
**Specification and qualification of welding
procedures for metallic materials —
Welding procedure test —**

**Part 8:
Welding of tubes to tube-plate joints**

*Descriptif et qualification d'un mode opératoire de soudage sur les
matériaux métalliques — Épreuve de qualification d'un mode opératoire —*

Partie 8 : Soudage de tubes sur plaques tubulaires



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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this part of ISO 15614 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 15614-8 was prepared by the European Committee for Standardization (CEN) in collaboration with ISO Technical Committee TC 44, *Welding and allied processes*, Subcommittee SC 10, *Unification of requirements in the field of metal welding*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

Throughout the text of this standard, read "...this European Standard..." to mean "...this International Standard...".

ISO 15614 consists of the following parts, under the general title *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*
- *Part 2: Arc welding of aluminium and its alloys*
- *Part 3: Arc welding of cast iron*
- *Part 4: Arc welding of aluminium castings*
- *Part 5: Arc welding of titanium, zirconium and their alloys*
- *Part 6: Arc welding of copper and copper alloys*
- *Part 7: Corrosion resistant overlay, cladding restore and hardfacing*
- *Part 8: Welding of tubes to tube-plate joints*
- *Part 9: Arc underwater hyperbaric wet welding*
- *Part 10: Underwater hyperbaric dry welding*
- *Part 11: Electron and laser beam welding*
- *Part 12: Spot, seam and projection welding*
- *Part 13: Flash and butt welding*

Annex ZA forms a normative part of this part of ISO 15614. Annex A of this part of ISO 15614 is for information only.

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Annex ZA provides a list of corresponding International and European Standards for which equivalents are not given in the text.

For the purposes of this part of ISO 15614, the CEN annex regarding fulfilment of European Council Directives has been removed.

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Foreword

This document (EN ISO 15614-8:2002) has been prepared by Technical Committee CEN/TC 121 "Welding", the secretariat of which is held by DS, in collaboration with Technical Committee ISO/TC 44 "Welding and allied processes".

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 October 2002, and conflicting national standards shall be withdrawn at the latest by October 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(s).

Annex A is informative. Annex ZA is normative.

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

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1 Scope

This European Standard specifies requirements for the qualification testing of welding procedures for the arc welding of tube to tube-plate joints in metallic materials by manual, partly mechanized, mechanized or automatic processes.

This standard is a part of a series of standards. Details of this series are given in prEN ISO 15607, Annex A.

Qualification by tube to tube-plate joint tests can be used for all joints even if they are fully loaded or only seal welded as required in application standards.

In such cases, one or more special test pieces should be made to simulate the production joint in all essential features, e.g. dimensions, restraint, heat sink effects. The test should be carried out prior to and under the conditions to be used in production.

This standard applies to fusion welding of metallic materials for tube to tube-plate joints with gap. This standard does not apply to tube-sheets with forged end connections with welded tubes (external/internal bore welds). For welding of tube to tube-plate joints without gap welding procedure test should be defined in the specification.

For other applications and/or requirements the standard can be used if required by the specification.

Repair welding should be considered in the welding procedure test.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

EN 287-2, *Approval testing of welders - Fusion welding - Part 2: Aluminium and aluminium alloys*

EN 439, *Welding consumables – Shielding gases for arc welding and cutting.*

EN 571-1, *Non destructive testing – Penetrant testing – Part 1 : General principles.*

EN 1043-1, *Destructive tests on welds in metallic materials – Hardness testing – Part 1 : Hardness test on arc welded joints.*

EN 1321, *Destructive tests on welds in metallic materials – Macroscopic and microscopic examination of welds.*

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

EN 1435, *Non destructive examination of welds – Radiographic examination of welded joints.*

EN 1708-1, *Welding – Basic weld joint details in steels – Part 1 : Pressurized components.*

EN ISO 4063, *Welding and allied processes – Nomenclature of processes and reference numbers (ISO 4063:1998).*

prEN ISO 9606-1, *Approval testing of welders - Fusion welding - Part 1: Steels (ISO/DIS 9606-1:2000)*

EN ISO 9606-3, *Approval testing of welders – Fusion welding – Part 3: Copper and copper alloys (ISO 9606-3:1999).*

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

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EN ISO 9606-5, *Approval testing of welders – Fusion welding – Part 5: Titanium and titanium alloys, zirconium and zirconium alloys (ISO 9606-5:2000)*.

prEN ISO 15607:2000, *Specification and qualification of welding procedures for metallic materials – General rules (ISO/DIS 15607:2000)*.

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

prEN ISO 15609-1:2000, *Specification and qualification of welding procedures for metallic materials – Welding procedure specification – Part 1 : Arc welding (ISO/DIS 15609-1:2000)*.

prEN ISO 15614-1:2000, *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/DIS 15614-1:2000)*.

EN ISO 6520-1, *Welding and allied processes - Classification of geometric imperfections in metallic materials – Part 1: Fusion welding (ISO 6520-1:1998)*.

EN 29692, *Metal-arc welding with covered electrode, gas-shielded metal-arc welding and gas welding - Joint preparations for steels (ISO 9692:1992)*.

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this European standard, the terms and definitions given in prEN ISO 15607:2000 apply.

3.2 Symbols

For the purposes of this standard, the following symbols apply and are shown in Figure 1, 2 and 3:

- a throat thickness (mm) (in this case, the minimal distance between root point and weld surface)
- d_p pore size (mm)
- d_a tube-outside diameter (mm)
- d_l minimum distance between two pipes (mm), see Figure 2
- g gap between tube and tube plate
- s_p starting point of the root run
- t tube-wall thickness (mm)
- t_1 cladding thickness (mm)
- t_2 tube-plate thickness (mm)

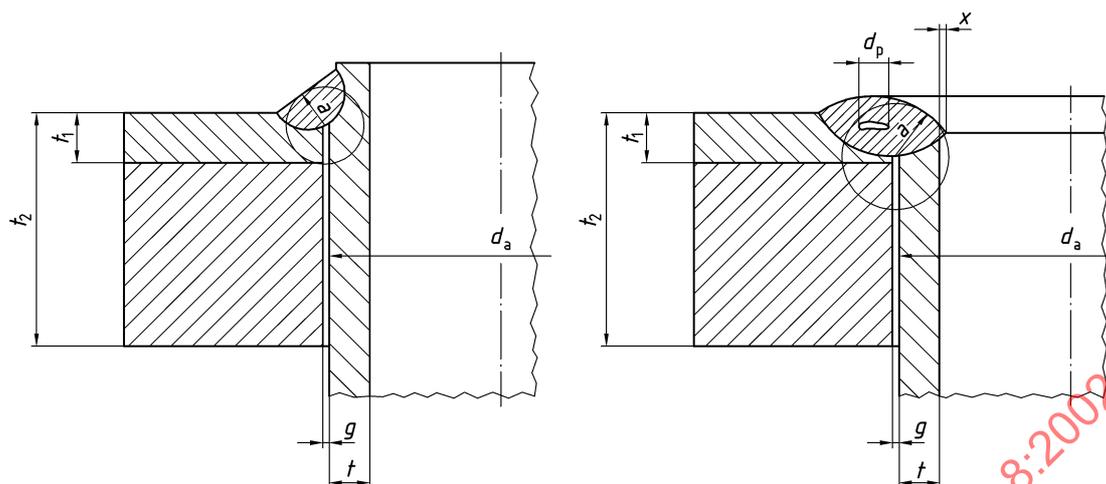


Figure 1 — Presentation of symbols in an example

4 Preliminary Welding Procedure Specification (pWPS)

4.1 General

The qualification for tube to tube-plate welding tests shall be based on a pWPS in accordance with prEN ISO 15609-1:2000. It shall specify the relevant parameters listed in 4.2 and 4.3.

4.2 Items for all welding processes

Details relating to the following items shall be recorded for all welding processes :

- a) welding process, or processes when more than one is used in making a complete joint ;
- b) tube-plate specification and thickness and details of any cladding and its thickness ;
- c) tube specification, thickness and outside diameter ;
- d) pitch type (square or triangular) and distance between pipes ;
- e) joint geometry, actual borehole diameter and fit-up tolerances (sketch) in accordance with EN 29692 ;
- f) cleaning and degreasing (time during the fabrication steps and type) ;
- g) jiggling or tacking, tacking position and expansion;
- h) tube-plate and welding position ;
- i) type and/or trade name of welding consumables ;
- j) size (diameter) and wire lengths per run ;
- k) pre-heating and interpass temperature, including method of control ;
- l) welding speed (mechanized welding) ;
- m) number and arrangement of runs, starting points of runs and weld dimensions (sketch) ;

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- n) welding sequence ;
- o) post-weld heat treatment, including method of control ;
- p) if necessary, the temperature and time recommended for drying/backing of welding consumables before use ;
- q) any special features, including heat input control requirements, any heat sinks effects or post-weld tube expansion.

4.3 Items for particular welding processes

Details relating to the items given in 4.3 a) to 4.3 d) shall be recorded for these particular processes, in addition to the items given in 4.2. The reference numbers of welding processes relate to EN ISO 4063.

a) Manual metal arc welding (111)

- alternating or direct current and polarity ;
- current.

b) MIG welding, MAG welding, solid wire or cored wire, with or without separate gas shield (114), (131), (135), (136), (137)

- shielding gas designation in accordance with EN 439 and flow rate ;
- arc voltage ;
- wire feed speed or current ;
- for pulsed welding : the pulse time and frequency, pulsed current and background current.

c) TIG welding (141)

- shielding gas designation in accordance with EN 439 and flow rate ;
- alternating current (AC) or direct current (DC) and polarity ;
- current in ampere ;
- for pulsed welding : the pulse time and frequency, pulsed current and background current ;
- whether filler metal is used.

d) Mechanized or automatic welding

- all items detailed in b) or c) and the following items if necessary :
 - arc length or arc voltage ;
 - where filler metal is used its rate of addition or wire feed speed relating to the wire diameter (see 4.2j));
 - other pre-programmed welding variables such as :
 - pre- and post-gas purge times ;
 - changes in current level ;
 - current slope up and down rates ;
 - welding travel speed and degree of overlap ;

- when considering front face welding, the following additional information :
 - radius of electrode rotation ;
 - electrode angle relative to the tube axis ;

For all other welding processes, the welding parameters shall be specified.

5 Qualification of welding procedure

The qualification of welding procedure for the tube to tube-plate welding shall be carried out by an examiner or examining body related to the appropriate application standard or specification.

6 Welding of test pieces

6.1 General

Procedure test pieces shall be produced in accordance with 6.2 and shall simulate the joint geometry to be used in production or a similar geometry within the requirements of clause 4. Welders shall be qualified in accordance with prEN ISO 9606-1, EN 287-2, EN ISO 9606-3, EN ISO 9606-4 or EN ISO 9606-5. For welding operators, the qualification can be carried out during the tests in accordance with EN 1418.

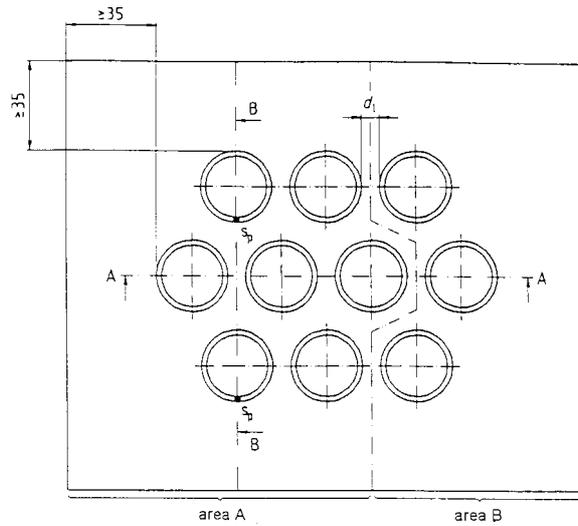
6.2 Type of test piece

6.2.1 Joint preparation and joint construction

Examples of joint preparation according to EN 29692 and joint construction are given in EN 1708-1.

6.2.2 Tube ends welded on triangular pitch

Where tube end welds are involved on a triangular pitch, a minimum of 10 tube ends with an outside diameter smaller than 40 mm (< 40 mm) or a minimum of 7 tube ends (area A) with an outside diameter greater than or equal to 40 mm (≥ 40 mm), shall be welded as shown in Figure 2.



Key

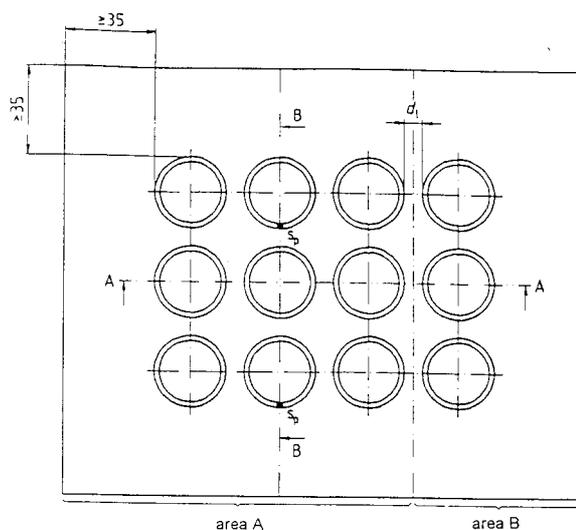
- d_1 Minimum distance between two pipes
- s_p Starting point of the root run
- A-A/B-B Ground sections of a test specimen (examples for the location of the cut lines)

Figure 2 — Test piece for tube ends on triangular pitch

6.2.3 Tube ends welded on square pitch

Where tube end welds are involved on a square pitch, a minimum of 12 tube ends with an outside diameter smaller than 40 mm (< 40 mm) or a minimum of nine tube ends (area A) with an outside diameter greater than or equal to 40 mm (≥ 40 mm) shall be welded as shown in Figure 3.

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Key

- d_t Minimum distance between two pipes
 s_p Starting point of the root run
 A-A/B-B Ground sections of a test specimen (examples for the location of the cut lines)

Figure 3 — Test piece for tube ends on square pitch

7 Examination and testing

7.1 Performance

7.1.1 General

For a welding procedure to be qualified the same test piece representing the welding procedure test shall comply with 7.1.2 to 7.1.6 and, when required, with the push-out tests described in 7.1.7.

7.1.2 Visual examination

After appropriate cleaning and if required any post-weld heat treatment, and prior to the cutting of test specimens, the test piece shall be examined visually 100 %.

The welds shall show uniform contour without excessive reinforcement, with the bores of the tube free from any spatter and shall be in accordance with Table 1.

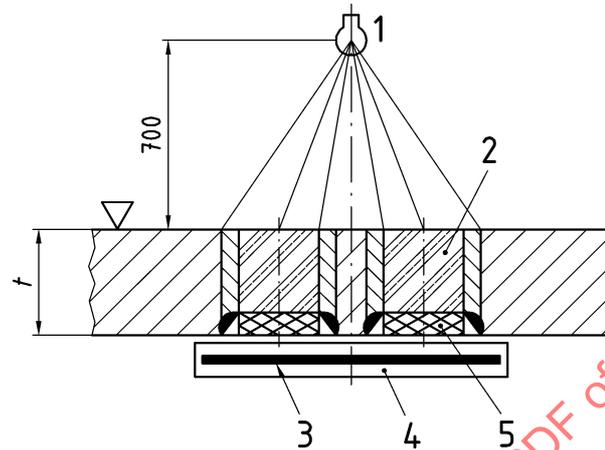
7.1.3 Penetrant examination

The external surfaces of all welds shall be subjected to a 100 % penetrant examination in accordance with EN 571-1.

7.1.4 Radiographic examination

All test welds, except those for push-out tests, shall be radiographed in accordance with EN 1435. An example is given in Figure 4. In this case, the tube-plate shall be reduced in thickness of 5 mm to 12 mm.

Dimensions in millimetres



Key

- 1) Ray source
- 2) Radiated marcassite (steel/lead)
- 3) Film
- 4) Film cassette
- 5) Stopper

Figure 4 — Performance of the radiographic examination

7.1.5 Macroscopic examination

After visual and non-destructive examination, the test piece shall be sectioned as shown in Figures 2 and 3, by sawing or machining and exposing two starting points of the root runs. The macroscopic examination specimens shall be prepared and examined in accordance with EN 1321.

Macroscopic examinations of additional sections to assess compliance with the acceptance levels in 7.2 shall be carried out where radiography reveals imperfections other than gas pores.

7.1.6 Hardness test

A hardness row normally HV 10 in accordance with EN 1043-1 shall be carried out only for the steel groups 2, 3, 4, 5, 6 and 7 in accordance with CR ISO 15608 and for dissimilar metal joints between austenitic and ferritic steels.

The hardness shall be recorded for the weld metal, both parent metals and the heat-affected zones.

7.1.7 Push-out or pull-out test

If required by the specification, push-out or pull-out tests can be required.

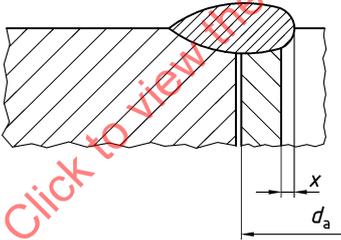
7.2 Acceptance levels

7.2.1 General

It should be appreciated that the following details are being used for the qualification testing of welding procedures and as such may be different from those specified for a particular application.

7.2.2 Visual examination

Table 1 — Visual examination

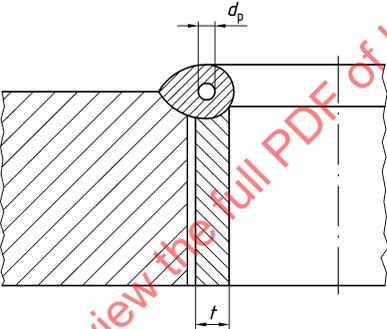
N°	Imperfection/ designation	EN ISO 6520-1 reference N°	Remarks	Limits for imperfections
1	Cracks	100	all types of cracks	not permitted
2	Crater crack	104		not permitted
3	Surface pore open end crater pipe	2017 2024	all types of pores, they are visible on the surface	not permitted
4	Burn through of tube wall			not permitted
5	Overlap	506	 <p>The diagram shows a cross-section of a weld overlap. A vertical dimension line labeled 'x' indicates the height of the overlap. A horizontal dimension line labeled 'd_a' indicates the diameter of the tube. The weld metal is shown with diagonal hatching.</p>	$x \leq 0,5$ mm for tubes, $d_a \leq 25$ mm outside diameter and $x \leq 1$ mm for tubes, $d_a > 25$ mm outside diameter
6	Burn down of tube end (only fillet welds)			Not permitted; where it reduces the weld below its required dimensions
7	Undercut	5011		0,1 t

7.2.3 Penetrant examination

Any indication of dimensions in the weld metal or heat-affected zone is not acceptable.

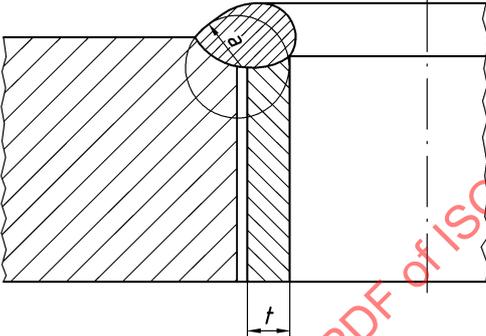
7.2.4 Radiographic examination

Table 2 — Radiographic examination

N°	Imperfection/ designation	EN ISO 6520-1 reference N°	Remarks	Limits for imperfections
8	Cracks	100	all types of cracks	not permitted
9	Elongated cavities, wormholes	2015 2016		not permitted
10	Clustered (localized) cavities	2013		not permitted
11	Gas pores uniformly distributed, porosity, linear porosity	2011 2012 2014	 <p>- per tube joint max. two pores with pore size d_p permitted - distance between two pores min. distance $2 \times d_p$ in direction of circumference</p>	$d_p \leq 0,25 t$ max. 1 mm
12	Solid inclusions	300		not permitted
13	Lack of fusion	401		not permitted
14	Lack of penetration	402		not permitted

7.2.5 Macroscopic examination

Table 3 — Macroscopic examination

N°	Imperfection/ designation	EN ISO 6520-1 reference N°	Remarks	Limits for imperfections
8 to 14	see Table 2			
15	Weld thickness		 <p>The throat dimension a is equal to the radius of the largest circle totally inscribed in the weld whose centre is situated in the root of weld</p>	$a \geq 0,9 t$

7.2.6 Hardness values

The results from the hardness test shall meet the requirements given in prEN ISO 15614-1:2000, Table 2.

7.2.7 Push-out or pull-out load

The requirements should be defined in the specification.

8 Range of qualification

8.1 General

All the conditions of validity stated below shall be met independently of each other. Changes outside of the ranges specified shall require a new welding procedure test.

8.2 Related to the manufacturer

A qualification of a WPS obtained by a manufacturer is valid for welding in workshops and sites under the same technical conditions and quality control of that manufacturer.

8.3 Related to the material

8.3.1 Parent metal

For the purposes of this standard, the groups of materials listed in CR ISO 15608 shall apply. For the range of qualification the relevant part of prEN ISO 15614¹⁾ shall be used.

8.3.2 Tube-plate and tube dimensions

For all geometrical details the ranges of qualification are given in Table 4.

Table 4 — Range of qualification for geometrical details

Designation	Test piece in mm	Range of approval in mm
Cladding thickness	$t_1 < 3$ $t_1 \geq 3$	$\geq t_1$ ≥ 3
Tube-plate thickness	$t_2 < 35$ $t_2 \geq 35$	$\geq t_2$ ≥ 35
Tube-wall thickness - manual welding	t	0,5 t to 2 t
Tube-wall thickness – mechanized or automatic welding	t	$t \pm 0,2 t$
Tube-outside diameter	d_a	$\geq d_a$

8.3.3 Tube pitch

The qualification of a welding procedure using a particular pitch of tubes shall include qualification for any other type of pitch provided that the minimum distance between two pipes d_1 (see Figures 2 and 3) is not reduced to below that used in the qualified welding procedure.

8.4 Common to all welding procedures

8.4.1 Welding process

The qualification is valid only for the welding process used in the welding procedure test. In a multi-process procedure test the qualification is only valid for the order used during the qualification test.

8.4.2 Welding position of tube-plate

The qualification is only valid for the welding position used in the welding procedure test.

8.4.3 Type of joint

The qualification is only valid for the type of welded joints used in the welding procedure test.

¹⁾ As long as relevant parts are under preparation the range of qualification should be in accordance with the specification.

8.4.4 Filler metal, classification

The qualification range of filler metals covers other filler metals as long as they are :

- either in the same group of tensile properties. Change in the type of coating will entail new qualification of the welding procedure ;
- or within the same nominal chemical composition.

8.4.5 Filler metal, dimensions

The qualification given is for the diameters of electrodes or for the diameters of wires or for special consumables, e.g. inserts, used in the welding procedure test.

8.4.6 Type of current

The qualification given is for the type of current (alternating, direct or pulsed current) and polarity used in the welding procedure test.

8.4.7 Heat input

The requirements of this clause only apply when the control of heat input is specified.

When hardness requirements apply, the lowest limit of heat input is that used in welding procedure test or may be 25 % greater than that used in welding the test piece.

8.4.8 Pre-heat temperature

The lower limit of qualification is the pre-heat temperature used at the start of the welding procedure test.

8.4.9 Interpass temperature

The upper limit of qualification is the nominal interpass temperature reached in the welding procedure test.

8.4.10 Post-weld heat treatment

Welding procedure test with heat treatment does not include welding procedure test without heat treatment and vice versa. The temperature range used for the welding procedure test is the range qualified. Where required, heating rates, cooling rates and holding time shall be related to the production component.

8.4.11 Shielding gas

The qualification given to the shielding gas is restricted to the type of gas (nominal composition) in accordance with EN 439 used in the welding procedure test.

9 Welding, Procedure Qualification Record form (WPQR)

A Welding Procedure Qualification Record (WPQR) is a statement of the results of assessment of each test piece including re-tests. The relevant items listed for the WPS in clause 4 of this standard shall be included, together with details of any features that would be rejectable by the requirements of clause 7.

If no rejectable features or unacceptable test results are found, a WPQR detailing the welding procedure test piece results is qualified and shall be signed and dated by the examiner or examining body.

A WPQR format shall be used to record details for the welding procedure and the test results, in order to facilitate uniform presentation and assessment of the parameters.

An example of the WPQR-form is shown in annex A.

Annex A (informative)

Welding Procedure Qualification Record form for tube to tube-plate joints (WPQR)

Welding procedure qualification - Test certificate

Manufacturer's welding procedure Reference N° : Examiner or examining body Reference N° :

Manufacturer :
Address :
Code/Testing standard :
Date of welding :

Extent of qualification

Welding process :
Joint type :
Parent metal (s) : tube-plate : Cladding : Tube :
Thickness of tube-plate (mm) : Cladding (mm) : Tube (mm) :
Tube-outside diameter (mm) : Gap (g) (mm) :
Filler metal type :
Shielding gas :
Type of welding current :
Welding positions :
Pre-heat :
Post-weld heat treatment :
Other information :

Certified that test welds prepared, welded and tested satisfactorily in accordance with the requirements of the code/testing standard indicated above

Location Date of issued Examiner or examining body Name, date and signature