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МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ

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

Compresseurs pour l'industrie de procédé — Turbocompresseurs — Spécifications et feuilles de données pour la conception et la construction

Reference number
ISO 8011 : 1988 (E)

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.

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 8011 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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Contents

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Compressors for the process industry — Turbo 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 turbo- 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 radial and axial flow turbo-compressors. It covers the minimum requirements for such compressors handling air or gas, and which have a specific compression work of more than 25 000 J/kg. It is recommended that this International Standard be used for other turbo-compressors if the standards set by this International Standard are required for the particular application.

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

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

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

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 3989-1, *Acoustics — Measurement of airborne noise emitted by compressor units including prime movers — Part 1: Engineering method for determination of sound power levels.* [1)]

ISO 5389, *Turbocompressors — Performance test code.* [1)]

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

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

VDI 2056, Verein Deutscher Ingenieure: Beurteilungsmaßstäbe für mechanische Schwingungen von Maschinen, VDI Richtlinie 2056, VDI GmbH Düsseldorf (D) 1964.

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 × 10^3 s)
—	for rotational speed:	r/min	(1 r/min = $\frac{2\pi}{60}$ rad/s)

1) At present at the stage of draft.

5 Definitions

Illustrations of various definitions are shown in figures 1 to 3.

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 arrangement sketch: A sketch to clarify, by the use of reference letters, the relative arrangement of the main components (e.g. compressor casings, process stages, intercoolers, gears and couplings).

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 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).

5.4.5 surge limit: The flow limit below which stable operation of the compressor is not possible.

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.

5.5.4 rated driver power: The maximum power continuously available from the motor.

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 impeller.

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.

5.7.5 100 % speed n_{100}: The speed necessary for operation at all the specified operating points.

5.7.6 trip speed n_t: The speed at which the prime mover is automatically tripped out.

5.7.7 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 (see figure 2)

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.

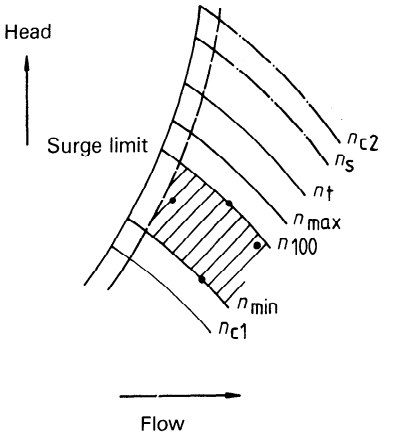
5.9.3 soleplate: A plate or structure supporting one or more baseplates.

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

6 Gas properties

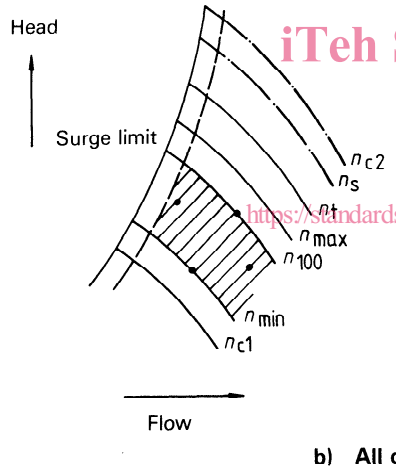
For the computation of gas properties, the advice given in ISO 5389 shall be followed.

The USER shall indicate to the SUPPLIER in data sheet 202 whether the gas is to be considered as toxic, flammable or corrosive and whether it contains solid impurities.



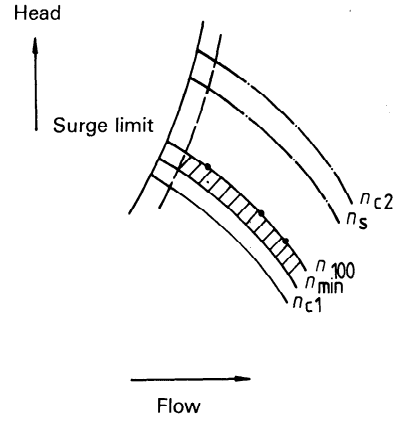
upper critical speed, $n_{c2} \geqslant 1{,}26\ n_{100}$
impeller overspeed test, $n_s = 1{,}18\ n_{100}$
trip speed, $n_t = 1{,}125\ n_{100}$
maximum continuous operating speed, $n_{max} = 1{,}05\ n_{100}$
100 % speed, n_{100}
minimum continuous operating speed, n_{min}
lower critical speed, $n_{c1} \leqslant 0{,}85\ n_{min}$
specified operating point, ●
normal operating range, ////
surge flow plus 5 %, — — —

a) Single-shaft turbine or expander drive



upper critical speed, $n_{c2} \geqslant 1{,}26\ n_{100}$
impeller overspeed test, $n_s = 1{,}21\ n_{100}$
trip speed, $n_t = 1{,}105\ n_{100}$
maximum continuous operating speed, $n_{max} = 1{,}05\ n_{100}$
100 % speed, n_{100}
minimum continuous operating speed, n_{min}
lower critical speed, $n_{c1} \leqslant 0{,}85\ n_{min}$
specified operating range, ●
normal operating range, ////
surge flow plus 5 %, — — —

b) All drives involving a split-shaft gas turbine



upper critical speed, $n_{c2} \geqslant 1{,}2\ n_{100}$
impeller overspeed test, $n_s = 1{,}12\ n_{100}$
100 % speed (synchronous speed-slip), n_{100}
minimum continuous operating speed, n_{min} ($= n_{100}$ for fixed-speed motors)
lower critical speed, $n_{c1} \leqslant 0{,}85\ n_{min}$
specified operating point, ●
normal operating range (variable-speed motors), ////
surge flow plus 5 %, — — —

c) Electric motor drive

Figure 1 — Illustration of various definitions in terms of a) a single-shaft turbine or expander drive, b) all drives involving a split-shaft gas turbine and c) an electric motor drive

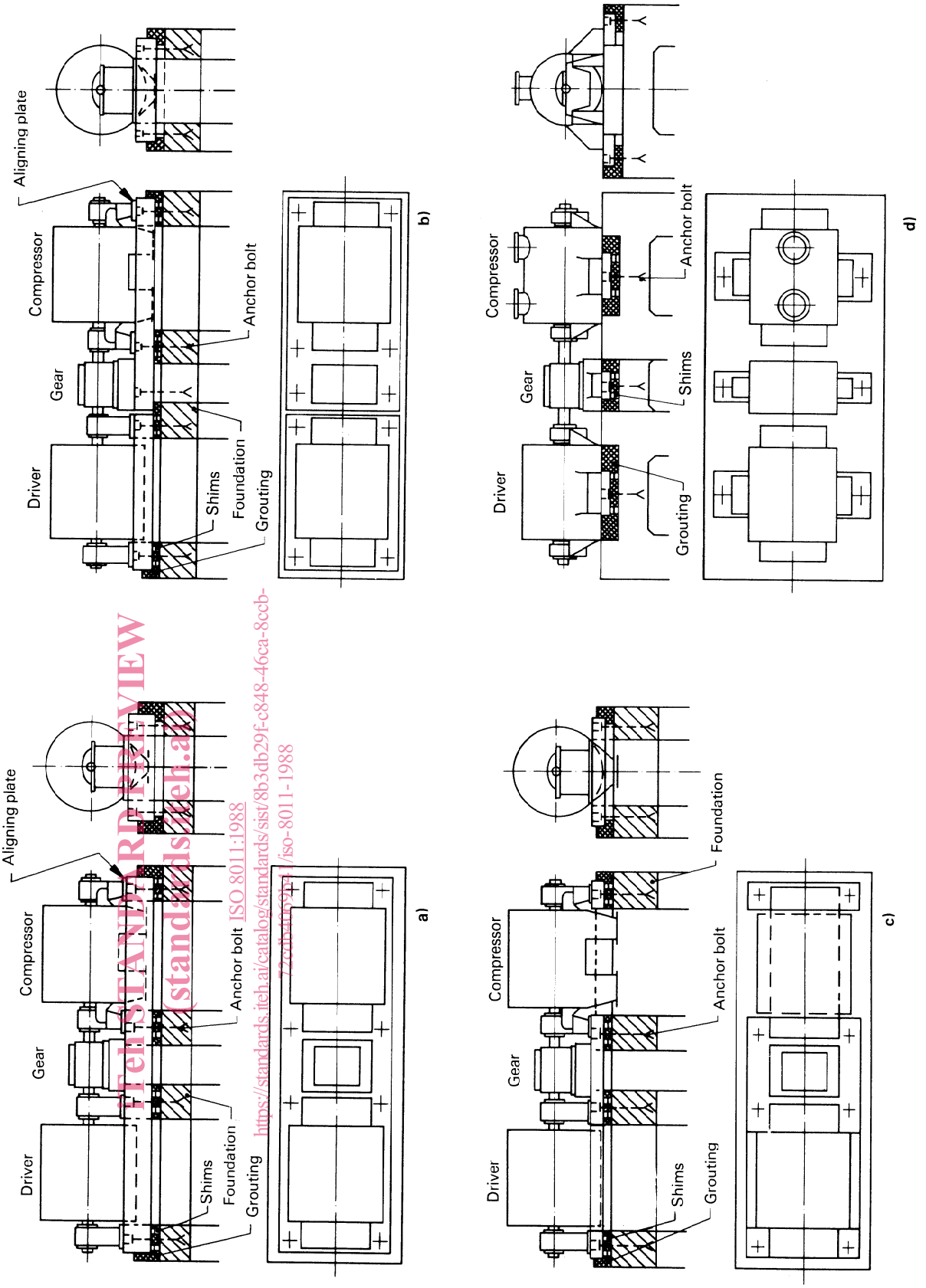
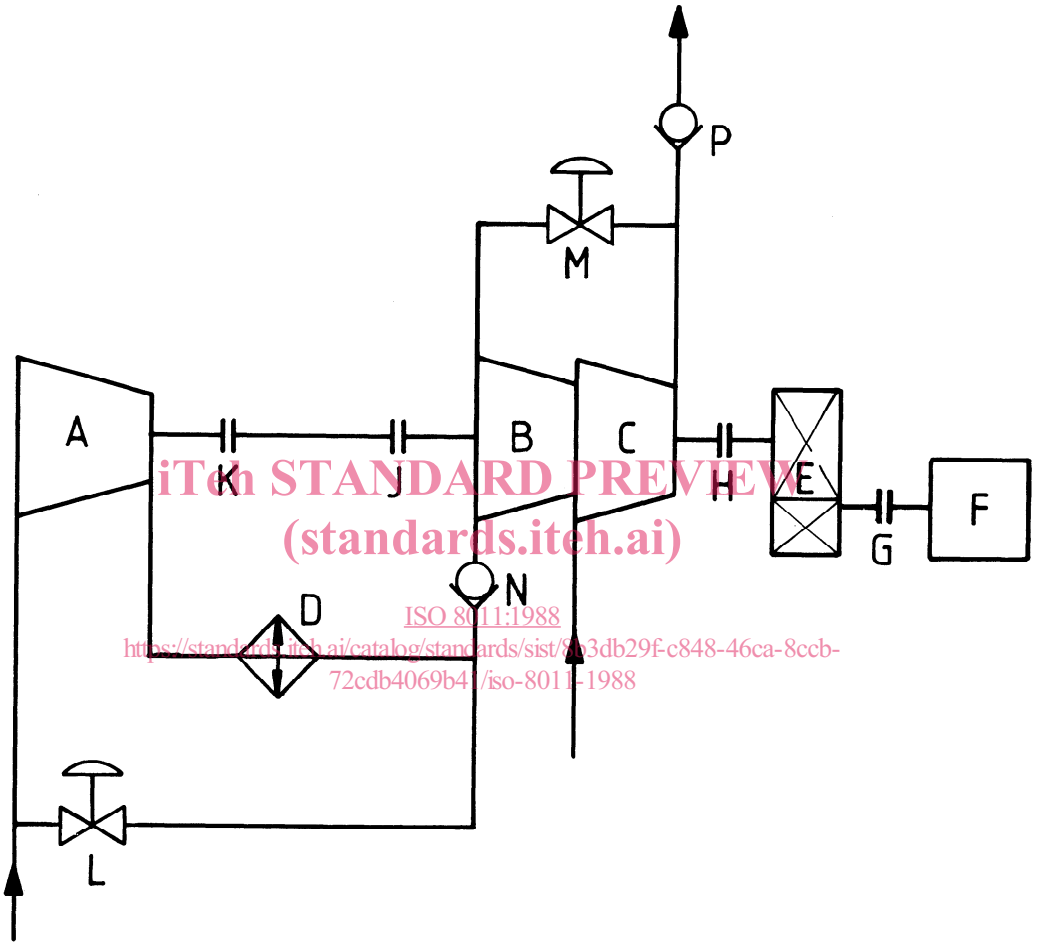


Figure 2 — Illustration of definitions of a) a common baseplate, b) a separate baseplate for driver and compressor, c) soleplates and d) mounting pads

Re-vision	Info.	COMPRESSOR DATA SHEET No. 210		
		ARRANGEMENT SKETCH		Page of
		USER:	**PROJECT:**	**SUPPLIER:**
		Ref. No.	Ref. No.	Ref. No.



A, B, C	stage cylinders
D	intercooler
E	gearbox
F	driver
G, H, J, K	couplings
L, M	pressure control valves
N, P	non-return valves

Figure 3 — An example of an arrangement sketch

USER to mark X in Info. column where data required in SUPPLIER's proposal

Revision No.	Original	1	2	3	4	5	6	7	8	9
Name										
Date										

7 Basic requirements

7.1 General

7.1.1 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.

7.1.2 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.

7.1.3 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.

7.1.4 The responsibilities with respect to the drive train coordination shall be defined prior to the contract.

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

7.2 The enquiry

7.2.1 The USER shall complete the data sheets to the extent possible and specify not only all process requirements, flow rate control and any known abnormal conditions but 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.

7.2.2 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.

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

7.3 The proposal

7.3.1 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.

Unless otherwise specified in the enquiry, the SUPPLIER shall quote only for the instrumentation listed as mandatory in 12.6 and shall supply equipment to his own standard.

Items not listed in the enquiry, but which are considered to be desirable by the SUPPLIER, shall be indicated in his proposal.

7.3.2 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).

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

7.3.4 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 equivalent to those specified.

7.4 Ratings

7.4.1 Performance rating

7.4.1.1 Constant-speed compressors

The flow rate shall be within $^{+5\ \%}_{\ \ 0\ \%}$ 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).

The specific energy requirement shall not exceed the rated value by more than 4 % at the rating point specified in the data sheets. Losses in external transmissions, such as gears, shall be stated in the data sheets.

7.4.1.2 Variable-speed compressors

The specific energy requirement shall not exceed the rated value by more than 4 % at the rating point specified in the data sheets.

Where changes in specified speeds beyond n_{max} are required to meet the rating point, the operating speed range of the compressor shall be adjusted as agreed between the SUPPLIER and the USER, provided that the mechanical integrity of the machine remains unaffected.

7.4.2 Tests

Test procedures shall be in accordance with ISO 5389 (see A.1.3.6).

7.5 Noise limitations

7.5.1 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.

7.5.2 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.

7.5.3 The methods of measurement and interpretation shall be as stated in ISO 3989-1.

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 acoustic properties of the room. It is therefore not possible for the SUPPLIER to predict the final sound pressure levels which will be present on site.

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

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

7.5.6 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.

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

8 Compressor

8.1 General

8.1.1 Compressors and auxiliary equipment shall be designed for continuous operation at all specified operating points for at least 3 years, taking into consideration the start-up, shut-down and momentary surge conditions.

It is recognized that this is a design criterion and that continuous operation for this period of time involves factors that are beyond the SUPPLIER's control.

8.1.2 The number and arrangement of the machine casings, including the driver and auxiliaries, shall be agreed upon between the USER and the SUPPLIER of the equipment.

8.1.3 The layout and structural detail of the compressor unit, including the auxiliaries, shall be planned so that sufficient space is available for operating and maintenance purposes.

8.1.4 The SUPPLIER shall specify and supply with the compressor all the special tools and equipment required to assemble the components. Special equipment required for barrel-type compressors shall be included. The main parts, such as casing components and bearing housings, shall be provided with centring spigots, alignment dowels etc. so that precise alignment within a machine is ensured on reassembly using the original parts.

To facilitate assembly and dismantling, lifting rings, eye bolts, jacking screws or similar devices and guide pins shall be provided. Where jacking screws are provided, precautions shall be taken to avoid damage to sealing surfaces. Tapped holes for eye bolts shall have the thread form clearly identified by adjacent stamping etc., to avoid the possibility of fitting incorrect eye bolts.

8.1.5 The control equipment, bearing arrangements, shaft seals and oil system shall be designed such that the penetration of moisture, dust and foreign bodies is minimized whilst the compressor and auxiliary equipment are both in service and at rest.

8.1.6 The compressor and auxiliary equipment shall be suitable for the local and climatic site conditions as specified by the USER on data sheet 203.

It shall be possible to drain, at rest, all parts of the casings and pipes where water can collect.

All parts and systems that could malfunction or be damaged by specified low temperature conditions shall be properly protected from so doing.

The SUPPLIER shall indicate any protection necessary, such as heat tracing or insulation, to be supplied by the USER.

Lubricating oil and control oil at the correct temperature shall be available at the points of consumption at start-up.

8.1.7 All welded connections (structural welds) on casings, pressure-containing castings and pipes, 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 8.2.3);

d) unless otherwise specified, all welds (including repairs) shall be carried out at the SUPPLIER's discretion and in accordance with his own practice.

8.1.8 The USER shall indicate in the data sheets those components where his approval is required prior to repairs being undertaken by the SUPPLIER.

8.2 Casing

8.2.1 The SUPPLIER shall state in the proposal whether the compressor has a horizontally or vertically split casing.

8.2.2 The casing and the casing nozzles shall be designed for the casing design pressure, taking into consideration the hydrostatic test pressure; the casing may be subdivided into chambers for design calculations and testing. (For interstage diaphragms see 8.7.)

For casings not made from corrosion-resistant materials, a suitable corrosion allowance shall be added to the wall thickness.

8.2.3 Structural welds that connect casing parts shall be stress relieved. (For pipes welded to the casings see 8.5.)

8.2.4 Cast iron casing repairs by welding, brazing or cramping are permitted if agreed between the SUPPLIER and the USER. Minor defects in cast iron casings may be repaired with screwed plugs.

Repair welding of steel casings is permitted if the execution and post-weld treatment are properly conducted (see also 8.1.7 and 8.1.8).

8.2.5 Unless otherwise agreed between the SUPPLIER and the USER, the casing material shall be selected in accordance with the following considerations.

a) Steel shall be used if

1) the casing design pressure is above 64 bar;

2) the maximum calculated operating temperature in the casing is above 260 °C.

b) For temperatures below -40 °C, special grade high impact strength materials shall be used, as agreed between the SUPPLIER and the USER.

c) For corrosive, toxic or flammable gases, the USER shall state in the enquiry any special requirements concerning the casing materials and design.

d) For pressures up to 64 bar nodular cast iron may be used.

e) For pressures up to 32 bar grey cast iron may be used.

8.2.6 Cast iron casing joints shall be of the flat-faced or double-raised-face type.

The use of sealing compounds is permissible.

8.3 External forces and moments

The SUPPLIER shall specify the casing nozzle displacements due to thermal movements of the compressor, and the permissible forces and moments on the casing nozzles to which the USER has to connect. These forces and moments shall not affect the safe operability of the compressor under any specified operating condition, including standstill (misalignment, internal clearances, stresses in casings and flanges etc.). Sole responsibility for the layout of the piping systems and their calculation on the basis of the nozzle displacement and permissible forces and moments shall be taken by the furnisher of the piping system who shall ensure that the permissible values are not exceeded. The result of the piping calculations shall be transmitted to the SUPPLIER. This does not affect the aforementioned responsibility of the piping furnisher.

8.4 Bolted connections

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

8.4.2 Threaded holes for bolts shall be kept to a minimum. Studs are to be preferred to cap bolts. Threaded holes shall not penetrate into pressure areas and the remaining base metal shall be thick enough to prevent any possibility of leakage; this thickness shall in any case be at least half the nominal bolt diameter.

8.4.3 The casing bolt materials shall be selected according to the casing design temperature range. At temperatures between -20 and $+300$ °C bolts of grade 4.6 shall be used for cast iron and of grade 5.6 for cast steel in accordance with ISO 898. For higher and lower temperatures, and for corrosive media, materials for bolts and nuts shall be selected according to the standards in the SUPPLIER's country, or equivalent.

8.5 Casing apertures for pipe connections

8.5.1 Inlet and discharge pipes shall be flanged and the connections shall be oriented as specified in the order. Unless otherwise specified, the SUPPLIER's standard design shall be used.

8.5.2 For the auxiliary piping connections on the casing, glands and bearing housings, flanged connections shall have a minimum inner diameter of 20 mm. If, for reasons of space, piping connections cannot be made as flanged connections, intermediate pieces of seamless steel tubing, inserted between the casing and the flanged connection, of the same nominal diameter as specified for the flanged connection, are permitted.

The intermediate pieces may be screwed into the casing wall. For oil, and toxic, corrosive or flammable gases, these screwed connections shall be brazed to cast iron casings or welded to steel casings. Threadless welding of intermediate pieces larger than 50 mm is also permissible provided that such welds are stress relieved. Screwed connections with gaskets are permitted for non-flammable and non-toxic gases and liquids (see figure 4). The USER shall specify in the data sheets which of these procedures is not acceptable in certain instances.

These conditions are applicable to the following auxiliary connections:

a) vent openings;

b) drain openings on casings and seals;

c) sealing gas connections and gas balancing pipes;

d) sealing fluid connections;

e) connections for liquid-injection equipment;

f) lubricating oil connections;

g) cooling water connections.

These conditions shall not apply to pipes, both ends of which are welded or brazed to the casing, forming an integral part of it (e.g. balance lines).