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МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ

Compressors for the process industry — Screw and related types — Specifications and data sheets for their design and construction

Compresseurs pour l'industrie de procédé — Types à vis et connexes — Spécifications et feuilles de données pour la conception et la construction

Reference number
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Foreword

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

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 8010 was prepared by Technical Committee ISO/TC 118, *Compressors, pneumatic tools and pneumatic machines*.

Users should note that all International Standards undergo revision from time to time and that any reference made herein to any other International Standard implies its latest edition, unless otherwise stated.

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Annexes

Compressors for the process industry — Screw and related types — Specifications and data sheets for their design and construction

0 Introduction

This International Standard contains two annexes in addition to the main text.

Annex A, which contains instructions subject to agreements in the contract, is given for information and guidance only and is not an integral part of this International Standard.

Annex B, which contains the data sheets, is an integral part of this International Standard.

1 Scope

This International Standard specifies the technical requirements for the design and construction of screw and related types of compressors used in the process industry. It also details the documentation requirements.

2 Field of application

This International Standard applies to rotary screw and related types of compressors used in the process industry. It covers the minimum requirements for dry and liquid-injected compressors and vacuum pumps with intermeshing rotors, e.g. Roots blowers.

This International Standard also covers certain requirements for compressor drivers, drive equipment, lubricating systems, controls, instrumentation and auxiliary equipment.

The compressors to which this International Standard applies are not normally used for critical process applications in refineries.

In addition, this International Standard will not normally apply to portable and other air compressors providing air power (for pneumatic tools etc.) nor to standard utility refrigeration compressors.

3 References

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

ISO 898-1, *Mechanical properties of fasteners — Part 1: Bolts, screws and studs.*

ISO 1000, *SI units and recommendations for the use of their multiples and of certain other units.*

ISO 1217, *Displacement compressors — Acceptance tests.*

ISO 1219, *Fluid power systems and components — Graphic symbols.*

ISO 1940, *Balance quality of rotating rigid bodies.*

ISO 2441, *Pipeline flanges for general use — Shapes and dimensions of pressure-tight surfaces.*

ISO 3511, *Process measurement control functions and instrumentation — Symbolic representation —*

Part 1: Basic requirements.

Part 2: Extension of basic requirements.

Part 3: Detailed symbols for instrument interconnection diagrams.

ISO 3989, *Acoustics — Measurement of airborne noise emitted by compressor units including prime movers —*

Part 1: Engineering method for determination of sound power levels. [1)]

Part 2: Method for determination of compliance with noise limits. [1)]

ISO 4126, *Safety valves — General requirements.*

ISO 7000, *Graphical symbols for use on equipment — Index and synopsis.*

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

IEC Publication 79, *Electrical apparatus for explosive gas atmospheres.*

IEC Publication 85, *Thermal evaluation and classification of electrical insulation.*

1) At present at the stage of draft.

4 Unit system

SI units (Système international d'unités) are used throughout this International Standard (see ISO 1000).

However, in addition to SI units, this International Standard also uses some non-SI units accepted by ISO 1000. These units are as follows:

- for pressure: bar (1 bar = 10^5 Pa)
- for volume: litre (1 litre = 10^{-3} m^3)
- for time: minute (1 min = 60 s)
- for time: hour (1 h = $3{,}6 \times 10^3$ s)

5 Definitions

5.1 General

5.1.1 oil-free, dry, compressor: A compressor where the medium being compressed is isolated from the lubricant system. The rotors, synchronized by timing gears, do not touch each other or the casing and therefore require no lubricant in the compression chamber. The air or gas is not contaminated by the lubricant nor any other liquid while passing through the compressor.

5.1.2 oil-free, liquid-injected, compressor: A compressor where the medium being compressed is isolated from the lubricant system but where a liquid is continuously injected into the compression chamber for the purpose of oil-free lubrication, cooling and sealing. Any separation of the liquid from the air or gas is carried out after the gas-liquid mixture leaves the compressor.

5.1.3 oil-flooded compressor: A compressor where oil is continuously injected into the compression chamber. Any separation of the oil from the air or gas is carried out after the gas-oil mixture leaves the compression chamber. Synchronizing gears may not be required.

5.1.4 standard inlet and discharge points: The points at the inlet and discharge flanges of the compressor.

NOTE — When the SUPPLIER provides piping or other parts between the points of demarcation, a separate agreement should be made to define the inlet and discharge points.

5.1.5 swept volume for a displacement compressor: The volume swept in one cycle by the compressing element(s) of the compressor first stage.

5.1.6 displacement for a displacement compressor: The volume swept by the compressing element(s) of the compressor first stage per unit of time.

5.2 Pressures

5.2.1 effective (gauge) pressure: The pressure measured with reference to atmospheric pressure.

5.2.2 absolute pressure: The pressure measured with reference to absolute zero, i.e. with reference to an absolute vacuum. It equals the algebraic sum of the atmospheric pressure and the effective pressure (static pressure or total pressure).

5.2.3 static pressure: The pressure measured in a fluid under such conditions that the fluid velocity has no effect on the measurement.

5.2.4 total pressure: The sum of the static and dynamic pressures.

It designates the fluid condition at which the flow energy of the fluid is converted into pressure without any losses in a stationary body of fluid. In a stationary gas, the static pressure and the total pressure are numerically equal.

5.2.5 inlet pressure: The total mean absolute pressure at the standard inlet point.

NOTE — The total absolute pressure may be replaced by the static absolute pressure provided that the gas velocity and density are sufficiently low.

5.2.6 discharge pressure: The total mean absolute pressure at the standard discharge point.

NOTE — The total absolute pressure may be replaced by the static absolute pressure provided that the gas velocity and density are sufficiently low.

5.2.7 rated discharge pressure: The highest discharge pressure required to meet the conditions specified by the USER for the intended service.

5.2.8 design pressure: The maximum pressure which the component is designed to withstand safely.

5.2.9 maximum allowable working pressure: The maximum operating pressure which the SUPPLIER's design permits when handling the specified gas at any service conditions specified for the compressor or any part to which the term is referred, such as an individual stage.

5.2.10 relief valve set pressure: The opening pressure on the inlet side of a relief valve.

NOTE — For a differential-type valve the set pressure is the pressure difference across the valve when opening commences. The downstream pressure is termed the back pressure.

5.3 Temperatures

5.3.1 inlet temperature: The temperature at the standard inlet point of the compressor.

5.3.2 discharge temperature: The temperature at the standard discharge point of the compressor.

5.3.3 rated discharge temperature: The highest predicted operating temperature.

5.3.4 maximum allowable working temperature: The maximum gas temperature which the SUPPLIER or USER permits in the compressor, when handling the specified gas at any service conditions specified.

5.3.5 design temperature: The extreme temperature level(s) which the compressor is designed to withstand safely.

NOTE — This covers gas, coolant and ambient temperatures.

5.3.6 maximum expected discharge temperature: The highest predicted operating temperature resulting from any specified service condition, including part-load operation.

5.3.7 casing design temperature range: The range of temperatures to which the compressor casing may be continuously subjected at the casing design pressure.

5.4 Flow rate

5.4.1 actual volume rate of flow of a compressor (deprecated: "actual capacity"): The actual volume rate of flow of gas compressed and delivered at the standard discharge point referred to conditions of total temperature, total pressure and composition (e.g. humidity) prevailing at the standard inlet point.

5.4.2 standard volume rate of flow (deprecated: "standard capacity"): The actual volume rate of flow of compressed gas as delivered at the standard discharge point, but referred to standard conditions (for temperature and pressure).

5.4.3 inlet mass rate of flow: The mass flow of gas or gas mixture induced by the compressor at the standard inlet point(s).

5.4.4 discharge mass rate of flow: The mass flow of gas mixture delivered by the compressor at its standard discharge point(s).

5.5 Power

5.5.1 theoretical required power: In a compressor without losses, the power which is theoretically required to compress a gas according to the chosen reference process, from a given inlet pressure to a given discharge pressure.

5.5.2 driver coupling power: The maximum power required at the driver shaft, including losses in external transmissions such as gears or belt drives when such transmissions form part of the SUPPLIER's scope of delivery.

5.5.3 shaft input power: The power required at the compressor shaft, excluding losses in external transmissions.

5.6 Specific energy requirement

5.6.1 actual specific energy requirement: The shaft input power per unit of compressor actual volume rate of flow.

5.7 Speed

5.7.1 compressor speed: The rotational speed of the fastest rotor within the compressor stage.

5.7.2 rated compressor speed: The compressor speed necessary to meet the specified service conditions.

5.7.3 minimum allowable compressor speed: The lowest compressor speed at which the compressor may be continuously operated.

5.7.4 maximum allowable compressor speed: The highest compressor speed at which the compressor may be continuously operated.

5.7.5 input drive shaft speed: The rotational speed at the coupling linking the driver and its gearbox to the compressor and its integrated gearbox, if any.

5.8 Operating point

5.8.1 specified operating point: Any point at which the operation of the compressor is specified in the data sheets.

5.8.2 normal operating point: The point at which the usual operation of the compressor is expected.

5.8.3 rating point: The operating point, specified by the USER, at which the performance test data must comply with the specified data.

5.9 Plates

5.9.1 baseplate: A plate or structure supporting one piece of machinery, e.g. compressor, gear or driver.

5.9.2 common baseplate: A plate or structure supporting more than one piece of machinery, e.g. compressor, gear or driver.

5.9.3 soleplate: A plate or structure supporting one or more baseplates.

5.9.4 mounting pad: A plate under an individual support point of a machine.

6 Basic requirements

6.1 General

6.1.1 In the case of conflict between this International Standard and the enquiry or order, the information included in the order shall govern. The completed data sheets form part of the order.

6.1.2 Any documentation pertaining to the enquiry, proposal or order is of a proprietary nature and shall not be divulged to a third party except as may be necessary for the execution of the proposal or the contract.

6.1.3 The approval of documents (drawings) does not constitute permission to deviate from the order requirements unless specifically agreed upon in writing. Any such approval does not release the respective party from his contractual responsibilities.

6.1.4 For budget proposals, the short-form data sheets may be used.

6.2 The enquiry

6.2.1 The USER shall complete the data sheets to the extent possible and specify all process requirements, any known abnormal conditions and also, where this International Standard provides a choice or requires that a decision be made, all other items necessary for the SUPPLIER to make out his proposal.

6.2.2 The USER shall indicate the relevant design and safety codes and the exceptions to, or deviations from, those codes which he wishes the SUPPLIER to comply with.

6.2.3 The USER shall indicate in the data sheets the major spare parts he wishes to be included in the proposal.

6.3 The proposal

6.3.1 The SUPPLIER shall include the data sheets in his proposal, completed as applicable and as indicated by the USER, amplifying these as necessary to describe clearly the nature of his supply.

6.3.2 Unless otherwise specified in the enquiry, the SUPPLIER shall quote only for the instrumentation listed as mandatory in the data sheets and shall supply equipment to his own standard.

6.3.3 The proposal shall state the delivery time as being from the date of receipt of an order, on the basis that the information necessary to proceed with manufacture is received by the SUPPLIER in due time (see A.4.1).

6.3.4 The SUPPLIER shall describe the compressor flow rate control system and shall state the limits of his supply.

6.3.5 The proposal shall include either a specific statement that all equipment is in strict accordance with the USER's specifications or a specific list of deviations therefrom.

Deviations may include alternative designs provided that these are equivalent to, and guaranteed for, the specified duties.

6.4 Rating

6.4.1 Performance rating

The following performance rating shall be given.

a) The flow rate of the compressor shall be within $^{+8}_{0}$ % of the rated flow specified in the data sheets.

NOTE — Larger tolerances may be required for machines with a low flow rate or which handle certain gases (e.g. helium).

b) The specific energy requirement shall not exceed the rated value by more than 6 % at the rating point(s) identified in the data sheets.

Losses in external transmissions, such as gears, shall be stated in the data sheets.

The actual corrected test results shall lie within the rating limits prescribed above, including any measuring tolerances.

6.4.2 Tests

Test procedures shall be in accordance with ISO 1217 (see annex A).

6.5 Noise limitations

6.5.1 The limitations, if any, on airborne noise emission levels of the compressor and its accessories shall be indicated by the USER at the time of enquiry. It shall be the USER's responsibility to consider any noise specifications that may be applicable at the plant site when stating his requirements to the SUPPLIER. The latter shall not be liable for any cost incurred owing to incomplete USER's requirements.

Consideration should be given to part-load as well as full-load operation.

The SUPPLIER's information with regard to noise levels applies only to equipment in his supply.

6.5.2 The maximum permissible A-weighted sound power level in decibels re 10^{-12} W for the relevant octave bands of the noise output of the compressor and its accessories shall be stated by the USER in his enquiry.

The SUPPLIER shall state in his proposal the expected A-weighted sound power level, in decibels, of the main components in his supply.

6.5.3 Methods of measurement and interpretation shall be as stated in ISO 3989.

The responsibility for carrying out noise tests on site shall be agreed between the USER and the SUPPLIER and shall be stated in the data sheets.

NOTE — The sound pressure level in a compressor room depends on the sound power emission from the machines installed and the acoustical properties of the room. It is therefore not possible for the SUPPLIER to predict the final sound pressure levels at the work site.

6.5.4 The SUPPLIER shall quote separately for any noise-abating treatment, other than that normally built into the equipment, if necessary to comply with the noise limitations imposed.

6.5.5 If silencers to comply with these limitations are furnished by the USER, the SUPPLIER shall indicate the respective noise levels at his limits of supply.

6.5.6 Silencers and valves shall be located relative to each other in the piping system in such a way as to avoid any undesirable mutual influence during any operating condition of the compressor. This shall be by mutual agreement between the SUPPLIER and the USER.

6.5.7 Any special noise measurement (e.g. in pipes) shall be performed as agreed between the USER and the SUPPLIER.

7 Compressor

7.1 General

7.1.1 All equipment shall be suitable for the specified operating conditions and shall be designed for continuous full-load duty for at least 2 years of service. Before the USER places the order, the SUPPLIER shall be advised of any special conditions which may render the operation more severe. It is recognized that the above-mentioned operating time is a design criterion and that continuous operation for this period of time involves factors that are beyond the SUPPLIER's control. Therefore, one must differentiate between the design service life and the duration of guarantee.

7.1.2 All equipment shall be suitable for the local and climatic conditions specified by the USER in the data sheets, e.g. for outdoor installation within process plants.

7.1.3 If winter-proof protection is specified, it shall meet the following requirements.

a) During shut-down it shall be possible to drain all parts and piping which may contain water.

b) All equipment which may suffer from frost shall be protected as necessary. The responsibility for this protection shall be agreed between the USER and the SUPPLIER before the order is placed.

7.1.4 The number of individual compressors, the number of compression stages, and the compressor arrangement including the driver shall be agreed upon before the order is placed.

7.1.5 The USER shall provide adequate space for the erection, maintenance and operation of the equipment. The compressor design shall allow adequate and safe access for operation and maintenance. Special demands in the plant arrangement shall be specified by the USER before the order is placed.

7.1.6 Where required by process conditions and specified by the USER, adequate openings shall be provided to drain the process side of the SUPPLIER's supply.

7.1.7 The SUPPLIER may offer a liquid-injection system serving the purpose of lubrication, cooling, sealing or flushing. The liquid to be used shall be agreed with the USER.

7.1.8 Bearing housings and shaft seals shall be designed to minimize the ingress of moisture, dust and other foreign matter during periods of operation and idleness.

7.1.9 All characteristics of the coolant shall be specified by the USER. If no information is given, the coolant system shall be designed for filtered fresh water at a nominal effective pressure of 4,5 bar, and for a maximum pressure drop of 1 bar, at 25 °C and to withstand vacuum. Preferably, the pressure of the coolant should be below that of the lubricant. For a closed liquid system, provision for expansion of the liquid shall be incorporated.

7.1.10 When tools and fixtures, not commercially available, are required to dismantle or assemble the unit, the supply of these shall be the subject of agreement between the USER and the SUPPLIER.

7.2 Materials

7.2.1 The USER shall specify the presence of corrosive agents in the gases handled, in the utilities and in the environment, including constituents which may cause stress corrosion [e.g. hydrogen sulfide (H_2S)].

7.2.2 All materials of construction shall be of the SUPPLIER's standard with the exception that all materials for compressors and auxiliaries in contact with process gases shall be compatible with the gases handled (see also 7.3.3).

If the USER has particular requirements, he shall specify these in the data sheets. The SUPPLIER may suggest more suitable materials, on the basis of his experience.

7.2.3 Steels used for rotors, internal bolting etc. in contact with any gas which contains H_2S in the presence of water, shall not have a hardness exceeding 22 HRC when the tensile strength is equal to or greater than 62 MN/m^2.

7.2.4 Castings subject to pressure shall be sound and free of penetrating shrink or blow holes, scales, blisters or other similar casting defects.

Castings subject to pressure shall not be peened, plugged, burned in or impregnated, except as may be approved by the USER or an appropriate certifying authority. Internal surfaces of castings shall be cleaned by sand- or shot-blasting, pickling or another recognized method.

All mould parting fins and remains of gates and risers shall be chipped, filed or ground flush.

7.2.5 The use of chaplets in castings subject to pressure shall be kept to a minimum. The chaplets shall be clean, rust free (plating is permitted) and compatible with the casting.

Chaplets not completely fused into castings shall be replaced by a weld equivalent in composition to the steel casting or by a screwed plug made of cast iron.

All welded connections (structural welds) on casings, pressure-containing castings, and repair welds shall be undertaken in accordance with the following conditions:

a) the materials shall be suitable for welding and the filler metals shall be compatible with the parent metal;

b) the welding process shall be selected according to the material properties, workpiece thickness and stress on the welded connection;

c) for welds requiring inspection authority approval, welders shall be suitably qualified by an agreed authorizing body (see also 7.2.4);

d) steel castings may be repaired by welding in accordance with the SUPPLIER's national specifications or equivalent for similar material.

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

7.3 Casings

7.3.1 The design pressure of the casings shall be at least the highest pressure which can occur during running or shut-down conditions. Pressures above normal working pressure which can occur during shut-down due to the process shall be stated in the enquiry.

7.3.2 The thicknesses of casings shall include allowance for corrosion caused by the gas handled, the coolant and/or the atmosphere, unless corrosion-resistant materials are used.

7.3.3 The following minimum requirements shall be observed when selecting casing materials, unless otherwise specified by the USER.

a) Cast iron with lamellar graphite (grey cast iron) is acceptable for air and all other gases up to an effective service pressure of 32 bar and at service temperatures between −60 and +260 °C.

b) Nodular cast iron is acceptable for air and all other gases up to an effective service pressure of 64 bar and at service temperatures between −60 and +320 °C.

c) If the gas handled is highly corrosive to cast iron and mild steel, stainless castings shall be used. Corrosion-proofed material may be used if agreed upon between the USER and the SUPPLIER.

d) For higher pressures and temperatures, steel castings shall be used.

e) For gas temperatures below −60 °C, the casing materials shall be agreed upon between the USER and the SUPPLIER.

f) Other materials may be used subject to agreement between the USER and the SUPPLIER.

7.3.4 Lifting lugs, eyebolts, jackscrews or equivalent, as well as dowel pins, shall be provided to facilitate assembly and dismantling. When jackscrews are furnished, provision shall be made to prevent damage to the mating flange.

7.4 External forces and moments

The piping connected to the compressor shall be arranged to eliminate as far as possible forces and moments at the connecting flanges.

The compressor shall be designed to withstand external forces and moments at least equal to a value calculated as follows.

The lateral forces shall be equal to $D \times 50$ N, where D is the nominal bore (in millimetres) of the flange concerned (suction or discharge).

The bending moment shall be equal to $D \times 10$ Nm, where D is as defined above.

7.5 Bolting

7.5.1 All threads shall be metric in accordance with ISO 262 unless otherwise agreed.

7.5.2 Tapped holes for bolting shall be kept to a minimum. Studs are preferred to bolts, except when threaded inserts are used.

A metal thickness of at least half the stud diameter shall be left at the bottom of such holes to prevent leakage in pressure sections and to prevent damage when inserting the threaded components.

7.5.3 Bolts or studs for casing joints shall be designed to withstand the compressor hydraulic test pressure. At temperatures between −60 and +320 °C, they shall meet a minimum property class of 4.6 for cast iron and 5.6 for steel casings according to ISO 898. For higher and lower temperatures, as well as for corrosive media, the materials for fasteners for casing joints shall be selected according to the SUPPLIER's standards.

7.6 Casing connections for piping

7.6.1 Casing connections should be flanged or studded bosses wherever possible. Flanges are mandatory for pipe sizes of 50 mm bore and larger, whilst threaded connections are permitted for smaller sizes. This requirement applies, in particular, to the following secondary connections:

a) lubricant;

b) vents;

c) casing drains;

d) seal gas and seal liquid;

e) pressure equalizing pipes, unless both ends are welded or brazed to the casing;

f) coolant;

g) flushing media;

h) instruments;

i) injection.

7.6.2 All connections to which the USER will connect equipment shall conform to the standards specified in the enquiry or be provided with mating flanges or screwed adaptors.

All flanged connections to which the SUPPLIER's secondary piping will be connected shall conform to ISO 7005-1 (metallic flanges) or as otherwise agreed.

7.6.3 The sealing faces shall conform to ISO 2441.

7.7 Rotors

7.7.1 Rotors with their shafts may be an assembled or a one-piece unit. Cast iron, steel or stainless steel may be used as rotor materials, depending on the operating conditions. Other materials may be agreed upon for special applications.

7.7.2 When timing gears are used, they shall allow adjustment of the relative rotor positions. The locking shall be accessible with the rotors mounted in the casing.

7.8 Bearings and bearing housings

7.8.1 All compressor bearings shall be replaceable.

7.8.2 Thrust bearings shall be designed to accommodate all axial thrust developed during all specified conditions of operation and also to handle reverse thrust, which may develop. Further, these bearings shall be adjustable axially. When thrust collars are used, they shall be replaceable.

7.8.3 Radial bearings and thrust bearings shall be designed for pressure lubrication and arranged to minimize lubricant foaming. Drain openings shall be liberally sized.

NOTE — Straight-lobed (Roots) blowers and light-duty compressors do not always require pressure lubrication.

7.9 Shaft sealing

7.9.1 Gas seals shall be provided to prevent or restrict leakage out of the compression chamber or the ingress of air or foreign matter into the compression chamber during operation and, if necessary, during shut-down periods. Any leakage limitation shall be specified by the USER in his enquiry. Variations in operating conditions that may occur during start-up and shut-down shall be taken into consideration. Shaft seals shall be designed to prevent uncontrolled leakage, in particular of harmful, toxic or flammable gases.

Such gases shall not be allowed to escape freely but shall be discharged from the compressor in a safe manner. Seals using liquid or gas as the sealing medium, or combination seals, may be used for this purpose. In special cases journal bearings may act as shaft seals.

7.9.2 Lubricant seals shall be provided to prevent leakage of lubricant either from the compressor or into the process through the gas shaft seal.

7.10 Balancing

Dry compressor rotors shall be dynamically balanced to balance quality grade 2,5 according to ISO 1940.

7.11 Baseplate

7.11.1 The baseplate, when included in the SUPPLIER's supply, should be sufficiently stiff to maintain alignment after initial installation and alignment. If a pillar-type foundation or other special compressor support is to be used, this shall be specified in the enquiry. The baseplate shall not be used by the USER for fixing other units or piping, unless agreed to by the SUPPLIER.

7.11.2 A foundation supplied by the USER shall be designed to protect the compressor from harmful external vibrations.

7.12 Rating plate and direction of rotation

7.12.1 The rating plate on the compressor shall be made of stainless steel or Monel. The plate shall be fixed at a clearly visible point.

The following minimum data shall be clearly stamped on the rating plate:

a) manufacturer;

b) model designation and serial number;

c) flow rate;

d) input drive shaft speed.

7.12.2 The direction of rotation of the compressor drive shaft shall be clearly shown by an arrow either cast into or permanently attached to the compressor casing.

8 Drivers and drive equipment

8.1 Drivers

8.1.1 General

The type of driver shall be specified by the USER. In the determination of the size of the driver, account shall be taken of the transmission losses (e.g. gear units or hydraulic couplings). The compressor starting torque curve, supplied by the SUPPLIER, shall be considered when selecting the driver.

Anticipated process variations, such as changes in gas composition and inlet or discharge pressures, shall be specified by the USER to permit sizing of the driver. When the USER supplies the driver or the gearbox, he shall specify any lubrication requirements to be met by the SUPPLIER.

The responsibility for drive train components (e.g. couplings) and for the torsional analysis shall be defined prior to the contract.

8.1.2 Electric motor

An electric motor serving as the main driver shall be rated for a continuous output power of at least 115 % of the maximum power required at any specified operating point. Area classification and other design characteristics shall be as specified in the data sheets.

8.1.3 Steam turbine

A steam turbine serving as the main driver shall be rated as follows.

a) It shall be capable of continuously producing a rated power of at least 115 % of the necessary power at each specified operating point and at the speeds specified in the data sheets.

b) It shall be possible to develop this power at the worst combination of steam conditions specified in the data sheets.

8.1.4 Combustion engine or gas turbine

These shall be sized by mutual agreement between the SUPPLIER and the USER.

8.1.5 Reciprocating-type driver

Where the driver is of the reciprocating type, a torsional analysis of the complete system shall be carried out; this analysis shall be the responsibility of the party supplying the driver.

8.1.6 Expander

If an expander is the only driver of the compressor, its rating shall be equal to that for the steam turbine (see 8.1.3).

8.1.7 Other types of driver

In all other cases, the sizing and operation of the drivers shall be agreed upon between the USER and the SUPPLIER.

8.2 Main transmission gear

8.2.1 Main transmission gears shall be according to the SUPPLIER's national standard or as specified by the USER.

8.2.2 Main transmission gears shall be capable of continuously transmitting the rated driver power multiplied by the application factor given in table 1 for various drivers.

Table 1

Driver	Application factor
Steam turbine	1,3
Gas turbine	1,3
Electric motor	1,3
Rotary expander	1,3
Reciprocating engine, 4 to 7 cylinders	1,8
Reciprocating engine, 8 cylinders or more	1,4

8.2.3 The main transmission gear shall be rated to transmit the maximum torque available from the driver under all operating conditions specified, including start-up.

8.2.4 Thrust bearings, if used, shall be sized to absorb axial gearing forces, as well as any axial thrust caused by friction in the couplings.

8.2.5 The rotating parts of the gear of dry compressors shall be dynamically balanced to balance quality grade 2,5 according to ISO 1940.

8.2.6 The directions of rotation of driven and driving shafts shall be clearly indicated by directional arrows either cast into or permanently attached to the gear casing.

8.2.7 The rating plate on a gearbox shall be made of stainless steel or Monel. The plate shall be fixed at a clearly visible point. The following minimum data shall be clearly stamped on the rating plate:

a) manufacturer;

b) model designation and serial number;

c) continuous power rating;

d) rated input/output speed;

e) input/output speed.

8.3 Main shaft couplings

In the connections between driver and compressor allowance shall be made for misalignment between the shafts. If the compressor and gearbox are mounted on a base frame and the driver is mounted separately, a coupling shall be used which takes up any differential expansion and minimizes additional forces on the shafts.

8.3.1 If the maximum peripheral speed of the coupling exceeds 25 m/s the metallic parts of the coupling shall be made of steel.

8.3.2 The coupling shall be capable of continuously transmitting the rated drive power multiplied by the application factor given in 8.2.2.

8.3.3 Couplings shall be rated to transmit the maximum torque available from the driver under start-up and all operating conditions.

8.3.4 Gear-type couplings for shaft speeds above 3 600 r/min shall be provided with through-flow lubrication and care shall be taken to avoid sludge build-up in the coupling. The lubricant filtration shall be agreed with the coupling manufacturer.

8.3.5 Couplings shall be designed to allow uncoupled operation of the driver, where the design of the driver permits such operation. The USER shall specify in the enquiry if it is necessary to remove the coupling with the compressor and driver in position.

Couplings with limited axial float shall be employed where an electric motor is used whose rotor is held axially by the magnetic field only. This shall be made known to the SUPPLIER in the enquiry if the USER is supplying the motor.

8.3.6 The USER and the SUPPLIER shall agree who is to supply the couplings between the driver and the compressor and who is responsible for the balancing and assembly. Coupling bolts shall be selected by mass to permit interchange without affecting the balance.

8.3.7 Coupling halves shall be mounted by cylindrical or conical fits.

8.3.8 Easily removable guards shall be provided on all exposed couplings and shafts. The guards shall be strong enough to prevent any mechanical contact with the coupling or shaft as a result of bodily contact.

9 Auxiliary equipment

9.1 General

9.1.1 All auxiliaries which come within the scope of pressure vessel codes (including gas coolers, silencers, separators and traps) shall be designed, manufactured, inspected and tested in accordance with a recognized code, stated by the SUPPLIER in the data sheets, unless the USER specifically invokes a particular code at the time of enquiry.

All flanges to which auxiliary pipes supplied by the SUPPLIER are connected shall conform to ISO 2441 unless otherwise agreed.

9.1.2 For carbon steel surfaces in gas cooler shells, silencers, separators, traps or other auxiliaries which are not classified as pressure vessels, but which are exposed to water or other corrosive media, a minimum corrosion allowance of 3 mm shall be incorporated, unless alternative methods of protection are agreed. This requirement does not apply to cooler tubes.

9.1.3 All welding of pressure vessels, pressure casings, piping and repairs shall be performed under the following conditions.

a) Materials shall be suitable for welding, and welding materials shall be compatible with the base material according to the SUPPLIER's national standard.

b) The welding method shall be chosen according to the material characteristics and the thickness and stress of the welded joint.

c) Only welders approved by the SUPPLIER's national authority shall be employed.

d) Components which 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.

e) Where any pressure casting is repaired by welding, the SUPPLIER shall inform the USER of the details of the repair.

9.1.4 Design pressures of auxiliaries in the process stream shall be at least the highest pressure which can occur during running or shut-down conditions.

9.1.5 Design temperatures of auxiliaries in the process stream shall comply with the definition of the maximum and minimum allowable working temperatures (see 5.3.4).

9.2 Coolers

9.2.1 All characteristics of the coolant shall be specified by the USER. If no information is given, the coolant system shall be designed for filtered fresh water at a nominal effective pressure of 4,5 bar, and for a maximum pressure drop of 1 bar, at 25 °C and to withstand vacuum.

In special applications (e.g. where chlorine is used) it may be desirable to keep the coolant pressure below the gas pressure.

9.2.2 The minimum fouling factors for the water side of coolers shall be as given in table 2.

Table 2

Water	Fouling factor $m^2 \cdot K/W$
Closed circuit (treated)	$0{,}85 \times 10^{-4}$
Normal cooling tower	$1{,}7 \times 10^{-4}$
Brackish	$3{,}4 \times 10^{-4}$

The velocity of the water inside the tubes should be greater than 1,0 m/s to avoid the build-up of silt.

9.2.3 All coolers shall be rated for the most severe operating conditions specified in the data sheets (e.g. coolant temperature, gas density and flow rate).

9.2.4 All flanges to which connections are made by the USER or another furnisher commissioned by him shall be executed in accordance with the standard specified by the USER in the enquiry or, alternatively, the mating flanges shall be provided by the SUPPLIER.

9.2.5 The coolant flow rate, temperature rise and pressure drop shall be stated in the data sheets.

9.3 Silencers

9.3.1 Except for liquid-injected compressors, the SUPPLIER shall supply first-stage inlet and final-stage discharge silencers and when necessary interstage silencers.

9.3.2 The design of the silencers shall take into account the most severe operating conditions (e.g. maximum flow rate, pressure and temperature) and corrosion specified in the data sheets.

9.3.3 All flanges to which connections are made by the USER or another furnisher commissioned by him shall be executed in accordance with the standards specified by the USER in the enquiry or, alternatively, the mating flanges shall be provided by the SUPPLIER.

9.4 Separators and traps

9.4.1 Liquid separators shall be provided downstream of the coolers if specified by the USER or deemed necessary by the SUPPLIER. The USER shall furnish pertinent information to the SUPPLIER.

9.4.2 Unless otherwise specified by the USER, each separator shall be fitted with a drain trap, complete with isolating and blow-down valves.

9.4.3 Manually drained separators shall have a holding volume or separate tank to permit continuous full-duty utilization without drainage for two shifts.

9.5 Pipework (general)

The piping provided by the SUPPLIER for each circuit shall be classified by him according to the following categories.

Category 1: Piping completely fabricated and installed at the SUPPLIER's works but which may be removed for transportation. Any removal shall be carried out in such a way that the piping will merely require assembly at site.

Category 2: Part of piping is fabricated and installed at the SUPPLIER's works (and, as in category 1, may be removed for transportation). The remainder of the SUPPLIER's supply is provided as category 3 or 4, as may be defined by him.

Category 3: Piping fabricated to match the intended site arrangement but supplied with closing lengths for final fabrication at site.

Category 4: Piping supplied as straight lengths (or coils as appropriate) with bends and other fittings necessary for fabrication at site to an agreed arrangement of pipe runs or to an agreed quantity.

9.6 Process gas pipework

9.6.1 The process gas pipework shall be in accordance with a relevant recognized national specification of the SUPPLIER's choice, unless the USER specifically invokes another specification at the time of enquiry.

Such a specification shall be supplemented by 9.6 of this International Standard except where the requirements of the specification and this International Standard are in conflict. In this case, the specification shall govern.

Pipe sizes not preferred in national standards shall be avoided.

9.6.2 The scope of supply of process gas pipework shall be defined in the data sheets.

9.6.3 Terminal point isolating valves shall not form part of the SUPPLIER's normal supply.

9.6.4 The SUPPLIER shall deliver all the jointing and bolting as necessary for the mating connections of his supply, excluding the terminal connections.

9.6.5 On wet-gas service, low-point drains or valves shall be provided in the gas pipework.

9.6.6 The SUPPLIER shall define precisely the location, size and type of his terminal connections.

9.6.7 The design pressure of all gas pipework, flanges and fittings shall be at least the highest pressure which can occur during running or shut-down conditions.

9.6.8 The USER shall state in the enquiry any pipe sizes which are not acceptable at the points to which he has to connect.

9.6.9 The minimum size for process gas pipework shall be 20 mm internal diameter.

9.6.10 Screwed connections sealed by brazing or welding shall not be coated beforehand with thread lubricant or sealing compound. The seal welds shall comprise at least two passes.

9.6.11 All pipes shall be routed to ensure adequate elasticity and access for operation, maintenance and cleaning.

9.6.12 All pipework and associated auxiliaries shall be supported such that the possibility of damage due to vibration, thermal expansion and the mass of the pipework and associated auxiliaries is minimized.

9.6.13 The USER's own piping installation shall not impose loads on the SUPPLIER's equipment except as specified in 7.4.

9.6.14 The use of flexible joints to allow for thermal expansion and to reduce stresses in the piping systems is subject to USER acceptance.

Express attention is drawn to the fact that the furnisher of such joints should be consulted by the SUPPLIER with regard to the necessary procedures to be adopted for installation.

9.7 Non-return and relief valves

9.7.1 A non-return valve shall be used with all screw compressors, whether single- or multi-stage plants.

9.7.2 Relief valves (see ISO 4126) shall be fitted to each separate compressor stage and dimensioned to handle the full compressor flow rate. The set pressure and the full-flow pressure shall be determined by the SUPPLIER to protect the equipment in his supply.

9.7.3 The SUPPLIER shall select the relief valve for the normal back pressure unless the USER specifies in his enquiry that a higher pressure may be developed downstream of the valve under special conditions.

9.8 Auxiliary pipework

9.8.1 The auxiliary systems are as follows:

a) lubrication;
b) venting;
c) drainage;
d) gas and liquid sealing;
e) gas equalization;
f) cooling;
g) flushing;
h) instrumentation;
i) injection;
j) heating;
k) control.

The associated fittings, control devices and measuring devices shall also be subject to the requirements of 9.5.

9.8.2 Except where the gas or lubricant demand special materials, seamless carbon steel pipe shall be used for the gas and lubricant lines. Coolant lines may be made of seam-welded pipe. If it is necessary that parts of the piping are made of corrosion-resistant material, the USER shall specify this in the enquiry.

9.8.3 Fittings and valves in auxiliary systems shall be made of steel with the exception of special valves where an agreement between the USER and the SUPPLIER shall be made.

A nominal effective pressure of 6 bar shall be taken as the minimum pressure rating for all connections.

Copper or plastic pipe is permissible for measuring and control lines with agreement of the USER.

9.8.4 The dimensions of piping shall be in accordance with the relevant International Standards or national standards.

9.8.5 Lubricant return lines shall be dimensioned and arranged so that a satisfactory discharge rate is obtained (allowing for possible foaming). Pipes running "horizontally" should have a constant slope of at least 20 mm per linear metre towards the oil reservoir (i.e. 1 in 50).

9.8.6 Drain lines, other than from instruments or controls, shall be of 20 mm internal diameter as a minimum. The USER shall arrange his drainage system to dispose safely of any process gas which accidentally gains access.

9.8.7 All auxiliary piping provided by the SUPPLIER and which is within the perimeter of the baseplate or part of an auxiliary unit (e.g. oil console or control panel) shall be complete, together with associated control and measuring devices. Interconnecting pipes outside the perimeter of the baseplate but within the SUPPLIER's scope of supply may be fabricated on site.

9.8.8 The pipe systems should preferably be made by bending and welding. Welded fittings and flanges shall be of butt weld, socket weld or slip-on types.

Threaded connections are permissible for pipe sizes up to 50 mm internal diameter and for a nominal effective pressure of 10 bar but they should be limited to a minimum.

9.8.9 Screwed connections sealed by brazing or welding shall not be coated beforehand with thread lubricant or sealing compound. The seal welds shall comprise at least two passes (see 9.6.10).

9.8.10 Auxiliary lubricant pipes made of carbon steel shall be pickled and passivated after fabrication.

9.8.11 All pipes shall be routed to ensure adequate elasticity and access for operation, maintenance and cleaning (see 9.6.11).

9.8.12 All pipework shall be well secured so that vibration is reduced to a minimum.

10 Lubricant and seal liquid system

10.1 General

10.1.1 A complete pressure lubricating system shall be furnished as applicable with each compressor unit to supply lubricant, at a suitable pressure, to the following:

a) the gearbox and bearings of the compressor;
b) the bearings of the main driver;
c) the couplings;
d) the turbine governor, trip and throttle valve;
e) the shaft seal system;
f) the timing gears.

10.1.2 When specified by the USER, a separate seal liquid system shall be provided by the SUPPLIER.

10.1.3 The SUPPLIER shall coordinate lubricant qualities, pressures and flows for the main driver, gearbox, if any, compressor and seals.

10.1.4 All equipment, including pumps, filters, strainers, coolers, pressure gauges and control valves, shall meet the SUPPLIER's national standard unless otherwise specified. Valved