BS EN 764-4:2014

BSI Standards Publication

Pressure equipment

Part 4: Establishment of technical delivery conditions for metallic materials

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National foreword

This British Standard is the UK implementation of EN 764-4:2014. It supersedes BS EN 764-4:2002 which is withdrawn.

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.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Foreword

This document (EN 764-4:2014) 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of an identical text or by endorsement, at the latest by June 2015 and conflicting national standards shall be withdrawn at the latest by June 2015.

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 supersedes EN 764-4:2002.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive.

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

Regarding the most significant technical changes that have been implemented in this new edition of EN 764-4, see Annex G.

EN 764, *Pressure equipment*, consists of the following parts:

— *Part 1: Terminology - Pressure, temperature, volume, nominal size*;

— *Part 2: Quantities, symbols and units*;

— *Part 3: Definition of parties involved*;

— *Part 4: Establishment of technical delivery conditions for metallic materials* (the present document);

— *Part 5: Inspection documentation of metallic materials and compliance with the material specification*;

— *Part 6: Structure and content of operating instructions* [Technical Report CEN/TR 764-6];

— *Part 7: Safety systems for unfired pressure equipment;*

— *Part 8: Proof test* [Technical Specification prCEN/TS 764-8, currently under development].

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, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

1 Scope

This European Standard specifies the requirements, under the regime of the EU Directive 97/23/EC on Pressure Equipment (PED), for the establishment of the technical delivery conditions in the form of:

— harmonized European Standards for material;

— European Approval for Materials (EAM);

— Particular Material Appraisal (PMA)

for metallic materials for pressure equipment in all product forms. Welding consumables are not covered by this standard.

This European Standard was developed predominantly on the basis of steel, nickel and nickel-based materials. However, application to other materials is not restricted but should consider specific aspects relevant to the material concerned.

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

EN 764-2:2012, *Pressure equipment - Part 2: Quantities, symbols and units*

EN 10028 (all parts), *Flat products made of steels for pressure purposes*

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

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

EN 10213, *Steel castings for pressure purposes*

EN 10216 (all parts), *Seamless steel tubes for pressure purposes - Technical delivery conditions*

EN 10217 (all parts), *Welded steel tubes for pressure purposes - Technical delivery conditions*

EN 10222 (all parts), *Steel forgings for pressure purposes*

EN 10272, *Stainless steel bars for pressure purposes*

EN 10273, *Hot rolled weldable steel bars for pressure purposes with specified elevated temperature properties*

EN 10314, *Method for the derivation of minimum values of proof strength of steel at elevated temperatures*

EN ISO 148-1, *Metallic materials - Charpy pendulum impact test - Part 1: Test method (ISO 148-1)*

EN ISO 204, *Metallic materials - Uniaxial creep testing in tension - Method of test (ISO 204)*

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

EN ISO 10052, *Acoustics - Field measurements of airborne and impact sound insulation and of service equipment sound - Survey method (ISO 10052)*

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

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

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

3 Terms and definitions, symbols and abbreviations

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1.1
European Approval for Materials
EAM
technical document defining the characteristics of materials intended for repeated use in the manufacture of pressure equipment which are not covered by any harmonized standard

Note 1 to entry: See Article 11 of the EU Directive 97/23/EC on Pressure Equipment (PED) and see also the PED Guideline 7/26.

3.2 Symbols and abbreviations

For the purposes of this standard, the symbols and abbreviations of EN 764-1:2004, EN 764-2:2012 and the following in Table 1 and Table 2 apply.

Table 1 — Symbols and units

Symbols	Characteristic	Units
b	width	mm
e	thickness	mm
h	max. permissible reinforcement of weld	mm
T	temperature	°C
T_D	design temperature	°C
A	elongation after fracture	%
C	constant	—
D	diameter	mm
E	modulus of elasticity	MPa
G	shear modulus	MPa
HV	Vickers hardness	—
KV_2	Charpy V-notch impact energy	J
L_o	original gauge length	mm
P	pressure	bar
P_{LM}	parameter according to Larson-Miller	—
R_e	yield strength	MPa
R_{eH}	upper yield strength	MPa
R_{eL}	lower yield strength	MPa
R_m	tensile strength	MPa
$R_{cm/t/T}$	creep rupture strength for t hours at T °C	MPa
$R_{m/T}$	tensile strength at temperature T	MPa
$R_{p0,2/T}$	0,2 % proof strength at temperature T	MPa
$R_{p0,2}$	0,2 % proof strength	MPa
$R_{p1,0}$	1,0 % proof strength	MPa
$R_{p1,0/T}$	1,0 % proof strength at temperature T	MPa
S_o	original cross sectional area	mm^2
t	time	h
α	linear expansion coefficient	K^{-1}
ε	strain	%
V	Poisson's ratio	—

Table 2 — Abbreviations

Abbreviation	Description
EAM	European Approval for Materials
EC	European Commission
PED	Pressure Equipment Directive
PMA	Particular Material Appraisal
OJEU	Official Journal of the European Union

4 Types of technical delivery conditions

4.1 Harmonized European Standards for material for pressure equipment

Harmonized European material standards under the regime of the PED define the technical requirements for materials frequently used in pressure equipment in Europe. It is within the remit of the responsible technical committee for materials to check at each occasion of the revision work whether related material grades covered by an EAM are used to an extent that justifies the incorporation of the grade into the relevant harmonized European material Standard.

4.2 European Approvals for Materials for pressure equipment (EAMs)

A European approval for materials means a technical document defining the characteristics of materials intended for repeated use in the manufacture of pressure equipment, the type of which is not covered by any harmonized European material standard. According to Guiding Principles for the contents of EAM drafts, agreed by the Member States of the European Union and the European Commission, it shall i.a. describe material properties in a concise, complete and correct manner.

The ways and means undertaken to achieve an EAM and a data sheet containing at least the applicable elements is given in Annex A.

An EAM shall not be issued for:

a) a grade of material listed in a current or former national material standard that has a specification covered by a harmonized European material standard;

b) a grade of material which is previously included in a European national material standard but which is not included in the harmonized European material standard which has replaced the European national material standard (ref. PED Guideline 7/26).

NOTE 1 Reference of available EAMs is published in the Official Journal of the European Union (OJEU).

NOTE 2 Actual EAMs are also published at the following website of the European Commission: http://ec.europa.eu/enterprise/sectors/pressure-and-gas/documents/ped/materials/index_en.htm.

4.3 Particular Material Appraisals for pressure equipment (PMAs)

Particular material appraisals apply for individual cases as for example:

a) a material grade or a product form or a thickness not covered by a harmonized European material standard, harmonized under the scope of the PED, or by an EAM;

b) a product specified in a harmonized European material standard for pressure purposes or in an EAM is intended in an exceptional case for service conditions outside its specified range of application.

For pressure equipment classified in category III and IV according to the PED, the PMA/PMAs, which irrespective of category (I to IV) always shall be drawn up by the equipment manufacturer, shall be appraised and confirmed by the Notified Body in charge of the conformity assessment for the actual piece of pressure equipment.

Where relevant to the pressure equipment under consideration the requirements given in Annex B to Annex E together with EN 13445-2:2014, 4.1 and 4.2, may be used as guidance. An example for PMA is given in Annex F.

5 Content of technical delivery conditions for materials for pressure equipment

5.1 General

Technical delivery conditions for materials for pressure equipment shall describe the material with its specific properties and shall at least contain clauses for scope, normative references, requirements, testing and inspection and marking and restriction on application where necessary with a distinction between mandatory and optional requirements.

EAMs and PMAs shall take account of material processing. If appropriate, information on the allocation of the material to the relevant material group in CR ISO 15608 shall be provided with the technical material specification. PMAs shall always specify in detail the range of application.

5.2 Requirements

5.2.1 Manufacture

The method of manufacture of the material shall be specified. Details need only be specified to an extent as is necessary to ensure the specified quality.

5.2.2 Treatment condition

The following conditions shall be specified:

— type of heat treatment condition;

— surface condition of the material at the time of delivery, where necessary.

5.2.3 Chemical composition

The chemical composition limits shall be specified. Where the composition of the product may be different from the composition of the cast, limit deviations from the cast analysis shall be specified.

The specification of the chemical composition shall include the following general statement:

Elements, which can influence the essential material characteristics, not specified for the specific material shall not intentionally be added. All reasonable precautions shall be taken to prevent the addition of elements from scrap or other materials used in the manufacture, but residual elements may be present, provided the specified mechanical properties are met and the applicability is not impaired.

5.2.4 Mechanical and technological properties

The technical material specification shall specify properties in the direction and location of test pieces which shall be representative of the material characteristics.

Where the form and thickness of the products permit the verification testing of transverse test pieces, the property characteristics shall be given for the transverse (radial for pipes) direction.

In those cases, where the properties in the longitudinal direction are lower, this shall be taken into account.

The following properties shall be specified for the individual steel grades:

a) Tensile properties at room temperature:

   1) Yield or proof strength:

      For austenitic steels minimum proof strength values for 1,0 % non proportional extension ($R_{p1,0/min}$ and, where appropriate, $R_{p0,2/min}$ values additionally) shall be specified;

      For all other materials the minimum value for the upper yield strength or, for cases where no yield phenomenon occurs, the minimum proof strength for 0,2 % non proportional extension shall be specified;

   2) Tensile strength:

      For the tensile strength, a minimum value shall be specified. A maximum value shall be specified additionally where no maximum yield or proof strength value is specified;

   3) Elongation after fracture:

      The minimum percentage elongation after fracture for the proportional gauge length $A = 5,65\sqrt{S_o}$ shall be specified;

b) Charpy V-notch impact properties:

   The impact properties of the material shall be specified with regard to the Essential Safety Requirements to avoid brittle fracture; A minimum level of Charpy energy shall be specified even if the product form and size does not allow to extract Charpy specimen;

c) Elevated temperature tensile properties:

   The following tensile properties shall be specified for temperatures in accordance with Table 3:

   1) for austenitic steels intended for an application at a temperature ≥ 50 °C and in accordance with Table 3 the minimum 1,0 % proof strength at elevated temperatures. It is also proposed to specify the minimum elevated temperature tensile strength;

   2) for all other steels intended for an application at a temperature in accordance with Table 3, but not higher than the maximum design temperature rounded up to 50 K, the minimum 0,2 % proof strength at elevated temperatures.

   The specified minimum proof strength values at elevated temperatures should be derived in accordance with EN 10314 on the basis of data determined in accordance with EN ISO 6892-1 and EN ISO 6892-2;

Table 3 — Elevated temperatures for steels

Steel group	Temperature		
in accordance with CR ISO 15608:2000	**from** °C	**to a maximum of** °C	**preferably in steps of** K
Clause 2, 7.1, 7.2, Clause 3 1.1 to 1.3	100	400	50
Clause 4, 5.1, 5.2	100	500	50
5.3, 5.4, Clause 6	100	600	50
Clause 8	50	600	50
Clause 10	50	250 [a]	50
[a] 250 °C if welded, 280 °C unwelded.			

d) Creep properties:

If a material shall be used at elevated temperatures, where creep rupture is likely to occur, the creep rupture strength shall be evaluated. For creep testing steps of 10 °C are recommended;

e) Technological properties:

Where necessary, requirements for formability, e.g. specified on the basis of flattening or ring expanding tests or on the basis of tests for the deformation properties perpendicular to the surface of the product (see EN 10164) or requirements for other technological properties, important for the processing or use of the material, shall be specified.

NOTE Direction of axis of test specimen: see EN ISO 3785 [16].

5.2.5 Other material properties

Where necessary, the requirements for properties other than those covered under 5.2.2 to 5.2.4, shall also be specified together with their methods of verification.

NOTE Other material properties could be weldability, corrosion resistance, fatigue, etc.

5.2.6 Freedom from surface and internal defects

The requirements for non-destructive testing and visual inspection shall be specified.

5.2.7 Dimensions, shape, mass and related tolerances

Dimensions, shape and mass and related tolerances shall be specified where necessary, preferably by reference to an appropriate dimensional standard.

5.3 Testing and inspection

Depending on product form and type of material, the location and preparation of samples and test pieces and frequency of testing shall as a minimum be based on the analogous European Standard (EN), e.g.: EN 10028 (all parts) for flat products, EN 10216 (all parts) and EN 10217 (all parts) for tubes, EN 10213 for castings, and EN 10222 (all parts) for forgings, EN 10272 and EN 10273 for bars.

The following requirements on inspection and testing shall be specified:

a) the types of applicable inspection documents (see EN 10204);

b) the requirements to be verified (e.g. chemical composition, tensile properties);

c) the conditions applicable for specific inspection and testing namely:

   1) the composition and maximum size of the test unit (e.g. the maximum weight or number of products of the same cast, heat treatment batch); and

   2) the number of sample products per test unit;

   3) the number of samples per sample product; and

   4) the number of test pieces per sample to be taken and tested;

   5) the location and direction of the test pieces in the product;

   6) where necessary, additional conditions for sampling and conditions for the preparation of the samples and test pieces;

   7) the European Standards in which the test methods are described;

   8) the provisions for retesting;

d) any other necessary specification for testing and inspection.

5.4 Marking

The marking of the delivery units or products shall ensure traceability between these and the inspection documents.

For European standardized materials the marking shall fulfil the requirements of the relevant product standard.

For other materials the marking shall at least contain:

a) the material specification (reference, material designation);

b) the material manufacturers name or mark;

c) the stamp of the inspection representative, if applicable;

d) an identification which permits the correlation between the product or delivery unit and the relevant inspection document.

Annex A
(normative)

Procedures for the establishment of European Approvals for pressure equipment Materials (EAM)

A.1 General

An EAM may be issued for a special or novel material grade not included in a European material standard harmonized under the Pressure Equipment Directive (PED). Such a material grade shall have a specification associated with particular chemistry and/or conferring specific mechanical properties or characteristics such as corrosion resistance. These mechanical properties or characteristics shall be supplementary to those in similar harmonized standards. See also PED Guideline 7/15.

An EAM is a route to facilitate the use of safe materials in absence of harmonized standards and to encourage material technology development and innovation.

An EAM shall not be issued for:

a) a grade of material listed in a current or former national material standard that has a specification covered by a harmonized European material standard;

b) a grade of material which was previously included in a European national material standard but which was not included in the harmonized European material standard which has replaced the European national material standard.

In those cases a PMA is to be drawn up, see PED guidelines 7/21 and 9/13.

A.2 European Approvals for Materials

European Approvals for new materials are to be established in accordance with A.3.

A.3 Requirements for the establishment of an EAM

A.3.1 When an application is made for an EAM the Notified Body shall establish that:

a) the material is not covered by any other existing EAM;

b) the proposal fulfils the requirements in Clause 5;

c) the material characteristics which are of importance for the intended processing and application of the material are available and whether these are at a level which does necessitate special precautions during processing and application, e.g.:

   1) cold and hot formability;

   2) weldability;

   3) hardening and tempering behaviour;

   4) ageing behaviour;

5) fatigue strength;

6) corrosion resistance;

d) the material characteristics necessary for the proposed EAM can be consistently fulfilled.

A.3.2 For the establishment of the EAM a test programme shall be developed in co-operation between the material manufacturer(s) and the Notified Body to fulfil the requirements in A.3.1 c) and A.3.1 d). The type and extent of testing shall consider the processing and use of the product forms as well as the expected minimum properties. Annex B to Annex E may be used as guidelines to select the relevant tests to be included in the test programme.

The test program shall involve at least five casts. The test program shall specify which tests shall be confirmed by the Notified Body.

A group of material manufacturers may cooperate in such a test program.

A.4 Title scheme and structure of an EAM

A data Sheet for an EAM shall contain the applicable elements given in Table A.1 and the title scheme of that table.

NOTE Examples of existing EAMs can be found under: http://ec.europa.eu/enterprise/sectors/pressure-and-gas/documents/ped/materials/index_en.htm.

Table A.1 — Title scheme and structure of a European Approval for Materials (EAM) for pressure purposes

Logo of the Notified Body	**European Approval for Materials**	**EAM No. .....**
	Title	**Date of issue:**
1	**Material designation**	
2	**Product form**	
3	**Dimensions**	
4	**Scope (Range of application)**	
5	**References**	
6	**Requirements**	
6.1	Delivery conditions (heat treatment)	
6.2	Type of manufacture (steelmaking process) [a]	
6.3	Deoxidization [a]	
6.4	Chemical composition	
	Cast analysis	
	Product analysis [a]	
6.5	Mechanical and technological properties	
	Tensile properties (e.g. R_{eH}, $R_{p0,2}$, $R_{p1,0}$, R_m) at room temperature	
	Tensile properties at elevated temperatures [a]	
	Charpy V-notch impact energy	
	Other properties, e.g. hardness properties	

Logo of the Notified Body	**European Approval for Materials**	**EAM No. .....**
	Title	**Date of issue:**
6.6	Surface treatment condition	
6.7	Internal soundness	
	Other properties[a], (e.g. corrosion)	
7	**Verification testing and inspection**	
7.1	Types and content of inspection documents	
7.2	Frequency of tests	
7.3	Sampling and test piece preparation	
7.4	Test procedures	
	Chemical composition	
	Tensile test at room temperature	
	Tensile test at elevated temperatures [a]	
	Charpy V-notch impact test	
	Visual and dimensional examination	
	Leak tightness test [a]	
	Intercrystalline corrosion resistance [a]	
	Identification test [a]	
	Non-destructive testing [a]	
	Other tests e.g. hardness test, ring tests, bend tests	
7.5	Re-tests	
8	**Marking**	
9	**Guidelines for processing**	
9.1	Cold and hot forming	
9.2	Welding, thermal cutting	
9.3	Post weld heat treatment	
10	**Design data** [a]	
11	**Other data** [a]	
12	**EAM prepared by**	

[a] Where applicable.

Annex B
(normative)

Appraisal schedule for ferritic and martensitic steels

B.1 General

The purpose of this annex is to provide a list of properties and test procedures which may be relevant in the characterization of new ferritic and martensitic steels and the determination of material property requirements.

When assessing the material property requirements, for each specific material, the material properties to be assessed for which parameters shall be specified shall be selected in accordance with A.3.1. The following requirements are valid for rolled or forged ferritic-perlitic steels, including normalized and thermomechanically rolled fine-grain steels (the ferritic grain size, in accordance with EN ISO 643, should at least be equal to or finer than 7) and martensitic or bainitic air or liquid quenched and tempered steels and copper bearing age hardened steels.

B.2 Test procedures

B.2.1 The type of the testing depends on the processing and use of the product forms in question. Tests shall be carried out in the normal delivery conditions unless otherwise specified.

The applicable verification test standards shall be indicated.

B.2.2 In the case of a simultaneous appraisal of a number of product forms or thicknesses, the samples to be tested shall be selected, that they cover the scope proposed for appraisal and the required manufacturing procedures. Endeavours shall be made to select as low a number of test samples as possible, covering the whole size range, see Table B.1.

B.2.3 The appraisal of the product forms shall be performed with respect to the thickness for each product form as given in Table B.1.

Table B.1 — Thickness for product forms

Dimensions in millimetres

Product form	Thickness		
	I	II	III
Strip	< 4,5	4,5 to 12	> 12
Plate	< 30	30 to 70	> 70
Tube	< 30	30 to 70	> 70
Forging/rolled bar	< 150	150 to 300	> 300

B.2.4 The products to be tested shall be at the upper limit (100 %) of the requested thickness range.

B.2.5 The tests may be divided into those, which shall be conducted before the first delivery (basic testing) and those, which shall be carried out during initial deliveries (subsequent testing).

B.2.6 Testing shall generally be performed as follows:

Normally the tensile testing is performed over the full thickness for a product thickness e ≤ 30 mm. For a product thickness e > 30 mm the thickness may be reduced to ≥ 30 mm retaining one rolled surface on the rectangular test piece, with the exception, that for quenched and tempered or thermomechanically rolled plates, the specimen shall be half the product thickness.

Circular test pieces are permissible but shall only be provided for a product thickness e > 30 mm. The specimen diameter shall be at least 10 mm.

For a product thickness e > 70 mm a circular test specimen taken from mid thickness of the product shall be tested additionally.

For the impact tests the test specimens shall be taken near the surface for a product thickness e ≤ 40 mm. For a product thickness e > 40 mm the location for the specimen shall be in e/4, for e > 50 mm additionally in e/2.

B.3 Required testing

B.3.1 General

Required testing shall be conducted on at least five casts, which should cover the specified range of analysis and of the heat treatment.

A group of material manufacturers may cooperate in such a test programme.

B.3.2 Determination of the chemical composition

The cast analysis shall be given by the material manufacturer. The product analysis shall be carried out on samples to determine all elements given by the material data sheet.

B.3.3 Tensile tests

B.3.3.1 Tensile tests at room temperature shall be carried out at 23 °C ± 5 °C in accordance with EN ISO 6892-1:2009, Clause 5 of to determine the upper yield strength (or should continuous yielding occur, the 0,2 % proof strength) tensile strength, elongation after fracture (A) and reduction of area.

Samples shall be tested in the longitudinal and transverse/tangential directions. The test results will indicate the degree of directionality occurring in the properties of a product and the direction with inferior mechanical properties.

B.3.3.2 Trend curves up to 50 K above the maximum operating temperature in accordance with EN 10314 shall be determined for steels for which the minimum strength values at elevated temperature are intended to be specified.

B.3.4 Charpy V-notch impact test

Charpy V-notch impact tests shall be carried out to determine the upper (100 % shear fracture) and lower shelf (100 % cleavage fracture) by a complete transition curve.

A complete transition curve shall consist of tests carried out in accordance with EN ISO 148-1 with a 2 mm striker (KV_2) for minimum six temperatures with maximum interval of 20 K. At each temperature a minimum of 3 tests shall be performed. The shear fracture percentage shall be determined in addition. The measurement of lateral expansion is optional.

The transition temperature curves are required for both longitudinal and transverse/tangential direction. The most critical curve of any direction tested shall be used for the qualification of the material.

A statistical derivation of all results from all tested casts shall be performed for each temperature to derive a lower bound value.

B.3.5 Technological tests

As far as for the new product specific technological properties need to be characterized, bend tests, flaring tests, flanging tests, ring tensile tests, ring flattening tests, ring expansion tests or other tests appropriate to the material shall be carried out.

B.3.6 Metallographic investigation

Metallographic examination shall be carried out to assess microstructure, grain size and non-metallic inclusions.

B.3.7 Hardness testing

In the case of quenched and tempered and thermomechanically rolled materials, a hardness survey over the product thickness shall be carried out to determine homogeneity.

B.3.8 Production of a tempering chart for quenched and tempered and age-hardened steels

The tempering characteristic shall be determined for yield strength, tensile strength, yield strength to tensile strength ratio, elongation after fracture, reduction of area and impact energy at a minimum of three different tempering temperatures between 550 °C and 700 °C and for two tempering times. Tempering temperatures and holding times shall be transformed in Hollomon-Jaffe parameters and the change of the mechanical properties shall be plotted over the Hollomon-Jaffe parameter[1)]. Temperatures and times should be fixed as to reveal any tendency towards tempering embrittlement.

Tensile tests shall be conducted and impact tests with Charpy V-notch transverse specimens at three typical temperatures in the transition range including the lowest specified temperature.

B.3.9 Determination of the transformation behaviour

In order to estimate the transformation behaviour of transformable steels the transition points shall be determined by tests.

A Continuous-Cooling-Transformation diagram (CCT diagram) shall be produced for quenched and tempered or age-hardened steels (see EN ISO 10052).

B.3.10 Investigation of the effect of stress relief

B.3.10.1 General

It shall be proven that materials and weldments after stress relief procedures meet the minimum properties specified for the materials to be joined.

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1) Hollomon Parameter:

$P = T_s \times (20 + \lg t) \times 10^{-3}$

where

T_s is the holding temperature, in Kelvin;

t is the holding time, in hours.

If stress relief will be performed for the material and its weldment it is necessary to provide information about the boundary conditions for the stress relief procedure. Such boundary conditions are:

— minimum and maximum holding time;

— minimum and maximum stress relief temperature;

— heating and cooling conditions.

B.3.10.2 Procedure

To derive the stress relief boundary conditions which fulfill the Essential Safety Requirements it is recommended to express the stress relief conditions by Hollomon-Jaffe Parameter and plot the results of the mechanical testing over the Hollomon-Jaffe Parameter.

The following mechanical testing is recommended:

— Tensile tests;

— Hardness tests;

— Charpy V-impact tests

to derive the boundary conditions in terms of maximum and minimum applicable values for time and temperature.

For base metal specimens shall be taken from the direction relative to rolling direction with the lower values. The position shall comply with the requirements in relevant European harmonized material standards.

If applied for weldments, Annex E applies for the positioning of test specimen.

The level of stress relief to be achieved for materials with brittle fracture transition behaviour is a reduction to a residual stress level of not more than 30 % of the guaranteed minimum yield strength at 23 °C ± 5 °C for the actual base material. Secondary stress measurement shall be performed to verify that the specified level of stress reduction has been achieved (Annex E).

The material manufacturer shall provide an assessment of the relevant boundary conditions. Deviations from these conditions shall be re-assessed.

B.3.11 Investigation of the effect of cold forming

B.3.11.1 Determination of the cold formability

Cold forming shall be carried out by straining with two levels of deformation, preferably 2 % and 5 %. If a higher level than 5 % deformation is required this shall be carried out in place of the 5 % deformation. Charpy V-notch impact tests on transverse specimens shall be carried out to determine Charpy V-notch impact energy-temperature curves in the cold formed condition. If the level of deformation is greater than 5 % similar tests shall also be carried out after stress relief heat treatment (in a typical stress relief condition). Where the level of deformation is 5 % or greater tensile tests shall be carried out additionally in both cold formed conditions and after stress relief heat treatment.

B.3.11.2 Determination of the susceptibility to strain age embrittlement

Susceptibility to strain age embrittlement is tested by subjecting the material to 5 % or to the highest permissible degree of cold forming followed by tempering at 250 °C for 30 min. Charpy V-notch impact tests shall then be carried out at three characteristic temperatures on transverse Charpy V-notch specimens including the lowest specified temperature.

B.3.12 Investigation of the weldability of the base material

B.3.12.1 General

Annex I, *Essential Safety Requirements*, of the Directive 97/23/EC on Pressure Equipment (PED) require in its Section 3.1.2 that *'The properties of permanent joints must meet the minimum properties specified for the materials to be joined unless other relevant property values are specifically taken into account in the design calculations'*. This implies that, in the case of a welded joint, the design strength value(s) used for the dimensioning shall be met not only in the base material (BM) but also in the weldmetal (WM) and in the heat affected zones (HAZs), i.e. in all parts of the weldment. Therefore, it shall be verified that weldments produced with a free selectable welding procedure fulfill the requirements of the base metal.

The choice of appropriate welding consumables should also be taken into account.

B.3.12.2 Procedure

The welding method(s) intended to be used shall be validated by welding procedure qualification(s) in accordance with the general rules of EN ISO 15607 and according to EN ISO 15614-1. It shall be demonstrated that the required properties for the BM can also be achieved for the WM and the HAZs.

The welding test shall be performed on 5 different casts.

Test for susceptibility to cold cracking shall be performed (see B.3.12.3).

Test on the effect of stress relief treatment (PWHT) shall be performed for WM and HAZ if necessary. The method given in B.3.10 applies.

The producer shall provide an assessment in terms of limiting boundary conditions for each welding procedure that shall be approved.

The assessment shall contain information about limits of heat input, pre-heating and interpass-temperature, cooling time, applicable thickness range, weld joint preparation, cold cracking susceptibility, effect of Post Weld Heat Treatment (if necessary).

NOTE Welding recommendations are provided in EN 1011-1 and EN 1011-2.

If weld surfacing is foreseen, or shall be qualified, it shall be demonstrated that it does not adversely affect the base material properties.

B.3.12.3 Susceptibility to cold cracking

Susceptibility of the material to hydrogen-induced cracking shall be investigated in fine-grain steels and quenched and tempered steels and thermomechanically treated steels with a specified minimum yield strength > 335 MPa and a product thickness ≥ 20 mm.

One of the following methods should be applied which are specified in EN ISO 17642-1, EN ISO 17642-2 or EN ISO 17642-3:

— Implant test;

— Tekken test;

— CTS test.

B.3.13 Thermal cutting

Investigation of the influence of thermal cutting is required. The material manufacturer shall verify by appropriate thermal cutting tests with and without preheating which conditions allow for thermal cutting without crack formation. Additionally it shall also be indicated which precautions shall be taken for cold bending of thermally cut parts.

B.4 Subsequent testing

B.4.1 General

Subsequent tests shall be carried out where necessary.

B.4.2 Long term tests

B.4.2.1 Ageing tests

In the case of quenched and tempered and age-hardened steels, for elevated temperature applications, ageing tests shall be carried out (see C.3.8.2).

B.4.2.2 Creep rupture tests

Creep rupture tests shall be performed in accordance with technically verified methods.

B.4.3 Further brittle fracture investigations

Other brittle fracture investigations, e.g. mechanical fracturing tests [J-Integral, Crack Tip Opening Displacement (CTOD) or K_{IC},] shall be carried out if the results of previous testing indicates they are necessary.

B.4.4 Investigation of behaviour after welding

B.4.4.1 Welded joints

If the specified range of the chemical analysis which had been defined during the basic testing will be significantly changed, which might happen during the widening of the production program, a new investigation of welded joints in accordance with B.3.12 shall be performed.

B.4.4.2 Brittle fracture behaviour of welded joints

If necessary, further investigations shall be performed to determine the brittle fracture behaviour of welded joints.

No investigations are necessary for a material thickness < 5 mm.

B.4.4.3 Long-term tests

The tests shall be conducted in accordance with B.3.12.2 and B.4.1.1 on welded specimens (with minimum and maximum heat input, tested in as-welded condition and after boundary conditions in terms of maximum and minimum applicable values for time and temperature). In addition, the hardness (HV 10) shall be determined in the heat affected zone.

B.4.4.4 Continuous-Cooling-Transformation diagram (CCT diagram)

In the case of high or multi alloyed steels, the transformation behaviour of which are difficult to estimate (e.g. 12 % chrome-molybdenum-vanadium steel), a CCT diagram shall be compiled for welding conditions. The $T_{8/5}$ range should be 5 s to 30 s and the austenitizing temperature ≥ 1 300 °C.

B.5 Collective tests

B.5.1 General

Collective tests may be executed to satisfy the outstanding necessary investigations by a number of manufacturers in a joint programme.

B.5.2 Fatigue tests

B.5.2.1 General

Fatigue tests shall be carried out with K = 0 and, as necessary, K = − 1 (K = minimum stress/maximum stress) on steels with a minimum tensile strength > 640 MPa, whereby testing shall be carried out on three stress levels within the tensile strength range and in addition, the fatigue strength (N = 2 × 10^6 cycles) shall be determined.

Should the material be used exclusively for components for which the number of cycles in the range of their service life-time is known, it will suffice if the tests are based on this number of cycles with an adequate safety factor.

Where fatigue testing is carried out on welded test pieces or if the results of corresponding tests carried out elsewhere are available, these investigations of the parent metal may be waived.

B.5.2.2 Fatigue tests on un-notched specimens

The above mentioned tests shall be carried out on plain specimens.

B.5.2.3 Fatigue tests on notched specimens

In order to verify the notch sensitivity, testing may be by:

a) round bar specimens with radius in the notch of R = 0,25 mm; or

b) flat specimens with a cross-section of 90 mm × 10 mm and a notch of 20 mm depth, 2 mm width and a radius in the notch of R = 1 mm.

B.5.2.4 Fatigue strength of welded joints

Fatigue tests shall be carried out on steels with a minimum tensile strength ≥ 640 MPa or a minimum yield strength ≥ 460 MPa. The tests shall be carried out with K = 0 or if necessary K = − 1 for 10^3 to 10^5 cycles whereby five specimen shall be tested for each of three stress levels in the region of the tensile strength.

The welding conditions, heat treatment conditions and joint types of Table B.2 are applicable.

Table B.2 — Welding conditions, heat treatment conditions and joint types

Welding conditions $t_{8/5}$ in s	**Heat treatment conditions**	**Joint type**
7	a	1, 2, 3
7	b	2
25	a	2

Key
1 butt welded seam, ground
2 butt welded seam with reinforcement (max. permissible reinforcement h = + 0,10 b)
3 double fillet weld, not ground
a welding condition, untreated
b PWHT with max. applicable time and temperature or maximum Hollomon-Jaffe Parameter as per B.3.10.2

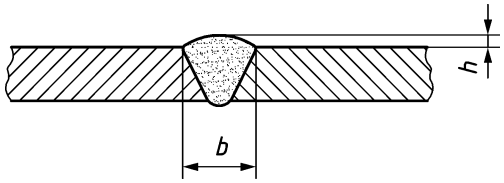

Figure B.1 — Butt welded joint

B.5.3 Corrosion behaviour

In cases where the resistance to a corrosion mechanism is important, this shall be verified.

Annex C
(normative)

Appraisal schedule for austenitic and austenitic-ferritic steels

C.1 General

The purpose of this annex is to provide a list of properties and test procedures which may be relevant in the characterization of new “materials” and the determination of material property requirements.

For each specific material, the properties to be used as basis for the assessment of the material property requirements shall be selected in accordance with A.3.1.

The following requirements are valid for austenitic and austenitic-ferritic (Duplex) rolled and forged steels including nickel and nickel-based alloys.

C.2 Test procedures

C.2.1 The type and extent of the testing is dependent upon the expected minimum requirements, in considering the processing and use of the product forms and range of dimensions in question. The tests are carried out in the normal delivery condition unless otherwise specified. Test pieces shall be taken from upper and lower range of dimensions in accordance with Table C.1. All following testing shall be performed on the base material:

— chemical analysis including accompanying and trace elements in accordance with C.3.2;

— tensile tests of the welded joint in accordance with C.3.3;

— Charpy V-notch impact tests for verifying the heat-affected zone in accordance with C.3.4;

— technological tests in accordance with C.3.5;

— metallographic investigations in accordance with C.3.6;

— testing of the resistance to corrosion in accordance with C.3.7;

— long term ageing tests in accordance with C.3.8;

— investigation of the effects of cold-forming in accordance with C.3.9.

C.2.2 In the case of the simultaneous appraisal of a number of product forms or thicknesses, the test pieces shall be selected in the way, that they cover the scope proposed for appraisal and the required manufacturing procedures. Endeavours shall be made to select a number of test pieces as low as possible, covering the whole size range (I, II or III, see Table C.1).

Normally the following ranges of thickness for each product form are applicable as given in Table C.1.

Table C.1 — Thickness for product forms

Dimensions in millimetres

Product form	Ranges of thickness		
	I	II	III
Strip	< 1,5	1,5 to 6	> 6
Plate	< 15	15 to 75	> 75
Tube	< 6	6 to 18	> 18
Forging/rolled bar	< 25	25 to 160	> 160

C.2.3 The products to be tested shall be at the upper limit (100 %) of the requested thickness range.

C.2.4 The position from which test pieces shall be removed, unless otherwise specified expressly in the following sections, shall be so arranged, that less favourable areas are also covered by the testing and a good general survey of the uniformity of the product is obtained.

C.3 Basic testing

C.3.1 General

Basic testing shall be conducted by each material manufacturer on at least five casts, which should cover the specified range of analysis and of the heat treatment.

A group of material manufacturers may cooperate in such a test program.

C.3.2 Determination of the chemical composition

The cast analysis shall be given by the material manufacturer. The product analysis shall be carried out on samples to determine all elements given by the material data sheet including accompanying and trace elements.

C.3.3 Tensile tests

C.3.3.1 Tensile tests at room temperature shall be carried out at 23 °C ± 5 °C in accordance with EN ISO 6892-1 to determine the 0,2 % and 1,0 % proof strength (for austenitic-ferritic steels only the 0,2 % proof strength), tensile strength, elongation after fracture and yield point ratio on flat test specimen and for product thicknesses > 16 mm, also on round test specimen, whereby the reduction of area is also to be determined. Should it be called for from the manufacturing process or type of material additional tests may be required in the case of plates with thickness > 15 mm on specimen in the thickness direction.

C.3.3.2 Tensile tests (round specimen) shall be carried out at elevated temperatures at intervals of 50 K to approximately 50 K above the maximum operating temperature for steels with specified minimum proof strength values at elevated temperatures. The characteristic values to be determined shall be in accordance with C.3.3.1.

C.3.4 Charpy V-notch impact tests

The Charpy V-notch impact tests shall be carried out at 20 °C on Charpy V-notch specimen in accordance with EN ISO 148-1. If necessary, impact energy temperature curves (KV_2-T) shall be produced.

C.3.5 Technological tests

According to the form of products, bend tests, flaring tests, flanging tests, ring tensile tests, ring flattening tests, ring expansion tests or other tests appropriate to the material shall be carried out as appropriate with the product form concerned.

C.3.6 Metallographic investigation

Metallographic examination shall be carried out to assess the grain size and impurities, intermetallic phases and, as necessary, the delta-ferrite content.

C.3.7 Corrosion tests

Where the resistance to intercristalline corrosion is guaranteed, this shall be checked. In the case of stabilized austenitic steel grades, the lowest possible stabilization ratio guaranteed by the material manufacturer shall be considered. Limit temperature and service life shall be determined in accordance with C.3.8.2. Where further guarantees have been provided by the material manufacturer in respect of resistance to corrosion (e.g. stress corrosion cracking), these shall be verified under the conditions of the guarantee.

C.3.8 Long term tests

C.3.8.1 Long-term tests shall be conducted on high-temperature materials on plain and notched test specimen.

C.3.8.2 Ageing tests shall be carried out over a minimum of 1 000 h, 2 000 h and 5 000 h to determine the tendency to precipitation induced embrittlement, if it is expected that such embrittlement may occur in the course of the service life. The estimation of the permissible upper operating temperature or temperature interval can be made if the occasion arise from parametric equations, e.g. in accordance with Larson-Miller:

$$P_{LM} = T \times (C + \lg t)$$

where

C is the constant (usually C = 20);

T is the temperature in K;

t is the time in h.

The testing shall be carried out on Charpy V-notched KV_2 specimens, with a 2 mm striker, in accordance with EN ISO 148-1.

C.3.9 Investigation of the effects of cold-forming

The influence of cold forming on the grain structure, strength and toughness properties, behaviour in the creep range, guaranteed resistance to corrosion and recrystallization behaviour shall be determined. Consideration shall be given to the further processing and operating temperatures required, and the maximum amount of cold forming possible without heat treatment. Testing shall be performed on cold formed specimens obtained either by stretching or by compressing.

C.3.10 Investigation of weldablility

The behaviour of the base material shall be investigated for the intended welding procedure(s), whereby the maximum permissible heat input and operating (interpass) temperature, with consideration of the wall thickness limits, shall be determined. For this purpose, steep bevel seams with max. five degree flange angle shall be welded.

C.3.11 Effects of heat treatment after further processing

Should heat treatment be provided for (e.g. solution heat treatment, stress relieving, stabilizing annealing), the above mentioned testing shall be conducted, appropriate to the proposed application. The limits for the time/temperature cycles of the heat treatment shall be determined.

C.4 Sampling

Position of standard specimen shall be in accordance with harmonized European material standards for the relevant product form.

C.5 Extent of testing

C.5.1 The tests in accordance with C.3.2, C.3.3.1, C.3.3.2, C.3.4, C.3.5, C.3.6 and C.3.7 shall be conducted for each size range (dimensional limits in accordance with C.2.3 for individual guaranteed values) of every product form.

C.5.2 The tests in accordance with C.3.8.2 and C.3.9 shall be carried out for one dimension of every product form.

C.5.3 In the case of testing in accordance with C.3.10, the identical relevant thickness of a formed product from one cast shall be provided. Normally regarded as relevant thicknesses are the thinnest and the thickest material provided for the welding. The lowest thickness shall be tested every time. For the upper limit, tests which have been carried out on thicknesses > 30 mm are sufficent for a range up to 1,5 times the thickness tested.

C.5.4 As a general rule, tests in accordance with C.3.11 are conducted on one cast only.

Annex D
(normative)

Appraisal schedule for cast steels

D.1 General

The purpose of this annex is to provide a list of properties and test procedures which may be relevant in the characterization of new “materials” and the determination of material property requirements.

For each specific material, the properties to be used as basis for the assessment of the material property requirements shall be selected in accordance with A.3.1.

The following requirements are valid for cast steels.

D.2 Test procedures

D.2.1 The type and extent of the testing is dependent upon the expected minimum requirements, in considering the processing and use of the product forms in questions. The tests are carried out in the normal delivery condition unless otherwise specified. The pieces shall be taken from upper and lower range of dimensions in accordance with Table D.1. All following testing shall be performed on the base material:

— chemical analysis including accompanying and trace elements in accordance with D.3.2;

— tensile tests in accordance with D.3.3;

— Charpy V-notch impact tests in accordance with D.3.4;

— metallographic investigations in accordance with D.3.5;

— hardness testing in accordance with D.3.6;

— investigation of tempering characteristics in accordance with D.3.7;

— determination of transformation behaviour in accordance with D.3.8;

— testing of the resistance to corrosion in accordance with D.3.9;

— long term ageing tests in accordance with D.3.10;

— investigation of weldability in accordance with D.3.11;

— effects of heat treatment in accordance with D.3.12;

— investigation of surface and internal imperfections in accordance with D.3.13.

D.2.2 In the case of the simultaneous assessment of a number of product forms or thicknesses, the test pieces shall be selected in the way, that they cover the scope proposed for assessment and the required manufacturing procedures. Endeavours shall be made to select a number of test pieces, covering the whole size range (I, II or III, see Table D.1).

The following range of wall thickness for each product form is to be applied as given in Table D.1.

Table D.1 — Wall thickness

Dimensions in millimetres

Ranges of wall thickness		
I	II	III
< 25	25 to 160	> 160

D.2.3 Where a casting contains more than one thickness range each of these ranges shall be subjected to separate testing.

D.2.4 The positions from which test pieces shall be taken, unless otherwise specified in the following sections, shall be so arranged, that critical areas are covered by the testing and a good general survey of the uniformity of the product is obtained.

D.2.5 Samples shall be taken for each casting technique.

D.3 Basic testing

D.3.1 General

Basic testing shall be conducted by each material manufacturer on at least five heats, which should cover the specified range of analysis and of the heat treatment.

D.3.2 Determination of the chemical composition

The cast analysis shall be given by the material manufacturer. The product analysis shall be carried out on samples to determine all fundamental elements and consider the segregation behaviour.

D.3.3 Tensile tests

D.3.3.1 Tensile tests at room temperature shall be carried out at 23 °C ± 5 °C in accordance with EN ISO 6892-1 out on round test specimens to determine the 0,2 % or 1,0 % proof strength, tensile strength, elongation after fracture and reduction of area.

D.3.3.2 Tensile tests (round specimen) shall be carried out at elevated temperatures at intervals of 50 K to approximately about 50 K above the maximum operating temperature for steels with specified minimum proof strength values at elevated temperatures. The characteristic values to be determined shall be in accordance with D.3.3.1.

D.3.3.3 In the case of austenitic cast steel intended for low temperatures:

a) plain test specimens at the lowest operating temperature but not lower than −196 °C, in order to determine the 0,2 % and 1,0 % proof strength, tensile strength, elongation after fracture and reduction of area;

b) plain and notched test specimens with the same area S_o at the base of the notch, in order to determine the notch tensile ratio. The ratio of maximum edge stress to mean stress shall be at least 4,5. The notch tensile tests shall result in a ratio of $R_{m\ notched}/R_{m\ plain} \geq 1$.

D.3.4 Charpy V-notch impact tests

Charpy V-notch impact tests shall be carried out to determine the upper (100 % shear fracture) and lower shelf (100 % cleavage fracture) by a complete transition curve.

A complete transition curve shall consist of tests carried out in accordance with EN ISO 148-1 with a 2 mm striker (KV_2) for minimum six temperatures with maximum interval of 20 K. At each temperature a minimum of 3 tests shall be performed. The shear fracture percentage shall be determined in addition. The measurement of lateral expansion is optional.

The transition temperature curves are required for both longitudinal and transverse/tangential direction. The most critical curve of any direction tested shall be used for the qualification of the material.

A statistical derivation of all results from all tested casts shall be performed for each temperature to derive a lower bound value.

For austenitic steel casts refer to C.3.4.

D.3.5 Metallographic investigation

Metallographic examination shall be carried out to assess microstructure, grain size and impurities and, as necessary, typical internal imperfections and the delta-ferrite content. In the case of spun-type casts, macro sections shall be produced in addition.

D.3.6 Hardness testing

In the case of quenched and tempered materials, a hardness survey shall be carried out to determine homogeneity.

The hardenability can be determined by the Jominy test in accordance with EN ISO 642 or calculation.

D.3.7 Production of a tempering chart for quenched and tempered and age-hardened steels

The tempering characteristic shall be determined for yield strength, tensile strength, yield strength to tensile strength ratio, elongation after fracture, reduction of area and notched bar impact energy at a minimum of five different tempering temperatures above 300 °C and for three tempering times. Temperatures and times should be fixed as to reveal any tendency towards tempering embrittlement and sensitivity to extended times.

Tensile tests shall be conducted and impact energy transition curves shall be compiled. According to the results of D.3.4 and D.3.5 the specimen should be selected such that the lowest results can be anticipated.

D.3.8 Determination of the transformation behaviour

In order to estimate the transformation behaviour of normalized cast steels the transition points shall be determined by tests.

A continuous time-temperature-transformation diagram shall be produced for quenched and tempered or age-hardened cast steels.

D.3.9 Corrosion tests

Where the resistance to intercristalline corrosion is guaranteed, this shall be checked. In the case of stabilized austenitic steel grades, the lowest possible stabilization ratio guaranteed by the material manufacturer shall be considered. Limit temperature and service life shall be determined in accordance with D.3.10.2. Where further guarantees have been provided by the material manufacturer in respect of resistance to corrosion (e.g. stress corrosion cracking), these shall be verified under the conditions of the guarantee.

D.3.10 Long term tests

D.3.10.1 Long-term tests shall be conducted on high-temperature materials on plain and notched test specimens.

D.3.10.2 Ageing tests shall be carried out over a minimum of 1 000 h, 2 000 h and 5 000 h to determine the tendency to precipitation induced embrittlement, if it is expected that such embrittlement may occur in the course of the service life. The estimation of the permissible upper operating temperature can be made if the occasion arise from parametric equations, e.g. in accordance with Larson-Miller:

$$P_{LM} = T\,(C + \log t)$$

where

C is the constant

T is the temperature in K,

t is the time in h.

The testing shall be carried out on Charpy V-notched specimens, with a 2 mm striker, in accordance with EN ISO 148-1.

D.3.11 Investigation of weldability

The behaviour of the base material shall be investigated for the intended welding procedure, whereby the maximum permissible heat input and operating (interpass) temperature, with consideration of the wall thickness limits, shall be determined.

D.3.12 Effects of heat treatment after further processing

Should heat treatment be provided for (e.g. solution heat treatment, stress relieving, stabilizing annealing), the above mentioned testing shall be conducted, appropriate to the proposed application. The limits for the time/temperature cycles of the heat treatment shall be determined.

D.3.13 Investigation of surface and internal imperfections

Applicable non-destructive testing shall be applied to monitor typical surface and internal imperfections.

D.4 Sampling

D.4.1 The specimens shall be taken in accordance with EN 10213 and additionally one specimen taken at mid thickness for wall thicknesses > 50 mm and one specimen at quarter thickness and mid thickness for wall thicknesses > 100 mm.

D.4.2 In the case of all Charpy V-notched impact tests, the notch shall be perpendicular to the surface.

D.4.3 Sampling for the testing of resistance to intergranular corrosion shall be agreed.

D.5 Extent of testing

D.5.1 The tests in accordance with D.3.2, D.3.3.1, D.3.3.2, D.3.4; D.3.5 and D.3.6 shall be conducted for each size range (dimensional limits in accordance with D.2.3 for individual guaranteed values) of every product form.

D.5.2 In the execution of creep rupture tests in accordance with D.3.10.1, the requirements of EN ISO 204 shall be noted.

D.5.3 The tests in accordance with D.3.10.2 and D.3.11 shall be carried out for one dimension at every product form.

D.5.4 For the tests in accordance with D.3.3.3 b) one form of product and one cast will suffice.

D.5.5 In the case of testing in accordance with D.3.11, the identical relevant thickness of a product from one cast shall be provided. Normally regarded as relevant thicknesses are the thinnest and the thickest material provided for the welding. The lowest thickness shall be tested every time. For the upper limit, tests which have been carried out on thicknesses > 30 mm are sufficient for a range up to 1,5 times the thickness tested.

D.5.6 As a general rule, tests in accordance with D.3.11 are conducted on one cast only.

Annex E
(normative)

Test programme for welded specimen after stress relief procedure

E.1 Test programme

The welded specimen shall be sufficiently large in relation to the intended purpose. The joint shall be prepared either as K- or half-V-bevel to obtain a straight HAZ perpendicular to the surface.

The following tests shall be applied in WM, HAZ and Base Metal before and after stress relief for each condition tested:

— Hardness measurement (Vickers);

— Tensile tests;

— Charpy V-testing;

— Metallographical investigation;

— Fracture Mechanics (optional);

— Secondary stress measurement.

E.2 Position of specimen

E.2.1 Hardness measurement

The hardness measurement shall be performed for WM, HAZ and Base Metal in critical positions such as top and bottom (root) and centre (root).

E.2.2 Tensile tests

Tensile tests shall be performed with round or flat tensile specimen taken perpendicular to the weldment.

E.2.3 Charpy V-specimen

Charpy specimen for base metal shall be taken in accordance with relevant harmonized product standards.

Specimen from the weldmetal and HAZ shall be performed in accordance with EN ISO 15614-1.

E.2.4 Metallographic investigation of cracks

A full section macro shall be prepared of each condition to prove if cracks have developed from stress relief.

E.2.5 Fracture mechanics

Fracture mechanics testing shall be performed with same specimen position as for Charpy tests or with full thickness specimen. In both cases for HAZ testing it is required to have one straight welding bevel (e.g K-shape or half-V-shape).

E.2.6 Secondary stress measurement

A secondary stress measurement to demonstrate that the given level of stress reduction according to B.3.10 has been achieved shall be performed with technically established methods.

Annex F
(informative)

Example for Particular Material Appraisal (PMA) for steel

Pressure equipment manufacturer (1)	PMA No. (2)
Material Standard	(3)
Material Grade and product form	(4)
Material Group per CR ISO 15608	(5)
Delivery condition	(6)
Dimensional range	(7)
Inspection document per EN 10204	(8)

Design Standard	(11)
Intended use of equipment	(12)
TS_{max}	(13)
TS_{min}	(14)

Material properties (21)						
Yield/proof strength (MPa)			(22)			
Tensile strength (MPa)			(23)			
Fracture elongation A_5 (%)			(24)			
Charpy-V-Impact energy KV_2 (J)			(25)			
Elevated temperature properties (26)	°C	°C	°C	°C	°C	°C
Chemical composition (27)	C					
	Si					
	Mn					
	S					
	P					
(28)						

Manufacturing	(31)

Notes (41)
1) The material mentioned in this PMA is suitable for the intended service and fulfils the requirements of EN 13445-2:2014/EN 13480:2012, Clause 4. 2) .....

Pressure equipment manufacturer	Notified Body
(51)	(52)

For guidance, see also Clause 5 of this standard.

Explanations:

(1) Pressure equipment manufacturer is the company issuing the PMA.

(2) The PMA shall be given a unique number. Note that the same PMA may be used for different projects as long as the material and conditions are similar.

(3) Where the material is taken from an existing, but not harmonized material standard, the material standard shall be stated. When no material standard is relevant insert “commercial” and state the producer.

(4) When the material exist in a material standard give the complete designation, including name and number where these exist. If the material is not listed in a standard insert the material grade as described by the steelmaker. Give the product form as appropriate (plate, pipe, casting, forging, etc.).

(5) The material group in accordance with CR ISO 15608.

(6) State the acceptable delivery conditions.

(7) Thickness and diameter range as applicable

(8) Required inspection documents as noted in EN 13445-2:2014, 4.1.2 and EN 764-5.

EXAMPLE Example for the specification of an inspection document:

“Inspection certificate shall be in accordance with EN 10204, Type 3.2.

Where a material manufacturer has an appropriate quality assurance system, certified by a competent body, established within the community and having undergone a specified assessment for materials, certificates issued by the manufacturer are presumed to certify conformity with the requirements of Section 4.3 of Annex I of the PED, a certificate Type 3.1 according to EN 10204 is adequate.”

(11) Give applicable design standard (e.g. EN 13445, EN 13480, EN 12952, EN 12953, etc.).

(12) State type of equipment and design parameters such as pressure, fluid.

(13) Maximum allowable design temperature °C (TS_{max})

(14) Minimum allowable design temperature in accordance with EN 13445-2/EN 13480-2, Method 2 or 3. (TS_{min})

(21) Material properties shall be in accordance with PED 97/23/EC, Annex 1 section 4. These values are required for design of the pressure equipment.

(22) Yield or proof strength as given in the material standard or manufacturer's datasheet. Where the yield strength requirements varies with thickness this should be stated. Yield or proof strength may be given as R_e, $R_{p0,2}$, $R_{p0,5}$ or $R_{p1,0}$ as relevant for the material.

(23) Tensile strength (R_m) as given in the material standard or manufacturer's datasheet. Where the tensile strength requirements varies with thickness this should be stated.

(24) Required elongation from standard or material manufacturer data. Refer also to EN 13445-2:2014, 4.1.4 and 4.1.5.

(25) Required Charpy-V-Impact toughness from standard or steelmakers data. Refer also to EN 13445-2:2014, 4.1.6.

(26) Elevated temperature properties at a range of temperature shall be given as relevant. The data may be given as yield strength ($R_{e/T}$), proof strength ($R_{p0,2/T}$), tensile strength ($R_{m/T}$) or creep strength ($R_{p1,0/T/t}$, $R_{m/T/t}$) as relevant. The temperature range is to be defined and the number of columns adjusted as appropriate.

These values are required for design calculation of the pressure equipment in combination with the safety factors given in PED 97/23/EC Annex 1 section 7.1.2 (same applies to Items (22) and (23)).

(27) Chemical composition on heat analysis as given in the standard or material datasheet, including restrictions imposed by process conditions. The list to be extended to include all intentionally added elements and required equivalents such as carbon equivalent, X-and J- factors. See also EN 13445-2:2014, Table 4.1.

(28) Other relevant properties may be defined as appropriate.

(31) The PMA should include as far as relevant information about:

— cold and hot formability;

— weldability;

— hardening and tempering behaviour;

— ageing behaviour;

— fatigue strength;

— corrosion resistance;

— heat treatment;

— testing;

— marking.

(41) Notes to be included as relevant.

(51) Name, signature and mark of pressure equipment manufacturer.

(52) Name, number, signature and mark of verifying notified body.

Annex G
(informative)

History of EN 764-4

The most important changes from EN 764-4:2002 to EN 764-4:2014 include:

— Change in Terminology. Established materials and New materials deleted;

— A.1 to A.3 deleted. A.4 transferred to EN 764-5:2014;

— Some subclauses completely worked over: B.3.4, B.3.10, B.3.12 and Annex F. Annex E was deleted. Annex F becomes new Annex E. New Annex F was added;

— B.3.1 and C.3.1 Number of casts for a single producer increased to 5. New: for one material a group of producers can perform tests, then each on three casts.

Annex ZA
(informative)

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

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

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 Pressure Equipment Directive 97/23/EC

Clause(s)/subclause(s) of this EN	Essential Requirements (ERs) of Pressure Equipment Directive 97/23/EC	Qualifying remarks/Notes
All normative clauses	Annex I, 4.2 (b)	Technical documentation for materials taken from harmonized standards, EAM or particular appraisals
Clause 5	Annex I, 4.3	Conformity of materials and inspection documents

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

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[4] EN 12074, *Welding consumables - Quality requirements for manufacture, supply and distribution of consumables for welding and allied processes*

[5] EN 12952 (all parts), *Water-tube boilers and auxiliary installations*

[6] EN 12953 (all parts), *Shell boilers*

[7] EN 13445-2:2014, *Unfired pressure vessels - Part 2: Materials*

[8] EN 13445 (all parts), *Unfired pressure vessels*

[9] EN 13480–2:2012, *Metallic industrial piping - Part 2: Materials*

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[11] EN ISO 377, *Steel and steel products - Location and preparation of samples and test pieces for mechanical testing (ISO 377)*

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[22] EN ISO 17642-3, *Destructive tests on welds in metallic materials - Cold cracking tests for weldments - Arc welding processes - Part 3: Externally loaded tests (ISO 17642-3)*

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