BS EN 13445-10:2015

BSI Standards Publication

Unfired pressure vessels

Part 10: Additional requirements for pressure vessels of nickel and nickel alloys

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National foreword

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The UK participation in its preparation was entrusted to Technical Committee PVE/1, Pressure Vessels.

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

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Récipients sous pression non soumis à la flamme - Partie 10 : Exigences complémentaires pour les récipients sous pression en nickel et alliages de nickel

Unbefeuerte Druckbehälter - Teil 10: Zusätzliche Anforderungen an Druckbehälter aus Nickel und Nickellegierungen

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European foreword

This document (EN 13445-10:2015) has been prepared by Technical Committee CEN/TC 54 “Unfired pressure vessels”, the secretariat of which is held by BSI.

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of an identical text or by endorsement, at the latest by June 2016, and conflicting national standards shall be withdrawn at the latest by June 2016.

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For relationship with EU Directive(s), see informative Annex ZA, which is an integral part of this document.

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1 Scope

This Part 10 of this European Standard specifies requirements for unfired pressure vessels and their parts made of nickel and nickel alloys (see 3.1) in addition to the general requirements for unfired pressure vessels under EN 13445-1:2014, EN 13445-2:2014, EN 13445-3:2014, EN 13445-4:2014 and EN 13445-5:2014.

NOTE Cast materials are not included in this version. Details regarding cast materials will be subject to an amendment to or a revision of this European Standard.

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 764-5:2014, *Pressure equipment — Part 5: Inspection documentation of metallic materials and compliance with the material specification*

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

EN 13445-1:2014, *Unfired pressure vessels — Part 1: General*

EN 13445-2:2014, *Unfired pressure vessels — Part 2: Materials*

EN 13445-3:2014, *Unfired pressure vessels — Part 3: Design*

EN 13445-4:2014, *Unfired pressure vessels — Part 4: Fabrication*

EN 13445-5:2014, *Unfired pressure vessels — Part 5: Inspection and testing*

EN ISO 9606-4:1999, *Approval testing of welders — Fusion welding — Part 4: Nickel and nickel alloys (ISO 9606-4:1999)*

EN ISO 14732, *Welding personnel — Qualification testing of welding operators and weld setters for mechanized and automatic welding of metallic materials (ISO 14732:2013)*

CEN ISO/TR 15608:2013, *Welding — Guidelines for a metallic materials grouping system (ISO/TR 15608:2013)*

3 Terms, definitions, symbols and units

For the purposes of this document, the terms, definitions, symbols and units given in EN 13445-1:2014, EN 13445-2:2014, EN 13445-3:2014, EN 13445-4:2014 and EN 13445-5:2014 and the following apply.

3.1
nickel alloys
those alloys which contain a minimum of 30 % nickel and contain more nickel than iron

4 General requirements

The general requirements of EN 13445-1:2014 shall apply.

5 Materials

5.1 General

The general requirements of EN 13445-2:2014 shall apply with the following additions/exclusions in 5.2 – 5.5.

NOTE There are presently no European Standards specifically for nickel or nickel alloys for pressure purposes. This part 10 of EN 13445 is therefore limited to European Approval of Materials (EAM) or the use of Particular Materials Appraisal (PMA). These may be used when they meet the requirements in 5.1 to 5.5 of this part 10 of EN 13445.

5.2 Material grouping system

Annex A of EN 13445-2:2014 is not applicable to pressure vessels of nickel and nickel alloys and is replaced by Annex A of this part 10 of EN 13445.

The grouping system for nickel and its alloys is shown in Table A.1 of this part 10 of EN 13445.

Only material having a minimum elongation after fracture greater than 25 % shall be used for construction of pressure vessels.

Materials which have mechanical properties enhanced by precipitation hardening are excluded from this part of EN 13445, unless they are to be used for bolting applications.

5.3 Material documentation

Materials for pressure bearing parts compliant with the requirements of this European Standard shall be accompanied by inspection documentation in accordance with EN 10204:2004.

The type of inspection document shall be in accordance with EN 764-5:2014 and include a declaration of compliance to the material specification.

5.4 Prevention of brittle fracture

There are no general requirements for nickel and nickel alloys at temperatures down to −196 °C. However, the specific requirements of individual EAMs/PMAs shall be taken into account.

5.5 Lamellar tearing

Failure by lamellar tearing is not normally applicable to nickel and nickel alloys.

6 Design

6.1 General

All the design methods included in EN 13445-3:2014 shall apply, with the following amendments, given in 6.2 – 6.5.

Physical properties of nickel and nickel alloys are given in Annex B.

6.2 Time-independent nominal design stress

The design stress for nickel and nickel alloy materials entering service without any subsequent heat treatment shall be evaluated in accordance with Table 6.2-1.

If any material is subjected to subsequent heat treatment (for example, in the manufacture of dished ends) representative material test coupons shall be heat treated with the components and subjected to the same mechanical tests as used to certify the material at the manufacturer's works. The nominal design stress shall then be calculated in accordance with Table 6.2-1. If this design stress is lower than

that used in the original calculations, the design of that component and any other related components shall be repeated using the nominal design stress derived from the properties of the heat treated material.

For designs using nickel and nickel alloys attention is drawn to the effect of heat treatment on the materials, and care should therefore be taken when determining the thickness of the materials that will receive subsequent heat treatments during manufacture.

Table 6.2–1 — Maximum allowed values of the nominal design stress for nickel and nickel alloy materials for pressure parts

Minimum specified elongation after fracture (A) (%)	**Design stress for normal operating load cases (MPa)**	**Design stress for testing and exceptional load cases (MPa)**
$A > 35$	$f_d = \min\left(\frac{R_{p1,0/T}}{1,2}; \frac{R_{m/T}}{3}\right)$	$f_{test} = \left(\frac{R_{p1,0/T_{test}}}{1,05}\right)$
$30 < A \leq 35$	$f_d = \left(\frac{R_{p1,0/T}}{1,5}\right)$	$f_{test} = \left(\frac{R_{p1,0/T_{test}}}{1,05}\right)$
$A \leq 30$	$f_d = \min\left(\frac{R_{p0,2/T}}{1,5}; \frac{R_{m/20}}{2,4}\right)$	$f_{test} = \left(\frac{R_{p0,2/T_{test}}}{1,05}\right)$

6.3 Creep design

Where sufficient material data is available, creep design may be applied to nickel and nickel alloys using the formulae and approach in Clause 19 of EN 13445-3:2014.

6.4 Shells under external pressure

The requirements in Clause 8 of EN 13445-3:2014 shall apply with the following modifications:

In EN 13445-3:2014, 8.4, for shells made in nickel or nickel alloys, the nominal elastic limit shall be given by:

$$\sigma_e = \frac{R_{p0,2/T}}{1,25}$$

and for stiffeners in the same material by:

$$\sigma_{es} = \frac{R_{p0,2/T,s}}{1,25}$$

6.5 Fatigue design

For loads up to 500 equivalent full pressure cycles no fatigue analysis is required. Above 500 cycles the requirements of Clause 17 of EN 13445-3:2014 shall apply with the following modifications:

The application of Clause 17 of EN 13445-3:2014 (see 17.4.4 of EN 13445-3:2014) to nickel and nickel alloys shall be limited to temperatures not exceeding 450 °C.

The correction factor to account for the influence of temperature on fatigue resistance (see 17.6.2.2 of EN 13445-3: 2014) is:

For T* ≥ 100 °C:

$$C_t = 1{,}0164 - 1{,}4 \times 10^{-4} T^* - 2{,}4 \times 10^{-7} (T^*)^2$$

The requirements of Clause 18 of EN 13445-3:2014 shall apply with the following modifications:

The application of Clause 18 of EN 13445-3:2014 (see 18.4.3 of EN 13445-3:2014) to nickel and nickel alloys shall be limited to temperatures not exceeding 450 °C.

The correction factor to account for the influence of temperature on fatigue resistance, f_{T^*} (see 18.10.6.2 of EN 13445-3:2014) is given by:

$$f_{T^*} = 1{,}0164 - 1{,}4 \times 10^{-4} T^* - 2{,}4 \times 10^{-7} (T^*)^2$$

7 Manufacture

7.1 General

EN 13445-4:2014 shall apply, with the following amendments, given in 7.2 – 7.14.

NOTE 1 Not all welding processes are suitable for all nickel alloys.

NOTE 2 Welding consumables may be selected from EN ISO 14172:2015 and EN ISO 18274:2010.

7.2 Qualification of welding procedure specifications (WPQR)

The requirements of 7.3 of EN 13445-4:2014 shall apply with the following modifications:

a) Annex B of EN 13445-2:2014 shall not apply.

b) Impact testing is not normally required for pressure vessels of nickel and nickel alloys at temperatures down to −196 °C except for alloys in group 47.

c) For nickel alloys in group 47 when the design temperature is below −105 °C, impact testing shall be carried out at −196 °C on the weld metal and heat affected zone of the WPQR.

7.3 Qualification of welders and welding operators

The requirements in 7.4 of EN 13445-4:2014 shall apply with the following modifications:

Replace reference to EN 287-1 with EN ISO 9606-4:1999.

7.4 Joint preparation

In addition to the requirements of 7.6 in EN 13445-4:2014 the following shall apply for pressure vessels of nickel and its alloys:

a) the edges of plates that have been thermally cut shall be dressed back by machining or grinding for a minimum distance of 1,5 mm to remove damaged material;

NOTE Nickel and nickel alloys are not subject to hardening by thermal cutting.

b) for plates less than 20 mm thickness cold shearing is permissible, provided that the cut edges are dressed back mechanically by not less than 1,5 mm to permit a satisfactory examination of the edges prior to welding;

c) plates less than 10 mm thick, which are cold sheared, need not be dressed prior to welding.

d) coated parts shall be free of coating products for a minimum distance of 50 mm from the edge of the weld preparation, in order that the coating does not interfere with the welding process, and to safeguard the coating itself;

e) after welding, the welded areas shall be cleaned, and any residues, slag, spatter, etc. shall be removed.

7.5 Preheat

Preheating is not normally necessary for nickel and nickel alloys.

When the metal temperature is less than 5 °C, heat should be applied to a maximum temperature of 75 °C to remove condensation.

7.6 Production test, reference criteria

The requirements in 8.2 of EN 13445-4:2014 shall apply with the following modifications:

The requirements for impact testing of production control test plates are not applicable to nickel and its alloys; 8.2 a) of EN 13445-4:2014 is not applicable.

Production control test plates for nickel and nickel alloys vessels shall be carried out in accordance with 8.2 d) of EN 13445-4:2014.

7.7 Extent of testing

The requirements of 8.3 of EN 13445-4:2014 shall apply with the following modifications:

Table 8.3-1 shall be replaced by Table 7.7-1 below:

Table 7.7–1 — Testing of production test plates

Material Group	**Thickness of test plate *e*[a] mm**	**Test specimens**[b]
All	*e ≤ 12*	1 FB, 1 RB, 1 TT, 1 Ma, 1 Mi
	12 < *e*	2 SB[c], 1 TT, 1Ma, 1Mi

a Thinner plate thickness.

b The symbols for Table 7.7–1 are given in Table 8.3–2 of EN 13445–4:2014.

c SB = side bends

7.8 Performance of test and acceptance criteria

The requirements in 8.4.1, 8.4.2, 8.4.3, 8.4.5, 8.4.6, 8.4.7, 8.4.9 and 8.4.10 of EN 13445-4:2014 shall apply.

7.9 Forming procedures

7.9.1 Cold forming

Cold forming of nickel and nickel alloy materials shall be carried out at temperatures below 300 °C. It is preferable that nickel and nickel alloys are cold formed whenever possible.

7.9.2 Hot forming

The requirements in 9.3.2 of EN 13445-4:2014 are not applicable for pressure vessels made of nickel and nickel alloys.

Hot forming of nickel and nickel alloy materials shall be carried out in accordance with the manufacturer's recommendations such that grain boundary liquation and overheating is avoided.

The material shall be heated uniformly without flame impingement.

NOTE Most fuels may be used provided that detrimental impurities, such as sulphur, are kept at low levels.

Nickel and nickel alloys shall be cleaned before heating.

Embrittlement by low melting point metals such as sulphur, phosphorus, lead, zinc and their alloys can occur from marking materials, die lubricants, pickling liquids, and any waste products encountered during the manufacturing process. Care should be taken to avoid contact with any foreign substances which may be taken into the surface of the material at elevated temperatures

7.10 Heat treatment after forming

7.10.1 General

Heat treatment after hot or cold forming shall be carried out in accordance with the requirements of 7.10.2, 7.10.3 or 7.10.4.

7.10.2 Heat treatment of flat products after cold forming

The requirements of 9.4.2 of EN 13445-4:2014 are not applicable for pressure vessels made of nickel and nickel alloys.

Heat treatment of flat products after cold forming shall be carried out in accordance with the material manufacturer's recommendations, when required by Table 7.10-1.

Table 7.10–1 — Heat treatment of flat products after cold forming

Material groups	**Ratio of deformation F**	**Heat treatment**
41	F ≤ 10 %	No
41	*F* > 10 %	Yes, annealing
42–48	F ≤ 5 %	No
42–48	*F* > 5 %	Yes, annealing

7.10.3 Heat treatment of tubular products after cold forming

The requirements of 9.4.3 of EN 13445-4:2014 are not applicable for pressure vessels made of nickel and nickel alloys.

Heat treatment of tubular products after cold forming shall be carried out in accordance with the material manufacturer's recommendations, when required by Table 7.10-2.

Table 7.10–2 — Heat treatment of tubular products after cold forming

Material groups	**Bending radius for the tube R**	**Heat treatment**
41	$R \geq 1{,}3\ D_e$	No
41	$R < 1{,}3\ D_e$	Yes, annealing
42–48	$R \geq 2{,}5\ D_e$	No
42–48	$R < 2{,}5\ D_e$	Yes, annealing
NOTE It should be noted that the degree of deformation at a bending radius of 1,3 D_e exceeds 5 %.		

7.10.4 Heat treatment after hot forming

The requirements of 9.4.5 and 9.4.6 of EN 13445-4:2014 are not applicable to pressure vessels made of nickel and nickel alloys.

Heat treatment of nickel and nickel alloys is required after hot forming; this shall be carried out in accordance with the material manufacturer's recommendations.

7.11 Sampling of formed products

7.11.1 Cold formed products without heat treatment

The requirements of 9.5.1 of EN 13445-4:2014 are not applicable to pressure vessels made of nickel and nickel alloys.

If heat treatment is not required by Table 7.10-1 or Table 7.10-2 after cold forming of plates or tubes, mechanical testing is not required.

7.11.2 Hot formed or cold formed products with heat treatment

The requirements of 9.5.2 of EN 13445-4:2014 are not applicable to pressure vessels made of nickel and nickel alloys.

Compliance with material specifications shall be verified by means of one of the following:

— test coupons taken from excess length of formed part;

— alternatively separately formed test coupons heat treated together with the formed parts;

— separately formed test coupons simulated heat treated.

The following number of test coupons shall be taken from each cast of material:

a) one test coupon from a batch of up to 10 parts;

b) two test coupons from a batch of up to 25 parts;

c) three test coupons from a batch of up to 100 parts;

d) one test coupon for every further 100 parts.

7.12 Tests

7.12.1 Base material

The requirements of 9.6.1 of EN 13445-4:2014 are not applicable to pressure vessels made of nickel and nickel alloys.

One tensile test specimen shall be taken from each test coupon required by 7.11.2. Test specimens shall be taken transverse to the rolling direction wherever possible.

7.12.2 Butt welds

The requirements of 9.6.2 of EN 13445-4:2014 are not applicable to pressure vessels made of nickel and nickel alloys.

Where multiple parts are formed after being welded together, one all weld metal tensile test specimen shall be taken from the weld metal, for each welding procedure specification (WPS), each cast of filler metal used and for each formed product.

7.13 Post weld heat treatment (PWHT)

The requirements of Clause 10 of EN 13445-4:2014 are not applicable to pressure vessels made of nickel and nickel alloys.

The following shall apply:

a) post weld heat treatment is not normally necessary for welded nickel or nickel alloy pressure vessels. When in service cracking is possible, e.g. vessels in contact with caustic soda, fluorosilicates or some mercury salts, a stress relieving procedure should be considered;

b) if post weld heat treatment is required then the annealing heat treatment shall be performed in accordance with a written procedure which describes the parameters required;

c) annealing shall be carried out in accordance with the material manufacturer's recommendations;

d) precautions shall be taken to avoid contamination and embrittlement (as described in 7.9.2); after annealing the surfaces shall be descaled.

7.14 Repairs

The requirements of Clause 11 of EN 13445-4:2014 shall apply, except that thermal gouging shall not be used.

Any NDT applied after the removal of accidental arc strikes on Group 46 only shall be carried out by PT.

8 Inspection and testing

8.1 General

The requirements of EN 13445-5:2014 shall apply with the following modifications:

8.2 Non-destructive testing of welded joints

8.2.1 General

The non-destructive testing of welded joints shall depend upon the testing group in Table 8.2-1.

All testing groups shall require 100 % visual inspection. Testing group 4 is not permitted for pressure vessels made of nickel and nickel alloys.

Table 8.2–1 — Testing groups for pressure vessels of nickel and nickel alloys

Requirements	**Testing group**		
	1	**2**	**3**
Permitted materials [e]	All	All (except Group 43)	All except Group 43
Extent of NDT for governing welded joints [c f]	100 %	100 % - 10 % [b]	10 %
NDT of other welds	Defined for each type of weld in Table 6.6.2–1 of EN 13445–5:2014		
Joint coefficient	1	1	0,85
Maximum thickness for which specific materials are permitted	Unlimited [d]	16 mm	40 mm
Welding process	Unlimited [d]	Fully mechanical welding only [a]	Unlimited [d]
Service temperature range	−196 °C to 450 °C	−196 °C to 450 °C	−196 °C to 450 °C

[a] Fully mechanized and/or automatic welding process (see EN ISO 14732).

[b] First figure: initially, second figure: after satisfactory experience. For definition of "satisfactory experience" see 8.2.2.

[c] Testing details are given in Table 8.3–1 of this Part 10.

[d] "Unlimited" means no additional restriction due to testing. The limitations mentioned in this table are limitations imposed by testing. Other limitations given in the various clauses of the standard (such as design, or material limitations, etc.) shall be taken into account.

[e] See Clause 5 of this Part 10 for permitted materials.

[f] The percentage relates to the percentage of welds of each individual vessel.

8.2.2 Demonstration of satisfactory experience for testing group 2

The requirements of 6.6.1.2.4 of EN 13445-5:2014 shall apply, with the following modification:

For material groups 41 – 48 (excluding 43) satisfactory experience is defined as the successful production of 25 consecutive pressure vessels or 50 consecutive metres of welded joints. For material group 43 satisfactory experience is defined as the successful production of 50 consecutive pressure vessels or 100 consecutive metres of welded joints.

8.3 Determination of extent of non-destructive testing

The requirements of 6.6.2 of EN 13445-5:2014 shall apply, with the following modification:

Table 6.6.2-1 of EN 13445-5:2014 shall be replaced by Table 8.3-1 of this Part 10.

6.6.2.2 shall be replaced by:

Table 8.3-1 is designed for the following types of welded joints:

a) multilayer welds welded as single or double sided welds;

b) performed by Metal Inert Gas (MIG 131) or Tungsten Inert Gas (TIG 141)

Special problems arising from elements such as those described below shall be considered especially for longitudinal joints.

c) other process, e.g. plasma 15, electron beam (EB) 76, friction welding 42;

d) single run weld, single run from one side or both sides;

e) automatic welding processes.

Table 8.3–1 — Extent of non-destructive testing

Type of weld [a]			**Testing** [b]	**Extent for testing group**		
				1	**2**	**3**
Full penetration butt weld	1	Longitudinal joints	RT or UT MT or PT	100 % 10 %	(100–10) % 10 %	25 % 10 %
	2a	Circumferential joints on a shell	RT or UT MT or PT	100 % 10 %	(100–10) % 10 %	10 % 10 %
	2b	Circumferential joints on a shell with backing strip [c]	RT or UT MT or PT	NA NA	NA NA	NA NA
	2c	Circumferential joggle joint [c]	RT or UT MT or PT	NA NA	NA NA	NA NA
	3a	Circumferential joints on a nozzle $d_i > 150$ mm or $e > 16$ mm	RT or UT MT or PT	100 % 10 %	(100–10) % 10 %	10 % 10 %
	3b	Circumferential joints on a nozzle $d_i > 150$ mm or $e > 16$ mm with backing strip [c]	RT or UT MT or PT	NA NA	NA NA	NA NA
	4	Circumferential joints on a nozzle $d_i \leq 150$ mm and $e \leq 16$ mm	RT or UT MT or PT	0 100 %	0 (100–10) %	0 10 %
	5	All welds in spheres, heads and hemispherical heads to shells	RT or UT MT or PT	100 % 10 %	(100–10) % 10 %	25 % 10 %
	6	Assembly of a conical shell with a cylindrical shell without a knuckle (large end of the cone) [d, e]	RT or UT MT or PT	100 % 100 %	(100–10) % 100 %	10 % 100 %
	7	Assembly of a conical shell with a cylindrical shell without a knuckle (small end of the cone)	RT or UT MT or PT	100 % 10 %	(100–10) % 100 %	10 % 10 %
Circumferential lapped joints [c]	8a	General application shell to head	RT or UT MT or PT	NA NA	NA NA	NA NA
	8b	Bellows to shell $e \leq 8$ mm	MT or PT RT or UT	100 % 0 %	100 % 0 %	25 % 0 %

Type of weld [a]			**Testing** [b]	**Extent for testing group**		
				1	**2**	**3**
Assembly of a flat head or a tubesheet, with a cylindrical shell Assembly of a flange or a collar with a shell	9	With full penetration	RT or UT MT or PT	100 % 10 %	(100–10) % 10 %	25 % 10 %
	10	With partial penetration if a > 16 mm	RT or UT MT or PT	NA NA	NA NA	NA NA
	11	With partial penetration if $a \leq 16$ mm	RT or UT MT or PT	NA NA	NA NA	0 10 %
Assembly of a flange or a collar with a nozzle	12	With full penetration	RT or UT MT or PT	100 % 10 %	(100–10) % 10 %	25 % 10 %
	13	With partial penetration	RT or UT MT or PT	NA NA	NA NA	NA NA
	14	With full or partial penetration $d_i \leq 150$ mm and $e \leq 16$ mm	RT or UT MT or PT	0 10 %	0 10 %	0 10 %
Nozzle or branch [e]	15	With full penetration d_i > 150 mm or e > 16 mm	RT or UT MT or PT	100 % 10 %	(100–25) % 10 %	25 % 10 %
	16	With full penetration $d_i \leq 150$ mm and $e \leq 16$ mm.	RT or UT MT or PT	0 100 %	0 (100–10) %	0 100 %
	17	with partial penetration for any d_i a > 16 mm	RT or UT MT or PT	100 % 10 %	(100–25) % 10 %	25 % 10 %
	18	with partial penetration d_i > 150 mm $a \leq 16$ mm	RT or UT MT or PT	NA NA	NA NA	0 10 %
	19	With partial penetration $d_i \leq 150$ mm	RT or UT MT or PT	0 100 %	0 (100–10) %	0 100 %
Tube ends into tubesheet	20		MT or PT	100 %	100 %	25 %
Permanent attachments [f]	21	With full penetration or partial penetration	RT or UT MT or PT	25 % 100 %	10 % 100 %	10 % 100 %
Pressure retaining areas after removal of	22		MT or PT	100 %	100 %	100 %

Type of weld [a]			**Testing** [b]	**Extent for testing group**		
				1	**2**	**3**
temporary attachments						
Cladding by welding [g]	23		MT or PT	100 %	100 %	100 %
Repairs	24		RT or UT MT or PT	100 %	100 %	100 %

a Annex A of EN 13445–3:2014 gives design limitations on welds.

b RT = Radiographic testing, UT = Ultrasonic testing, MT = Magnetic particle testing, PT = Penetrant testing.

c For limitations of application see EN 13445–3:2014, 5.7.4.2.

d Unless the design is such that the thickness at the weld exceeds 1,4 ej (See 7.6.6 of EN 13445–3: 2014). In which case, use NDT of line 2a.

e For connections with a knuckle, case 2a applies.

f No RT or UT for weld throat thickness ≤ 16 mm.

g Volumetric testing if risks of cracks due to parent material or heat treatment.

8.4 Selection of non destructive testing methods for surface imperfections

The requirements of 6.6.3.4 of EN 13445-5:2014 shall apply, with the following modification: Testing shall be carried out by penetrant testing (PT) only.

8.5 Standard hydrostatic test

For a vessel designed according to testing group 1, 2 or 3 the test pressure shall be not less than that determined by 10.2.3.3 of EN 13445-5:2014.

10.2.3.3.2 is not applicable.

Annex A
(normative)

Table A.1 — Grouping system for nickel alloys from CEN ISO/TR 15608:2013

Group	Type of nickel and nickel alloys
41	Pure nickel
42	Nickel-copper alloys (Ni-Cu) Ni ≥ 45 %, Cu ≥ 10 %
43	Nickel-chromium alloys (Ni-Cr-Fe-Mo) Ni ≥ 40 %
44	Nickel-molybdenum alloys (Ni-Mo) Ni ≥ 45 %, Mo ≤ 32 %
45	Nickel-iron-chromium alloys (Ni-Fe-Cr) Ni ≥ 30 %
46	Nickel-chromium-cobalt alloys (Ni-Cr-Co) Ni ≥ 45 %, Co ≥ 10 %
47	Nickel-iron-chromium-copper alloys (Ni-Fe-Cr-Cu) Ni ≥ 45 %
48	Nickel-iron-cobalt alloys (Ni-Fe-Co-Cr-Mo-Cu) 31 % ≤ Ni ≤ 45 % and Fe ≥ 20 %

Table A.2 — Materials listed in harmonized standards

Material group	Material number	Material name	Product form	Standard
43	2.4952	NiCr20TiAl	Bars and rod	EN 10269
43	2.4669	NiCr15Fe7TiAl	Bars and rod	EN 10269
43	2.4668	NiCr19Fe19Nb5Mo3	Bars and rod	EN 10269
45	1.4558	X2NiCrAlTi32–10	Seamless tubes	EN 10216–5
45	1.4959	X8NiCrAlTi32–21	Flat products	EN 10028–7
45	1.4959	X8NiCrAlTi32–21	Seamless tubes	EN 10216–5
46	2.4654	NiCr20Co13Mo4Ti3Al	Bars and rod	EN 10269

Table A.3 — Materials covered by EAM as of March 2013

CEN ISO/TR 15608 **group no.**	**EN and ISO materials designation**	**Product form**	**EAM Reference**
41	–** –** NW2201** Ni99,0-LC**	Hot and cold rolled plates, sheets and strips	0879–1:2001/05
		Forgings	0879–2:2001/05
		Bars	0879–3:2001/05
		Seamless tubes	0879–4:2001/05
43	2.4602* NiCr21Mo14W* NW6022** NiCr21Mo13Fe4W3**	Flat products	0526–16:2004/07
		Bars and rods	0526–16–1:2006/03
		Forgings	0526–16–2:2006/03
	2.4819* NiCr16Mo15W* NW0276** NiMo16Cr15Fe6W4**	Flat products	0526–18:2004–7
		Bars and rods	0526–18–1:2004–7
		Forgings	0526–18–2:2004–7
		Seamless tubes	0526–18–3:2004–7
	2.4605* NiCr23Mo16Al* –** –**	Flat products	0526–20:2004–07
		Bars and rods	0526–20–1:2004–07
		Forgings	0526–20–2:2004–07
	2.4610* NiMo16Cr16Ti* NW6455** NiCr16Mo16Ti**	Flat products	0526–28:2004–07
		Bars and rods	0526–28–1:2004–07
		Forgings	0526–28–2:2004–07
		Seamless tubes	0526–28–3:2004–07
	2.4675* NiCr23Mo16Cu* –** –**	Flat products	0526–30:2006/03
		Bars and rods	0526–30–1:2006/03
	2.4856* NiCr22Mo9Nb* NW6625 NiCr22Mo9Nb**	Flat products	0526–40:2006/03
		Forgings	0526–40–2:2006/03
		Seamless tubes	0526–40–3:2006/03
	2.4816* NiCr15Fe* NW6600** NiCr15Fe8**	Flat products	0526–43–1:2004/05
		Bars and rods	0526–43–2:2004/05
		Forgings	0526–43–3:2004/05
		Seamless tubes	0526–43–4:2004/05
44	2.4617* NiMo28* NW0665** NiMo28**	Flat products	0526–22:2004/07
		Bars and rods	0526–22–1:2004/07
		Forgings	0526–22–2:2004/07
	–* NiMo30Cr* –** –**	Flat products	0526–24:2004/07
		Bars and rods	0526–24–1:2004/07
		Forgings	0526–24–2:2004/07
	2.4600* NiMo29Cr* –**	Flat products	0526–26:2004/07

* EN designation; ** ISO designation

Annex B
(informative)

Designations of some nickel alloys

Table B.1 — Designations of some nickel alloys

Material group	EN no.	EN name	ISO no.	ISO name	BS name	DIN	W no.	AFNOR	UNS no.	Names [a]
41			NC 2100	C-Ni99, -HC		GNi99,2	2.4066	N-100M	N02100	CZ100
41			NW2200	Ni99,0	NA11	Ni99.2	2.4066		N02200	Nickel 200
41			NW2201	Ni99,0-LC	NA12	LC-Ni99	2.4068		N02201	Nickel 201
42			NC 4030	C-NiCu30Si3	NA2	GNiCu30Si3	2.4367	NU-30SiM	N24030	M30H, cast Monel H [b]
42			NC 4130	C-NiCu30Nb2Si2					N24130	M30C, cast Monel E [b]
42			NC 4135	C-NiCu30	NA1	GNiCu30Nb	2.4365	NU-30M	N24135	M35–1, cast Monel [b]
42			NW4400	NiCu30	NA13	NiCu30Fe	2.4360	NU30	N04400	Monel 400 [b], Nicorros [c]
42			NW5500	NiCu30Al3Ti	NA18	NiCu30Al	2.4375	NU30AT	N05500	Monel K-500 [b], Nicorros Al [c]
43			NC 0002	C-NiMo17Cr16Fe6W4		GNiMo17Cr	2.4686		N30002	CW12MW, cast alloy C
43			NC 6022	C-NiCr21Mo14Fe4W3					N26022	CX-2MW, cast alloy C22
43	2.4815	G-NiCr15	NC 6040	C-NiCr15Fe		GNiCr15Fe	2.4816	NC 16Fe11M	N06040	CY40, cast alloy 600
43			NC 6455	C-NiCr16Mo16		GNiMo16Cr16Ti	2.4610	NC 16D16M	N26455	CW2M, cast alloy C4
43			NC 6625	C-NiCr22Mo9Nb4		GNiCr22Mo9Nb	2.4856	NC 22D9Nb4M	N26625	CW6MC, cast alloy 625
43			NC 6985	C-NiCr22Fe20Mo7Cu2		GNiCr22Mo7Cu	2.4619		N06985	Cast alloy G-3 [d]
43			NC 8826	C-NiFe30Cr20Mo3CuNb		GNiCr21Mo	2.4858	NFe30C20DUM	N08826	CU5MCuC, cast alloy 825
43						GNiCr23Mo6	2.4607		N26059	CX2M, cast alloy 59
43	2.4879	G-NiCr28W				GNiCr28W	2.4879			
43			NC 0107	C-NiCr18Mo18		GNiMo16Cr15W	2.4886		N30107	CW6MZ, cast alloy C

Material group	EN no.	EN name	ISO no.	ISO name	BS name	DIN	W no.	AFNOR	UNS no.	Names [a]
43	2.4665	NiCr22Fe18Mo	NW6002	NiCr21Fe18Mo9		NiCr22Fe18Mo	2.4665	NC 22FeD	N06002	Hastelloy X [d], Nicrofer 4722Co [c]
43			NW6007	NiCr22Fe20Mo6Cu2Nb		NiCr22Mo6Cu	2.4618		N06007	Hastelloy G [d], Nicrofer 4520hMo [c], Illium F [e]
43			NW6022	NiCr21Mo13Fe4W3		NiCr21Mo14W	2.4602		N06022	Hastelloy C-22 [d], Nicrofer 5621hMoW [c]
43			NW6455	NiCr16Mo16Ti		NiMo16Cr16Ti	2.4610		N06455	Hastelloy C-4 [d], Nicrofer 6616hMo [c]
43	2.4816	NiCr15Fe	NW6600	NiCr15Fe8	NA14	NiCr15Fe	2.4816	NC 15Fe	N06600	Inconel 600 [b], Nicrofer 7216 [c]
43	2.4851	NiCr23Fe	NW6601	NiCr23Fe15Al		NiCr23Fe	2.4851	NiC23FeA	N06601	Inconel 601 [b], Nicrofer 6023 [c]
43			NW6602	NiCr15Fe8-LC		LC-NiCr15Fe	2.4817		N06600	Inconel 600L [b], Nicrofer 7216LC [c]
43	2.4951	NiCr20Ti	NW6621	NiCr20Ti		NiCr20Ti	2.4951	NC 20T	N06075	Nimonic 75 [b] Nicrofer 7520 [c]
43	2.4856	NiCr22Mo9Nb	NW6625	NiCr22Mo9Nb	NA21	NiCr22Mo9Nb	2.4856	NC 22DNb	N06625	Inconel 625 [b] Nicrofer 6020hMo [c]
43	2.4642	NiCr29Fe	NW6690	NiCr29Fe9		NiCr29Fe	2.4642	NC 30Fe	N06690	Inconel 690 [b], Nicrofer 6030 [c]
43			NW6985	NiCr22Fe20Mo7Cu2		NiCr22Mo7Cu	2.4619		N06985	hastelloy G3 [d] Nicrofer 4823hMo [c]
43	2.4952	NiCr20TiAl	NW7080	NiCr20Ti2Al	NA20	NiCr20TiAl	2.4952	NC 20A	N07080	Nimonic 80A [b], Nicrofer 7520Ti [c]
43	2.4668	NiCr19Fe19Nb5Mo3	NW7718	NiCr19Fe19Nb5Mo3		NiCr19NbMo	2.4668	NC 19FeNb	N07718	Inconel 718 [b], Nicrofer 5219Nb [c], Udimet 630 [b]

Material group	EN no.	EN name	ISO no.	ISO name	BS name	DIN	W no.	AFNOR	UNS no.	Names [a]
43	2.4669	NiCr15Fe7TiAl	NW7750	NiCr15Fe7Ti2Al		NiCr15Fe7TiAl	2.4669	NC 15FeTNbA	N07750	Inconel X-750 [b] Nicrofer 7016TiNb
43			NW8825	NiFe30Cr21Mo3	NA18	NiCr21Mo	2.4858	NC 21FeDU	N08825	Incoloy 825 [b], Nicrofer 4221 [c]
43			NW6686	NiCr21Mo16W4		NiCr21Mo16W	2.4606		N06686	Inconel 686 [b], Nicrofer 6032 [c]
43	2.4633	NiCr25FeAlY				NiCr25FeAlY	2.4633		N06025	Alloy 602CA, Nicro6025HT
43						NiCr30Fe15Mo	2.4603		N06030	Hastelloy G30 [d]
43	2.4889	NiCr28FeSiCe				NiCr28FeSiCe	2.4889		N06045	Alloy 45 TM, Nicrofer 45TM [c]
43						NiCr23Mo16Al	2.4605		N06059	Alloy 59, Nicrofer 5923hMo[c]
43			NW6200	NiCr23Mo16Cu2		NiCr23Mo16Cu	2.4675		N06200	Hastelloy C2000 [d]
43	2.4608	NiCr26MoW	NW6333	NiCr26Fe20Mo3W3		NiCr26MoW	2.4608		N06333	RA-333 [f], Nicrofer 4626 MoW [c]
43						NiCr33Mo8	2.4643			Hastelloy G-35 [d]
43			NW0276	NiMo16Cr15Fe6W4		NiMo16Cr15W	2.4819	NC 17D	N10267	Hastelloy C276 [d], Nicrofer 5716hMoW [c]
44			NC 0007	C- NiMo31		GNiMo28	2.4685	ND30M	N30007	N7M cast alloy B2
44			NC 0012	C-NiMo30Fe5	ANC15	GNiMo30	2.4882		N30012	N12MV cast alloy B
44			NW0001	NiMo30Fe5		NiMo30	2.4810		N10001	Hastelloy B [d]
44	2.4617	NiMo28	NW665	NiMo28		NiMo28	2.4617		N10665	Hastelloy B2 [d], Nimofer 6928 [c]
44	2.4600	NiMo29Cr				NiMo29Cr	2.4600		N10629	Alloy B4, Nimofer 6629 [c]
44						NiMo30Cr	2.4695		N10675	Hastelloy B3 [d]
45	1.4876	X10NiCrAlTi32–20	NW8800	FeNi32Cr21AlTi	NA15	X10NiCrAlTi32 20	1.4876		N08800	Incoloy 800 [b] Nicrofer 3220 [c]
45			NW8801	FeNi32Cr21Ti					N08801	Incoloy 801 [b]

Material group	EN no.	EN name	ISO no.	ISO name	BS name	DIN	W no.	AFNOR	UNS no.	Names [a]
45	1.4958	X5NiCrAlTi31–20	NW8810	FeNi32Cr21AlTi-HC	NA15(H)	X5 NiCrAlTi31 20	1.4958		N08810	Incoloy 800H [b], Nicrofer 3220H [c]
45			NW8811	FeNi32Cr21AlTi-HT		X8 NiCrAlTi32 21	1.4959	Z8NC 33–21	N08811	Incoloy 800HT [b] Nicrofer 3220HP [c]
46	2.4663	NiCr23Co12Mo	NW6617	NiC22Co12Mo9		NiCr23Co12Mo	2.4663		N06617	Inconel 617 [b], Nicrofer 5520Co [c]
46	2.4654	NiCr20Co13Mo4Ti3Al	NW7001	NiCr20Co13Mo4Ti3Al		NiCr19Co14Mo4Ti	2.4654	NC 20K14	N07001	Waspalloy [f]
46	2.4632	NiCr20Co18Ti	NW7090	NiCr20Co18Ti3		NiCr20Co18Ti	2.4632	NCK20TA	N07090	Nimonic 90 [b]
46	2.4650	NiCo20Cr20MoTi	NW7263	NiCo20Cr20Mo5Ti2Al		NiCo20Cr20MoTi	2.4650		N07263	Nimonic C-263 [b], Nicrofer 5020CoTi [c]
46	2.4878	NiCr25Co20TiMo								
47						NiCr20Fe18Mo			N06950	Hastelloy G50 [d]
47			NW6985	NiCr22Fe20MoCu2		NiCr22Mo7Cu	2.4619		N06985	Hastelloy G-3 [d], Nicrofer 4023hMo [c]

[a] Trade names or trademarks of products given in the final column of this table are examples of products available commercially. This information is given for the convenience of users of this European Standard and does not constitute an endorsement by CEN/TC 54 of these products.

[b] Monel, Inconel, Nimonic, Incoloy and Udimet are trade names of products supplied by Special Metals. This information is given for the convenience of users of this European Standard and does not constitute an endorsement by CEN/TC 54 of the product named. Equivalent products may be used if they can be shown to lead to the same results.

[c] Nicorros, Nicrofer and 253SLX are trade names of products supplied by VDM (Outokumpu). This information is given for the convenience of users of this European Standard and does not constitute an endorsement by CEN/TC 54 of the product named. Equivalent products may be used if they can be shown to lead to the same results.

[d] Hastelloy is the trade name of products supplied by Haynes International. This information is given for the convenience of users of this European Standard and does not constitute an endorsement by CEN/TC 54 of the product named. Equivalent products may be used if they can be shown to lead to the same results.

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Annex ZA
(informative)

Relationship between this European Standard and the Essential Requirements of EU Directive 97/23/EC

This European Standard has been prepared under a mandate given to CEN by the European Commission to provide a means of conforming to Essential Requirements of the New Approach Directive 97/23/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 97/23/EC

Clause(s)/subclause(s) of this part 10 of EN 13445	Essential Requirements (ERs) of Pressure Equipment Directive 97/23/EC	Qualifying remarks/Notes
Clause 5	2.2.3 (b), 5th indent	Provision and consideration of appropriate material properties
5.3	4.3	Material documentation
5.4	4.1 (a)	Prevention of brittle fracture
Clause 6	2.2	Design for adequate strength
6.1	2.2.3 (a)	Calculation method — Design by Formula (DBF)
6.2	7	Equivalent overall level of safety
7.2, 7.6, 7.7, 7.8	3.1.2	Operating procedure to carry out permanent joints
7.3	3.1.2	Qualified personnel to carry out permanent joints
7.4	3.1.1	Preparation of component parts
7.9	3.1.1	Forming
7.10, 7.11, 7.12, 7.13	3.1.4	Heat treatment
8.2, 8.3, 8.4	3.2.1	Internal and surface defect
8.5	3.2.2	Proof test

Bibliography

[1] EN 10028-7:2007, *Flat products made of steels for pressure purposes — Part 7: Stainless steels*

[2] EN 10216-5:2013, *Seamless steel tubes for pressure purposes — Technical delivery conditions — Part 5: Stainless steel tubes*

[3] EN 10269:2013, *Steels and nickel alloys for fasteners with specified elevated and/or low temperature properties*

[4] EN ISO 14172:2015, *Welding consumables — Covered electrodes for manual metal arc welding of nickel and nickel alloys — Classification (ISO 14172:2015)*

[5] EN ISO 18274:2010, *Welding consumables — Solid wire electrodes, solid strip electrodes, solid wires and solid rods for fusion welding of nickel and nickel alloys — Classification (ISO 18274:2010)*

[6] EN ISO 16826:2014, *Non-destructive testing — Ultrasonic testing — Examination for discontinuities perpendicular to the surface (ISO 16826:2012)*

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