INTERNATIONAL STANDARD

ISO 10439

First edition
2002-10-15

Corrected version
2003-06-15

Petroleum, chemical and gas service industries — Centrifugal compressors

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

Reference number
ISO 10439:2002(E)

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Printed in Switzerland

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.

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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.

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.

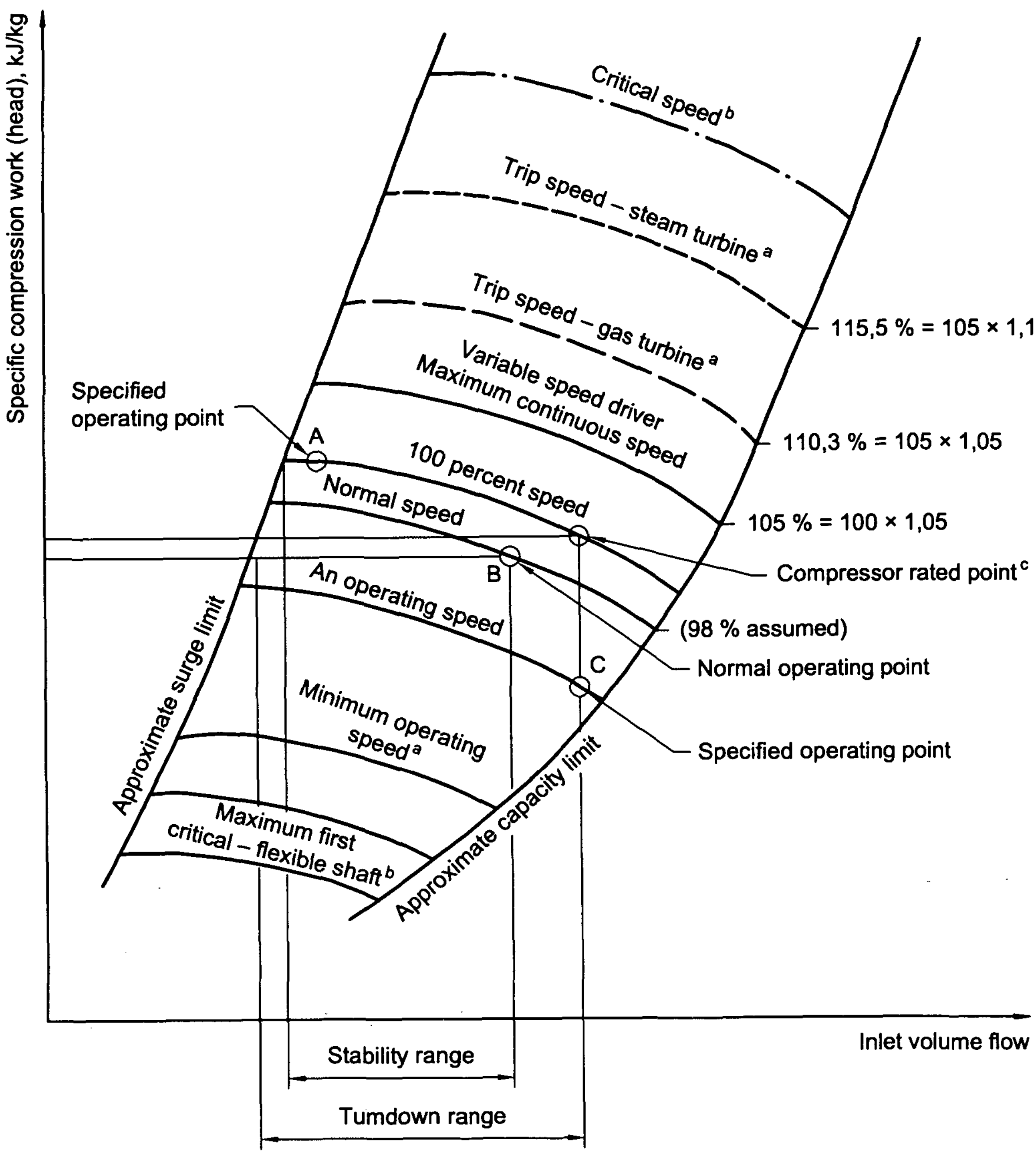
NOTE See the optional performance test criteria in 6.3.6.2 and handling of excess head for constant speed drivers.

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.

4.4.3.5 If socket welded and flanged or machined and studded openings cannot be provided, threaded openings in sizes DN 20 (NPS ¾) to DN 40 (NPS 1½) may be used if approved by the purchaser. These threaded openings shall be installed as follows.

a) Threaded openings and bosses for pipe threads shall comply with the pressure design code.

b) Pipe threads shall be taper threads (e.g. ISO 7 or ASME B 1.20.1) and shall comply with the pressure design code.

c) Threaded connections shall not be used for flammable or toxic fluids. Where threaded joints are permitted, they shall not be seal welded.

4.4.3.6 A pipe nipple, which should not be more than 150 mm (6 in) long, shall be installed in a threaded or socket weld opening. Pipe nipples shall be a minimum of schedule 160 seamless for threaded connections and schedule 80 for socket welded connections. Each pipe nipple shall be provided with a welding neck, socket weld or slip-on flange.

NOTE The schedules are as specified in ASME B 36.10M.

4.4.3.7 Tapped openings not connected to piping shall be plugged with solid steel plugs. As a minimum these plugs shall meet the material requirements of the casing. Plugs that may later require removal shall be of corrosion-resistant material. Threads shall be lubricated. Tape shall not be applied to threads of plugs inserted into oil passages. Plastic plugs shall not be used.

4.5 External forces and moments

4.5.1 The compressor shall be designed to withstand external forces and moments on each nozzle calculated in accordance with Annex G. The vendor shall furnish the allowable forces and moments for each nozzle in tabular form together with the co-ordinates.

4.5.2 Casing and supports shall be designed to have sufficient strength and rigidity to limit coupling misalignment caused by imposing allowable forces and moments to 50 µm (0,002 in).

4.6 Rotating elements

4.6.1 Shafts shall be made of one-piece heat-treated steel, 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, with the purchaser's approval, hot rolled bar stock, providing that the bar stock meets all quality and heat treatment criteria established for shaft forgings.

4.6.2 Shaft ends for coupling fits shall be in accordance with ISO 10441.

4.6.3 Unless other shaft protection is approved by the purchaser, renewable shaft sleeves shall be furnished at all close clearance points unless rotating seals are used. These sleeves shall be made of a material that is corrosion-resistant in the specified service. The sleeves under close clearance bushing end seals shall be suitably treated to resist wear, and sealed to prevent leakage between the shaft and sleeve (see 4.11.1.7 for limitations).

4.6.4 The design of shaft-sleeve-impeller assemblies shall not create temporary or permanent distortions of the rotor assembly. The method of attaching the impeller shall adequately maintain concentricity and balance under all specified operating conditions, including overspeed to trip speed.

4.6.5 The rotor shaft sensing areas to be observed by radial vibration probes shall be concentric with the bearing journals. All shaft sensing areas (both radial vibration and axial position) shall be free from stencil and scribe marks or any other surface discontinuity, such as an oil hole or a keyway. These areas shall not be metallised, sleeved, or plated. The final surface finish shall be 0,4 µm to 0,8 µm (16 to 32 micro-inches) *Ra*, preferably obtained by honing or burnishing. These areas shall be properly demagnetized or otherwise treated so that the combined total electrical and mechanical runout does not exceed 25 % of the maximum allowed peak-to-peak vibration amplitude or the following value, whichever is greater:

a) for areas to be observed by radial vibration probes, 6 µm (250 micro-inches);

b) for areas to be observed by axial position probes, 13 µm (250 micro-inches).

If all reasonable efforts fail to achieve these limits, the vendor and the purchaser shall mutually agree on alternate acceptance criteria.

4.6.6 Each rotor shall be clearly marked with a unique identification number. This number shall be on the end of the shaft opposite the coupling or in an accessible area that is not prone to maintenance damage.

4.6.7 Impellers may be closed, consisting of a disk, vanes, and a cover, or they may be semi-open, consisting of a disk and vanes. Impellers shall be of welded, brazed, milled or cast construction. Other manufacturing methods, such as electroerosion and riveting, may be used if approved by the purchaser. Each impeller shall be marked with a unique identification number.

4.6.8 Welded, brazed and riveted impellers may consist of forged and cast components. Welds in the gas passageway shall be smooth and free from weld spatter. Impellers shall be heat-treated and stress-relieved after welding or brazing. Vane entrance and exits shall not have knife edges.

4.6.9 Cast impellers shall be finished all over except for gas passageways. Upgrade or repair welding may be permitted only with the purchaser's approval.

4.6.10 Welding as a means of balancing an impeller is not permitted.

4.6.11 The design of stressed parts shall include proper evaluation of the stress concentration factor (SCF) for the geometry. The design of stressed rotating parts shall include fillets that limit the SCF.

NOTE Areas of concern include the impeller vane-to-disk intersections, keyways and shaft section changes.

4.6.12 Integral thrust collars are preferred. Replacement thrust collars shall be furnished if required for removal of liquid film type, mechanical contact type or gas type shaft seals. If integral collars are furnished, they shall be provided with at least 3 mm (⅛ in) of additional stock to enable refinishing if the collar is damaged. If replaceable collars are furnished (for assembly and maintenance purposes), they shall be positively locked to the shaft to prevent fretting.

4.6.13 Both faces of thrust collars shall have a surface finish of not more than 0,4 µm (16 micro-inches) *Ra* and the axial total indicated runout of either face shall not exceed 13 µm (500 micro-inches).

4.6.14 Compressor designs that do not require a balance drum are acceptable.

4.6.15 If required, a balance drum, line and porting shall be provided to limit 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.

4.6.16 The balance line shall be flanged and sized to handle balance drum gas leakage at twice the initial design labyrinth clearance without exceeding the load rating of the thrust bearings (see 4.7.3.3). If the balance line requires a purchaser connection to this piping, then the connection sizes shall be indicated on the data sheets (see Annex A).

4.6.17 To prevent the build-up of potential voltages in the shaft, residual magnetism of the rotating element shall not exceed 0,000 5 T (5 gauss).

4.7 Bearings and bearing housings

4.7.1 General

4.7.1.1 Hydrodynamic radial and thrust bearings shall be provided unless specific approval to the contrary is obtained from the purchaser.

NOTE Annex J gives application considerations for use of active magnetic bearings, where specified. These bearings are new technology at this time.

4.7.1.2 Unless otherwise specified, thrust bearings and radial bearings shall be fitted with bearing metal temperature sensors installed in accordance with API 670.

4.7.2 Radial bearings

4.7.2.1 Radial bearings of the sleeve or pad type 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-backed, babbitted replaceable liners, pads or shells. The bearings shall be equipped with anti-rotation pins and shall be positively secured in the axial direction.

4.7.2.2 The bearing design shall suppress hydrodynamic instabilities and provide sufficient damping over the entire range of allowable bearings clearances to limit rotor vibration to the maximum specified amplitudes (see 4.9.5.6) while the equipment is operating loaded or unloaded at any speed (see 4.9.1.3) within the specified speed range.

4.7.2.3 The liners, pads or shells shall be in axially split housings and shall be replaceable. 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. The bearing design shall not require removal of the coupling hub to permit replacement of the bearing liners, pads or shells unless approved by the purchaser.

4.7.2.4 Compressors equipped with sleeve type journal bearings shall be designed for field installation of tilting pad type radial bearings without remachining of the bearing bracket.

4.7.3 Thrust bearings

4.7.3.1 Hydrodynamic thrust bearings shall be of the steel-backed, babbitted multiple segment type, designed for equal thrust capacity in both directions and arranged for continuous pressurized lubrication to each side. Both sides shall be of the tilting pad type incorporating a self-levelling feature assuring that each pad carries an equal share of the thrust load, even with minor variations, in pad thickness.

4.7.3.2 Each pad shall be designed and manufactured with dimensional precision (thickness variation) such that interchangeability or replacement of the individual pads is allowed.

4.7.3.3 Thrust bearings shall be sized for continuous operation under the most adverse specified operating conditions. Calculation of the thrust force 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) external thrust forces transmitted through the couplings;

f) the maximum thrust force from the drive motor if the motor is directly connected.

4.7.3.4 For gear type coupling, the external thrust force shall be calculated from the following formula:

$$F = \frac{(0{,}25) \times (9\,550)\, P_r}{N_r \times D}$$

Or, in US customary units:

$$F = \frac{(0{,}25) \times (63\ 300)\ P_r}{N_r \times D}$$

where

F is the external force, kilonewtons (pound force);

P_r is the rated power, in kilowatts (horsepower);

N_r is the rated speed, in revolutions per minute;

D is the shaft diameter of the coupling, in millimetres (inches).

4.7.3.5 Thrust forces for flexible element type couplings shall be calculated on the basis of the maximum allowable deflection permitted by the coupling manufacturer.

4.7.3.6 If two or more rotor thrust forces are to be carried by one thrust bearing (such as in a gear box) the resultant of the forces shall be used, provided the directions of the forces make them numerically additive; otherwise, the largest of the forces shall be used.

4.7.3.7 Hydrodynamic thrust bearings shall be selected such that, under any operating condition, the load does not exceed 50 % of the bearing manufacturer's ultimate load rating. The ultimate load rating shall be the load that will produce the minimum acceptable oil film thickness without inducing failure during continuous service, or the greatest load that does not exceed the creep initiation or yield strength of the babbit at the location of maximum temperature on the pad, whichever load is the lesser of the two. In sizing thrust bearings, consideration shall be given to the following for each specific 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 temperature of the oil;

f) design configuration of the bearing;

g) babbitt alloy and pad material;

h) turbulence of the oil film.

The basis for the sizing of thrust bearings shall be reviewed and approved by the purchaser.

4.7.3.8 Thrust bearings shall be arranged to allow axial positioning of each rotor relative to the casing and setting of the thrust bearings' clearance.

4.7.4 Bearing housings

4.7.4.1 Rotor support system parts (bearings, bearing housings, bearing shells, and bearing brackets) shall be axially split, non-pressurized (vented to atmosphere) and furnished with plugged connections for dry air or inert gas purge to any atmospheric labyrinth seals. Axial split bearing housings shall have a metal-to-metal split joint whose halves are located by means of dowels.

4.7.4.2 Compressors that use semi-enclosed coupling guards shall have bearing housings equipped with replaceable labyrinth type end seals and deflectors where the shaft passes through the housing; lip type seals shall not be used. The seals and deflectors shall be made of non-sparking materials. The design of the seals and deflectors shall effectively retain oil in the housing and prevent entry of foreign material into the housing.

4.7.4.3 Bearing housings for pressure-lubricated hydrodynamic bearings shall be arranged to minimize foaming. The drain system shall be adequate to maintain the oil and foam level below shaft end seals. Oil outlets from flooded thrust bearings shall be tangential and in the upper half of the control ring or, if control rings are not used, in the thrust bearing cartridge.

4.7.4.4 The rise in oil temperature through the bearing and housing shall not exceed 30 °C (50 °F) under the most adverse specified operating conditions. The bearing outlet oil temperature shall not exceed 85 °C (180 °F). If the inlet oil temperature exceeds 50 °C (120 °F), special consideration shall be given to bearing design, oil flow and allowable temperature rise.

4.7.4.5 Shaft support structures bolted to casings shall be of steel.

4.7.4.6 Oil connections on bearing housings shall be in accordance with 4.4.3.

4.7.4.7 Provision shall be made for mounting two radial vibration probes in each bearing housing, two axial position probes at the thrust end of each machine, and a one event per revolution probe in each machine shaft line. The probe installation shall be as specified in API 670.

4.8 Shaft seals

4.8.1 General

● **4.8.1.1** Shaft seals shall be provided to restrict or prevent process gas leakage to the atmosphere or seal fluid leakage into the process gas stream over the range of specified operating conditions, including start-up and shutdown. Seal operation shall be suitable for specified variations in suction conditions that may prevail during start-up, shutdown or settling out, or during any other special operation specified by the purchaser, such as slow roll or reverse rotation. The maximum sealing pressure shall be at least equal to the settling out pressure. The shaft seals and seal system shall be designed to permit safe compressor pressurization with the seal system in operation prior to process start-up.

The purchaser should establish a realistic value for the settling out pressure. The value should be shown on the data sheets.

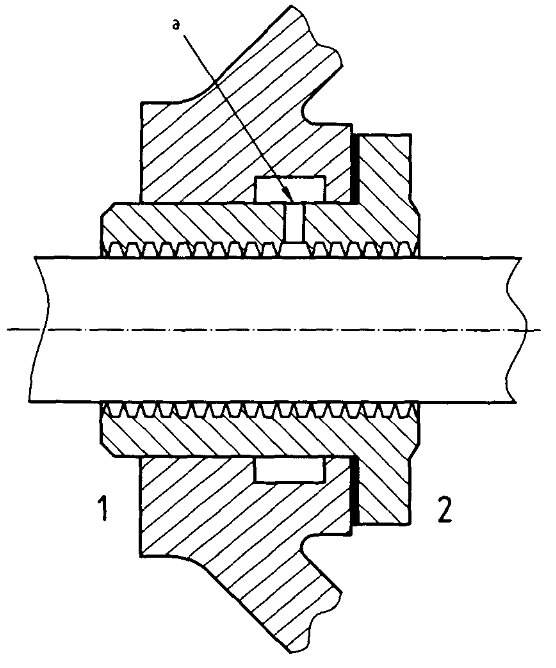
● **4.8.1.2** Shaft seals and, if specified, shaft sleeves shall be accessible for inspection and replacement without removing the top half of the casing of an axially split compressor or the heads of a radially split unit.

NOTE *It is recognized that this requirement may not be feasible for overhung designs or shrink fit sleeves.*

● **4.8.1.3** Shaft seals may be one or a combination of the following (4.8.2.1 to 4.8.2.5) types as specified by the purchaser on the data sheets. The materials for component parts shall be suitable for the service.

4.8.2 Requirements for types

4.8.2.1 The labyrinth seal (a typical seal is shown in Figure 2) may include carbon rings in addition to the labyrinths, if approved by the purchaser. Labyrinths may be stationary or rotating. Eductors or injection systems, if used, shall be furnished complete with piping regulation and control valves, pressure gauges, strainers, and so forth. Each item shall be piped and valved to permit its removal during operation of the compressor. Where gas from the compressor discharge is used for the motivating power of the eductor, provisions shall be made for sealing during start-up and shutdown (see 4.8.3.4 and 5.5.1.6).



Key

1 Internal gas pressure

2 Atmosphere

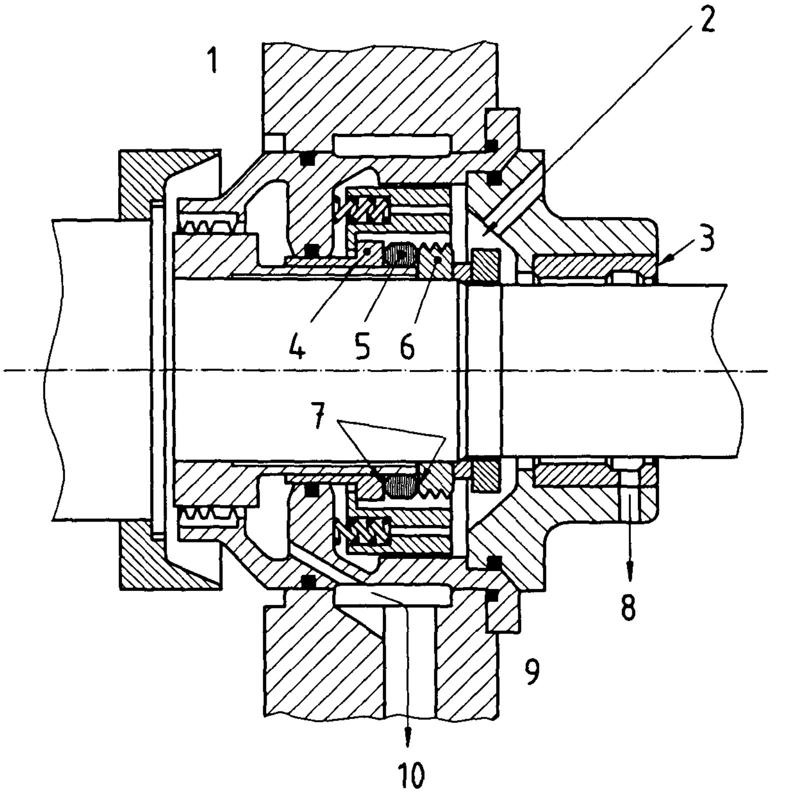
a Ports may be added for scavenging, inert-gas sealing or both.

Figure 2 — Labyrinth shaft seal

● **4.8.2.2** The mechanical (contact) seal (see Figure 3) shall be provided with labyrinths and slingers. Oil or another suitable liquid furnished under pressure to the rotating seal faces may be supplied from the lube oil system or from an independent seal system. Mechanical seals shall be designed to prevent gas leakage while the compressor is pressurized and being shut down, and after it is stopped in the event of seal oil failure. Various supplemental devices may be provided to ensure sealing when the compressor is pressurized but not running and the seal oil system is shut down. The purchaser shall specify whether such a device is to be provided. The final design shall be mutually agreed upon by the purchaser and the vendor.

4.8.2.3 The restrictive ring seal (see Figure 4) shall include rings of carbon or another suitable material mounted in retainers or in spacers. The seal may be operated dry, as in the labyrinth type, or with a sealing liquid, as in the mechanical type or with a buffer gas.

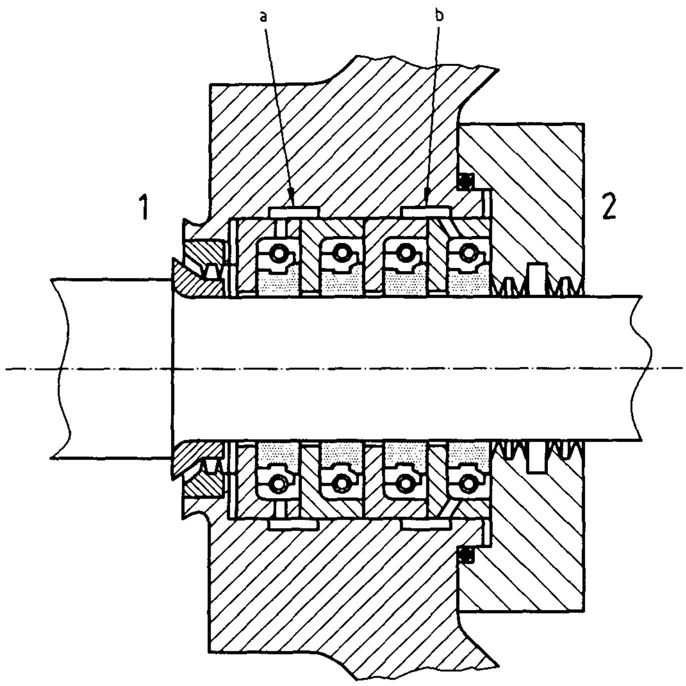
4.8.2.4 The liquid film seal (see Figures 5 and 6) shall be provided with sealing rings or bushings and labyrinths. A sealing liquid shall be supplied as in the mechanical type. Liquid film seals may be of the cylindrical bushing type shown in Figure 5 or the pumping type shown in Figure 6. An elevated tank to maintain static head in excess of the compressor sealing pressure shall be provided. The vendor shall state the height of the tank above the compressor centreline. Other means of maintaining this differential pressure and positive seal may be used with the purchaser's approval.



Key

1 Internal gas pressure
2 Clean oil in
3 Pressure breakdown sleeve
4 Stationary seat
5 Sealing ring
6 Rotating seat
7 Running faces
8 Oil out
9 Atmosphere
10 Contaminated oil out

Figure 3 — Mechanical (contact) shaft seal

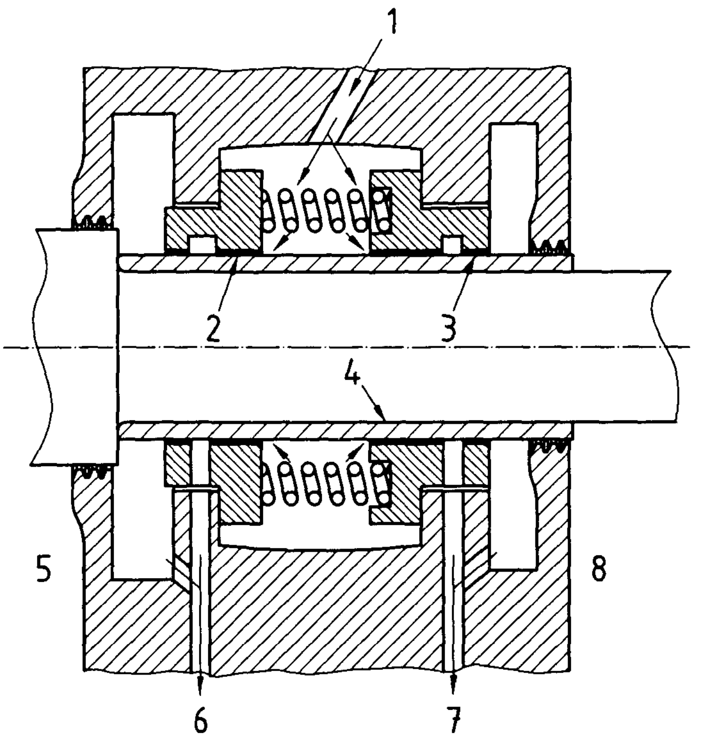


Key

1 Internal gas pressure
2 Atmosphere

a Ports may be added for sealing.
b Scavenging port may be added for vacuum application.

Figure 4 — Restrictive ring shaft seal



Key

1 Clean oil in

2 Inner bushing

3 Outer bushing

4 Shaft sleeve

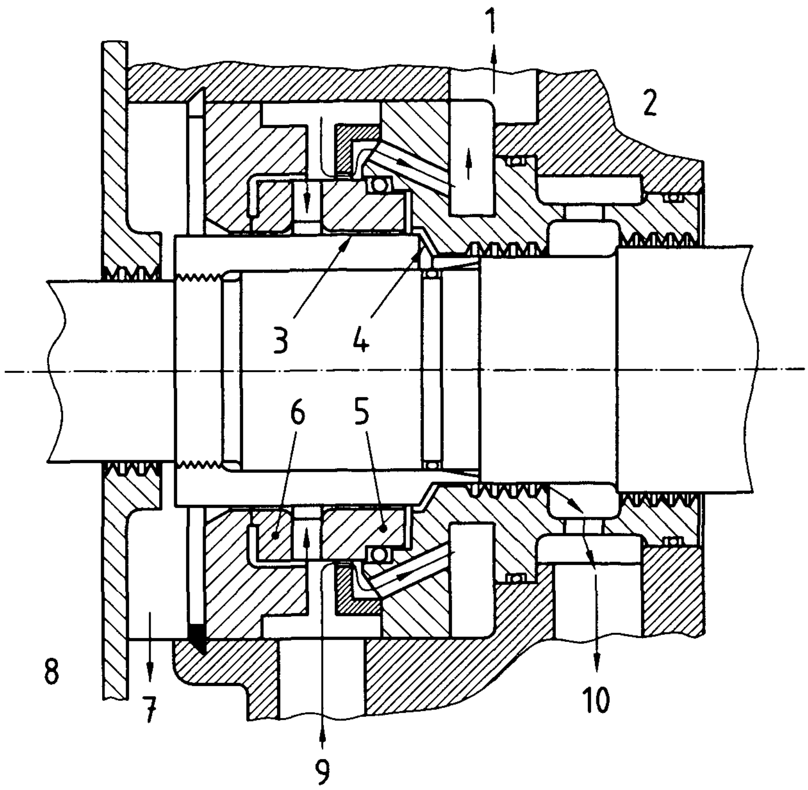
5 Internal gas pressure

6 Contaminated oil out

7 Oil out

8 Atmosphere

Figure 5 — Liquid film shaft seal with cylindrical bushings



Key

1 Clean oil recirculation
2 Internal gas pressure
3 Shaft sleeve
4 Pumping area
5 Inner bushing
6 Outer bushing
7 Oil out
8 Atmosphere
9 Clean oil in
10 Contaminated oil out

Figure 6 — Liquid film seal with pumping bushings

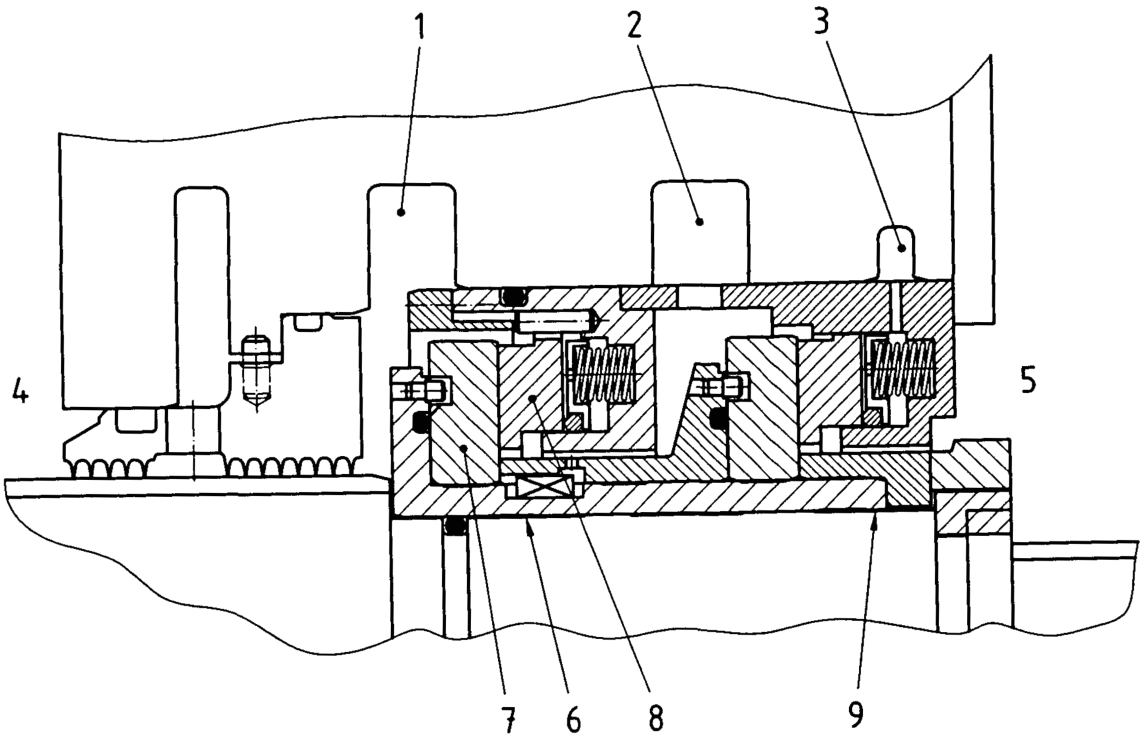
4.8.2.5 The self-acting gas seal may require a clean seal gas supply but does not require any liquid lubrication. The purchaser may specify the required seal configuration. Typical tandem seal configurations are shown in Figures 7 and 8. In these configurations, two identical seals are arranged in series as primary and back-up seals, one configuration without an internal labyrinth (Figure 7), and the other configuration with an internal labyrinth (Figure 8). Where there is danger of leakage of toxic or flammable gases to the atmosphere, then the arrangement in Figure 8 shall be used. A separation seal is generally required to prevent leakage to the atmosphere or to the bearing housing as well as oil leakage to the seal.

The seal gas shall be filtered and free from any contaminants that form residues. The seal gas may be taken from the compressor discharge or interstage point. An alternative seal gas source may be used and may be required during start-up and shutdown. Suitable measures shall be taken to protect the seal against reverse pressurization. The method of control shall be mutually agreed between purchaser and vendor. For testing considerations at the seal manufacturer's shop for this type of seal, see annex I and the data sheets (annex A).

Other configurations, for example, single, double (back-to-back) or triple, may be used, depending on the application.

NOTE 1 For certain applications external cooling of seals could be required.

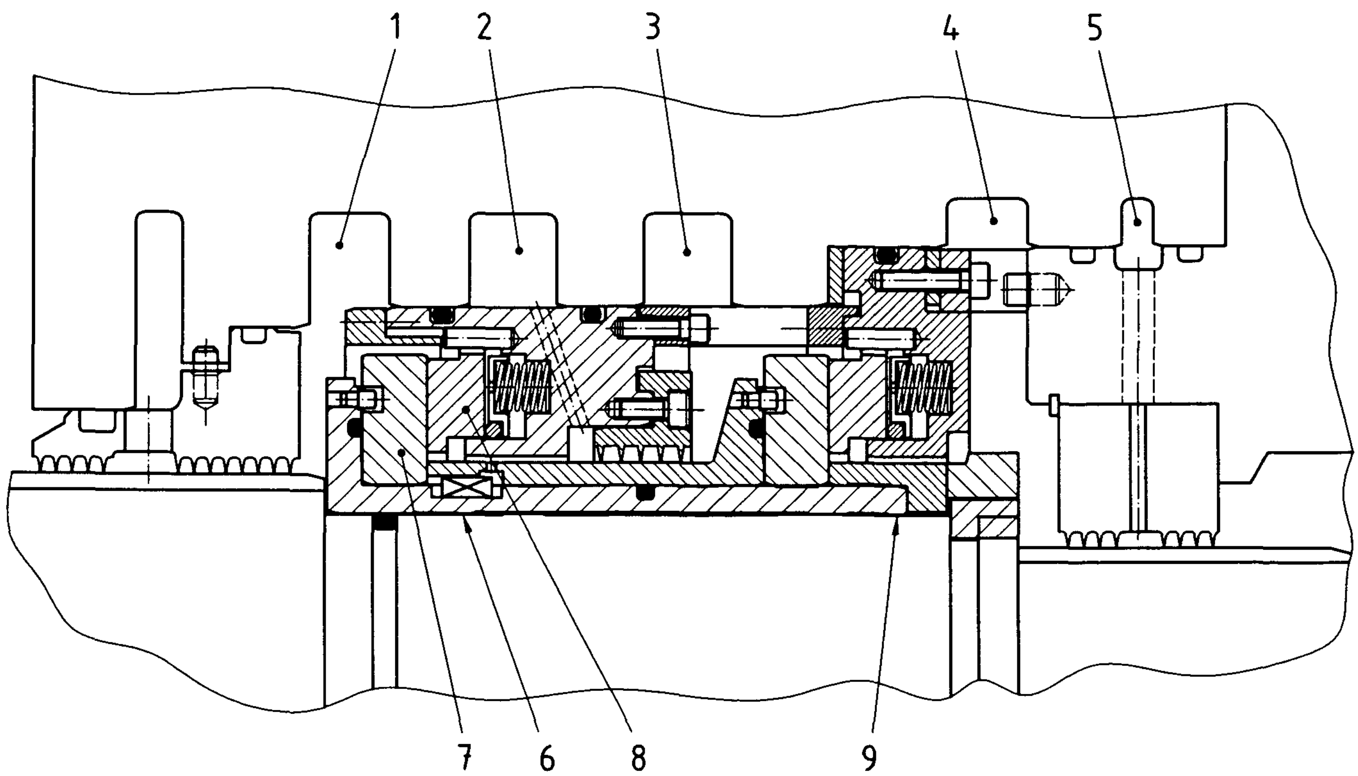
NOTE 2 The seal will leak a small amount of seal gas.



Key

1 Seal gas in
2 Primary seal leakage
3 Buffer gas supply
4 Internal gas pressure
5 Atmospheric or bearing housing
6 Primary seal
7 Rotating seat
8 Stationary seat
9 Backup seal

Figure 7 — Self-acting tandem gas seal



Key

1 Seal gas in
2 Primary seal leakage
3 Buffer gas
4 Atmospheric vent
5 Separation gas
6 Primary seal
7 Rotating seat
8 Stationary seat
9 Backup seal

Figure 8 — Self-acting tandem gas seal with internal labyrinth

4.8.3 Other requirements

4.8.3.1 For any shaft end seals that use sealing liquid, the inward leakage from each seal shall be piped to an independent drain pot. The individual shaft end inward seal leakages shall be adequate to prevent outward migration of process gas. No individual shaft end seal shall have a leakage rate greater than 70 % of the total expected leakage from all shaft end seals in a single machine.

4.8.3.2 Oil contaminated by process gas that would damage components such as bearings, seal rings, O-rings and couplings shall be piped away separately to allow disposal or reconditioning.

4.8.3.3 Seal pressure equalizing lines and associated gas passages (including those for reference gas and axial thrust force balancing) shall be sized to maintain design shaft end seal performance at twice the maximum initial design clearances. The lines and passages shall also be sized to maintain substantially equal pressures at both shaft end seals during acceleration.

● **4.8.3.4** Unless otherwise specified, the seal design shall have provision for buffer gas injection to each seal. The purchaser shall specify whether buffer gas injection is to be used and, if so, the composition of that gas. In addition, the vendor shall state whether buffer gas injection is required for any specified operating conditions. If buffer gas injection is required (see Figure 8), the vendor shall state the gas requirements, and, if specified, furnish the complete control system schematic and bill of material. The method of control shall be mutually agreed between vendor and purchaser.

● **4.8.3.5** If specified for compressors with sub-atmospheric pressure at the shaft end seals, provision shall be made to pressurize these seals with gas at a pressure that is higher than atmospheric.

4.9 Dynamics

4.9.1 Critical speeds

4.9.1.1 If the frequency of a periodic forcing phenomenon (exciting frequency) applied to a rotor-bearing support system corresponds to a natural frequency of that system, the system may be in a state of resonance.

4.9.1.2 A rotor-bearing support system in resonance shall have its normal vibration displacement amplified. The magnitude of amplification and the rate of phase angle change are related to the amount of damping in the system and the mode shape taken by the rotor.

NOTE The mode shapes are commonly referred to as the first rigid (translatory or bouncing) mode, the second rigid (conical or rocking) mode and the (first, second, third ....*n*th) bending mode.

4.9.1.3 When the rotor amplification factor (see Figure 9) as measured on the test stand at the vibration probe is greater than or equal to 2,5, that frequency is called critical and the corresponding shaft rotational frequency is called a "critical speed". For the purposes of this International Standard, a critically damped system is one in which the amplification factor is less than 2,5.

4.9.1.4 Critical speeds shall be determined analytically by means of a damped, unbalanced rotor response analysis and shall be confirmed by test stand data.

4.9.1.5 An exciting frequency may be less than, equal to, or greater than the rotational speed of the rotor. Potential forced and self-exciting frequencies considered in system design shall include, but are not limited to, the following sources:

a) unbalance in the rotor system;

b) oil film instabilities (whirl);

c) internal rubs;

d) blade, vane, nozzle, and diffuser passing frequencies;

e) gear tooth meshing and side bands;

f) coupling misalignment;

g) loose rotor system components;

h) hysteretic and friction whirl;

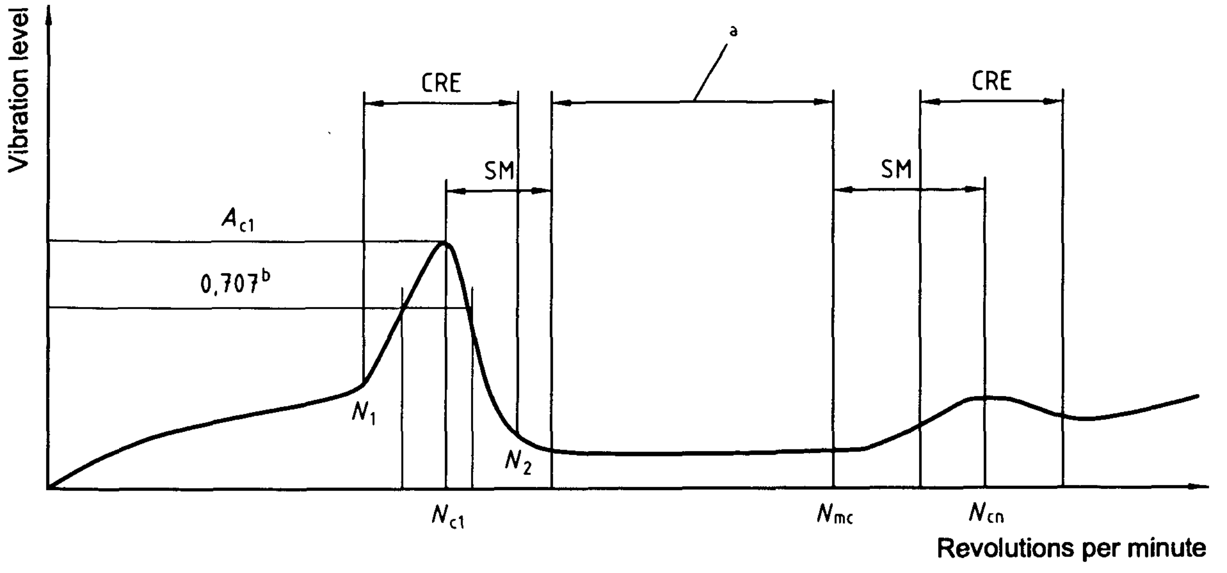
i) boundary layer flow separation;

j) acoustic and aerodynamic cross coupling forces;

k) asynchronous whirl.

4.9.1.6 Resonances of support systems within the vendor's scope of supply shall not occur within the specified operating speed range or the specified separation margins, unless the resonances are critically damped.

4.9.1.7 The vendor having unit responsibility shall ensure the compatibility of drive-train critical speeds (rotor lateral, system torsional, blading modes, and the like) with the critical speeds of the machinery being supplied and that the combination is suitable for the specified operating speed range, including any starting speed detent (hold point) requirements of the train. A list of all undesirable speeds from zero to trip shall be submitted to the purchaser for review and included in the instruction manual for the guidance of the purchaser (see annex C).



Key

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

NOTE The curve shape is for illustration only and does not necessarily represent any actual rotor response plot.

a Operating speeds.

b Peak.

Figure 9 — Rotor response plot

4.9.2 Lateral analysis

4.9.2.1 The vendor shall provide a damped, unbalanced response analysis for each machine in order to ensure acceptable amplitudes of vibration at any speed from zero to trip. An example of the logic diagram of the lateral analysis and test procedures is provided in annex E.

4.9.2.2 The damped, unbalanced response analysis shall include, but shall not be limited to, the following considerations.

a) Support (base, frame, and bearing housing) stiffness, mass and damping characteristics, including effects of rotational speed variation. The vendor shall state the assumed support system values.

b) Bearing lubricant film stiffness and damping changes due to speed, load, preload, oil temperatures, accumulated assembly tolerances and maximum-to-minimum clearances.

c) Rotational speed, including the various starting speed detents, operating speed and load ranges (including agreed upon test conditions if different from those specified), trip speed, and coast-down conditions.

d) Rotor masses, including the mass moment of coupling halves, stiffness and damping effects (for example, accumulated fit tolerances, and frame and casing effects).

e) The influence over the operative range of the calculated values for hydrodynamic stiffness and damping generated by the casing, seals and labyrinths.

● **4.9.2.3** If specified, the effects of other equipment in the train shall be included in the damped, unbalanced response analysis (i.e. a train lateral analysis shall be performed).

EXAMPLE *A train lateral analysis should be specified for trains with a rigid coupling.*

4.9.2.4 The damped unbalanced response analysis shall include items a) to e) as follows. (See annex C).

a) A plot and identification of the mode shape at each resonant speed (critically damped or not) from zero to trip, as well as the next mode occurring above the trip speed.

b) Frequency, phase and response amplitude data at the vibration probe locations through the range of each critical speed, using the following arrangement of unbalance for the particular mode. This unbalance shall be sufficient to raise the displacement of the rotor at the probe locations to the vibration limit defined by the following equation:

$$L_V = 25{,}4\sqrt{12\,000 / N}$$

or in US customary units,

$$L_V = \sqrt{12\,000 / N}$$

where

L_V is the vibration limit (amplitude of unfiltered vibration), in micrometres (mil), peak-to-peak;

N is the operating speed nearest the critical of concern, in revolutions per minute.

The unbalance shall be no less than two times the unbalance limit specified in 4.9.5.3. The unbalance mass or masses shall be placed at the location or locations within the bearing span that have been analytically determined as affecting the particular mode most adversely (e.g. at mid-span for translatory modes or near both ends and 180° out of phase for conical modes). For bending modes with maximum deflections at the shaft's ends, the amount of unbalance shall be based on the overhung mass rather than the static bearing loading.

c) Modal diagrams for each response in b), indicating the phase and major axis amplitude at each coupling engagement plane, the centrelines of the bearings, the locations of the vibration probes, at each seal area throughout the machine. The minimum design diametrical running clearance of the seals shall also be indicated.

d) For the purposes of the verification test (see 4.9.3), an additional plot of a test unbalance, as specified in b) (based on static bearing loading for rigid modes or based on overhung mass for bending modes). This test mass shall be at least two times and no more than eight times the unbalance limit specified in 4.9.5.3, and shall be placed at a location determined by the vendor.

● e) If specified, the generation of a stiffness map of the undamped rotor response from which the damped unbalance response analysis specified in c) has been derived. This plot shall show frequency versus support system stiffness with the calculated support system stiffness curves superimposed.

4.9.2.5 The damped unbalance response analysis shall indicate that the machine in the unbalanced condition 4.9.2.4, b), shall meet the following acceptance criteria (see Figure 9).

a) If the amplification factor is less than 2,5, the response is considered critically damped and no separation margin is required.

b) If the amplification factor is 2,5 to 3,55, a separation margin of 15 % above the maximum continuous speed and 5 % below the minimum operating speed is required.

c) If the amplification factor, μ, is greater than 3,55 and the critical response peak is below the minimum operating speed, the required separation margin (a percentage of minimum speed) is calculated as follows:

$$\text{SM} = 100 - \left(84 + \frac{6}{\mu - 3}\right)$$

d) If μ is greater than 3,55 and the critical response peak is above the trip speed, the required SM (a percentage of maximum continuous speed) is equal to the following:

$$\text{SM} = \left(126 - \frac{6}{\mu - 3}\right) - 100$$

4.9.2.6 The calculated unbalanced peak-to-peak rotor amplitudes [see 4.9.2.4.b)] at any speed from zero to trip shall not exceed 75 % of the minimum design diametrical running clearances throughout the machine (with the exception of floating ring and abradable seal locations).

4.9.2.7 If, after the purchaser and the vendor have agreed that all practical design efforts have been exhausted, the analysis indicates that the separation margins still cannot be met or that a critical response peak falls within the operating speed range, acceptable amplitudes shall be mutually agreed upon by the purchaser and the vendor, subject to the requirement of 4.9.2.6.

● **4.9.2.8** If specified, or when average gas density in a compressor casing exceeds 60 kg/m^3 (3,75 lb/ft^3), the vendor shall carry out a rotor stability analysis. This shall be made at rated speed for constant speed machines and over the speed range from minimum to maximum continuous speed for variable speed compressors. The analysis shall be performed without, and then with, destabilizing aerodynamic effects, taking into account the highest gas density. The results are to be provided as plots showing the damped critical speeds and the log decrement as a function of speed. The vendor should demonstrate the acceptability of the calculated value of log decrement by reference to similar machines in satisfactory operation. This should be over the speed range from minimum to maximum continuous speed. This stability analysis should also take into account all items listed in 4.9.2.2.

4.9.3 Shop verification of unbalanced response analysis

● **4.9.3.1** If specified, the vendor shall demonstrate the accuracy of the vendor's unbalanced responce calculation by performing an unbalanced responce test in accordance with 4.9.

4.9.3.2 The actual critical speed responses, as revealed on the test stand with a rotor unbalance magnitude in accordance with 4.9.2.4, d), placed at a location (usually the coupling) determined by the vendor, shall be the criteria for confirming the validity of the damped unbalanced response analysis.

NOTE It is recognized that the dynamic response of the machine on the test stand will be a function of the agreed upon test conditions and that unless the test stand results are obtained at the conditions of pressure, temperature, speed, and load expected in the field, they may not be the same as the results expected in the field.

4.9.3.3 The parameters to be measured during the test shall be speed and shaft vibration amplitudes with corresponding phase. The vibration amplitudes and phase from each pair of $x-y$ vibration probes shall be vectorially summed at each response peak to determine the maximum amplitude of vibration. The major axis amplitude of each response peak shall not exceed the limits specified in 4.9.2.6. The gain of the recording instrumentation used shall be predetermined and preset before the test so that the highest response peak is within 60 % to 100 % of the recorder's full scale on the test unit coast-down (deceleration).

NOTE 1 It is recognized that vectorial subtraction of slow roll (300 r/min to 600 r/min) total electrical and mechanical runout is always required for this verification and that vectorial subtraction of bearing housing motion is normally required.

NOTE 2 The phase on each vibration signal, x or y, is the angular measure, in degrees, of the phase difference (lag) between a phase reference signal (from a phase transducer sensing a once per revolution mark on the rotor, as described in API 670) and the next positive peak, in time, of the synchronous (lx) vibration signal. (If proximity probes are used, this is the lag angle between the vibration probe and the high spot on the rotor).

NOTE 3 The major axis amplitude is properly determined from a lissajous (orbit) display on an oscilloscope, oscillograph or equivalent. If the phase angle between the x and y signals is not 90°, the major axis amplitude can be approximated by $(x^2+y^2)^{½}$. If the phase angle between the x and y signals is 90°, the major axis value is the greater of the two vibration signals.

4.9.3.4 Additional testing and correction of the original damped, unbalanced rotor response analysis shall be required if, from the test data described above, or from a phase or amplitude indication in the damped unbalanced response analysis [based on the unbalance conditions described in 4.9.2.4, b)], or both, it appears that either of the following conditions exists:

a) any critical response fails to meet the separation margin requirements (see 4.9.2.5) or falls within the operating speed range;

b) the requirement of 4.9.2.6 has not been met.

Unbalance masses shall be determined and placed as mutually agreed upon by the purchaser and the vendor (see 4.9.2.4, b) and d). Unbalance magnitudes shall be achieved by adjusting the residual unbalance that exists in the rotor from the initial run to raise the displacement of the rotor at the probe locations to the vibration limit defined by the equation in 4.9.2.4, b) at the maximum continuous speed. The measurements from this test, taken in accordance with 4.9.3.2, shall indicate the following acceptance criteria for the machine.

a) at no speed shall the shaft deflections exceed 90 % of the minimum design running clearances.

b) at no speed within the operating speed range shall the shaft deflections exceed 55 % of the minimum design running clearances or 150 % of the allowable vibration limit at the probes [see 4.9.2.4, b)].

The internal deflection limits specified in a) and b) immediately above shall be based on the calculated displacement ratios between the probe locations and the areas of concern identified in 4.9.2.4, c). Actual internal displacements for these tests shall be calculated by multiplying these ratios by the major axis amplitudes (see 4.9.3.2). Acceptance shall be based on these calculated displacements, not on inspection of seals after testing; however, damage to any portion of the machine as a result of this testing shall constitute failure of the test. Minor internal seal rubs that do not cause clearance changes outside the vendor's new part tolerance do not constitute damage.

4.9.4 Torsional analysis

4.9.4.1 Excitations of torsional natural frequency may come from many sources, which should be considered in the analysis. These sources may include, but are not limited to, the following:

a) gear problems such as unbalance and pitch line runout;

b) start-up conditions such as speed detents (under inertial impedances) and other torsional oscillations;

c) torsional transients such as switch on and terminal short circuit of all kinds of electric motors, start-up, operation and worst-case transient of variable speed electric motors, and start-up of synchronous electric motors.

4.9.4.2 The torsional natural frequency of the complete train shall be at least 10 % above or 10 % below any possible excitation frequency within the specified operating speed range (from minimum to maximum continuous speed).

4.9.4.3 Torsional criticals at two times running speed as well as one and two times the supply frequency for motor driven systems shall preferably be avoided or, in systems in which corresponding excitation frequencies occur, shall be shown to have no adverse effect. In addition to multiples of running speeds, torsional excitations that are not a function of operating speeds or that are non-synchronous in nature shall be considered in the torsional analysis if applicable. Identification of these frequencies shall be the mutual responsibility of the purchaser and the vendor.

4.9.4.4 For the torsional analysis of variable-speed motor-driven compressors, the vendor, together with the variable speed motor supplier shall identify all excitation frequencies and their consequences on the train. These frequencies shall include but not be limited to

— non-speed dependant excitations such as ripple,

— integer harmonics,

— non-integer harmonics,

— carrier frequency harmonics, and

— switching harmonics between speed-control windows.

4.9.4.5 If torsional resonances are calculated to fall within the margin specified above, and the purchaser and vendor have agreed that all efforts to remove the critical from within the limiting frequency range have been exhausted, the vendor shall demonstrate that the resonances have no adverse effect on the complete train.

● **4.9.4.6** For motor-driven units and units including gears, or — if specified — for turbine driven units, the vendor shall perform a torsional vibration analysis of the complete train and shall be responsible for directing the modifications necessary to meet the requirements of 4.9.4.1 to 4.9.4.4.

4.9.4.7 In addition to the torsional analyses required in 4.9.4.2 to 4.9.4.5, the vendor shall perform a transient torsional vibration analysis for motor-driven units. The acceptance criteria for this analysis shall be mutually agreed upon by the purchaser and the vendor.

4.9.5 Vibration and balancing

4.9.5.1 Major parts of the rotating element, such as the shaft, balancing drum and impellers, shall be individually dynamically balanced before assembly to ISO 1940-1 grade G2,5 (with respect to the maximum continuous speed) or better. If a bare shaft with a single key way is dynamically balanced, the key way shall be filled with a fully crowned half-key in accordance with ISO 8821. A shaft with key ways 180° apart, but not in the same transverse plane, shall also be filled thus. The initial balance correction to the bare shaft shall be recorded.

4.9.5.2 The complete rotor shall be balanced either at low speed in accordance with 4.9.5.3 or at high speed in accordance with 4.9.5.5.

4.9.5.3 For low-speed balancing, the rotating element shall be multiplane dynamically balanced during assembly. This shall be accomplished after the addition of no more than two major components. Balancing correction shall be applied only to the elements added. Minor correction of other components may be required during the final trim balancing of the rotor (see 4.9.5.1). In the sequential balancing process, any half-keys used in the balancing of the bare shaft shall continue to be used until they are replaced with the final key and mating element. The mass of all half-keys used during final balancing of the assembled element shall be recorded on the residual unbalance work sheet (see annex D). The maximum allowable residual unbalance per plane (journal) shall be calculated as follows:

$$U_{max} = 6\,350\ W / N$$

or, in US customary units,

$$U_{max} = 4\ W / N$$

where

U_{max} is the residual unbalance, in gram millimetres (ounce inches);

W is the journal static mass load, in kilograms (pounds);

N is the maximum continuous speed, in revolutions per minute.

If spare rotors are supplied they shall be dynamically balanced to the same tolerances as the main rotor.

4.9.5.4 After the final low-speed balancing of each assembled rotating element has been completed, a residual unbalanced check shall be performed and recorded as described in annex D.

4.9.5.5 High-speed balancing may be done (balancing in a high-speed balancing machine at the operating speed). The acceptance criteria for this balancing shall be mutually agreed upon by the purchaser and the vendor.

4.9.5.6 During the shop test of the machine, assembled with the balanced rotor, operating at its maximum continuous speed or at any other speed within the specified operating speed range, the peak-to-peak amplitude of unfiltered vibration in any plane, measured on the shaft adjacent and relative to each radial bearing, shall not exceed the following value or 50 µm (2,0 mil), whichever is less:

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

or, in US customary units,

$$A = \sqrt{12\,000 / N}$$

where

A is the amplitude of unfiltered vibration, in micrometres (mil), peak-to-peak;

N is the maximum continuous speed, in revolutions per minute

At any speed greater than the maximum continuous speed, up to and including the trip speed of the driver, the vibration shall not exceed 150 % of the maximum value recorded at the maximum continuous speed, unless the unbalance response analysis indicates a steeper rise of vibration levels, when the limit shall be that given by calculation or 150 % of those given by the equation above, whichever is the lower.

NOTE These limits are not to be confused with the limits specified in 4.9.3. for shop verification of unbalanced response.

4.9.5.7 Electrical and mechanical runout shall be determined and recorded.

4.9.5.8 If the vendor can demonstrate that electrical or mechanical runout is present, a maximum of 25 % of the test level calculated from the equation in 4.9.5.6 or 6,5 µm (0,25 mil), whichever is greater, may be vectorially subtracted from the vibration signal measured during the factory test.

4.10 "Lube" oil and seal oil systems

4.10.1 Unless otherwise specified, a pressurized oil system or systems shall be furnished to supply oil at a suitable pressure or pressures, as applicable, to the following:

a) the bearings of the driver and of the driven equipment (including any gear);

b) the continuously lubricated couplings;

c) the governing and control oil system;

d) the seal oil system;

e) the purchaser's control system (if hydraulic).

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

● **4.10.3** The purchaser shall specify whether the seal oil and "lube" oil systems are to be separate or combined. If separate systems are specified, the means of preventing the interchange of oil between the two systems shall be described in the vendor's proposal.

4.10.4 Unless otherwise specified, bearings and bearing housings shall be arranged for hydrocarbon oil lubrication.

4.10.5 Unless otherwise specified, pressurized oil systems shall conform to the requirements of ISO 10438. If approved by the purchaser, a pressurized integral oil system may be provided for a closed loop, non-hydrocarbon refrigerant refrigeration system.

4.11 Materials

4.11.1 General

4.11.1.1 Construction materials shall be at the manufacturer's discretion for the specified operating conditions, except as required or prohibited by the data sheets or otherwise by this International Standard. Table B.1 in annex B lists material specifications that, if used with appropriate heat treatment or impact testing requirements or both, are generally considered acceptable for major component parts. Other international material specifications may, by agreement between purchaser and vendor, be used for major component parts. The metallurgy of all major components shall be clearly stated in the vendor's proposal. See 5.5 for requirements for auxiliary piping materials.

4.11.1.2 Materials and the material grade shall be identified in the proposal using established international, national or industry designations. If no such designation is available, the vendor's material specification, giving physical properties, chemical composition and test requirements, shall be included in the proposal.

● **4.11.1.3** Copper and copper alloys (excluding Monel or its equivalent, bearing babbitt, and precipitation hardening stainless steels) shall not be used for parts of compressors or auxiliaries in contact with corrosive gas or with gases capable of forming explosive copper compounds. The purchaser shall note such gas characteristics on the inquiry data sheets.

4.11.1.4 The vendor shall specify optional tests and inspection procedures necessary to ensure that materials are satisfactory for the service. Such tests and inspections shall be listed in the proposal. The purchaser should consider specifying additional tests and inspections, especially for materials in critical service.

4.11.1.5 Selection of casing material shall be restricted by the limits imposed by 4.2.7 and 4.2.8.

4.11.1.6 Material that is notch-sensitive and prone to brittle fracture at ambient temperatures (e.g. ASTM A 515) shall not be used.

● **4.11.1.7** Materials exposed to Hydrogen-sulfide (H_2S) gas service as defined by NACE MR 0175 shall be in accordance with the requirements of NACE MR 0175. Ferrous materials not covered by NACE MR 0175 shall be limited to a yield strength not exceeding 620 MPa (90 000 psi) and a Rockwell hardness not exceeding HRC 22. Components that are fabricated by welding shall be stress relieved, if required, so that both the welds and the heat-affected zones meet the yield strength and hardness requirements. The purchaser shall specify on the data sheets the presence of H_2S in the process gas.

NOTE Shafts in compressors of between-bearing design can exceed the stated limits of yield strength and hardness because of requirements for higher strength at reduced shaft sections near couplings and because of the low levels of working stress in the portion of the shaft between bearings.

● **4.11.1.8** The purchaser shall specify the presence of any corrosive agents in the process gas, the process stream and the environment, including constituents that may cause stress corrosion cracking.

4.11.1.9 If parts made from austenitic stainless steels are exposed to a process gas or environmental conditions that promote corrosion, and they could be fabricated, hard-surfaced, repaired or overlaid by welding, then stabilized or low-carbon grades shall be used.

4.11.1.10 Austenitic steels shall not be used in services where stress corrosion cracking is a possibility.

NOTE Overlays or hard surface that contain more than 0,10 % carbon can sensitize both low-carbon and stabilized grades of austenitic stainless steel unless a buffer layer that is not sensitive to inter-granular corrosion is applied.

4.11.1.11 In hydrogen gas service at partial gauge pressures greater than 700 kPa (100 psi) or at concentrations greater than a molal percentage of 90 % at any pressure, impeller materials that have a yield strength in excess of 830 MPa (120 000 psi) or a hardness in excess of Rockwell HRC 34 are prohibited.

4.11.1.12 Materials, casting factors and the quality of any welding shall be in accordance with the pressure design code.

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

4.11.1.14 Minor parts that are not identified (e.g. nuts, springs, washers, gaskets and keys) shall have corrosion resistance at least equal to that of specified parts in the same environment.

4.11.1.15 Bolting material for pressure joints shall be in accordance with the pressure design code.

4.11.1.16 If mating parts such as studs and nuts of austenitic stainless steel or materials with similar galling tendencies are used, they shall be lubricated with a suitable anti-seizure compound compatible with the process conditions.

NOTE Torque loading values will differ considerably with and without anti-seizure compound.

4.11.1.17 O-rings shall be compatible with all specified services. For high-pressure services, special consideration shall be given to the selection of O-rings that will not be damaged by rapid depressurization of the compressor.

4.11.2 Pressure-containing parts

4.11.2.1 The vendor shall specify on the data sheets (see annex A) the material grade of castings.

4.11.2.2 Welding of piping and pressure-containing parts, as well as any dissimilar metal welds and weld repairs, shall be performed and inspected by operators and using procedures qualified in accordance with the pressure design code.

4.11.2.3 The vendor shall be responsible for establishing weld repair procedures that are in accordance with the pressure design code and for the implementation of repairs in accordance with these procedures as well as for defect description, including post-repair heat treatment, if required, and non-destructive examination of repairs. Such procedures are subject to review by the purchaser before any repair is made.

4.11.2.4 Castings shall be sound and free from porosity, hot tears, shrink holes, blow holes, cracks, scale, blisters and similar injurious defects. Surfaces of castings shall be cleaned by sandblasting, shot-blasting, chemical cleaning, pickling or any other standard method. Mould parting fins and remains of gates and risers shall be chipped, filed or ground flush.

4.11.2.5 The use of chaplets in pressure castings shall be held to a minimum. The chaplets shall be clean and corrosion free (plating permitted) and of a composition compatible with the casting.

4.11.2.6 Cast grey iron or nodular iron castings shall not be repaired by welding, peening, burning or impregnating.

4.11.2.7 Weldable grades of steel castings may be repaired by welding, using a qualified welding procedure in accordance with the pressure design code.

4.11.2.8 Cast grey iron or nodular iron may be repaired by plugging within the limits specified in the selected materials specification. The holes drilled for plugs shall be carefully examined, using liquid penetrant, to ensure that all defective material has been removed. All repairs that are not covered by the specification shall be subject to the purchaser's approval.

4.11.2.9 Fully enclosed cored voids, including voids closed by plugging, shall not be used.

4.11.2.10 Nodular iron castings shall be in accordance with the pressure design code, or a standard agreed by the purchaser (e.g. ASTM A 395).

4.11.2.11 Pressure-containing casings made of wrought materials or combinations of wrought and cast materials shall conform to the following conditions.

a) Plate edges shall be inspected by magnetic particle or liquid penetrant examination in accordance with the pressure design code.

b) Accessible surfaces of welds shall be inspected by magnetic particle or liquid penetrant examination after back chipping or gouging and again after stress relieving.

c) Pressure-containing welds, including welds of the case to horizontal and vertical joint flanges, shall be full penetration (complete joint) welds unless otherwise approved by the purchaser prior to any fabrication. For exceptions see 4.4.3.

d) Fabricated casings, including main nozzles, shall be post weld heat treated, regardless of thickness. For exceptions see 4.4.3.

e) Welded casings shall be examined radiographically or ultrasonically (see 4.11.4.). All pressure-containing welds shall be examined in accordance with the pressure design code. Requirements for additional examination shall be mutually agreed upon by the vendor and the purchaser.

● **4.11.2.12** If specified, proposed connection designs shall be submitted to the purchaser for approval before fabrication. The drawings shall show weld designs, size, materials and both pre- and post-weld heat treatments.

4.11.3 Low temperature

● For operating temperatures below –30 °C (–20 °F), or if specified for other low ambient temperatures, steels shall have, at the lowest specified temperature, an impact strength sufficient to qualify under the minimum Charpy V-notch impact energy requirements of the pressure design code. For materials and thickness not covered by the code, the purchaser shall specify the requirements on the data sheets.

4.11.4 Material inspection of pressure-containing parts

4.11.4.1 Regardless of these generalized limits, it shall be the vendor's responsibility to review the design limits of all castings in the event that more stringent requirements are specified.

4.11.4.2 If radiographic, ultrasonic, magnetic particle, or liquid penetrant inspection of welds or materials is required or specified, the following procedures and acceptance criteria shall apply, except as noted (see 6.2.2.1.2).

a) Radiographic examination shall be in accordance with the pressure design code. Spot radiography shall consist of a minimum of one 150 mm (6 in) spot radiograph for each 7,5 m (25 ft) of weld on each casing. As a minimum one spot radiograph is required for each welding procedure and welder used for pressure containing welds.

b) Ultrasonic examination shall be in accordance with the pressure design code.

c) Magnetic particle examination shall be in accordance with the pressure design code. Linear indications shall be considered relevant only if the major dimension exceeds 1,5 mm ($^1/_{16}$ in). Individual indications that are separated by less than 1,5 mm ($^1/_{16}$ in) shall be considered continuous.

d) Liquid penetrant examination shall be in accordance with the pressure design code.

4.11.4.3 Cast steel casing parts shall be examined by magnetic particle methods. If magnetic particle inspection as described in ASTM E 709 is required, acceptability of defects shall be based on a comparison with the photographs in ASTM E 125. For each type of defect, the degree of severity shall not exceed the limits specified in Table 2. Defects that exceed the limits imposed in Table 2 shall be cleaned out to meet the quality standards cited above, as determined by additional magnetic particle inspection before repair welding.

Table 2 — Maximum severity of defects in casings

Type	Defect	Degree
I	Linear discontinuities	0 (None acceptable)
II	Shrinkage	2
III	Inclusions	2
IV	Chills and chaplets	1
V	Porosity	1
VI	Welds	1

4.11.5 Impellers

4.11.5.1 All accessible areas of welds on welded impellers shall be inspected by magnetic particle or liquid penetrant examination.

4.11.5.2 Cast impellers shall be inspected by radiographic or ultrasonic means prior to finish machining. Details of inspection techniques and acceptance criteria shall be mutually agreed upon by the vendor and the purchaser.

4.11.5.3 Brazed impellers shall be inspected by ultrasonic means. Details of inspection techniques and acceptance criteria shall be mutually agreed by the vendor and the purchaser.

4.11.5.4 After the overspeed test described in 6.3.3, each impeller shall be examined all over by means of magnetic particle or liquid penetrant methods.

4.12 Nameplates and rotation arrows

4.12.1 A nameplate shall be securely attached at a readily visible point on the equipment and on any other major piece of auxiliary equipment.

4.12.2 Rotation arrows shall be cast in, or attached to, each major item of rotating equipment. Nameplates and rotation arrows (if attached) shall be of austenitic stainless steel or of nickel copper alloy (Monel or its equivalent). Attachment pins shall be of the same material.

4.12.3 The purchaser's item number, the vendor's name, the machine's serial number and the machine's size and type as well as its minimum and maximum allowable working pressures and temperatures, hydrostatic test pressures, and critical speeds, shall appear on the machine's nameplate.

4.12.4 Any lateral critical speeds determined on the running tests shall be stamped on the nameplate followed by the word test. Critical speeds that are predicted by calculation up to and including the critical speed above trip speed and are not identifiable by test shall be stamped on the nameplate and noted as calculated value.

5 Accessories

5.1 Drivers

● **5.1.1** The type of driver shall be specified by the purchaser. The driver shall be sized to meet the maximum specified operating conditions, including external gear or coupling losses or both, and shall be in accordance with applicable specifications, as stated in the inquiry and order. The driver shall be suitable for satisfactory operation under the utility and site conditions specified by the purchaser.

● **5.1.2** Anticipated process variations that may affect the sizing of the driver (such as changes in the pressure, temperature or properties of the fluid handled, as well as special plant start-up conditions) shall be specified by the purchaser.

● **5.1.3** The starting conditions for the driven equipment shall be specified by the purchaser and the starting method shall be mutually agreed upon by the purchaser and the vendor. The driver's starting torque capabilities shall exceed the speed torque requirements of the driven equipment.

5.1.4 Steam turbine drivers shall be in accordance with ISO 10437. Steam turbine drivers shall be sized to continuously deliver 110 % of the maximum power (including gear, fluid coupling or other losses, as applicable) required for the purchaser's specified conditions while operating at a corresponding speed with the specified steam conditions.

5.1.5 For motor-driven units, the motor nameplate rating (exclusive of the service factor) shall be at least 110 % of the greatest power (including gear, fluid coupling or other losses, as applicable) required for any of the specified operating conditions. Consideration should be given to starting the compressor at the normal suction pressure. Compressors driven by induction motors shall be rated at the actual motor speed for the rated load condition.

If variations in operating conditions (e.g. as molar mass) are expected the purchaser should consider specifying a higher margin.

● **5.1.6** The motor's starting torque requirements shall be met at a reduced voltage specified by the purchaser and the motor shall accelerate to full speed within a period of time agreed upon by the purchaser and the vendor.

NOTE For most applications the starting voltage is typically 80 % of the normal voltage and the time required to accelerate to full speed is generally less than 30 s.

5.1.7 Gas turbine drivers shall conform to ISO 3977-5 and shall be sized as mutually agreed upon by the purchaser and the vendor.

5.1.8 Speed increasers and reducers shall be in accordance with ISO 13691. Epicyclic gears may be used with the purchaser's approval.

5.1.9 The trip speed of variable speed drivers shall be as given in Table 3.

Table 3 — Trip speed values

Driver type	Trip speed (percentage of maximum continuous speed)
Steam Turbine	110
Gas Turbine	105
Variable speed motor	105
Reciprocating engine	110

5.2 Couplings and guards

5.2.1 Unless otherwise specified, the compressor vendor shall furnish all couplings and guards for the entire compressor train, including gears if they are part of the train. The vendor shall arrange for complete machining of all couplings halves, shall mount the compressor coupling half and shall arrange for mounting of the drive train half, *couplings*.

● **5.2.2** Couplings shall be in accordance with ISO 10441. The make, type, and mounting arrangement of the couplings shall be agreed upon by the purchaser and the vendors of the driver and driven equipment. Guards shall comply with the specified national code.

5.2.3 The coupling-to-shaft juncture shall be designed and manufactured to be capable of transmitting power at least equal to the power rating of the coupling.

● **5.2.4** If uncoupled operation is specified, idling adaptors (solo plates) or coupling mass simulators in accordance with ISO 10441, or both, shall be provided as necessary to enable the driver and any gearbox or drive-through casing to be run uncoupled.

● **5.2.5** Plug and ring gauges supplied shall be in accordance with ISO 10441.

5.3 Mounting plates

5.3.1 General

● **5.3.1.1** The equipment shall be furnished with sole plates or a baseplate as specified on the data sheets (see annex A).

5.3.1.2 In the following, the term "mounting plate" refers to both baseplates and sole plates.

a) Axial, lateral and vertical jackscrews shall be provided for all equipment in the compressor train. Vertical jackscrews shall be arranged to prevent marring of shimming surfaces.

b) Compressor supports shall be provided with austenitic stainless steel shim packs, 3 mm to 15 mm (⅛ in to ½ in) thick, with jack screws for easy removal or addition of shims. All shims shall straddle hold-down bolts and jackscrews.

c) The upper and lower surfaces of bearing pedestals and mounting plates shall be machined parallel.

d) If centreline supports are provided, they shall be designed and manufactured to permit the machine to be moved using the horizontal jackscrews.

e) Anchor bolts shall not be used to fasten machinery to the mounting plates.

f) Mounting plates shall not be drilled for equipment to be mounted by others. Mounting plates intended for installation on concrete shall be supplied with levelling screws. Mounting plates that are to be grouted shall have 50 mm (2 ") radiused outside corners (in the plan view). See Figures 10 and 11.

g) Anchor bolts shall be furnished by the purchaser.

h) Fasteners for attaching the components to the mounting plates and jackscrews for levelling the pedestal sole plates shall be supplied by the vendor.

i) The equipment feet shall be drilled with pilot holes that are accessible for use in final doweling.

● j) If epoxy grout is specified on the data sheets, the vendor shall precoat all the grouting surfaces of the mounting plates with a catalyzed epoxy primer applied to degreased near-white metal. The purchaser shall specify the primer and the method of application.

k) Mounting surfaces that are not to be grouted shall be coated with a rust-preventive immediately after machining.

Dimensions in millimetres

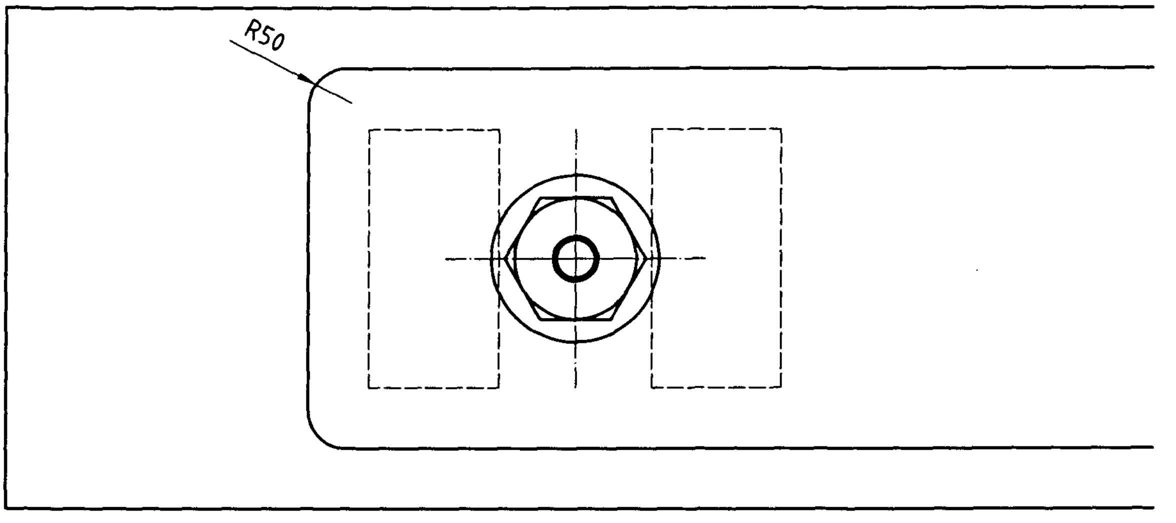
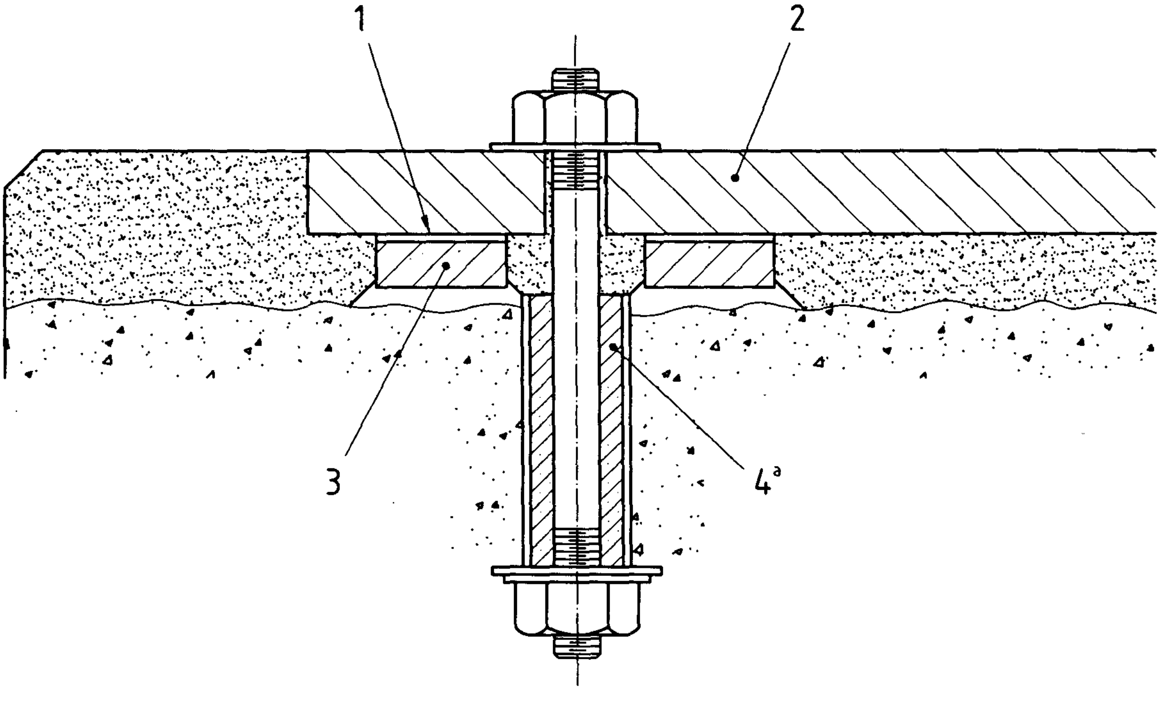


Figure 10 — Sole plate arrangement (top view)



Key

1 Shim pack

2 Sole plate

3 Sub-sole plate

4 Typical anchor bolt sleeve

a These areas shall be filled with grout, which is then left to set, after which the normal sole plate areas shall be grouted.

Figure 11 — Sole plate arrangement (cross-section)

5.3.2 Baseplate

5.3.2.1 A baseplate shall be a single fabricated steel unit unless the purchaser and the vendor mutually agree that it may be fabricated in multiple sections. Multiple section baseplates shall have machined and doweled mating surfaces to ensure accurate field reassembly.

NOTE A baseplate with a nominal length of more than 12 m (40 ft) or a nominal width of more than 3,5 m (12 ft) might have to be fabricated in multiple sections because of shipping restrictions.

● **5.3.2.2** If specified, the baseplate shall be provided with levelling pads or targets protected with removable covers. The pads or targets shall be accessible for field levelling after installation, with the equipment mounted and the baseplate on the foundation.

● **5.3.2.3** If specified, the baseplate shall be suitable for column mounting (i.e. of sufficient rigidity to be supported at specific points) without continuous grouting under structural members. The baseplate design shall be mutually agreed upon by the purchaser and the vendor.

5.3.2.4 The baseplate shall be provided with lifting lugs for at least a four-point lift. Lifting the baseplate complete with all equipment mounted shall not permanently distort or otherwise damage the baseplate or the machinery mounted on it.

5.3.2.5 The bottom of the baseplate between structural members shall be open. If the baseplate is installed on a concrete foundation, accessibility shall be provided for grouting under all load-carrying structural members. The mounting pads on the bottom of the baseplate shall be in one plane in order to permit use of a single-level foundation.

5.3.2.6 Unless otherwise specified, non-skid decking covering all walk and work areas shall be provided on the top of the baseplate.

5.3.2.7 Oil reservoirs shall be separate from the baseplate (see ISO 10438) unless otherwise approved by the purchaser.

● **5.3.2.8** If specified, the baseplate shall be extended as necessary to support the driver, other compressors, and gear units or the control panel or both.

5.3.3 Sole plates and sub sole plates

5.3.3.1 If sole plates are specified, they shall meet the following requirements, in addition to those of 5.3.2.

a) Sole plates shall be larger than the individual mounting pad area for each mating pad.

b) Working clearance for hold-down bolts and levelling screws shall be provided.

c) Sole plates shall be steel plates thick enough to transmit the expected loads from the equipment feet to the foundation but in no case shall they be less than 40 mm (1,5 in) thick. See Figures 10 and 11.

d) Corners shall be rounded to a minimum 50 mm (2 in) radius in the plan view (see Figure 10).

● **5.3.3.2** If specified, sub-sole plates shall be furnished. They shall be steel plates a minimum of 25 mm (1 in) thick having a mating surface finish that matches the sole plates.

5.4 Controls and instrumentation

5.4.1 General

● **5.4.1.1** The purchaser shall outline in the inquiry the control philosophy to be followed. The vendor shall provide sufficient compressor performance data (in accordance with clause 7) to enable the purchaser to properly design a control system for start-up operation, for all specified operating conditions and shutdowns, and for surge prevention. If requested by the purchaser, the vendor shall review the purchaser's overall compressor control system for compatibility with vendor furnished control equipment.

● **5.4.1.2** Instrumentation and installation shall conform to all detailed specifications in the purchaser's inquiry. If no detailed specifications are furnished, instrumentation and installation shall be in accordance with ISO 10438.

5.4.1.3 If applicable, controls and instrumentation shall be in accordance with API RP 550.

5.4.1.4 Unless otherwise specified, controls and instrumentation shall be suitable for outdoor installation.

5.4.1.5 Instrument and electrical wiring shall be installed, protected and shall comply with the relevant standards, and shall be designed so that it can be easily removed without damage or located so as not to hamper removal of bearings, seals or the compressor internals.

5.4.1.6 If operation from a Distributed Control System (DCS) is specified, the vendor shall indicate all signals for operating the machinery from the DCS.

● **5.4.1.7** If specified, a dynamic simulation study shall be carried out to verify the satisfactory behaviour of the anti-surge protection system and process control system under all operating conditions.

5.4.2 Control systems

● **5.4.2.1** The compressor may be controlled on the basis of inlet pressure, discharge pressure, flow or some combination of these parameters. This may be accomplished by suction or discharge throttling, variable inlet guide vanes, speed variation, discharge blowoff (if a constant-speed driver is used) or a cooled bypass from discharge to suction. The control system may be mechanical, pneumatic, hydraulic, electric or any combination of these. The system may be manual, or it may be automatic with a manual override. The purchaser shall specify the source of the control signal, its sensitivity and range, and the equipment to be furnished by the vendor.

NOTE A combination of control modes could be required on drives with a limited speed range and on multiservice or multi-stream applications.

● **5.4.2.2** If specified, an anti-surge system shall be provided.

NOTE Anti-surge systems are generally required to prevent operation in unstable regions that might cause damage to the compressor.

● **5.4.2.3** If the driver is an electric motor, and automatic capacity control with automatic override control is specified, the override control shall prevent overloading the motor. The override control shall limit motor current to avoid overcurrent tripping of the motor. Such controls shall include

a) a motor current indicator at the compressor control panel, and

b) a current transformer/transducer in the motor switch gear to generate a milliampere signal for the control current indicator.

● **5.4.2.4** For a constant-speed drive, the control signal shall actuate either a purchaser-furnished control valve or the adjustable inlet guide vanes furnished by the vendor as an integral part of the compressor, as specified. In the later case, the vendor shall also furnish a guide vane positioner compatible with the type of control signal specified by the purchaser and shall include a hand wheel or other means of local manual override during operation. A direct-driven vane position indicator shall be provided that is visible during operation of the machine.

5.4.2.5 For a variable-speed drive, the control signal shall act to adjust the set point of the driver's speed control system. Unless otherwise specified, the control range shall be from the maximum continuous speed to 95 % of the minimum speed required for any specified operating case, or 70 % of the maximum continuous speed, whichever is the lower.

5.4.2.6 The full range of the purchaser's specified control signal shall correspond to the required operating range of the driven equipment. Unless otherwise specified, the maximum control signal shall correspond to the maximum continuous speed or the maximum flow.

5.4.3 Instrument and control panels

● **5.4.3.1** If specified, a panel shall be provided that includes all panel-mounted instruments for the driven equipment and the driver. Such panels shall be designed and fabricated in accordance with the purchaser's description. The purchaser shall specify whether the panel is to be free-standing, located on the base of the unit, or in another location. The instruments on the panel shall be clearly visible to the operator from the driver control point. A lamp test push button shall be provided. The instruments to be mounted on the panel shall be specified by the purchaser on the data sheets (see annex A).

● **5.4.3.2** Panels shall be completely piped and wired, requiring only connection to the purchaser's external piping and wiring circuits. If more than one wiring point is required on a unit for control or instrumentation, the wiring to each switch or instrument shall be provided from a terminal box with terminal posts mounted on the unit (or its base, if any). The purchaser shall specify whether the wiring protection shall be by conduit or by armoured cabling. All leads and posts on terminal strips switches, and instruments shall be tagged for identification.

5.4.4 Instrumentation

5.4.4.1 General

5.4.4.1.1 Unless otherwise specified, all leads on terminal strips, switches and instruments shall be permanently tagged for identification. All terminal boards in junction boxes and control panels shall have at least 20 % spare terminal points.

● **5.4.4.1.2** If specified, air purging shall be used to avoid moisture problems, even if weatherproof and watertight housings are used. Purge air shall be clean and dry, conforming to ISA RP 12.4 type X and Y and NFPA 496.

5.4.4.2 Thermometers and temperature gauges

5.4.4.2.1 Dial-type temperature gauges shall be heavy-duty and corrosion-resistant. They shall be at least 125 mm (5 in) in diameter and bimetallic or liquid-filled.

NOTE Black printing on a white background is standard for gauges.

5.4.4.2.2 The sensing elements of thermometers and temperature gauges shall be in the flowing fluid.

5.4.4.3 Thermowells

Thermometers and temperature gauges that are in contact with flammable or toxic fluids, or that are located in pressurized or flooded lines, shall be furnished with austenitic stainless steel separable-flange type, solid-bar thermowells, at least 19 mm (¾ ") in diameter.

5.4.4.4 Thermocouples and resistance temperature detectors

If practicable, the design and location of thermocouples and resistance temperature detectors, except bearing temperature sensors (see 4.7.1.2), shall permit replacement while the unit is operating. The lead wires of thermocouples and resistance temperature detectors shall be installed as continuous leads between the thermowell or detector and the terminal box. Conduit or armoured cable runs from thermocouple heads to a pull box or boxes located on the base plate shall be provided.

5.4.4.5 Pressure gauges

● Pressure gauges (not including built-in instrument air gauges), unless otherwise specified, shall be furnished with Type 316 stainless steel bourdon tubes and stainless steel movements, 100 mm (4½ in) dials [160 mm dials for the range over 5 500 kPa (800 psi)] and DN 12 (NPS ½) pipe-thread, male, alloy steel connections. If specified, oil filled gauges shall be furnished in locations subject to vibration. Gauge ranges shall preferably be selected so that the normal operating pressure is at the middle of the gauge's range. In no case, however, shall the maximum reading on the dial be less than the applicable relief valve setting plus 10 %. Each pressure gauge shall be provided with a device, such as a disk insert or blowout back, designed to relieve excess case pressure.

NOTE Black printing on a white background is standard for gauges.

5.4.4.6 Solenoid valves

5.4.4.6.1 Direct solenoid-operated valves shall be used only in clean, dry instrument air service, shall have Class F insulation or better, and shall have a continuous service rating. If required for other services, the solenoid shall act as a pilot valve to pneumatic valves, hydraulic valves and the like.

5.4.4.6.2 Solenoid valves shall not be used in continuous services that may affect normal operations, such as fuel controls. They may be used in intermittent instrument services such as starting cycle controls.

5.4.5 Alarms and shutdowns

5.4.5.1 General

● **5.4.5.1.1** Each alarm switch and each shutdown switch shall be furnished in a separate housing located to facilitate inspection and maintenance. Hermetically sealed, single-pole, double-throw switches with a minimum capacity of 5 A at 120 V AC shall be used. Unless otherwise specified, mercury switches shall not be used. If specified, the vendor shall furnish sensors and transmitters for necessary alarms and shutdown functions. Field instruments shall be of the electronic transmitter type, with analog signals for interface to the control system. For the compressor shutdown functions, separate sensors and transmitters shall be used. For control and alarm functions, combined sensors and transmitters may be used.

5.4.5.1.2 Unless otherwise specified, electric switches that open (de-energize) to alarm and trip shall be furnished by the vendor.

5.4.5.1.3 The sequence of alarm and shutdown operation shall be the following.

a) Any alarm or shutdown condition shall be initiated by the action of locally mounted contacts, unless transmitters are used.

b) Alarm and shutdown indications shall consist of a corresponding panel light illumination and the sounding of a horn.

c) Acknowledgement of the alarm or shutdown condition, or both, shall be accomplished by operating a common horn-silencing push button suitably located on the panel. This shall silence the horn.

d) After the alarmed field condition has been corrected, the corresponding panel alarm light shall remain lit until a common panel mounted reset push button is operated (manual reset). In the interim, any additional field alarm condition or conditions shall again sound the horn and illuminate the corresponding additional panel light or lights.

e) Shutdown panel lights shall contain a first-out feature (i.e. only the first shutdown light shall be illuminated). After a shutdown occurs, operation of the reset push button shall be required before the unit can be restarted.

5.4.5.1.4 Connections shall be provided to actuate a remote alarm whenever any of the locally displayed compressor alarms or shutdowns operate.

5.4.5.2 Alarm and trip devices

5.4.5.2.1 Alarm and trip device settings shall not be adjustable from outside the housing. Alarm and trip devices shall be arranged to permit testing of the control circuit, including, if possible, the actuating element, without interfering with normal operation of the equipment. The vendor shall provide a clearly visible light on the panel to indicate when trip circuits are in a test bypass mode. Unless otherwise specified, shutdown systems shall be provided with switches or another suitable means to permit testing without shutting down the unit.

5.4.5.2.2 Pressure sensing elements shall be of austenitic stainless steel. Low-pressure alarms shall be equipped with a valved bleed or vent connection to allow controlled depressurizing so that the operator can note the alarm set pressure on the associated pressure gauge. High-pressure alarms shall be equipped with valved test connections so that a portable test pump can be used to raise the pressure.

5.4.5.3 Removal of instruments and controls

All instruments and controls other than shutdown sensing devices shall be installed with sufficient valving to permit their removal while the system is in operation.

5.4.5.4 Housings for arcing switches

Attention is called to the requirements of 4.1.15 concerning the characteristics of housings for arcing type switches outlined in the applicable codes.

5.4.6 Electrical systems

● **5.4.6.1** The characteristics of electrical power supplies for motors, heaters and instrumentation shall be specified by the purchaser. A pilot light shall be provided on the incoming side of each supply circuit to indicate that the circuit is energized. The pilot lights shall be installed on the control panels.

● **5.4.6.2** Electrical equipment located on the unit or on any separate panel shall be suitable for the area classification specified (see 4.1.15). Electrical starting and supervisory controls may be either alternating or direct current.

5.4.6.3 Power and control wiring within the confines of the base plate shall be resistant to heat, moisture and abrasion. Stranded conductors shall be used within the confines of the base plate and in other areas subject to vibration. Measurement and remote control panel wiring may be solid-conductor. Where rubber insulation is used, a neoprene or equivalent high-temperature thermoplastic sheath shall be provided for insulation protection. Wiring shall be suitable for environmental temperatures.

5.4.6.4 Unless otherwise specified, all leads on terminal strips, switches and instruments shall be permanently tagged for identification. All terminal boards in junction boxes and control panels shall have at least 20 % spare terminal points.

5.4.6.5 To facilitate maintenance, liberal clearances shall be provided for all energized parts (such as terminal blocks and relays) on equipment. The clearances required for 600 V service shall also be provided for lower voltages. To guard against accidental contact, enclosures shall be provided for all energized parts.

● **5.4.6.6** Electrical materials, including insulation, shall be corrosion-resistant and nonhygroscopic as far as possible. If specified for a tropical location, materials shall be given the following treatments:

— parts (such as coils and windings) shall be protected from fungus attack;

— unpainted surfaces shall be protected from corrosion by plating or another suitable coating.

● **5.4.6.7** The purchaser shall specify whether control, instrumentation and power wiring (including thermocouple leads) within the limits of the base plate shall be installed in rigid conduit or armoured cabling installed in cable trays and boxes, properly bracketed to minimize vibration, and isolated or shielded to prevent interference between voltage levels. Conduits and armoured cables may terminate (and in the case of temperature, element heads shall terminate) with a flexible metallic conduit long enough to permit access to the unit for maintenance without removal of the conduit. If thermocouple heads are to be exposed to temperatures above 60 °C (140 °F), they shall be installed with suitable heat protection.

5.4.6.8 Power and control wiring terminations shall be liquid-tight and in accordance with applicable national regulations, taking into account the area classification.

5.4.7 Vibration, position and bearing temperature detectors

5.4.7.1 Unless otherwise specified, vibration and axial position transducers shall be supplied, installed and calibrated in accordance with API 670.

● **5.4.7.2** If specified, vibration and axial position monitors shall be supplied and calibrated in accordance with API 670.

● **5.4.7.3** If specified, a bearing temperature monitor shall be supplied and calibrated according to API 670. See 4.7.1.2.

● **5.4.7.4** If specified, acceleration-based vibration transducers shall be supplied, installed and calibrated in accordance with API 670.

● **5.4.7.5** If specified, monitors shall be supplied, installed and calibrated in accordance with API 670.

5.5 Piping and appurtenances

5.5.1 General

5.5.1.1 All auxiliary piping provided by the vendor shall be in accordance with ISO 10438.

5.5.1.2 Auxiliary systems are those piping systems in the following services:

— instrument and control air;

— lubricating oil;

— control oil;

— seal oil;

— cooling water;

— balance gas;

— reference gas;

— buffer gas;

— seal gas;

— separation gas;

— drains.

NOTE See 4.4 for casing connections.

● **5.5.1.3** If a base plate has been specified, the vendor shall furnish all piping systems, including mounted appurtenances, located within its confines. The piping shall terminate with flanged connections at the edge of the base plate. The purchaser shall furnish only the interconnecting piping between equipment groupings and off-base facilities. If sole plates are specified, the extent of the piping system supplied by the vendor shall be agreed between the vendor and the purchaser.

5.5.1.4 Instrument lines for gas or oil shall be provided with shutoff valves at the points of measurement.

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

● **5.5.1.6** If gas manifolds for buffer gas, seal gas or separation gas are specified, the required components such as valves, flow meters, check valves, pressure indicators, controllers and control valves shall be furnished by the vendor.

5.5.1.7 Provision for bypassing the bearings (and seals, if applicable) of compressor and drivers during oil system flushing operations shall be provided.

5.5.2 Instrument piping

5.5.2.1 Unless otherwise specified, the vendor's standard instrument tubing and fittings shall be supplied.

5.5.2.2 Connections on equipment and piping for pressure instruments and test points shall be in accordance with ISO 10438. Beyond the initial 19 mm (¾ in) isolating valve, DN 12 (NPS ½) piping, valves and fittings may be used. If convenient, a common connection may be used for remotely mounted instruments that measure the same pressure. Separate secondary 12 mm (½ in) isolating valves are required for each instrument on a common connection. If a pressure gauge is to be used for testing pressure alarm or shutdowns switches, common connections are required for the pressure gauge and switches.

5.5.3 Process piping

● **5.5.3.1** The extent of process piping to be supplied by the vendor shall be specified by the purchaser.

● **5.5.3.2** If specified, the vendor shall review all piping, appurtenances (intercoolers, after-coolers, separators, knockout drums, air intake filters and expansion joints), and vessels immediately upstream and downstream of the equipment and supports. The purchaser and the vendor shall mutually agree on the scope of review.

5.6 Special tools

5.6.1 If special tools and fixtures are required to disassemble, assemble or maintain the unit, they shall be included in the quotation and furnished as part of the initial supply of the machine. For multi-unit installations, the requirements for quantities of special tools and fixtures shall be mutually agreed upon by the purchaser and the vendor. These or similar special tools shall be used during shop assembly and post-test disassembly of the equipment.

5.6.2 If special tools are provided, they shall be packaged in separate, rugged boxes and marked "Special tools for (tag/item)". Each tool shall be stamped or tagged to indicate its intended use.

6 Inspection, testing and preparation for shipment

6.1 General

6.1.1 After advance notification of the vendor by the purchaser, the purchaser's representative shall have entry to all vendor and subvendor plants where manufacturing, testing or inspection of the equipment is in progress.

6.1.2 The vendor shall notify subvendors of the purchaser's inspection and testing requirements.

6.1.3 The vendor shall provide sufficient advance notice to the purchaser before conducting any inspection or test that the purchaser has specified be witnessed or observed (see 6.1.4.2 and 6.1.4.3).

● **6.1.4** The purchaser shall specify the extent of purchaser participation in the inspection and testing.

a) The purchaser and the vendor shall meet to coordinate manufacturing hold points and inspector's visits.

b) "Witnessed" means that a hold shall be applied to the production schedule and that the inspection or test shall be carried out with the purchaser or purchaser's representative in attendance. For mechanical running or performance tests, this requires written notification of a successful preliminary test.

c) "Observed" means that the purchaser shall be notified of the timing of the inspection or test. However the inspection or test shall be performed as scheduled and if the purchaser or purchaser's representative is not present, the vendor shall proceed to the next step. (The purchaser should expect to be in the factory longer than for a witnessed test).

6.1.5 Equipment for the specified inspection and tests shall be provided by the vendor.

• **6.1.6** If specified, the purchaser's representative, the vendor's representative or both shall indicate compliance in accordance with the inspector's checklist (see annex H) by initialing, dating and submitting the completed form before shipment.

6.2 Inspection

6.2.1 General

6.2.1.1 The vendor shall keep the following data available for at least five years for examination by the purchaser or his representative upon request:

a) necessary certification of materials, such as mill test reports;

b) purchaser specifications for all items on bills of materials;

c) test data for verifying that the requirements of the specifications have been met;

d) fully identified records of all heat treatment, whether performed in the normal course of manufacture or as part of a repair procedure;

e) results of quality control tests and inspections;

f) running test data (see 6.3.4);

g) final assembly maintenance and running clearances.

6.2.1.2 Pressure containing parts shall not be painted until the specified hydrotest is completed.

• **6.2.1.3** The purchaser shall specify

a) parts that are to be subjected to surface and subsurface examination, and

b) the type of examination required, such as magnetic particle, liquid penetrant, radiographic and ultrasonic examination.

6.2.1.4 During assembly of the compressor and before testing, each component (including cast-in passages of these components) and all piping and appurtenances shall be cleaned by pickling or by another appropriate method to remove foreign materials, corrosion products and mill scale.

• **6.2.1.5** If specified, the purchaser may inspect for cleanliness of the equipment and all piping and appurtenances furnished by or through the vendor before heads are welded to vessels, openings in vessels or exchangers are closed or piping is finally assembled.

• **6.2.1.6** If specified, the hardness of parts, welds and heat-affected zones shall be verified as being within the allowable values by testing of the parts, welds or heat-affected zones. The method, extent, documentation and witnessing of the testing shall be mutually agreed upon by the purchaser and the vendor.

6.2.2 Material inspection

6.2.2.1 General

● **6.2.2.1.1** If radiographic, ultrasonic, magnetic particle or liquid penetrant inspection of welds or materials is specified, the recommended practices in 6.2.2.2 to 6.2.2.5 shall apply unless other procedures are specified or agreed by the purchaser. Cast iron may be inspected in accordance with 6.2.2.4 and 6.2.2.5. Welds, cast steel and wrought material may be inspected in accordance with 6.2.2.2. to 6.2.2.5. The material inspection of pressure-containing parts is covered in 4.11.2 and 4.11.4, and impellers are dealt with in 4.11.5.

The examination techniques concerned are applicable to great varieties of sizes and shapes of materials and widely varying examination requirements. Since the specification for the actual component being inspected depends on metallurgy, component configuration and method of manufacture, specific procedures and acceptance standards for the application should be covered by written standards, developed by the manufacturer for the specific application.

● **6.2.2.1.2** Acceptance criteria for 6.2.2.2 to 6.2.2.5 shall be mutually agreed upon between the purchaser and the vendor.

6.2.2.2 Radiographic inspection

Radiography shall be based upon the procedures of ASTM E 94.

6.2.2.3 Ultrasonic inspection

Ultrasonic inspection shall be based upon the procedures of ASTM A 609 (castings), ASTM A 388 (forgings) or ASTM A 578 (plate).

6.2.2.4 Magnetic particle inspection

Both wet and dry methods of magnetic particle inspection shall be based upon the procedures of ASTM E 709.

6.2.2.5 Liquid penetrant inspection

Liquid penetrant inspection shall be based upon the procedures of ASTM E 165.

6.3 Testing

6.3.1 General

6.3.1.1 Equipment shall be tested in accordance with 6.3.2, 6.3.3, 6.3.4, and 6.3.5. Other tests that may be specified by the purchaser are described in 6.3.6.

NOTE See annex I for typical gas seal testing considerations.

6.3.1.2 At least six weeks before the first scheduled tests, the vendor shall submit to the purchaser, for review and comment, detailed procedures for all the running tests, including acceptance criteria for all monitored parameters.

6.3.1.3 The vendor shall notify the purchaser not less than five working days before the date the equipment will be ready for testing. If the testing is rescheduled, the vendor shall notify the purchaser not less than five working days before the new test date.

6.3.2 Hydrostatic test

6.3.2.1 Pressure-containing parts (including auxiliaries) shall be tested hydrostatically with liquid at a minimum of 1,5 times the maximum allowable working gauge pressure but not less than 140 kPa (20 psi) pressure.

6.3.2.2 Tests shall be maintained for a period of time sufficient to permit complete examination of parts under pressure. The hydrostatic test shall be considered satisfactory if neither leaks nor seepage through the casing or casing joint is observed for a minimum period of 30 min. Large, heavy castings may require that a longer testing period be agreed upon by the purchaser and the vendor. Seepage past internal closures required for testing of segmented cases and operation of a test pump to maintain pressure are acceptable.

6.3.2.3 The chloride content of liquids used to test austenitic stainless steel materials shall not exceed 50 µg/g. To prevent deposition of chlorides as a result of evaporative drying, all residual liquid shall be removed from tested parts at the conclusion of the test.

6.3.2.4 If the part tested is to operate at a temperature at which the strength of a material is below the strength of that material at room temperature, the hydrostatic test pressure shall be multiplied by a factor obtained by dividing the allowable working stress for the material at room temperature by that at operating temperature. The stress values used shall comply with the pressure design code. The pressure thus obtained shall then be the minimum pressure at which the hydrostatic test shall be performed. The data sheets shall list actual hydrostatic test pressures.

6.3.3 Impeller overspeed test

Each impeller shall be subjected to an overspeed test at not less than 115 % of maximum continuous speed for a minimum duration of 1 min. Impeller dimensions identified by the manufacturer as critical (e.g. bore, eye seal and outside diameter) shall be measured before and after each overspeed test. All such measurements and the test speeds shall be recorded and submitted for the purchaser's review following the test. Any permanent deformation of the bore or other critical dimension outside drawing tolerances might be cause for rejection.

6.3.4 Mechanical running test

6.3.4.1 Prior to testing

6.3.4.1.1 The contract shaft seals and bearings shall be used in the machine for the mechanical running test. The contract inner seal shall be subjected to design differential pressure during the test (not valid for tests under vacuum conditions, see 6.3.4.2.4). If permitted by the purchaser, the atmospheric breakdown bushing or bushings on an oil-buffered seal may be replaced with a test bushing. (Low-pressure mechanical testing may require greater than design clearance or fewer elements, or both, for proper heat removal).

6.3.4.1.2 All oil pressures, viscosities and temperatures shall be within the range of operating values recommended in the vendor's operating instructions for the specific unit being tested. Oil viscosity of test stand oil may be adjusted by temperature if different oil viscosity indexes are used. If it is proposed that the test oil temperatures be different from service temperatures, acceptance levels shall be agreed. Oil flow rates for each oil supply line shall be determined.

6.3.4.1.3 Test stand oil filtration shall be 10 µm (0,4 mil) nominal or better. Oil system components downstream of the filters shall meet the cleanliness requirements of ISO 10438 before any test is started.

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

6.3.4.1.5 All warning, protective and control devices used during the test shall be checked, and adjustments shall be made as required.

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

6.3.4.1.7 Testing with the contract coupling is preferred. If this is not practical, the mechanical running test shall be performed with coupling hub idling adapters in place, resulting in moments equal (± 10 %) to the moment of the contract coupling hub plus one half that of the coupling spacer. If all testing is completed, the idling adapters shall be furnished to the purchaser as part of the special tools (see 5.6).

6.3.4.1.8 All purchased vibration probes, transducers, oscillator demodulators and accelerometers shall be in use during the test. If vibration probes are not furnished by the compressor vendor, or if the purchased probes are not compatible with shop readout facilities, then shop probes and readouts that meet the accuracy requirements of API 670 shall be used.

6.3.4.1.9 Shop test facilities shall include instrumentation with the capability of continuously monitoring and plotting revolutions per minute, peak-to-peak displacement and phase angle *(x-y-y')*. Presentation of vibration displacement and phase marker shall also be by oscilloscope.

6.3.4.1.10 The vibration characteristics determined by the use of the instrumentation specified in 6.3.4.1.8 and 6.3.4.1.9 shall serve as the basis for the acceptance or rejection of the machine (see 4.9.5.6).

6.3.4.2 Test procedure

CAUTION — Care should be exercised when operating equipment at or near critical speeds.

6.3.4.2.1 Operate the equipment at speed increments of approximately 10 %, from zero to the maximum continuous speed, and run at the maximum continuous speed until bearings, "lube" oil temperatures and shaft vibrations have stabilized.

6.3.4.2.2 Increase to trip speed, and run the equipment for a minimum period of 15 min. For complete unit test with turbine drivers, increase the speed to within 2 % of trip speed if this requirement has been met.

6.3.4.2.3 Reduce the speed to the maximum continuous speed and run the equipment for 4 h.

6.3.4.2.4 Measure the inner seal oil leakage rate at each seal. Where, because of design considerations or test stand conditions, contract seal performance cannot be duplicated during the four-hour test, an additional reduced speed test or some other acceptable means of demonstrating contract seal performance shall be substituted (see 6.3.4.1.1). Any such alternate procedures shall be described in the vendor's proposed test plan and must be approved in advance by the purchaser.

● **6.3.4.2.5** If specified, "lube" oil and seal oil inlet pressures and temperatures shall be varied through the range permitted in the compressor operating manual. This shall be done during the four-hour test. This option, if specified, does not constitute a waiver of the other specified test requirements.

6.3.4.3 Requirements — During mechanical running testing

6.3.4.3.1 During the 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 4.9.5.6 and shall be recorded throughout the operating speed range.

6.3.4.3.2 While the equipment is operating at maximum continuous speed and at other speeds that may have been specified in the test agenda, sweeps shall be made for vibration amplitudes at frequencies other than synchronous. As a minimum, these sweeps shall cover a frequency range from 5 % to 8 times the maximum continuous speed but not more than 90 000 r/min (1 500 Hz). If the amplitude of any discrete, nonsynchronous vibration exceeds 20 % of the allowable vibration as defined in 4.9.5.6, the purchaser and the vendor shall mutually agree on requirements for any additional testing and on the equipment's suitability for shipment.

● **6.3.4.3.3** Plots showing synchronous vibration amplitude and phase angle versus speed for acceleration and deceleration shall be made before and after the four-hour run. Plots shall be made of both the filtered (one per revolution) and unfiltered vibration levels. If specified, these data shall also be furnished in polar form. The speed range covered by these plots shall be zero to the specified driver trip speed.

6.3.4.3.4 The mechanical running test shall verify that lateral critical speeds conform to the requirements of 4.9.2 and 4.9.3.

6.3.4.3.5 Shop verification of the unbalanced response analysis shall be performed in accordance with 4.9.3.

● **6.3.4.3.6** If specified, tape recordings shall be made of all real-time vibration data as mutually agreed upon by the purchaser and the vendor.

● **6.3.4.3.7** If specified, the tape recordings of real-time vibration data shall be given to the purchaser.

6.3.4.4 Requirements — After mechanical running testing

● **6.3.4.4.1** Unless otherwise specified, all bearings shall be removed, inspected and reassembled after the test is completed. If specified, shaft end seals shall be removed for inspection following a successful running test.

6.3.4.4.2 Unless otherwise specified, if replacement or modification of bearings or seals, or dismantling of the case to replace or modify other parts is required to correct mechanical or performance deficiencies, the initial test shall not be accepted and the final shop tests shall be run after these replacements or corrections are made. A mechanical retest is not required if the compressor case must be dismantled simply to comply with the requirements of 6.3.5.

6.3.4.4.3 Unless otherwise specified, if minor scuffs and scratches occur on bearings or shaft end seal surfaces, minor cosmetic repairs of these parts is not a cause for rerunning the test. Shaft end seal contacts that result in a measurable change in dimension or metal transfer may be cause for rejection.

6.3.4.4.4 Unless otherwise specified, if spare rotors are ordered to permit concurrent manufacture, each spare rotor shall also be given a mechanical running test in accordance with the requirements of this International Standard.

6.3.4.4.5 Immediately upon completion of each witnessed mechanical or performance test, copies of the log data recorded during the test shall be given to the witnesses.

6.3.5 Assembled compressor gas leakage test

6.3.5.1 After the mechanical running test is completed, each completely assembled compressor casing intended for toxic, hazardous, flammable or hydrogen-rich service shall be tested as specified in 6.3.5.2 to 6.3.5.4 and subject to a soap-bubble test or other approved for gas leaks.

NOTE This test is intended to verify the integrity of the casing joint. It is recognized that certain shaft seals designs are not gas-tight during this test, and therefore a small leakage from seals could be acceptable.

6.3.5.2 Pressurize the casing (including end seals) to the maximum sealing pressure or the maximum seal design pressure, with an inert gas as agreed upon by the purchaser and the vendor. Hold at that pressure for a minimum period of 30 min.

NOTE Nitrogen is normally specified as the inert gas used, however in the case of low mole weight applications, a lighter gas such as helium could be specified.

● **6.3.5.3** If specified, pressurize the casing (with or without end seals installed) to the rated discharge pressure and hold at this pressure for a minimum period of 30 min. The test shall be considered satisfactory if no casing or casing joint leaks are observed.

6.3.5.4 The procedures of 6.3.5.2 and 6.3.5.3. may necessitate two separate tests.

6.3.5.5 Immediately upon completion of each witnessed mechanical or performance test, copies of the log data recorded during the test shall be given to the witnesses.

6.3.6 Optional tests

6.3.6.1 Shop tests — General

● The purchaser shall specify in the inquiry or in the order whether any of the following shop tests shall be performed. Test details shall be mutually agreed upon by the purchaser and the vendor.

6.3.6.2 Performance test

6.3.6.2.1 The compressor shall be performance-tested in accordance with ISO 5389 or ASME PTC 10 as mutually agreed between purchaser and vendor before ordering. A minimum of five points, including surge and overload, shall be taken at normal speed. For variable-speed machines, additional points may be specified.

Agreement should also be reached on the method of testing for multiple section compressors.

6.3.6.2.2 Head (specific compression work) and capacity shall have zero negative tolerance at the normal operating point (or other points as specified) and the power at this point shall not exceed 104 % of the specified value. Surge shall comply with the provisions of 4.1.4. This 104 % includes all tolerances.

6.3.6.2.3 For variable speed compressors, a speed other than the normal speed may be used if necessary to achieve the specified performance and performance tolerances, provided that this adjusted speed meets the criteria specified in 4.9.

6.3.6.2.4 For constant speed compressors, the capacity shall be as in 6.3.6.2.2. The head shall be within the range of 100 % to 105 % of the head at normal operating point. The power, based on measured head at normal inlet flow volume, shall not exceed 107 % of the value at the specified normal operating point, including the 4 % tolerance on power. If the power required at this point exceeds 107 %, excess head may be removed by trimming impellers or other means at the purchaser's option.

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

6.3.6.2.6 Multicase compressor trains and compressors with intermediate process pressures shall have individual sectional head (pressure) tolerances as mutually agreed upon.

6.3.6.3 Complete unit test

Components such as compressors, gears, drivers and auxiliaries, which make up a complete unit, shall be tested together during the mechanical running test (see 6.3.4). A separate, auxiliary test may be performed with the purchaser's approval. If specified, torsional vibration measurements shall be made to verify the vendor's analysis. The complete unit test shall be performed in place of, or in addition to, separate tests of individual components specified by the purchaser.

6.3.6.4 Tandem test

Casings arranged for tandem drive shall be tested as a unit during the mechanical running test (see 6.3.4), using the shop driver and oil systems.

6.3.6.5 Gear test

The gear shall be tested with the machine unit during the mechanical running test (see 6.3.4).

6.3.6.6 Helium test

The compressor casing shall be tested for gas leakage with helium at the maximum allowable working pressure. The test shall be conducted with the casing submerged in water. The maximum allowable working pressure shall be maintained for a minimum of 30 min, with no bubbles permitted. As an alternative, a non-submerged soap bubble test may be performed if approved by the purchaser.

6.3.6.7 Sound level test

The sound level test shall be performed in accordance with ISO 3744 or ISO 9614.

6.3.6.8 Auxiliary equipment test

Auxiliary equipment such as oil systems, gears and control systems shall be tested in the vendor's shop. Details of the auxiliary equipment tests shall be developed jointly by the purchaser and the vendor.

6.3.6.9 Post-test inspection of casing internal

The compressor shall be dismantled, inspected, and reassembled after satisfactory completion of the mechanical running test. The purchaser shall specify whether the gas test required by 6.3.5 shall be performed before or after the post-test inspection.

NOTE The merits of post-test inspection of the casing internal need to be evaluated against the benefits of shipping a unit with proven mechanical assembly and casing joint integrity.

6.3.6.10 Full-pressure/full-load/full-speed test

The details of the full-pressure/full-load/full-speed test shall be developed jointly by the purchaser and vendor. This test may be substituted for the mechanical running test (see 6.3.4).

6.3.6.11 Post test inspection of the hydraulic coupling fit

After the running tests, the shrink fit of hydraulically mounted couplings shall be inspected by comparing hub/shaft match marks and ascertaining that the coupling hub has not moved on the shaft during the test.

6.3.6.12 Spare parts test

Spare parts, such as rotors, gears, diaphragms, bearings and seals, shall be tested as specified by the purchaser.

6.4 Preparation for shipment

● **6.4.1** Equipment shall be suitably prepared for the type of shipment specified, including blocking of the rotor if necessary. The preparation shall be mutually agreed upon and, unless otherwise specified, shall make the equipment suitable for six months of outdoor storage from the time of shipment, with no disassembly required before operation, except for inspection of bearings and seals. If storage for a longer period is contemplated, the purchaser shall consult with the vendor regarding the recommended procedures to be followed.

6.4.2 The vendor shall provide the purchaser with the instructions necessary to preserve the integrity of the storage preparation after the equipment arrives at the job site and before start-up.

6.4.3 The equipment shall be prepared for shipment after all testing and inspection has been completed and the equipment approved by the purchaser. The preparation shall include that specified as follows.

a) Exterior surfaces, except for machined surfaces, shall be given at least one coat of the manufacturer's standard finish paint. The paint shall not contain lead or chromates.

b) Exterior machined surfaces shall be coated with a suitable rust preventive.

c) The interior of the equipment shall be clean and free from scale, welding spatter and foreign objects. Any selection and application of preservatives or rust preventives shall be mutually agreed upon by the purchaser and the vendor.

d) Internal steel areas of bearing housings and carbon steel oil system auxiliary equipment such as reservoirs, vessels and piping shall be coated with a suitable oil-soluble rust preventive.

e) Flanged openings shall be provided with metal closures consisting of one or two plates with a combined thickness of at least 5 mm ($^{3}/_{16}$"), with rubber gaskets and at least four full diameter bolts. For studded openings, studs should be shipped loose to avoid being damaged. If studs are installed for shipment, all nuts needed for the intended service shall be used to secure closures. The arrangement of the closure is such that it is evident that the enclosure has been disturbed.

f) Threaded openings shall be provided with steel caps or solid shank steel plugs. In no case shall non-metallic (e.g. plastic) plugs or caps be used.

g) Openings that have been bevelled for welding shall be provided with closures designed to prevent entrance of foreign materials and damage to the bevel.

h) Lifting points and lifting lugs shall be clearly identified on the equipment or equipment package. The recommended lifting arrangement shall be identified on boxed equipment.

i) The equipment shall be identified with item and serial numbers. Material shipped separately shall be identified with securely affixed, corrosion-resistant metal tags indicating the item and serial number of the equipment for which it is intended. In addition, crated equipment shall be shipped with duplicate packing lists — one inside and one on the outside of the shipping container.

● j) If a spare rotor is purchased, the rotor shall be prepared for unheated indoor storage for a period of at least three years. The rotor shall be treated with a rust preventative and shall be housed in a vapour-barrier envelope with a slow-release, vapour-phase inhibitor. The rotor shall be suitably crated for shipment. Lead sheeting, at least 3 mm (⅛") thick, or a purchaser-approved equivalent, shall be used between the rotor and the cradle at the support areas. The rotor shall not be supported at journals.

● k) If specified, the fit-up and assembly of machine mounted piping, intercoolers and so forth shall be completed in the vendor's shop prior to shipment.

l) Exposed shafts and shaft couplings shall be protected against rust and damage.

6.4.4 Auxiliary piping connections furnished on the purchased equipment shall be impression-stamped or permanently tagged to agree with the vendor's connection table or general arrangement drawing.

6.4.5 Connections on auxiliary piping removed for shipment shall be match-marked clearly for reassembly.

7 Vendor data

7.1 General

7.1.1 The information to be furnished by the vendor is specified in 7.2 and 7.3 and further detailed in annex C.

7.1.2 The data shall be identified on transmittal (cover) letters and in title blocks or title pages with the following information (see 7.2.1, 7.3.1.1, 7.3.5 and 7.3.6.1):

a) the purchaser/user's corporate name;

b) the job/project number;

c) the equipment item number and service name;

d) the inquiry or purchase order number;

e) any other identification specified in the inquiry or purchase order;

f) the vendor's identifying proposal number, serial number, or other reference required to identify return correspondence completely.

7.1.3 A coordination meeting shall be held, preferably at the vendor's plant, within four to six weeks after the purchase commitment. Unless otherwise specified, the vendor shall prepare and distribute an agenda prior to this meeting, which, as a minimum, shall include review of the following items:

a) the purchase order, scope of supply unit responsibility, and sub-vendor items;

b) the data sheets;

c) applicable specifications and previously agreed-upon exceptions;

d) schedules for transmittal of data, production and testing;

e) the quality assurance program and procedures;

f) inspection, expediting and testing;

g) schematics and bills of material for auxiliary systems;

h) the physical orientation of the equipment piping and auxiliary systems;

i) coupling selections;

j) thrust-bearing sizing and estimated loadings;

k) the rotor dynamics analysis;

l) other technical items.

7.2 Proposals

7.2.1 General

The vendor shall forward the original proposal and the specified number of copies to the addresses given in the inquiry documents. The proposal shall include the data specified in 7.2.2 to 7.2.4, as well as a statement that the system and all its components are in strict accordance with this International Standard. If the system and components are not in accordance, the vendor shall include a list that details and explains each deviation. The vendor shall provide details to enable the purchaser to evaluate any proposed alternative designs. All correspondence shall be clearly identified in accordance with 7.1.2.

7.2.2 Drawings

7.2.2.1 As a minimum, the following drawings shall be furnished in the proposal.

a) A general arrangement or outline drawing for each major skid or system, showing overall dimensions, maintenance clearance dimensions, overall weights, erection weights and maximum maintenance weights (indicated for each piece). The direction of rotation and the size and location of major purchaser connections shall also be indicated.

b) Cross-sectional drawings showing the details of the proposed equipment.

c) Schematics of all auxiliary systems, including the fuel, "lube" oil, seal oil or self-acting gas, and the control and electrical systems. Bills of material shall be included.

d) Sketches that show methods for lifting the assembled machine or machines and major components. (This information may be included on the drawings specified in a).

7.2.2.2 If typical drawings, schematics and bills of material are used, they shall be marked up to show the correct weight and dimension data and to reflect the actual equipment and scope proposed.

7.2.3 Technical Data

The following data shall be included in the proposal.

a) The purchaser's data sheets, with complete vendor's information entered thereon and literature to fully describe details of the offering.

b) The purchaser's noise data sheet.

c) The schedule according to which the vendor agrees to transmit all the data specified as part of the contract.

d) A schedule for shipment of the equipment, in weeks after receipt of the order.

e) A list of major wearing components, showing interchangeability with other units in the proposal.

f) A list of recommended start-up spares, including any items that the vendor's experience indicates are likely to be required.

g) A list of the special tools furnished for maintenance. The vendor shall identify any metric items included in the offering.

h) A statement of any special protection required for start-up, operation and periods of idleness under the site conditions specified on the data sheets (see annex A). The list shall show the protection to be furnished by the purchaser, as well as that included in the vendor's scope of supply.

i) A complete tabulation of utility requirements, such as those for steam, water, electricity, air gas, and "lube" oil, including the quantity of "lube" oil required and the supply pressure, the heat load to be removed by the oil, and the nameplate power rating and operating power requirements of auxiliary drivers. (Approximate data shall be defined and clearly identified as such).

j) A description of the tests and inspection procedures for materials, as required by 4.11.1.4.

k) A description of any special requirements specified in the purchaser's inquiry and as outlined in 4.10.3 and 4.11.1.2.

l) A list of similar machines installed and operating under conditions analogous to those specified in the proposal.

m) Any start-up, shutdown, or operating restrictions required to protect the integrity of the equipment.

n) A summary of the materials of construction for the compressor, including hardness for materials exposed to H_2S (see 4.11.1.7) and a detailed description of the impeller (type of construction, materials and methods of attachment to the shaft).

o) Indicated maximum seal-gas rates (injection or eduction) and rated or expected inner seal-oil leakage rates, or both, if applicable. The inner seal-oil leakage shall be given on the basis of volume per day per machine at design gas or oil differential pressures and normal compressor speed. If self-acting gas seals are supplied, expected seal gas consumption, minimum seal gas supply flow, and primary vent flow should be given at the maximum sealing pressure, and at the conditions over the operating envelope of the compressor.

p) If interstage coolers are furnished by the vendor, data for the purchaser's heat and material balances and details of provisions for separating and withdrawing the condensate, including drawings that show cooling system details, and the vendor's recommendations regarding provision for support and piping expansion.

q) Drawings, details and descriptions of the operation of instrumentation and controls, as well as the makes, materials and types of auxiliary equipment. The vendor shall also include a complete description of the alarm and shutdown facilities to be provided.

r) A specific statement that the system and all its components are in strict accordance with this International Standard. If the system and components are not in strict accordance, the vendor shall include a specific list that details and explains each deviation.

s) The minimum length of straight pipe required for proper flow characteristics at the inlet and at any side connection.

t) Typical sound pressure levels for each item of equipment in the train covered by the proposal.

u) A description of the buffer gas system for oil seals or barrier gas system for dry seals, if required.

v) Maximum and minimum allowable seal pressures for each compressor.

w) A statement of the manufacturer's capability regarding testing, including performance testing of the compressor and any other specified items on the train. Details of each optional test specified shall be included.

7.2.4 Curves

7.2.4.1 The vendor shall provide complete performance curves that fully define the envelope of operations and the point at which the manufacturer has illustrated the equipment. Performance curves shall be submitted for each section (between process nozzles) of each casing, in addition to an overall curve for the train. All curves shall be marked "predicted".

7.2.4.2 Curves for variable-speed compressors shall include the following.

a) Discharge pressure, power, polytropic head and polytropic efficiency versus inlet capacity (from predicted surge point to 115 % rated capacity) at minimum operating speed and 80 %, 90 %, 100 % and 105 % speed, with an indication of the effect of specified inlet pressure, temperatures, and molar mass. Any specified operating points shall be noted within the envelope of the performance curve predicted.

b) Steam flow of steam-turbine-driven units, first under the conditions specified in a), at normal steam conditions, and then at maximum horsepower under the most adverse steam conditions.

c) Fuel flow for gas-turbine driven units, first under conditions specified in a), based upon normal fuel and site-ambient conditions, and then at maximum horsepower under the most adverse fuel and site-ambient conditions.

7.2.4.3 Curves and data for fixed speed compressors shall include the following.

a) Discharge pressure, power, polytropic head and polytropic efficiency versus capacity (from surge point to 115 % rated capacity) at normal speed, indicating the effect of specified molar mass, suction pressures and temperatures. Alternative operating conditions requiring throttling shall be shown.

b) Speed versus torque to overcome friction and windage for the compressor and gear unit, if any, for normal starting conditions (throttled suction) and also with specified suction conditions for emergency starting (open suction).

c) Motor torque versus speed at rated voltage and at 80 % of rated voltage.

d) Motor current versus speed at rated voltage and at 80 % of rated voltage.

e) Moment of inertia of the compressor, gear, motor and coupling or couplings referred to motor speed.

f) Estimated times for acceleration to rated speed for throttled suction and for open suction at 80 % of the nameplate motor voltage, unless otherwise specified.

7.2.5 Options

If specified, the vendor shall furnish a list of the procedures for any special or optional tests required by the purchaser or proposed by the vendor.

7.3 Contract data

7.3.1 General

7.3.1.1 The contract data to be furnished by the vendor is specified in annex C. Each drawing, bill of material and data sheet (see annex A) shall have a title block in its lower right-hand corner showing the date of certification, a reference to all identification data specified in 7.1.2, the revision number and date, and the title (see 7.3.2 and 7.3.3).

7.3.1.2 The purchaser shall promptly review the vendor's data after receiving them; however, this review shall not constitute permission to deviate from any requirements in the order unless specifically agreed upon in writing. After the data has been reviewed, the vendor shall furnish certified copies in the quantity specified.

7.3.1.3 A complete list of vendor data shall be included with the first issue of the major drawings. The list shall contain titles, drawing numbers and a schedule for transmission of all the data to be furnished by the vendor (see annex C).

7.3.2 Drawings

The drawings furnished shall contain sufficient information so that with the drawings and the manuals specified in 7.3.6, the purchaser can properly install, operate and maintain the ordered equipment. Drawings shall be clearly legible, and shall be identified in accordance with 7.3.1.1. As a minimum, the drawings shall include the details listed in annex C.

7.3.3 Technical data

7.3.3.1 General

The data shall be submitted in accordance with annex C and identified in accordance with 7.3.1.1. Any comments on the drawings or revisions of specifications that necessitate a change in the data shall be noted by the vendor. These notations shall result in the purchaser's issue of completed, corrected data sheets (see annex A) as part of the order specifications.

7.3.3.2 Curves

7.3.3.2.1 In accordance with the schedule set at the coordination meeting, the vendor shall provide complete performance curves encompassing the map of operations, with any limitations indicated. The curves shall comply with the requirements of 7.3.3.2.2 to 7.3.3.2.6.

7.3.3.2.2 The compressor serial number shall be shown on all curves.

7.3.3.2.3 All curves submitted prior to final performance testing (if required) shall be marked "predicted". Any set of curves resulting from a test shall be marked "tested".

7.3.3.2.4 If a performance test is specified, the vendor shall provide test data and curves when the test has been completed. The surge points shall be shown on the performance curves.

● **7.3.3.2.5** If specified, the vendor shall supply a nomograph (quadrant-type performance curve) for each compressor section. These curves typically shall show the influence of variation in speed, inlet volume, inlet pressure, inlet temperature and molecular mass or composition (or both) of the gas on discharge pressure, discharge temperature, gas power and efficiency. If a performance test is requested in the vendor's plant, the quadrant curves shall be based on the test results. The normal or rated point shall be plotted through each curve.

7.3.3.2.6 For compressors that have back-to-back impeller arrangements, the vendor shall furnish a curve showing the expected loading on the active or inactive side if the thrust bearing goes, versus any combination of the differential pressures across the low-pressure and high-pressure sections of the casing.

7.3.3.3 Data sheets (see annex A)

Completion of the data sheets is the joint responsibility of the purchaser and vendor. The purchaser is responsible for the process data on the datasheets. The vendor shall provide full information to enable completion of the data sheets for the train and auxiliary equipment, first for "as purchased", and then for "as built".

7.3.4 Progress reports

The vendor shall submit progress reports to the purchaser at the intervals specified. The reports shall include engineering, purchasing and manufacturing schedules for all major components. Planned and actual dates and the percentage completed shall be indicated for each "milestone" in the schedule.

7.3.5 Recommended parts

The vendor shall submit a complete list of spare parts, including those shown in the original proposal. The list shall include spare parts for all equipment and accessories supplied, with cross-sectional or assembly-type drawings for identification, part numbers and delivery times. Parts numbers shall identify each part for purposes of interchangeability. Standard purchased items shall be identified by the original manufacturer's numbers. The vendor shall forward the list to the purchaser promptly after receipt of the reviewed drawings and in time to permit order and delivery of the parts before field start-up. The transmittal letter shall be identified with the data specified in 7.1.2.

7.3.6 Installation, operation, maintenance and technical data manuals

7.3.6.1 General

The vendor shall provide sufficient written instructions, including a list of all drawings, to enable the purchaser to correctly install and maintain the complete equipment ordered. This information shall be compiled in a manual (or manuals), with a cover sheet containing all identifying data required in 7.1.2, and an index sheet containing section titles as well as a complete list of referenced and enclosed drawings by title and drawing number. The manual shall be prepared for the specified installation; the typical manual is not acceptable.

7.3.6.2 Installation manual

All special information required for proper installation design that is not on the drawings shall be compiled in a manual separate from the operating and maintenance instructions. This manual shall be forwarded at a time mutually agreed upon in the order, but no later than the final issue of prints. The manual shall contain information such as special alignment or grouting procedures, utility specifications (including quantities) and all installation design data, including the drawings and data specified in C.37.

7.3.6.3 Operating and maintenance manual

The manual containing operating and maintenance data shall be forwarded no more than thirty days after all specified tests have been successfully completed. This manual shall include a clause providing special instructions for operation at specified extreme environmental conditions (such as temperature). As a minimum, the manual shall also include all of the data listed in C.38.

7.3.6.4 Technical data manual

● If specified, the vendor shall provide the purchaser with a technical data manual within thirty days of completion of shop testing. (see C.44).

Annex A
(informative)

Typical data sheets

This annex comprises 12 centrifugal compressor data sheets for use with SI units, followed by the same data sheets for use with US customary units.

NOTE References between parentheses are to subclauses in this International Standard.

CENTRIFUGAL COMPRESSOR DATA SHEETS (SI units)

ENQUIRY/ORDER NO.
JOB NO. ____________ ITEM NO.____________

REVISION	BY	DATE	CH'KD	DATE	APP'D	DATE

1 APPLICABLE TO: O PROPOSAL O PURCHASE O DESIGN O AS BULT
2 FOR____________ UNIT____________
3 SITE ____________ SERIAL No. ____________
4 SERVICE ____________ NO. REQUIRED ____________
5 O CONTINUOUS O INTERMITTENT O STANDBY DRIVER TYPE (5.1.1) ____________
6 VENDOR____________ O MODEL ____________ DRIVER ITEM NO. ____________
7 NOTE: INFORMATION TO BE COMPLETED: O BY PURCHASER ☐ BY VENDOR

8 OPERATING CONDITIONS

		NORMAL	RATED	OTHER CONDITIONS (5.1.2) A	B	C	D
9							
10	**(ALL DATA PER PROCESS STAGE)**	NORMAL	RATED	A	B	C	D
11	**GAS FLOW**						
12	O GAS HANDLED (ALSO SEE PAGE 2)						
13	O VOLUME FLOW, AT 101,3 kPa & 0 °C, Z=1, DRY (m^3/h)						
14	O MASS FLOW, [WET/DRY] (kg/h)						
15	**INLET CONDITIONS (4.3.1)**						
16	O PRESSURE (kPa)						
17	O TEMPERATURE (°C)						
18	O RELATIVE HUMIDTY (%)						
19	O MOLECULAR MASS (mw)						
20	O ISENTROPIC EXPONENT CP/CV (K_1)						
21	☐ COMPRESSIBILITY (Z_1)						
22	☐ INLET VOLUME FLOW, [WET/DRY] (m^3/h)						
23	**DISCHARGE CONDITIONS (4.3.1)**						
24	☐ PRESSURE (kPa)						
25	☐ TEMPERATURE (°C)						
26	☐ ISENTROPIC EXPONENT (K_2)						
27	☐ COMPRESSIBILITY (Z_2)						
28	**PERFORMANCE(4.1.4)(4.1.5)**						
29	☐ POLYTROPIC HEAD, SPECIFIC COMPRESSION WORK FLANGE TO FLANGE (kJ/kg)						
30	☐ POLYTROPIC EFFICIENCY FLANGE TO FLANGE (%)						
31	☐ COMPRESSOR MECHANICAL LOSSES (kW)						
32	☐ COMPRESSOR ABSORBED POWER (kW)						
33	☐ COMPRESSOR POWER REQUIRED, AT DRIVER COUPLING (kW)						
34	☐SPEED (r/min)						
35	O ESTIMATED SURGE AT ABOVE SPEED (m^3/h)						
36	☐ GUARANTEE POINT FLANGE TO FLANGE						
37	☐ PERFORMANCE CURVE NUMBER						

38 **O PROCESS CONTROL**
39 METHOD O SUCTION THROTTLING O VARIABLE O SPEED VARIATION O DISCHARGE O COOLED BYPASS
40 FROM ______(kPa) GUIDE VANES FROM ______% BLOWOFF FROM ____________
41 TO ______(kPa) (5.4.2.4) TO ______% TO ______ TO ____________
42 SIGNAL O SOURCE (5.4.2.1)____________
43 TYPE O ELECTRONIC O PNEUMATIC O OTHER____________ O RANGE ________(mA) ________ (kPa)
44 **O ANTI-SURGE SYSTEM (5.4.2.2)**
45 ANTI-SURGE BYPASS O MANUAL O AUTOMATIC O NONE
46 A.-S. VALVE SIZING BY:________ Vendor _____ OTHERS, A.-S. VALVE SUPPLIED BY: _____ Vendor ______Purchaser
47 A.-S. CONTROLLER SUPPLIED BY: _____ Vendor _____ Purchaser
48 FLOW/PRESSURE SENSING ELEMENTS SUPPLIED BY: ______ Vendor ___ Purchaser
49 FLOW/PRESSURE SENSING ELEMENT POSITIONS: O INLET O DISCHARGE
50 LOAD SHARE CONTROLLER SUPPLIED BY:_______ Vendor____Purchaser

CENTRIFUGAL COMPRESSOR DATA SHEETS (SI units)

ENQUIRY/ORDER NO.

JOB NO. ______ ITEM NO. ______

REVISION	BY	DATE	CH'KD	DATE	APP'D	DATE

OPERATING CONDITIONS (Continued) (5.1.2) (4.11.1.8)

GAS ANALYSIS:		NORMAL	RATED	OTHER CONDITIONS				REMARKS: (4.11.1.3) (4.11.1.8)
O MOL% O				A	B	C	D	
	M kg/kmol							
AIR	28,966							
OXYGEN	32,000							
NITROGEN	28,016							
WATER VAPOUR	18,016							
CARBON MONOXIDE	28,010							
CARBON DIOXIDE	44,010							
HYDROGEN SULPHIDE	34,076							(4.11.1.7)
HYDROGEN	2,016							
METHANE	16,042							
ETHYLENE	28,052							
ETHANE	30,068							
PROPYLENE	42,078							
PROPANE	44,094							
I-BUTANE	58,120							
N-BUTANE	58,120							
I-PENTANE	72,146							
N-PENTANE	72,146							
HEXANE PLUS								
TOTAL								
AVG. MOL. MASS								

REMARKS:

CENTRIFUGAL COMPRESSOR DATA SHEETS (SI units)

ENQUIRY/ORDER NO.
JOB NO. ____________ ITEM NO. ____________

REVISION	BY	DATE	CH'KD	DATE	APP'D	DATE

CONSTRUCTION FEATURES

☐ **SPEEDS:**

MAX. CONT. ________ r/min TRIP ________ r/min

MAX. TIP SPEEDS: ________ m/s @ RATED SPEED

________ m/s @ MAX. CONT. SPEED

☐ **LATERAL CRITICAL SPEEDS (DAMPED)**

FIRST CRITICAL ________ r/min ________ MODE

SECOND CRITICAL ________ r/min ________ MODE

THIRD CRITICAL ________ r/min ________ MODE

FOURTH CRITICAL ________ r/min ________ MODE

○ TRAIN LATERAL ANALYSIS REQUIRED (4.9.2.3)

○ UNDAMPED STIFFNESS MAP REQUIRED (4.9.2.4)

○ TRAIN TORSIONAL ANALYSIS REQUIRED (TUBINE DRIVEN TRAIN (4.9.4.6)

☐ **TORSIONAL CRITICAL SPEEDS:**

FIRST CRITICAL ________ r/min

SECOND CRITICAL ________ r/min

THIRD CRITICAL ________ r/min

FOURTH CRITICAL ________ r/min

☐ **VIBRATION:**

ALLOWABLE TEST LEVEL ________ µm

(PEAK TO PEAK)

☐ **ROTATION, VIEWED FROM DRIVEN END [CW/CCW]**

○ MATERIALS INSPECTION REQUIREMENTS (6.2.2)

○ SPECIAL CHARPY TESTING (4.11.3)

○ RADIOGRAPHY REQUIRED FOR ________

○ MAGNETIC PARTICLE REQUIRED FOR ________

○ LIQUID PENETRANT REQUIRED FOR ________

☐ **CASING:**

MODEL ________

CASING SPLIT ________

Pressure design code (4.1.20) ________

MATERIAL ________

THICKNESS (mm) ________ CORR. ALLOW. (mm) ________

MAX WORKING PRESS. ________ kPa

MAX DESIGN PRESS ________ kPa

TEST PRESS (kPa) : ________ HELIUM ________ HYDRO ________

MAX. OPER. TEMP. ________ °C MIN. OPER. TEMP. ________ °C

MAX. NO. OF IMPELLERS FOR CASING ________

MAX. CASING CAPACITY VOLUME FLOW (m^3/h) ________

RADIOGRAPH QUALITY ○ YES ○ NO

CASING SPLIT SEALING ________

○ SYSTEM RELIEF VALVE SET PT. (4.2.4) ________ kPa

☐ **DIAPHRAGMS:**

MATERIAL ________

☐ **IMPELLERS:**

NO. ________ DIAMETERS (mm) ________

NO. VANES EACH IMPELLER ________

____

____

TYPE (OPEN, ENCLOSED, ETC.) ________

TYPE FABRICATION ________

MATERIAL ________

MAX. YIELD STRENGTH (MPa) ________

HARDNESS [HB/HRC] MAX ________ MIN ________

SMALLEST TIP INTERNAL WIDTH (mm) ________

MAX. MACH. NO. @ IMPELLER EYE ________

MAX. IMPELLER HEAD @ RATED SPEED (kJ/kg) ________

☐ SHAFT:

MATERIAL ________

DIA @ IMPELLERS (mm) ________ DIA @ COUPLING (mm) ________

SHAFT END: ________ TAPERED ________ CYLINDRICAL

MAX. YIELD STRENGTH (MPa) ________

HARDNESS [HB/HRC] ________

STRESS AT COUPLING (MPa) ________

☐ **BALANCE PISTON:**

MATERIAL ________ AREA ________ mm^2

FIXATION METHOD ________

☐ **SHAFT SLEEVES (4.8.1.2):**

AT INTERSTG. CLOSE CLEARANCE POINTS MATL ________

AT SHAFT SEALS ________ MATL ________

☐ **LABYRINTHS:**

INTERSTAGE

TYPE ________ MATERIAL ________

BALANCE PISTON

TYPE ________ MATERIAL ________

SHAFT SEALS: ☐ GAS SEALS use pages 10 to 12

○ SEAL TYPE (4.8.1.3) ________

○ SETTLING OUT PRESSURE (kPa) ________

○ SPECIAL OPERATION (4.8.1.1) ________

○ SUPPLEMENTAL DEVICE REQUIRED FOR CONTACT SEALS (4.8.2.2)

TYPE ________

○ BUFFER GAS SYSTEM REQUIRED (4.8.2.4) (SEE ALSO PAGE 10)

○ TYPE BUFFER GAS ________

○ BUFFER GAS CONTROL SYSTEM SCHEMATIC BY VENDOR

○ PRESSURIZING GAS FOR SUBATMOSPHERIC SEALS (4.8.2.5)

☐ TYPE SEAL ________

☐ INNER LEAKAGE GUAR. (litre/DAY/SEAL) ________

BUFFER GAS REQUIRED FOR:

☐ AIR RUN-IN ☐ OTHER ________

☐ BUFFER GAS FLOW (PER SEAL):

NORM: ________ kg/h @ ________ kPa (g) ΔP ________

MAX: ________ kg/h @ ________ kPa (g) ΔP ________

○ LUBE/SEAL OIL SYSTEM SEPARATE ________ COMBINED ________ (4.10.3)

☐ **BEARING HOUSING CONSTRUCTION:**

TYPE (SEPARATE, INTEGRAL) ________ SPLIT ________

MATERIAL ________

CENTRIFUGAL COMPRESSOR DATA SHEETS (SI units)

ENQUIRY/ORDER NO.						
JOB NO. ____			ITEM NO. ____			
REVISION	BY	DATE	CH'KD	DATE	APP'D	DATE

1 CONSTRUCTION FEATURES (CONTINUED)

2 BEARINGS AND BEARING HOUSINGS

	RADIAL	DRIVE END	NON-DRIVE END	THRUST	ACTIVE	INACTIVE
4	☐ TYPE			☐ TYPE		
5	☐ MANUFACTURER			☐ MANUFACTURER		
6	☐ LENGTH (mm)			☐ UNIT LOADING (MAX) (kPa)		
7	☐ SHAFT DIA (mm)			☐ UNIT LOADING (ULT) (kPa)		
8	☐ Unit load (Act/allow) (kPa)			☐ AREA (mm^2)		
9	☐ BASE MATERIAL			☐ NO. PADS		
10	☐ BABBIT THICKNESS (mm)			☐ PIVOT: CTR/OFFSET (%)		
11	☐ NO. PADS			☐ PAD BASE MATERIAL		
12	☐ LOAD: BETWEEN/ON PAD			☐ ____		
13	☐ PIVOT: CTR/OFFSET (%)			LUBRICATION: O FLOODED O DIRECTED		
14	☐ BEARING SPAN (mm)			THRUST COLLAR: O INTEGRAL O REPLACEABLE		
15	☐ SQUEEZE FILM DAMPING			MATERIAL ____		
16	☐ ____					

17 **BEARING TEMPERATURE DEVICES**
O SEE ATTACHED API 670 DATA SHEET
18 O THERMISTORS
19 O TYPE ____ POS. TEMP COEFF ____ NEG. TEMP COEEF
20 O TEMP SWITCH & INDICATOR BY: ____ PURCH ____ MFR
21 O THERMOCOUPLES
22 O SELECTOR SWITCH & INDICATOR BY: ____PURCH ____ MFR
23 O RESISTANCE TEMP DETECTORS
24 O RESISTANCE MATL. ____ ☐ OHM
25 O SELECT SWITCH & INDICATOR BY: ____ PURCH____MFR
26 O LOCATION-JOURNAL BRG
27 NO. ____ EA. PAD __ EVERY OTHER PAD ___ PER BRG
OTHER ____ ____
28 O LOCATION-THRUST BRG
29 NO. ____ EA. PAD __ EVERY OTHER PAD ___ PER BRG
OTHER ____
30 NO. (INACT)____ EA. PAD __ EVERY OTHER PAD ___ PER BRG
OTHER ____
31 O MONITOR SUPPLIED BY (5.4.7.3) ____
32 O LOCATION ____ ENCLOSURE ____
33 O MFR ____ ☐ MODEL ____
34 ☐ SCALE ____ ALARM ☐ SET @ ____ °C
35 O SHTDWN ☐ SET @ ____ °C O TIME DELAY ____ S

VIBRATION DETECTORS:
O SEE ATTACHED API 670 DATA SHEET
O TYPE ____ ☐ MODEL ____
O MFR ____
O NO. AT EA SHAFT BEARING ____ TOTAL NO. ____
O OSCILLATOR-DETECTORS SUPPLED BY ____
MFR ____ ☐ MODEL ____
MONITOR SUPPLIED BY (5.4.7.2) ____
O LOCATION ____ ENCLOSURE ____
O MFR. ____ ☐ MODEL ____
☐ SCALE ____ ALARM ☐ SET @ ____ µm
O SHTDWN: ☐ SET @ ____ µm O TIME DELAY ____ S

AXIAL POSITION DETECTOR:
O SEE ATTACHED API 670 DATA SHEET
O TYPE ____ ____ ☐ MODEL ____
O MFR ____ ____ O NO. REQUIRED
O OSCILLATOR-DEMODULATOR SUPPLIED BY:
O MFR ____ ____ ☐ MODEL ____
MONITOR SUPPLIED BY (5.4.7.2) ____
O LOCATION ____ ENCLOSURE ____
O MFR ____ ☐ MODEL ____
☐ SCALE ____ ALARM ☐ SET @ ____ mm
O SHTDWN ☐ SET @ ____mm O TIME DELAY ____ S

36 CONNECTIONS

	COMPRESSOR CASING	O DESIGN APPROVAL REQUIRED (4.11.2.12)	☐ SIZE	☐ RATING/ FACING	O POSITION (4.4.2.1)	O FLANGED OR STUDDED (4.4.2.1)	O MATING FLG & GASKET BY VENDOR (4.4.2.2)	GAS VELOCITY m/s
38	INLET							
39	DISCHARGE							
40								
41								
42								
43								
44								
45								
46								
47								
48								
49								
50								

CENTRIFUGAL COMPRESSOR DATA SHEETS (SI units)

ENQUIRY/ORDER NO.
JOB NO. ______ ITEM NO. ______

REVISION	BY	DATE	CH'KD	DATE	APP'D	DATE

☐ OTHER CONNECTIONS [DIRECT/SKID EDGE]

SERVICE:	NO	SIZE	TYPE
LUBE -OIL INLET			
LUBE-OIL OUTLET			
SEAL-OIL INLET			
SEAL-OIL OUTLET			
CASING DRAINS			
STAGE DRAINS			
VENTS			
COOLING WATER			
PRESSURE			
TEMPERATURE			
PURGE FOR:			
BRG. HOUSING			
BTWN BRG & SEAL			
BTWN SEAL & GAS			
SOLVENT INJECTION			

☐ ALLOWABLE PIPING FORCES AND MOMENTS:

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

O INDIVIDUAL STAGE DRAINS REQUIRED (4.4.3.2)
O VALVED & BLINDED
O VALVED & BLINDED & MANIFOLD
O VALVE ACTUATION O MANUAL O AUTO
O ______

O VIBRATION TRANSDUCER [CASING/BEARING HOUSING] (5.4.7.4)
O SEE ATTACHED API 670 DATA SHEET
O TYPE ______ ☐ MODEL
O MFR ______ NO. REQUIRED ______
O LOCATION ______
O OSCILATOR-DEMODULATORS SUPPLIED BY ______
O MFR ______ ☐ MODEL ______
O MONITOR SUPPLIED BY (5.4.7.5) ______
O LOCATION ______ ENCLOSURE ______
O MFR ______ ☐ MODEL ______
☐ SCALE RANGE ______ O ALARM: ☐ SET @ ______ mm/s²
O SHTDWN ☐ SET @ ______ mm/s² O TIME DELAY ______ s

ACCESSORIES

COUPLINGS AND GUARDS (5.2.2)

O SEE ATTACHED ISO 14691 DATA SHEET FOR FULL DETAILS ON ROTATING ELEMENTS AND SHAFT ENDS
COUPLING FURNISHED BY ______
MANUFACTURER ______ TYPE ______ MODEL ______
COUPLING GUARD FURNISHED BY: ______
TYPE: O FULLY ENCLOSED O SEMI-OPEN O OTHER MATERIAL: ______

COUPLING DETAILS
☐ SHAFT MOUNTING ______
☐ MAX O.D mm
☐ HUB MASS ______ kg
☐ SPACER LENGTH ______ mm
☐ SPACER MASS ______ kg

O VENDOR MOUNT HALF COUPLING
O IDLING ADAPTER/SOLO PLATE REQUIRED (5.2.4)
LUBRICATING REQUIREMENTS:
O NON-LUBE O GREASE O CONT. OIL LUBE O OTHER
QUANTITY PER HUB ______ m³/h
O PLUG AND RING GAUGES REQUIRED (5.2.5)

MOUNTING PLATES

O BASEPLATES: FURNISHED BY (5.3.1.1) ______
O COMPRESSOR ONLY (5.3.2.8) O DRIVER O GEAR
O OTHER ______
O DRIP TRIM O LEVELLING PADS (5.3.2.2.)
O COLUMN MOUNTING (5.3.2.3)
O SUB-SOLE PLATES REQUIRED (5.3.2.5)
O STAINLESS STEEL SHIM THICKNESS ______ mm
O PRIMER FOR EPOXY GROUT REQUIRED (5.3.1.2)
TYPE ______
O LIMIT OF PIPING (5.5.1.3)

O SOLEPLATES: FURNISHED BY: ______
☐ THICKNESS ______ mm
O SUBSOLE PLATES REQUIRED (5.3.3.2)
O LEVELLING BLOCKS REQUIRED
O STAINLESS STEEL SHIM
☐ THICKNESS ______ mm
O DRIVER O GEAR O COMPRESSOR
O PRIMER FOR EPOXY GROUT REQUIRED (5.3.1.2)
TYPE ______

CENTRIFUGAL COMPRESSOR DATA SHEETS (SI units)

ENQUIRY/ORDER NO.
JOB NO. ____________ ITEM NO. ____________

REVISION	BY	DATE	CH'KD	DATE	APP'D	DATE

LOCATION, SITE DATA, UTILITIES AND MASS & SPACE REQUIREMENTS

LOCATION: COMPRESSOR SKID

O INDOOR	O HEATED	O UNDER ROOF
O OUTDOOR	O UNHEATED	O PARTIAL SIDES
O GRADE	O MEZZANINE	O ________

O WINTERIZATION REQD. (4.1.10) O TROPICALISATION REQD. (5.4.6.6)

SITE DATA:

O ELEVATION ____m BAROMETER ____________ kPa

O RANGE OF AMBIENT TEMPS:

	°C	RELATIVE HUMIDITY
SITE RATED		
NORMAL		
MAXIMUM		
MINIMUM		

LOCATION: AUXILIARY EQUIPMENT

O CONTROL PANEL ____________

O *LUBE/SEAL OIL CONSOLE* ____________

O NITROGEN GENERATOR ____________

O ____________

UNUSUAL CONDITIONS: O DUST O FUMES

O OTHER (4.11.1.8)

O AREA CLASSIFICATION (4.1.16)

	ZONE	GAS GROUP	TEMP CLASS
COMPRESSOR SKID			
LUBE/SEAL OIL CONSOLE			
CONTROL PANEL			
NITROGEN GENERATOR			
____________			

O UTILITY CONDITIONS:

STEAM:

	DRIVERS		HEATING	
INLET MIN	____ kPa	____ °C	____ KPa	____ °C
NORM	____ kPa	____ °C	____ KPa	____ °C
MAX	____ kPa	____ °C	____ KPa	____ °C
EXHAUST. MIN	____ kPa	____ °C	____ KPa	____ °C
NORM	____ kPa	____ °C	____ KPa	____ °C
MAX	____ kPa	____ °C	____ KPa	____ °C

ELECTRICAL SUPPLY (5.4.6.1)

	DRIVERS	HEATING	CONTROL	SHUTDOWN
VOLTAGE				
HERTZ				
PHASE				

COOLING WATER:

TEMP. INLET ____________ °C MAX RETURN ____________ °C

PRESS NORM ____________ kPa DESIGN ____________ kPa

MIN RETURN ____________ kPa MAX ALLOW ΔP ____________ kPa

WATER SOURCE ____________

INSTRUMENT AIR:

MAX PRESS ____________ kPa MIN PRESS ____________ kPa

NITROGEN:

MAX PRESS ____________ kPa MIN PRESS ____________ kPa

☐ TOTAL UTILITY CONSUMPTION:

O COOLING WATER ____________ m^3/h

O STEAM, NORMAL ____________ kg/h

O STEAM, MAX ____________ kg/h

O INSTRUMENT AIR ____________ kg/h

O POWER (DRIVER) ____________ kW

O POWER (AUXILIARIES) ____________ kW

O POWER (HEATERS) ____________ kW

O PURGE (AIR/N_2) ____________ kg/h

☐ MASSES (kg):

COMPR. ____ GEAR ____ DRIVER ____ BASE ____

ROTORS: COMPR. ____ ____ DRIVER ____ GEAR

COMPR UPPER CASE/CARTRIDGE ____________

SOUR SEAL OIL TRAPS ____________

LUBE OIL CONSOLE (WET/DRY) ____ ____

SEAL OIL CONSOLE (WET/DRY) ____ ____

OVERHEAD BRG RUNDOWN TANK (WET/ DRY) ____ ____

NITROGEN GENERATOR PACKAGE ____________

CONTROL PANEL ____________

MAX. FOR MAINTENANCE (IDENTIFY) ____________

TOTALS FOR SHIPPING ____________

☐ SPACE REQUIREMENTS (m):

	L	W	H
COMPLETE UNIT:			
LUBE OIL CONSOLE:			
SEAL OIL CONSOLE:			
O'HD S.O. TANK			
O'HD BRG. R.D. TANK			
N_2 GEN PACKAGE			
CONTROL PANEL			

REMARKS:

CENTRIFUGAL COMPRESSOR DATA SHEETS (SI units)

ENQUIRY/ORDER NO.
JOB NO. ____________ ITEM NO. ____________

REVISION	BY	DATE	CH'KD	DATE	APP'D	DATE

INSPECTION AND TEST

☐ SHOP INSPECTION AND TESTS: (6.1.4) (6.2.1.3)

	REQ'D	WITNS'D	OBSV'D
SHOP INSPECTION	O		
CLEANLINESS (6.2.1.5)	O		
HYDROSTATIC	●	O	O
IMPELLER OVERSPEED	●	O	O
MECHANICAL RUN	●	O	O
☐ CONTRACT COUPLING ☐ IDLING ADAPTOR(S)			
☐ CONTRACT PROBES ☐ SHOP PROBES			
VARY LUBE & SEAL OIL PRESSURES AND TEMPERATURES (6.3.4.2.5)	O		
POLAR FORM VIB DATA (6.3.4.3.3)	O		
TAPE RECORD VIB (6.3.4.3.6)	O		
TAPE DATA TO PURCHASER (6.3.4.3.7)	O		
RESIDUAL UNBALANCE CHECK (4.9.3.1)	O	O	O
SHAFT END SEAL INSP. (6.3.4.4.1)	O		
GAS LEAK TEST DISCH. PRESS (6.3.5.2) (6.3.5.3)	O	O	O
O BEFORE O AFTER MECH RUN			
PERFORMANCE TEST [GAS/AIR] (6.3.6.2)	O	O	O
O ISO 5389 O PTC 10			
SINGLE POINT TEST	O	O	O
________ POINTS TEST	O	O	O
________ SPEED LINES	O	O	O
______________________	O	O	O
______________________	O	O	O
COMP. WITH SHOP DRIVER	O	O	O
COMP. WITH JOB DRIVER	O	O	O
USE SHOP LUBE/SEAL OIL SYSTEM	O	O	O
USE JOB LUBE/SEAL OIL SYSTEM	O	O	O
CHECK BRG'S AND SEALS AFTER TEST	O	O	O
NITROGEN GENERATOR PACKAGE TEST	O	O	O
DRY GAS SEAL SYSTEM TEST	O	O	O
DRY GAS SEAL TESTING AT SEAL VDR	O	O	O
CONTROL PANEL FUNCTIONAL TEST	O	O	O
MECHANICAL RUN USING SPARE ELEMENTS	O	O	O
COMPLETE UNIT TEST (6.3.6.3)	O	O	O
TORSIONAL VIB MEAS	O	O	O
TANDEM TEST (6.3.6.4)	O	O	O
GEAR TEST (6.3.6.5)	O	O	O
HELIUM LEAK TEST (6.3.6.6)	O	O	O
SOUND LEVEL TEST (6.3.6.7)	O	O	O
FULL LOAD/SPEED/PRESS TEST (6.3.6.10)	O	O	O
HYDRAULIC COUPLING INSP (6.3.6.11)	O	O	O
CERTIFIED COPIES OF TEST DATA	O	O	O
______________________	O	O	O
______________________	O	O	O
______________________	O	O	O
______________________	O	O	O
______________________	O	O	O

SPECIFICATIONS AND MISCELLANEOUS

NOISE SPECIFICATIONS: (4.1.11)

O APPLICABLE TO MACHINE:

SEE SPECIFICATION ____________

O APPLICABLE TO NEIGHBOURHOOD:

SEE SPECIFICATION ____________

ACOUSTIC HOUSING: O YES O NO

APPLICABLE REGULATIONS: (4.1.21)

____

____

____

____

____

PAINTING:

O MANUFACTURER'S STD.

O OTHER ____________

____

SHIPMENT: (6.4.1)

O DOMESTIC O EXPORT O EXPORT BOXING REQD.

O OUTDOOR STORAGE MORE THAN 6 MONTHS (6.4.1)
SPARE ROTOR ASSEMBLY PACKAGED FOR (6.4.3)

O HORIZONTAL STORAGE O VERTICAL STORAGE

MISCELLANEOUS:

☐ RECOMMENDED STRAIGHT RUN OF PIPE DIAMETERS
BEFORE SUCTION ____________

O VENDOR'S REVIEW & COMMENTS ON PURCHASER'S PIPING & FOUNDATION (4.1.15) (5.3.2)

O COMPRESSOR TO BE SUITABLE FOR FIELD RUN IN ON AIR (4.1.18)

O PROVISION FOR LIQUID INJECTION (4.1.12) ____________

____

O VENDOR'S REVIEW & COMMENTS ON PURCHASER'S CONTROL SYSTEMS (5.4.1.1)

O EXTENT OF PROCESS PIPING BY VENDOR (5.5.3.1) ________

O SHOP FITUP OF VENDOR PROCESS PIPING (6.4.3)

O WELDING HARDNESS TESTING (6.2.1.6)

O INSPECTION CHECKLIST REQUIRED (6.1.6)

O TECHNICAL DATA MANUAL REQUIRED (7.3.6.4)

O ____________
O ____________
O ____________
O ____________
O ____________
O ____________
O ____________
O ____________
O ____________
O ____________
O ____________
O ____________
O ____________
O ____________
O ____________

CENTRIFUGAL COMPRESSOR DATA SHEETS (SI units)

ENQUIRY/ORDER NO.
JOB NO. ________ ITEM NO. ________

REVISION	BY	DATE	CH'KD	DATE	APP'D	DATE

CONTROLS AND INSTRUMENTATION

CONTROL PANEL: (5.4.3.1)

O CONTROLS AND INSTRUMENTATION PER SPECIFICATION
O METHOD OF OPERATION
☐ VIBRATION ISOLATORS ☐ STRIP HEATERS ☐ PURGE CONNECTIONS (5.4.4.1.2)
O METAL CASE, GLASS FRONT, STEM-TYPE LIQUID FILLED/BIMETALLIC THERMOMETERS FURNISHED
O LIQUID-FILLED PRESSURE GAUGES FURNISHED
O HIGH VIBRATION DRIVER ALARM AND SHUTDOWN
O
O

LOCAL GAUGE BOARD/PANEL:

O ON SKID O LOCAL TO SKID ________

INSTRUMENT SUPPLIERS:

O PRESSURE GAUGES: (5.4.4.5)	MANUFACTURER ________	SIZE & TYPE ________
TEMPERATURE GAUGES:	MANUFACTURER ________	SIZE & TYPE ________
LEVEL GAUGES:	MANUFACTURER ________	SIZE & TYPE ________
DIFF. PRESSURE GAUGES:	MANUFACTURER ________	SIZE & TYPE ________
PRESSURE SWITCHES:	MANUFACTURER ________	SIZE & TYPE ________
DIFF. PRESSURE SWITCHES:	MANUFACTURER ________	SIZE & TYPE ________
TEMPERATURE SWITCHES:	MANUFACTURER ________	SIZE & TYPE ________
LEVEL SWITCHES;	MANUFACTURER ________	SIZE & TYPE ________
CONTROL VALVES:	MANUFACTURER ________	SIZE & TYPE ________
PRESSURE RELIEF VALVES:	MANUFACTURER ________	SIZE & TYPE ________
SIGHT FLOW INDICATORS:	MANUFACTURER ________	SIZE & TYPE ________
GAS FLOW INDICATOR:	MANUFACTURER ________	SIZE & TYPE ________
VIBRATION MEASUREMENT:	MANUFACTURER ________	SIZE & TYPE ________
TEMPERATURE MEASUREMENT:	MANUFACTURER ________	SIZE & TYPE ________
PRESSURE MEASUREMENT:	MANUFACTURER ________	SIZE & TYPE ________
FLOW MEASUREMENT:	MANUFACTURER ________	SIZE & TYPE ________
TACHOMETER:	MANUFACTURER ________	RANGE & TYPE ________
SOLENOID VALVES:	MANUFACTURER ________	SIZE & TYPE ________
ANNUNCIATOR:	MANUFACTURER ________	MODEL & NO. POINTS ________
ANTI-SURGE CONTROLLER	MANUFACTURER ________	MODEL ________
LOAD SHARE CONTROLLER	MANUFACTURER ________	MODEL ________
________	________	________
________	________	________

CONTROL PANEL DESIGN AND CONSTRUCTION

INSTRUMENTATION REQUIREMENTS: (5.4.1.2)

O TUBING: MATERIAL ________ SIZE ________ FITTINGS ________
O WIRING PROTECTION (5.4.3.2) (5.4.6.7) IN CONDUIT ________ ARMOURED CABLE ________
O TRANSMITTERS REQUIRED (5.4.5.1.1) ALL ________ SHUTDOWN ________
ALARM ________

CENTRIFUGAL COMPRESSOR DATA SHEETS (SI units)

ENQUIRY/ORDER NO.
JOB NO. ____________ ITEM NO. ____________

REVISION	BY	DATE	CH'KD	DATE	APP'D	DATE

COMPRESSOR INSTRUMENTATION SCHEDULE

FUNCTION	PANEL IDENTIFICATION L	B	C	D	ALARM	TRIP		PANEL IDENTIFICATION L	B	C	D
PRESSURE	L	B	C	D	ALARM & SHUTDOWN SWITCHES			L	B	C	D
					ALARM	TRIP	FUNCTION				
LUBE OIL HEADER (NOTE 1)											
COMPRESSOR SUCTION EACH STAGE											
COMPRESSOR DISCHARGE EACH STAGE											
BALANCE CHAMBER(S)											
BALANCE DRUM											
PURGE GAS SUPPLY					O	O	HIGH RADIAL SHAFT VIBRATION				
O ______					O	O	HIGH AXIAL DISPLACEMENT				
O ______					O	O	OVER SPEED				
DIFFERENTIAL PRESSURE					O	O	REVERSE ROTATION				
BALANCE DRUM					O	O	HIGH JOURNAL BRG. METAL TEMP.				
BUFFER GAS					O	O	HIGH THRUST BRG. METAL TEMP.				
O ______					O	O	HIGH COMPR. SUCTION GAS TEMP.				
O ______					O	O	HIGH COMPR. DISCHARGE GAS TEMP.				
TEMPERATURE					O	O	LOW COMPR. SUCTION GAS TEMP.				
COMPRESSOR SUCTION EA. STG.					O	O	LOW COMPR. BALANCE DRUM ΔP				
COMPRESSOR DISCHARGE EA. STG.					O	O	LOW COMPR. SUCTION PRESS				
COMPRESSOR JOURNAL BEARING					O	O	HIGH COMPR. DISCHARGE PRESS				
COMPRESSOR THRUST BEARING					O	O	UNIT SHUTDOWN				
BEARING DRAIN					O	O	LOW BUFFER GAS DIFFER. PRESS				
O ______					O	O	LOW BUFFER GAS FLOW				
O ______					O	O	HIGH LEVEL IN SEPARATORS				
LEVEL INDICATORS/CONTROLLERS					O	O	______				
SUCTION SEPARATOR EACH STAGE					O	O	______				
INTERSTAGE SEPARATOR(S)					O	O	______				
DISCHARGE SEPARATOR					O	O	______				
O ______					MONITORS:						
PUSH BUTTON STATIONS:					VIBRATION:						
MAIN EQUIPMENT START					AXIAL POSITION						
MAIN EQUIPMENT STOP					THRUST BEARING METAL TEMP.						
COMPRESSOR BLOCK IN					JOURNAL BEARING METAL TEMP.						
COMPRESSOR UNBLOCK					______						
EMERGENCY STOP BUTTON(S)					______						
O ______					NOTES:						
MISCELLANEOUS:					1) SEE ISO 10438 FOR OIL SYSTEM REQUIREMENTS						
EQUIPMENT TACHOMETER					2) ALL ALARMS AND TRIPS SHALL BE ANNUNCIATED						
EQUIPMENT SPEED CONTROL					3) PURCH. TO INDICATE PRESSURE GAUGES WHICH SHALL BE OIL-FILLED						
COMPR. INLET CONTROLLER					4) PURCHASER TO INDICATE WHERE TRANSMITTERS ARE REQUIRED						
ANNUNCIATOR SYSTEM					5) THE FOLLOWING CODE IS USED FOR PANEL INDICATION						
EQUIPMENT FLOW METER					L = LOCALLY MOUNTED ON PIPING		B = LOCAL GAUGE BOARD/PANEL				
GUIDE VANE POSITIONER					C = CONTROL PANEL		D = DISTRIBUTED CONTROL SYSTEM				
SUCTION THROTTLE VALVE					6) USE THE FOLLOWING CODE LETTERS TO SHOW DETAILS ETC.						
ANTI SURGE EQUIPMENT:					F-FLUSH MOUNT ON FRONT		H-PURCH. REMOTE MOUNT				
CAPACITY CONTROL EQUIPMENT:					S-SURFACE MOUNT ON FRONT		P-PURCH. SPPLY AND MOUNT				
O ______					M-MNT BY VENDOR OF PURCHR'S ITEM		V-VENDOR SPPLY. AND MOUNT				
O ______					R-REAR OF PANEL MOUNT		C- CUT-OUT FOR PURCH.'S ITEM				
O ______					D. INTERFACE WITH DCS						

CENTRIFUGAL COMPRESSOR DATA SHEETS (SI units)

ENQUIRY/ORDER NO.
JOB NO. ______ ITEM NO. ______

REVISION	BY	DATE	CH'KD	DATE	APP'D	DATE

SELF ACTING GAS SEAL INSTRUMENTATION SCHEDULE (NOTE 1)(4.8.2.5)

FUNCTION (EACH SEAL/SEAL SUPPLY)	PANEL IDENTIFICATION L	B	C	D
PRESSURE				
O SEAL GAS SUPPLY	__	__	__	__
O BUFFER GAS SUPPLY (NOTE 3)	__	__	__	__
O SEPARATION GAS SUPPLY (NOTE 2)	__	__	__	__
O PRIMARY SEAL VENT	__	__	__	__
O INTERMEDIATE SEAL VENT	__	__	__	__
O BACK-UP SEAL VENT	__	__	__	__
O ______	__	__	__	__
O ______	__	__	__	__
DIFFERENTIAL PRESSURE	__	__	__	__
O SEAL GAS SUPPLY FILTER	__	__	__	__
O SEAL GAS TO COMPRESSOR	__	__	__	__
O SEAL GAS SUPPLY DIFF. CONTROL	__	__	__	__
O ______	__	__	__	__
O ______	__	__	__	__
PRESSURE RELIEF				
O SEAL GAS SUPPLY TO FILTER	__	__	__	__
O PRIMARY SEAL VENT	__	__	__	__
O INTERMEDIATE SEAL VENT	__	__	__	__
O ______	__	__	__	__
O ______	__	__	__	__
TEMPERATURE				
O SEAL GAS SUPPLY	__	__	__	__
O BUFFER GAS SUPPLY	__	__	__	__
O ______	__	__	__	__
O ______	__	__	__	__
MISCELLANEOUS				
O FLOW INDICATOR SEAL GAS SUPPLY	__	__	__	__
O FLOW INDICATOR BUFFER GAS SUPPLY	__	__	__	__
O FLOW INDICATOR SEPARATION GAS	__	__	__	__
O FLOW INDICATOR PRIMARY SEAL VENT	__	__	__	__
O FLOW INDICATOR INTERIM SEAL VENT	__	__	__	__
O GAS DETECTION BACK-UP SEAL VENT	__	__	__	__
O NITROGEN SUPPLY PURITY ANALYSER	__	__	__	__
O ______	__	__	__	__
O ______	__	__	__	__
O ______	__	__	__	__
O ______	__	__	__	__
O ______	__	__	__	__

ALARM & SHUTDOWN

ALARM	TRIP	FUNCTION	L	B	C	D
O	O	LOW SEAL GAS SUPPLY PRESSURE	__	__	__	__
O	O	HIGH PRIMARY SEAL VENT PRESSURE	__	__	__	__
O	O	LOW BUFFER GAS SUPPLY PRESSURE	__	__	__	__
O	O	LOW SEPARATION GAS SUPPLY PRESS	__	__	__	__
O	O	HIGH ΔP SEAL GAS SUPPLY FILTER	__	__	__	__
O	O	HIGH ΔP SEAL GAS TO COMPRESSOR	__	__	__	__
O	O	HIGH SEAL GAS SUPPLY TEMP.	__	__	__	__
O	O	HIGH BUFFER GAS SUPPLY TEMP.	__	__	__	__
O	O	HIGH FLOW SEAL GAS SUPPLY	__	__	__	__
O	O	HIGH FLOW PRIMARY SEAL VENT	__	__	__	__
O	O	HIGH FLOW INTERMEDIATE SEAL VENT	__	__	__	__
O	O	GAS DETECTION BACK-UP SEAL VENT	__	__	__	__
O	O	UNIT SHUTDOWN	__	__	__	__
O	O	LOW NITROGEN SUPPLY PURITY	__	__	__	__
O	O	______	__	__	__	__
O	O	______	__	__	__	__
O	O	______	__	__	__	__

NOTES:

1) THE ABOVE INSTRUMENTATION SHOULD COVER ALL SINGLE, DOUBLE, TANDEM AND TRIPLE SEAL CONFIGURATIONS. PURCHASER TO DELETE/ADD WHERE NECESARY.
2) SEPARATION GAS MAY BE EITHER AIR OR NITROGEN
3) BUFFER GAS, POSSIBLY INERT, MAY BE NEEDED FOR DOUBLE SEALS AND SOUR/TOXIC DUTIES.
4) ALL ALARMS AND TRIPS SHALL BE ANNUNCIATED.
5) PURCH. TO INDICATE PRESSURE GUAGES WHICH SHALL BE OIL-FILLED.
6) PURCHASER TO INDICATE WHERE TRANSMITTERS ARE REQUIRED.
7) THE FOLLOWING CODE IS USED FOR PANEL INDICATION
   L = LOCALLY MOUNTED ON PIPING C = CONTROL PANEL
   B = LOCAL GAUGE BOARD/PANEL D = DISTRIBUTED CONTROL SYSTEM
8) USE THE FOLLOWING CODE LETTERS TO SHOW PANEL MNTG DTLS.
   F- FLUSH MOUNT ON FRONT
   H- PURCH. REMOTE MOUNT
   S- SURFACE MOUNT ON FRONT
   P- PURCHR. SUPPLY AND MOUNT
   R- REAR OF PANEL MOUNT
   C- CUT-OUT FOR PURCH'S ITEM
   D- INTERFACE WITH DCS

REMARKS

______
______
______
______
______
______

CENTRIFUGAL COMPRESSOR DATA SHEETS (SI units)

ENQUIRY/ORDER NO.
JOB NO. ______ ITEM NO. ______

REVISION	BY	DATE	CH'KD	DATE	APP'D	DATE

SELF ACTING GAS SEAL (4.8.2.5)

SEAL MFR. ______ ☐ MODEL ______
☐ SERIAL NO. ______

O Gas ANALYSIS SEAL GAS ______
BUFFER GAS ______
SEPARATION GAS ______

☐ SEAL CONFIGURATION

☐ SINGLE ☐ DOUBLE ☐ TANDEM ☐ TRIPLE ☐ OTHER ______
SEPARATION FROM OIL SYSTEM BY: ☐ CARBON RING ☐ LABYRINTHS
SEPARATION GAS ______ ☐ OTHER

SEAL OPERATING CONDITIONS

OPERATING CASE	NORMAL	MAX RATED	START-UP	SETTLE OUT	
☐ PRIMARY SEAL PRESSURE (kPa)					
☐ INTERMEDIATE SEAL PRESSURE (kPa)					
☐ SEAL GAS INLET TEMPERATURE (°C)					
O PRIMARY SEAL BACK PRESSURE (kPa)					
O INTERMEDIATE SEAL BACK PRESSURE (kPa)					
O BACK-UP SEAL BACK PRESSURE (kPa)					

O DEPRESSURISATION TIME (min) ______ * PROCESS UPSET CONDITION

O SLOW ROLL REQUIRED: YES/NO SPEED (r/min) ______ DURATION (min) ______
☐ BARRING DEVICE : YES/NO METHOD ______
O REVERSE ROTATION CAPABILITY REQUIRED: YES/NO SPEED (r/min) ______ DURATION (min) ______
O AT SEALING PRESSURES (kPa) ______ PRIMARY ______ INTERMEDIATE ______ BACK-UP
MAX. PERIPHERAL SPEED AT MAX. CONT. SPEED (m/s) ______ OUTER SEAL FACE DIAMETER (mm) ______

☐ MATERIALS OF CONSTRUCTION

FACE ______ SLEEVES ______
SEAT ______
ELASTOMERS ______ SCREWS ______
HOUSING ______ SPRINGS ______
LABYRINTHS ______ NACE REQUIREMENTS ______

☐ GAS REQUIREMENTS

(ALL DATA PER SEAL)	NORMAL OPERATION			ON SEAL FAILURE (ALL GAS SEAL ELEMENTS)
	RUNNING	START-UP	SETTLE OUT	
SEAL GAS				
TYPE				
PRESSURE, MIN/MAX. (kPa)				
TEMPERATURE, MIN/MAX. (°C)				
FLOW, NORMAL/MAX. *(kg/h)	*		*	
BUFFER GAS				
TYPE				
PRESSURE, MIN/MAX. (kPa)				
TEMPERATURE, MIN/MAX. (°C)				
FLOW, NORMAL/MAX. *(kg/h)	*		*	
SEPARATION GAS				
TYPE				
PRESSURE, MIN/MAX. (kPa)				
TEMPERATURE, MIN/MAX. (°C)				
FLOW, NORMAL/MAX. *(kg/h)	*		*	

* MAX.TO BE GUARANTEED

CENTRIFUGAL COMPRESSOR DATA SHEETS (SI units)

ENQUIRY/ORDER NO.
JOB NO. ____________ ITEM NO. ____________

REVISION	BY	DATE	CH'KD	DATE	APP'D	DATE

SELF ACTING GAS SEAL (CONT.) (4.8.2.5)

TESTING

ROTATING FACE OVERSPEED TO ____________ % FOR ____________ MIN

BALANCE OF ROTATING COMPONENTS TO ____________ TEST GAS ____________

TEST		STATIC		DYNAMIC		STATIC		REVERSE
		DE	NDE	DE	NDE	DE	NDE	
GAS PRESSURES (kPa)	PRIMARY							
	INTERMEDIATE							
	BACK-UP							
GAS TEMPERATURES (°C)								
SEAL SPEED (r/min)								
SEAL BACK PRESSURES (kPa)	PRIMARY							
	INTERMEDIATE							
	BACK-UP							
DURATION (min)								
LEAKAGE LIMITS (kg/h)								
PRIMARY (kg/h)								
INTERMEDIATE (kg/h)								
BACK-UP (kg/h)								

SEAL STRIP AFTER TEST (AND RETEST) YES/NO, REQUIREMENTS ____________ * IF SPECIFIED

O AT COMPRESSOR MANUFACTURERS CONTRACT SEALS FITTED DURING:

	SPEED (r/min)	GAS TYPE	PRESSURE (kPa)	TEMPERATURE (°C)
O PERFORMANCE TEST @				
O MECHANICAL RUNNING TEST @				
O MECHANICAL STRING TEST @				
O GAS LEAKAGE TEST @				
O SETTLE-OUT PRESSURE TEST @	ZERO			

O OPTIONAL TESTS

CENTRIFUGAL COMPRESSOR DATA SHEETS (US customary units)

ENQUIRY/ORDER NO.						
JOB NO. ____			ITEM NO. ____			
REVISION	BY	DATE	CH'KD	DATE	APP'D	DATE

1 APPLICABLE TO: O PROPOSAL O PURCHASE O DESIGN O AS BUILT
2 FOR ____ UNIT ____
3 SITE ____ SERIAL No. ____
4 SERVICE ____ NO. REQUIRED ____
5 O CONTINUOUS O INTERMITTENT O STANDBY DRIVER TYPE (5.1.1) ____
6 VENDOR ____ O MODEL ____ DRIVER ITEM NO. ____
7 NOTE: INFORMATION TO BE COMPLETED: O BY PURCHASER ☐ BY VENDOR

8 **OPERATING CONDITIONS**

9				OTHER CONDITIONS (5.1.2)			
10	**(ALL DATA ON PER PROCESS STAGE)**	NORMAL	RATED	A	B	C	D
11	**GAS FLOW**						
12	O GAS HANDLED (ALSO SEE PAGE 2)						
13	O VOLUME FLOW, AT 14,7 PSI & 32 °F, Z=1, DRY (CFM)						
14	O MASS FLOW, [WET/DRY] (lb/h)						
15	**INLET CONDITIONS (4.3.1)**						
16	O PRESSURE (PSI)						
17	O TEMPERATURE (°F)						
18	O RELATIVE HUMIDTY (%)						
19	O MOLECULAR MASS (%)						
20	O ISENTROPIC EXPONENT CP/CV (K_1)						
21	☐ COMPRESSIBILITY (Z_1)						
22	☐ INLET VOLUME FLOW, [WET/DRY] (CFM)						
23	**DISCHARGE CONDITIONS (4.3.1)**						
24	☐ PRESSURE (PSI)						
25	☐ TEMPERATURE (°F)						
26	☐ ISENTROPIC EXPONENT (K_2)						
27	☐ COMPRESSIBILITY (Z_2)						
28	**PERFORMANCE(4.1.4)(4.1.5)**						
29	☐ POLYTROPIC HEAD, SPECIFIC COMPRESSION WORK FLANGE TO FLANGE (FT·LBF/LB)						
30	☐ POLYTROPIC EFFICIENCY FLANGE TO FLANGE (%)						
31	☐ COMPRESSOR MECHANICAL LOSSES (BHP)						
32	☐ COMPRESSOR ABSORBED POWER (BHP)						
33	☐ COMPRESSOR POWER REQUIRED, AT DRIVER COUPLING (BHP)						
34	☐SPEED (r/min)						
35	O ESTIMATED SURGE AT ABOVE SPEED (CFM)						
36	☐ GUARANTEE POINT FLANGE TO FLANGE						
37	☐ PERFORMANCE CURVE NUMBER						

38 **O PROCESS CONTROL**
39 METHOD O SUCTION THROTTLING O VARIABLE O SPEED VARIATION O DISCHARGE O COOLED BYPASS
40 FROM ____ (PSI) GUIDE VANES FROM ____ % BLOWOFF FROM ____
41 TO ____ (PSI) (5.4.2.4) TO ____ % TO ____ TO ____
42 SIGNAL O SOURCE (5.4.2.1) ____
43 TYPE O ELECTRONIC O PNEUMATIC O OTHER ____ O RANGE ____ (mA) ____ (PSI)
44 **O ANTI-SURGE SYSTEM (5.4.2.2)**
45 ANTI-SURGE BYPASS O MANUAL O AUTOMATIC O NONE
46 A.-S. VALVE SIZING BY: ____ Vendor ____ OTHERS, A.-S. VALVE SUPPLIED BY: ____ Vendor ____ Purchaser
47 A.-S. CONTROLLER SUPPLIED BY: ____ Vendor ____ Purchaser
48 FLOW/PRESSURE SENSING ELEMENTS SUPPLIED BY: ____ Vendor ____ Purchaser
49 FLOW/PRESSURE SENSING ELEMENT POSITIONS: O INLET O DISCHARGE
50 LOAD SHARE CONTROLLER SUPPLIED BY: ____ Vendor ____ Purchaser

CENTRIFUGAL COMPRESSOR DATA SHEETS (US customary units)

ENQUIRY/ORDER NO.						
JOB NO.				ITEM NO.		
REVISION	BY	DATE	CH'KD	DATE	APP'D	DATE

OPERATING CONDITIONS (Continued) (5.1.2) (4.11.1.8)

GAS ANALYSIS:		NORMAL	RATED	OTHER CONDITIONS				REMARKS: (4.11.1.3) (4.11.1.8)
O MOL% O				A	B	C	D	
	MW							
AIR	28,966							
OXYGEN	32,000							
NITROGEN	28,016							
WATER VAPOUR	18,016							
CARBON MONOXIDE	28,010							
CARBON DIOXIDE	44,010							
HYDROGEN SULPHIDE	34,076							(4.11.1.7)
HYDROGEN	2,016							
METHANE	16,042							
ETHYLENE	28,052							
ETHANE	30,068							
PROPYLENE	42,078							
PROPANE	44,094							
I-BUTANE	58,120							
N-BUTANE	58,120							
I-PENTANE	72,146							
N-PENTANE	72,146							
HEXANE PLUS								
TOTAL								
AVG. MOL. MASS								

REMARKS:

CENTRIFUGAL COMPRESSOR DATA SHEETS (US customary units)

ENQUIRY/ORDER NO.
JOB NO. ___ ITEM NO. ___

REVISION	BY	DATE	CH'KD	DATE	APP'D	DATE

CONSTRUCTION FEATURES

☐ **SPEEDS:**

MAX. CONT. ___ RPM TRIP ___ RPM

MAX. TIP SPEEDS: ___ FPS @ RATED SPEED

___ FPS @ MAX. CONT. SPEED

☐ **LATERAL CRITICAL SPEEDS (DAMPED)**

FIRST CRITICAL ___ RPM ___ MODE

SECOND CRITICAL ___ RPM ___ MODE

THIRD CRITICAL ___ RPM ___ MODE

FOURTH CRITICAL ___ RPM ___ MODE

O TRAIN LATERAL ANALYSIS REQUIRED (4.9.2.3)

O UNDAMPED STIFFNESS MAP REQUIRED (4.9.2.4)

O TRAIN TORSIONAL ANALYSIS REQUIRED (TUBINE DRIVEN TRAIN (4.9.4.6)

☐ **TORSIONAL CRITICAL SPEEDS:**

FIRST CRITICAL ___ RPM

SECOND CRITICAL ___ RPM

THIRD CRITICAL ___ RPM

FOURTH CRITICAL ___ RPM

☐ **VIBRATION:**

ALLOWABLE TEST LEVEL ___ MIL (PEAK TO PEAK)

☐ **ROTATION, VIEWED FROM DRIVEN END [CW/CCW]**

O *MATERIALS INSPECTION REQUIREMENTS (6.2.2)*

O SPECIAL CHARPY TESTING (4.11.3)

O RADIOGRAPHY REQUIRED FOR ___

O MAGNETIC PARTICLE REQUIRED FOR ___

O LIQUID PENETRANT REQUIRED FOR ___

☐ **CASING:**

MODEL ___

CASING SPLIT ___

Pressure design code (4.1.20) ___

MATERIAL ___

THICKNESS (IN) ___ CORR. ALLOW. (IN)

MAX WORKING PRESS. ___ PSI

MAX DESIGN PRESS ___ PSI

TEST PRESS (PSI): HELIUM ___ HYDRO ___

MAX. OPER. TEMP. ___ °F MIN. OPER. TEMP. ___ °F

MAX. NO. OF IMPELLERS FOR CASING ___

MAX. CASING CAPACITY VOLUME FLOW (CFM) ___

RADIOGRAPH QUALITY O YES O NO

CASING SPLIT SEALING ___

O SYSTEM RELIEF VALVE SET PT. (4.2.4) ___ PSI

☐ **DIAPHRAGMS:**

MATERIAL ___

☐ **IMPELLERS:**

NO. ___ DIAMETERS (IN) ___

NO. VANES EACH IMPELLER ___

TYPE (OPEN, ENCLOSED, ETC.) ___

TYPE FABRICATION ___

MATERIAL ___

MAX. YIELD STRENGTH (PSI) ___

HARDNESS [HB/HRC] MAX ___ MIN ___

SMALLEST TIP INTERNAL WIDTH (IN) ___

MAX. MACH. NO. @ IMPELLER EYE ___

MAX. IMPELLER HEAD @ RATED SPEED (FT-LBF/LB) ___

☐ **SHAFT:**

MATERIAL ___

DIA @ IMPELLERS (IN) ___ DIA @ COUPLING (IN) ___

SHAFT END: ___ TAPERED ___ CYLINDRICAL

MAX. YIELD STRENGTH (PSI) ___

HARDNESS [HB/HRC] ___

STRESS AT COUPLING (PSI) ___

☐ **BALANCE PISTON:**

MATERIAL ___ AREA ___ IN^2

FIXATION METHOD ___

☐ **SHAFT SLEEVES (4.8.1.2):**

AT INTERSTG. CLOSE CLEARANCE POINTS MATL ___

AT SHAFT SEALS ___ MATL ___

☐ **LABYRINTHS:**

INTERSTAGE

TYPE ___ MATERIAL ___

BALANCE PISTON

TYPE ___ MATERIAL ___

SHAFT SEALS: ☐ GAS SEALS use pages 10 to 12

O SEAL TYPE (4.8.1.3) ___

O SETTLING OUT PRESSURE (PSI) ___

O SPECIAL OPERATION (4.8.1.1) ___

O SUPPLEMENTAL DEVICE REQUIRED FOR CONTACT SEALS (4.8.2.2)

TYPE ___

O BUFFER GAS SYSTEM REQUIRED (4.8.2.4) (SEE ALSO PAGE 10)

O TYPE BUFFER GAS ___

O BUFFER GAS CONTROL SYSTEM SCHEMATIC BY VENDOR

O PRESSURIZING GAS FOR SUBATMOSPHERIC SEALS (4.8.2.5)

☐ TYPE SEAL ___

☐ INNER LEAKAGE GUAR. (GAL/DAY/SEAL) ___

BUFFER GAS REQUIRED FOR:

☐ AIR RUN-IN ☐ OTHER ___

☐ BUFFER GAS FLOW (PER SEAL):

NORM: ___ LB/min @ ___ PSI ΔP ___

MAX: ___ LB/min @ ___ PSI ΔP ___

O LUBE/SEAL OIL SYSTEM SEPARATE ___ COMBINED ___ (4.10.3)

☐ **BEARING HOUSING CONSTRUCTION:**

TYPE (SEPARATE, INTEGRAL) ___ SPLIT ___

MATERIAL ___

CENTRIFUGAL COMPRESSOR DATA SHEETS (US customary units)

ENQUIRY/ORDER NO.
JOB NO. ____________ ITEM NO. ____________

REVISION	BY	DATE	CH'KD	DATE	APP'D	DATE

CONSTRUCTION FEATURES (CONTINUED)

BEARINGS AND BEARING HOUSINGS

RADIAL	DRIVE END	NON-DRIVE END
□ TYPE		
□ MANUFACTURER		
□ LENGTH (IN)		
□ SHAFT DIA (IN)		
□ Unit load (Act/allow) (PSI)		
□ BASE MATERIAL		
□ BABBIT THICKNESS (IN)		
□ NO. PADS		
□ LOAD: BETWEEN/ON PAD		
□ PIVOT: CTR/OFFSET (%)		
□ BEARING SPAN (IN)		
□ SQUEEZE FILM DAMPING		
□ ____________		

THRUST	ACTIVE	INACTIVE
□ TYPE		
□ MANUFACTURER		
□ UNIT LOADING (MAX) (PSI)		
□ UNIT LOAD (ULT) (PSI)		
□ AREA (IN^2)		
□ NO. PADS		
□ PIVOT: CTR/OFFSET (%)		
□ PAD BASE MATERIAL		
□ ____________		

LUBRICATION: O FLOODED O DIRECTED
THRUST COLLAR: O INTEGRAL O REPLACEABLE
MATERIAL ____________

BEARING TEMPERATURE DEVICES

O SEE ATTACHED API 670 DATA SHEET
O THERMISTORS
O TYPE ____ POS. TEMP COEFF ____ NEG. TEMP COEEF
O TEMP SWITCH & INDICATOR BY: ____ PURCH ____ MFR
O THERMOCOUPLES
O SELECTOR SWITCH & INDICATOR BY: ____ PURCH ____ MFR
O RESISTANCE TEMP DETECTORS
O RESISTANCE MATL. ________ □ OHM
O SELECT SWITCH & INDICATOR BY: ____ PURCH ____ MFR
O LOCATION-JOURNAL BRG
NO. ________ EA. PAD EVERY OTHER PAD PER BRG
OTHER ____________
O LOCATION-THRUST BRG
NO. ________ EA. PAD __ EVERY OTHER PAD ____ PER BRG
OTHER ____________
NO. (INACT) ____ EA. PAD __ EVERY OTHER PAD ____ PER BRG
OTHER ____________
O MONITOR SUPPLIED BY (5.4.7.3) ____________
O LOCATION ________ ENCLOSURE ________
O MFR ________ □ MODEL ________
□ SCALE ________ ALARM □ SET @ ________ °F
O SHTDWN □ SET @ ____ °F O TIME DELAY ____ SEC

VIBRATION DETECTORS:

O SEE ATTACHED API 670 DATA SHEET
O TYPE ________ □ MODEL ________
O MFR ____________
O NO. AT EA SHAFT BEARING ________ TOTAL NO. ________
O OSCILLATOR-DETECTORS SUPPLED BY ____________
MFR ________ □ MODEL ________
MONITOR SUPPLIED BY (5.4.7.2) ____________
O LOCATION ________ ENCLOSURE ________
O MFR ________ □ MODEL ________
□ SCALE ________ ALARM □ SET @ ________ MIL
O SHTDWN: □ SET @ ____ MIL O TIME DELAY ____ SEC

AXIAL POSITION DETECTOR:

O SEE ATTACHED API 670 DATA SHEET
O TYPE ________ □ MODEL ________
O MFR ________ O NO. REQUIRED ________
O OSCILLATOR-DEMODULATOR SUPPLIED BY: ________
O MFR ________ □ MODEL ________
MONITOR SUPPLIED BY (5.4.7.2) ________
O LOCATION ____ ENCLOSURE ________
O MFR ________ □ MODEL ________
□ SCALE ________ ALARM □ SET @ ________ MIL
O SHTDWN □ SET @ ____ IN O TIME DELAY ____ SEC

CONNECTIONS

COMPRESSOR CASING	O DESIGN APPROVAL REQUIRED (4.11.2.12)	□ SIZE	□ RATING/ FACING	O POSITION (4.4.2.1)	O FLANGED OR STUDDED (4.4.2.1)	O MATING FLG & GASKET BY VENDOR (4.4.2.2)	GAS VELOCITY FPS
INLET							
DISCHARGE							

CENTRIFUGAL COMPRESSOR DATA SHEETS (US customary units)

ENQUIRY/ORDER NO.						
JOB NO. ______			ITEM NO. ______			
REVISION	BY	DATE	CH'KD	DATE	APP'D	DATE

☐ OTHER CONNECTIONS [DIRECT/SKID EDGE]

SERVICE:	NO	SIZE	TYPE
LUBE -OIL INLET			
LUBE-OIL OUTLET			
SEAL-OIL INLET			
SEAL-OIL OUTLET			
CASING DRAINS			
STAGE DRAINS			
VENTS			
COOLING WATER			
PRESSURE			
TEMPERATURE			
PURGE FOR:			
BRG. HOUSING			
BTWN BRG & SEAL			
BTWN SEAL & GAS			
SOLVENT INJECTION			

☐ ALLOWABLE PIPING FORCES AND MOMENTS:

CONNECTION	INLET		DISCHARGE			
	LBF	MOMT FT·LBF	FORCE LBF	MOMT FT·LBF	FORCE LBF	MOMT FT·LBF
AXIAL						
VERTICAL						
HORIZ. 90°						
CONNECTION						
AXIAL						
VERTICAL						
HORIZ. 90°						

O INDIVIDUAL STAGE DRAINS REQUIRED (4.4.3.2)
O VALVED & BLINDED
O VALVED & BLINDED & MANIFOLD
O VALVE ACTUATION O MANUAL O AUTO
O ______

O VIBRATION TRANSDUCER [CASING/BEARING HOUSING] (5.4.7.4)
O SEE ATTACHED API 670 DATA SHEET
O TYPE ______ ☐ MODEL
O MFR ______ NO. REQUIRED ______
O LOCATION ______
O OSCILATOR-DEMODULATORS SUPPLIED BY ______
O MFR ______ ☐ MODEL ______
O MONITOR SUPPLIED BY (5.4.7.5) ______
O LOCATION ______ ENCLOSURE ______
O MFR ______ ☐ MODEL ______
☐ SCALE RANGE ______ O ALARM: ☐ SET @ ____IN/SEC²
O SHTDWN ☐ SET @ ____IN/SEC² O TIME DELAY ______ SEC

ACCESSORIES

COUPLINGS AND GUARDS (5.2.2)

O SEE ATTACHED ISO 14691 DATA SHEET FOR FULL DETAILS ON ROTATING ELEMENTS AND SHAFT ENDS
COUPLING FURNISHED BY ______
MANUFACTURER ______ TYPE ______ MODEL ______
COUPLING GUARD FURNISHED BY: ______
TYPE: O FULLY ENCLOSED O SEMI-OPEN O OTHER MATERIAL: ______

COUPLING DETAILS
☐ SHAFT MOUNTING ______
☐ MAX O.D IN
☐ HUB MASS ______ LB
☐ SPACER LENGTH ______ IN
☐ SPACER MASS ______ LB

O VENDOR MOUNT HALF COUPLING
O IDLING ADAPTER/SOLO PLATE REQUIRED (5.2.4)
LUBRICATING REQUIREMENTS:
O NON-LUBE O GREASE O CONT. OIL LUBE O OTHER
QUANTITY PER HUB ______ GPM
O PLUG & RING GAUGES REQUIRED (5.2.5)

MOUNTING PLATES

O BASEPLATES: FURNISHED BY (5.3.1.1) ______
O COMPRESSOR ONLY (5.3.2.8) O DRIVER O GEAR
O OTHER ______
O DRIP TRIM O LEVELLING PADS (5.3.2.2.)
O COLUMN MOUNTING (5.3.2.3)
O SUB-SOLE PLATES REQUIRED (5.3.2.5)
O STAINLESS STEEL SHIM THICKNESS ______ IN
O PRIMER FOR EPOXY GROUT REQUIRED (5.3.1.2)
TYPE ______
O LIMIT OF PIPING (5.5.1.3) ______

O SOLEPLATES: FURNISHED BY: ______
☐ THICKNESS ______ IN
O SUBSOLE PLATES REQUIRED (5.3.3.2)
O LEVELLING BLOCKS REQUIRED
O STAINLESS STEEL SHIM
☐ THICKNESS ______ IN
O DRIVER O GEAR O COMPRESSOR
O PRIMER FOR EPOXY GROUT REQUIRED (5.3.1.2)
TYPE ______

CENTRIFUGAL COMPRESSOR DATA SHEETS (US customary units)

ENQUIRY/ORDER NO.						
JOB NO. ______			ITEM NO. ______			
REVISION	BY	DATE	CH'KD	DATE	APP'D	DATE

LOCATION, SITE DATA, UTILITIES AND MASS & SPACE REQUIREMENTS

LOCATION: COMPRESSOR SKID

O INDOOR | O HEATED | O UNDER ROOF
O OUTDOOR | O UNHEATED | O PARTIAL SIDES
O GRADE | O MEZZANINE | O ______

O WINTERIZATION (4.1.10) REQD. O TROPICALISATION REQD. (5.4.6.6)

SITE DATA:

O ELEVATION ____ FT BAROMETER ______ PSI

O RANGE OF AMBIENT TEMPS:

	°F	RELATIVE HUMIDITY
SITE RATED	______	______
NORMAL	______	______
MAXIMUM	______	______
MINIMUM	______	______

LOCATION: AUXILIARY EQUIPMENT

O CONTROL PANEL ______
O LUBE/SEAL OIL CONSOLE ______
O NITROGEN GENERATOR ______
O ______

UNUSUAL CONDITIONS: O DUST O FUMES

O OTHER (4.11.1.8)

O AREA CLASSIFICATION (4.1.16)

	ZONE	GAS GROUP	TEMP CLASS
COMPRESSOR SKID			
LUBE/SEAL OIL CONSOLE			
CONTROL PANEL			
NITROGEN GENERATOR			
______			

O UTILITY CONDITIONS:

STEAM:	DRIVERS		HEATING	
INLET MIN	______ PSI	______ °F	______ PSI	______ °F
NORM	______ PSI	______ °F	______ PSI	______ °F
MAX	______ PSI	______ °F	______ PSI	______ °F
EXHAUST. MIN	______ PSI	______ °F	______ PSI	______ °F
NORM	______ PSI	______ °F	______ PSI	______ °F
MAX	______ PSI	______ °F	______ PSI	______ °F

ELECTRICAL SUPPLY (5.4.6.1)

	DRIVERS	HEATING	CONTROL	SHUTDOWN
VOLTAGE				
HERTZ				
PHASE				

COOLING WATER:

TEMP. INLET ______ °F MAX RETURN ______ °F
PRESS NORM ______ PSI DESIGN ______ PSI
MIN RETURN ______ PSI MAX ALLOW ΔP ______ PSI
WATER SOURCE ______

INSTRUMENT AIR:

MAX PRESS ______ PSI MIN PRESS ______ PSI

NITROGEN:

MAX PRESS ______ PSI MIN PRESS ______ PSI

□ TOTAL UTILITY CONSUMPTION:

O COOLING WATER ______ GPM
O STEAM, NORMAL ______ LB/HR
O STEAM, MAX ______ LB/HR
O INSTRUMENT AIR ______ CFM
O POWER (DRIVER) ______ BHP
O POWER (AUXILIARIES) ______ BHP
O POWER (HEATERS) ______ BHP
O PURGE [AIR/N²] ______ LB/HR

□ MASSES (LB):

COMPR. ____ GEAR ____ DRIVER ____ BASE ____
ROTORS: COMPR. ____ ____ DRIVER ____ GEAR
COMPR UPPER CASE/CARTRIDGE ______
SOUR SEAL OIL TRAPS ______
LUBE OIL CONSOLE (WET/DRY) ______ ______
SEAL OIL CONSOLE (WET/DRY) ______ ______
OVERHEAD BRG RUNDOWN TANK (WET/ DRY) ____ ____
NITROGEN GENERATOR PACKAGE ______
CONTROL PANEL ______
MAX. FOR MAINTENANCE (IDENTIFY) ______
TOTALS FOR SHIPPING ______

□ SPACE REQUIREMENTS (FT):

	L	W	H
COMPLETE UNIT:			
LUBE OIL CONSOLE:			
SEAL OIL CONSOLE:			
O'HD S.O. TANK			
O'HD BRG. R.D. TANK			
N_2 GEN PACKAGE			
CONTROL PANEL			

REMARKS:

CENTRIFUGAL COMPRESSOR DATA SHEETS (US customary units)

ENQUIRY/ORDER NO.						
JOB NO. ______			ITEM NO. ______			
REVISION	BY	DATE	CH'KD	DATE	APP'D	DATE

1	**INSPECTION AND TEST**				**SPECIFICATIONS AND MISCELLANEOUS**
2	☐ SHOP INSPECTION AND TESTS: (6.1.4) (6.2.1.3)				NOISE SPECIFICATIONS: (4.1.11)
3		REQ'D	WITNS'D	OBSV'D	O APPLICABLE TO MACHINE:
4	SHOP INSPECTION	O			SEE SPECIFICATION ______
5	CLEANLINESS (6.2.1.5)	O			O APPLICABLE TO NEIGHBOURHOOD:
6	HYDROSTATIC	●	O	O	SEE SPECIFICATION ______
7	IMPELLER OVERSPEED	●	O	O	ACOUSTIC HOUSING: O YES O NO
8	MECHANICAL RUN	●	O	O	APPLICABLE REGULATIONS: (4.1.21)
9	☐ CONTRACT COUPLING ☐ IDLING ADAPTOR(S)				______
10	☐ CONTRACT PROBES ☐ SHOP PROBES				______
11	VARY LUBE & SEAL OIL PRESSURES AND TEMPERATURES (6.3.4.2.5)				______
12	POLAR FORM VIB DATA (6.3.4.3.3)	O			______
13	TAPE RECORD VIB (6.3.4.3.6)	O			______
14	TAPE DATA TO PURCHASER (6.3.4.3.7)	O			PAINTING:
15	RESIDUAL UNBALANCE CHECK (4.9.3.1)	O	O	O	O MANUFACTURER'S STD.
16	SHAFT END SEAL INSP. (6.3.4.4.1)	O			O OTHER ______
17	GAS LEAK TEST DISCH. PRESS (6.3.5.2) (6.3.5.3)	O	O	O	______
18	O BEFORE O AFTER MECH RUN				SHIPMENT: (6.4.1)
19	PERFORMANCE TEST [GAS/AIR] (6.3.6.2)	O	O	O	O DOMESTIC O EXPORT O EXPORT BOXING REQD.
20	O ISO 5389 O PTC 10				O OUTDOOR STORAGE MORE THAN 6 MONTHS (6.4.1) SPARE ROTOR ASSEMBLY PACKAGED FOR (6.4.3)
21	SINGLE POINT TEST	O	O	O	O HORIZONTAL STORAGE O VERTICAL STORAGE
22	______ POINTS TEST	O	O	O	MISCELLANEOUS:
23	______ SPEED LINES	O	O	O	☐ RECOMMENDED STRAIGHT RUN OF PIPE DIAMETERS
24	______	O	O	O	BEFORE SUCTION ______
25	______	O	O	O	O VENDOR'S REVIEW & COMMENTS ON PURCHASER'S PIPING & FOUNDATION (4.1.15) (5.3.2)
26	COMP. WITH SHOP DRIVER	O	O	O	O COMPRESSOR TO BE SUITABLE FOR FIELD RUN IN ON AIR (4.1.18)
27	COMP. WITH JOB DRIVER	O	O	O	O PROVISION FOR LIQUID INJECTION (4.1.12) ______
28	USE SHOP LUBE/SEAL OIL SYSTEM	O	O	O	______
29	USE JOB LUBE/SEAL OIL SYSTEM	O	O	O	O VENDOR'S REVIEW & COMMENTS ON PURCHASER'S CONTROL SYSTEMS (5.4.1.1)
30	CHECK BRG'S AND SEALS AFTER TEST	O	O	O	O EXTENT OF PROCESS PIPING BY VENDOR (5.5.3.1) ______
31	NITROGEN GENERATOR PACKAGE TEST	O	O	O	O SHOP FITUP OF VENDOR PROCESS PIPING (6.4.3)
32	DRY GAS SEAL SYSTEM TEST	O	O	O	O WELDING HARDNESS TESTING (6.2.1.6)
33	DRY GAS SEAL TESTING AT SEAL VDR	O	O	O	O INSPECTION CHECKLIST REQUIRED (6.1.6)
34	CONTROL PANEL FUNCTIONAL TEST	O	O	O	O TECHNICAL DATA MANUAL REQUIRED (7.3.6.4)
35	MECHANICAL RUN USING SPARE ELEMENTS	O	O	O	O ______
36	COMPLETE UNIT TEST (6.3.6.3)	O	O	O	O ______
37	TORSIONAL VIB MEAS	O	O	O	O ______
38	TANDEM TEST (6.3.6.4)	O	O	O	O ______
39	GEAR TEST (6.3.6.5)	O	O	O	O ______
40	HELIUM LEAK TEST (6.3.6.6)	O	O	O	O ______
41	SOUND LEVEL TEST (6.3.6.7)	O	O	O	O ______
42	FULL LOAD/SPEED/PRESS TEST (6.3.6.10)	O	O	O	O ______
43	HYDRAULIC COUPLING INSP (6.3.6.11)	O	O	O	O ______
44	CERTIFIED COPIES OF TEST DATA	O	O	O	O ______
45	______	O	O	O	O ______
46	______	O	O	O	O ______
47	______	O	O	O	O ______
48	______	O	O	O	O ______
49	______	O	O	O	O ______
50					

CENTRIFUGAL COMPRESSOR DATA SHEETS (US customary units)

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REVISION	BY	DATE	CH'KD	DATE	APP'D	DATE

CONTROLS AND INSTRUMENTATION

CONTROL PANEL: (5.4.3.1)

O CONTROLS AND INSTRUMENTATION PER SPECIFICATION
O METHOD OF OPERATION
□ VIBRATION ISOLATORS □ STRIP HEATERS □ PURGE CONNECTIONS (5.4.4.1.2)
O METAL CASE, GLASS FRONT, STEM-TYPE LIQUID FILLED/BI METALLIC THERMOMETERS FURNISHED
O LIQUID-FILLED PRESSURE GAUGES FURNISHED
O HIGH VIBRATION DRIVER ALARM AND SHUTDOWN
O
O

LOCAL GAUGE BOARD/PANEL:

O ON SKID O LOCAL TO SKID ____________

INSTRUMENT SUPPLIERS:

O PRESSURE GAUGES: (5.4.4.5)	MANUFACTURER ______	SIZE & TYPE ______
TEMPERATURE GAUGES:	MANUFACTURER ______	SIZE & TYPE ______
LEVEL GAUGES:	MANUFACTURER ______	SIZE & TYPE ______
DIFF. PRESSURE GAUGES:	MANUFACTURER ______	SIZE & TYPE ______
PRESSURE SWITCHES:	MANUFACTURER ______	SIZE & TYPE ______
DIFF. PRESSURE SWITCHES:	MANUFACTURER ______	SIZE & TYPE ______
TEMPERATURE SWITCHES:	MANUFACTURER ______	SIZE & TYPE ______
LEVEL SWITCHES;	MANUFACTURER ______	SIZE & TYPE ______
CONTROL VALVES:	MANUFACTURER ______	SIZE & TYPE ______
PRESSURE RELIEF VALVES:	MANUFACTURER ______	SIZE & TYPE ______
SIGHT FLOW INDICATORS:	MANUFACTURER ______	SIZE & TYPE ______
GAS FLOW INDICATOR:	MANUFACTURER ______	SIZE & TYPE ______
VIBRATION MEASUREMENT:	MANUFACTURER ______	SIZE & TYPE ______
TEMPERATURE MEASUREMENT:	MANUFACTURER ______	SIZE & TYPE ______
PRESSURE MEASUREMENT:	MANUFACTURER ______	SIZE & TYPE ______
FLOW MEASUREMENT:	MANUFACTURER ______	SIZE & TYPE ______
TACHOMETER:	MANUFACTURER ______	RANGE & TYPE ______
SOLENOID VALVES:	MANUFACTURER ______	SIZE & TYPE ______
ANNUNCIATOR:	MANUFACTURER ______	MODEL & NO. POINTS ______
ANTI-SURGE CONTROLLER	MANUFACTURER ______	MODEL ______
LOAD SHARE CONTROLLER	MANUFACTURER ______	MODEL ______
______	______	______
______	______	______

CONTROL PANEL DESIGN AND CONSTRUCTION

O INSTRUMENTATION REQUIREMENTS (5.4.1.2):

TUBING: MATERIAL ______ SIZE ______ FITTINGS ______
O WIRING PROTECTION (5.4.3.2) (5.4.6.7) IN CONDUIT ______ ARMOURED CABLE ______
O TRANSMITTERS REQUIRED (5.4.5.1.1) ALL ______ SHUTDOWN ______
ALARM ______

CENTRIFUGAL COMPRESSOR DATA SHEETS (US customary units)

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JOB NO. ______ ITEM NO. ______

REVISION	BY	DATE	CH'KD	DATE	APP'D	DATE

COMPRESSOR INSTRUMENTATION SCHEDULE

	FUNCTION	PANEL IDENTIFICATION L	B	C	D	ALARM	TRIP		PANEL IDENTIFICATION L	B	C	D
3	PRESSURE	L	B	C	D	ALARM & SHUTDOWN SWITCHES			L	B	C	D
4						A L A R M	T R I P	FUNCTION				
5	LUBE OIL HEADER (NOTE 1)											
6	COMPRESSOR SUCTION EACH STAGE											
7	COMPRESSOR DISCHARGE EACH STAGE											
8	BALANCE CHAMBER(S)											
9	BALANCE DRUM											
10	PURGE GAS SUPPLY					O	O	HIGH RADIAL SHAFT VIBRATION				
11	O ______					O	O	HIGH AXIAL DISPLACEMENT				
12	O ______					O	O	OVER SPEED				
13	DIFFERENTIAL PRESSURE					O	O	REVERSE ROTATION				
14	BALANCE DRUM					O	O	HIGH JOURNAL BRG. METAL TEMP.				
15	BUFFER GAS					O	O	HIGH THRUST BRG. METAL TEMP.				
16	O ______					O	O	HIGH COMPR. SUCTION GAS TEMP.				
17	O ______					O	O	HIGH COMPR. DISCHARGE GAS TEMP.				
18	TEMPERATURE					O	O	LOW COMPR. SUCTION GAS TEMP.				
19	COMPRESSOR SUCTION EA. STG.					O	O	LOW COMPR. BALANCE DRUM ΔP				
20	COMPRESSOR DISCHARGE EA. STG.					O	O	LOW COMPR. SUCTION PRESS				
21	COMPRESSOR JOURNAL BEARING					O	O	HIGH COMPR. DISCHARGE PRESS				
22	COMPRESSOR THRUST BEARING					O	O	UNIT SHUTDOWN				
23	BEARING DRAIN					O	O	LOW BUFFER GAS DIFFER. PRESS				
24	O ______					O	O	LOW BUFFER GAS FLOW				
25	O ______					O	O	HIGH LEVEL IN SEPARATORS				
26	LEVEL INDICATORS/CONTROLLERS					O	O	______				
27	SUCTION SEPARATOR EACH STAGE					O	O	______				
28	INTERSTAGE SEPARATOR(S)					O	O	______				
29	DISCHARGE SEPARATOR					O	O	______				
30	O ______					MONITORS:						
31	PUSH BUTTON STATIONS:					VIBRATION:						
32	MAIN EQUIPMENT START					AXIAL POSITION						
33	MAIN EQUIPMENT STOP					THRUST BEARING METAL TEMP.						
34	COMPRESSOR BLOCK IN					JOURNAL BEARING METAL TEMP.						
35	COMPRESSOR UNBLOCK					______						
36	EMERGENCY STOP BUTTON(S)					______						
37	O ______					NOTES:						
38	MISCELLANEOUS:					1) SEE ISO 10438 FOR OIL SYSTEM REQUIREMENTS						
39	EQUIPMENT TACHOMETER					2) ALL ALARMS AND TRIPS SHALL BE ANNUNCIATED						
40	EQUIPMENT SPEED CONTROL					3) PURCH. TO INDICATE PRESSURE GAUGES WHICH SHALL BE OIL-FILLED						
41	COMPR. INLET CONTROLLER					4) PURCHASER TO INDICATE WHERE TRANSMITTERS ARE REQUIRED						
42	ANNUNCIATOR SYSTEM					5) THE FOLLOWING CODE IS USED FOR PANEL INDICATION						
43	EQUIPMENT FLOW METER					L = LOCALLY MOUNTED ON PIPING		B = LOCAL GAUGE BOARD/PANEL				
44	GUIDE VANE POSITIONER					C = CONTROL PANEL		D = DISTRIBUTED CONTROL SYSTEM				
45	SUCTION THROTTLE VALVE					6) USE THE FOLLOWING CODE LETTERS TO SHOW DETAILS ETC.						
46	ANTI SURGE EQUIPMENT:					F-FLUSH MOUNT ON FRONT		H-PURCHR. REMOTE MOUNT				
47	CAPACITY CONTROL EQUIPMENT:					S-SURFACE MOUNT ON FRONT		P-PURCHR. SPPLY AND MOUNT				
48	O ______					M-MNT BY VENDOR OF PURCHR'S ITEM		V-VENDOR SPPLY. AND MOUNT				
49	O ______					R-REAR OF PANEL MOUNT		C- CUT-OUT FOR PURCH'S ITEM				
50	O ______					D. INTERFACE WITH DCS						

CENTRIFUGAL COMPRESSOR DATA SHEETS (US customary units)

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JOB NO. ____________ ITEM NO. ____________

REVISION	BY	DATE	CH'KD	DATE	APP'D	DATE

SELF ACTING GAS SEAL INSTRUMENTTATION SCHEDULE (NOTE 1) (4.8.2.5)

FUNCTION (EACH SEAL/SEAL SUPPLY)	PANEL IDENTIFICATION L	B	C	D
PRESSURE				
O SEAL GAS SUPPLY	__	__	__	__
O BUFFER GAS SUPPLY (NOTE 3)	__	__	__	__
O SEPARATION GAS SUPPLY (NOTE 2)	__	__	__	__
O PRIMARY SEAL VENT	__	__	__	__
O INTERMEDIATE SEAL VENT	__	__	__	__
O BACK-UP SEAL VENT	__	__	__	__
O ____________	__	__	__	__
O ____________	__	__	__	__
DIFFERENTIAL PRESSURE	__	__	__	__
O SEAL GAS SUPPLY FILTER	__	__	__	__
O SEAL GAS TO COMPRESSOR	__	__	__	__
O SEAL GAS SUPPLY DIFF. CONTROL	__	__	__	__
O ____________	__	__	__	__
O ____________	__	__	__	__
PRESSURE RELIEF				
O SEAL GAS SUPPLY TO FILTER	__	__	__	__
O PRIMARY SEAL VENT	__	__	__	__
O INTERMEDIATE SEAL VENT	__	__	__	__
O ____________	__	__	__	__
O ____________	__	__	__	__
TEMPERATURE				
O SEAL GAS SUPPLY	__	__	__	__
O BUFFER GAS SUPPLY	__	__	__	__
O ____________	__	__	__	__
O ____________	__	__	__	__
MISCELLANEOUS				
O FLOW INDICATOR SEAL GAS SUPPLY	__	__	__	__
O FLOW INDICATOR BUFFER GAS SUPPLY	__	__	__	__
O FLOW INDICATOR SEPARATION GAS	__	__	__	__
O FLOW INDICATOR PRIMARY SEAL VENT	__	__	__	__
O FLOW INDICATOR INTER. SEAL VENT	__	__	__	__
O GAS DETECTION BACK-UP SEAL VENT	__	__	__	__
O NITROGEN SUPPLY PURITY ANALYSER	__	__	__	__
O ____________	__	__	__	__
O ____________	__	__	__	__
O ____________	__	__	__	__
O ____________	__	__	__	__
O ____________	__	__	__	__

ALARM & SHUTDOWN

ALARM	TRIP	FUNCTION	L	B	C	D
O	O	LOW SEAL GAS SUPPLY PRESSURE	__	__	__	__
O	O	HIGH PRIMARY SEAL VENT PRESSURE	__	__	__	__
O	O	LOW BUFFER GAS SUPPLY PRESSURE	__	__	__	__
O	O	LOW SEPARATION GAS SUPPLY PRESS.	__	__	__	__
O	O	HIGH ΔP SEAL GAS SUPPLY FILTER	__	__	__	__
O	O	HIGH ΔP SEAL GAS TO COMPRESSOR	__	__	__	__
O	O	HIGH SEAL GAS SUPPLY TEMP.	__	__	__	__
O	O	HIGH BUFFER GAS SUPPLY TEMP.	__	__	__	__
O	O	HIGH FLOW SEAL GAS SUPPLY	__	__	__	__
O	O	HIGH FLOW PRIMARY SEAL VENT	__	__	__	__
O	O	HIGH FLOW INTERMEDIATE SEAL VENT	__	__	__	__
O	O	GAS DETECTION BACK-UP SEAL VENT	__	__	__	__
O	O	UNIT SHUTDOWN	__	__	__	__
O	O	LOW NITROGEN SUPPLY PURITY	__	__	__	__
O	O	____________	__	__	__	__
O	O	____________	__	__	__	__
O	O	____________	__	__	__	__

NOTES:

1) THE ABOVE INSTRUMENTATION SHOULD COVER ALL SINGLE, DOUBLE, TANDEM AND TRIPLE SEAL CONFIGURATIONS. PURCHASER TO DELETE/ADD WHERE NECESARY.
2) SEPARATION GAS MAY BE EITHER AIR OR NITROGEN
3) BUFFER GAS, POSSIBLY INERT, MAY BE NEEDED FOR DOUBLE SEALS AND SOUR/TOXIC DUTIES.
4) ALL ALARMS AND TRIPS SHALL BE ANNUNCIATED.
5) PURCH. TO INDICATE PRESSURE GUAGES WHICH SHALL BE OIL-FILLED.
6) PURCHASER TO INDICATE WHERE TRANSMITTERS ARE REQUIRED.
7) THE FOLLOWING CODE IS USED FOR PANEL INDICATION
   L = LOCALLY MOUNTED ON PIPING C = CONTROL PANEL
   B = LOCAL GAUGE BOARD/PANEL D = DISTRIBUTED CONTROL SYSTEM
8) USE THE FOLLOWING CODE LETTERS TO SHOW PANEL MNTG DTLS.
   F- FLUSH MOUNT ON FRONT H- PURCHR. REMOTE MOUNT
   S- SURFACE MOUNT ON FRONT P- PURCH. SUPPLY AND MOUNT
   R- REAR OF PANEL MOUNT C- CUT-OUT FOR PURCH.'S ITEM
   D- INTERFACE WITH DCS

REMARKS

____
____
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____
____
____

CENTRIFUGAL COMPRESSOR DATA SHEETS (US customary units)

ENQUIRY/ORDER NO.
JOB NO. ______ ITEM NO. ______

REVISION	BY	DATE	CH'KD	DATE	APP'D	DATE

SELF ACTING GAS SEAL (4.8.2.5)

SEAL MFR. ______ ☐ MODEL ______
☐ SERIAL NO. ______

○ Gas ANALYSIS SEAL GAS ______
BUFFER GAS ______
SEPARATION GAS ______

☐ SEAL CONFIGURATION

☐ SINGLE ☐ DOUBLE ☐ TANDEM ☐TRIPLE ☐OTHER ______
SEPARATION FROM OIL SYSTEM BY: ☐ CARBON RING ☐ LABYRINTHS
SEPARATION GAS ______ ☐ OTHER

SEAL OPERATING CONDITIONS

OPERATING CASE	NORMAL	MAX RATED	START-UP	SETTLE OUT	
☐ PRIMARY SEAL PRESSURE (PSI)					
☐ INTERMEDIATE SEAL PRESSURE (PSI)					
☐ SEAL GAS INLET TEMPERATURE (°F)					
○ PRIMARY SEAL BACK PRESSURE (PSI)					
○ INTERMEDIATE SEAL BACK PRESSURE (PSI)					
○ BACK-UP SEAL BACK PRESSURE (PSI)					

○ DEPRESSURISATION TIME (min) ______ * PROCESS UPSET CONDITION

○ SLOW ROLL REQUIRED: YES/NO SPEED (RPM) ______ DURATION (min) ______
☐ BARRING DEVICE : YES/NO METHOD ______
○ REVERSE ROTATION CAPABILITY REQUIRED: YES/NO SPEED (RPM) ______ DURATION (min) ______
○ AT SEALING PRESSURES (PSI) PRIMARY ______ INTERMEDIATE ______ BACK-UP ______
MAX. PERIPHERAL SPEED AT MAX. CONT. SPEED (FPS) ______ OUTER SEAL FACE DIAMETER (IN) ______

☐ MATERIALS OF CONSTRUCTION

FACE ______ SLEEVES ______
SEAT ______
ELASTOMERS ______ SCREWS ______
HOUSING ______ SPRINGS ______
LABYRINTHS ______ NACE REQUIREMENTS ______

☐ GAS REQUIREMENTS

(ALL DATA PER SEAL)	NORMAL OPERATION			ON SEAL FAILURE (ALL GAS SEAL ELEMENTS)
SEAL GAS	RUNNING	START-UP	SETTLE OUT	
TYPE				
PRESSURE, MIN/MAX. (PSI)				
TEMPERATURE, MIN/MAX. (°F)				
FLOW, NORMAL/MAX. *(LB/MIN)	*		*	
BUFFER GAS				
TYPE				
PRESSURE, MIN/MAX. (PSI)				
TEMPERATURE, MIN/MAX. (°F)				
FLOW, NORMAL/MAX. *(LB/MIN)	*		*	
SEPARATION GAS				
TYPE				
PRESSURE, MIN/MAX. (PSI)				
TEMPERATURE, MIN/MAX. (°F)				
FLOW, NORMAL/MAX. *(LB/MIN)	*		*	

* MAX.TO BE GUARANTEED

CENTRIFUGAL COMPRESSOR DATA SHEETS (US customary units)

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JOB NO. ______________ ITEM NO. ______________

REVISION	BY	DATE	CH'KD	DATE	APP'D	DATE

SELF ACTING GAS SEAL (CONT.) (4.8.2.5)

TESTING

ROTATING FACE OVERSPEED TO ______________ % FOR ______________ MIN

BALANCE OF ROTATING COMPONENTS TO ______________ TEST GAS ______________

TEST	STATIC		DYNAMIC		STATIC		REVERSE
	DE	NDE	DE	NDE	DE	NDE	
GAS PRESSURES (PSI) PRIMARY							
INTERMEDIATE							
BACK-UP							
GAS TEMPERATURES (°F)							
SEAL SPEED (rpm)							
SEAL BACK PRESSURES (PSI) PRIMARY							
INTERMEDIATE							
BACK-UP							
DURATION (min)							
LEAKAGE LIMITS (LB/MIN)							
PRIMARY (LB/MIN)							
INTERMEDIATE (LB/MIN)							
BACK-UP (LB/MIN)							

SEAL STRIP AFTER TEST (AND RETEST) YES/NO, REQUIREMENTS ______________ * IF SPECIFIED

O AT COMPRESSOR MANUFACTURERS CONTRACT SEALS FITTED DURING:-

	SPEED (r/min)	GAS TYPE	PRESSURE (bar)	TEMPERTURE (°C)
O PERFORMANCE TEST @				
O MECHANICAL RUNNING TEST @				
O MECHANICAL STRING TEST @				
O GAS LEAKAGE TEST @				
O SETTLE-OUT PRESSURE TEST @	ZERO			

O OPTIONAL TESTS

Annex B
(informative)

Material specifications for major component parts

Table B.1 — Typical specifications for major component parts

Part	Material [a]	Specification	Form	Temperature Limits [c]			
				Minimum		Maximum	
				°C	(°F)	°C	(°F)
Cast casings	Cast iron	ASTM A 278, Class 30	Cast	−45	(−50)	230	(450)
		ASTM A 278, Class 40	Cast	−30	(−20)	260	(500)
	Austenitic cast iron	ASTM A 436, Type 2	Cast	−45	(−50)	260	(500)
		ASTM A 571, Type D-2M Classes 1 & 2	Cast	−195	(−320)	260	(500)
	Ductile iron	ASTM A 395	Cast	−30	(−20)	260	(500)
	Cast steel	ASTM A 216, Grade WCB	Cast	−30	(−20)	400	(750)
		ASTM A 352, Grade LCB	Cast	−45	(−50)	345	(650)
		ASTM A 352, Grade LC2	Cast	−75	(−100)	345	(650)
		ASTM A 352, Grade LC3	Cast	−100	(−150)	345	(650)
		ASTM A 352, Grade LC4	Cast	−115	(−175)	345	(650)
		ASTM A 217	Cast	−30	(−20)	400	(750)
	Cast stainless steel	ASTM A 743, ASTM A 744 or ASTM A 351, Grades CF3,	Cast	−195	(−320)	345	(650)
		CF3M, CF8 or CF 8M					
	Cast titanium	ASTM B 367, Grades C3 or C4	Cast	−45	(−50)	150	(300)
Fabricated casings	Steel	ASTM A 285, Grade C	Plate	−45	(−50)	345	(650)
		ASTM A 516, Grade 55, 60, 65, 70	Plate	−45	(−50)	345	(650)
		ASTM A 203, Grade A or B	Plate	−60	(−75)	345	(650)
		ASTM A 203, Grade D or E	Plate	−105	(−160)	345	(650)
		ASTM A 537, Class 1 or 2	Plate	−60	(−75)	345	(650)
		ASTM A 353	Plate	−195	(−320)	345	(650)
		ASTM A 553, Type I	Plate	−195	(−320)	345	(650)
		ASTM A 553, Type II	Plate	−170	(−275)	345	(650)
		ASTM A 266, Class 1 or 4	Forged	−30	(−20)	345	(650)
		ASTM A 336, Class F1	Forged	−30	(−20)	345	(650)
		ASTM A 414	Sheet	−30	(−20)	345	(650)
		ASTM A 508, Class 5a	Forged	−30	(−20)	345	(650)
	Stainless steel	ASTM A 240, Type 304, 304L, 316, 316L or 321	Plate	−195	(−320)	345	(650)

Table B.1 *(continued)*

Part	Material [a]	Specification	Form	Temperature Limits [c]			
				Minimum		Maximum	
				°C	(°F)	°C	(°F)
Diaphragms and guide vanes	Cast iron	ASTM A 48 or ASTM A 278, Class 30	Cast	−195	(−320)	345	(650)
	Ductile iron	ASTM A 536	Cast	−195	(−320)	345	(650)
	Cast steel	ASTM A 216, Grade WCB	Cast	−195	(−320)	345	(650)
	Steel	ASTM A 283, ASTM A 285, ASTM A 516 or ASTM A 543	Plate	−195	(−320)	345	(650)
	Stainless steel	ASTM A 743, ASTM A 744 or ASTM A 351, Grades	Cast	−195	(−320)	345	(650)
		CA15, CF3, CF3M, CF8 or CF8M					
	Aluminium	ASTM B 26, Alloy 355 or C355	Cast	−195	(−320)	150	300
Shaft	Steel	ASTM A 470, Class 1	Forged	−30	(−20)	345	(650)
		ASTM A 470, Class 7	Forged	−115	(−175)	400	(750)
		AISI Types 1040 to 1050 [b]	Bar or forged	−30	(−20)	345	(650)
		AISI Types 4140 to 4150 [b]	Bar or forged	−30	(−20)	400	(750)
		AISI Types 4340 to 4345 [b]	Bar or forged	115	(−175)	425	(800)
		AISI Types 2320 [b]	Bar or forged	−110	(−170)	345	(650)
		ASTM A 522, Type 1	Forged	−195	(−320)	345	(650)
	Stainless steel	ASTM A 336, Grade F6	Forged	−60	(−75)	345	(650)
		ASTM A 473, Type 410	Forged	−60	(−75)	345	(650)
	Precipitation hardening stainless steel	ASTM A 705, Types 630 or XM-12	Forged	−75	(−100)	345	(650)
Cast impellers	Aluminum	ASTM B 26, Alloy C355	Cast	−195	(−320)	150	(300)
	Precipitation hardening stainless steel	ASTM A 747, Types CB7CU-1 or CBCU-2	Cast	−75	(−100)	345	(650)
	Steel	ASTM A 148	Cast	−30	(−20)	345	(650)
		ASTM A 487 Gs 4Q	Cast	−45	(−50)	345	(650)
	Stainless steel	ASTM A 743, ASTM A 744 or ASTM A 351, Grade	Cast	−45	(−50)	345	(650)
		CA15 or CA6NM					
		ASTM A 743, ASTM A 744 or ASTM A 351, Grade	Cast	−195	(−320)	345	(650)

Table B.1 *(continued)*

Part	Material [a]	Specification	Form	Temperature Limits [c] Minimum °C	(°F)	Maximum °C	(°F)
		CF3, CFM, CF8, CF8M					
	Titanium	ASTM B 367, Grade C3 or C4	Cast	–45	(–50)	345	(650)
Fabricated impellers (covers, hubs blades)	Steel	AISI Types 4130-4140 [b]	Plate or forged	–30	(–20)	400	(750)
		AISI Types 4320-4345 [b]	Plate or forged	–115	(–175)	400	(750)
		AISI Type 3140 [b]	Forged	–45	(–50)	400	(750)
		ASTM A 543	Plate	–115	(–175)	400	(750)
		ASTM A 522, Type I	Forged	–145	(–230)	345	(650)
		ASTM A 522, Type II	Forged	–170	(–275)	345	(650)
		ASTM A 353 or ASTM A 583, Type I	Plate	–195	(–320)	345	(650)
		AISI Type 403 [b]	Forged	–60	(–75)	345	(650)
		ASTM A 473, Type 410	Forged	–60	(–75)	345	(650)
		ASTM A 240, Type 304, 304L, 316, 316L	Plate	–195	(–320)	345	(650)
		ASTM A 473, Type 304, 304L, 316, 316L	Forged	–195	(–320)	345	(650)
	Precipitation hardening stainless steel	ASTM A 705, Types 630 or XM-12	Forged	–75	(–100)	345	(650)
		ASTM A 693, Types 630 or XM-12	Plate	–75	(–100)	345	(650)
	Ni-Cu alloy	SAE AMS 4646	Forged	–115	(–175)	345	(650)
		ASTM B 127	Plate	–115	(–175)	345	(650)
		QQ-N-286	Plate	–115	(–175)	345	(650)
Labyrinths							
Impeller interstage shaft seal and balance piston	Aluminum	ASTM B 26, Alloys 443, 335, 850, A850, B850	Cast	–195	(–320)	315	(600)
		6061-T6 or 1100	Plate	–195	(–320)	315	(600)
	Babbitt	ASTM B 23	Cast	–195	(–320)	175	(350)
	Stainless steel	AISI Type 403, 410, 416, 303, 304 or 316 [b]	Wrought	–195	(–320)	345	(650)
	Cr-Ni-Fe-Mo-Cu-Cb Alloy	ASTM B 462	Wrought	–195	(–320)	345	(650)
	Stainless steel honeycomb	ASTM A 240, Types 304, 304L, 316 or 316L	Fabricated	–195	(–320)	345	(650)
	Ni-Cu alloy	ASTM B 164	Wrought	–115	(–175)	345	(650)
	Nonmetallic TFE[d]		Molded	–195	(–320)	260	(500)

Table B.1 *(continued)*

Part	Material [a]	Specification	Form	Temperature Limits [c] Minimum °C	(°F)	Maximum °C	(°F)
	Nonmetallic TFE[d] carbon-filled		Molded	–30	(–20)	260	(500)
	Nonmetallic TFE[d] mica-filled		Molded	–55	(–65)	260	(500)
	Lead	ASTM B 29	Cast	–100	(–150)	205	(400)
Balance	Steel	ASTM A 470, Class1	Forged	–30	(–20)	345	(650)
piston		ASTM A 470, Class 7	Forged	-115	(–175)	400	(750)
		AISI Types1040 to 1050 [b]	Forged	–30	(–20)	345	(650)
		AISI Types 4130 to 4145 [b]	Forged	–30	(–20)	400	(750)
		AISI Types 4330, 4345 [b]	Forged	–115	(–175)	455	(850)
		AISI Type 2320 [b]	Forged	–110	(–170)	345	(650)
		ASTM A 522, Type 1	Forged	–195	(–320)	345	(650)
	Stainless steel	ASTM A 336, Grade F6	Forged	–60	(–75)	345	(650)
		ASTM A 473, Type 410	Forged	–60	(–75)	345	(650)
		AISI Type 403 or 410 [b]	Forged	–30	(–20)	345	(650)
	Precipitation hardening stainless steel	ASTM A 705, Types 630 or XM-12	Forged	–75	(–100)	345	(650)
	Ni-Cu-alloy	SAE AMS 4676	Forged	–115	(–175)	345	(650)
Shaft sleeves	Steel	AISI Types 4130 to 4150 [b]	Forged	–45	(–50)	345	(650)
		AISI Types 4320 to 4345 [b]	Forged	–115	(–175)	400	(750)
		ASTM A 470, Class 7	Forged	–115	(–175)	400	(750)
		ASTM A 522, Type I	Forged	–195	(–320)	345	(650)
	Stainless steel	AISI Types 403 or 410 [b]	Forged	–75	(–100)	400	(750)
	Ni-Cu alloy	ASTM B 164 or SAE AMS 4676	Forged	–115	(–175)	345	(650)
	Ni-Mo-Cr alloy	ASTM B 574, Alloy N10276	Wrought	–115	(–175)	345	(650)
		ASTM A 494, Grade CW-12M-1	Cast	–115	(–175)	345	(650)

Table B.1 *(continued)*

Part	Material [a]	Specification	Form	Temperature Limits [c]			
				Minimum		Maximum	
				°C	(°F)	°C	(°F)
	Precipitation hardening stainless steel	ASTM A 705 Type 630 or XM-12	Forged	−75	(−100)	345	(650)

[a] The materials shown on this table are those commonly used by compressor manufacturers, but the list is not all inclusive. Other suitable materials may exist and may be used by compressor manufacturers as indicated by specific design considerations (4.11.1.1).

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

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

[d] TFE = tetrafluorethylene.

Annex C
(normative)

Centrifugal compressor vendor drawing and data requirements

C.1 A certified dimensional outline drawing and a list of connections is required, which shall include the following:

a) size, rating and location of all customer connections;

b) approximate overall handling weights;

c) overall dimensions;

d) shaft centreline height;

e) dimensions of base plates (if furnished), complete with diameter, number and locations of bolt holes and thickness of the metal through which the bolts must pass, centres of gravity and details for foundation design;

f) the weight and center of gravity of the machine, of the heaviest piece of equipment that must be handled for erection, and of significant items to be handled for maintenance;

g) principal dimensions, including those required for the piping design, maintenance clearances, and dismantling clearances, and the maximum loading limit on the main process flanges (both forces and moments);

h) the direction of rotation of each drive train component;

i) the size, type, location and identification of all the purchaser's connections, including vents, drains, lubricating oil, conduits and instruments (the vendor's plugged connections shall be identified);

j) if couplings are furnished, their make, size, and type and the style of the coupling guards;

k) a list of reference drawings;

l) a list of special weather protection and climatization features;

m) cold alignment setting data for equipment furnished by the vendor which shall include a composite diagram or data on expected thermal growth, including transient effects, shall be included;

n) completed information to permit adequate foundation design by the purchaser, which shall include but not be limited to

1) grouting details,

2) size and location of foundation on bolts, and

3) weight distribution for each bolt/sub-sole plate location;

o) the location of the center of gravity and rigging provisions to permit removal of the top half of the casing, the rotor, and any subassemblies with a mass of more than 100 kg (250 lb);

p) equipment furnished by the vendor for mounting by the purchaser.

C.2 A cross-sectional drawing and bill of materials is required, which shall include the following:

a) journal-bearing clearances and tolerances;

b) axial rotor float for all rotors (compressor, gas generator, power turbine);

c) shaft end and internal labyrinth seal clearances and tolerances;

d) axial position of rotor disks, blades relative to inlet nozzles or vanes, tolerances allowed;

e) outside diameter of all disks (impellers) at the blade tip.

C.3 Rotor assembly drawings and bills of materials are required, which shall include the following:

a) axial position from the active thrust-collar face to

   1) each impeller or rotating disc, inlet side,

   2) each radial probe,

   3) each journal-bearing centreline,

   4) phase-angle notch, and

   5) coupling face or end of shaft;

b) thrust-collar assembly details, including

   1) collar-shaft with tolerance,

   2) concentricity (or axial runout) tolerance,

   3) required torque,

   4) surface finish requirements for collar faces, and

   5) preheat method and temperature requirements for shrunk-on collar installation;

c) dimensioned shaft ends for coupling mountings.

C.4 A thrust-bearing assembly drawing and a bill of material shall be provided.

C.5 Journal-bearing assembly drawings and bills of materials for all field-maintainable rotors shall be provided.

C.6 Shaft coupling assembly drawings and bills of materials are required, which shall include the following:

a) hydraulic mounting procedure;

b) shaft end gap and tolerance;

c) coupling guards;

d) thermal growth from a baseline of 15 °C (60 °F).

C.7 A seal and seal system schematic are required, which include the following:

a) steady-state and transient fluid flows and pressures;

b) control, alarm, and trip settings;

c) heat loads;

d) utility requirements, including electrical, water, air and nitrogen;

e) pipe and valve sizes;

f) bill of materials.

C.8 Seal and seal system assembly and arrangement drawings, including size, rating and location of all customer connections, shall be provided.

C.9 Seal and seal system component drawings and data are required, which shall include the following, as applicable:

a) pumps and drivers or seal gas equipment, including

   1) certified dimensional outline drawings,

   2) cross-section and bill of material,

   3) mechanical seal drawing and bill of materials (pumps and drivers),

   4) list of recommended spare parts,

   5) instruction and operating manuals, and

   6) completed data sheets;

b) overhead tank, reservoir, and drain tanks, including

   1) fabrication drawings,

   2) maximum, minimum and normal liquid levels, and

   3) completed data sheets;

c) coolers, filters, accumulators and other seal system components, including

   1) fabrication drawings,

   2) spare parts, and

   3) data sheets;

d) instrumentation, including

   1) switches,

   2) control valves, and

   3) gauges.

C.10 A "lube" oil/control oil schematic and bills of materials are required, which shall include the following:

a) steady-state and transient oil flows and pressures to each use point;

b) control, alarm and trip settings (pressures and recommended temperatures);

c) heat loads at each use point at maximum load;

d) utility requirements, including electricity, water and air;

e) pipe and valves sizes;

f) instrumentation, safety devices and control schemes.

C.11 "Lube" oil assembly and arrangement drawings, including size, rating and location of all customer connections, shall be provided.

C.12 "Lube" oil component drawings and data shall be provided.

C.13 Electrical and instrumentation schematics and bills of materials for all systems shall be provided. The schematics shall show all alarms and shutdown limits (set points).

C.14 An electrical and instrumentation arrangement drawing and list of connections shall be carried out.

C.15 Tabulation of utility requirements shall be carried out.

C.16 Curves shall be furnished showing polytropic head and polytropic efficiency versus inlet volume flow curves for each section or casing on multiple-section or multiple-casing units, in addition to composite curves at 80 %, 90 %, 100 % and 105 % of rated speed.

C.17 Curves shall be furnished showing discharge pressure and shaft power versus inlet volume flow at rated conditions for each section or casing on multiple-section or multiple-casing units, in addition to composite curves of 80 %, 90 %, 100 % and 105 % of rated speed. For service with gases of varying molecular mass (M), curves shall also be furnished at maximum and minimum M. For air compressors, curves shall also be furnished at three additional specified inlet temperatures.

C.18 A curve shall be furnished showing the pressure above inlet pressure behind the balance drum versus unit loading of the thrust shoes, both in kilopascals (psi), using rated conditions as the curve basis. The curve shall extend from a pressure equal to inlet pressure behind the drum to a pressure corresponding to at least 3 500 kPa (500 psi) unit loading on the thrust shoes. Balance drum outer diameter, effective balance drum area, and expected and recommended maximum allowable pressure behind the balance drum shall be shown on the curve sheet.

C.19 A speed-versus-starting-torque curve shall be given. A speed-versus-torque curve for the compressor, superimposed over the motor-speed-versus-torque starting curve and with the motor values based on the specified starting voltage shall also be provided.

C.20 Vibration analysis data, is required, which shall include, the following:

a) number of vanes — each impeller;

b) number of vanes — each guide vane.

C.21 A lateral critical analysis report is required, which shall include, but is not limited to, the following:

a) complete description of the method used;

b) graphic display of critical speeds versus operating speeds;

c) graphic display of bearing and support stiffness and its effect on critical speeds;

d) damped unbalanced response analysis (see 4.9.2.4);

e) journal static loads;

f) stiffness and damping coefficients;

g) tilting-pad bearing geometry and configuration, including:

   1) pad angle (arc) and number of pads,

   2) pivot offset,

3) pad clearance (with journal radius, pad bore radius, and bearing-set bore radius), and

4) preload.

C.22 Torsional critical analysis report shall be provided, which shall include, but is not limited, to the following:

a) complete description of the method used;

b) graphic display of the mass elastic system;

c) tabulation identifying the mass moment and torsional stiffness of each component identified in the mass elastic system;

d) graphic display of exciting forces versus speed and frequency;

e) graphic display of torsional critical speeds and deflections (mode-shape diagram);

f) effects of alternative coupling on analysis (if required).

C.23 A transient torsional analysis for all synchronous motor driven units shall be provided.

C.24 The allowable flange loading for all customer's casing connections, including anticipated thermal movements referenced to a defined point, shall be given.

C.25 An alignment diagram, including recommended coupling limits during operation shall be provided. All shaft-end position changes and support growth from a reference ambient temperature of 15 °C (60 °F), or another temperature specified by the purchaser, shall be shown. Include the recommended alignment method and cold setting targets.

C.26 Welding procedures for fabrication and repair shall be given.

C.27 Certified hydrostatic test logs shall be given.

C.28 Mechanical running test logs shall be provided, including, but not limited to, the following:

a) oil flows, pressures, and temperatures;

b) vibration, including an x-y plot of amplitude and phase angle versus revolutions per minute during start-up and coast-down;

c) bearing metal temperatures;

d) observed critical speeds (for flexible rotors);

e) if specified, tape recording of real-time vibration data.

C.29 Performance test logs and report in accordance with ISO 5389 or ASME PTC 10 shall be provided.

C.30 Non-destructive test procedures, as itemized on the purchase order data sheets or the vendor drawing and data requirements form, shall be given.

C.31 Procedures for any special or optional tests (see 6.3.6) shall be given.

C.32 Certified mill test reports of items, as agreed upon shall be given.

C.33 Rotor balancing logs, including a residual unbalance report in accordance with annex D, shall be provided.

C.34 Rotor combined mechanical and electrical runout in accordance with 4.9.5.7 shall be given.

C.35 As-built data sheets shall be provided.

C.36 As-built dimensions (including nominal dimensions with design tolerances) and data shall be provided for the following listed parts:

a) shaft or sleeve diameters at

   1) thrust collar (for separate collars),

   2) each seal component,

   3) each wheel (for stacked rotors) or bladed disk,

   4) each interstage labyrinth, and

   5) each journal bearing;

b) each wheel or disk bore (for stacked rotors) and outside diameter;

c) each labyrinth or seal-ring bore;

d) thrust-collar bore (for separate collars);

e) each journal-bearing inside diameter;

f) thrust-bearing concentricity (axial runout);

g) metallurgy and heat treatment for

   1) shaft,

   2) impellers or bladed disks,

   3) thrust collar, and

   4) blades, vanes and nozzles.

C.37 An installation manual shall be provided describing the following (see 7.3.6.2):

a) storage procedures,

b) foundation plan,

c) grouting details,

d) setting equipment, rigging procedures, component masses and lifting diagrams,

e) coupling alignment diagram (per C.25),

f) piping recommendations, including allowable flange loads,

g) composite outline drawings for the driver/driven-equipment train, including anchor-bolt locations, and

h) dismantling clearances.

C.38 Operating and maintenance manuals shall be provided describing:

a) start-up;

b) normal shutdown;

c) emergency shutdown;

d) list of undesirable speeds (see 4.9.1.7);

e) lube-oil recommendations;

f) routine operational procedures, including recommended inspection schedules and procedures;

g) instructions for

   1) disassembly and reassembly of rotor in casing,

   2) rotor unstacking and restacking procedures,

   3) disassembly and reassembly of journal bearings (for tilting-pad bearings, the instruction shall include "go/no go" dimensions with tolerances for three-step plug gauges),

   4) disassembly and reassembly of thrust bearing,

   5) disassembly and reassembly of seals (including maximum and minimum clearances), and

   6) disassembly and reassembly of thrust collar;

h) performance data, including

   1) polytropic head and polytropic efficiency versus inlet volume flow,

   2) discharge pressure and shaft power versus inlet volume flow,

   3) balance drum differential pressure versus thrust loading, and

   4) speed versus starting torque;

i) vibration analysis data, per C.20 to C.23;

j) as-built data, including

   1) as-built data sheets,

   2) as-built dimensions or data, including assembly clearances,

   3) hydrostatic test logs, per C.27,

   4) mechanical running test logs, per C.28,

   5) rotor balancing logs, per C.33, and

   6) rotor mechanical and electrical runout at each journal, per C.34;

k) drawings and data, including

   1) certified dimensional outline drawing and list of connections,

   2) cross-sectional drawings and bills of materials,

   3) rotor assembly drawings and bills of materials,

4) thrust-bearing assembly drawings and bills of materials,

5) journal-bearing assembly drawings and bills of materials,

6) seal component drawings and bills of materials,

7) "lube" oil schematic and bills of materials,

8) "lube" oil assembly drawing and list of connections,

9) "lube" oil component drawings and data,

10) electrical and instrumentation schematics and bills of materials, and

11) electrical and instrumentation assembly drawings and list of connections;

l) maintenance information, comprising

1) maximum and minimum bearing, labyrinth, and seal clearances,

2) instructions for measuring and adjusting cold clearances,

3) rotor float allowance,

4) interference fits on parts that are required to be removed or replaced for maintenance or normally consumable spares,

5) runout and concentricity tolerances on parts of assembled rotors, and

6) balancing tolerances;

m) reassembly information, comprising

1) bolting sequence and torque values for such items as casing, bolting and internal bolting,

2) reassembly sequences together with required inspection checks,

3) adjustment procedures to achieve required positions, clearances and float,

4) detailed procedures for proportional checks, including settings and adjustments, and

5) coupling installation procedures.

C.39 The following spare-parts recommendations shall be included:

a) pattern, stock or production numbers and materials or construction;

b) identification of original equipment manufacturer of each part to determine interchangeability.

C.40 Progress reports and delivery schedule, including vendor buy-outs and milestones, shall be provided.

C.41 A list of drawings, including latest revision numbers and dates, shall be provided.

C.42 Shipping lists, including all major components that shall be shipped separately and the preservation, package and shipping procedure, shall be provided.

C.43 A list of special tools furnished for maintenance (see 5.6), shall be provided.

C.44 A technical data manual shall be provided, which shall include the following:

a) as-built purchaser's data sheets, per C.35;

b) certified performance curves, per C.17 and C.18;

c) drawings in accordance with 7.3.2;

d) as-built assembly clearances;

e) spare parts lists, in accordance with 7.3.5;

f) utility data, per C.15;

g) vibration data, C.20;

h) reports and data, per C.21, C.22, C.23, C.25, C.28, C.29, C.33 and C.34.

C.45 Material safety data sheets (in accordance with local regulations) shall be included.

C.46 Pressure vessel fabrication data including the manufacturer's data report, rubbings of the code stamp, stress relief charts and mill test reports shall be provided.

Annex D
(normative)

Procedure for determination of residual unbalance

D.1 General

This annex gives the procedure used to determine residual unbalance in machine rotors. Residual unbalance is the amount of unbalance remaining in a rotor after balancing. Unless otherwise specified, it shall be expressed in gram millimetres (ounce inches). Although some balancing machines may be set up to read out the exact amount of unbalance, the calibration can be in error. The only sure method of determining residual unbalance is to test the rotor with a known amount of unbalance.

D.2 Maximum allowable residual unbalance

D.2.1 The maximum allowable residual unbalance per plane shall be calculated using the equation given in 4.9.5.3.

D.2.2 If the actual static weight load on each journal is not known, assume that the total rotor weight is equally supported by the bearings.

EXAMPLE A two-bearing rotor of mass 3 000 kg (6 600 lb) would be assumed to impose a static weight force of 15 000 N (3 300 lbf) on each journal.

D.3 Residual unbalance check

D.3.1 General

D.3.1.1 When the balancing machine readings indicate that the rotor has been balanced to within the specified tolerance, a residual unbalance check shall be performed before the rotor is removed from the balancing machine.

D.3.1.2 For residual unbalance checking, a known trial weight is attached to the rotor sequentially in six (or twelve, if specified by the purchaser) equally spaced radial positions, each at the same radius. The check is run in each correction plane, and the readings in each plane are plotted on a graph using the procedure specified in D.3.2.

D.3.2 Procedure

D.3.2.1 Select a trial weight and radius that will be equivalent to between one and two times the maximum allowable residual: i.e. if U_{max} is 1 000 g·mm (1,4 oz·in), the trial weight should cause 1 000 g·mm to 2 000 g·mm (1,4 oz·in to 2,8 oz·in) unbalance.

D.3.2.2 Starting at the last known heavy spot in each correction plane, mark off the specified number of radial positions (six or twelve) in equal (60° or 30°) increments around the rotor. Add the trial weight to the last known heavy spot in one plane. If the rotor has been balanced very precisely and the final heavy spot cannot be determined, add the trial weight to any one of the marked radial positions.

D.3.2.3 In order to verify that an appropriate trial weight has been selected, operate the balancing machine and note the units of unbalance indicated on the meter. If the meter pegs, a smaller trial weight should be used. If little or no meter reading results, a larger trial weight should be used. (Little or no meter reading also generally indicates that the rotor was not balanced precisely enough.) If the trial weight was added to the heavy spot, the first meter reading should be at least twice that of the last reading taken before the trial weight was added. All checks shall be run using one sensitivity range on the unbalance machine.

D.3.2.4 Locate the mass at each of the equally spaced positions in turn and record the amount of unbalance indicated on the meter for each position.

D.3.2.5 Plot the readings on the residual unbalance work sheet (see Figure D.1) and calculate the amount of residual unbalance. The maximum meter reading occurs when the trial weight is added at the rotor's heavy spot; the minimum reading occurs when the trial weight is opposite the heavy spot. Thus, the plotted readings should form an approximately sinusoidal curve. An average of the maximum and minimum meter readings represents the effect of the trial weight. One-half the sinusoidal variation represents the effect of the residual unbalance.

D.3.2.6 Repeat the steps given in D.3.2.1 to D.3.2.5 for each balance plane. This procedure shall not be considered complete until the readings have been plotted and the residual unbalance has been calculated for each balancing plane. If the specified maximum allowable residual unbalance has been exceeded in any balance plane, the rotor shall be balanced more precisely and checked again. If a correction is made in any balance plane, the residual unbalance check shall be repeated in all planes.

D.4 Example

Using twelve trial weight positions, a residual unbalance check is run on a centrifugal compressor that operates at 3 600 r/min. The two bearing rotor is symmetrical and mass per the journal W is approximately one half the total mass of rotor 408,2 kg. Therefore, the maximum allowable residual unbalance in each plane is calculated as follows:

$$U_{\max} = \frac{6\,350 \times W}{N} = \frac{6\,350 \times 408{,}2}{3\,600} = 720$$

in gram millimetres.

The trial value should be 720 to 1 440 g·mm. In this case 720 g·mm is selected. The results of the trial mass runs are plotted in Figure D.1, the trial mass effect (z) on the meter readings can be calculated as the average of the maximum and minimum readings. The maximum reading shown in Figure D.1 is 9, and the minimum reading is 7; therefore, $z = 8$.

The average meter reading is equivalent to trial unbalance. A trial unbalance of 720 g·mm was selected, thus, a meter reading of 8 represents 720 g·mm. The residual unbalance's effect (y) on the meter reading is represented on the graph by one half the sinusoidal variation or one half the difference between the maximum and minimum readings.

Therefore $y = (9 - 7)/2 = 1$

The one unit of residual unbalance indicated on the meter readings can now be converted to residual unbalance in gram millimetres as follows:

$$U = \frac{y \times m_{tu}}{z}$$

where

U is the residual unbalance in gram millimetres;

y is the effect of residual unbalance on the meter reading (one half the difference between the maximum and minimum meter readings);

z is the effect of the trial unbalance mass on the meter reading (one-half the sum of the maximum and minimum meter readings);

m_{tu} is the trial unbalance mass;

$$U = \frac{1 \times 720}{8} = 90$$

in gram millimetres.

This is less than the maximum allowable residual unbalance of 720 g·mm calculated at the beginning of the procedure.

Figure D.2 shows an example of residual unbalance calculated and plotted on a completed worksheet.

Equipment (rotor) No.: ____________________

Purchase order No.: ____________________

Correction plane (inlet, drive-end, etc. — use sketch): ____________________

Balancing speed: ____________________ r/min

N = Maximum allowable rotor speed: ____________________ r/min

W = Weight of journal (closest to its correction plane): ____________________ kg (lb)

U_{max} = Maximum allowable residual unbalance =
6350 W/N (4 W/N) =

6350 × __________ kg/__________ r/min (4 × _____ lb/_____ r/min) ____________________ g·mm (oz·in)

Trail unbalance (2 × U_{max}) = ____________________ g·mm (oz·in)

R = Radius (at which weight will be placed):
Trial unbalance weight = trial unbalance / R = ____________________ mm (in)

__________ g·mm/ __________ mm (_____ oz·in/ _____ in) = ____________________ g (oz)

TEST DATA

Position	Amplitude	Angular position
1		
2		
3		
4		
5		
6		
Repeat 1		

ROTOR SKETCH

Test data graphic analysis

Step 1: Plot data on the polar chart (see next page). Scale the chart so the largest and smallest amplitude will fit conveniently.

Step 2: With the compass, draw the best fit circle through the six points and mark the centre of this circle.

Step 3: Measure the diameter of the circle in units of scale chosen in Step 1 and record: _____ units.

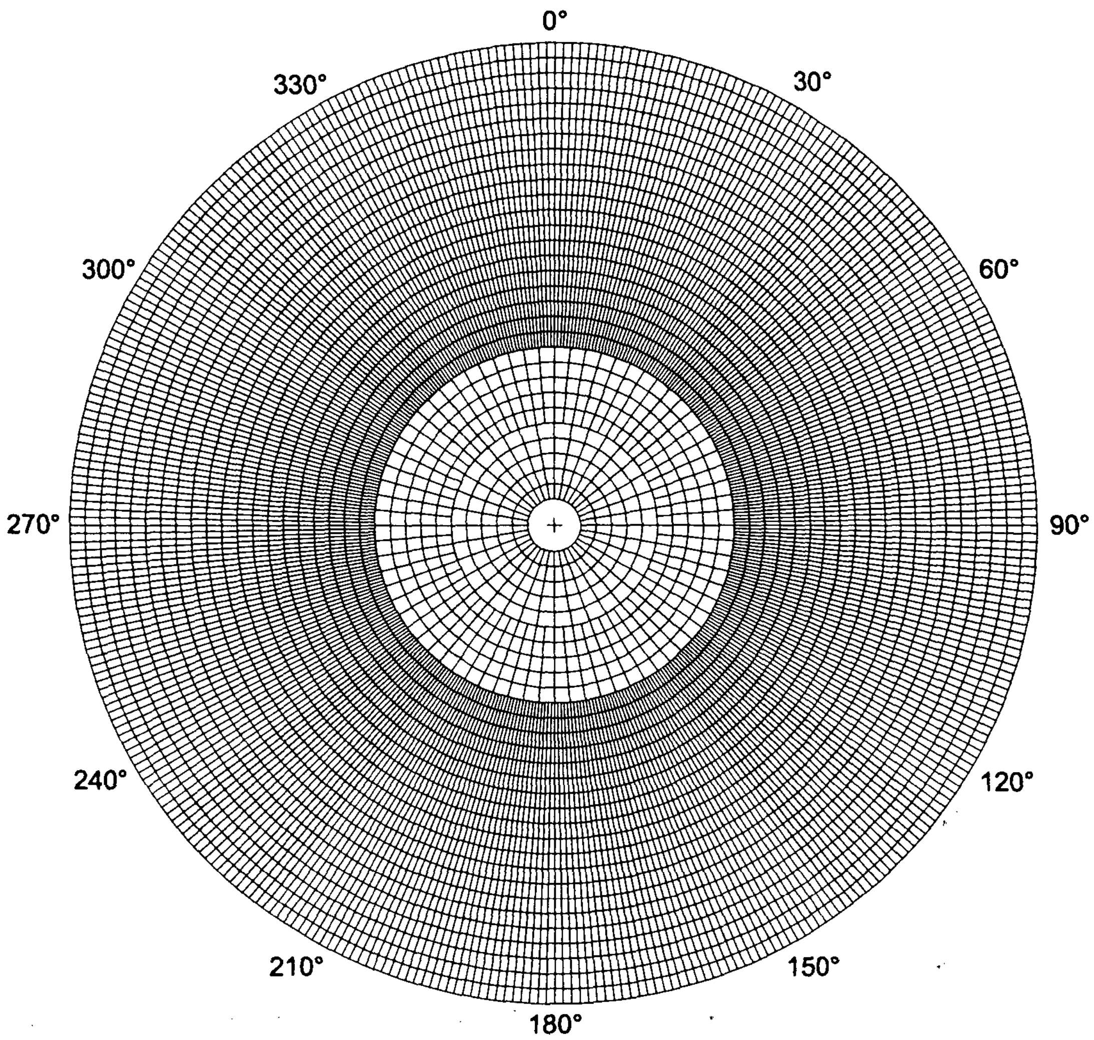
Step 4: Record the trial unbalance from above: _____ g·mm (oz·in).

Step 5: Double the trial unbalance in Step 4 (may use twice the actual residual unbalance): _____ g·mm (oz·in).

Step 6 Divide the answer in Step 5 by the answer in Step 3: _____ Scale factor.

You now have a correlation between the units in the polar chart and the g·mm (oz·in) of actual balance.

Figure D.1 — Residual unbalance work sheet



The circle drawn must contain the origin of the polar chart. If it does not, the residual unbalance of the rotor exceeds the applied test unbalance. Proceed with the balacing machine sensitivity check before rebalancing is attempted.

If the circle does contain the origin of the polar chart, the distance between origin of the chart and the centre of the circle is the actual residual unbalance present on the rotor correction plane. Measure the distance in units of scale chosen Step 1 and multiply this number by the scale factor determined in Step 6. Distance in units of scale between origin and centre of the circle times scale factor equals actual residual balance.

Record actual residual unbalance ______ g·mm (oz·in)

Record allowable residual unbalance (from polar chart) ______ g·mm (oz·in)

Correction plane ______________ for rotor No. ______ (has/has not) passed

By ____ Date ________________________

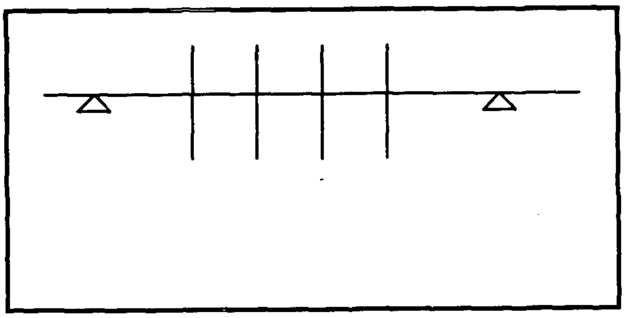
Figure D.1 — Residual unbalance work sheet *(continued)*

Equipment (rotor) No.:	C-101
Purchase order No.:	
Correction plane (inlet, drive-end, etc. — use sketch)	A
Balancing speed:	800 r/min
N = Maximum allowable rotor speed:	10 000 r/min
W = Weight of journal (closest to its correction plane):	410 kg
U_{max} = Maximum allowable residual unbalance = 6 350 W/N =	
6 350 × 410 kg/ 10 000 r/min =	260 g·mm
Trial unbalance (2 × U_{max}) =	520 g·mm
R = Radius (at which weight will be placed): Trial unbalance weight = trial unbalance / R =	175 mm
520 g·mm / 175 mm =	3,0 g

TEST DATA

Position	Amplitude	Angular position
1	16,2	0°
2	12,0	60°
3	12,5	120°
4	17,8	180°
5	24,0	240°
6	23,0	300°
Repeat 1	16,2	0°

ROTOR SKETCH



Test data graphic analysis

Step 1: Plot data on the polar chart (see next page). Scale the chart so the largest and smallest amplitude will fit conveniently.

Step 2 With the compass, draw the best fit circle through the six points and mark the centre of this circle.

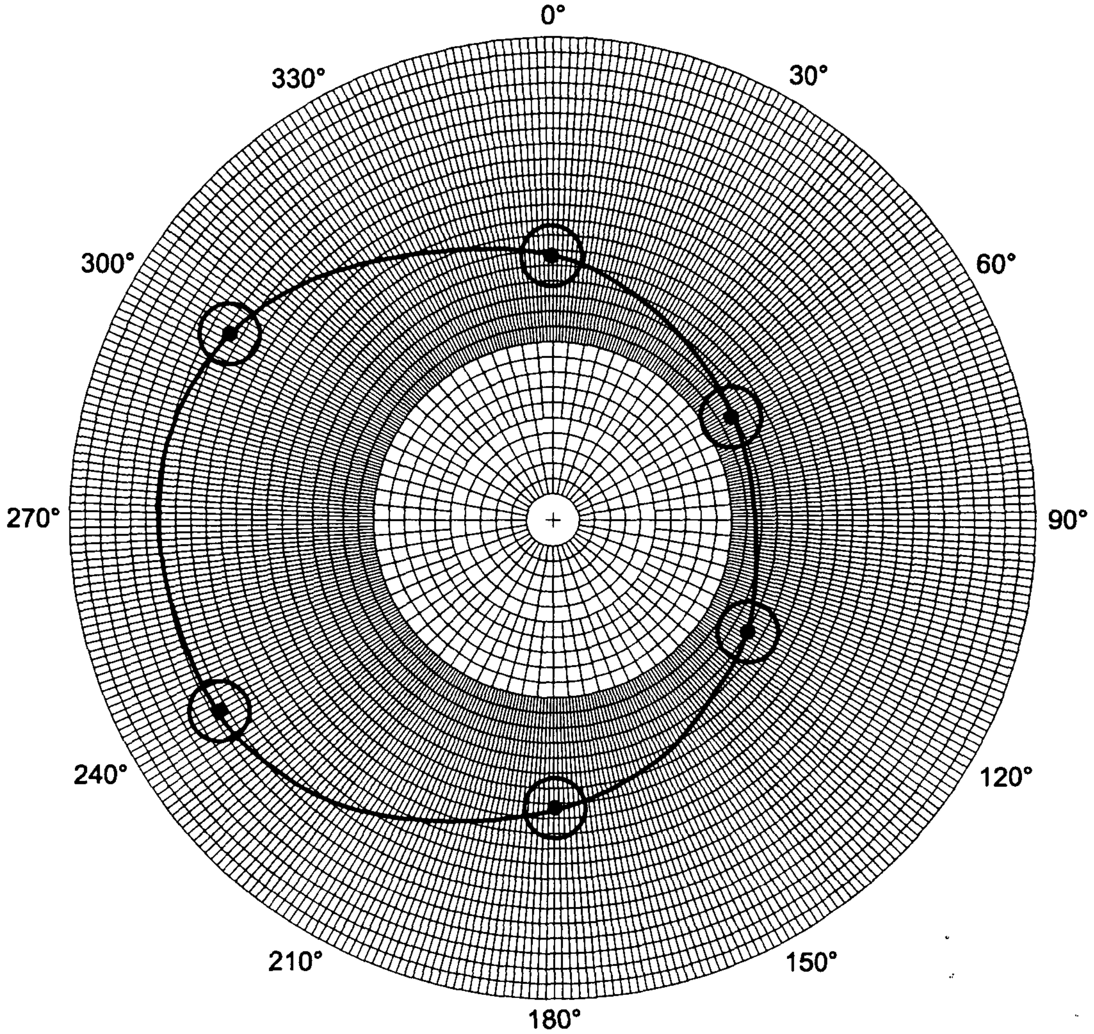
Step 3: Measure the diameter of the circle in units of scale chosen in Step 1 and record: 35 units

Step 4: Record the trial unbalance from above: 520 g·mm

Step 5: Double the trial unbalance in Step 4 (may use twice the actual residual unbalance): 1 040 g·mm

Step 6: Divide the answer in Step 5 by the answer in Step 3: 30,0 Scale factor

Figure D.2 — Residual unbalance work sheet — Sample calculations



The circle drawn must contain the origin of the polar chart. If it does not, the residual unbalance of the rotor exceeds the applied test unbalance. Proceed with the balacing machine sensitivity check before rebalancing is attempted.

If the circle does contain the origin of the polar chart, the distance between origin of the chart and the center of your circle is the actual residual unbalance present on the rotor correction plane. Measure the distance in units of scale you choose in Step 1 and multiply this number by the scale factor determined in Step 6. Distance in units of scale between origin and center of the circle times scale factor equals actual residual balance.

Record actual residual unbalance ______ 6,5 × 30 = 195 ______ g·mm

Record allowable residual unbalance (from polar chart) ______ 260 ______ g·mm

Correction plane ___A___ for rotor No. ___C-101___ (has/~~has not~~) passed

By ___John Inspector___ Date ___1998-11-16___

Figure D.2 — Residual unbalance work sheet — Sample calculations *(continued)*

Annex E
(informative)

Rotor dynamic logic diagrams

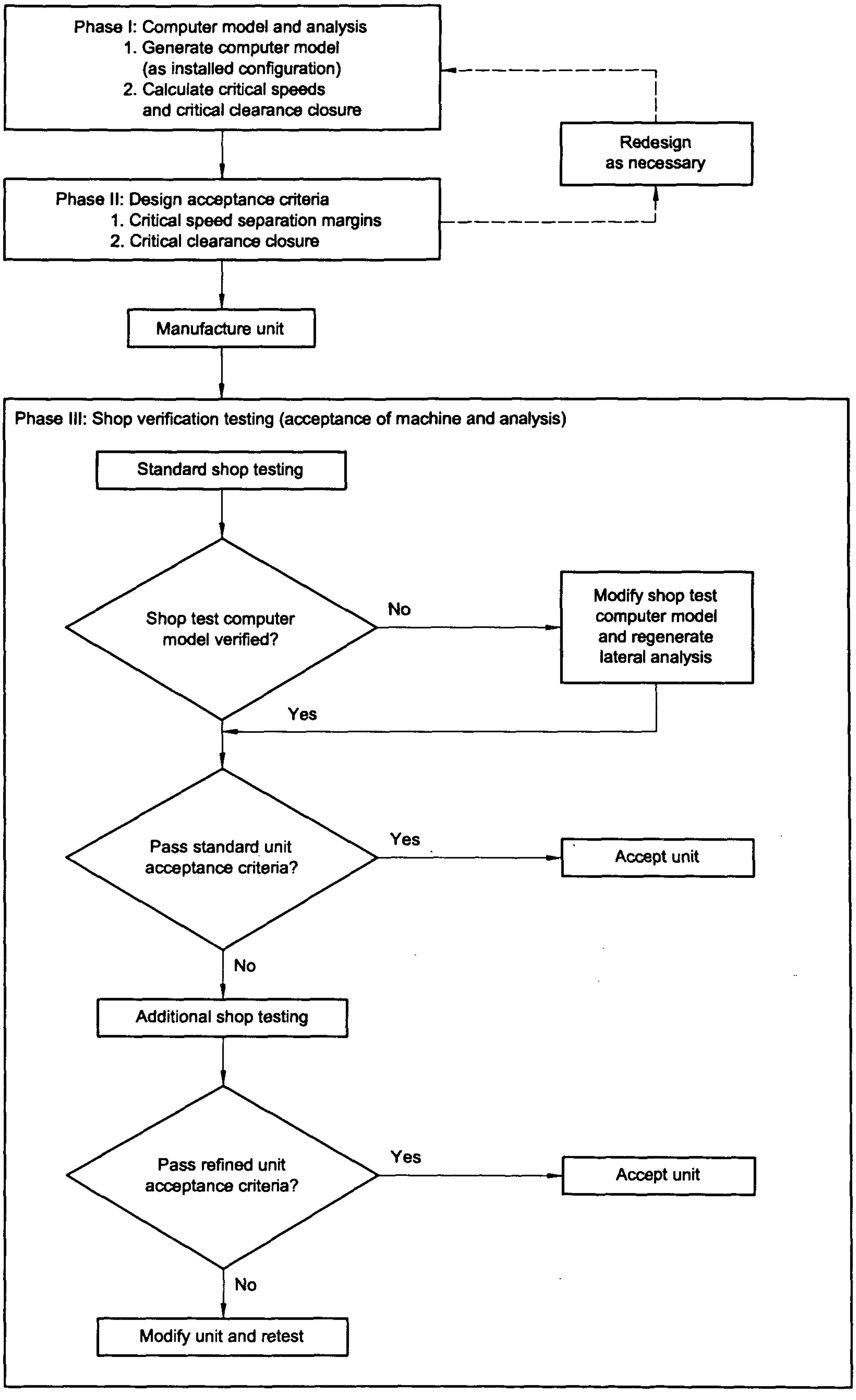


Figure E.1 — Three-phase vibration acceptance program and flow chart

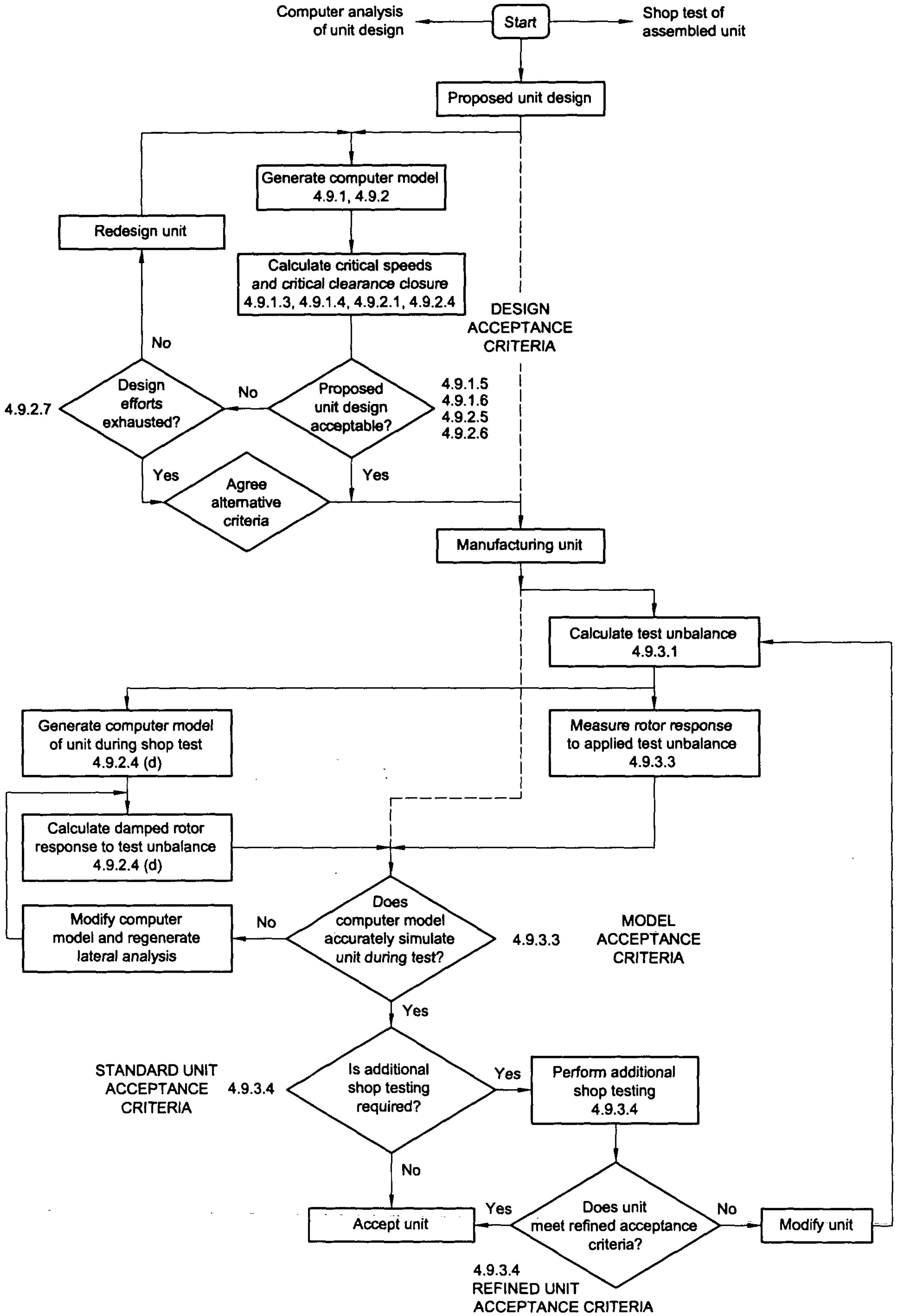


Figure E.2 — Detailed flow chart of vibration acceptance program

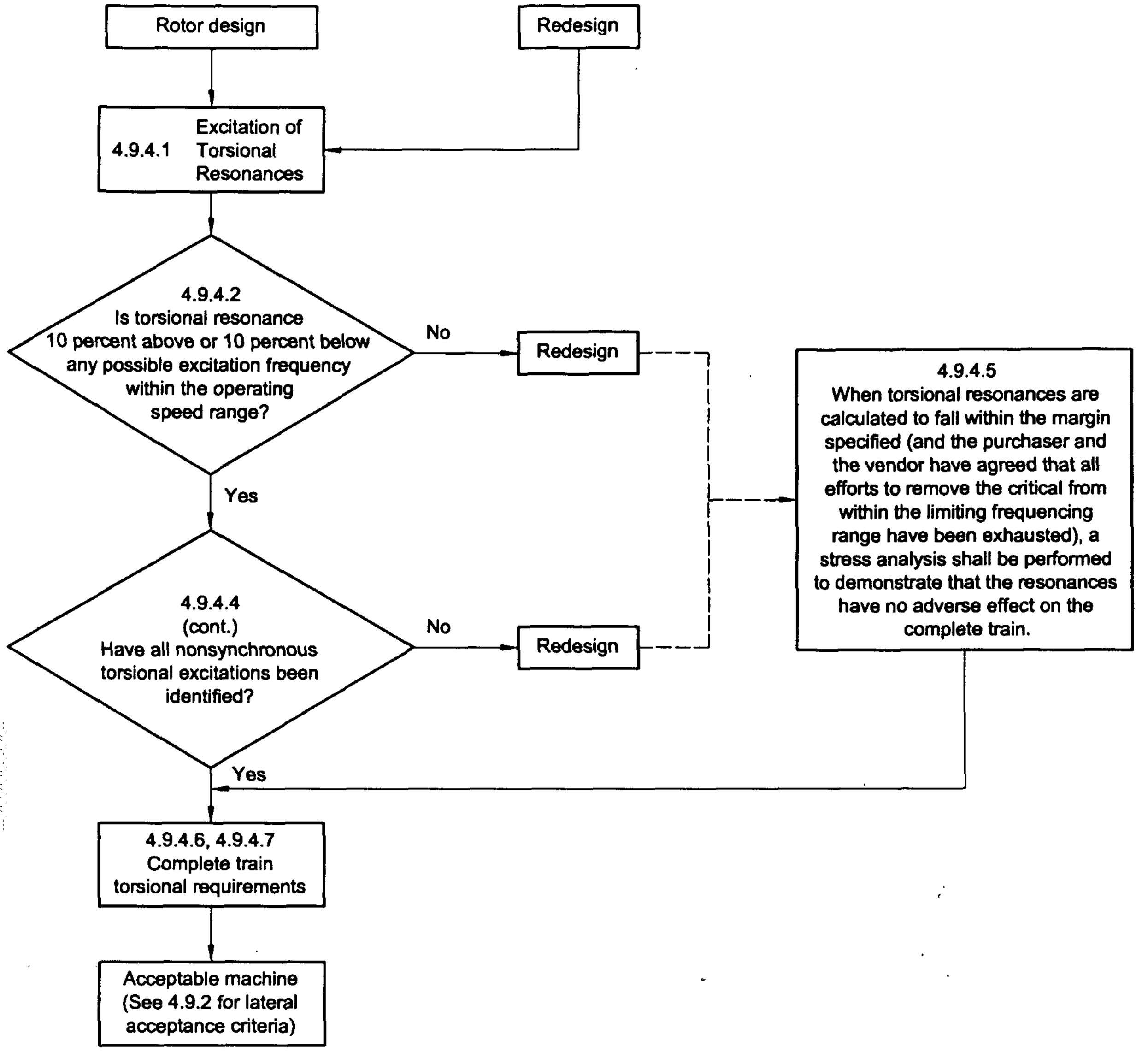
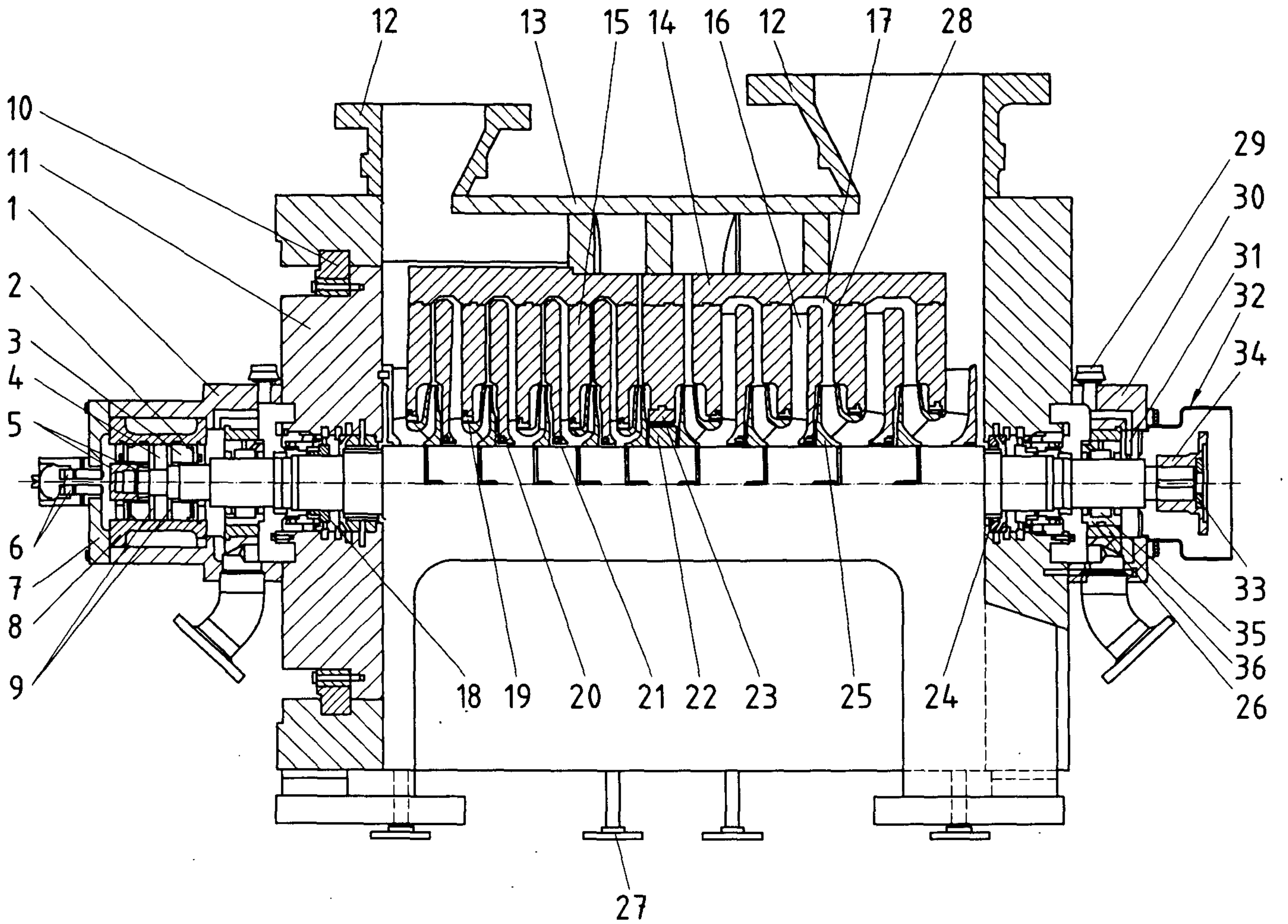


Figure E.3 — Rotor dynamics logic diagram (torsional analysis)

Annex F
(informative)

Centrifugal compressor nomenclature



NOTE Some compressors may use bolted-head construction.

Key

1 Bearing housing
2 Thrust shims
3 Thrust base ring
4 Thrust collar
5 Thrust collar locknuts
6 Axial-position probes
7 End cover
8 Thrust-bearing carrier
9 Thrust-bearing shoes
10 Shear ring
11 End head
12 Main process connections
13 Casing
14 Inner barrel
15 Diaphragm
16 Return channel
17 Crossover
18 End seal
19 Impeller-eye labyrinth
20 Shaft sleeve
21 Diaphragm labyrinth
22 Balance piston
23 Balance piston labyrinth
24 Labyrinth seal
25 Impeller
26 Journal-bearing housing
27 Case drains
28 Diffuser passage
29 Beather/Vent
30 Bearing house
31 Radial-vibration probe
32 Coupling guard
33 Coupling locknut
34 Coupling hub
35 Journal-bearing shoes
36 Journal-bearing carrier

Figure F.1 — Centrifugal compressor nomenclature

Annex G
(normative)

Forces and moments

G.1 General

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

G.2 Equations

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

G.2.2 All compressor nozzles shall be designed at least to withstand the total resultant force, F_r, and the moment, M_r, as calculated in the following equations:

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

Or, in US customary units:

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

where

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

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

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

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

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

$$D_e = D_{nom}$$

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

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

in millimetres

Or, in US customary units:

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

in inches

where

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

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

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

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

Or, in US customary units:

$$2F_c + M_c \leqslant 462\, D_c$$

where

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

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

$D_c = D_{calc}$

where D_{calc} = diameter [in millimetres (inches)] of one circular opening whose area is equal to the total area of all the inlet, sidestream and discharge openings. If D_{calc} is greater than 230 mm (9 in), then:

$$D_c = \frac{(460 + D_{calc})}{3}$$

in millimetres

Or, in US customary units:

$$D_c = \frac{(18 + D_{calc})}{3}$$

in inches

G.2.4 The individual components (see Figure G.1) of these combined resultants should not exceed

$F_x = 16{,}1\, D_c$ $\quad M_x = 24{,}6\, D_c$

$F_y = 40{,}5\, D_c$ $\quad M_y = 12{,}3\, D_c$

$F_z = 32{,}4\, D_c$ $\quad M_z = 12{,}3\, D_c$

Or, in US customary units:

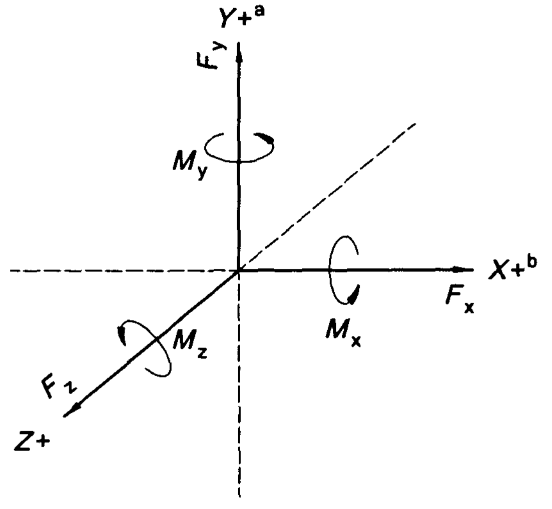
$F_x = 92\, D_c$ $\quad M_x = 462\, D_c$

$F_y = 231\, D_c$ $\quad M_y = 231\, D_c$

$F_z = 185\, D_c$ $\quad M_z = 231\, D_c$

G.2.5 These values of allowable forces and moments pertain to the compressor structure only. They do not pertain to the forces and moments in the connecting piping, flanges or flange bolting, which should not exceed the allowable stress as defined by the applicable codes and regulatory bodies.

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



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

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

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

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

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

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

[a] Vertical

[b] Parallel to compressor shaft

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

Annex H
(informative)

Inspector's checklist

This inspector's checklist shown in Table H.1 represents a summary of the inspection points mentioned this International Standard. The final inspection plan shall be agreed between purchaser and vendor.

Table H.1 — Inspector's checklist

Item	Clause	Reviewed	Observed	Witnessed	Inspected by	Status
Mechanical inspection						
Casing connection accessibility	4.4.1.2					
Nozzle flange dimensions	4.4.2					
Casing connections size/finish	4.4.1 4.4.2 4.4.3					
Coupling fit	4.6.2					
Shaft and thrust collar surface finishes	4.6.5 4.6.13					
Rotor identification	4.6.6					
Shaft and thrust collar electrical and mechanical runout	4.6.5 4.6.13 4.9.5.8					
Shaft gauss	4.6.17					
Rotor balance (balance machine residual)	4.9.5.3 4.9.5.4 4.9.5.5					
Rotor arrow/nameplate data/units	4.12					
Equipment feet (vertical and horizontal) jackscrews	5.3.1.2					
Foot/baseplate shims	5.3.1.2					
Mounting surfaces epoxy primed	5.3.1.2					
Mounting surface coated	5.3.1.2					
Vendor data records	6.2.1.1					
Final assembly maintenance and running clearances	6.2.1.1.g					
Surface and subsurface inspection	6.2.1.3					
Equipment cleanliness	6.2.1.5					
Material hardness	6.2.1.6					
Oil system cleanliness	6.3.4.1.3					
Material inspection						
Material inspection certification/testing	6.2.2.1					
Mechanical running test						
Contract shaft seals and bearings	6.3.4.1.1					
Oil flows, pressures and Temperatures as specified	6.3.4.1.2					
No leaks observed	6.3.4.1.4					
Control devices operational	6.3.4.1.5					
Protective devices operational	6.3.4.1.5					
Testing with contract coupling	6.3.4.1.7					

Table H.1 *(continued)*

Item	Clause	Reviewed	Observed	Witnessed	Inspected by	Status
Contract vibration instrumentation	6.3.4.1.8					
15-minute test at trip speed complete	6.3.4.2.2					
4-hour test at maximum continuous speed complete	6.3.4.2.3					
Inner seal oil leakage rate measured	6.3.4.2.4					
Vibration measured at different speeds	6.3.4.3.1					
Vibration acceptance	4.9.5.6					
Non synchronous vibration criteria met	6.3.4.3.2					
Vibration plots completed	6.3.4.3.3					
Lateral critical speeds as predicted	6.3.4.3.4					
Tape recordings complete	6.3.4.3.6					
Bearing inspection after test satisfactory	6.3.4.4.1					
Spare rotor fit and run	6.3.4.4.4					
Casing maximum seal pressure test complete	6.3.5.2					
Casing rated discharge pressure test complete	6.3.5.3					
Copies of recorded test data obtained	6.3.5.5					
Optional tests						
Performance test complete	6.3.6.2.1					
Complete unit test performed	6.3.6.3					
Tandem test complete	6.3.6.4					
Gear test complete	6.3.6.5					
Helium test complete	6.3.6.6					
Sound level test complete	6.3.6.7					
Auxiliary equipment testing complete	6.3.6.8					
Post test casing internal inspection complete	6.3.6.9					
Full pressure/full load/full speed test complete	6.3.6.10					
Post test inspection of hydraulic coupling fit	6.3.6.11					
Spare parts test complete	6.3.6.12					
Preparation for shipment						
Special tools complete	5.6.2					
Preparation complete	6.4.1 6.4.3					
Exterior surface painting acceptable	6.4.3, a)					
Rust preventative (exterior and interior)	6.4.3, b) 6.4.3, c)					
Internal steel areas coated	6.4.3, d)					
Openings covered, studs shipped lose or installed complete with nuts	6.4.3, e) 6.4.3, f) 6.4.3, g)					
Identification of lifting points / lugs	6.4.3, h)					
Tags complete	6.4.3, i) 6.4.4 6.4.5					
Exposed shafts and couplings wrapped	6.4.3, l)					
Spare parts complete	7.3.5					
Installation instructions shipped	7.3.6					

Annex I
(informative)

Typical gas seal testing considerations

I.1 Self-acting gas seal shop test

I.1.1 The self-acting gas seal shall be tested at the seal vendor's shop. Details of the test procedure and the performance on the test gas shall be mutually agreed upon by the purchaser, compressor vendor and seal vendor.

I.1.2 Test records shall include time, temperatures, pressures, speed, power and flow across each sealing interface. The test record shall note any discontinuities in the measured parameters.

I.2 Overspeed test

Prior to assembly of the seal, the rotating face shall be subject to an overspeed test of 115 % of maximum continuous speed for one minute.

I.3 Static test

Increase the pressure across each sealing interface to maximum sealing pressure in at least four increments, including normal sealing pressure. Hold each pressure to ensure steady state. For gauge pressures of less than 500 kPa (70 psi) only two measurements at maximum sealing pressure and half the maximum sealing pressure are required.

I.4 Dynamic test

I.4.1 Maintain seal gas pressure or pressures at normal sealing pressure, and increase from zero speed to maximum continuous speed in at least four increments. Record two sets of data at each speed increment. Ensure steady state.

I.4.2 At normal sealing pressure, run for 15 min at 110 % of maximum continuous speed.

I.4.3 At normal sealing pressure, run for 60 min at maximum continuous speed.

I.4.4 Reduce speed to zero, reduce the pressure to the minimum sealing pressure, then increase to maximum continuous speed. Increase pressure to maximum sealing pressure in at least four increments. Record two sets of data at each test point. Ensure steady state.

I.4.5 Reduce pressure to normal sealing pressure run for 15 min.

I.4.6 Reduce speed to zero. Maintain normal sealing pressure, record two sets of static data.

I.4.7 For a tandem seal that is normally pressurized across only one sealing interface, repeat I.4.1 to I.4.6 inclusive for the second sealing interface.

I.4.8 Pressurize the seal for normal sealing at normal sealing pressure. Record the static data.

I.4.9 Gradually increase the speed to maximum continuous speed and hold for 15 min. Record data every 5 min.

I.4.10 Repeat I.4.8 and I.4.9 to steady or decreasing leakage trend.

I.4.11 Reverse running test of a seal at agreed conditions if specified.

I.5 Visual inspection

Following the test, disassemble the seal, ensuring that critical parts are matched marked. Examine the components for wear, build-up and general condition. Record any observations. Reassemble the seal.

I.6 Confirmation test

After reassembly, repeat I.4.8 and I.4.9 to verify proper reassembly of the seal.

I.7 Special optional tests

The purchaser may specify additional tests such as temperature cycling, breakaway and running torque. Test details shall be mutually agreed upon by the purchaser, compressor vendor and seal vendor.

Subject to agreement between purchaser and vendor, the following test may replace the tests specified in I.4.6 and I.4.8 to I.6.

Static test with the seals still hot, increasing the pressure across each sealing interface to maximum sealing pressure in at least four increments, including normal sealing pressure. Hold each pressure to ensure steady state. For gauge pressures less than 500 kPa (70 psi) only two measurements at maximum sealing pressure and half the maximum sealing pressure are required.

If the static leakage before and after test are not comparable within ± 30 % then the seal shall be dismantled for visual inspection of the seal faces and O-rings. Signs of contact or damage shall be cause for rejection. If static leakage is comparable then the seal should not be dismantled.

I.8 Balancing

Rotating seal parts shall be balanced unless otherwise specified.

Annex J
(informative)

Application considerations for active magnetic bearings

J.1 General

This annex outlines the special considerations that are necessary if applying active magnetic bearings systems. These areas require detailed interaction between the compressor vendor, the bearing vendor and the end user.

An active magnetic bearing is a bearing which generates load-bearing capacity by means of actively controlled electromagnets. These magnets are positioned radially around the circumference of a shaft to comprise a journal bearing, or are positioned on either side of a rotating disc to form a double-acting thrust bearing. Materials used in both the stationary and rotating parts are magnetic iron or steel.

Shaft position sensors are used to detect the shaft axial and radial positions. The sensor signals are input to a control system that modulates the current flowing through power amplifiers to the electromagnets to stably maintain the shaft position in the centre of the magnets.

J.2 Bearing loads

J.2.1 It is difficult to predict all the axial and radial loads on bearings. Active magnetic bearings have a lower inherent transient overload capacity than hydrodynamic bearings.

J.2.2 For accurate prediction of the bearing load requirements, it is critical that the purchaser and compressor vendor mutually define the operating envelope, including: start-up, shut-down, emergency and unusual operating conditions.

J.2.3 Bearings should be selected to have a load capacity higher than the calculated static and dynamic loads at the most adverse operating condition, including operation at minimum and maximum flows (see 4.7.3.3 and 4.7.3.7).

J.2.4 The amount of additional bearing capacity should depend on the confidence in the accuracy of the load prediction.

J.2.5 Magnetic bearings should be tested to verify their force generating capability. The test procedure should be mutually agreed.

J.2.6 The allowable operating envelope for an active magnetic bearing machine may be different than for a hydrodynamic bearing machine.

J.2.7 Special testing may be considered to simulate site bearing loading.

J.3 Balance

Special rotor balancing set-ups may be required.

J.4 Rotating elements

The bearing area and the sensor viewing area on the shaft may be sleeved (see 4.6.5).

J.5 Auxiliary bearing systems

Auxiliary bearing systems are required to support the rotor when the active magnetic bearings are de-energized at rest, and to permit rundown if the active magnetic bearing system is de-energized at running speed. Considerations should include

a) location of the auxiliary bearing relative to other components,

b) axial loadings and location of the auxiliary bearing considering thermal expansion, and inertial landing loads,

c) life, i.e. the number of uncontrolled rundowns allowed before inspection of replacement of the auxiliary bearings, and

d) labyrinth clearances with the rotor resting on the auxiliary bearings.

J.6 Rotor dynamic design

J.6.1 Bearing stiffness and damping characteristics are adjustable electronically and can be adapted to optimize rotor dynamic behaviour.

J.6.2 Rotor dynamics should be evaluated with both normal magnetic bearing support and on auxiliary bearings under rundown conditions, and should consider sensor location relative to rotor nodes and bearings.

J.6.3 An estimate should be made of the maximum rotor unbalance which will not overload the bearings.

J.7 Operator interface

J.7.1 Minimum instrumentation should include

a) vibration level per axis,

b) bearing current per amplifier-controlled sector,

c) bearing temperature per bearing located in the carrier sector to control the hottest point of the bearing, and

d) bearing control panel diagnostic.

J.7.2 Other information can be made available for monitoring and analysing compressor and bearing system behaviour.

Vibration levels on each controlled axis are required to assess the relative health of the bearing system. Similarly, bearing currents and temperatures for each bearing segment or amplifier-specific portion are required.

J.8 Protection from the process environment

Considerations should include the following

a) compatibility of the magnet assembly with the process environment.

NOTE 1 Exposure of the magnetic bearing to the process requires the compatibility of the bearing windings, their insulation, the laminations and any encapsulant.

b) electrical feed through the pressure boundary. Location should be above the shaft centreline if possible.

NOTE 2 Avoidance of connection locations in areas subject to process liquid pooling.

c) bearing heating during shutdown.

d) low points drains in bearing cavities.

J.9 Schedule

Allow time in the compressor vendor's shop and on-site for calibrating the control system.

J.10 Bearing cooling

Cooling is required to remove heat from electrical losses in the bearing windings and heat generated by windage losses.

J.11 Electrical design

Considerations should include the following

a) Electrical insulation.

NOTE 1 Local regulations are usually used to describe active magnetic bearing winding insulation systems.

b) Insulation on bearing laminations.

NOTE 2 Failures due to induction heating can be sudden and cause substantial damage. This is related to design for manufacturing process, and also quality assurance and control.

c) Length of the cable run from the control system to the bearings.

d) An uninteruptable power supply or battery backup to maintain shaft levitation during electrical utility disruption.

Backup systems are recommended for either continuous operation in the event of a power disturbance, or to permit safe and orderly shutdown.

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[7] ASME B 36.10M, *Welded and seamless wrought steel pipe*

[8] ASTM A 148/A 148M, *Steel castings, high strength, for structural purposes*

[9] ASTM A 203/A 203M, *Pressure vessel plates, alloy steel, nickel*

[10] ASTM A 216/A 216M, *Steel castings, carbon, suitable for fusion welding, for high-temperature service*

[11] ASTM A 217/A 217M, *Steel castings, martensitic stainless and alloy, for pressure-containing parts, suitable for high-temperature service*

[12] ASTM A 240/A 240M, *Standard specification for chromium and chromium-nickel stainless steel plate, sheet, and strip for pressure vessels*

[13] ASTM A 266/A 266M, *Standard specification for carbon steel forgings for pressure vessels components*

[14] ASTM A 278, *Standard specification for gray iron casting for pressure — Containing parts for temperatures up to 650 °F*

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

[16] ASTM A 285/A 285M, *Standard specification for pressure vessel plates, carbon steel, low-and intermediate-tensile strength*

[17] ASTM A 336/A 336M, *Standard specification for alloy steel forgings for pressure and high-temperature parts*

[18] ASTM A 351/A 351M, *Standard specification for castings, austenitic, austenitic-ferritic (Duplex), for pressure-containing parts*

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

[20] ASTM A 353/A 353M, *Standard specification for pressure vessel plates, alloy steel, 9 percent nickel, double-normalized and tempered*

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

[22] ASTM A 414/A 414M, *Standard specification for steel sheet, carbon, for pressure vessels*

[23] ASTM A 436, *Standard specification for austenitic gray iron castings*

[24] ASTM A 470, *Standard specification for vacuum-treated carbon and alloy steel forgings for turbine rotors and shafts*

[25] ASTM A 473, *Standard specification for stainless steel forgings*

[26] ASTM A 48, *Standard specification for gray iron castings*

[27] ASTM A 487/A 487M, *Standard specification for steel castings suitable for pressure service*

[28] ASTM A 494/A 494M, *Standard specification for castings, nickel and nickel alloy*

[29] ASTM A 508/A 508M, *Standard specification for quenched and tempered vacuum-treated carbon and alloy steel forgings for pressure vessels*

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

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

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

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

[34] ASTM A 537/A 537M, *Standard specification for pressure vessel plates, heat-treated, carbon-manganese-silicon steel*

[35] ASTM A 543/A 543M, *Standard specification for pressure vessel plates, alloy steel, quenched and tempered nickel-chromium-molybdenum*

[36] ASTM A 553/A 553M, *Standard specification for pressure vessel plates, alloy steel, quenched and tempered 8 and 9 percent nickel*

[37] ASTM A 571, *Standard specification for austenitic ductile iron castings for pressure-containing parts suitable for low-temperature service*

[38] ASTM A 583, *Standard specification for cast steel wheels for railway service*

[39] ASTM A 693, *Standard specification for precipitation-hardening stainless and heat-resisting steel plate, sheet, and strip*

[40] ASTM A 705/A 705M, *Standard specification for age-hardening stainless steel forgings*

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

[42] ASTM A 744/A 744M, *Standard specification for castings, iron-chromium-nickel, corrosion resistant, for severe service*

[43] ASTM A 747/A 747M, *Standard specification for steel castings, stainless, precipitation hardening*

[44] ASTM B 23, *Standard specification for white metal bearing alloys (known commercially as 'babbitt metal')*

[45] ASTM B 26/B 26M, *Standard specification for aluminum-alloy sand castings*

[46] ASTM B 29, *Standard specification for refined lead*

[47] ASTM B 127, *Standard specification for nickel-copper alloy (UNS N04400) plate, sheet and strip*

[48] ASTM B 164, *Standard specification for nickel-copper alloy rod, bar, and wire*

[49] ASTM B 367, *Standard specification for titanium and titanium alloy castings*

[50] ASTM B 462, *Specification for Forged or Rolled UNS N06030, UNS N06022, UNS N06200, UNS N08020, UNS N08024, UNS N08026, UNS N08367, UNS N10276, UNS N10665, UNS N10675 & UNS R20033 Alloy Pipe Flanges, Forged Fittings & Valves & Parts for Corrosive High-Temperature Svc*

[51] ASTM B 574, *Specification for low-carbon nickel-molybdenum-chromium, low-carbon nickel-chromium-molybdenum, low-carbon nickel-molybdenum-chromium-tantalum, low-carbon nickel-chromium-molybdenum-copper, and low-carbon nickel-chromium-molybdenum-tungsten alloy rod*

[52] ASTM DS 56E, *ASTM Publication: Metals and alloys in the unified numbering system*

[53] ASTM E 125, *Standard reference photographs for magnetic particle indications on ferrous castings*

[54] NEMA[8] SM 23, *Steam turbines for mechanical drive service*

[55] SAE[9] AMS 4646, *Hose assembly, polytetrafluoroethylene, CRES reinforced, 400 degrees F, 4000 psi, flared, 45 degrees to 90 degrees, CRES fittings*

[56] SAE AMS 4676, *Nickel-copper alloy corrosion resistant, bars and forgings 66.5Ni — 3.0Al — 0.62Ti — 28Cu hot-finished precipitation hardenable (UNS N05500)*

8) US National Electric Manufacturers Association

9) (American) Society of Automotive Engineers

ICS 71.120.99; 75.180.20

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