BRITISH STANDARD

BS EN
12693:2008

Refrigerating systems and heat pumps — Safety and environmental requirements — Positive displacement refrigerant compressors

ICS 23.140; 27.080

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National foreword

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A list of organizations represented on this committee can be obtained on request to its secretary.

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Kälteanlagen und Wärmepumpen - Sicherheitstechnische und umweltrelevante Anforderungen - Verdrängerverdichter für Kältemittel

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Foreword

This document (EN 12693:2008) has been prepared by Technical Committee CEN/TC 182 "Refrigerating systems, safety and environmental requirements", the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by November 2008, and conflicting national standards shall be withdrawn at the latest by November 2008.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directives 98/37/EC and 2006/42/EC.

For relationship with EU Directive(s) see informative Annexes ZA and ZB, which are an integral part of this document.

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Introduction

This standard is a type C standard as stated in EN ISO 12100.

The machinery concerned and the extent to which hazards, hazardous situations and hazardous events are covered are indicated in the scope of this standard.

When provisions of this type C standard are different from those which are stated in type A or B standards, the provisions of this type C standard take precedence over the provisions of the other standards, for machines that have been designed and built according to the provisions of this type C standard.

1 Scope

This standard applies to positive displacement refrigerant compressors for stationary and mobile refrigerating systems and heat pumps defined in 3.1, hereafter called compressors.

It applies for compressors used in commercial and industrial appliances and with electrical energy supply including integral motors, up to 1 000 VAC and 1 500 VDC.

It applies to open drive, semi hermetic and hermetic motor compressors, which contain a positive compression function.

This standard is not applicable to:

— compressors used in household appliance for which EN 60335-2-34 applies;

— compressors using water or air as refrigerant.

This standard does not deal with requirements for vibration and noise.

NOTE 1 Compressors for automotive comfort air conditioning systems can be developed according e.g. SAE J 639.

NOTE 2 Noise emission depends on the complete installation of the built-in compressors and the corresponding operating conditions.

For semi-hermetic and open drive compressors which include moving parts and for which the external envelope is primarily designed for mechanical loads, thermal loads (to limit the possible deformation due to temperature), stiffness of the structure (external mechanical loads and weight of the equipment), taking into account established safe industrial practice, it is considered that pressure is not a significant design factor.

Attached parts covering other functions e.g. oil separators, oil coolers, suction accumulators shall comply to EN 14276-1 or EN 13445-6 (cast iron) or EN 13445-8 (aluminium) or showing compliance to the relevant European requirements. This applies also to shells for hermetic compressors either welded or with any kind of permanent joint.

Requirements for compressors used in explosive atmospheres are not covered by this standard.

NOTE 3 For further guidance see EN 13463-1.

This standard deals with all significant hazards, hazardous situations and events relevant to compressors, when they are used as intended and under conditions for misuse which are reasonably foreseeable by the manufacturer (see Clause 4).

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This standard specifies safety requirements for the design, construction, manufacture and testing, documentation and marking of compressors, including integral accessories, e.g. shut-off valve, if necessary.

The requirements in this standard take account of the intended use, as defined in 3.12 of EN ISO 12100-1:2003.

This standard relates to the compressor itself which is to be incorporated in a refrigerating system.

This standard is not applicable to compressors as defined in the scope which are manufactured before the date of publication as EN.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 287-1, *Qualification test of welders — Fusion welding — Part 1: Steels*

EN 294, *Safety of machinery — Safety distance to prevent danger zones being reached by the upper limbs*

EN 378-1:2008, *Refrigerating systems and heat pumps — Safety and environmental requirements — Part 1: Basic requirements, definitions, classification and selection criteria*

EN 378-2:2008, *Refrigerating systems and heat pumps — Safety and environmental requirements — Part 2: Design, construction, testing, marking and documentation*

EN 378-3, *Refrigerating systems and heat pumps — Safety and environmental requirements — Part 3: Installation site and personal protection*

EN 378-4, *Refrigerating systems and heat pumps — Safety and environmental requirements — Part 4: Operation, maintenance, repair and recovery*

EN 837-1, *Pressure gauges — Part 1: Bourdon tube pressure gauges — Dimensions, metrology, requirements and testing*

EN 837-3, *Pressure gauges — Part 3: Diaphragm and capsule pressure gauges — Dimensions, metrology, requirements and testing*

EN 953, *Safety of machinery — Guards — General requirements for the design and construction of fixed and movable guards*

EN 1050, *Safety of Machinery — Principles for risk assessment*

EN 1515 (all parts), *Flanges and their joints — Bolting*

EN 1561, *Founding — Grey cast irons*

EN 1563, *Founding — Spheroidal graphite cast irons*

EN 1779, *Non-destructive testing — Leak testing — Criteria for method and technique selection*

EN 10045-1, *Metallic materials — Charpy impact test — Part 1: Test method*

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EN 10204, *Metallic products — Types of inspection documents*

EN 12178, *Refrigerating systems and heat pumps — Liquid level indicating devices — Requirements, testing and marking*

EN 12516-2, *Industrial valves — Shell design strength — Part 2: Calculation method for steel valve shells*

EN 13136:2001, *Refrigerating systems and heat pumps — Pressure relief devices and their associated piping — Methods for calculation*

EN 13445-2:2002, *Unfired pressure vessels — Part 2: Materials*

EN 13445-3, *Unfired pressure vessels — Part 3: Design*

EN 20898 (all parts), *Mechanical properties of fasteners*

EN 60034-1:2004, *Electrical rotating machinery — Part 1: Rating and performance (IEC 60034-1:2004)*

EN 60204-1:2006, *Safety of machinery — Electrical equipment of machines — Part 1: General requirements (IEC 60204-1:2005, modified)*

EN 60335-2-34, *Household and similar electrical appliances — Safety — Part 2-34: Particular requirements for motor-compressors (IEC 60335-2-34:2002)*

EN 60529, *Degrees of protection provided by enclosures (IP Code) (IEC 60529:1989)*

EN 60947-4-1, *Low-voltage switchgear and controlgear — Part 4-1: Contactors and motor-starters — Electromechanical contactors and motor-starters (IEC 60947-4-1:2000)*

EN 60999 (all parts), *Connecting Devices — Electrical copper conductors — Safety requirements for srew-type and screwless-type clamping units*

EN 61010-1, *Safety requirements for electrical equipment for measurement, control and laboratory use — Part 1: General requirements (IEC 61010-1:2001)*

EN ISO 898 (all parts), *Mechanical properties of fasteners made of carbon steel and alloy steel*

EN ISO 4126-2, *Safety devices for protection against excessive pressure — Part 2: Bursting disc safety devices (ISO 4126-2:2003)*

EN ISO 9606-2, *Qualification test of welders — Fusion welding — Part 2: Aluminium and aluminium alloys (ISO 9606-2:2004)*

EN ISO 12100-1:2003, *Safety of machinery — Basic concepts, general principles for design — Part 1: Basic terminology, methodology (ISO 12100-1:2003)*

EN ISO 12100-2:2003, *Safety of machinery — Basic concepts, general principles for design — Part 2: Technical principles (ISO 12100-2:2003)*

EN ISO 15607, *Specification and qualification of welding procedures for metallic materials — General rules (ISO 15607:2003)*

EN ISO 15614-1, *Specification and qualification of welding procedures for metallic materials — Welding procedure test — Part 1: Arc and gas welding of steels and arc welding of nickel and nickel alloys (ISO 15614-1:2004)*

EN ISO 15614-2, *Specification and qualification of welding procedures for metallic materials — Welding procedure test — Part 2: Arc welding of aluminium and its alloys (ISO 15614-2:2005)*

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CR ISO 15608:2000, *Welding — Guidelines for a metallic material grouping system (ISO/TR 15608:2000)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 378-1:2008, EN ISO 12100-1:2003 and the following apply.

NOTE All pressures are gauge pressures unless otherwise specified.

3.1
positive displacement compressor
compressor in which compression is obtained by changing the internal volume of the compression chamber

3.2
specified maximum allowable pressure, PS
maximum allowable pressure as stated by the compressor manufacturer

3.3
specified maximum allowable standstill pressure, PS_S
maximum allowable value for the equalisation pressure in the compressor as stated by the compressor manufacturer

NOTE 1 This pressure corresponds to different maximum permissible ambient temperatures for different refrigerants (see 6.5.2).

NOTE 2 $PS_S \leq PS$

3.4
compressor overflow device
device specifically intended to protect the compressor against bursting caused by abnormal conditions, e.g. the discharge valve shut. The device relieves from the high pressure/intermediate side of the compressor to a lower pressure side

NOTE The device may be a bursting disc or may be a spring loaded overflow valve. Spring loaded overflow valves can be either back pressure compensating or back pressure dependent type.

3.5
Temperature load cases

3.5.1
min $t_{0\ 100}$
lowest temperature at which component material can be used at a load of up to 100 % of the allowable design stress at 20 °C, taking the safety factors according to Table B.2 into account

3.5.2
min $t_{0\ 75}$
lowest temperature at which component material can be used, at a load of up to 75 % maximum of the allowable design stress at 20 °C, taking the safety factors according to Table B.2 into account

3.5.3
min $t_{0\ 25}$
lowest temperature at which component material can be used, at a load of up to 25 % maximum of the allowable design stress at 20 °C, taking the safety factors according to Table B.2 into account

3.5.4
fasteners
screws, double end studs, reduced shank bolts, studs and nuts with designation system according to EN ISO 898 and EN 20898 or EN 1515 (property classes)

3.6 Symbols

For the purposes of this document, the following symbols apply.

Table 1 — Symbols

Symbol	Term	Unit
A	Elongation after fracture	%
KV	Impact rupture energy	J
KV_0	Threshold value of impact rupture energy, where the impact rupture energy is defined as independent of the temperature	J
KV_0^t	Standard value of impact rupture energy at standard temperature of the material	J
$KV_{\text{TS min.}}$	Impact rupture energy at minimum operating temperature $TS_{\text{min.}}$	J
P_{burst}	Burst pressure	MPa
min $t_{0\ 100}$	The lowest temperature according to the European Standards of the respective materials at which the compressor can be used at a load of up to 100 % of the allowable design stress at 20 °C, taking into account the safety factors	
min $t_{0\ 75}$	The lowest temperature at which the compressor can be used, if its load amounts to 75 % maximum of the allowable design stress at 20 °C, taking into account the safety factors	
min $t_{0\ 25}$	The lowest temperature at which pressure parts can be used, if their load amounts to 25 % maximum of the allowable design stress at 20 °C, taking into account the safety factors	
P_{F}	Maximum allowable design test pressure	MPa
PS	Maximum allowable pressure in common sense, without regarding any influence of temperature	MPa or bar [a]
PS_{S}	Maximum allowable standstill pressure	MPa or bar [a]
PS_0	Maximum allowable pressure at ambient temperature (– 10 °C to + 50 °C) according to strength design (without temperature correction)	MPa or bar [a]
$PS_{\text{TS max.}}$	Maximum allowable pressure at maximum operating temperature	MPa or bar [a]
$PS_{\text{TS min.}}$	Maximum allowable pressure at minimum operating temperature	MPa or bar [a]
$R_{\text{p 0,2}}$	Proof strength, 0,2 % offset at room temperature	MPa, N/mm^2
$R_{\text{p 1,0}}$	Proof strength, 1,0 % offset at room temperature	MPa, N/mm^2
$R_{\text{p 0,2 TS max.}}$	Proof strength, 0,2 % offset at highest operating temperature	MPa, N/mm^2
$R_{\text{p 1,0 TS max.}}$	Proof strength, 1,0 % offset at highest operating temperature	MPa, N/mm^2
R_{eH}	Upper yield strength	MPa, N/mm^2
$R_{\text{eH TS max.}}$	Upper yield strength at highest operating temperature	MPa, N/mm^2

Table 1 (*continued*)

Symbol	Term	Unit
R_m	Tensile strength	MPa, N/mm^2
$R_{m\ TS\ max.}$	Tensile strength at highest operating temperature	MPa, N/mm^2
S_{con}	Safety factor	—
$S_{TS\ min.}$	Factor taking into consideration the impact strength reduction due to the minimum operating temperature	—
$S_{TS\ max.}$	Factor to allow for the reduction in strength due to the highest operating temperature	—
σ_{con}	Initial design stress	MPa, N/mm^2
TS	Operating temperature	°C
$TS_{min.}$	Lowest operating temperature	°C
$TS_{max.}$	Highest operating temperature	°C
[a] 1 MPa = 10 bar. NOTE 1 bar = 0,1 MPa = 100 kPA = 100 000 PA = 14,5 PSI.		

4 List of significant hazards

See Table 2.

This clause contains all significant hazards, hazardous situations and events, as far as they are dealt with in this standard, identified by risk assessment as significant for type of compressors and which requires action to eliminate or reduce the risk. The risk assessment shall be made according to EN 1050. The compressors shall be manufactured in accordance with the principle listed in EN ISO 12100-2 to eliminate or reduce the foreseeable risk.

Table 2 — List of significant hazards, hazardous situations, safety requirements and/or measures

Significant hazard according to EN 1050	Hazardous situation	Safety requirements and/or measures	Reference	Verification
Mechanical				
Moving parts	Possible injuries to human body	Guards	5.2	V
Loss of stability	Possible injuries at transport and operation	Fixing points Lifting points Lifting points	5.3 5.4, 7.3.1 6.2.5	V D / V T
Rupture or bursting	Possible injuries from ejected parts or fluid	Design criteria Strength test Tightness test	5.5 6.2.2, 6.2.3, 6.3.2 6.3.3	D T T V
Electrical				
Contact live parts	Possible injuries from electrocution	Design criteria Earthing Internal wiring High potential test Protection devices	5.6.1, 5.6.2, 5.6.3, 5.6.4, 5.6.5, 5.6.9 5.6.6 5.6.7 5.6.8,6.2.4, 6.3.4 5.6.10	D D D T V
Electrostatic phenomena	Possible injuries from electric shock	Earthing	5.6.6	D
Thermal				
Contact with hot or cold objects	Possible injuries to the skin	Warning	8.2	

Table 2 (*continued*)

Significant hazard according to EN 12100-1	Hazardous situation	Safety requirements and/or measures	Reference	Verification
Materials and substances				
Contact or inhaling gasses	Possible injuries from aggressive media at draining	Means and instructions Warning	5.7 7.3.2	V V

NOTE Verification methods:

V Visual inspection, verifies the required features of the components

T A test or check verifies that the features provided perform their function in such a way that the requirement is met

M Measurement verifies that requirements are met to the specified limits

D Drawing and / or calculations verify that the design characteristics meet the requirements

5 Safety requirements and/or protective measures

5.1 General

Compressors shall comply with the safety requirements and/or measures of this clause.

In addition, the compressors shall be designed according to the principles of EN ISO 12100 for relevant but not significant hazard, which are not dealt with by this standard.

Furthermore, the refrigerating system which the compressor is part of, shall be in accordance with the requirements of the EN 378 series.

As surface temperatures on a refrigerant compressor and the attached parts and piping depend on operating conditions and properties of specific refrigerants, protection shall be provided considering the requirements in EN ISO 13732-1.

5.2 Protection of moving parts

Protection shall be provided for moving parts such as automatic drives, fans or indicators of capacity controls by fixed guards according to EN 953. Openings such as slots, holes, etc. shall comply with EN 294.

5.3 Safety to prevent loss of stability

Compressors shall be equipped with fixing points to ensure that they shall not tip or fall over during transport and operation.

5.4 Safety during handling

Compressors above 25 kg weight shall be equipped with lifting points or arrangement to enable safe lifting, installation and maintenance. Lifting points or arrangements shall be designed for to carry 1,25 times the weight of the compressor allocated to the individual lifting point.

NOTE For design it is sufficient to use a factor 2 against deformation and a factor 3 against fracture correlated to vertical lifting.

5.5 Safety to prevent rupture or bursting

5.5.1 General

Compressors and associated components shall be designed and manufactured to withstand the pressure and temperatures which can occur during operation, standstill and transportation taking into account the thermal, chemical and mechanical stresses to be expected.

The materials shall be selected based upon suitability for the application. The choice of materials and selection of dimensions shall be based on the need for sufficient strength, rigidity and stability to cope with dynamic effects. The ability of the compressor to withstand internal pressure shall be demonstrated by type test (see 6.2) or by individual test (see 6.3).

5.5.2 Pressure requirements

The compressor design pressure for standard applications shall be in accordance with the refrigerant saturation pressures corresponding to the temperatures given in EN 378-2 or as specified by the compressor manufacturer.

For refrigerants and applications not covered by EN 378-2, the maximum allowable pressure PS and the specified maximum allowable standstill pressure PS_S shall be specified by the manufacturer in the Instructions for use under consideration of the required application ranges. For further requirements, see 6.2 and 6.3.

5.5.3 Materials

5.5.3.1 General

The materials shall be selected to allow for the thermal, chemical and mechanical stresses expected during operation, standstill and transportation throughout the foreseeable life of the compressor parts.

Compressor and compressor parts shall comply with the requirements of Annexes B, C, D and E.

NOTE Basic design criteria for refrigerant compressors are described in Annex A.

5.5.3.2 Requirements to avoid brittle fracture

For compressor and compressor parts with reduced ductility at low temperatures below – 10 °C, the allowable temperature should be reduced according Annex F.

Examples are given in Annex E.

5.5.4 Sight glasses

If sight glasses are used, safety requirements according to EN 12178 shall apply.

5.5.5 Application of pressure relief devices

5.5.5.1 Protection against discharge shut off valve closed

The manufacturer shall protect compressor stages fitted with a shut-off valve between stages and compressors with a nominal swept volume > 90 m^3/h (25 l/s) against rupture by incorporating either a compressor overflow device or an external relief device or safety valve. In case of multiple stage compressors, the swept volume of the high pressure stage shall be considered as the 'nominal swept volume' for the purposes of this clause.

NOTE Internal damage of the compressor from overloading and overheating may result if the overflow device operates.

The compressor overflow device shall be sized to relieve the refrigerant flow produced by the compressor at a suction pressure corresponding to 10 °C saturated. If the maximum allowable evaporation temperature differs from the value of 10 °C by more than 5 K then the overflow device shall be sized to the pressure corresponding to that temperature.

The compressor overflow device shall relieve to a lower pressure part of the compressor/system or to a special container.

Relief devices discharging to atmosphere or external safety valves discharging to the compressor/system shall be in accordance to EN 13136.

Bursting discs shall be in accordance with EN 13136:2003, 7.3 and EN ISO 4126-2.

The dimensions of the compressor overflow device shall be verified by testing according to 6.2.3.

It shall not be possible to isolate compressor overflow devices, relief devices or safety valves.

The compressor overflow device shall not be used for system pressure protection.

5.5.5.2 Protection against standstill pressure higher than operating pressure

In case of CO_2, a relief device discharging to the atmosphere shall be used in order to protect the compressor against pressure higher than *PS*. This shall be carried out in a safe manner to avoid risk for personnel, see EN 378-2.

5.6 Electrical safety

5.6.1 General

The electrical components and system of which the compressor is part as far as relevant shall conform to the requirements of EN 60204-1 and the requirements of the following additions.

Open type compressors as far as relevant are concerned insofar as they are equipped with accessories e.g. fans, heaters, solenoid valves, electrical control devices.

5.6.2 Classification

Motor compressors and electrical devices enclosures shall be Class I and at least IP 21 as defined in EN 60529.

5.6.3 Determination of current ratings

The following current ratings shall be determined for the compressor:

— max. operating current

  is the maximum current that the compressor consumes at the running condition within its intended operating range, at the minimum specified operating voltage, for the refrigerant which gives the highest power consumption.

  NOTE Usually, compressors are released for more than one refrigerant.

— locked rotor amps

  shall be indicated at the rated voltage or at the average medium voltage if a range is specified, and at the frequency giving the highest locked rotor amperage value. Measurements shall be taken with rotor firmly locked against movement and at stabilized current level maximum 4 s after the stator has been energized. Test shall start with the compressor enclosure at a temperature of 32 °C ± 8 K.

5.6.4 Protection against access to live parts

Compressors shall be constructed and contained such that unintended touching of live parts is impossible as defined in Clause 6 of EN 60204-1:2006. Covers shall only be removable by using tools.

Flow of refrigerant gas shall be conducted such that condensation of moisture around electrical connectors and terminals is avoided. Spacings between live parts (energized parts) and dead metal parts (non-conductive, non-energized parts) inside and outside the compressor enclosure shall be at least as given in Table 3.

Table 3 — Spacings

Minimum acceptable spacings at un-insulated live parts of opposite polarity and between an un-insulated live part and a dead metal part [mm]		
Voltage range	Through-space	Over-surface
≤ 130 V	1,5	2,0
> 130 V and ≤ 250 V	3,0	4,0
> 250 V and ≤ 480 V	4,0	5,0
> 480 V and ≤ 750 V	4,5	6,0
750 V and ≤ 1 000 V	5,5	7,5

Spacings at the leads of tubed heaters for voltage range up to 250 V may be at least 1,0 mm if surroundings are protected against dirt.

5.6.5 Connecting devices

Connecting devices shall comply with EN 60999.

5.6.6 Provisions for earthing

Motor compressors shall be equipped with provisions for earthing according to 10.1 of EN 60034-1:2004.

5.6.7 Internal wiring

Internal wiring shall be routed, supported or otherwise protected against bending and cutting. Insulation and supports shall be resistant against impact of vibration. Rough surfaces, sharp edges or contact to moving parts shall be avoided where wiring is installed. Sleeves shall be applied on motor winding lead ends where they are extended and fitted to connectors.

Openings through which insulated wires pass shall have smooth, rounded surfaces. In case of sheet metal, openings shall be protected by bushings or sleeves.

5.6.8 High potential test

The high potential test shall be made according to 6.2.4 and 6.3.4.

5.6.9 Insulating materials

Insulating materials shall be resistant against refrigerants and lubricants used in the compressor and the refrigerant circuit installation. They shall be made from materials resistant against corrosion or coated to be corrosion protected. Impact of temperature by cooling and heating to temperatures which occur during operation of the motor compressor shall be respected.

5.6.10 Motor compressors protection devices

Motor compressors shall be equipped with protection devices interrupting the motor current. These devices shall be such that the temperature of any accessible surface shall not exceed 150 °C under normal or abnormal operating conditions, e.g. locked rotor or failed phase / single phase condition (3 phase motors). Thermal protection devices shall switch off the motor current directly (e.g. line break device located inside the compressor housing) or act to interrupt the motor contactor in the control panel (e.g. electronic module). These devices may be of the automatic or manual reset type and shall comply with the requirements of EN 61010-1.

If the protection device is of automatic reset type, it may be used in case the manufacturer's documentation/guidelines indicate the compressor has passed a 2 000 cycles locked rotor type test.

In addition to the over-current protection devices described above, motor compressors may also be equipped with external manual reset over-current devices rated in accordance with EN 60947-4-1. In such cases the locked rotor test does not need to be performed, provided that the use of such over-current devices is a mandatory requirement recorded in the compressor manufacturer's documentation.

5.7 Measures to reduce emissions of substances

Compressors shall be designed so that recovery of lubricant and refrigerant is possible in a safe and environmentally acceptable manner (for example service connections, see EN 378-4). Special instructions shall be given in the documentation for the user (manufacturer manual).

6 Verification of safety requirements and/or protective measures

6.1 General

For each safety requirement and/or protective measure, except if it is self-evident, a method of verification shall be established:

a) by testing according to 6.2;

b) by measures (e.g. "strength");

c) by calculation;

d) by visual inspection.

Compressors shall be tested by the manufacturer: Either a type test according to 6.2 together with an individual test according to 6.3.2.2 shall be performed or an individual test according to 6.3.2.3.

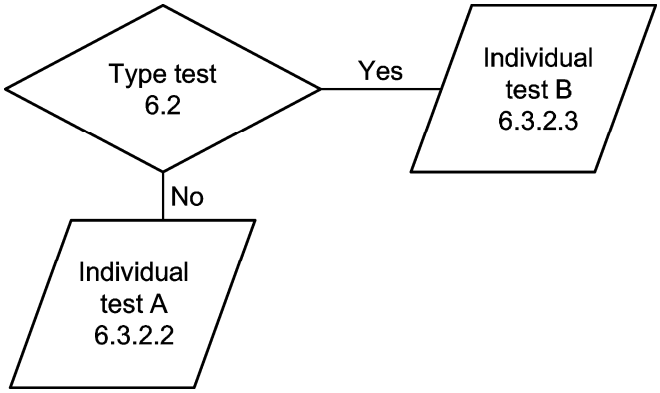

Figure 1 — Flowchart: tests

If a compressor is released by the manufacturer for different applications, the tests shall be made according to the most demanding requirements.

All test results shall be recorded.

NOTE Instead of a strength type test (6.2.2) also an individual strength test according to 6.3.2.2 can be performed.

6.2 Type test

6.2.1 General

All types of compressor shall be type tested for strength, function of the pressure relieve device if installed, and electrical safety.

6.2.2 Strength test

If an individual strength test is chosen according to 6.3.2.1, following type test shall be performed.

Two representative samples of each compressor design platform shall be selected and tested. This selection shall reflect worst case conditions with regard to strength. The test shall be made at least once a year.

NOTE 1 Verification can be made by a notified body or within the manufacture's certified Quality Management system.

The high pressure side enclosure of the compressor shall withstand without rupture a test pressure of at least $3{,}0 \times PS$.

The low pressure side enclosure of the compressor shall withstand without rupture test pressure of at least $3{,}0 \times PS_S$.

The pressure shall be increased gradually until the required maximum test pressure is reached. The pressure shall be maintained for at least 30 min. The pressure shall be relieved gradually. The test shall be reported.

Arrangements for sealing openings and applying test pressures shall not influence the response of the compressor being tested.

The compressor shall be considered to be acceptable if on completion of the pressure test, an examination shows there are no signs of rupture.

The sample tested shall not be returned for use in normal production.

NOTE 2 A hydraulic test is recommended for safety. During this test, leaks and permanent deformations at a pressure greater than 2 times PS or PS_S, as appropriate, are acceptable. For the purposes of this test special gaskets may be used.

NOTE 3 If compressor design is such that high and low pressure side cannot be separated for type testing, the test pressures specified for the high pressure side can be used.

6.2.3 Pressure relief device

Compressors with a compressor pressure relief device between the high pressure and the low or intermediate pressure side shall also withstand on the high pressure side a pressure at least 3 times the pressure developed while the device is relieving — based on conditions specified in 5.5.5.

In case of backpressure compensating relief valves, a calculation according to EN 13136 under the conditions that

— the opening pressure is $1{,}1 \times PS$,

— the massflow is calculated to critical flow, and

— the calculated massflow shall be higher than the delivery rate of the compressor,

is sufficient.

NOTE If it can be established that the combination of the size of the motor and the size of the compressor is such that the compressor could not run with a suction pressure corresponding to 10 °C saturated, the test should be carried out at the highest suction pressure at which the compressor will run.

6.2.4 Verification of electrical safety

6.2.4.1 High potential test

Each motor compressor shall be tested according to 8.1 of EN 60034-1:2004. The test-voltage is determined by Table 14 of EN 60034-1:2004.

During the test, the compressor shall be filled with dry air, nitrogen or a relevant refrigerant at the manufacturer's choice.

6.2.4.2 Requirements on motor protection

Motor compressors shall be type tested for temperature protection under locked rotor conditions. This requires preparation by using specific parts to prevent the rotor from turning. The test compressor shall be equipped with thermal probes recording surface temperature at places where highest surface temperatures will occur.

Motor compressors equipped with automatic reset thermal protection devices shall withstand 2 000 locked rotor cycles at rated voltage. The maximum surface temperature shall not exceed 150 °C. After completion of the locked rotor test, the motor compressor shall pass a high potential test according to EN 60034-1:2004, 8.1. The test voltage is determined by reference to Table 14 of EN 60034-1:2004. The leakage current shall not exceed 3,5 mA or 3,5 mA per kW rated input power, whichever is higher. Independent of input power rating, leakage current shall not exceed 30 mA for motors up to 25 A maximum rated current.

The test may be terminated after 15 days if 2 000 cycles are not completed, provided that the temperature of the enclosure has been measured after 12 and 15 days and has not risen by more than 5 K between these measurements.

Motor compressors equipped with manual reset thermal protection devices shall withstand 50 locked rotor cycles at rated voltage or until the maximum surface temperature remains constant within 5 K for 1 h, whichever is the longer. The maximum surface temperature shall not exceed 150 °C.

After completion of the locked rotor test, the motor compressor shall pass a high potential test according to EN 60034-1:2004, 8.1. The test voltage is determined by reference to Table 14 of EN 60034-1:2004. The leakage current shall not exceed 3,5 mA or 3,5 mA per kW rated input power, whichever is higher. Independent of input power rating, leakage current shall not exceed 30 mA for motors up to 25 A maximum rated current.

The motor compressor shall be filled with oil and gaseous refrigerant in appropriate quantities during the locked rotor test. If a compressor is released for several refrigerants, the manufacturer may choose the type of refrigerant for the test. Only one refrigerant needs to be tested.

The voltage during the locked rotor test shall be at the maximum of the specified operating voltage range. Motor compressors having a dual voltage rating shall be tested at each voltage.

NOTE For test evaluation purposes, it is recommended that the motor compressors are also subjected to the high potential test as defined before the locked rotor test.

6.2.5 Lifting points

The lifting points or arrangements shall be tested by lifting up the compressor including an additional weight of 25 % for the period of 10 min.

NOTE This test does not avoid damage in case of an emergency stop.

6.3 Individual test

6.3.1 General

All individual compressors (enclosure and optional components greater than 50 mm equivalent diameter) shall be tested on strength, tightness and electrical safety during or after manufacture.

6.3.2 Strength test

6.3.2.1 General

If no type strength test is performed, an individual strength test according to 6.3.2.2 (strength test A) shall be performed during manufacture.

If a type strength test is performed according to 6.2, an individual strength test according to 6.3.2.3 (strength test B) shall be performed during manufacture.

The test shall be made with dry air or inert gas or an equivalent alternative testing procedure.

If compressor design is such that high and low pressure side cannot be separated during the test, the pressures specified for the high pressure side shall be used.

6.3.2.2 Individual strength test A

The high pressure side enclosure of the compressor shall withstand without rupture a test pressure of $1{,}5 \times PS$.

The low pressure side enclosure of the compressor shall withstand without rupture a test pressure of $1{,}5 \times PS_S$.

6.3.2.3 Individual strength test B

The high pressure side enclosure of the compressor shall withstand without rupture a test pressure of $1{,}1 \times PS$.

The low pressure side enclosure of the compressor shall withstand without rupture a test pressure of $1{,}1 \times PS_S$.

6.3.3 Test for tightness

The high pressure side enclosure of the compressor shall be tested and proven tight at no less than $1{,}0 \times PS$.

The low pressure side enclosure of the compressor shall be tested and proven tight at no less than $1{,}0 \times PS_S$.

The test shall be made with dry air or inert gas.

If compressor design is such that high and low pressure side cannot be separated during the test, the pressures specified for the high pressure side shall be used.

For tightness test, a procedure according to EN 1779 shall be applied where the sensitivity of detection is a minimum 10^{-4} Pa m^3/s.

NOTE A method other than pressure testing at the design pressure may be employed if it can be demonstrated that the alternative test method (e.g. helium test) produces results that are at least equivalent to the pressure test method.

6.3.4 Verification of electrical safety

Each motor compressor shall pass a high potential test according to EN 60034-1:2004, 8.1. The test voltage is determined by Table 14 of EN 60034-1:2004, 8.1. The one minute test may be replaced by a 5 s test in case

of rated motor power up to 200 kW or a 1 sec test in case of rated motor power up to 5 kW if the increased test voltage is applied.

During the test, the compressor shall be filled with dry air, nitrogen or a relevant refrigerant at the manufacturer's choice.

7 Marking, graphical symbols, written warnings

7.1 General

When compressors present residual hazards to personnel, safety signs and warning devices shall be used.

The means of warning devices has to be described (e.g. which hazard is involved).

Markings, graphical symbols and written warnings shall be permanently fastened and clearly visible. They shall be resistant to the atmosphere in which the compressor is installed, be of suitable materials and be so manufactured that they are able to withstand normal operation and maintenance.

7.2 Marking

The information given in Table 4 shall be permanently marked on the name plate or stamped on the housing:

Table 4 — Marking

Marking	Units
Minimum marking for all types of compressors:	
— manufacturer, supplier or importer	
— compressor model, type designation	
— year of manufacture and serial number (may be coded)	
— specified maximum allowable pressure, PS	MPa or bar [a] [b]
— specified maximum allowable standstill pressure, PS_S (only when different from PS)	MPa or bar [a] [b]
Additional marking for motor compressors with a power consumption up to 3 kW:	
— type of current	
— direct	
— alternating-single	
— three phase	
— specified voltage(s) / voltage range(s)	V
— specified frequency(ies)	Hz
— locked rotor current	A [b] [c]
Additional marking for motor compressors with a power consumption exceeding 3 kW:	
— type of current	
— direct	
— alternating-single	
— three phase	
— specified voltage(s) / voltage range(s)	V
— specified frequency(ies)	Hz
— specified speed	rev/s or rev/min [b]
— locked rotor current	A [b] [c]
— swept volume at specified speed or per revolution	m^3/h or m^3/rev [b]
— motor wiring, if more than one option	A [b]
— maximum operating current	A [b]
— class of protection	IPXX [b]
Additional marking for open compressors:	
— specified speed or speed range	rev/s or rev/min [b]
— swept volume at specified speed or per revolution	m^3/h or m^3/rev [b]
Marking of electrical accessories:	
— type and manufacturer (also symbol)	
— type of current	
— specified voltage(s) / voltage range(s)	V
— specified frequency (if required)	Hz
— specified capacity or nominal current	W or A [b]

[a] 1 MPa = 10 bar.

[b] These items shall be either marked on the compressor or on the accessory or specified in the technical documentation.

NOTE This information can also be coded if electrical accessories are produced in series.

[c] The locked rotor current shall be measured at the maximum of the specified operating nominal voltage range. For motor compressors with more than one permitted operating voltage, all related locked rotor currents have to be given.

7.3 Graphical symbols, written warnings and information

7.3.1 Lifting points

Where a compressor may be lifted only at certain points during transport and mounting, these points shall be marked and described in the technical documentation.

7.3.2 Pressurising the housing

If before installation the housing of a compressor is charged with positive pressure > 0,5 bar at 25 °C ambient temperature, a warning notice shall be attached. This does not apply to compressors sealed with rubber plugs.

7.3.3 Lubricant charge

When a compressor is delivered with a lubricant charge, the type and volume of lubricant shall be shown in the technical documentation and may be indicated on the compressor.

8 Documentation and information for the user

8.1 General

The essential requirements for the instruction handbook are listed in Clause 6 of EN ISO 12100-2:2003.

8.2 Instruction handbook

The compressor manufacturer shall provide documentation (including safety instructions) which shall at least contain the following information, if relevant:

a) the description of the compressor and its basic application;

b) the electrical circuit diagram;

c) the electrical safety requirements;

d) instructions concerning starting, stopping and standstill of the compressor;

e) instructions concerning the disposal of operating fluid and equipment;

f) causes of the most common defects and measures to be taken, e.g. instructions concerning leakage detecting by authorized personnel and the need to contact competent maintenance technicians in the event of leakage or breakdown;

g) precautions to be taken when lifting or transporting the compressor;

h) maintenance instructions for the compressor;

i) instructions concerning charging and discharging of refrigerant and oil;

j) instructions concerning the handling of refrigerant and the hazards associated with it;

k) liquid slugging and measures to prevent damage / fracture to the compressor and other components or pipework;

l) instructions concerning function and maintenance of safety devices;

m) whether personal protection equipment (PPE) is required;

n) instructions and/or warnings to prevent contact with hot or cold surfaces.

When delivering identical compressors for series production it is sufficient to supply the documents once. In case of technical modifications the documentation shall be amended, completed or completely substituted as necessary.

Annex A
(informative)

Basic design criteria for refrigerant compressors

A.1 General

For a refrigerant compressor which includes moving parts, the external and internal contour should be designed for stiffness of the structure, mechanical and chemical stresses, sound attenuation and thermal load.

Design, dimensioning, choice of material and manufacturing rules are carried out taking into account the main following primarily technical considerations which are necessary to ensure the compressor capability against technical performance and user requirements taking into account established safe industrial practice.

A.2 Compressor capability against technical performance

A.2.1 Design, dimensioning and manufacturing rules

— Stiffness against stresses due to internal mechanical movements of moving parts (dynamic effects) in order to have sufficient strength, rigidity and stability, taking into account deformation of structure which could compromise compressing moving parts rotation or tightness, because of low dimensional tolerances between shaft and bearings.

— Increase of local heat transfer in order to allow an optimal cooling by adding heat transfer fins (heat produced by friction due to moving parts and compression).

— Shapes should allow good lubrication of the internal mechanism.

A.2.2 Choice of material

— Good and reproducible casting properties are necessary because of complex shape.

— Good ability for machining (without creating deformation due to surface temperature increase, production of short breaking chips which are easily removable and securing a long tool life).

— Low friction properties connected to good lubricant retention.

— Small thermal coefficient of expansion in order to avoid deformations in operation.

A.3 Compressor capability against user requirements

A.3.1 Design, dimensioning and manufacturing rules

— Reduction of noise level due to internal mechanical movements of moving parts (by increasing material thickness and forming of specific shapes).

— Reduction of vibrations due to internal mechanical movements of moving parts (by increasing material thickness and forming of specific shapes).

A.3.2 Choice of material

— Optimal vibration and noise attenuation/absorption behaviour.

— In some applications, reduction of weight.

— Environmentally friendly (low energy manufacturing and easy to recycle).

Annex B
(normative)

Procedure for the design of a refrigerant compressor

B.1 Guideline for the application of this annex

B.1.1 General

The procedure described as follows for the design of casings and casing parts is a procedure to be applied to design a compressor by formula (DBF) or by burst test. Alternatively, a design calculation by analysis can be carried out by means of a more sophisticated method based on fracture mechanics, or the finite element method.

Materials as specified in Table B.2 should be used (see also the tables of materials in Annex F).

B.1.2 Method of design and field of application (DBF)

In this procedure for the design of compressor casings and casing parts, the design calculation is carried out for the dimensioning of compressor components on the basis of EN 12516-2 or EN 13445-3 or equivalent methods with a strength value at a temperature between – 10 °C and + 50 °C.

Any use of material at temperatures below – 10 °C is only allowed when the requirements of Annex E are fulfilled. Any use of material at temperatures above + 50 °C is only allowed when the requirements of Annex D are fulfilled.

NOTE DBA Design by Formula.

B.1.3 Strength values for the design calculation and proof of material properties

B.1.3.1 Strength values for the design calculation

The strength values (i.e. 0,2 % proof strength $R_{p0,2}$, tensile strength R_m) for the design calculation shall be taken from the EN material standards. In Annex F, the EN standards which correspond to the listed materials are given. If the strength values are not taken from the EN material standards, these shall be verified by means of material certificates in accordance with EN 10204.

B.1.3.2 Material properties

The material properties used for calculation of pressure-bearing parts of compressors (except fasteners — see B.1.3.3) shall be taken from relevant standards (see Annex F) or test certificates in accordance with EN 10204.

B.1.3.3 Design calculation of screws and fasteners

Screws and fasteners shall be dimensioned in accordance with the design requirements of Table B.1 (utilization 100 %). Modifications in length as a result of the temperature difference between the lowest and the highest temperature of the intended temperature range shall be taken into consideration during the design of screws, fasteners, nuts and seals. Property class testing and marking shall comply with EN ISO 898 and EN 20898 or EN 1515.

Table B.1 — Allowable stresses for the design calculation or testing at test pressure of fasteners

Material	Design requirement [a] at maximum allowable pressure PS Individual test (according to 7.3)	Design requirement at test pressure P_F Individual test (according to 7.3)
Non-austenitic steel	MIN {$R_{m\,t}$ / 4,0; $R_{p\,0,2\,t}$ / 3,0}	MIN {$R_{m\,t}$ / 2,67; $R_{p\,0,2\,t}$ / 2,0}
Austenitic steel	$R_{m\,t}$ / 4,0	$R_{m\,t}$ / 2,67

[a] Index t means: The lower material strength values at the lowest or the highest operating temperature shall be used. The allowable stress shall not be exceeded within the operating temperature range. See Table E.2

B.1.4 Determination of the maximum allowable pressure by a burst test

If calculations cannot be performed on an enclosure part due to its complex shape and material deviative properties, etc., an experimental method to determine the maximum allowable pressure by using a burst pressure P_{burst} shall be applied.

The following procedure shall be used in cases where wall thickness cannot be adequately calculated due to the special shape. The burst test is also a part of the technical documentation.

a) Verify that the part to be tested is cast according to the specified drawing and revision. The material used shall be the same type and grade as for the production part.

b) Verify that the parts are machined to the same dimensions as the production part.

c) Verify that the material properties meet the requirements of Annexes B and C.

d) Verify that a calibrated pressure gauge is used; maximum tolerance shall conform to at least Class 1 or better according to EN 837-1 and 3.

e) The scale of the pressure gauge shall be approximately 4/3 of the anticipated burst test pressure.

f) The pressure shall be raised in intervals of max. 5 bar increasing and with a minimum of five minutes dwell per stage until rupture occurs and the pressure (P_b) shall be recorded together with the burst test data, details of material, part number, material specification and measured wall thickness from at least five (5) different locations in a proof test report.

During the burst test, it is acceptable for leaks and lack of tightness to occur between flanged, gasketed or bolted parts as long as the pressure P_{burst} can be reached during the test. It is acceptable for gasket(s) to break during the burst test if they can be satisfactorily calculated in their properties for the anticipated maximum pressures PS or PS_S.

For test purposes, it is acceptable to use bolting of a higher quality class than specified in the design specification. For production series, part bolt diameter and thread size shall be in accordance with the design specification.

The burst test or any hydrostatic test shall not be performed by means of a clamped construction on a hydraulic press which can counteract the shell bending stress giving no free movement of the wall under pressure.

The complete enclosure except shaft seal and sight glasses shall be tested.

Calculated maximum PS or PS_S:

$$PS \text{ or } PS_S \leq \frac{P_{burst}}{3{,}0} - 0{,}05 \text{ (MPa)}$$

B.1.5 Documentation

The chosen design method, the strength values used for the calculation, e.g. for the tensile strength or proof strength, as well as the consideration of additional stress or other influences (e.g. corrosion), shall be recorded in the design documents.

Table B.2 — Design stress σ_{con} as quotient of characteristic strength value and indicated numerical value (safety factor S_{con})

No.	Material [a]	σ_{con}		S_{con}
		Proof strength [b c]	Tensile strength [b d]	
1	Steel group 1.1 and 1.2	MIN { $R_{p\,0,2}$ / 1,5; R_m / 2,4 }		2,4
		$R_{p\,0,2}$ / 1,5	R_m / 2,4	
	Steel group 8.1			
2	at A ≥ 30 %	$R_{p\,1,0}$ / 1,5	R_m / (0,5 + $R_m/R_{p\,1,0}$)	0,5 + $R_m/R_{p\,1,0}$
3	at A ≥ 35 %	MAX {MIN[R_m/3; $R_{p\,1,0}$ / 1,2]; $R_{p\,1,0}$ / 1,5 }		
		$R_{p\,1,0}$ / [1,2 or 1,5]	R_m/3,0	3,0
4	Cast steel group 1.1 and 1.2	MIN { $R_{p\,0,2}$ / 1,9; R_m / 3 }		
		$R_{p\,0,2}$ / 1,9	R_m / 3,0	3,0
5	Aluminium group 21	R_{eH} / 1,5	R_m / (0,5 + R_m/R_{eH})	0,5 + R_m/R_{eH}
6	Aluminium groups 22 to 26	MIN { $R_{p\,0,2}$ / 1,5; R_m / 2,4 }		
		$R_{p\,0,2}$ / 1,5	R_m / 2,4	2,4
7	Copper groups 31 to 38	MIN { $R_{p\,0,2}$ / 1,5; R_m / 3,5 }		
		$R_{p\,0,2}$ / 1,5	R_m / 3,5	3,5
8	Spheroidal graphite cast iron group 72.2	$R_{p\,0,2}$ / 2,4	R_m / 3,8	3,8
9	Spheroidal graphite cast iron group 72.1	$R_{p\,0,2}$ / 2,5	R_m / 4,0	4,0
10	Grey cast iron group 71	$R_{p\,0,2}$ / 2,5	R_m / 4,5	4,5

[a] The classification into groups of materials shall be carried out in accordance with CR ISO 15608; materials from this group are contained in Annex F. The safety factors relate to the calculation methods of B.1.2.

[b] Stress values at a temperature of 20 °C or 25 °C shall be used. As a deviation, stress values within the temperature range from – 10 to + 50 °C can be used. Stress values at other temperatures shall not be used in connection with these safety factors.

[c] For steel (ferritic and austenitic, as well as cast steel), $R_{p\,0,2}$ can be assessed by reducing $R_{p\,1,0}$ by 25 MPa.

[d] The values and terms of the denominator shall be used for the calculation of the maximum allowable design test pressures P_F in accordance with Annex C compare column S_{con}.

Annex C
(normative)

Materials

C.1 General

C.1.1 Using metallic materials

Metallic materials, including structural materials and welding consumables, solders, brazing metals and sealants shall allow for the thermal, chemical and mechanical stresses arising in system operation. Materials shall be resistant to the refrigerants and lubricants used in each particular case.

NOTE Extensive lists of suitable metallic materials are given in Annex F.

C.1.2 Materials for compressor casings and casing parts

Compressor casings and casing parts manufactured from the following materials with group numbers according to CR ISO 15608 meet the requirements of this standard:

— steels, groups St 1.1, St 1.2, St 8.1;

— aluminium and aluminium alloys, groups 21 to 26;

— copper and copper alloys, groups 31 to 36;

— spheroidal graphite cast iron, group 72.2;

— spheroidal graphite cast iron, group 72.1;

— grey cast iron, group 71.

Other metallic materials than those given in Annex F may be used provided that the mechanical properties are not altered by the manufacturing process of the casing.

At higher operating temperature ($TS \geq 50$ °C) the maximum allowable design stress shall be in accordance with Annex D.

For casings and casing parts made from steel, groups 1.1, 1.2, and 8.1 or cast iron, groups 72.2, 72.1 and 71, the minimum allowable design stress shall be in accordance with Annex E.

C.1.3 Using non-metallic materials

It is permitted to use non-metallic materials, e.g. for gaskets, coatings, insulating materials and sight glasses, provided that they are compatible with other materials, refrigerants and lubricants.

C.1.4 Requirements for welders and welding procedures

C.1.4.1 Approval testing of welders shall be in accordance with EN 287-1 and EN ISO 9606-2.

C.1.4.2 Approval testing of welding procedures shall be carried out in accordance with EN ISO 15607, EN ISO 15614-1 and EN ISO 15614-2.

C.1.5 Material certificates

C.1.5.1 Materials for compressor enclosure parts > [0,001 m^3] shall be supplied with a specific inspection certificate for the product in accordance with the specifications of EN 10204 (e.g. 3.1, 3.2).

C.1.5.2 If material properties are changed during the method of manufacture to such an extent that the strength and/or notched impact energies are reduced, these reduced values shall be taken into consideration by corrections or shall be subject to suitable compensatory material treatment (e.g. heat treatment).

Annex D
(normative)

Determination of the allowable pressure at the maximum operating temperature

D.1 Guideline for the application of this annex

D.1.1 General

At higher operating temperature ($TS \geq 50$ °C) the allowable pressure PS based on the calculated or experimentally confirmed PS (according to Annex B) is to be corrected to the maximum allowable pressure $PS_{\text{TS max.}}$ at the highest operating temperature $TS_{\text{max.}}$.

D.1.2 Choice of materials and proof of material properties

Material properties of pressure parts of the compressor shall meet the requirements of B.1.3.

Screws, bolts, nuts and fasteners shall be designed in accordance with the requirements of Table B.1 for the highest operating temperature. Elongation resulting from the difference in temperature between the highest operating temperature and the ambient temperature (– 10 °C) shall be taken into consideration for the design of screws, fastenings and seals.

If parts of the compressor are used within the range from a minimum to a maximum allowable operating temperature, this complete temperature range shall be taken into consideration in the design of screws, fasteners, nuts and seals.

D.1.3 Documentation

The reduction of the maximum allowable pressure at a higher operating temperature shall be documented.

D.2 Determination of the maximum allowable pressure at higher temperatures

The maximum allowable pressure at the maximum operating temperature is derived from the intended operating pressure PS_0.

$$PS_{\text{TS max.}} = PS_0 \times S_{\text{TS max.}}$$

where according to Table A.2

$S_{\text{TS max.}} = R_{\text{p 0,2 TS max.}} / R_{\text{p0,2}}$, if design is with $R_{\text{p 0,2}}$;

$S_{\text{TS max.}} = R_{\text{p 1,0 TS max.}} / R_{\text{p1,0}}$, if design is with $R_{\text{p 1,0}}$;

$S_{\text{TS max.}} = R_{\text{eH TS max.}} / R_{\text{eH}}$, if design is with R_{eH};

$S_{\text{TS max.}} = \text{R}_{\text{m TS max.}} / R_{\text{m}}$, if design is with R_{m}.

Annex E
(normative)

Determination of the allowable pressure at minimum operating temperature (requirements to avoid brittle fracture)

E.1 Guideline for the application of the methods and the choice of materials

E.1.1 General

At a lower operating temperature (TS < – 10 °C) or when the impact rupture energy values are less than the values given in B.1.2, the operating pressure based as the calculated or experimentally confirmed pressure PS is to be corrected to the maximum allowable pressure, $PS_{\mathrm{TS\ min.}}$ at the minimum operating temperature $TS_{\mathrm{min.}}$.

Possible procedures to avoid brittle fracture at minimum operating temperature $TS_{\mathrm{min.}}$ are given in E.3 and E.4.

E.1.2 Requirements of materials and proof of material properties

The impact rupture energy shall be confirmed by material certificates according EN 10204.

For the design by fracture mechanics (KV-Method) described in E.3, the KV-values at the minimum operating temperature or at a temperature not more than 30 K below the minimum operating temperature shall be determined and verified by means of an ISO V impact energy (Charpy-V-impact test specimen according to EN 10045-1).

For the empirical method (min-t_{o}-Method) indicated in E.4, the impact value KV for steel and cast steel, groups 1.1 and 1.2, of 27 J or higher values or for spheroidal cast iron group 72.2, (material LT for low temperatures) of at least 12 J or higher values is to be taken from the material standards (see E.4.1 and Annex F). An impact energy test shall be carried out at min $t_{0\ 100}$ in accordance with the conditions of the material standards.

Aluminium and/or aluminium alloys, groups 21 to 26 with the exception of aluminium-magnesium alloys with a content of magnesium of more than 6 %, copper or copper alloys, groups 31 to 38, are not susceptible to brittle fracture and no particular arrangements for their use at temperatures down to – 196 °C.

Aluminium-Magnesium alloys with a content of magnesium of more than 6 % should be used to a temperature of – 100 °C only.

NOTE The lattice (face-centred lattice) of aluminium and aluminium alloys, groups 21 to 26, and copper and/or copper alloys, groups 31 to 38, according to CR ISO 15608:2000 is different in comparison to steel, groups 1.1 and 1.2 (body-centred lattice). Because of that, these materials (groups 1.1 and 1.2) have more the tendency to embrittle at deep temperatures.

Fasteners shall be designed for the minimum operating temperature in accordance with the requirements of Table B.1. Elongation due to the difference between the minimum operating temperature and the ambient temperature (50 °C) shall be taken into consideration in the design of fasteners and seals (see Table E.2).

E.1.3 Documentation

The reduction of the maximum allowable pressure of a compressor when used at the minimum operating temperature shall be documented. The method chosen according to E.3 or E.4 shall be declared.

E.2 Determination of the maximum allowable pressure at the minimum operating temperature

The maximum allowable pressure at the minimum operating temperature is derived from the maximum allowable pressure at ambient temperature PS_0 as:

$$PS_{\mathrm{TS\ min.}} = PS_0 \times S_{\mathrm{TS\ min.}}$$

$S_{\mathrm{TS\ min.}}$ is calculated in accordance with the method described in E.3 or taken as stated in E.4. With respect to the application for strength design, both methods are equivalent.

E.3 Determination of the maximum allowable pressure at the minimum operating temperature on the basis of fracture mechanics theory for steel and cast iron

This method is based on fracture mechanics theory and describes the temperature-related influence of a reduced ductility (relative reduction in the absorbed impact energy KV) at decreasing temperature. Defining the threshold value of impact rupture energy, where the impact rupture energy is independent of the temperature as KV_0, the influence of continuous reduction of impact energy with decreasing temperatures is calculated as follows (see Annex F of EN 12284:2003):

$S_{\mathrm{TS\ min.}} = 1{,}0$ for $KV \geq KV_0$

and KV_0 = 27 J for steel and cast steel
at temperatures ≤ 20 °C

and KV_0 = 14 J or 17 J for spheroidal cast iron (material RT) **at temperatures ≤ 20 °C** according to Annex F, Table F.6

and KV_0 = 12 J for spheroidal cast iron (material LT) **at temperatures of ≤ (– 20 or – 40 °C)** according to Annex F, Table F.6

$S_{\mathrm{TS\ min.}} = (KV_0^{\mathbf{2}} / KV_0^{\mathbf{t}} / KV_{\mathrm{TS\ min.}})^{-0{,}75}$ for $6 \leq KV_{\mathrm{TS\ min.}} < KV_0^{\mathrm{t}}$

$KV_{\mathrm{TS\ min.}}$ < 27 J at temperature $TS_{\mathrm{min.}}$ and $KV_0^{\mathbf{t}} \geq 27$ J for steel and cast steel
KV_0 = 27 J **at temperatures of ≤ 20 °C**

and $KV_{\mathrm{TS\ min.}}$ < 12 J at temperature $TS_{\mathrm{min.}}$ and $KV_0^{\mathbf{t}} \geq 12$ J for spheroidal cast iron (material LT)
KV_0 = 12 J **at temperatures of ≤ (– 20 or – 40 °C)** according to Annex F, Table F.6.

The limit of use for the materials is the temperature at which the impact energy KV or KV_0^{t} reaches a minimum value of 6 J. If the value for $KV_{\mathrm{TS\ min.}}$ is below 6 J, the design of a component by this method is not allowed. Measured values of KV, $KV_0^{\mathbf{t}}$ and $KV_{\mathrm{TS\ min.}}$ in connection with the corresponding temperature values shall be certified in an inspection document 3.1 B according to EN 10204.

E.4 Determination of the maximum allowable pressure at the minimum operating temperature on the basis of an empirical method (min-t_0-Method; procedure according to the individual temperature load case) for steel and cast iron

E.4.1 General

With this method, the prevention of brittle fracture is taken into consideration by various reduction factors, according to the individual temperature load case. The procedure described as follows is based on experience by using compressors at low temperatures of refrigerating systems over a long period of time.

This procedure is based on the fact that the pressure decreases with decreasing saturating temperature of the refrigerant.

Therefore, the stresses due to the refrigerant pressure at low temperatures are always less than the stresses at the design pressure according to Table 2 in EN 378-2:2008.

Safety against brittle fracture is given if the temperature load cases described in the following are complied with. This method cannot be used for fully or semi-killed types of steel or cast steel. A heat treatment shall be applied for welded constructions in accordance with the requirements of E.4.3.

E.4.2 Temperature load cases

Load case min $t_{0\,100}$**:**

The lowest temperature according to the European Standards of the respective materials at which the compressor can be used at a load of up to 100 % of the allowable design stress at 20 °C, taking the safety factors according to Table B.2 into account.

Load case min $t_{0\,75}$**:**

The lowest temperature at which the compressor can be used, if its load amounts to 75 % maximum of the allowable design stress at 20 °C, taking the safety factors according to Table B.2 into account.

In the case of boiling fluids the calculated allowable design stress shall be for application temperatures down to min $t_{0\,75}$, reduced to 75 % of the allowable design stress calculated for min $t_{0\,100}$.

Load case min $t_{0\,25}$**:**

The lowest temperature at which pressure parts can be used, if their load amounts to 25 % maximum of the allowable design stress at 20 °C, taking the safety factors according to Table B.2 into account.

In the case of boiling fluids the calculated allowable design stress shall be for application temperatures down to min $t_{0\,25}$ reduced to 25 % of the design stress calculated for min $t_{0\,100}$.

E.4.3 Lowest application temperatures for the load cases min $t_{0\,100}$, min $t_{0\,75}$ and min $t_{0\,25}$

E.4.3.1 Load case min $t_{0\,100}$

Compressors which are subjected to a load of up to 100 % of the calculated allowable design stress may be used down to the lowest application temperature (see E.4.1) which is given for the corresponding materials in connection with this method (see Annex F).

If the minimum impact energy is given for the ambient temperature or 0 °C, the material may be used down to – 10 °C (for austenitic steels see E.4.2.2).

E.4.3.2 Load cases min $t_{0\,75}$ and min $t_{0\,25}$

a) The following load cases apply to steel and cast steel (groups 1.1 and 1.2), for which min $t_{0\,100}$ is at a temperature of – 10 °C:

   — min $t_{0\,75}$ down to a temperature difference of 50 K, related to min $t_{0\,100}$; and
   — min $t_{0\,25}$ down to a temperature difference of 75 K, related to min $t_{0\,100}$.

b) For steel and cast steel (group 1.1 and 1.2), for which min $t_{0\,100}$ is at a temperature of ≤ – 20 °C, it is to be established that an impact value of 27 J is given at ≤ – 20 °C. The following load cases apply:

   — min $t_{0\,75}$ down to a temperature difference of – 50 K, related to min $t_{0\,100}$; and
   — min $t_{0\,25}$ down to a temperature difference of – 80 K, related to min $t_{0\,100}$.

c) Austenitic steels according group 8.1 with A ≥ 35 % may be used down to a temperature min $t_{0\,100}$ of – 196 °C.

d) Aluminium or aluminium-alloys (groups 21 to 26) — with the exception of aluminium–magnesium alloys — with a content of magnesium of more than 6 % as well as titanium (group 51), copper or copper alloys (groups 31 to 38 according CR ISO 15608:2000) may be used down to an operating temperature min $t_{0\,100}$ of – 196 °C. The use of semi finished products and castings is allowed. Aluminium-magnesium alloys with a content of more than 6 % magnesium should be used down to an operating temperature min $t_{0\,100}$ – 100 °C, only.

e) On the basis of practical experience over many years in compressor design, spheroidal graphite cast iron (group 72.1 and 72.2) according to EN 1563 without impact rupture energy certificate may be used down to min $t_{0\,75}$ and only down to a temperature of – 60 °C.

f) On the basis of practical experience over many years using grey cast iron (group 71) according to EN 1561 in manufacturing compressors may be used in load case min $t_{0\,75}$ down to a temperature of – 40 °C and in load cases min $t_{0\,25}$ down to – 60 °C.

Examples of materials and their application limits are given in Annex F.

E.4.4 Welded joints for material groups 1.1 and 1.2

E.4.4.1 Conditions for welded joints

Under the following conditions, the same rules apply to welded joints as to the parent material:

— for testing of the weld seam, the lowest temperature at 100 % load (min $t_{0\,100}$) shall be established as the test temperature for the impact test; and

— with the ambient temperature as the lowest application temperature, the determination min $t_{0\,100}$ = – 10 °C is sufficient. For weld seams subjected to these tests, the minimum application temperature for min $t_{0\,75}$ and for min $t_{0\,25}$ shall be determined on the basis of the difference between the temperature according to E.4.2 and the test temperature (compare Table E.1).

Table E.1 — Determination of the lowest application temperature taking into account different test temperatures for weld seams, for example for materials with min t_0 100 = – 10 °C

Test temperature of weld seam °C	min $t_{0\ 100}$ °C	Temperature difference test temperature (compare E.4.2) K	min $t_{0\ 75}$ °C	Temperature difference test temperature (compare E.4.2) K	min $t_{0\ 25}$ °C
– 10	– 10	50	– 60	75	– 85
+ 20	– 10	50	– 30	75	– 55

E.4.4.2 Heat treatment after welding

For application temperatures below min $t_{0\ 100}$, heat treatment by stress-relieving is necessary for welded constructions.

For materials belonging to groups 1.1 and 1.2, heat treatment by stress-relieving is not necessary if the reference thickness is less than 10 mm; the reference thickness shall be determined in accordance with Annex D of EN 13445-2:2002.

E.4.5 Determination of the safety factor

Taking the above mentioned preconditions into account, the safety factor $S_{\mathrm{TS\ min.}}$ is calculated by this method as:

$S_{\mathrm{TS\ min.}}$ = 1,0 for $TS_{\mathrm{min.}} \geq$ min $t_{0\ 100}$,

= 0,75 for min $t_{0\ 75} \leq TS_{\mathrm{min.}} <$ min $t_{0\ 100}$,

= 0,25 for min $t_{0\ 25} <$ $TS_{\mathrm{min.}} <$ min $t_{0\ 75}$.

If the value for the intended low operating temperature $TS_{\mathrm{min.}}$ is below min $t_{0\ 25}$, a design of the component is no longer permitted by this method. As an alternative, a fracture mechanics analysis may be carried out.

E.5 Determination of fasteners below – 10 °C

Fasteners (bolts, nuts, etc.) in materials specified for use down to – 10 °C may be used at lower temperatures with the safety factors defined in Table E.2.

Table E.2 — Safety factors for fasteners (intended use down to – 10 °C**) below** – 10 °C

Temperature °C	Property class used				
	12.9	**10.9**	**8.8**	**6.8**	**5.6**
– 10	0,8	1,0	1,0	1,0	1,0
– 30	—	0,7	0,90	0,85	0,80
– 60	—	—	0,75	0,70	0,65

Safety factor S_{fast} is defined as:

S_{fast} is the relation between maximum allowable strength at operating temperature and the maximum allowable strength at ambient temperature.

EXAMPLE If the property class used is 8.8 at – 60 °C, the allowable strength at ambient temperature shall be reduced by the safety factor of 0,75.

NOTE Material for low temperature can be used with design values for nominal property class i.e.: A.2 equals property class 5.6 below – 10 °C.

Annex F
(informative)

Compilation of material characteristics of often used materials

The material characteristics of often used materials, sorted by the material group, are listed in Tables F.1 to F.10.

NOTE Values of one standard are indicated as an example in case of more than one standard.

Table F.1 — Unalloyed steel (group 1.1 and 1.2)

Material				EN standard	Strength values		Elong. after fracture	Impact energy KV_0			Product form					Operating temperature [°C]				US-nomenclature	
Symbol	Number	Group	Condition		$R_{p0,2}$ [a] [MPa]	R_m [MPa]	A [%]	[J]	at [°C]	L/q	1	2	3	4	5	min. $t_{0\ 25}$	min. $t_{0\ 75}$	min. $t_{0\ 100}$	max.	Standard ASTM	Grade
P235GH	1.0345	1.1	N	10028-2 10273 10216-2	235	360 480	25	27	0	L			X	 X	X	– 85	– 60	– 10	400	A.42/414/ 515/516	55/C/65
P265GH	1.0425	1.1	N	10028-2 10273 10216-2	265	410 530	23	27	0	L			 X 	 X	X	– 85	– 60	– 10	400	A285/414/ 442/515/ 516	B/C/60/55
P295GH	1.0481	1.2	N	10028-2 10273	295	460 580	22	27	0	L			 X		X	– 85	– 60	– 10	400	A106/414/ 516	C/70/F,G
P355GH	1.0473	1.2	N	10028-2 10273	355	510 650	21	27	0	L			 X		X	– 85	– 60	– 10	400	A414/573	G/Class 1
P245GH	1.0352	1.1	NT QT	10222-2	220	410 530	25	27	0	q	X					– 85	– 60	– 10	400		
P280GH	1.0426	1.2	N, NT, QT	10222-2	255	460 580	23	27	0	q	X					– 85	– 60	– 10	400		
P235S	1.0112	1.1	N	10207	235	360 480	20	28	– 20	L			X		X	– 100	– 70	– 20	300		
P265S	1.0130	1.1	N	10207	265	410 530	17	28	– 20	L			X		X	– 100	– 70	– 20	300		
P275SL	1.1100	1.1	N	10207	275	390 510	19	28	– 50	L			X		X	– 130	–	– 50	300		

NOTE Measuring condition: L – in rolling direction, q – at right angles rolling direction. Product forms: 1-forging; 2-casting; 3-rolled bars; 4-tube; 5-plate.

[a] Nominal value up to a determined thickness as noted in the standard.

Table F.1 (*continued*)

Material				EN standard	Strength values		Elong. after fracture	Impact energy KV_0			Product form					Operating temperature [°C]				US-nomenclature	
Symbol	Number	Group	Condition		$R_{p0,2}$ [a] [MPa]	R_m [MPa]	A [%]	[J]	at [°C]	L/q	1	2	3	4	5	min. $t_{0\ 25}$	min. $t_{0\ 75}$	min. $t_{0\ 100}$	max.	Standard ASTM	Grade
S235JR	1.0038			10025-2	235	340 470	26	27	20						X	**-85**	**-60**	**-10**			
S235J2	1.0117	1.1	N	10025-2	235	340 470	26	27	– 20	L			X		X	– 100	– 70	– 20			
S275JR	1.0044			10025-2	275	410 560	22	27	20						X						
S275J2	1.0145	1.1	N	10025-2	275	410 560	22	27	– 20	L			X		X	– 100	– 70	– 20			
S355J2	1.0577	1.1	N	10025-2	355	490 630	22	27	– 20	L			X		X	– 100	– 70	– 20			
S355K2	1.0596			10025-2	355	490 630	22	40	– 20						X	**-85**	**-60**	**-10**			
P275N	1.0486			10028-3	275	390 510	24								X	**-85**	**-60**	**-10**			
P275NH	1.0487			10028-3	275	390 510	24								X	**-85**	**-60**	**-10**			
P275NL1	1.0488	1.1	N	10028-3 10216-3	275	390 510	24	27	– 20	q				X	X	– 100	– 70	– 20	400	A662	A
P275NL2	1.1104	1.1	N	10028-3 10216-3	275	390 510	24	27	– 50	q				X	X	– 130	– 100	– 50	400		
P355NL1	1.0566	1.2	N	10028-3 10216-3	355	490 630	22	27	– 20	q				X	X	– 100	– 70	– 20	400		

NOTE Measuring condition: L –rolling direction, q – at right angles to rolling direction. Product forms: 1-forging; 2-casting; 3-rolled bars; 4-tube; 5-plate.

[a] Nominal value up to a determined thickness as noted in the standard.

Table F.1 (*continued*)

Material				EN Standard	Strength Values		Elong. after fracture	Impact Energy KV_0			Product form					Operating Temperature [°C]				US-nomenclature	
Symbol	Number	Group	Condition		$R_{p0,2}$ [a] [MPa]	R_m [MPa]	A [%]	[J]	at [°C]	L/q	1	2	3	4	5	min. $t_{0\ 25}$	min. $t_{0\ 75}$	min. $t_{0\ 100}$	max.	Standard ASTM	Grade
P355NL2	1.1106	1.2	N	10028-3 10216-3	355	490 630	22	27	– 50	q				X	X	– 130	– 100	– 50	400		
P255QL	1.0452	1.1	N	10216-4	255	360 490	23	27	– 50	q				X		– 130	– 100	– 50	400		
P265NL	1.0453	1.1	N	10216-4	265	410 570	24	27	– 40	q				X		– 120	– 90	– 40	400		
P285QH	1.0478	1.2	+ QT	10222-4	245	370 510	22	34	– 40	L	X					– 120	– 90	– 40			
P355QH1	1.0571	1.2	+ QT	10222-4	315	470 630	21	34	– 40	L	X					– 120	– 90	– 40			
13MnNi6-3	1.6217	1.4	NT	10222-3	285	420 610	22	27	– 60	q	X					– 140	– 110	– 60			
15NiMn6	1.6228	9.1	N, NT, QT	10222-3	355	470 640	20	27	– 80	q	X					– 160	– 130	– 80			
12Ni14	1.5637	9.2	N, NT, QT	10222-3	355	470 640	20	27	– 100	q	X					– 180	– 150	– 100			
X12Ni5	1.5680	9.2	N, NT,QT	10222-3	390	510 710	19	27	– 120	q	X					– 200	– 170	– 120			
P285NH	1.0477	1.2	N	10222-4	285	390 510	24	28	– 40	L	X					– 120	– 90	– 40	400		
P355NH	1.0565	1.2	N	10222-4	355	490 630	23	28	– 40	L	X					– 120	– 90	– 40	400		
DC04	1.0338	1.1	RR	10130	140 210	270 350	38	—	—	—	—				X	– 85	– 60	– 10			

NOTE Measuring condition: L – in rolling direction, q – at right angles to rolling direction. Product forms: 1-forging; 2-casting; 3-rolled bars; 4-tube; 5-plate.

[a] Nominal value up to a determined thickness as noted in the standard.

Table F.1 (*continued*)

Material				EN standard	Strength values		Elong. after fracture	Impact energy KV_0			Product form					Operating temperature [°C]				US-nomenclature	
Symbol	Number	Group	Condition		$R_{p0,2}$[a] [MPa]	R_m [MPa]	A [%]	[J]	at [°C]	L/q	1	2	3	4	5	min. $t_{0\ 25}$	min. $t_{0\ 75}$	min. $t_{0\ 100}$	max.	Standard ASTM	Grade
C15	1.0401			10277-2																	
new = P250GH DIN EN 10222-2 see National Annex NB1 to NB7	1.0460			10222-2																	
DC01	1.0330			10130																	
DD11	1.0332			10111																	
DD13	1.0335			10111																	
DD14				10111																	

NOTE Measuring condition: L – in rolling direction, q – at right angles to rolling direction. Product forms: 1-forging; 2-casting; 3-rolled bars; 4-tube; 5-plate.

[a] Nominal value up to a determined thickness as noted in the standard.

Table F.1a — Free-cutting steel

Material				EN standard	Strength values		Elong. after fracture	Impact energy KV_0			Product form					Operating temperature [°C]				US-nomenclature	
Symbol	Number	Group	Condition		$R_{p0,2}$ [a] [MPa]	R_m [MPa]	A [%]	[J]	at [°C]	L/q	1	2	3	4	5	min. $t_{0\ 25}$	min. $t_{0\ 75}$	min. $t_{0\ 100}$	max.	Standard ASTM	Grade
9S20	1.0711			10087																	
11SMn30	1.0715			10087																	
11SMnPb230	1.0718			10087																	

NOTE Measuring condition: L – in rolling direction, q – at right angles to rolling direction. Product forms: 1-forging; 2-casting; 3-rolled bars; 4-tube; 5-plate.

[a] Nominal value up to a determined thickness as noted in the standard.

Table F.2 — Steel (group 8.1)

Material				EN standard	Strength values		Elong. after fracture	Impact energy KV_0			Product form					Operating temperature [°C]				US-nomenclature	
Symbol	Number	Group	Condition		$R_{p0,2}$ [a] [MPa]	R_m [MPa]	A [%]	[J]	at [°C]	L/q	1	2	3	4	5	min. $t_{0\ 25}$	min. $t_{0\ 75}$	min. $t_{0\ 100}$	max.	Standard ASTM	Grade
X5CrNi 18-10	1.4301	8.1		10028-7 10216-5 10222-5 10272	230	540 750	45	60	– 196	q	X		X	X	X			– 196	550	A213/A240/ A276/A312/ A403	TP304/304/ WP304
X2CrNi 19-11	1.4306	8.1		10028-7 10216-5 10272	220	520 670	45	60	– 196	q			X	X	X			– 196	550	A213/A240/ A276/A312/ A403	TP304L/304L/ WP304L
X2CrNi 18-9	1.4307	8.1		10028-7 10216-5 10222-5 10272	220	520 670	45	60	– 196	q	X		X	X	X			– 196	550		
X2CrNiN 18-10	1.4311	8.1		10028-7 10216-5 10222-5 10272	290	550 750	40	60	– 196	q	X		X	X	X			– 196	550	A312	TP304NL
X5CrNiN 19-9	1.4315	8.1		10028-7	270	550 750	40								X			– 196	550		
X1CrNi 25-21	1.4335	8.1		10216-5	190	490 690	40	60	– 196	q				X				– 196			

NOTE Measuring condition: L – in rolling direction, q – at right angles to rolling direction. Product forms: 1-forging; 2-casting; 3-rolled bars; 4-tube; 5-plate.

[a] Nominal value up to a determined thickness as noted in the standard (EN 13480-2, EN 13445-2).

Table F.2 (*continued*)

Material				EN standard	Strength values		Elong. after fracture	Impact energy KV_0			Product form					Operating temperature [°C]				US-nomenclature	
Symbol	Number	Group	Condition		$R_{p0,2}$ [a] [MPa]	R_m [MPa]	A [%]	[J]	at [°C]	L/q	1	2	3	4	5	min. $t_{0\ 25}$	min. $t_{0\ 75}$	min. $t_{0\ 100}$	max.	Standard ASTM	Grade
X5CrNiMo 17-12-2	1.4401	8.1		10028-7 10222-5 10216-5	220	530 680	40	60	– 196	q	X			X	X			– 196	550	A276/A312/ A403	316/WP316/
X2CrNiMo 17-12-2	1.4404	8.1		10028-7 10216-5 10272 10222-5	220	530 680	40	60	– 196	q	X		X	X	X			– 196	550	A213/A276 A312/A403/ A240	TP316L/ TP316LN/ 316L/ WP316L
X2CrNiMo 17-11-2	1.4406	8.1		10028-7 10222-5 10272	300	580 780	40	60	– 196	q	X		X		X			– 196	550	A276	316L
X2CrNiMoN 17-13-3	1.4429	8.1		10028-7 10216-5 10222-5	300	580 780	35	60	– 196	q	X			X	X			– 196	550	A213/A240/ A276	TP316LN/ 316L
X2CrNiMo 17-12-3	1.4432	8.1		10028-7 10222-5 10272	240	550 700	40	60	– 196	q	X		X					– 196	550		
X2CrNiMo 18-14-3	1.4435	8.1		10028-7 10222-5 10272	240	550 700	40	60	– 196	q	X		X		X			– 196	400	A240	317L

NOTE Measuring condition: L – in rolling direction, q – at right angles to rolling direction. Product forms: 1-forging; 2-casting; 3-rolled bars; 4-tube; 5-plate.

[a] Nominal value up to a determined thickness as noted in the standard (EN 13480-2, EN 13445-2).

Table F.2 (*continued*)

Material				EN standard	Strength values		Elong. after fracture	Impact energy KV_0			Product form					Operating temperature [°C]				US-nomenclature	
Symbol	Number	Group	Condition		$R_{p0,2}$ [a] [MPa]	R_m [MPa]	A [%]	[J]	at [°C]	L/q	1	2	3	4	5	min. $t_{0\ 25}$	min. $t_{0\ 75}$	min. $t_{0\ 100}$	max.	Standard ASTM	Grade
X3CrNiMo 17-13-3	1.4436	8.1		10222-5	205	510 710	45	60	– 196	q	X		X					– 196		A213/A240	TP316/317
X2CrNiMo 17-13-5	1.4439	8.1		10028-7	290	580 780	35	60	– 196	q					X			– 196	400		
X3CrNiMo 18-12-3	1.4449	8.1		10222-5	220	520 720	45	60	– 196	q	X							– 196			
X6CrNiTi 18-10	1.4541	8.1		10222-5 10028-7	220	520 720	40	60	– 196	q	X				X			– 196	550	A213/A240/ A276/A312/ A403/A 479	TP321/321/ TP311/ WP321
X6CrNiMoTi 17-12-2	1.4571	8.1		10222-5 10028-7	240	540 690	40	60	– 196	q	X				X			– 196	550	A213/A240/ A276/A312/ A403/A479	TP316L/316Ti/ TP316Ti/ WP316Ti
X6CrNiMo Nb17-12-2	1.4580	8.1		10272	215	510 740		60					X							A276	316CB
X6CrNi 18-10	1.4948	8.1		10216-5 10222-5	185	500 700	40	60	+ 20		X			X		– 85	– 60	– 10			
X8CrNiNb 16-13	1.4961	8.1		10216-5	205	510 690	35	60	+ 20					X		– 85	– 60	– 10	600		

NOTE Measuring condition: L – in rolling direction, q – at right angles to rolling direction. Product forms: 1-forging; 2-casting; 3-rolled bars; 4-tube; 5-plate.

[a] Nominal value up to a determined thickness as noted in the standard (EN 13480-2, EN 13445-2).

Table F.3 — Cast steel

Material				EN standard	Strength values		Elong. after fracture	Impact energy KV_0			Product form					Operating temperature [°C]				US-nomenclature	
Symbol	Number	Group	Condition		$R_{p0,2}$ [a] [MPa]	R_m [MPa]	A [%]	[J]	at [°C]	L/q	1	2	3	4	5	min. $t_{0\ 25}$	min. $t_{0\ 75}$	min. $t_{0\ 100}$	max.	Standard ASTM	Grade
GP240GH	1.0619	1.1	N	10213-2	240	420 600	22	27	20	L		X				– 85	– 60	– 10	450	A216	WCA, WCB, WCC
GP240GH	1.0619	1.1	QT	10213-2	240	420 600	22	40	20	L		X				– 85	– 60	– 10	450	A216	WCA, WCB, WCC
GP280GH	1.0625	1.2	N	10213-2	280	480 640	22	27	20	L		X				– 85	– 60	– 10	450		
GP280GH	1.0625	1.2	QT	10213-2	280	480 640	22	35	20	L		X				– 85	– 60	– 10	450		
G20Mo5	1.5419	1.2	QT	10213-2	245	440 590	22	27	20	L		X				– 85	– 60	– 10	450	A217	WC1
G17Mn5	1.1131	1.1	QT	10213-3	240	450 600	24	27	– 40	L		X				– 120	– 90	– 40	300		
G17CrMo 5-5	1.7357		QT	10213-2	315	490 690	20	27											550		
G20Mn5	1.6220	1.2	N	10213-3	300	480 620	20	27	– 30	L		X				– 110	– 80	– 30	300		
G20Mn5	1.6220	1.2	QT	10213-3	300	500 650	22	27	– 40	L		X				– 120	– 90	– 40	300		
G18Mo5	1.5422	1.2	QT	10213-3	240	440 790	23	27	– 45	L		X				– 125	– 95	– 45	300		

NOTE Measuring condition: L – in rolling direction, q – at right angles to rolling direction. Product forms: 1-forging; 2-casting; 3-rolled bars; 4-tube; 5-plate.

[a] Nominal value up to a determined thickness as noted in the standard.

Table F.3 (*continued*)

Material				EN standard	Strength values		Elong. after fracture	Impact energy KV_0			Product form					Operating temperature [°C]				US-nomenclature	
Symbol	Number	Group	Condition		$R_{p0,2}$ [a] [MPa]	R_m [MPa]	A [%]	[J]	at [°C]	L/q	1	2	3	4	5	min. $t_{0\ 25}$	min. $t_{0\ 75}$	min. $t_{0\ 100}$	max.	Standard ASTM	Grade
GX2CrNi 19-11	1.4309	8.1	+ AT	10213-4	210	440 640	30	70	– 196	L		X				—	—	– 196	350		
GX5CrNi 19-10	1.4308	8.1	+ AT	10213-4	200	440 640	30	60	– 196	L		X				—	—	– 196	300	A743/A744	CF8
GX2CrNiMo 19-11-2	1.4409	8.1	+ AT	10213-4	220	440 640	30	70	– 196	L		X				—	—	– 196	300		
GX5CrNiMo 19-11-2	1.4408	8.1	+ AT	10213-4	210	440 640	30	60	– 196	L		X				—	—	– 196	300	A351/A744	CF8M

NOTE Measuring condition: L – in rolling direction, q – at right angles to rolling direction. Product forms: 1-forging; 2-casting; 3-rolled bars; 4-tube; 5-plate.

[a] Nominal value up to a determined thickness as noted in the standard.

Table F.4 — Aluminium and Aluminium alloys (groups 21 to 26)

Material				EN standard	Strength values		Elong. after fracture	Impact energy KV_0			Product form					Operating temperature [°C]				US-nomenclature	
Symbol	Number	Group	Condition		$R_{p0,2}$ [a] [MPa]	R_m [MPa]	A [%]	[J]	at [°C]	L/q	1	2	3	4	5	min. $t_{0\ 25}$	min. $t_{0\ 75}$	min. $t_{0\ 100}$	max.	Standard ASTM	Grade
EN Al CuMg1	EN AW -2017A			573-3																	
EN Al CuMgPb	EN AW -2030			573-3																	
EN AW-Al 99,8 (A)	EN AW -1080A	21	H12 H22	573-3 12392	55	80									X			– 196	200		
EN AW-Al 99,7	EN AW -1070A	21	H12 H22	573-3 12392	55	80									X			– 196	200		
EN AW-Al 99,5	EN AW -1050A	21	H12 H22	573-3 12392	65	85							X	X	X			– 196	250 200		
EN AW-Al Mn1Cu	EN AW -3003	22.1	H12 H22	573-3 12392	90	120							X	X	X			– 196	250		
EN AW-Al Mn1	EN AW -3103	22.1	H12 H22	573-3 12392	85	115							X	X	X			– 196	200 250		
EN AW-Al Mn0,5Mg0,5	EN AW -3105	22.1	H12 H22	573-3 12392	105	130									X			– 196	200		
EN AW-Al Mg1(B)	EN AW -5005	22.1	H12 H32	573-3 12392	95	125							X	X	X			– 196	200		
EN AW-Al Mg1,5(C)	EN AW -5050	22.1	H12 H32	573-3 12392	130	155									X			– 196	200		
EN AW-Al Mg2	EN AW -5251	22.1	H12 H32	573-3 12392	150	190							X	X	X			– 196	200		
EN AW-Al Mg2,5	EN AW -5052	22.1	H12 H32	573-3 12392	160	210							X	X	X			– 196	200		

NOTE Measuring condition: L – in rolling direction, q – at right angles to rolling direction. Product forms: 1-forging; 2-casting; 3-rolled bars; 4-tube; 5-plate.

[a] Nominal value up to a determined thickness as noted in the standard.

Table F.4 (*continued*)

Material				EN standard	Strength values		Elong. after fracture	Impact energy KV_0			Product form					Operating temperature [°C]				US-nomenclature	
Symbol	Number	Group	Condition		$R_{p0,2}$ [a] [MPa]	R_m [MPa]	A [%]	[J]	at [°C]	L/q	1	2	3	4	5	min. $t_{0\ 25}$	min. $t_{0\ 75}$	min. $t_{0\ 100}$	max.	Standard ASTM	Grade
EN AW-Al Mg3Mn	EN AW -5454	22.3	H12 H32	573-3 12392	190	250							X	X	X			– 196	200		
EN AC-Al Mg3(b)	EN AC -51000	22.3	F	1706	70	140						X [b]						– 196			
EN AC-AlMg3(a)	EN AC -51100	22.3	F	1706	70	140						X [b]						– 196			
EN AC-Al Mg5	EN AC -51300	22.3	F	1706	90	160						X [b]						– 196			
EN AC-Al Mg3(b)	EN AC -51000	22.3	F	1706	70	150						X [c]						– 196			
EN AC-Al Mg3(a)	EN AC -51100	22.3	F	1706	70	150						X [c]						– 196			
EN AC-Al Mg5	EN AC -51300	22.5	F	1706	100	180						X [c]						– 196			
EN AC-Al Mg9	EN AC -51200	22.5	F	1706	130	200						X [d]						– 196			
EN AW-Al Mg3,5A	EN AW -5154A	22.3	H12 H32	573-3 12392	190	250							X	X	X			– 196	100		
EN AW-Al Mg3	EN AW -5754	22.3	H12 H32	573-3 12392	170	220					X		X	X	X			– 196	100		
EN AW-Al Mg4,5Mn0,7	EN AW -5083	22.5	H116	573-3 12392	215	305					X		X	X	X			– 196	65		
EN AW-Al Mg4	EN AW -5086	22.5	H116	573-3 12392	195	275							X	X	X			– 196	65		

NOTE Measuring condition: L – in rolling direction, q – at right angles to rolling direction. Product forms: 1-forging; 2-casting; 3-rolled bars; 4-tube; 5-plate.

[a] nominal value up to a determined thickness as noted in the standard
[b] sand casting
[c] permanent moulds casting
[d] pressure die casting

Table F.4 (*continued*)

Material				EN standard	Strength values		Elong. After fracture	Impact energy KV_0			Product form					Operating temperature [°C]				US-nomenclature	
Symbol	Number	Group	Condition		$R_{p0,2}$ [a] [MPa]	R_m [MPa]	A [%]	[J]	at [°C]	L/q	1	2	3	4	5	min. $t_{0\ 25}$	min. $t_{0\ 75}$	min. $t_{0\ 100}$	max.	Standard ASTM	Grade
EN AC-Al Si12	EN AC -44100			1706																	
EN AC-Al Si6Cu4	EN AC -4500			1706																	
EN AC-Al Si8Cu3	EN AC -46200			1706																	
EN AC-Al Si7MG	EN AC -42000	23.1	T6	1706	180	220						X [b]						– 196			
EN AC-Al Si7Mg0,3	EN AC -42100	23.1	T6	1706	190	230						X [b]						– 196			
EN AC-Al Si7Mg0,6	EN AC -42200	23.1	T6	1706	210	250						X [b]						– 196			
EN AC-Al Si10Mg(a)	EN AC -43000	23.1	T6	1706	180	220						X [b]						– 196			
EN AC-Al Si10Mg(b)	EN AC -43100	23.1	T6	1706	180	220						X [b]						– 196			
EN AC-Al Si9Mg	EN AC -43300	23.1	T6	1706	190	230						X [b]						– 196			
EN Al Si7Mg	EN AC -42000	23.1	T64	1706	200	240						X [d]						– 196			
EN AC-Al Si7Mg0,3	EN AC -42100	23.1	T64	1706	180	250						X [d]						– 196			
EN AC-Al Si7Mg0,6	EN AC -42200	23.1	T64	1706	210	290						X [d]						– 196			

NOTE Measuring condition: L – in rolling direction, q – at right angles to rolling direction. Product forms: 1-forging; 2-casting; 3-rolled bars; 4-tube; 5-plate.

[a] nominal value up to a determined thickness as noted in the standard
[b] sand casting
[d] pressure die casting

Table F.4 (*continued*)

Material				EN standard	Strength values		Elong. after fracture	Impact energy KV_0			Product form					Operating temperature [°C]				US-nomenclature	
Symbol	Number	Group	Condition		$R_{p0,2}$ [a] [MPa]	R_m [MPa]	A [%]	[J]	at [°C]	L/q	1	2	3	4	5	min. $t_{0\ 25}$	min. $t_{0\ 75}$	min. $t_{0\ 100}$	max.	Standard ASTM	Grade
EN AC-Al Si10Mg(a)	EN AC -43000	23.1	T64	1706	200	240						X [d]						– 196			
EN AC-Al Si10Mg(b)	EN AC -43100	23.1	T64	1706	200	240						X [d]						– 196			
EN AC-Al Si9Mg	EN AC -43300	23.1	T64	1706	200 180	240 250						X [d]						– 196			
EN AC-Al Si10Mg(Cu)	EN AC -43200			1706																	

NOTE Measuring condition: L – in rolling direction, q – at right angles to rolling direction. Product forms: 1-forging; 2-casting; 3-rolled bars; 4-tube; 5-plate.

[a] nominal value up to a determined thickness as noted in the standard
[d] pressure die casting

Table F.5 — Copper and copper alloys (groups 31 to 38)

Material				EN standard	Strength values		Elong. after fracture	Impact energy KV_0			Product form					Operating temperature [°C]				US-nomenclature	
Symbol	Number CW ...	Group	Condition		$R_{p0,2}$ [a] [MPa]	R_m [MPa]	A [%]	[J]	at [°C]	L/q	1	2	3	4	5	min. $t_{0\ 25}$	min. $t_{0\ 75}$	min. $t_{0\ 100}$	max.	Standard ASTM	Grade
Cu-ETP	004A	31	R200 H040	1652	100 140	200 260									X			– 196	150		
Cu-FRTP	006A	31	R220 H040	1652	100 140	220 260									X			– 196	150		
Cu-OF	008A	31	R220 H040	1652	100 140	220 260									X			– 196	150		
Cu-DLP	023A	31	R200	1653	40	200									X			– 196	150		
Cu-DHP	024A	31	R200	1653	40	200									X			– 196	150		
CuZn5	500L	32.1	R230 H045	1652	130	230 280									X			– 196	150		
CuZn10	501L	32.1	R240 H050	1652 12449	140	240 290								X	X			– 196	150		
CuZn15	502L	32.1	R260 H055	1652	170	260 310									X			– 196	150		
CuZn20	503L	32.1	R270 H055	1652	150	270 320									X			– 196	150		
CuZn30	505L	32.1	R270 H055	1652	160	270 350									X			– 196	150		
CuZn33	506L	32.1	R280 H155	1652	170 450	500 280 380									X			– 196	150		
CuZn36	507L	32.1	R300 H140	1652	180 390	470 300 370									X			– 196	150		
CuZn37	508L	32.1	R300 H140	1652	180 390	470 300 370									X			– 196	150		
CuZn40	509L	32.1	R340 H140	1652	240 390	470 340 420									X			– 196	150		
CuZn20 Al2As	702R	32.2	R300 R390	1653	90 240	300 390									X			– 196	150		

NOTE Measuring condition: L – in rolling direction, q – at right angles to rolling direction. Product forms: 1-forging; 2-casting; 3-rolled bars; 4-tube; 5-plate.

[a] Nominal value up to a determined thickness as noted in the standard.

Table F.5 (*continued*)

Material				EN standard	Strength values		Elong. after fracture	Impact energy KV_0			Product form					Operating temperature [°C]				US-nomenclature	
Symbol	Number CW ...	Group	Condition		$R_{p0,2}$ [a] [MPa]	R_m [MPa]	A [%]	[J]	at [°C]	L/q	1	2	3	4	5	min. $t_{0\ 25}$	min. $t_{0\ 75}$	min. $t_{0\ 100}$	max.	Standard ASTM	Grade
CuZn38 AlFeNiPbSn	715R	32.2	R390 R430	1653	140 200	390 430	25 20								X			– 196	150		
CuZn38 Sn1As	717R	32.2	R320 R340	1653	100 120	320 340	30 30								X			– 196	150		
CuZn39Sn1	719R	32.2	R400	1653	200	400	18								X			– 196	150		

NOTE Measuring condition: L – in rolling direction, q – at right angles to rolling direction. Product forms: 1-forging; 2-casting; 3-rolled bars; 4-tube; 5-plate.

[a] Nominal value up to a determined thickness as noted in the standard.

Table F.6 — Cast iron

Material				EN standard	Strength values		Elong. after fracture	Impact energy KV_0			Product form					Operating temperature [°C]				US-nomenclature	
Symbol	Number	Group	Condition		$R_{p0,2}$ [a] [MPa]	R_m [MPa]	A [%]	[J]	at [°C]	L/q	1	2	3	4	5	min. $t_{0\ 25}$	min. $t_{0\ 75}$	min. $t_{0\ 100}$	max.	Standard ASTM	Grade
EN-GJL-200	EN-JL 1030			1561																	
EN-GJL-250	EN-JL 1040			1561															300		
EN-GJL-300	EN-JL 1050			1561															300		
EN-GJS-350-22-RT	EN-JS 1014			1563	220	350	22	17	20			X				—	—	– 10	300		
EN-GJS-400-18-RT	EN-JS 1024			1563	250	400	18	14	20			X				—	—	– 10	300		
EN-GJS-350-22U-RT	EN-JS 1029			1563	220	350	22	17	20			X				—	—	– 10	300		
EN-GJS-400-15	EN-JS 1030			1563															350		
EN-GJS-500-7	EN-JS 1050			1563															350		
EN-GJS-600-7	EN-JS 1060			1563																	
EN-GJS-700-2	EN-JS 1070			1563																	
EN-GJS-400-18U-RT	EN-JS 1059			1563	250	400	18	14	20			X				—	—	– 10	300		
EN-GJS-400-18-LT	EN-JS 1025			1563	240	400	18	12	– 20			X				– 60	– 60	– 20	300		

NOTE Measuring condition: L – in rolling direction, q – at right angles to rolling direction. Product forms: 1-forging; 2-casting; 3-rolled bars; 4-tube; 5-plate.

[a] Nominal value up to a determined thickness as noted in the standard.

Table F.6 (*continued*)

Material				EN standard	Strength values		Elong. after fracture	Impact energy KV_0			Product form					Operating temperature [°C]				US-nomenclature	
Symbol	Number	Group	Condition		$R_{p0,2}$ [a] [MPa]	R_m [MPa]	A [%]	[J]	at [°C]	L/q	1	2	3	4	5	min. $t_{0\,25}$	min. $t_{0\,75}$	min. $t_{0\,100}$	max.	Standard ASTM	Grade
EN-GJS-400-18U-LT	EN-JS 1049			1563	240	400	18	12	– 20			X				– 60	– 60	– 20	300		
EN-GJS-350-22-LT	EN-JS 1015			1563	220	350	22	12	– 40			X				– 70	– 70	– 20	300		
EN-GJS-350-22U-LT	EN-JS 1019			1563	220	350	22	12	– 40			X				– 70	– 70	– 20	300		

NOTE Measuring condition: L – in rolling direction, q – at right angles to rolling direction. Product forms: 1-forging; 2-casting; 3-rolled bars; 4-tube; 5-plate.

[a] Nominal value up to a determined thickness as noted in the standard.

Table F.7 — Unalloyed steel (automatically manufacturing)

Material [b]				EN standard	Strength values		Elong. after fracture	Impact Energy KV_0			Product form					Operating temperature [°C]				US-nomenclature	
Symbol	Number	Group	Condition		$R_{p0,2}$ [a] [MPa]	R_m [MPa]	A [%]	[J]	at [°C]	L/q	1	2	3	4	5	min. $t_{0\ 25}$	min. $t_{0\ 75}$	min. $t_{0\ 100}$	max.	Standard ASTM	Grade
11SMn30	1.0715		[a]	10087		380 570							X			– 60	– 40	– 10	300		
11SMnPb30	1.0718		[a]	10087		380 570							X			– 60	– 40	– 10	300		
11SMn37	1.0736		[a]	10087		370 570							X			– 60	– 40	– 10	300		
11SMnPb37	1.0737		[a]	10087		360 520							X			– 60	– 40	– 10	300		

NOTE Measuring condition: L – in rolling direction, q – at right angles to rolling direction. Product forms: 1-forging; 2-casting; 3-rolled bars; 4-tube; 5-plate.

[a] Nominal value up to a determined thickness as noted in the standard.

[b] Not qualified for welding; should not be used for valves bodies with DN greater than 10 mm for bonnets ≤ DN 40, see E.4.2.2, g).

Table F.8 — Materials for spindles

Material				EN standard	Strength values		Elong. after fracture	Impact energy KV_0			Product form					Operating temperature [°C]				US-nomenclature	
Symbol	Number	Group	Condition		$R_{p0,2}$ [a] [MPa]	R_m [MPa]	A [%]	[J]	at [°C]	L/q	1	2	3	4	5	min. $t_{0\ 25}$	min. $t_{0\ 75}$	min. $t_{0\ 100}$	max.	Standard ASTM	Grade
X20Cr13	1.4021			10088-3									X					– 10	400		
X5CrNi 18-10	1.4301	8.1		10088-3 10028-7	230	540 750	45	60	– 196	q			X		X			– 196	300		
X8CrNiS 18-9	1.4305			10088-3	190	500 750	35	—	—	L			X					+ 20	300		
X2CrNiMoN 22-5-3	1.4462	10.1		10088-3 10028-7	460	660 840	25	40	– 40	q			X		X			– 40	300		
X6CrNiTi 18-10	1.4541	8.1		10088-3 10028-7	220	520 720	40	60	– 196	q			X		X			– 196	300		
CuAl10 Ni5Fe4	CW307G	35	R590	EN 1653	230	590	14	—	—				X					– 196	250		
			R620		250	620															
X12CrS13	1.4005	—		10088-3	450	650 850	12	60	—				X					– 50	300		
X3CrNiMo 13-4	1.4313	7.2		10088-3 10028-7	520	650 830	15	60	– 60	q			X		X			– 100	300		

NOTE Measuring condition: L – in rolling direction, q – at right angles to rolling direction. Product forms: 1-forging; 2-casting; 3-rolled bars; 4-tube; 5-plate.

[a] Nominal value up to a determined thickness as noted in the standard (prEN 13480-2, EN 13445-2).

Table F.9 — Steel for bolts, screws, nuts and other fasteners

Material						Elongation after fracture	Impact energy KV_0			Strength values		Mat. group	PN class up to	Mark-ing of product	Operating temperature [°C]			
bolts			nuts															
Symbol	Num-ber	EN standard	Symbol	Num-ber	EN standard	A [%]	[J]	at [°C]	L/q	$R_{p0,2}$ [a] [MPa]	R_m [MPa]				min. $t_{0\ 25}$	min. $t_{0\ 75}$	min. $t_{0\ 100}$	max.
C-St-5.6		ISO 898-1 1515-1											40 300	5.6			– 10	300
			C-ST-5		20898-2 1515-1								40 300	5			– 10	300
C-St-6.8																		
C-St-8.8		ISO 898-1 1515-1											40 300	8.8			– 10	300
			C-St-8		20898-2 1515-1								40 300	8			– 10	300
10.9	1.7035	ISO 898-1															– 50	300
12.9	1.7225	ISO 898-1															– 50	300
25CrMo4	1.7218	10269 1515-1											all				– 10	450
			C 35 E C-St elev. temp	1.1181	10269 1515-1								all				– 10	450
42CrMo4	1.7225	10269 1515-1											all				– 10	450
			C 45 E C-St elev. temp	1.1191	10269 1515-1								all				– 10	450
25CrMo4	1.7218	10269 1515-1											all				– 60	400

NOTE Measuring condition: L – in rolling direction, q – at right angles to rolling direction. Product forms: 1-forging; 2-casting; 3-rolled bars; 4-tube; 5-plate.

[a] Nominal value up to a determined thickness as noted in the standard.

Table F.10 — Steel for bolts, screws, nuts and other fasteners

Material						Elongation after fracture	Impact energy KV_0			Strength values		Mat. group	PN class up to	Mark-ing of product	Operating temperature [°C]			
bolts			nuts															
Symbol	Num-ber	EN standard	Symbol	Num-ber	EN standard	A [%]	[J]	at [°C]	L/q	$R_{p0,2}$ [a] [MPa]	R_m [MPa]				min. $t_{0\ 25}$	min. $t_{0\ 75}$	min. $t_{0\ 100}$	max.
			A2-50 A2-70		1515-1 ISO 3506-2								all	A2-50 A2-70			– 60	400
42CrMo4	1.7225	10269 1515-1											all				– 100	450
			42CrMo4	1.7225	10269 1515-1								all				– 100	450
19MnB4	1.5523	10269											all				– 60	300
			42CrMo4	1.7225	10269 1515-1								all				– 100	300
20Mn5	1.1133	10269											all				– 50	300
			25CrMo4	1.7218	10269 1515-1								all				– 60	300
30CrNi Mo8	1.6580	10269 1515-1											all				– 40	300
			42CrMo4	1.7225	10269 1515-1								all				– 40	300
A4-50		1515-1 ISO 3506-1											40 300	A4-50			– 200	400

NOTE Measuring condition: L – in rolling direction, q – at right angles to rolling direction. Product forms: 1-forging; 2-casting; 3-rolled bars; 4-tube; 5-plate.

[a] Nominal value up to a determined thickness as noted in the standard.

Table F.10 (*continued*)

Material						Elongation after fracture	Impact energy KV_0			Strength values		Mat. group	PN class up to	Mark-ing of product	Operating temperature [°C]			
bolts			nuts															
Symbol	Num-ber	EN standard	Symbol	Num-ber	EN standard	A [%]	[J]	at [°C]	L/q	$R_{p0,2}$ [a] [MPa]	R_m [MPa]				min $t_{0\ 25}$	min $t_{0\ 75}$	min $t_{0\ 100}$	max
			A4-50		1515-1 ISO 3506-2								40 300	A4-50			– 200	400
A4-70		1515-1 ISO 3506-1											100 600	A4-70			– 200	400
			A4-70		1515-1 ISO 3506-2								100 600	A4-70			– 200	400
A2-50		1515-1 ISO 3506-1											40 300	A2-50			– 200	400
			A2-50		1515-1 ISO 3506-2								40 300	A2-50			– 200	400
A2-70		1515-1 ISO 3506-1											100 600	A2-70			– 200	400
			A2-70		1515-1 ISO 3506-2								100 600	A2-70			– 200	400

NOTE Measuring condition: L – in rolling direction, q – at right angles to rolling direction. Product forms: 1-forging; 2-casting; 3-rolled bars; 4-tube; 5-plate.

[a] Nominal value up to a determined thickness as noted in the standard.

Annex ZA
(informative)

Relationship between this European Standard and the Essential Requirements of EU Directive 98/37/EC

This European standard has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association to provide a means of conforming to Essential Requirements of the New Approach Directive 98/37/EC of the European Parliament and of the Council of 29 May 1997 on the approximation of the laws of the Member States concerning pressure equipment.

Once this standard is cited in the Official Journal of the European Union under that Directive and has been implemented as a national standard in at least one Member State, compliance with the clauses of this standard given in Table ZA.1 confers, within the limits of the scope of this standard, a presumption of conformity with the corresponding Essential Requirements of that Directive and associated EFTA regulations.

Table ZA.1 — Correspondence between this European Standard and Directive 98/37/EC

Clauses/sub-clauses of this European Standard	Essential requirements (ERs) of Directive 98/37/EC	Qualifying remarks/Notes
5.1	1.1.2	Principles of safety integration
5.5	1.1.3	Materials and products
5.1, 5.2, 5.3, 5.4	1.1.5	Handling
5.3, 5.4, 7.3.1	1.3.1	Stability
5.5.6	1.3.2	Break up during operation
5.2	1.3.7	Moving parts
5.2	1.3.8	Moving parts
5.6	1.5.1	Electricity supply
5.6	1.5.2	Static electricity
5.7	1.5.13	Emission of hazardous material and substances
7.3.2	1.7.0	Information device
7.3.2	1.7.1	Warning device
7.2	1.7.3	Marking
8.1, 8.2	1.7.4[a]	Instructions

[a] 1.7.4 f) is excluded.

WARNING — Other requirements and other EU Directives may be applicable to the products falling within the scope of this standard.

Annex ZB
(informative)

Relationship between this European Standard and the Essential Requirements of EU Directive 2006/42/EC

This European Standard has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association to provide a means of conforming to Essential Requirements of the New Approach Directive 2006/42/EC on machinery.

Once this standard is cited in the Official Journal of the European Communities under that Directive and has been implemented as a national standard in at least one Member State, compliance with the normative clauses of this standard given in Table ZB.1 confers, within the limits of the scope of this standard, a presumption of conformity with the relevant Essential Requirements of that Directive and associated EFTA regulations.

Table ZB.1 – Correspondence between this European Standard and Directive 2006/42/EC

Clauses/sub-clauses of this European Standard	Essential requirements (ERHRs) of Directive 2006/42/EC	Qualifying remarks/Notes
5.1	1.1.2	Principle of safety integration
5.5	1.1.3	Materials and products
5.1, 5.2, 5.3, 5.4	1.1.5	Handling
5.5.6	1.3.2	Risk of break up
5.5, 6	1.3.3	Falling or ejected objects
5.2	1.3.7	Moving parts
5, 6	1.5.1	Electrical safety
5.6, 6	1.5.2	Static electricity
5.7	1.5.13	Emission of hazardous material and substances
7.3.2	1.7.1	Information and worming
7.1	1.7.2	Residual risks
7.2	1.7.3	Marking
8	1.7.4 [a]	Instruction
[a] 1.7.4 f) is excluded.		

WARNING — Other requirements and other EU Directives may be applicable to the product(s) falling within the scope of this standard.

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[3] EN 764-4, *Pressure equipment — Part 4: Establishment of technical delivery conditions for metallic materials*

[4] EN 764-5, *Pressure equipment — Part 5: Compliance and inspection documentation of materials*

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[6] EN 1653, *Copper and copper alloys — Plate, sheet and circles for boilers, pressure vessels and hot water storage units*

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