INTERNATIONAL STANDARD

ISO 10439-2

First edition
2015-02-15

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

Part 2: Non-integrally geared centrifugal and axial compressors

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

Reference number
ISO 10439-2:2015(E)

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

Contents

Page

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.

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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT), see the following URL: Foreword - Supplementary information

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*

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.

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.

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

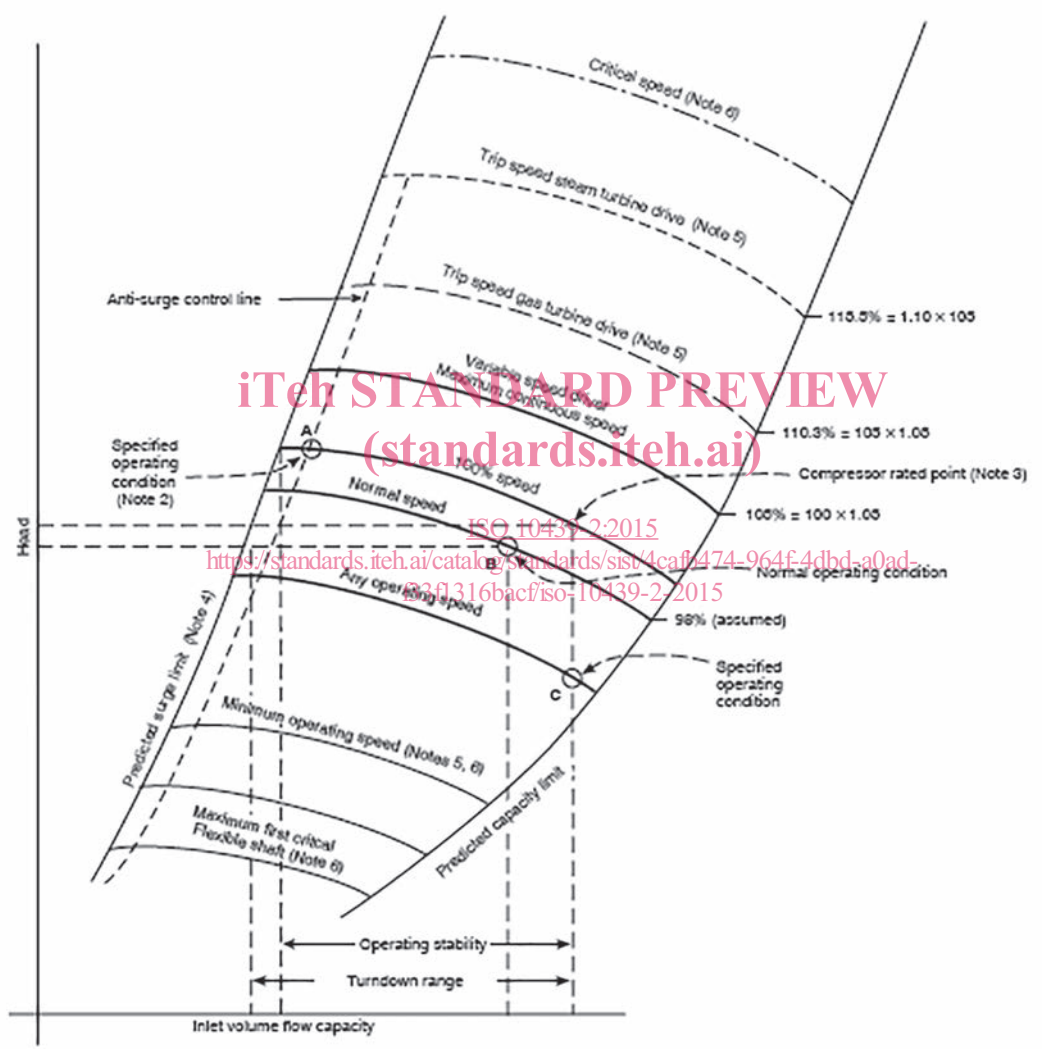

Figure 1 — Centrifugal compressor performance map — Illustration of terms

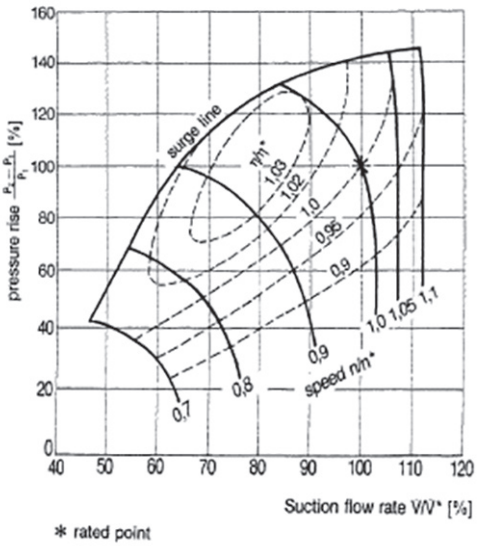

Figure 2 — Axial compressor performance map — variable speed

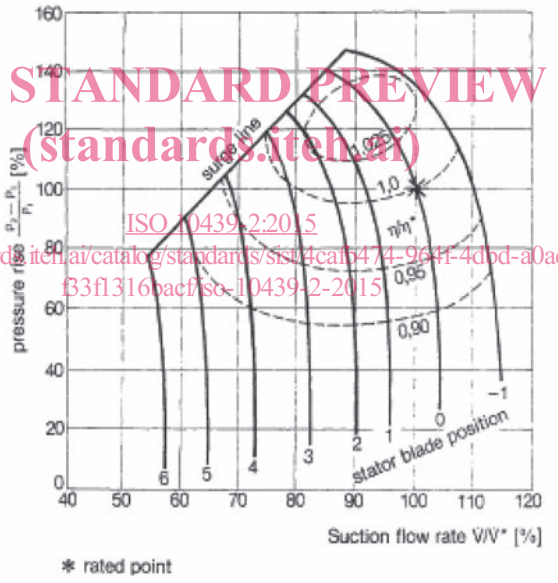

Figure 3 — Axial compressor performance map — variable stator vanes

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.

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.

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

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

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.

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.

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.