

Pressure equipment for refrigerating systems and heat pumps —

Part 1: Vessels — General requirements

ICS 23.020.30; 27.080; 27.200

National foreword

This British Standard is the official English language version of EN 14276-1:2006+A1:2011. It supersedes BS EN 14276-1:2006, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee RHE/18, Refrigeration safety.

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

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Foreword

This document (EN 14276-1:2006+A1:2011) 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of an identical text or by endorsement, at the latest by August 2011, and conflicting national standards shall be withdrawn at the latest by August 2011.

This document includes Amendment 1, approved by CEN on 2010-12-13.

This document supersedes EN 14276-1:2006.

The start and finish of text introduced or altered by amendment is indicated in the text by tags **A1** **A1**.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association to support Essential Requirements of EU Directive 97/23/EC concerning Pressure Equipment.

For relationship with EU Directive 97/23/EC see informative Annex ZA, which is an integral part of this document.

This document consists of the following parts under the general title "*Pressure equipment for refrigerating systems and heat pumps*":

— *Part 1: Vessels – General requirements*

— *Part 2: Piping – General requirements*

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

Introduction

This standard recognises the unique nature of vessels for refrigerating systems or heat pumps and is intended to address the specific needs of the refrigeration and heat pump industry. This standard should be read in conjunction with the various parts of EN 13445.

When the text of this standard modifies or supplements a clause within EN 13445, then this standard should prevail. Where this standard does not modify or supplement the requirements of a clause, the requirements of EN 13445 should prevail.

The unique nature of a refrigerating system is defined as follows:

- a) the purpose of the refrigerating system is to extract and reject heat (this involves both cooling and heating);
- b) to operate the refrigerating system a pressure-imposing element (e.g. a compressor or an energy source) is necessary;
- c) the refrigerating system has a defined refrigerant charge in a closed circuit;
- d) the refrigerant has a chemical composition and purity defined in the relevant standards;
- e) the pressure of the refrigerant decreases when the temperature decreases (see typical curve in Annex A of this standard);
- f) due to the maximum temperature limit of 200 °C and the maximum pressure limit of 64 bar, the time dependent creep and fatigue due to pressure variation or vibrations are not significant design factors except for some materials such as aluminium, copper and titanium where the fatigue shall be taken into account;
- g) the risk of overpressure is due to:
 - the pressure imposing element;
 - an external heat source (e.g. fire or hot water);
 - improper operation.
- h) the refrigerating system is designed to minimise refrigerant emissions and the ingress of contaminants.

Only hermetic compressors are covered by this standard.

1 Scope

This European Standard specifies the requirements for material, design, manufacturing, testing and documentation for stationary pressure vessels intended for use in refrigerating systems and heat pumps. These systems are referenced in this standard as refrigerating systems as defined in EN 378-1.

This European Standard applies to vessels including welded or brazed attachments up to and including the nozzle flanges, screwed, welded or brazed connectors or to the edge to be welded or brazed at the first circumferential joint connecting piping or other elements.

This European Standard applies to pressure vessels with an internal pressure down to – 1 bar, to account for the evacuation of the vessel prior to charging with refrigerant.

This European Standard applies to both the mechanical loading conditions and thermal conditions as defined in EN 13445-3 associated with refrigerating systems. It applies to pressure vessels subject to the maximum allowable temperatures for which nominal design stresses for materials are derived using EN 13445-2 and EN 13445-3 or as specified in this standard. In addition vessels designed to this standard should have a maximum design temperature not exceeding 200 °C and a maximum design pressure not exceeding 64 bars. Outside of these limits, it is important that EN 13445 be used for the design, construction and inspection of the vessel. Under these circumstances it is important that the unique nature of refrigerating plant, as indicated in the introduction to this standard, also be taken into account.

It is important that pressure vessels used in refrigerating systems and heat pumps of category less than II as defined in Annex H comply with other relevant clauses of EN 378-2 for vessels.

This European Standard applies to pressure vessels where the main pressure bearing parts are manufactured from metallic ductile materials as defined in Clause 4 and Annex I of this standard.

This European Standard does not apply to vessels of the following types:

- vessels of riveted construction;
- multilayered, autofrettaged or prestressed vessels;
- vessels directly heated by a flame;
- « roll bond » heat exchangers.

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 287-1:2004, *Qualification test of welders — Fusion welding — Part 1: Steels*

[A1] EN 378-1:2008+A1:2010, *Refrigerating systems and heat pumps — Safety and environmental requirements — Part 1: Basic requirements, definitions, classification and selection criteria*

EN 378-2:2008+A1:2009, *Refrigerating systems and heat pumps — Safety and environmental requirements — Part 2: Design, construction, testing, marking and documentation*

EN 378-4:2008, *Refrigerating systems and heat pumps — Safety and environmental requirements — Part 4: Operation, maintenance, repair and recovery* **[A1]**

EN 764-1:2004, *Pressure equipment — Part 1: Terminology — Pressure, temperature, volume, nominal size*

EN 764-2:2002, *Pressure equipment — Part 2: Quantities, symbols and units*

EN 764-3:2002, *Pressure equipment — Part 3: Definition of parties involved*

EN 764-4:2002, *Pressure equipment — Part 4: Establishment of technical delivery conditions for metallic materials*

EN 764-5:2002, *Pressure equipment — Part 5: Compliance and inspection documentation of materials*

EN 837-1:1996, *Pressure gauges — Part 1: Bourdon tube pressure gauges — Dimensions, metrology, requirements and testing*

EN 910:1996, *Destructive tests on welds in metallic materials — Bend tests*

EN 1005-2:2003+A1:2008, *Safety of machinery — Human physical performance — Part 2: Manual handling of machinery and component parts of machinery*

EN 1045:1997, *Brazing — Fluxes for brazing — Classification and technical delivery conditions*

EN 1045:1997, *Brazing — Fluxes for brazing — Classification and technical delivery conditions*

EN 1173:2008, *Copper and copper alloys — Material condition designation*

EN 1418:1997, *Welding personnel — Approval testing of welding operators for fusion welding and resistance weld setters for fully mechanized and automatic welding of metallic materials*

EN 10111:2008, *Continuously hot-rolled low carbon steel sheet and strip for cold forming — Technical delivery conditions*

EN 10130:2006, *Cold-rolled low carbon steel flat products for cold forming — Technical delivery conditions*

EN 10160:1999, *Ultrasonic testing of steel flat product of thickness equal or greater than 6 mm (reflection method)*

EN 10164:2004, *Steel products with improved deformation properties perpendicular to the surface of the product — Technical delivery conditions*

EN 10204:2004, *Metallic products — Types of inspection documents*

EN 12517-1:2006, *Non-destructive testing of welds — Part 1: Evaluation of welded joints in steel, nickel, titanium and their alloys by radiography — Acceptance levels*

EN 12517-1:2006, *Non-destructive testing of welds — Part 1: Evaluation of welded joints in steel, nickel, titanium and their alloys by radiography — Acceptance levels*

EN 12797:2000 + A1:2003, *Brazing — Destructive tests of brazed joints*

EN 12799:2000 + A1:2003, *Brazing — Non-destructive examination of brazed joints*

EN 13445-2:2009, *Unfired pressure vessels — Part 2: Materials*

EN 13445-3:2009, *Unfired pressure vessels — Part 3: Design*

EN 13445-4:2009, *Unfired pressure vessels — Part 4: Fabrication*

EN 13445-5:2009, *Unfired pressure vessels — Part 5: Inspection and testing*

EN 13445-6:2009, *Unfired pressure vessels — Part 6: Requirements for the design and fabrication of pressure vessels and pressure vessel parts constructed from spheroidal graphite cast iron*

EN 13445-8:2009, *Unfired pressure vessels — Part 8: Additional requirements for pressure vessels of aluminium and aluminium alloys*

EN 22553:1994, *Welded, brazed and soldered joints — Symbolic representation on drawings (ISO 2553:1992)*

EN ISO 3677:1995, *Filler metal for soft soldering, brazing and braze welding — Designation* (ISO 3677:1992)

Ⓐ EN ISO 4063:2009, *Welding and allied processes — Nomenclature of processes and reference numbers* (ISO 4063:2009) Ⓐ

Ⓐ EN ISO 5817:2007, *Welding — Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded) — Quality levels for imperfections* (ISO 5817:2003, corrected version:2005, including Technical Corrigendum 1:2006) Ⓐ

Ⓐ EN ISO 6892-1:2009, *Metallic materials — Tensile testing — Part 1: Method of test at room temperature* (ISO 6892-1:2009) Ⓐ

EN ISO 7438:2005, *Metallic materials — Bend test* (ISO 7438:2005)

EN ISO 10012:2003, *Measurement management systems — Requirements for measurement processes and measuring equipment* (ISO 10012:2003)

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

EN ISO 15609-1:2004, *Specification and qualification of welding procedures for metallic materials — Welding procedure specification — Part 1: Arc welding* (ISO 15609-1:2004)

EN ISO 15611:2003, *Specification and qualification of welding procedures for metallic materials — Qualification based on previous welding experience* (ISO 15611:2003)

EN ISO 15612:2004, *Specification and qualification of welding procedures for metallic materials — Qualification by adoption of a standard welding procedure* (ISO 15612:2004)

EN ISO 15614-1:2004, *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 15614-8:2002, *Specification and qualification of welding procedures for metallic materials — Welding procedure test — Part 8: Welding of tubes to tube-plate joints* (ISO 15614-8:2002)

Ⓐ EN ISO 17672:2010, *Brazing — Filler metals* (ISO 17672:2010) Ⓐ

ISO 817:2005, *Refrigerants — Designation system*

ISO 857-1:1998, *Welding and allied processes — Vocabulary — Part 1: Metal welding processes*

ISO 5187:1985, *Welding and allied processes — Assemblies made with soft solders and brazing filler metals — Mechanical test methods*

3 Terms and definitions

Ⓐ For the purposes of this document, the terms and definitions given in EN 378-1:2008+A1:2010, EN 764-1:2004, EN 764-2:2002, EN 764-3:2002, EN 764-4:2002, EN 764-5:2002, ISO 857-1:1998 and the following apply. Ⓐ

3.1 Definitions

3.1.1 Temperatures stress cases

3.1.1.1

min $t_{0\ 100}$

lowest temperature at which pressurised parts are allowed to be used at a stress of up to 100 % of the design stress at 20 °C (standard design stress)

3.1.1.2

min $t_{0\ 75}$

lowest temperature at which pressurised parts are allowed to be used when their stress is a maximum of 75 % of the design stress at 20 °C (reduced stress)

3.1.1.3

min $t_{0\ 50}$

lowest temperature at which pressurised parts are allowed to be used when their stress is a maximum of 50 % of the design stress at 20 °C (medium stress)

3.1.1.4

min $t_{0\ 25}$

lowest temperature at which pressurised parts are allowed to be used when their stress is a maximum of 25 % of the design stress at 20 °C (low stress)

3.1.2

corrosion

all forms of material wastage (e.g. oxidation, erosion, wear and abrasion)

3.1.3

safety data sheet

document which gives all necessary information for prevention, safety, storage, transportation, labelling, use and disposal of substances and preparations which have a risk for health, safety or environment 

3.1.4

maximum design temperature

highest temperature that can occur during operation or standstill of the refrigerating system or during testing under test conditions

NOTE This temperature is equivalent to the maximum allowable temperature as defined in article 1.2.4 of the PED.

3.1.5

minimum design temperature

lowest temperature that can occur during operation or standstill of the refrigerating system or during testing under test conditions

NOTE This temperature is equivalent to the minimum allowable temperature as defined in article 1.2.4 of the PED.

3.1.6

main pressure bearing part

components of the vessel retaining the pressure and contributing to the vessel strength such as shell, tubesheet, end plate, dished ends, connection or fitting

3.1.7

volume

internal volume of a compartment ready for operation, including the volume of nozzles to the first connection (flange, coupling, weld, braze) and excluding the volume of permanent internal part

3.1.8

« roll bond » heat exchanger

heat exchanger consisting of two plates which are weld-bonded together with the exception of the printed circuit forming the refrigerant passage which is obtained by inflation under pressure

3.1.9

maximum operating pressure

maximum pressure which the vessel can withstand without the operation of any safety accessory with a continuous operation of the pressure generator (compressor, heat source...)

NOTE This pressure determines the maximum operating conditions for equipment users.

3.1.10

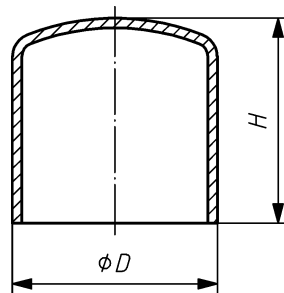
maximum standstill pressure

maximum pressure which the vessel can withstand without operation of any safety accessory when the pressure generator is not in operation. This pressure occurs during transportation, storage or shut down of the pressure generator

3.1.11

deep drawing

process of forming by stamping when the ratio of depth (H) by diameter (D) is greater than or equal to 0,45, see Figure 1



Key

H depth
 D diameter

Figure 1 — Deep drawing

3.1.12

manual brazing

brazing operation performed and controlled by hand

3.1.13

semi-automatic brazing

brazing with equipment which controls only the brazing filler metal feed.

NOTE The advance of the brazing is manually controlled

3.1.14

machine brazing

brazing with equipment which performs the brazing operation under the constant control of a brazing operator

3.1.15

automatic brazing

brazing with equipment which performs the brazing operation without constant observation and adjustment by a brazing operator

3.1.16

brazer

person who performs a manual or semiautomatic brazing operation

3.1.17

brazing operator

person who operates a machine or automatic brazing equipment

3.1.18

semiautomatic expansion

expansion with equipment which controls the operation and where the operator manually introduces the equipment to the inside of the tube

3.1.19

machine expansion

expansion with equipment which performs the expansion operation under the constant control of operator

3.1.20

automatic expansion

expansion with equipment which performs the expansion operation without constant observation and adjustment by an expansion operator

3.1.21

expansion operator

person who makes an expansion joint

3.1.22

rolling

plastic cold forming of tubes by means of a tool which have several rolls turning during the operation

3.2 Symbols, quantities and units

Symbols, quantities and units used in this standard are listed in Table 1.

Table 1 — Symbols, quantities and units

Symbol	Quantity	Unit
A	elongation after fracture	%
A_t	strengthened area tube side	mm ²
A_v	strengthened	mm ²
A_w	effective area of expanded joint	mm ²
c	corrosion allowance	mm
d_{tube}	nominal outside diameter of tubes	mm
d_e	external diameter of tube	mm
d_i	internal diameter of tube	mm
D_s	internal shell diameter	mm
DN	Nominal diameter	—
e	thickness	mm
e_{act}	actual thickness	mm
e_b	brazing joint size of tube in the tubesheet	mm
e_w	welding joint size of tube in the tubesheet	mm
e_n	nominal thickness	mm
E_{tube}	Elasticity modulus for tube material at design temperature	MPa
f	nominal design stress at design temperature	MPa
f_{tube}	nominal design stress of tube material at design temperature t °C	MPa
f_{test}	nominal design stress at test temperature t °C	MPa
F_s	tube force generated by shell side	N
F_{tube}	tube force generated by tube side	N
l_{tx}	expanded length on tube inside tubesheet	mm
l_k	unsupported tube length	mm
L_0	gauge length for tensile test	mm
N_{tube}	Number of tube for a tubular heat exchanger	—
p	tube pitch for tubesheet	mm
P_c	calculation pressure (in formula, P_c can be replaced by P)	MPa or bar ^a
P_d	design pressure	MPa or bar ^a
$P_{(\text{max})}$	maximum design pressure	MPa or bar ^a
PS	maximum allowable pressure	MPa or bar ^a
P_{test}	test pressure	MPa or bar ^a
P_v	shell side calculation pressure	MPa or bar ^a
P_{tube}	tube side calculation pressure	MPa or bar ^a
PED	Pressure Equipment Directive n° 97/23/EC	—
Q_{tube}	tube force due to tube side	N
Q_v	tube force due to tubesheet	N

Table 1 (continued)

Symbol	Quantity	Unit
R_{eH}	upper yield strength	MPa
R_m	tensile strength	MPa
$R_{m \min}$	minimum tensile strength	MPa
$R_{m \text{ avg}}$	average value of tensile strength of several test specimens	MPa
$R_{m \max}$	maximum tensile strength specified in the standard	MPa
$R_{m/t}$	tensile strength at temperature t °C	MPa
$R_{m/t\text{test}}$	tensile strength at test temperature t °C	MPa
$R_p \text{ avg}$	average value of proof strength of several test specimens	MPa
$R_{p0,2}$	0,2 % proof strength	MPa
$R_{p0,2/t}$	0,2 % proof strength at temperature t °C	MPa
$R_{p0,2/t\text{test}}$	0,2 % proof strength at test temperature t °C	MPa
$R_{p1,0}$	1,0 % proof strength	MPa
$R_{p1,0/t}$	1,0 % proof strength at temperature t °C	MPa
$R_{p1,0/t\text{test}}$	1,0 % proof strength at test temperature t °C	MPa
S_0	original cross section area	mm ²
S_F	safety factor	—
t_c	calculation temperature	°C
t_d	design temperature	°C
t_{ha}	temperature of heat absorbing fluid	°C
t_{he}	temperature of heat emitting fluid	°C
z	joint coefficient	—
α	thermal expansion	—
δ_e	negative wall thickness tolerance	mm
ν	Poisson's ratio	—
μ	basic ligament efficiency of the tubesheet	—

^a 1 bar = 100 000 Pa = 0,1 MPa = 0,1 N/mm²

4 Materials

4.1 General

The requirements for materials referenced in this standard shall conform to EN 13445-2, unless modified by the clauses of this section. This standard or reference to other relevant standards shall cover materials not included in EN 13445-2.

It is permitted to use non-metallic materials (e.g. gaskets, coatings, insulating materials, sightglasses) provided they are compatible with the other materials, refrigerants and lubricants present.

4.2 Requirements for materials to be used for pressurised parts

Materials listed in this standard have been identified for use in refrigerating vessels. If it is required to utilise a material not listed in this standard, the requirements of EN 13445-2 shall be followed where applicable and the unique nature of refrigerating plant requirements shall also be taken into account.

4.3 Requirements for materials

4.3.1 Vessels manufactured from the following materials satisfy the requirements of this standard for the pressurised parts:

4.3.1.1 Where mechanical properties may be modified by the vessel manufacturing process, the material shall be selected from the following material groups as defined in Annex I

- Steel groups: 1.1, 1.2, 8.1 in accordance with Annex I;
- Aluminium and aluminium alloys groups: 21, 22 with a limitation of 150 °C of maximum allowable temperature;
- Copper group: 31, 34 with a limitation of 150 °C of maximum allowable temperature;
- Spheroidal graphite cast iron: EN 13445-6.

Tubular products for heat exchange surfaces or for connection with DN less than or equal to 50 can also be selected from the following material groups:

- Copper and copper alloys groups 32, 33, 35 with a limitation of 150 °C of maximum allowable temperature;
- Titanium with a limitation of 150 °C of maximum allowable temperature.

4.3.1.2 For deep drawing, the following steels are particularly suitable:

A1

- EN 10130, all grades excluding DC 01; **A1**
- EN 10111: grade DD12, DD13, DD14.

After forming and possible heat treatment, the material selected shall have a minimum elongation of 14 % when measured as defined in 4.3.3.3, and the test sample is taken close to the edge of the end cap.

Other materials can be considered provided they conform to this requirement.

4.3.1.3 Where the vessel manufacturing process does not modify mechanical properties, metallic materials other than those quoted in 4.3.1.1 can be used.

4.3.2 Cladding

The base metal of clad materials shall be selected from steel groups listed in 4.3.1.1. The cladding materials may be selected from other material groups.

A1 The requirements of EN 13445-2:2009, Annex D shall apply when the strength of the cladding material is included in the design calculation. **A1**

4.3.3 Special considerations

4.3.3.1 Copper and copper alloys shall be ordered in material condition R or Y as defined in the material standard in accordance with the designation system given in EN 1173.

4.3.3.2 With steel grades, where the vessel manufacturer perceives that there is a risk of lamellar tearing due to joint design and loading, one of the following solutions shall be employed:

- Testing in accordance with EN 10164 with a minimum value of Z15
- Ultrasonic inspection of the area where the joint is made. The minimum area to be inspected is a band of material equivalent to five times the weld joint width. The inspection shall be carried out to EN 10160 with class S3 or E4 acceptance levels. The examination shall be conducted after manufacturing processes to the part in question are complete.

4.3.3.3 The minimum values for the elongation after fracture (A) specified for gauge length $L_0 = 5,65 \sqrt{S_0}$ are:

- Steel for transverse direction: 14 %;
- Steel for longitudinal direction: 16 %;
- Aluminium and aluminium alloys: 14 %;
- Copper and copper alloys in wrought condition: 14 %;
- Copper alloys in cast condition: 12 %;
- Titanium: 14 %.

In case of tubular copper and copper alloy material where the elongation values fall below the values given above, their use shall be restricted to use within the following limits:

- $PS \times DN = 50\,000$ bar mm and $PS = 64$ bar for $A > 5$ %;
- $PS \times DN = 10\,000$ bar mm and $PS = 20$ bar for $A \leq 5$ %.

4.3.3.4 $\square A_1$ When the gauge length is different from $L_0 = 5,65 \sqrt{S_0}$ and for a non-proportional gauge length, the requirements of EN ISO 6892-1 shall apply to determine the minimum value of elongation after fracture. $\square A_1$

4.3.3.5 Design temperatures above room temperature

These are specified for steel in EN 13445-2. The values for aluminium and its alloys, copper and its alloys and for titanium may be determined by the material standard or by the Annex F of this standard.

The values specified at room temperature may be used for temperature equal to or less than 50 °C.

4.4 Requirements for prevention of brittle fracture

4.4.1 General

$\square A_1$ For pressure vessels the allowed stress at the minimum design temperature is applied as per EN 13445-2:2009, Annex B or Annex A of this European Standard. $\square A_1$

Annex A takes into account that due to the physical conditions during the phase change in refrigerating systems, the pressure in the refrigerant containing part of the vessel drops when the refrigerant temperature decreases. Thus at lower temperatures the stresses due to refrigerant pressure are always lower than the stresses at the design pressure according to the relevant table of EN 378-2 (vapour pressure curve of a common refrigerant, see Figure A.1).

In the case of fluids without phase change, e.g. brine, the pressure does not change at low temperatures, therefore in Annex A the permissible stress of the component parts is determined by higher safety factors (see Table A.1).

4.4.2 Material requirements

[A1] For steel materials listed in 4.3.1.1 the test temperature and the minimum value of the impact test energy measured on an ISO V notch bending test specimen are determined in accordance with EN 13445-2:2009, Annex B or Annex A of this European Standard. **[A1]**

For spheroidal cast iron, refer to EN 13445-6 requirements.

The copper, copper alloys with the exception of alloy groups 32.2 and 35, aluminium, aluminium alloys and titanium are not susceptible to brittle fracture due to low temperature and no special provisions are necessary for their use to a minimum design temperature of – 196 °C.

4.5 Material documentation

[A1] The material of the main pressure bearing parts of vessels of categories II, III, IV shall be delivered with a specific product control document as defined in EN 10204:2004 (e.g. 3.1, 3.2).

The materials for other pressure bearing parts, and for vessels where the category is I or lower. Filler materials used for welding and brazing shall be delivered with a test report 2.2 as defined in EN 10204:2004. **[A1]**

4.6 Materials for non-pressure retaining parts

Materials for non pressurised parts, such as lifting lugs, supporting skirts, baffles etc., which are permanently joined to pressurised parts of the vessel, and welding and brazing consumables, shall be selected by the vessel manufacturer in order to avoid undesirable effects with the material to which they are attached. The materials shall be supplied against materials specifications covering as a minimum the requirements for chemical composition and tensile properties. The vessel manufacturer shall specify impact properties when required by the design conditions. These materials shall be compatible with the materials to which they are attached.

5 Pressure Vessel classification

5.1 Category of vessel

The pressure vessels are classified into 4 categories in accordance with the following:

- a) the product of maximum allowable pressure in bar times the volume in litres;
- b) the fluid classification as defined in 5.2;
- c) the fluid state:
 - 1) gases, liquefied gases, gases dissolved under pressure and those liquids whose vapour pressure at the maximum allowable temperature is greater than 0,5 bar;
 - 2) liquids having a vapour pressure at the maximum allowable temperature of not more than 0,5 bar.

For this standard, the refrigerant containing parts are always considered as a gas circuit.

The informative Annex H of this standard defines the limits of the 4 categories.

5.2 Fluid classification

5.2.1 Refrigerants

EN 378-1:2008+A1:2010, Annex E gives the classification of the refrigerant within Group 1 (dangerous fluid) or Group 2 (non dangerous fluid).

5.2.2 Other fluids

Other fluids used shall be classified according to their Material Safety Data Sheets as follows:

- Fluids and mixtures other than refrigerants shall be classified as Group 1 or 2.

NOTE Regulation CLP 1272/2008 gives the classification of chemical products and mixtures.

- Group 2 (non-dangerous fluids): fluids with no risk or other risks not quoted above associated with them.

When a mixture of fluids contains at least one fluid classified as Group 1, the mixture shall be classified as Group 1 unless there is evidence available either in the details given in the material safety data sheet or in the manufacturer's supporting documents to classify the mixture as Group 2.

6 Design

6.1 General

This clause covers pressure vessels constructed of materials as defined in Clause 4. The dimensions of pressurised parts shall withstand the design pressure (P_d) at the design temperature (t_d).

The requirements for design referenced in this standard shall meet the requirements of EN 13445-3 unless modified by the clauses of this section.

6.2 Corrosion and corrosion protection

6.2.1 General

The corrosion allowances specified in this clause are based on the assumption that the vessel shall be maintained as prescribed in EN 378-2. If it is intended to maintain the system to any other requirement, the other allowances may have to be used and stated in the vessel documentation.

6.2.2 Internal corrosion

For surfaces in contact with HFC's type refrigerants listed in EN 378-1:2008+A1:2010, Annex E, internal corrosion is negligible and the minimum corrosion allowance may be taken to be 0 mm. Other values, greater than zero, may be selected by the manufacturer.

For other types of refrigerant and for other fluids, the minimum corrosion allowance shall be assumed to be 0 mm. Other values, greater than zero, may be selected by the manufacturer.

6.2.3 External corrosion

External corrosion allowance shall be either:

A1

- 0 mm for pressurised parts, if appropriate protection (e.g.: paint, zinc plating, vapour barriers, non corrosive materials) is applied prior to putting into service, and the protection is properly maintained by the end user during the operational lifetime and checked at least according to EN 378-2:2008+A1:2009 (Annexes D and G) and EN 378-4; **A1**
- Not less than 1 mm if pressurised parts are not protected during the operational life time as prescribed above;
- As specified by the contracting parties at the time of order.

NOTE The low temperatures associated with the operation of evaporators vessels and other vessels working on the “low pressure side” of the system may result in condensation forming of the cold surfaces. Special attention should be given to these vessels, by for example properly applying insulation and vapour seal, to avoid corrosion of the surface.

6.2.4 Corrosion allowance information

The corrosion allowance value shall be stated on the vessel documentation.

6.3 Stress corrosion cracking

Pressure vessels in contact with refrigerants other than ammonia are not subject to stress corrosion cracking.

For vessels containing ammonia, stress corrosion cracking does not occur if vessels are made from steel with

$R_{eH} \leq 360 \text{ N/mm}^2$ and the refrigerating system is designed, operated and maintained according to EN 378-1 to EN 378-4.

If by design or contract both of the above conditions do not apply, then it may be necessary to stress relieve the vessel according to EN 13445-4. Under these conditions the manufacturer shall assess the conditions that may exist in the plant and stress relieve the vessel when it is considered necessary.

6.4 Loading

The requirements of EN 13445-3 shall apply.

6.5 Maximum allowable pressure PS

A1 The design temperature of the pressurised refrigerant containing parts shall not be less than the fluid temperature given in EN 378-2:2008+A1:2009, Table 2. For fluids other than refrigerants the design temperature shall be determined according to the relevant clauses of EN 13445-3:2009. **A1**

The maximum allowable pressure PS shall not be exceeded except during the short period of time necessary for the safety accessory to operate and the maximum value of pressure shall be $1,1 \times PS$. The value of PS shall be determined by taking into account the intended safety protection of the vessel or the assembly. Annex D of this standard gives the relationship between the different pressures occurring into refrigerating or heat pumps systems.

6.6 Design pressure P_d

The design pressure shall not be less than PS .

The refrigerant containing compartment of a vessel and the refrigerant side of a heat exchanger vessel shall be designed to withstand the exceptional situation of a pressure of – 1 bar (e.g. vacuum inside with atmospheric pressure on the outside), which may occur during refrigerant charging or recovery operations.

6.7 Calculation pressure P or P_c

The calculation pressure P or P_c to be used shall be based on the most severe condition of coincident pressure and temperature. It shall be based on the maximum possible differential pressure between two sides of a pressure bearing component.

6.8 Design temperature t_d

The design temperature of the pressurised refrigerant containing parts shall not be less than the fluid temperature given in [A1](#) EN 378-2:2008+A1:2009, Table 2 [A1](#).

For fluids other than refrigerants the design temperature shall be determined according to the relevant clauses of EN 13445-3.

Localised high temperatures (e.g. super heated refrigerant) shall be taken into account in the relevant pressure vessel area.

6.9 Minimum material temperature

The minimum material temperature is the minimum temperature which can occur during operation or during stand-still conditions. This temperature shall be used to select materials to avoid brittle fracture. This minimum material temperature shall not be greater than 20 °C.

Localised low temperatures associated with the rapid charging of refrigerants/refrigerant blends into the vessel (expanding a volatile liquid into a vacuum) shall be taken into account in the relevant area of the pressure vessel.

The requirements for impact test properties shall be considered in this localised area.

6.10 Calculation temperature t_c

6.10.1 General

The calculation temperature t_c is used to determine the appropriate design stress for the selected material.

6.10.2 Vessel without heater

The calculation temperature, unless determined on the basis of detailed calculations or tests based on measurements, shall be determined as follows:

- When the fluid temperature is below or equal to 50 °C, the calculation temperature shall be equal to the fluid temperature;
- When the fluid temperature is above 50 °C, the calculation temperature shall be taken from Table 2:

Table 2 — Calculation temperature for vessels without heater

Calculation temperature t_c °C		heat absorbing fluid		
		gas or vapour	liquid (boiling or not)	
			flowing	Stationary
Heat emitting Fluid	gas or vapour	$\text{Max} \left(\frac{t_{ha} + t_{he}}{2}, 50 \right)$	$\text{Max} (t_{ha}, 50)$	$\text{Max} (t_{he}, 50)$
	Liquid (boiling or not)	$\text{Max} (t_{he}, 50)$	$\text{Max} \left(\frac{t_{ha} + t_{he}}{2}, 50 \right)$	$\text{Max} (t_{he}, 50)$

The calculation of nozzles or opening reinforcements shall be carried out with these localised temperature variations.

When one side of the vessel is exposed to the ambient temperature the calculation temperature shall be equal to t_{he} .

NOTE For single sided insulated walls, the value of the mean wall temperature may be considered the same as the value for the non-insulated side.

6.10.3 Vessel with heater

When the vessel is equipped with a heater, the calculation temperature shall be determined by test or taken to be equal to the temperature determined in 6.10.2 + 50 K.

The manufacturer when selecting the heater shall quantify the risk that exists of overheating for the fluid or for the material and shall take appropriate measures to restrict this risk by for example the inclusion of safety accessories and/or the inclusion of appropriate warning labels and/or adding instructions to the documentation.

6.11 Joint coefficient

The joint coefficient “z” takes into account the risk associated with the introduction of a weld as well as the risk of a defect remaining undetected due to the level of Non Destructive Examination (NDE) conducted on the joint.

The joint coefficient applies to longitudinal and helical joints in shells, longitudinal joints in conical shells and the main joints between plates used to fabricate dished heads.

The joint coefficient does not apply to non governing joints such as circumferential joints on vessels, conical sections, nozzle to shell joints or any type of joint where only compressive stresses are present.

The manufacturer shall select one of the following values:

- 1 for equipment subjected to destructive and non destructive tests that confirm that 100 % of the joint is defect free. This can be used for vessels assessed under testing group 1 b and 2 b;
- 0,85 for equipment subject to random non-destructive testing equivalent to 10 % of the joint length. This can be used for vessels assessed under testing group 3 b;
- 0,7 for equipment where no non destructive testing has been carried out other than the visual inspection of the joint. This can be used for vessels assessed under testing group 4.
- The joint coefficient shall be used to define the testing group of the vessels as per Table 3.

Table 3 — Testing groups

Joint coefficients	1	1	0,85	0,7
Testing groups ^a	1b	2b	3b	4
Permitted material Steel group	1.1/1.2/8.1	1.1/1.2/8.1	1.1/1.2/8.1	1.1/1.2/8.1
Maximum thickness per material category Steel group 1.1 / 8.1	Unlimited ^b	≤ 50	≤ 50	≤ 16
Steel group 1.2	Unlimited ^b	≤ 30	≤ 30	≤ 12
Welding process	Unlimited ^b	Fully mechanical welding only ^c	Unlimited ^b	Unlimited ^b
Service temperatures range	Unlimited ^b	Unlimited ^b	Unlimited ^b	- 50 °C + 200 °C
Groups of fluid	1/2	1/2	1/2	2
Extent of NDT of governing welded joints	100 %	100-10 % ^d	10 %	0 %
^a Definition of testing groups by analogy with EN 13445-5. All testing groups require visual examination. ^b Unlimited means no additional restriction due to testing. The limitations mentioned in the table are limitations imposed by testing. Other limitations given in various clauses of this standard (such as design, material limitations) shall also be taken in account. ^c Fully mechanised and/or automatic welding process where at least the weld head and the welding consumable movement is mechanised. ^d First figure applies initially, Second figure applies after experience. For definition of experience see EN 13445-5. The percentage relates to the percentage of welds of each individual vessel.				

When assessing exceptional situations e.g. vacuum – 1 bar, no joint coefficient is necessary for calculation purposes.

6.12 Design stress

6.12.1 General

The value of design stress shall take into account the design and tests conditions. The values of yield and tensile strength of the material shall be those which apply to the materials in the final fabricated condition, and shall conform with the values given in the appropriate design specification.

These values can be used for design purposes unless heat treatment is known to lead to lower values.

6.12.2 For non-ferrous materials used in welded or brazed construction, the design stresses shall not exceed the values given for annealed material at the design temperature.

6.12.3 For metallic material, the value at 23 °C ± 5 °C may be used for temperatures up to and including 50 °C. If the weld or brazed metal gives lower strength values after fabrication, then these values shall be used instead.

6.12.4 When assessing exceptional conditions (e.g. vacuum – 1 bar), the design stress shall be taken for the test condition with the temperature of material taken to be that existing at the exceptional condition.

The design stresses shall be in accordance with the following values:

Table 4 — Nominal design stress

Material	Design conditions	Testing conditions	K coefficient
Steel group 1.1, 1.2	min. ($R_{m/20}/2.4$, $R_{p0.2/t}/1.5$)	$R_{p0.2/ttest}/1.05$	2,4
Steel group 8.1 with A% > 30% with A% > 35%	$R_{p1.0/t}/1.5$ max. (min ($R_{m/t}/3$, $R_{p1.0/t}/1.2$), $R_{p1.0/t}/1.5$)	$R_{p1.0/ttest}/1.05$ max. ($R_{p1.0/ttest}/1.05$, $R_{m/ttest}/2$)	3
Steel casting	min. ($R_{m/20}/3$, $R_{p0.2/t}/1.9$)	$R_{p0.2/ttest}/1.33$	3
Aluminium group 21	$R_{eH}/1.5$	$R_{eH/ttest}/1.05$	Not applicable
Aluminium group 22	min. ($R_{m/20}/2.4$, $R_{p0.2/t}/1.5$)	$R_{p0.2/ttest}/1.05$	2,4
Copper group 31-32-33-34-35	min. ($R_{m/t}/3.5$, $R_{p0.2/t}/1.5$)	$R_{m/ttest}/2.22$	2,4
Titanium tube	$R_{m/t}/3$	$R_{m/ttest}/2.22$	3,5
Spheroidal graphite cast iron	see EN 13445-6		4
Bolt and fasteners			4
non austenitic steel	min. ($R_{m/20}/4$, $R_{p0.2/t}/3$)	min. ($R_{m/20}/2.67$, $R_{p0.2/t}/2$)	
austenitic steel	$R_{m/t}/4$	$R_{m/ttest}/2.67$	
NOTE Upper yield strength R_{eH} may be used instead of $R_{p0.2}$.			

6.13 Access and inspection openings, venting and draining provisions, filling and discharge provisions and handling devices

6.13.1 Non corrosive fluids

Where the fluids are considered to be non corrosive, no provisions are required for access and inspection openings other than the connections used on the vessels.

6.13.2 Corrosive fluids

[A1] Where corrosive fluids have been specified, the requirements of EN 13445-5:2009, Annex C apply unless alternative technical inspection has been indicated in the manufacturer's documentation. **[A1]**

6.13.3 Venting and draining provisions

The design of the vessel shall ensure provision for adequate venting of air during the hydraulic test and draining of the test fluid after the hydraulic test.

6.13.4 Filling and discharge provision

The provision given in EN 378 parts 2, 3 and 4 shall apply to prevent the risk of refrigerant emission during the filling or discharging of the refrigerating system.

If the vessel can be used for refrigerant storage, the documentation shall recommend the maximum liquid level and the use of safety accessories to avoid any over-pressure.

6.13.5 Handling devices

When the mass of the vessel exceeds 25 kg, the vessel shall be equipped with handling devices or the manufacturer shall indicate, where appropriate, the recommended handling procedures (See EN 1005-2).

The same requirement applies to parts or components which can be removed during servicing.

6.14 Methods for design

6.14.1 General

A1 The basic design method is the design by formula (DBF) method. In addition two other methods can be used to either supplement or replace DBF:

- a) Design by analysis (DBA):
The rules are given in EN 13445-3:2009, Annexes B and C;
- b) Experimental techniques:
The rules are given in Annex E of this European Standard.

The minimum required thickness is defined in EN 13445-3:2009, 5.2.3. **A1**

6.14.2 Design by formulas (DBF)

6.14.2.1 General

A1 All requirements of EN 13445-3:2009, Clauses 7 to 21 apply with the following exceptions of 13.4.2.1 d, 13.5.2.1 d, 13.6.2.1 e of EN 13445-3:2009 “Heat exchanger tubesheet” and which are not applicable for heat exchanger vessels in refrigerating systems. **A1**

For tubesheet calculations, when the tube thickness is not uniform throughout, the thickness e_t used in the formula shall be the thickness which gives the same axial rigidity for the tube.

6.14.2.2 Additional formula

6.14.2.2.1 Fixed tubesheet not uniformly perforated

A1 To supplement EN 13445-3:2009, Clause 13 for a tubesheet which is not uniformly perforated: **A1**

This clause concerns flat tubesheets of shell and tube vessel types where the tubesheet is not uniformly perforated in a circular area or where the unperforated diametral rows exceed four times the tube pitch.

It takes into account loads caused by pressure only. Special consideration shall be given to possible thermal stresses caused by temperature differences between the plate and the other elements (shell and heat transfer tubes).

The minimum thickness e of those portions of flat plate supported by tubes shall be determined from the following formulae:

$$e = C_1 \times d_2 \times \sqrt{\frac{P}{f \times \mu}} \quad (1)$$

where

C_1 = a constant depending on the method of support of tubesheet:

- plate insert inside shell:
 - welded from 2 sides $C_1 = 0,35$
 - welded from 1 side $C_1 = 0,45$
- plate welded to the shell:
 - welded from 2 sides $C_1 = 0,40$
 - welded from 1 side $C_1 = 0,50$

d_2 diameter of the largest circle which can be inserted in the unperforated area

$$\mu = \frac{p - d_t}{p} \quad (2)$$

The design shall be sufficient to prevent the tube pulling out of the tube sheet during test and normal operating conditions. The calculation of the tube force Q_v and Q_t is based on the strengthened areas A_v and A_t related to one tube. For the portion of the tubesheet that is fully perforated, the strengthened areas A_v and A_t are designated by the shaded part in Figure 2.

In the case of the border areas of an unperforated zone, the strength of border area may be assumed to be taken up to 50 % by the direct adjoining wall of the vessel.

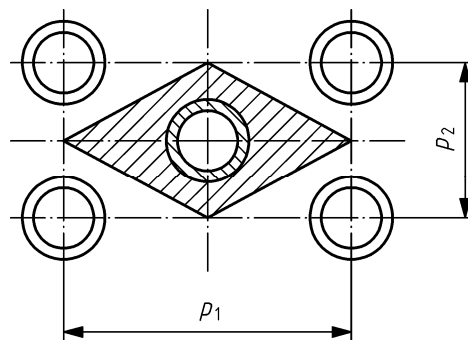


Figure 2 — Portion of tubesheet

$$Q_v = P \times A_v \quad (3)$$

$$Q_t = P \times A_t \quad (4)$$

for a triangular pattern:

$$A_v = p^2 \times \cos(30^\circ) - \pi \times \frac{d_t^2}{4} \quad (5)$$

$$A_t = p^2 \times \cos(30^\circ) - \pi \times \frac{d_i^2}{4} \quad (6)$$

- a) Where the tube is expanded inside the tubesheet the ratio of load Q and the area supporting F_w shall not exceed the value of e given by the formulae (1):

Table 5 — Permissible strength for tube expanded into tubesheet

Type of expanded joint	Maximum (Q_v/A_v ; Q_t/A_t)
hole without groove inside tubesheet	150 MPa
hole with grooves inside tubesheet	300 MPa

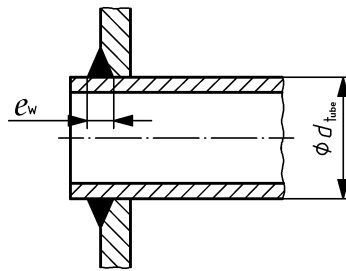
The expanded length $l_{t,x}$ shall be at least 12 mm and for the purpose of determining the effective area A_w , $l_{t,x}$ shall not exceed 40 mm.

The effective area A_w is given by:

$$A_w = \max \left[0,1 \times d_{\text{tube}} \times l_{t,x}; (d_{\text{tube}} - d_i) \times l_{t,x} \right] \quad (7)$$

- b) Where the tube is welded into the tubesheet (see Figure 3), the welds shall be sized to transmit the load Q and the weld size e_w is given by:

$$e_w \geq \frac{0,4 \times \max. (P_v \times A_v; P_{\text{tube}} \times A_t)}{d_{\text{tube}} \times f_{\text{tube}}} \quad (8)$$



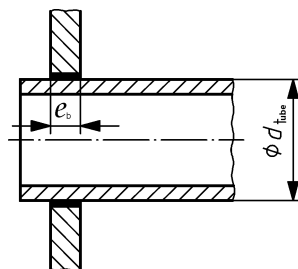
Key

e_w welding joint size of tube in the tube sheet
 d_{tube} nominal outside diameter of tube

Figure 3 — Weld size of welded tube

- c) where the tube is brazed into the tubesheet (see Figure 4), the brazed joint shall be sized to transmit the load Q and the size e_b is given by:

$$e_b \geq \frac{0,5 \times \max. (P_v \times A_v; P_{\text{tube}} \times A_t)}{d_{\text{tube}} \times f_{\text{tube}}} \quad (9)$$



Key

e_b thickness
 d_{tube} nominal outside diameter of tube

Figure 4 — Size of brazed joint