INTERNATIONAL STANDARD

ISO 10439

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Petroleum, chemical and gas service industries — Centrifugal compressors

Industries du pétrole, de la chimie et du gaz — Compresseurs centrifuges

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Foreword

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

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

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

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

ISO 10439 was prepared by a Joint Working Group of Technical Committees ISO/TC 118, *Compressors, pneumatic tools and pneumatic machines*, and ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*, Subcommittee SC 6, *Processing equipment and systems*.

Annexes C, D and G form a normative part of this International Standard. Annexes A, B, E, F, H, I and J are for information only.

In this corrected version of ISO 10439 an oversight which saw the words “Final Draft” and its abbreviation left in the header of page 1 has been corrected.

Introduction

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

Users of this International Standard should be aware that further or differing requirements may be needed for individual applications. This International Standard is not intended to inhibit a vendor from offering, or the purchaser from accepting, alternative equipment or engineering solutions for the individual application. This may be particularly applicable where there is innovative or developing technology. Where an alternative is offered, the vendor should identify any variations from this International Standard and provide details.

Petroleum, chemical and gas service industries — Centrifugal compressors

1 Scope

This International Standard specifies requirements and gives recommendations for the design, materials, fabrication, inspection, testing and preparation for shipment of centrifugal compressors for use in the petroleum, chemical and gas service industries. It is not applicable to machines that develop less than 35 kPa above atmospheric pressure, nor is it applicable to packaged, integrally geared centrifugal air compressors, which are covered in ISO 10442.

NOTE In this International Standard, where practical, US customary units have been included in brackets for information.

2 Normative references

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

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

ISO 3744, *Acoustics — Determination of sound power levels of noise sources using sound pressure — Engineering method in an essentially free field over a reflecting plane*

ISO 3977-5, *Gas turbines — Procurement — Part 5: Applications for petroleum and natural gas industries*

ISO 5389, *Turbocompressors — Performance test code*

ISO 7005-2, *Metallic flanges — Part 2: Cast iron flanges*

ISO 8821, *Mechanical vibration — Balancing — Shaft and fitment key convention*

ISO 9614 (both parts), *Acoustics — Determination of sound pressure levels of noise sources using sound intensity*

ISO 10437, *Petroleum and natural gas industries — Special-purpose steam turbines for refinery service*

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

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

ISO 13691, *Petroleum and natural gas industries — High-speed special-purpose gear units*

1) To be published. (Revision of ISO 1940-1:1986)

IEC 60079-10, *Electrical apparatus for explosive gas atmospheres — Part 10: Classification of hazardous areas*

API[2] RP 550, *Manual on installation of refinery instruments and control systems*

API Std 670, *Machinery protection systems, fourth edition*

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

ASTM[4] A 388/A 388M, *Standard practice for ultrasonic examination of heavy steel forgings*

ASTM A 578/A 578M, *Standard specification for straight-beam ultrasonic examination of plain and clad steel plates for special applications*

ASTM A 609/A 609M, *Standard practice for casting, carbon, low-alloy, and martensitic stainless steel, ultrasonic examination thereof*

ASTM E 94, *Standard guide for radiographic examination*

ASTM E 165, *Standard test method for liquid penetrant examination*

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

ISA[5] RP 12.4, *Pressurized enclosures*

NACE[6] MR 0175, *Sulfide stress cracking resistant metallic materials for oilfield equipment*

NFPA[7] 496, *Standard for purged and pressurized enclosures for electrical equipment*

3 Terms and definitions

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

3.1
alarm condition
preset value of a parameter at which an alarm is actuated to warn of a condition requiring corrective action

3.2
axially split
casing or other component in which the main joint is parallel to the axis of the shaft

3.3
compressor rated point
point on the 100 % speed curve at the highest capacity of any specified operating point

NOTE The use of the word “design” in any term (such as design power, design pressure, design temperature, or design speed) should be avoided in the purchaser's specification. This terminology should be used only by the equipment designer and manufacturer.

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2) American Petroleum Institute.

3) American Society of Mechanical Engineers.

4) American Society for Testing and Materials.

5) Instrument Society of America.

6) US National Association of Corrosion Engineers.

7) US National Fire Protection Association.

3.4
head
specific compression work

3.5
inlet volume flow
volume flow rate determined at the conditions of pressure, temperature, compressibility and gas composition, including moisture, at the compressor inlet flange

3.6
maximum allowable temperature
maximum continuous temperature for which the manufacturer has designed the equipment (or any part to which the term is referred) when handling the specified fluid at the specified pressure

3.7
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 it is operating at the maximum allowable temperature

3.8
maximum continuous speed
highest rotational speed at which the machine is capable of continuous operation

3.9
maximum sealing pressure
highest pressure the seals are required to seal during any specified static or operating conditions and during start-up and shutdown

3.10
minimum allowable speed
lowest speed at which the manufacturer's design will permit continuous operation

3.11
normal operating point
point at which usual operation is expected and optimum efficiency is desired

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

3.12
normal speed
speed corresponding to the requirements of the normal operating point

3.13
100 % speed
highest speed required for any specified operating point

3.14
pressure design code
recognized pressure vessel standard specified or agreed by the purchaser (e.g. ASME VIII)

3.15
radially split
casing or other component in which the main joint is perpendicular to the axis of the shaft

3.16
stability
difference in inlet volume flow (as percentage of rated inlet volume flow) between the rated inlet volume flow and the surge point at rated speed

3.17
settling out pressure
pressure of the compressor system when the compressor is shut down

3.18
shutdown condition
preset value of a parameter requiring automatic or manual shutdown of the system

3.19
trip speed
speed at which the independent emergency overspeed device operates to shut down a prime mover

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

3.20
turndown
percentage of change in inlet volume flow (referred to rated inlet volume flow) between the rated inlet volume flow and the surge point inlet volume flow at the rated head, when the unit is operating at rated suction temperature and gas composition

3.21
unit responsibility
responsibility for coordinating the technical aspects of the equipment train and all auxiliary systems

4 Basic design

4.1 General

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

4.1.2 The equipment (including auxiliaries) covered by this International Standard shall be designed and constructed for a minimum service life of 20 years and at least 3 years of uninterrupted operation.

4.1.3 Unless otherwise specified, the compressor vendor shall assume unit responsibility.

4.1.4 The compressor shall be designed to deliver required head and capacity at the normal operating point without negative tolerance. The input power at the above condition shall not exceed 104 % of the predicted value for this point.

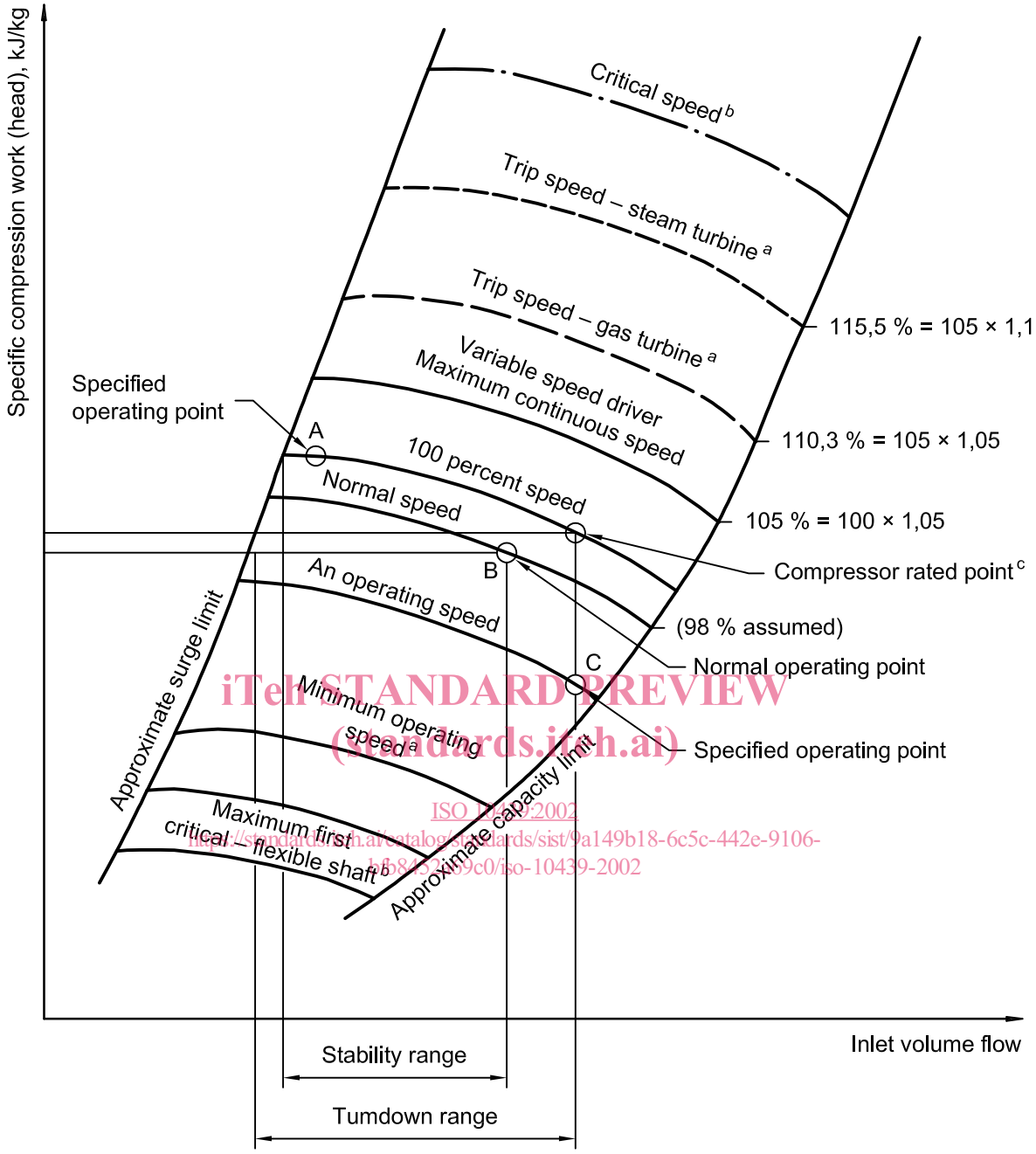
NOTE See the optional performance test criteria in 6.3.6.2 and handling of excess head for constant speed drivers.

4.1.5 The head versus capacity characteristic curve (see Figure 1) shall rise continuously from the rated point to the 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 approximate surge capacity shown in the proposal.

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

The vendor shall notify the purchaser if the criteria for minimum temperature rise and velocity over heat exchange surfaces result in a conflict. The criterion for velocity overheat exchange surfaces is intended to minimize the use of cooling water. The purchaser shall approve the final selection.

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



The head versus capacity curve at 100 % speed shall extend to at least 115 % capacity of the CRP. Head versus capacity curves at other speeds shall be extended to equivalent capacity at each speed. For example, the head versus capacity curve at 105 % speed shall be extended to 1,05 times 1,15 times capacity of the CRP; the head versus capacity curve at 90 % speed shall be extended to 0,9 times 1,15 times capacity at the CRP; and so on. These points define the “approximate capacity limit” curve.

Except where specific numerical relationships are stated, the relative values implied in this figure are assumed values for illustration only.

The 100 % speed is determined from the operating point requiring the highest head — point A in the illustration.

The compressor rated point (CRP) is the intersection on the 100 % speed line corresponding to the highest flow of any operating point — point C in the illustration.

a Refer to the applicable standard for the compressor driver (e.g. ISO 10437 or ISO 3977-5) for trip speed and minimum operating speed limits.

b See 4.9 for allowable margins of critical speeds to operating speeds.

c The maximum continuous speed shall be 105 % for variable speed drivers. The maximum continuous speed shall be the speed corresponding to the synchronous speed of the motor.

Figure 1 — Illustration of terms

Table 1 — Cooling water systems — Design requirements

Velocity over heat exchange surfaces	1,5 m/s to 2,5 m/s (5 ft/s to 8 ft/s)
Maximum allowable gauge working pressure	⩾ 500 kPa (75 psi)
Test gauge pressure	⩾ 750 kPa (110 psi)
Maximum inlet temperature	30 °C (90 °F)
Maximum temperature rise	20 K (35 °F)
Fouling factor on water side	0,35 m^2 K/kW (0,002 $h.ft^2$ °F/Btu)
Maximum pressure drop	100 kPa (15 psi)
Maximum outlet temperature	50 °C (120 °F)
Minimum temperature rise	10 K (20 °F)
Shell corrosion allowance	3,0 mm (⅛ in)

4.1.8 All equipment shall be designed to permit rapid and economical maintenance. Major parts such as casing components and bearings housings shall be designed and manufactured to ensure accurate alignment on reassembly. This may be accomplished by the use of shouldering, cylindrical dowels or keys.

4.1.9 The inner casing of radially split barrel type compressors shall be designed for easy withdrawal from the outer shell and easy disassembly for inspection or replacement of parts.

- **4.1.10** The equipment, including all auxiliaries, shall be suitable for operation under the environmental conditions specified by the purchaser. These conditions shall include whether the installation is indoors (heated or unheated) or outdoors (with or without a roof), maximum and minimum temperatures, unusual humidity, and dusty or corrosive conditions. For the purchaser's guidance, the vendor shall list in the proposal any special protection that the purchaser is required to supply.

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

- **4.1.12** The purchaser shall advise the vendor of any requirements for liquid injection.

4.1.13 Equipment shall be designed to run without damage to the trip speed and the maximum allowable working pressure.

4.1.14 The machine and its driver shall perform on the test stand and on their permanent foundation within the specified acceptance criteria. After installation, the performance of the combined units shall be the joint responsibility of the purchaser and the vendor having unit responsibility.

4.1.15 Many factors (such as piping loads, alignment at operating conditions, supporting structure, handling during shipment, and handling and assembly at site) may adversely affect site performance. To minimize the influence of these factors, the vendor shall review and comment on the purchaser's piping and foundation drawings. If specified, the vendor's representative shall

a) observe a check of the piping performed by parting the flanges,

b) check alignment at the operating temperature, and

c) be present during the initial alignment check.

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

4.1.17 Spare parts for the compressor and all furnished auxiliaries shall meet all the criteria of this International Standard.

● **4.1.18** If specified, the compressor or compressors shall be suitable for field running on air. Performance parameters, including any required precautions, shall be mutually agreed upon by the purchaser and the vendor.

4.1.19 A guide to centrifugal compressor nomenclature is given in annex F.

● **4.1.20** The pressure design code shall be specified or agreed by the purchaser.

Pressure components shall comply with the pressure design code and the supplemental requirements given in this International Standard.

● **4.1.21** The purchaser and the vendor shall agree on the measures to be taken in order to comply with governmental regulations, ordinances or rules that are applicable to the equipment.

4.2 Casings

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

4.2.2 The equipment feet shall be provided with vertical jackscrews and shall be drilled with pilot holes that are accessible for use in final doweling.

4.2.3 Supports and alignment bolts shall be rigid enough to permit the machine to be moved by the use of its lateral and axial jackscrews.

● **4.2.4** The maximum allowable working pressure of the casing shall be at least equal to the specified relief valve setting; if a relief valve setting is not specified or if a relief valve is not installed, the maximum allowable working pressure shall be at least 1,25 times the maximum specified discharge pressure.

NOTE System protection is normally provided by the purchaser.

4.2.5 Casings designed for more than one maximum allowable pressure level (split-pressure-level casings) are not permitted unless specifically approved by the purchaser, and if so, the vendor shall define the physical limits and the maximum allowable working pressure of each part of the casing.

4.2.6 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.

4.2.7 Casings shall be made of steel for the following:

a) air or non-flammable gas at a maximum allowable gauge working pressure above 2 500 kPa (360 psi);

b) air or non-flammable gas at a calculated discharge temperature that is over 260 °C (500 °F) at maximum continuous speed at any point within the operating range;

c) flammable or toxic gas.

4.2.8 Cast iron or other materials of construction may be offered for operating conditions other than those specified in 4.2.7.

4.2.9 Unless otherwise specified, casings shall be radially split if the partial pressure of hydrogen (at maximum allowable gauge working pressure) exceeds 1 400 kPa (200 psi).

NOTE The partial pressure of hydrogen is calculated by multiplying the highest specified mole (volume) percent of hydrogen by the maximum allowable working pressure.

4.2.10 Axially split casings shall use a metal-to-metal joint (with a suitable joint compound) that is tightly maintained by suitable bolting. Gaskets (including string type) shall not be used on the axial joint. O-rings with ring grooves machined into the flange facing of an axially split casing joint may be used with the purchaser's approval. If

gasketed joints are used between the end covers and the cylinder of radially split casings, they shall be securely maintained by confining the gaskets. Gasket materials shall be suitable for all specified service conditions.

4.2.11 Jackscrews, guide rods and cylindrical casing alignment dowels shall be provided to facilitate disassembly and reassembly. If 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 an improper fit caused by marring of the face. Guide rods shall be of sufficient length to prevent damage to the internals or casing studs from the casing during disassembly and reassembly. Lifting lugs or eyebolts shall be provided for lifting only the top half of the casing. Methods of lifting the assembled machine shall be specified by the vendor.

4.2.12 The use of threaded holes in pressure parts shall be minimized. To prevent leakage in pressure sections of casings, metal equal in thickness to at least half the nominal bolt diameter, in addition to the allowance for corrosion, shall be left around and below the bottom of drilled and threaded holes. The depth of threaded holes shall be at least 1,5 times the stud diameter.

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

4.2.14 The machined finish of the compressor mounting surfaces shall be 3,2 µm to 6,4 µm (125 micro-inches to 250 micro-inches) arithmetical average roughness (Ra). Hold-down or foundation bolt holes shall be drilled perpendicular to the mounting surface or surfaces and spot faced to a diameter three times that of the hole.

4.2.15 Studded connections shall be furnished with studs installed. Blind stud holes should be drilled only deep enough 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 each stud shall be removed.

4.2.16 External and internal bolting shall be furnished as follows.

a) Bolting external to the casing shall be in accordance with the pressure design code. Internal bolting shall have the same thread form.

b) Studs should be used instead of cap screws (external only).

c) Adequate clearance shall be provided at bolting locations to permit the use of socket or box wrenches (external only).

d) Socket, slotted-nut or spanner-type bolting shall not be used unless specifically approved by the purchaser (external only).

4.3 Interstage diaphragms and inlet guide vanes

4.3.1 Interstage diaphragms and inlet guide vanes shall be suitable for all specified operating conditions, start-up, shutdown, trip-out, settling out and momentary surge. If intermediate main process connections are used, the purchaser shall specify the maximum and minimum pressures at each connection. The vendor shall confirm that the diaphragms furnished are suitable for the maximum differential pressure.

4.3.2 Internal joints shall be designed to minimize leakage and permit easy disassembly.

4.3.3 Renewable labyrinths shall be provided at all internal close clearance points to minimize internal leakage. These shall be easily replaceable.

4.3.4 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.

4.3.5 If diaphragm cooling is specified, the top and bottom halves of axially split diaphragms shall have independent cooling passages. Each coolant inlet and outlet connection shall be manifolded at both the top and bottom of each casing.

4.4 Casing connections

4.4.1 General

4.4.1.1 All process gas connections to the casing shall be suitable for the maximum allowable working pressure of the casing (see 4.2.4).

4.4.1.2 All of the purchaser's connections shall be accessible for maintenance without the machine being moved.

4.4.1.3 Connections, pipe, valves and fittings of nominal pipe size DN 32 (NPS 1¼), DN 65 (NPS 2½), DN 90 (NPS 3½) or DN 125 (NPS 5) shall not be used.

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

4.4.1.5 All welding of connections shall be done before hydrostatic testing (see 6.3.2).

4.4.2 Main process connections

- **4.4.2.1** Inlet and outlet connections shall be flanged or machined and studded and oriented as specified in the data sheets (see annex A). Inlet and outlet connections for barrel type compressors shall be located in the outer casing, not in the end covers. On radially split overhung design compressors, the process inlet connection may be in the end cover.

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

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

4.4.2.2.2 Unless otherwise specified, flanges that are thicker or have a larger outside diameter than that required by the pressure design code may be used.

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

4.4.2.4 The concentricity of the bolt circle and the bore of all casing flanges shall be such that the area of the machined gasket-seating surface is adequate to accommodate a complete standard gasket without protrusion of the gasket into the fluid flow.

4.4.2.5 The finish of all flanges and nozzles shall conform to the requirements of 4.4.2.2 as applicable to the material furnished, including flange finish roughness requirements.

4.4.3 Auxiliary connections

4.4.3.1 Auxiliary connections may include, but are not limited to, those for vents, liquid injection, drains (see 4.4.3.2) water cooling, “lube and seal” oil, flushing, buffer gas and the balance piston cavity.

- **4.4.3.2** For axially split casings, the vendor shall provide connections for complete drainage of all gas passages. For radially split casings, the drains shall be located at the lowest point of each inlet section, the lowest point of the section between the inner and outer casings and the lowest point of each discharge section. If specified, individual stage drains, including a drain for the balance piston cavity, shall be provided.

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

4.4.3.4 Auxiliary connections shall be at least nominal pipe size DN 20 (NPS ¾) (see 4.4.1.3) and shall be socket welded and flanged, or machined and studded. For socket welded construction, a 1,5 mm gap, as measured prior to welding, shall be left between the pipe end and the bottom of the socket in the casing.