stators on axial compressors shall be supplied.

NOTE All or some of the stator blade rows can be adjustable.

4.6.7.3 The guide vane housing shall incorporate an external shell capable of providing an external purge of filtered air or inert gas.

4.6.7.4 A vane control system consisting of a positioner with direct driven local position indicator shall be provided that will be visible during operation of the machine.

4.6.7.5 Additional components to the vane control system in 4.6.7.4 shall be as specified.

4.6.7.6 Guide vanes shall be mounted in replaceable bushings. Vanes can be positioned in the housing by replaceable permanently sealed rolling element bearings if approved by the purchaser.

4.6.7.7 When inlet guide vanes or variable stators are used for toxic, flammable or explosive process gas, the linkage passing through the casing or enclosure shall be sealed to prevent leakage.

4.6.7.8 The inlet guide vanes shall be located sufficiently close to the eye of the impeller to be effective.

4.6.7.9 The vanes shall open on loss of the control signal.

4.6.7.10 When intermediate main suction or discharge process connections are used, the purchaser shall specify the maximum differential pressure between the connections if intermediate check valves

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are used. The supplier shall design the intermediate diaphragm between the process connections for the expected maximum differential including a suitable safety factor as agreed.

4.6.8 Internal joints

4.6.8.1 Internal joints shall be designed to minimize leakage and permit ease of disassembly.

4.6.9 Seal components

Seal components shall be separate parts and be renewable or replaceable in order to restore design clearances.

4.6.10 Diaphragms

4.6.10.1 Diaphragms shall be axially split unless otherwise approved by the purchaser. The diaphragms shall be furnished with threaded holes for eyebolts or with another means to facilitate removal.

4.6.10.2 Upper half diaphragms shall be fastened to the upper half casing or to each other in such a manner that they are lifted as a unit.

4.6.10.3 * If specified, the upper half diaphragms shall be attached to the lower half diaphragms.

NOTE For very large machines, this can have advantages in reducing the top half casing weight.

4.6.10.4 The internals of radially split multistage compressors shall be designed with an inner barrel assembly for withdrawal from the outer casing and disassembly for inspection or replacement of parts.

4.6.10.5 The supplier shall advise if a cartridge bundle assembly can be provided.

NOTE 1 This option can reduce maintenance time in the field.

NOTE 2 This feature is not available on all designs.

4.7 Rotating elements

4.7.1 General

4.7.1.1 Each assembled rotor shall be clearly marked with a unique identification number. This number shall be on the non-drive end of the shaft or in another accessible area that is not prone to maintenance damage.

4.7.1.2 Unless other shaft protection is approved by the purchaser, renewable components shall be furnished at interstage close-clearance points. Sleeves, spacers, or bushings shall be made of materials that are corrosion-resistant in the specified service.

4.7.1.3 Shaft sleeves shall be provided under shaft end seals. Sleeves shall be treated to resist wear and sealed to prevent gas leakage between the shaft and sleeve.

4.7.1.4 Shaft sleeves shall be provided under interstage seals. Closed impeller eye seals, which are stationary, do not require replaceable sleeves on the impeller.

4.7.2 Shafts

4.7.2.1 Shafts for non-through bolt rotors shall be made of one-piece, heat treated steel that is suitably machined. Shafts that have a finished diameter larger than 200 mm (8 in) shall be forged steel. Shafts that

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have a finished diameter of 200 mm (8 in) or less shall be forged steel or hot rolled barstock, providing such barstock meets all quality and heat treatment criteria established for shaft forgings.

4.7.2.2 When modular (through bolt) rotors are provided the stub-shafts shall meet all quality and heat treatment criteria for shaft forgings.

NOTE Refer to Annex C for rotor arrangements and nomenclature.

4.7.2.2.1 The studs or tie-bolts used to clamp a built-up rotor shall be made from bar or forgings. Threads shall be formed by rolling. Each tie-bolt shall be tested with a proof load corresponding to at least 110 % of maximum stretch that occurs during assembly or in operation.

4.7.2.2.2 Ferromagnetic material shall be DC wet magnetic particle inspected. Non-magnetic material shall be fluorescent penetrant inspected. These inspections shall be performed subsequent to proof-load test, and shall not reveal cracks, seams, or laps.

4.7.2.3 Proven methods of axial compressor rotor construction shall be offered. This includes solid (one-piece), disk-on-shaft, or stub shaft using through bolt, disk or drum construction, or other approved means.

4.7.3 Thrust balancing

4.7.3.1 A balance piston, balance line, and porting shall be provided if required to reduce axial loads on the thrust bearings. A separate pressure-tap connection or connections shall be provided to indicate the pressure in the balancing chamber, not in the balance line.

4.7.3.2 The balance line, if required, shall be flanged and sized to handle balance piston gas leakage at twice the initial design balance piston seal clearance without exceeding the load rating of the thrust bearings (see 4.9.3.3). If the balance line involves a connection to purchaser's piping, then the connection size and locations shall be indicated on the data sheets.

4.7.3.3 * If specified, a pressure tap connection shall be supplied in the downstream end of the balance line to allow measurement of differential pressure in the balance line.

NOTE This connection can be in the compressor supply or in the process piping.

4.7.3.4 * If specified, a differential pressure gage or transmitter shall be supplied to monitor differential balance line pressure.

4.7.4 Impellers

The impellers shall be in accordance with ISO 10439-1:2015, 4.7.10.

4.7.5 Axial compressor rotor blading

4.7.5.1 The blade natural frequencies shall not coincide with any source of excitation from 10 % below minimum allowable speed to 10 % above maximum continuous speed. If this is not feasible, blading shall be designed with stress levels low enough to allow unrestricted operation, at any specified operating speed for the minimum service life defined in ISO 10439-1:2015, 4.4.1.2. This shall be verified by Goodman diagrams or their equivalent. The supplier shall identify unacceptable speeds. Goodman diagrams for all blades shall be submitted to the purchaser for review.

NOTE Excitation sources include fundamental and first and second harmonic passing frequencies of rotating and stationary blades upstream and downstream of each blade row, gas passage splitters, irregularities in vane and periodic impulses caused by nozzle segment design at horizontal casing flanges, and the first 10 rotor speed harmonics.

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4.7.5.2 For each blade row, the supplier shall present bending and torsional blade natural frequencies under both operating and static conditions by Campbell diagrams or their equivalent.

NOTE Static frequencies can be used for comparison to "ring" testing on the blades installed in the rotor.

4.7.5.3 * If specified, or if blade natural frequencies are based on theoretical predictions, at least one blade from each stage shall be verified by ring testing.

4.7.5.4 All blades shall be peened. Peening intensity and media depend upon base material, compressive layer depth desired and material thickness. The compressive layer induced shall be checked by using Alnen strip.

4.7.5.5 Axial compressor rotor blading can be attached through axial dovetail, tangential fir tree, tangential, or T-slot. Other attachment methods are acceptable if approved by purchaser.

4.8 Dynamics

Dynamics requirements shall be in accordance with ISO 10439-1:2015.

4.9 Bearings and bearing housings

Bearing and bearing housing requirements shall be in accordance with ISO 10439-1:2015 and 4.9.1 to 4.9.4 of this part of ISO 10439.

4.9.1 General

4.9.1.1 Unless otherwise specified, hydrodynamic radial and thrust bearings shall be provided.

4.9.1.1.1 * If specified, active magnetic bearings shall be provided.

NOTE ISO 10439-1:2015, Annex E gives application considerations for use of active magnetic bearings.

4.9.1.2 Thrust bearings and radial bearings shall be fitted with bearing-metal temperature sensors installed in accordance with API 670.

4.9.1.3 As design criteria, bearing metal temperatures shall not exceed 100 °C (212 °F) at specified operating conditions with a maximum inlet oil temperature of 50 °C (120 °F). Suppliers shall provide bearing temperature alarm and shutdown limits.

In the event that the design criteria in 4.9.1.3 cannot be met, purchaser and supplier shall agree on acceptable bearing metal temperatures.

4.9.2 Hydrodynamic radial bearings

4.9.2.1 Unless otherwise specified, hydrodynamic bearings shall have flood lubrication. Directed lube can be used if agreed.

NOTE Directed lube has advantages in power losses, but has small passages with greater potential to plug. Radial bearings do not normally have significant power losses.

4.9.2.2 Sleeve or pad radial bearings shall be used and shall be split for ease of assembly. The use of non-split designs requires the purchaser's approval. The bearings shall be precision bored with steel or copper alloy backed babbitted replaceable liners, pads, or shells. The bearing design shall not require removal of the coupling hub to permit replacement of the bearing liners, pads, or shells unless approved by purchaser.

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4.9.2.3 * If specified, tilting pad bearings shoes shall be copper-alloy backed.

4.9.2.4 The removal of the top half of the casing of an axially split machine or the head of a radially split unit shall not be required for replacement of these elements. This might not be possible for overhung designs.

4.9.3 Hydrodynamic thrust bearings

4.9.3.1 Thrust bearings shall be steel-backed, babbitted multiple segments designed for equal thrust capacity in both axial directions and arranged for continuous pressurized lubrication to each side. Both sides shall be tilting pads, incorporating a self-levelling feature, which ensures that each pad carries an equal share of the thrust load even with minor variation in pad thickness.

NOTE Some low inlet pressure overhung compressors or axials will not need to meet the equal thrust load bi-directional criteria.

4.9.3.2 Hydrodynamic thrust bearings shall be selected at no more than 50 % of the bearing manufacturer's ultimate load rating. In sizing thrust bearings, consider the following for each specified application:

a) shaft speed;

b) temperature of the bearing babbitt;

c) deflection of the bearing pad;

d) minimum oil film thickness;

e) feed rate, viscosity, and supply conditions of the oil over the specified allowable oil supply condition range;

f) design configuration of the bearing;

g) babbitt or other bearing surface material alloy and pad material;

h) turbulence of the oil film;

i) load changes due to process changes over the specified operating range.

NOTE See ISO 10439-1:2015, 3.1.60 for a definition of ultimate load rating for hydrodynamic thrust bearings.

4.9.3.3 Thrust bearings shall be sized for continuous operation under the most adverse specified operating conditions. Calculations of the thrust forces shall include, but shall not be limited to the following factors:

a) seal maximum design internal clearances and twice the maximum design internal clearances;

b) pressurized rotor diameter step changes;

c) stage maximum differential pressures;

d) specified extreme variations in inlet, interstage, and discharge pressures;

e) the maximum thrust force that can be transmitted to the compressor thrust bearing by other equipment in the train (i.e. couplings, gears, or a motor without a thrust bearing);

f) the maximum thrust force from the sleeve bearing type drive if the motor or generator is directly connected.

4.9.3.4 The thrust bearing shall be arranged to allow both axial positioning of the rotor relative to the casing and setting the bearings' clearance.

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4.9.3.5 Each pad within one side of the thrust bearing, shall be designed and manufactured to tolerances to allow interchange or replacement of the individual pads.

NOTE Instrumented and offset pivot designs do not allow interchange side to side.

4.9.3.6 Unless otherwise specified, directed lube thrust bearings shall be used. Flooded lube can be used if agreed.

NOTE Directed lube has advantages in power losses, but has small passages with greater potential to plug.

4.9.3.7 * If specified, thrust bearings pads shall be copper-alloy backed.

4.9.4 Bearing housings

4.9.4.1 Rotor support system parts (bearings, bearing housings, bearing carriers, and bearing brackets) shall be separable from the casing, axially split, non-pressurized (vented to atmosphere), and furnished with plugged connections for dry air or inert gas purge to any atmospheric labyrinth seals.

4.9.4.2 Axially split-bearing housings shall have a metal-to-metal split joint whose halves are located by means of cylindrical dowels.

4.9.4.3 Shaft support structures bolted to casings shall be steel. Shaft support structures bolted to cast iron casings can be made from cast iron.

4.10 Shaft end seals

4.10.1 Shaft end seals shall be in accordance with ISO 10439-1:2015, 4.10 and 4.10.2 to 4.10.4 of this part of ISO 10439.

NOTE 1 Typical cross sections of various shaft seals are given in ISO 10439-1:2015, Annex C.

NOTE 2 Equipment covered in this part can be available with any of the shaft end seal types covered in ISO 10439-1:2015, or additional hybrid types can be available.

4.10.2 * Purchaser shall specify the type of shaft end seal(s) to be provided and all operating conditions including start-up, shutdown and settling-out conditions.

NOTE Axial compressors in process air service will generally be supplied with labyrinth shaft end seals. Process compressors can have any type of shaft end seal specified.

4.10.3 Shaft end seals shall be accessible for inspection and replacement without removing the top half of the casing for an axially split compressor or the heads of a radially split unit. This requirement is not applicable for overhung designs.

4.10.4 * If specified for non-cartridge seal types, shaft sleeves under shaft end seals shall be accessible for inspection and replacement without removing the top half of the casing for an axially split compressor or the heads of a radially split unit. This requirement is not applicable for overhung designs.

NOTE This is of benefit for seal types where the wearing component is in close proximity to the sleeve. Example seal types are labyrinth and carbon ring.

4.11 Integral gearing

Internal gearing is not applicable for equipment covered in this part. For external gearing, refer to API 613.

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4.12 Nameplates and rotation arrows

4.12.1 Nameplates and rotation arrows shall be in accordance with ISO 10439-1:2015, 4.12 and 4.12.2 and 4.12.3 of this part of ISO 10439.

4.12.2 The following data shall be clearly stamped or engraved on the nameplate:

a) supplier's name;

b) serial number;

c) size, type, and model;

d) rated capacity;

e) rated power;

f) lateral critical speeds up to and including the next lateral above maximum continuous speed;

g) purchaser item number or other reference;

h) maximum allowable working pressure;

i) minimum and maximum allowable working temperature;

j) minimum operating speed;

k) maximum continuous speed;

l) trip speed;

m) hydrostatic test pressure;

n) maximum sealing pressure.

4.12.3 Rotation arrows shall be cast-in or attached to each major item of rotating equipment at a readily visible location.

5 Accessories

5.1 General

Accessories shall be in accordance with ISO 10439-1:2015, Clause 5 and 5.2 to 5.8 of this part of ISO 10439.

5.2 Drivers and gearing

Drivers and external gearing shall be in accordance with ISO 10439-1:2015, 5.1.

5.3 Couplings and guards

Couplings and guards shall be in accordance with ISO 10439-1:2015, 5.2.

5.4 Lubrication and sealing systems

Lubrication and sealing systems shall be in accordance with ISO 10439-1:2015, 5.3.

5.5 Mounting plates

Mounting plates shall be in accordance with ISO 10439-1:2015, 5.4.

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5.6 Controls and instrumentation

5.6.1 Controls and instrumentation shall be in accordance with ISO 10439-1:2015, 5.5.

5.6.2 Control systems when supplied, shall be in accordance with ISO 10439-1:2015, 5.5.2 and 5.6.2.1 to 5.6.7.6 of this part of ISO 10439.

5.6.2.1 Axial compressors shall be supplied with a map of allowable operating range to permit the design of control logic to prevent operation in the region of choke (overload) and therefore avoid potentially dangerous blade stresses.

NOTE Figures 2 and 3 show typical performance maps for axial compressors.

5.6.2.2 When an anti-surge system as described in ISO 10439-1:2015, 5.5.2.2 is furnished for an axial compressor, the system shall also include overload protection.

5.6.2.3 * For constant-speed centrifugal compressors, when adjustable inlet guide vanes are required, the supplier shall also furnish a guide-vane positioner capable of supplying a compatible control signal as specified by the purchaser.

NOTE See ISO 10439-1:2015, 5.5.2.1.

5.6.2.4 For constant-speed axial compressors supplied with adjustable vanes, the supplier shall also furnish a vane positioner compatible with the type of control signal specified by the purchaser. A direct-driven local vane position indicator shall be provided that will be visible during operation of the machine.

5.6.3 Instrument and control panels, when supplied, shall be in accordance with ISO 10439-1:2015, 5.5.3.

5.6.4 Instrumentation, when supplied, shall be in accordance with ISO 10439-1:2015, 5.5.4.

5.6.5 Alarms, shutdowns, and control systems, when supplied, shall be in accordance with ISO 10439-1:2015, 5.5.5.

5.6.6 Electrical systems, when supplied, shall be in accordance with ISO 10439-1:2015, 5.5.6.

5.6.7 Vibration, position, and bearing temperature detectors

5.6.7.1 Radial shaft vibration and axial-position transducers and bearing temperature sensors shall be supplied, installed, and calibrated in accordance with API 670.

5.6.7.2 * If specified, radial shaft vibration and axial position monitors shall be supplied and calibrated in accordance with API 670.

5.6.7.3 * Purchaser shall specify the type of temperature detector to be supplied. Installation shall be per API 670.

5.6.7.4 * If specified, a bearing temperature monitor shall be supplied and calibrated in accordance with API 670.

5.6.7.5 * If specified, casing vibration transducers shall be supplied, installed, and calibrated in accordance with API 670.

5.6.7.6 * If specified, casing vibration monitors shall be supplied, installed and calibrated in accordance with API 670.

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5.7 Piping and appurtenances

5.7.1 General

Piping and appurtenances furnished shall be in accordance with ISO 10439-1:2015, 5.6 and 5.7.1.1 to 5.7.2 of this part of ISO 10439.

5.7.1.1 When a baseplate has been specified, the supplier shall furnish all piping systems, including mounted appurtenances, located within its confines. The piping shall terminate with flanged connections at the edge of the baseplate. When soleplates have been specified, the extent of the piping system supplied by the supplier shall be defined by the purchaser. The purchaser will furnish-interconnecting piping between equipment groupings and off base facilities.

5.7.1.2 * If specified, a liquid injection manifold shall be supplied. It shall include a throttle valve, an armored flow meter, a check valve, a pressure indicator, and a block valve for each injection point.

5.7.2 Process piping

Process piping, if furnished, shall be in accordance with ISO 10438-1:2007, 2.4.

5.8 Special tools

Special tools shall be in accordance with ISO 10439-1:2015, 5.7.

6 Inspection, testing, and preparation for shipment

6.1 General

General requirements for inspection, testing and preparation for shipment shall be in accordance with ISO 10439-1:2015, 6.1. Also refer to Annex E for the inspector's checklist.

6.2 Inspection

Requirements for inspection shall be in accordance with ISO 10439-1:2015, 6.2.

6.3 Testing

In addition to the requirements of ISO 10439-1:2015, 6.3, the compressor(s) shall be tested in accordance with 6.3.1 and 6.3.2. Optional tests that might be specified are described in 6.3.3. Immediately upon completion of each witnessed mechanical or performance test, copies of the data recorded during the test shall be given to the witnesses.

6.3.1 Mechanical running test

6.3.1.1 The requirements of 6.3.1.1.1 to 6.3.1.1.12 shall be met before the mechanical running test is performed.

6.3.1.1.1 The contract shaft seals and bearings shall be used in the machine for the mechanical running test, except that the atmospheric breakdown bushing(s) on oil seals can be replaced with a test bushing, if required.

NOTE Low-pressure mechanical testing can require increased clearance or fewer elements for proper heat removal.

6.3.1.1.2 Oil viscosity, pressures, and filtration shall be within the range of operating values recommended in the supplier's operating instructions for the unit being tested. Oil flow rates to each oil

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seal and bearing housing shall be measured. Oil inlet temperature can be varied for the mechanical test to match the design oil viscosity.

6.3.1.1.3 * If specified, oil temperatures and supply pressures shall be varied over the allowable operating range during test as agreed.

6.3.1.1.4 Oil system components downstream of the filters shall meet the cleanliness requirements of ISO 10438 before any test is started.

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

6.3.1.1.6 All warning, protective, and control devices used during the test shall be checked, and adjusted as required.

6.3.1.1.7 Facilities shall be installed to prevent the entrance of oil into the process gas section of the compressor during the mechanical running test. These facilities shall be in operation throughout the test.

6.3.1.1.8 Testing with the contract coupling(s) is preferred. If this is not practical, the mechanical running test shall be performed with coupling(s) or simulators that have overhung moments within 10 % of the contract coupling(s).

6.3.1.1.9 The circumferential location of a hydraulically mounted coupling hub relative to the shaft shall be non-permanently marked before starting the test.

It can be required to ramp thru certain speed ranges to avoid resonant frequencies.

6.3.1.1.10 The equipment shall be operated at speed increments of approximately 10 % from zero to the maximum continuous speed and run at the maximum continuous speed until bearing metal temperatures and shaft vibrations have stabilized (see Figure 4).

NOTE Operating equipment at or near critical speeds is normally avoided. For axial compressors, other speeds at or near blade resonant frequencies are also avoided (see 4.7.5.1).

6.3.1.1.11 The speed shall be increased to trip speed and the equipment shall be run for a minimum of 15 min.

6.3.1.1.12 The speed shall be reduced to the maximum continuous speed, and the equipment shall be run for 4 h continuous operation.

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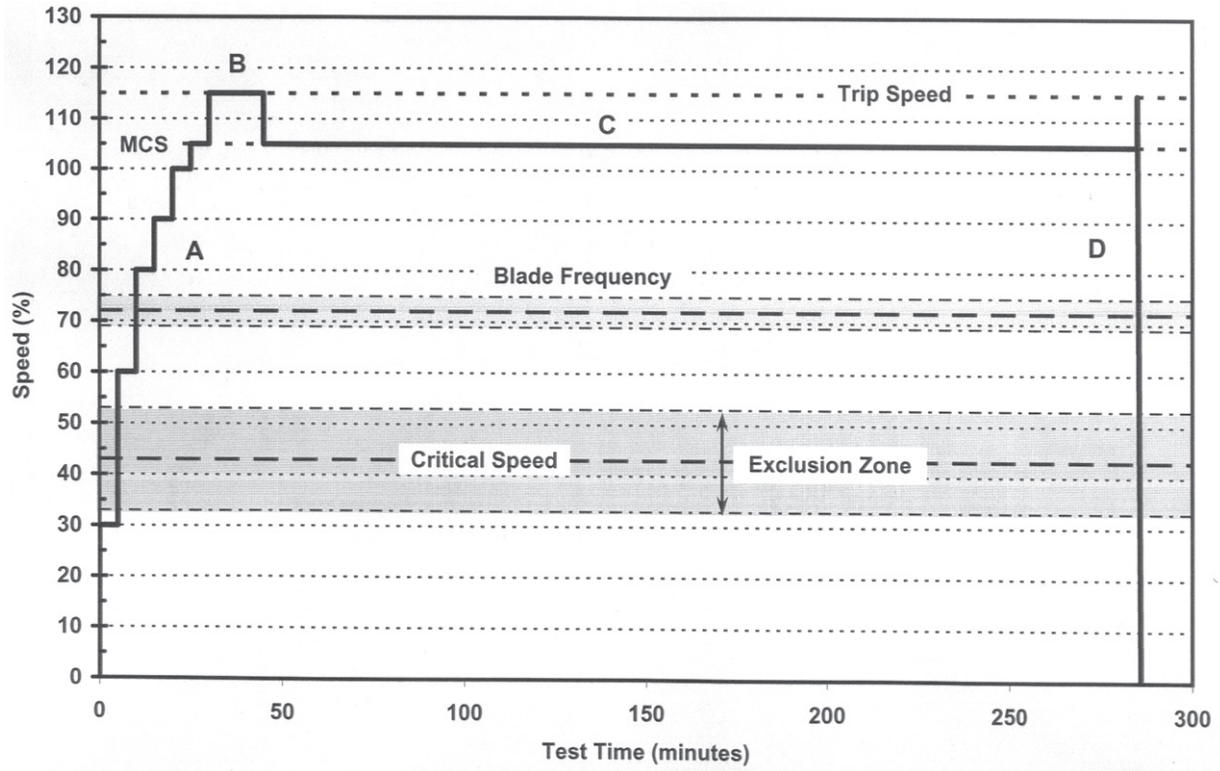

Key

A warm up phase
- — speed increased multiple increments
- — avoid critical speeds, blade frequencies, etc.

B trip speed operation
- — 15 min

C maximum continuous speed 4 h test
- — oil supply variations performed
- — operating conditions recorded

D shutdown/ramp down
- — momentary increase to trip speed
- — transient operation recorded
- — used as baseline for verification testing

Figure 4 — Mechanical test

6.3.1.2 During the mechanical running test, the requirements of 6.3.1.2.1 to 6.3.1.2.9 shall be met.

6.3.1.2.1 During the mechanical running test, the mechanical operation of all equipment being tested and the operation of the test instrumentation shall be satisfactory. The measured unfiltered vibration shall not exceed the limits of ISO 10439-1:2015, 4.8.8.8 and shall be recorded throughout the operating speed range. Any other test acceptance criteria shall be agreed and stated in the test agenda.

6.3.1.2.2 While the equipment is operating at maximum continuous speed, or other speed required by the test agenda, vibration data shall be acquired to determine amplitudes at frequencies other than synchronous. This data shall cover a frequency range from 0,25 times to 8 times the maximum continuous speed. If the amplitude of any discrete, nonsynchronous vibration exceeds 20 % of the allowable vibration as defined in ISO 10439-1:2015, 4.8.8.8, the purchaser and the supplier shall agree on requirements for any additional testing and on the equipment's acceptability.

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6.3.1.2.3 The mechanical running test shall verify that lateral critical speeds conform to the requirements of ISO 10439-1:2015, 4.8.3.

6.3.1.2.4 Shop verification of the unbalanced response analysis shall be performed in accordance with ISO 10439-1:2015, 4.8.2.

6.3.1.2.5 When spare rotors are supplied to permit concurrent manufacture, each spare rotor shall also be given a mechanical running test in accordance with the requirements of this part of ISO 10439.

6.3.1.2.6 When spare inner barrel assemblies or cartridges bundle assemblies are supplied, the spare rotor shall be tested with the inner barrel assembly.

NOTE 1 Spare cartridge bundle assemblies can result in reduced turnaround time.

NOTE 2 See ISO 10439-1:2015, 3.1.3 and ISO 10439-1:2015, 3.1.15 for definitions of cartridge bundle assembly and inner barrel assembly.

6.3.1.2.7 When spare axial blade stator vane assemblies are supplied, the spare rotor shall be tested with the spare stator vanes.

6.3.1.2.8 The purchaser shall advise additional testing requirements for spare parts.

6.3.1.2.9 Axial compressors with variable stators shall be exercised throughout the entire range of movement using the contract linkage and linkage positioner during the mechanical test.

6.3.2 Assembled compressor gas leakage test

6.3.2.1 After the mechanical running test is completed, each completely assembled compressor casing intended for toxic, hazardous, or flammable service shall be tested as required in 6.3.2.2 and/or, when specified, 6.3.2.3.

NOTE These tests are intended to verify the integrity of the casing joint. Some shaft seal designs are not gas tight. Therefore, leakage from these seals is acceptable.

6.3.2.2 The assembled compressor (including end seals) shall be pressurized, with an inert gas, to the maximum sealing pressure or the maximum seal design pressure, as agreed by the purchaser and the supplier; held at no less than this pressure for a minimum of 30 min and subjected to a soap-bubble test, or alternate method, to check for gas leaks. The test shall be considered satisfactory when no casing or casing joint leaks are observed.

NOTE Test gas mole weight will approximate or be less than contract gas mole weight. Helium for low mole weight contract gas, and nitrogen or refrigerant gas for high mole weight can be considered.

6.3.2.3 * If specified, the assembled compressor (with or without end seals installed) shall be pressurized with an inert gas to the maximum specified discharge pressure, held at this pressure for a minimum of 30 min, and subjected to a soap bubble test, or alternate method, to check for gas leaks. The test shall be considered satisfactory when no casing or casing joint leaks are observed.

NOTE The requirements of 6.3.2.2 and 6.3.2.3 can necessitate two separate tests.

6.3.3 * Optional tests

The purchaser should specify whether any of the following shop tests shall be performed. Test details shall be agreed prior to the test.

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6.3.3.1 Factory performance test

6.3.3.1.1 The compressor shall be performance tested in accordance with ASME PTC 10-1997 or ISO 5389 as specified. A minimum of five points, including surge and overload, shall be taken at the speed equivalent to normal speed.

NOTE Refer to the applicable test code for general instructions. ASME PTC 10-1997 cannot apply to some low pressure ratio compressors. Refer to the scope, 1.2.2, of ASME PTC 10-1997 for the selection of the appropriate test code to be used.

6.3.3.1.2 * If specified, surge line testing or additional speed lines can be tested for variable speed machines.

6.3.3.1.3 For variable speed machines, head and capacity shall have zero negative tolerance at the certified point, and the power at this point shall not exceed 104 % of the supplier predicted shaft power value. This tolerance shall be inclusive of all test tolerances. Surge shall comply with provisions of 4.4.1.1.

NOTE Both of the performance test codes referred to have provision for calculating inaccuracy based on instrumentation and procedures. These test inaccuracies are already included in the above tolerance and, therefore, are not to be further additive.

6.3.3.1.4 For variable-speed compressors, a speed other than the normal speed can be used, if necessary, to achieve the specified conditions, provided that this adjusted speed meets the criteria specified in ISO 10439-1:2015, 4.8.

6.3.3.1.4.1 Variable speed compressors shall have maximum continuous speed increased if necessary after performance testing to maintain a minimum 5 % margin over adjusted rated speed based on test.

When a speed increase is necessary to achieve specified performance, all design margins such as separation margins, overspeed margins, maximum continuous margins, etc. shall be maintained.

NOTE This maintains a 5 % speed margin for future process changes.

6.3.3.1.5 For constant-speed compressors, the capacity shall be as specified in 6.3.3.1.2. The head shall be within the range of 100 % to 105 % of the normal head. The horsepower, based on measured head at certified capacity, shall not exceed 107 % of the value at the specified certified point. If the power required at this point exceeds 107 %, or head exceeds 105 % of the normal head, excess head can be removed by trimming impellers at the purchaser's option.

6.3.3.1.6 If hardware modifications are required to meet performance, the performance test shall be repeated.

6.3.3.1.7 The performance test shall be conducted using only one contract rotor, unless otherwise specified.

6.3.3.1.8 * If specified, purchaser shall state the intermediate pressures. Manufacturer shall state the pressure tolerance at each connection.

6.3.3.1.9 For trains with multiple compressors, intermediate pressures and individual power tolerances can be adjusted as agreed. Overall power tolerances shall be as stated in 6.3.3.1.

6.3.3.2 Complete unit test

The scope of this test shall be detailed by the purchaser. Such components as compressors, gears, drivers, and auxiliaries that make up a complete unit shall be tested together during the mechanical running test. A separate auxiliary test can be performed. The complete unit test can be performed in place of, or in addition to, separate tests of individual components.

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6.3.3.2.1 * If specified for the complete unit test, torsional vibration measurements shall be made to verify the supplier's analysis.

6.3.3.3 Tandem test

Compressor bodies arranged for tandem drive shall be tested as a unit during the mechanical running test, using the shop driver and oil systems as specified.

6.3.3.4 Gear test

For units with external gears, the contract gear shall be tested with the machine(s) during the mechanical running test.

6.4 Preparation for shipment

Equipment shall be prepared for shipment in accordance with ISO 10439-1:2015, 4.4 and 6.4.1 of this part of ISO 10439.

6.4.1 * If specified, dry gas seals shall be removed for shipment.

NOTE Seals will be reinstalled in the field or cover plates fabricated if the compressor is to be provided with a nitrogen blanket during construction.

7 Supplier's data

7.1 General

7.1.1 Supplier's data shall be in accordance with ISO 10439-1:2015, Clause 7 and 7.1 to 7.3 of this part of ISO 10439.

7.1.2 The information to be furnished by the supplier is specified in Annex B of this part of ISO 10439 and Clause 7 of ISO 10439-1. The supplier shall complete and forward the VDDR form in Annex B, to the address or addresses noted on the inquiry or order. This form shall detail 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 Proposals

Proposal data shall be in accordance with ISO 10439-1:2015, 7.2.

7.3 Contract data

Contract data shall be in accordance with ISO 10439-1:2015, 7.3.

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