SLOVENSKI STANDARD
SIST-TP CEN/TR 13445-101:2015

01-julij-2015

Neogrevane tlačne posode - Primer uporabe

Unfired pressure vessels - Example of application

Unbefeuerte Druckbehälter - Teil 101: Anwendungsbeispiel

Récipients sous pression non soumis à la flamme - Partie 101 : Exemple d'application

Ta slovenski standard je istoveten z: **CEN/TR 13445-101:2015**

ICS:

23.020.30	Tlačne posode, plinske jeklenke	Pressure vessels, gas cylinders

SIST-TP CEN/TR 13445-101:2015 **en**

TECHNICAL REPORT

RAPPORT TECHNIQUE

TECHNISCHER BERICHT

CEN/TR 13445-101

April 2015

ICS 23.020.30

English Version

Unfired pressure vessels - Example of application

Récipients sous pression non soumis à la flamme - Partie 101 : Exemple d'application

Unbefeuerte Druckbehälter - Teil 101: Anwendungsbeispiel

This Technical Report was approved by CEN on 10 February 2015. It has been drawn up by the Technical Committee CEN/TC 54.

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Ref. No. CEN/TR 13445-101:2015 E

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Foreword

This document (CEN/TR 13445-101:2015) has been prepared by Technical Committee CEN/TC 54 “Unfired pressure vessels”, the secretariat of which is held by BSI.

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1 Scope

This Technical Report presents an application of EN 13445 through an example of design and fabrication of an unfired pressure vessel. Every step is described as far as possible:

— Material choice;

— Design and calculation;

— Fabrication;

— Inspection and testing;

using the following part of EN 13445:

— EN 13445-1:2009;

— EN 13445-2:2009;

— EN 13445-3:2009;

— EN 13445-4:2009;

— EN 13445-5:2009 .

As applicable, some choices for design or fabrication are made according to “the state of art” practice.

Some parts of EN 13445 are reproduced in order to show which requirements are relevant to the design and fabrication of the target vessel.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. 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+A2:2006, *Approval testing of welders — Fusion welding — Part 1: Steels*

EN 473:2008, *Non-destructive testing — Qualification and certification of NDT personnel — General principles*

EN 764-5:2002, *Pressure Equipment — Part 5: Compliance and Inspection Documentation of Materials*

EN 1092-1:2007, *Flanges and their joints — Circular flanges for pipes, valves, fittings and accessories, PN designated*

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 1515-3:2005, *Flanges and their joints — Bolting — Part 3: Classification of bolt materials for steel flanges, class designated*

EN 1515-4:2009, *Flanges and their joints — Bolting — Part 4: Selection of bolting for equipment subject to the Pressure Equipment Directive 97/23/EC*

EN 1759-1:2004, *Flanges and their joint — Circular flanges for pipes, valves, fittings and accessories, Class designated — Part 1: Steel flanges, NPS 1/2 to 24*

EN 10025-2:2004, *Hot rolled products of structural steels — Part 2: Technical delivery conditions for non-alloy structural steels*

EN 10028-1:2007, *Flat products made of steels for pressure purposes — Part 1: General requirements*

EN 10028-2:2003, *Flat products made of steels for pressure purposes — Part 2: Non-alloy and alloy steels with specified elevated temperature properties*.

EN 10029:2010, *Hot-rolled steel plates 3 mm thick or above —Tolerances on dimensions and shape*

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

EN 10216-3:2002, *Seamless steel tubes for pressure purposes — Technical delivery conditions — Part 3: Alloy fine grain steel tubes*

EN 10222-4:1998, *Steel forgings for pressure purposes — Part 4: Weldable fine grain steels with high proof strength*.

EN 10269:1999+A1:2006, *Steels and nickel alloys for fasteners with specified elevated and/or low temperature properties*

EN 12560-4:2001, *Flanges and their joints — Gaskets for Class-designated flantes — Part 4: Corrugated, flat or grooved metallic and filled metallic gaskets for use with steel flanges*

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

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)*

3 Presentation of example

3.1 General

The target vessel consists of several components:

— a cylindrical shell,

— two elliptical ends,

— a welding neck flange,

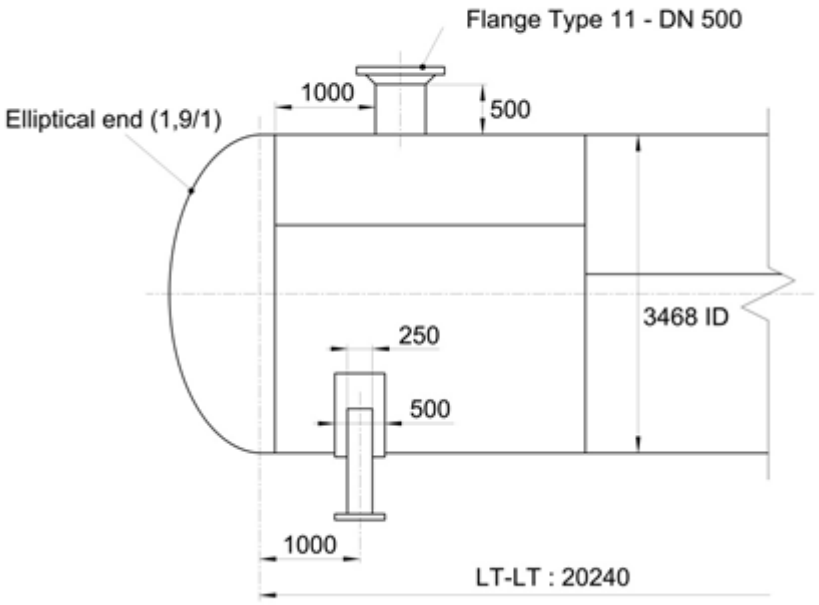
— a nozzle,

— two saddle supports arranged symmetrically

3.2 Pressure vessel data

The data specified for the present example are the following:

— Vessel data:



Key

D_i = 3 468 mm

L = 20 000 mm (cylindrical shell length)

Figure 1 — Pressure vessel data

Material: steel

— Service data:

Normal service conditions:

— Internal pressure: 44 bar

— Maximum temperature: 50 °C

— Minimum metal temperature: -20 °C

— Liquid group 1, density: 0,54

— Pressure loading predominantly of non-cyclic nature

There are not exceptional service conditions.

PED 97/23/CE regulation applies.

The calculation of all components is performed by formulas (DBF: Design By Formula). According to the specified operating conditions, the pressure vessel is neither subjected to fatigue nor to creep.

It is supposed that there is only a risk of atmospheric corrosion during operation of the vessel. Thus, a corrosion allowance of 3 mm is added.

3.3 PED 97/23/CE Category

The maximum allowable pressure *PS* used as a first approach is 44 bar and the fluid is a liquid of group 1.

The category which applied for the target vessel is category II as defined in Clause 3 paragraph 1.1(b) of the PED which indicates the use of Table 3 of Annex II of PED to set the category.

3.4 Extracts from EN 13445-1 to EN 13445-5:2009 and from others standards

The extracts from the EN 13445 Standard clauses which are the most relevant at each step of the example are reproduced in black frames. When necessary, the adequate requirements in these extracts are framed in red.

Other extracts of standards referenced in EN 13445 are reproduced, also in black frames, and the standard from which they are extracted is mentioned. When necessary, the adequate requirements in these extracts are framed in red.

4 Materials

4.1 General

EN 13445-2:2009 gives the minimum requirements to be fulfilled for steel entering the manufacturing of pressure vessel. The informative Annex E of this standard references European materials usable for pressure vessel manufacturing. The corresponding steel grades come from harmonized European standards. The Grouping according to CEN ISO/TR 15608:2000 is also given for each grade.

The minimum requirements concern elongation, impact test and chemical composition. These requirements for steel should ensure toughness and good behaviour of materials during manufacturing (weldability and forming).

Table 4.1-1 of this report summarizes some properties of the materials which have been chosen for fabrication of the target vessel. This table shows how the requirements of EN 13445-2:2009 are fulfilled.

4.2 Minimum requirements for materials

4.2.1 General

The following clauses of EN 13445-2:2009 shall be fulfilled:

4.2.2 Minimum elongation

The requirements for minimum elongation are fulfilled by the chosen materials, see Table 4.1-1.

4.1.4 Steels shall have a specified minimum elongation after fracture measured on a gauge length

$$L_o = 5{,}65\sqrt{S_o} \qquad (4.1\text{-}1)$$

where

S_o is the original cross sectional area within the gauge length.

The minimum elongation after fracture in any direction shall be ≥ 14 %;

However, lower elongation values may also be applied (e.g. for fasteners or castings), provided that appropriate measures are taken to compensate for these lower values and the specific requirements are verifiable.

Figure 2 — Abstract from EN 13445-2:2009

4.2.3 Impact test for ferritic steel

The requirements for impact test are fulfilled by the chosen materials, see Table 4.1-1. Requirements of Annex B of EN 13445-2:2009 shall also apply; see 4.5 of this report.

> **4.1.6** Steels shall have a specified minimum impact energy measured on a Charpy-V-notch impact test specimen (EN 10045-1:1990) as follows:
>
> — ≥ 27 J for ferritic and 1,5 % to 5 % Ni alloy steels;
>
> — ≥ 40 J for steels of material group 8, 9.3 and 10
>
> at a test temperature in accordance with Annex B, but not higher than 20 °C. The other requirements of Annex B shall also apply.

Figure 3 — Abstract from EN 13445-2:2009

4.2.4 Chemical composition of selected grade

The requirements for chemical composition are fulfilled by the chosen materials, see Table 4.1-1, except for the bolting grade *42CrMo4* (1.7225), but this product is not intended for welding or forming as stated in 4.1.7 of EN 13445-2:2009. Indeed, following EN 10269:1999, EN 10269:1999+A1:2006, the specified chemical composition for this grade of bolting is:

— %C: 0,38 to 0,45;

— % P: 0,035 max;

— % S: 0,035 max.

4.1.7 The chemical composition of steels intended for welding or forming shall not exceed the values in Table 4.1-1. Line 2 of the table refers to vessels or parts designed using Design by Analysis – Direct Route according to Annex B of EN 13445-3:2009. Exceptions shall be technically justified.

Table 4.1-1 — Maximum carbon-, phosphorus- and sulphur contents for steels intended for welding or forming

Steel group (according to Table A-1)	Maximum content of cast analysis		
	% C	% P	% S
Steels (1 to 6 and 9)	0,23[a]	0,035	0,025
Steels (1 to 6 and 9) when DBA – Direct Route is used [c]	0,20	0,025	0,015
Ferritic stainless steels (7.1)	0,08	0,040	0,015
Martensitic stainless steels (7.2)	0,06	0,040	0,015
Austenitic stainless steels (8.1)	0,08	0,045	0,015[b]
Austenitic stainless steels (8.2)	0,10	0,035	0,015
Austenitic-ferritic stainless steels (10)	0,030	0,035	0,015

[a] Maximum content of product analysis 0,25 %.
[b] For products to be machined a controlled sulphur content of 0,015 % to 0,030 % is permitted by agreement provided the resistance to corrosion is satisfied for the intended purpose.
[c] In addition the ratio on thickness reduction (ratio of initial thickness of slab/ingot to the thickness of the final plate) shall be equal or greater than:
- 4 for NL2 steels and steels of material group 9;
- 3 for other materials.

Figure 4 — Abstract from EN 13445-2:2009

4.3 Mechanical properties of the chosen materials

The selected grades and their appropriate properties are summarized in Table 4.1-1.

All the mechanical properties presented in this table are minimum values from transversal specimen and are specified in the relevant technical specification. Transversal specimens are defined as specimen taken in a direction perpendicular to the direction of principal deformation of the product (e.g. for flat products the transversal direction is perpendicular to the rolling direction).

Since the minimum yield strength and tensile strength values are specified in the material technical specification as a function of the product thickness the values to be used for the design of each specific component are not known at first. They can be set only once the design calculations performed according to the relevant EN 13445-3:2009 rules have shown that the thickness assumed for calculation is acceptable. In some cases an iteration on the thickness and the corresponding mechanical properties is necessary to get the correct values (see Clause 5 of this report).

For determination of the material characteristics above 20 °C, the interpolation rules which apply are those defined in 4.2.2 of EN 13445-2:2009:

4.2.2 Design temperature above 20 °C

4.2.2.1 A material shall only be used for pressure parts within the range of temperatures for which the material properties required by EN 13445-3:2009 are defined in the technical specification for the material. If the technical delivery condition does not contain the specific material values required for the allowable temperature TS the values required in EN 13445-3:2009 for the design shall be determined by linear interpolation between the two adjacent values. Values shall not be rounded up.

For other than austenitic and austenitic-ferritic stainless steels, the specified value of R_{eH} ($R_{p0,2}$) at room temperature (RT) may be used for temperatures less than or equal to 50 °C. Interpolation between 50 °C and 100 °C shall be performed with the values of RT and 100 °C and using 20 °C as the starting point for interpolation. Above 100 °C linear interpolation shall be performed between the tabulated values given in the table.

Figure 5 — Abstract from EN 13445-2:2009

Table 4.1-1

Component	**Standard(s)**	**Grades (Steel Number)**	**Specified minimum yield strength at room temperature Rp0,2 (MPa)**	**Specified minimum yield strength at 50 °C Rp0,2/t (MPa)**	**Specified minimum tensile strength at room temperature Rm (MPa)**	**Specified minimum elongation after fracture A%** (EN 13445-2:2009, 4.1.4)	**Impact energy *KCV*** (EN 13445-2:2009, 4.1.6)	**Heat treatment condition**	**Classification according to CR** ISO 15608:2000
Cylindrical shell	EN 10028-2:2003	P295GH (1.0481)	285	276	460	21	27 J @ -20 °C	+N	1.2
Elliptical end	EN 10028-2:2003	P295GH (1.0481)	285	276	460	21	27 J @ -20 °C	+N	1.2
Nozzle	EN 10216-3:2002	P275NL2 (1.1104)	275	EN 13445-2:2009, 4.2.2	390	22	47 J @ -20 °C	+N	1.1
Flange	EN 1759-1:2004 EN 10222-4:1998	P285QH (1.0478)	255	EN 13445-2:2009, 4.2.2	390	23	27 J @ -20 °C	+QT	1.2
Bolting	EN 10269:1999	42CrMo4 (1.7225)	730	720	860	14	40 J @ -40 °C	+QT	3.2
Reinforcing plate	EN 10028-2:2003	P295GH (1.0481)	285	276	460	21	27 J @ -20 °C	+N	1.2
Saddle support	EN 10025-2: 2004	S275J2 (1.0145)	275	No value	430	21	27 J @ -20 °C	+N	1.1

4.4 Type of material certificate

4.4.1 PED requirements

Annex I paragraph 4.3 of the PED states that for the Category II main pressure-bearing parts of pressure equipment, the material certificate shall be a certificate of specific control. In accordance with EN 10204:2004, this certificate shall be, as a minimum, of type 3.1.

4.4.2 Type of certificate for pressure vessel components

Material certificate may be selected in accordance with EN 764-5:2002 which specifies the type of material certificate to obtain from the material producer following the considered part (main pressure-bearing parts, pressure parts other than main pressure-bearing parts or non pressure-bearing parts).

> **4.1.2** Materials for pressure-bearing parts compliant with the requirements of this European Standard shall be accompanied by inspection documents in accordance with EN 10204:2004. Certificate of specific control (3.1 or 3.2 certificate) shall be required for all steels if Design by Analysis – Direct Route according to Annex B of EN 13445-3:2009 is used.
>
> NOTE The type of inspection document should be in accordance with EN 764-5:2002 and include a declaration of compliance to the material specification.

Figure 6 — Abstract from EN 764-5:2002

Figure 1 of EN 764-5:2002 below is useful to determine the type of certificate:

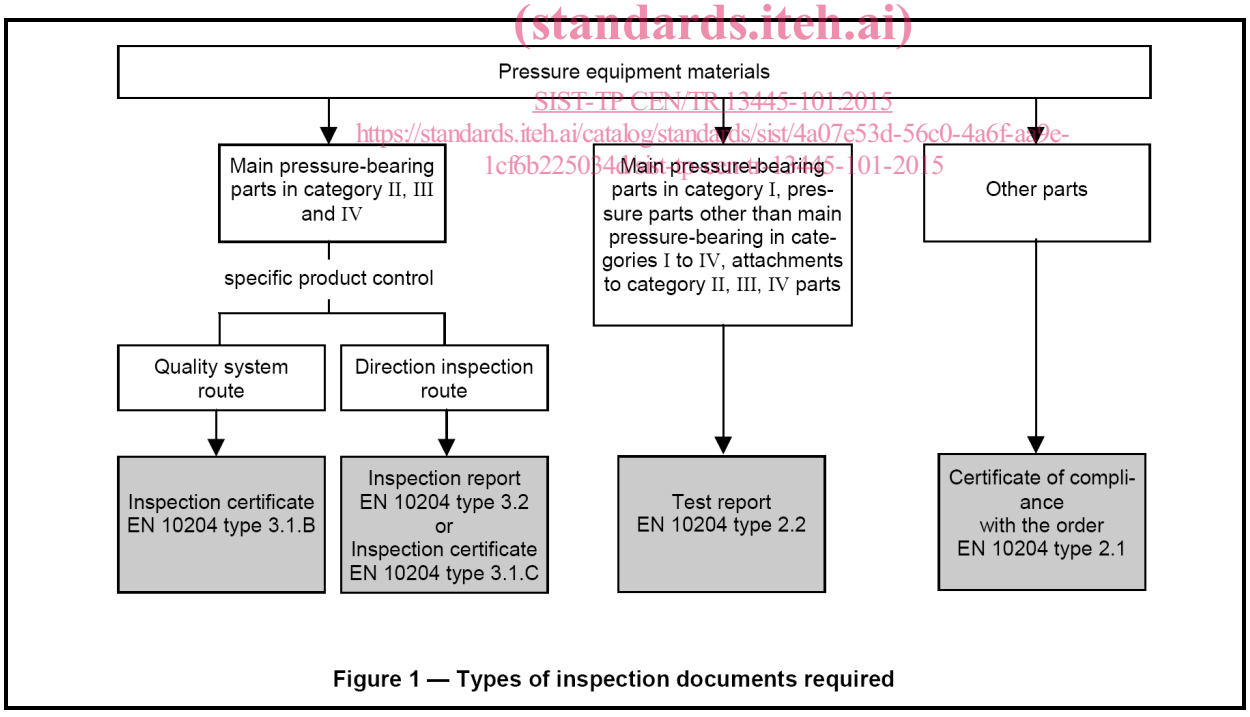


Figure 1 — Types of inspection documents required

NOTE Edition of EN 10204:1991 is used for application of EN 764-5:2002 and edition of EN 10204:2004 is used for application of EN 13445-2:2009. Type 3.1B of EN 10204:1991 is replaced by 3.1 of EN 10204:2004. Types 3.1A and 3.1C is replaced by 3.2 of EN 10204:2004.

Figure 7 — Abstract from EN 764-5:2002

Table 4.4.2-1 below summarizes the type of material certificate according to EN 764-5:2002:

Table 4.4.2-1

Components	Type of components	Minimum type of certificate according to EN 10204:2004
Cylindrical shell	Main pressure-bearing parts	3.1 (3.1B as defined in EN 10204:1991)
Elliptical end	Main pressure-bearing parts	3.1 (3.1B as defined in EN 10204:1991)
Nozzle	Pressure part other than main pressure-bearing parts	2.2
Flange	Pressure part other than main pressure-bearing parts	2.2
Bolting	Pressure part other than main pressure-bearing parts	2.2
Reinforcing plate (for saddle support)	Non-pressure-bearing parts	2.2
Saddle support	Non-pressure-bearing parts	2.2

NOTE The type of certificate for the saddle support reinforcing plate could be of type 3.1 because the material grade is chosen for being the same as for the cylindrical shell. To manufacture the reinforcing plate, the vessel manufacturer could use a plate from the lot used to manufacture the cylindrical shell.

4.5 Prevention of brittle fracture

4.5.1 General

Annex B of EN 13445-2:2009 proposes three methods to prevent the risk of brittle fracture. The two first methods are applied to the target vessel. The last one, Method 3, is not used because it would need to perform a complete fracture mechanics analysis.

4.5.2 Method 1 (B.2.2 of EN 13445-2:2009)

4.5.2.1 General

As stated in B.2.2.1 of EN 13445-2:2009, Method 1 permits to select steels taken from harmonized European standards. The assumptions are that $T_R = T_{27J} = T_{KV}$ and the required toughness values shall be obtained after manufacturing.

4.5.2.2 Determination of test temperature T_{KV}

The Tables in B.2.2 give reference temperature T_R as a function of grade, reference thickness (depending on whether PWHT is performed or not). Corresponding table for each product shall apply for each type of products. Results corresponding to PWHT shall be taken into account (see 6.5.2 of this report):

— Plates and strip