
**Petroleum and natural gas industries —
Induction bends, fittings and flanges for
pipeline transportation systems —**

**Part 2:
Fittings**

*Industries du pétrole et du gaz naturel — Coudes d'induction, raccords
et brides pour systèmes de transport par conduites —*

Partie 2: Raccords



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Contents

Page

Foreword	iv
Introduction	v
1 Scope	1
2 Normative references	1
3 Terms and definitions	3
4 Symbols and abbreviated terms	4
5 Designation	5
6 Pressure rating and design	5
6.1 General	5
6.2 Tees and headers	5
6.3 Extruded outlet headers	5
7 Information to be supplied by the purchaser	6
7.1 Principal information	6
7.2 Supplementary information	6
8 Manufacturing	7
8.1 Manufacturing procedure specification	7
8.2 Starting material	7
8.3 Fitting manufacture	8
9 Testing and inspection	10
9.1 General requirements	10
9.2 Extent of testing and inspection	10
9.3 Chemical composition	12
9.4 Mechanical testing	12
9.5 Non-destructive testing	17
9.6 Dimensions	19
9.7 Gauging	20
9.8 Hydrostatic testing	20
10 Inspection document	20
11 Marking	20
Annex A (normative) Design calculations	21
Annex B (normative) Proof test	23
Bibliography	26

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 2.

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 document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 15590-2 was prepared by Technical Committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*, Subcommittee SC 2, *Pipeline transportation systems*.

ISO 15590 consists of the following parts, under the general title *Petroleum and natural gas industries — Induction bends, fittings and flanges for pipeline transportation systems*:

— *Part 1: Induction bends*

— *Part 2: Fittings*

The following part is under preparation:

— *Part 3: Flanges*

Introduction

Users of this part of ISO 15590 should be aware that further or differing requirements may be needed for individual applications. This part of ISO 15590 is not intended to inhibit a manufacturer from offering, or the purchaser from accepting, alternative equipment or engineering solutions for the individual application. This can be particularly applicable where there is innovative or developing technology. Where an alternative is offered, the manufacturer should identify any variations from this part of ISO 15590 and provide details.

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Petroleum and natural gas industries — Induction bends, fittings and flanges for pipeline transportation systems —

Part 2: Fittings

1 Scope

This part of ISO 15590 specifies the technical delivery conditions for unalloyed or low-alloy steel seamless and welded pipeline fittings for use in pipeline transportation systems for the petroleum and natural gas industries as defined in ISO 13623.

This part of ISO 15590 is applicable to welding-end fittings such as elbows, caps, tees, single or multiple extruded headers, reducers, and transition sections made from seamless and welded pipe of unalloyed or low-alloy steels.

This part of ISO 15590 specifies three classes of fitting corresponding to increasing quality requirements in accordance with the technical delivery conditions of ISO 3183 for pipe as indicated in Table 1.

Table 1 — Fitting class and corresponding pipe standard

Fitting class	Corresponding pipe standard
Class A	ISO 3183-1
Class B	ISO 3183-2
Class C	ISO 3183-3

This part of ISO 15590 is not applicable to the selection of the fitting class.

This part of ISO 15590 is not applicable to the materials for, or the attachment of, factory-welded extensions.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 148 (all parts), *Steel — Charpy impact test (V-notch)*

ISO 377:1997, *Steel and steel products — Location and preparation of samples and test pieces for mechanical testing*

ISO 783, *Metallic materials — Tensile testing at elevated temperature*

ISO 2566-1, *Steel — Conversion of elongation values — Part 1: Carbon and low alloy steels*

ISO 3183-1, *Petroleum and natural gas industries — Steel pipe for pipelines — Technical delivery conditions — Part 1: Pipes of requirement class A*

ISO 3183-2, *Petroleum and natural gas industries — Steel pipe for pipelines — Technical delivery conditions — Part 2: Pipes of requirement class B*

ISO 3183-3, *Petroleum and natural gas industries — Steel pipe for pipelines — Technical delivery conditions — Part 3: Pipes of requirement class C*

ISO 3834-2, *Quality requirements for welding — Fusion welding of metallic materials — Part 2: Comprehensive quality requirements*

ISO 4885, *Ferrous products — Heat treatments — Vocabulary*

ISO 6507-1, *Metallic materials — Vickers hardness test — Part 1: Test method*

ISO 6892, *Metallic materials — Tensile testing at ambient temperature*

ISO 7438, *Metallic materials — Bend test*

ISO/TR 7705:1991, *Guidelines for specifying Charpy V-notch impact prescriptions in steel specifications*

ISO 9712, *Non-destructive testing — Qualification and certification of personnel*

ISO 10474, *Steel and steel products — Inspection documents*

ISO 11496, *Seamless and welded steel tubes for pressure purposes — Ultrasonic testing of tube ends for the detection of laminar imperfections*

ISO 12095, *Seamless and welded steel tubes for pressure purposes — Liquid penetrant testing*

ISO 12096, *Submerged arc-welded steel tubes for pressure purposes — Radiographic testing of the weld seam for the detection of imperfections*

ISO 13623, *Petroleum and natural gas industries — Pipeline transportation systems*

ISO 13664, *Seamless and welded steel tubes for pressure purposes — Magnetic particle inspection of the tube ends for the detection of laminar imperfections*

ASME¹⁾ B16.9, *Factory-made wrought butt welding fittings*

ASME B31.8, *Gas transmission and distribution piping systems*

ASME IX, *Boiler and pressure vessel code, Section IX — Welding and brazing procedures, welders, brazers, and welding and brazing operators*

ASTM²⁾ E 112, *Standard test methods for determining average grain size*

ASTM E 709, *Standard guide for magnetic particle examination*

EN 287-1, *Approval testing of welders — Fusion welding — Part 1: Steels*

EN 288-3, *Specification and approval of welding procedures for metallic materials — Part 3: Welding procedure tests for the arc welding of steels*

1) American Society of Mechanical Engineers, 345 East 47th Street, NY 10017-2392, USA

2) American Society for Testing and Materials, 100 Bar Harbor Drive, West Conshohocken, PA 19428-2959, USA

MSS³⁾ SP-75, *Specification for high test wrought butt welding fittings*

EFC Publication 16:1995⁴⁾, *Guidelines on materials requirements for carbon and low alloy steels for H₂S containing environments in oil and gas production*

3 Terms and definitions

For the purposes of this part of ISO 15590 the terms and definitions given in ISO 4885 and the following apply.

3.1

by agreement

agreed between manufacturer and purchaser

[ISO 15590-1:2001]

3.2

extrados

outer curved section of the elbow

NOTE Adapted from ISO 15590-1:2001.

3.3

heat, noun

batch of steel prepared in one steel-making process

NOTE Adapted from ISO 15590-1:2001.

3.4

intrados

inner curved section of the elbow

NOTE Adapted from ISO 15590-1:2001.

3.5

manufacturing procedure specification

MPS

document which specifies the process control parameters and the acceptance criteria to be applied for all manufacturing, inspection and testing activities performed during fitting manufacture

3.6

tangent

straight section at the ends of the fitting

NOTE Adapted from ISO 15590-1:2001.

3.7

test unit

fitting or test piece of the same designation, starting material wall thickness, heat, manufacturing procedure specification, and heat treatment condition

3) Manufacturers Standardization Society of the Valve & Fittings Industry, 127 Park Street, N.E., Vienna, Virginia 22180, USA

4) European Federation of Corrosion, c/o The Institute of Materials, 1 Carlton House Terrace, London SW1Y 5DB, United Kingdom

4 Symbols and abbreviated terms

A_o	original cross-sectional area of the parallel length of a tensile test specimen
D	outside diameter
D_p	specified outside diameter of matching pipe
D_n	minor outside diameter of a conical reducer or reducing tee at any point, n , under consideration, measured perpendicular to the longitudinal axis
E	factor used to calculate t_i (see A.1)
f	factor used to calculate proof test pressure (see Table B.1)
P_{cm}	crack measurement parameter (see Table 4)
p	design pressure
p_p	numerical value of the computed proof pressure
R_m	tensile strength
$R_{m, red}$	allowable tensile strength of a reducer
$R_{t0,5}$	yield strength for 0,5 % total elongation
R_{smys}	specified minimum yield strength
$T_{d, min}$	minimum design temperature specified by the purchaser
t	nominal wall thickness
t_D	wall thickness of thicker component for joints of unequal thickness (see Figure 1)
t_i	minimum wall thickness required in the intrados
t_p	nominal wall thickness of matching pipe
t_n	specified wall thickness of reducers and reducing tees at diameter D_n
α	included angle of a conical reducer
ρ_o	radius of curvature of the external contoured portion of the outlet of a tee
CE	carbon equivalent (see Table 4)
CTOD	crack tip opening displacement
DN	nominal size
HIC	hydrogen-induced cracking
MT	magnetic particle testing
NDT	non-destructive testing
PT	liquid penetrant testing
RT	radiographic testing
SMYS	specified minimum yield strength
SSC	sulfide stress-cracking
UT	ultrasonic testing

5 Designation

Designation of fittings shall take the form:

ISO 15590-2 YY xxx-Z,

where

- YY is a textual description of the type of fitting, corresponding to one of the following: EL for elbow, TE for tee, CA for cap, CR for concentric reducer, ER for eccentric reducer and NR for conical reducer, preceded by the size designation (e.g. "DN 600 EL" is a DN 600 elbow);
- xxx is the specified minimum yield strength requirement in MPa;
- Z is the suffix A or B or C, to identify the fitting class for use in non-sour service, or the suffix CS to identify class C fittings for use in sour-service conditions.

6 Pressure rating and design

6.1 General

The capability of the fitting to withstand internal pressure shall equal or exceed that of the matching pipe. The verification of the capability shall be made by calculation and/or proof testing. The calculations shall be made in accordance with Annex A. The proof test procedure shall be as defined in Annex B. Additional requirements on strength design verifications, such as resistance to internal pressure under special load cases in accordance with ISO 13623, shall be indicated at the time of enquiry or order.

The design calculations and/or results of proof testing shall be available for review at the manufacturer's facility.

If the SMYS of the fitting material is less than that of the matching pipe, the minimum thickness of the fitting end shall be increased such that the product of its thickness times its SMYS shall at least equal the product of the specified wall thickness and the SMYS of the matching pipe, in accordance with MSS SP-75.

6.2 Tees and headers

Outlet branches in tees and headers manufactured from seam-welded pipe shall be positioned diametrically opposite the longitudinal weld. When this positioning is not possible, the location shall be decided by agreement.

The design and welding for the attachment of guide bars of barred tees shall be decided by agreement prior to manufacture of the tee.

6.3 Extruded outlet headers

Extruded outlet headers shall be designed to comply with ASME B31.8.

7 Information to be supplied by the purchaser

7.1 Principal information

The purchaser shall provide the following information in the order given below:

- a) fitting designation;
- b) required fitting dimensions, including
 - 1) nominal outside diameters,
 - 2) minimum wall thicknesses at the welding ends,
 - 3) radius and type of radius (e.g. long-radius),
 - 4) the angle (for elbows);

NOTE Guidance on specific dimensions to specify is given in ISO 3545-3.

- c) end-preparation details;
- d) whether the purchaser wishes to approve the MPS prior to commencement of manufacturing.

7.2 Supplementary information

If applicable, the purchaser shall specify the following supplementary information:

- a) minimum design temperature;
- b) maximum design temperature;
- c) maximum wall thickness;
- d) special dimensional requirements;
- e) requirements for supplementary inspection and testing;
- f) requirements for gauging and other measurements of dimensions where different from this part of ISO 15590;
- g) pipeline design standard or design factors if different from ISO 13623;
- h) pipeline operating conditions;
- i) mechanical property requirements at the maximum design temperature;
- j) requirements for proof, burst, or hydrostatic testing;
- k) activities for witnessing and approval by purchaser;
- l) coating or painting requirements;
- m) marking requirements where different from this part of ISO 15590;
- n) packaging and shipping instructions;
- o) third-party inspection organization;
- p) ISO 10474 standard designation of inspection document required;

- q) requirements for format and additional content of the inspection document;
- r) whether testing of welding procedures, welders, or welding operators specific to the order is required;
- s) whether approval of the MPS is to be by review of previous production data or by testing;
- t) PWHT (see 9.1);
- u) HIC testing (see 9.4.7);
- v) SCC testing (see 9.4.8).

8 Manufacturing

8.1 Manufacturing procedure specification

Fittings shall be manufactured in accordance with a documented MPS. If specified by the purchaser, manufacturing shall not proceed until the MPS has been accepted by the purchaser.

The MPS shall specify the following items:

- a) for the starting material:
 - 1) name of manufacturer,
 - 2) steel-making process,
 - 3) steel grade,
 - 4) product form and dimensions,
 - 5) chemical composition, including that of the weld seam,
 - 6) welding procedure specification;
- b) for fitting manufacture:
 - 1) forming procedure,
 - 2) welding procedure specification and approval record,
 - 3) heat treatment procedure including thermal cycles,
 - 4) machining requirements,
 - 5) inspection and test requirements,
 - 6) traceability;
- c) additional requirements such as end preparation, coating, and marking.

An approval of the MPS may be required, either by review of the manufacturer's previous production data or by performance of the mandatory tests listed in Table 2, at the beginning of production.

8.2 Starting material

The starting material for forming into fittings shall be blooms, billets, slabs, forging quality bar, plate, fusion-welded with filler metal or seamless tubular products, produced from fully-killed steels.

High-frequency welded (HFW) and helical-seam submerged-arc welding (SAWH) pipes shall not be used.

8.3 Fitting manufacture

8.3.1 Forming

All forming operations shall be performed in accordance with the MPS.

8.3.2 Welding

Welding operations shall be conducted in accordance with those elements of ISO 3834-2 decided by agreement and the requirements of this part of ISO 15590.

Welding and repair welding shall be performed in accordance with procedures qualified in accordance with ASME IX or EN 288-3. Welders and welding operators shall be qualified in accordance with ASME IX or EN 287-1.

Acceptance criteria for all tests shall be as specified in Clause 9.

Where practicable, longitudinal butt welds should be double-sided. Backing rings shall not be used. All welds shall have complete penetration and shall be finished in accordance with Clause 9.

Temporary welded attachments shall be removed, where possible, before heat treatment and the weld area shall be treated in accordance with 9.5.3.4 and 9.5.3.5.

Fittings shall not contain girth welds.

All welds that will remain in the fitting shall be heat-treated in accordance with 8.3.3.

8.3.3 Heat treatment

All fittings shall be normalized, normalized and tempered, or quenched and tempered after welding and/or forming. The heat treatment shall be performed in accordance with a documented procedure. The procedure shall define the following parameters, where appropriate, for the type of heat treatment:

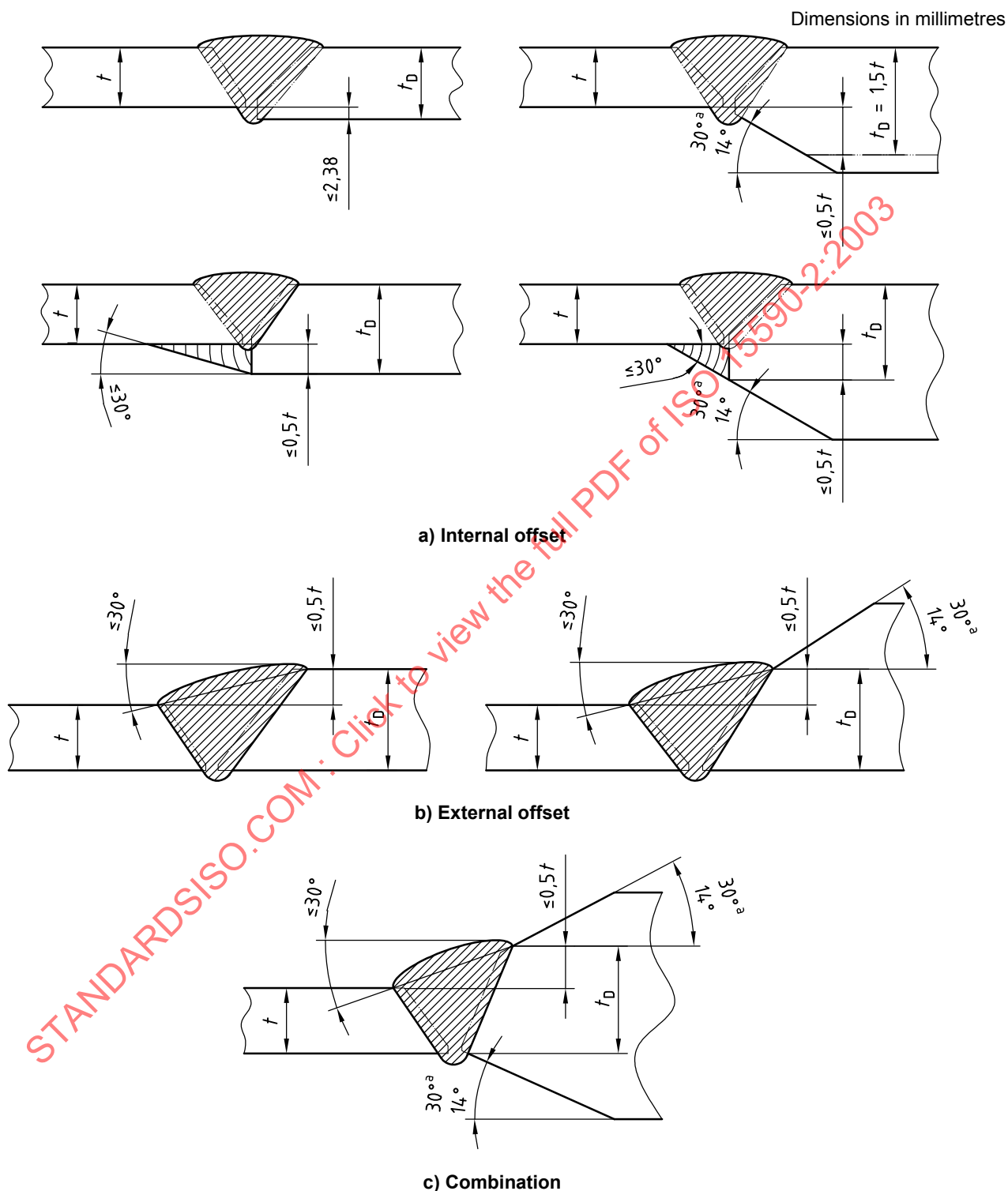
- a) heating schedule;
- b) soaking temperature;
- c) soaking time;
- d) cooling schedule;
- e) quenching temperature;
- f) quenching medium, including commencing and final medium temperature.

A record shall be maintained of each heat treatment. When submission of the heat treatment record is specified, it shall be included in the inspection document.

The tolerances on specified nominal values of soaking temperature and soaking time shall be ± 15 °C and + 20 %, respectively.

8.3.4 End preparation

For unequal wall thicknesses, the joint design shall be as shown in Figure 1.



If the SMYSs of the sections to be joined are not equal, the minimum thickness, t_D , shall be not less than t times the ratio of the SMYS of the pipe and fitting, but shall not exceed $1,5t$.

- a There is no restriction on the minimum angle if the materials joined have equal SMYS.

Figure 1 — Bevel designs for unequal wall thicknesses

9 Testing and inspection

9.1 General requirements

Testing and inspection shall be carried out on fittings after final heat treatment.

If the pipeline installation techniques will require post-weld heat treatment (PWHT) of the fitting, additional testing may be requested to demonstrate that the mechanical properties of the fitting are also achieved after PWHT. Details of the PWHT thermal cycle to be used during pipeline installation shall be specified. The test requirements and acceptance criteria shall be by agreement.

Where the procedure requirements of 8.3.3 are not met, test pieces shall be taken from each heat treatment batch.

9.2 Extent of testing and inspection

The testing and inspection to be performed during qualification and production shall be as summarized in Table 2 for each fitting class.

Production testing shall be performed at the minimum frequency specified in Table 3.

Test pieces for mechanical testing shall be taken from one or more of the following:

- extension lengths, formed and heat-treated as part of the fitting and/or test piece attached to the fitting;
- starting material which has been subjected to the same forging reduction and heat treatment as the proposed fitting;
- a fitting.

Locations for the test pieces to be taken from a fitting shall be established by agreement. The sample of starting material shall be heat-treated with or as part of the fittings in the same heat treatment batch in accordance with ISO 377:1997, Clause 5.

Fittings heat-treated within the tolerance requirements of 8.3.3 may be considered as being in the same heat treatment condition.

Table 2 — Summary of testing and inspection requirements

Test		Class A	Class B	Class C	Clause number specifying acceptance criteria
Chemical analysis	Chemical composition	M	M	M	9.3
Physical tests	Tensile – base metal	M	M	M	9.4.2.3
	Transverse weld tensile	M ^a	M ^a	M ^a	9.4.2.3
	Impact – fitting body	O	M	M	9.4.3.3
	Impact – weld seam	O	M	M	9.4.3.3
	Through-thickness hardness	O	M	M	9.4.4.2
	Surface hardness	O	O	O	9.4.5
	Metallography	Q	Q	Q ^b	9.4.6.2
	HIC	N	N	O ^{c,d}	9.4.7
	SSC	N	N	O ^{c,d}	9.4.8
	CTOD	N	N	O	9.4.9
	Guided bend (weld seam)	Q	Q	Q	9.4.10.3
NDT	Visual inspection	M	M	M	9.5.3
	End preparation (MT or PT)	M	M	M	9.5.4
	Fitting end (UT)	N	M	M	9.5.4
	Weld seam (RT or UT) ^d	M	M	M	9.5.5
	Fitting body (UT or MT) ^e	O	O	O	9.5.7
	Residual magnetism	O	M	M	9.5.8
Dimensions	Wall thickness	M	M	M	9.6
	Inside diameter at ends	M	M	M	9.6
	Out-of-roundness at ends	M	M	M	9.6
	Specific dimensions	M	M	M	9.6
NOTE The abbreviations mean as follows: M = Requirement mandatory in production N = Not required O = Requirement for test or inspection at the purchaser's option Q = Required for approval of the welding procedure only, otherwise at the purchaser's option					
^a May be omitted for fittings with $D < 210$ mm. ^b Production test which shall be performed for fittings intended for sour service. ^c Option need not be considered for fittings intended for non-sour service. If applied, this testing may be performed as part of the MPS qualification testing. ^d May be carried out on the starting material by agreement. ^e By agreement.					

Table 3 — Extent of testing and inspection

Type of test	Number of tests
Chemical composition	One per heat
Tensile — base metal	One per test unit
Transverse weld tensile	One per test unit
Impact — base metal	One set per test unit
Impact — weld seam	37 mm thickness and above: two sets per test unit less than 37 mm: 1 set per test unit
Through-thickness hardness	One per test unit
Surface hardness	By agreement
Metallography	By agreement
HIC	By agreement
SSC	By agreement
CTOD	By agreement
Guided bend (weld seam)	Two per qualification test
NDT	Every fitting ^a
Dimensional inspection	Every fitting

^a Except for determining residual magnetism, which shall be at a frequency to be established by agreement for fittings demagnetized during production, otherwise 25 % of the fittings shall be selected at random.

9.3 Chemical composition

The product analysis shall be in accordance with Table 4.

9.4 Mechanical testing

9.4.1 Preparation of test pieces

Test pieces shall be prepared in accordance with ISO 377.

9.4.2 Tensile testing

9.4.2.1 Test pieces

Orientation of the base metal test pieces shall be as follows:

- transverse to the major axis of the fitting for $D \geq 210$ mm;
- longitudinal to the major axis of the fitting for $D < 210$ mm.

Transverse test pieces shall be cold-flattened. Round bar made from a test piece may be used. Round-bar test pieces machined from unflattened samples may be used by agreement.

Welds shall be ground flush. Local imperfections and mill scale shall be removed.

9.4.2.2 Test method

Tensile testing at ambient temperature shall be carried out in accordance with ISO 6892. If specified, tensile testing at elevated temperatures shall be carried out in accordance with ISO 783. The frequency and acceptance criteria shall be by agreement.

For base metal, $R_{t0,5}$, R_m , and percentage elongation after fracture shall be determined. For tensile tests transverse to the weld, it is required only to determine R_m .

The percentage elongation after fracture shall be reported with reference to a gauge length of $5,65\sqrt{A_0}$. If other gauge lengths are used, the elongation referred to a gauge length of $5,65\sqrt{A_0}$ shall be determined in accordance with ISO 2566-1.

9.4.2.3 Requirements

The tensile properties shall meet the requirements of the corresponding part of ISO 3183.

Table 4 — Chemical composition for product analyses

Element	Maximum permitted alloy content, mass fraction, %		
	Class A	Classes B and C	Class CS
C	0,20	0,18	0,18
Mn	1,60	1,60	1,30
Si	0,40	0,40	0,40
P	0,025	0,025	0,025
S	0,010	0,010	0,003 ^a
V	0,10	0,10	0,10
Nb	0,05	0,05	0,05
Ti	0,04	0,04	0,04
Cr	0,25	0,25	0,25
Mo	0,10	0,10	0,10
Ni	0,50	0,50	0,50
Cu	0,35	0,35	0,35
Al	0,05	0,05	0,05
N	0,012	0,012	0,012
B	0,000 5	0,000 5	0,000 5
Ca ^a	0,006	0,006	0,006
CE ^b	0,45	0,43	0,43
P_{cm}^c	0,23	0,21	0,21
V+Nb+Ti shall not exceed 0,15 %. Cr+Mo+Ni+Cu shall not exceed 0,6 %. Higher Cr, Mo and Ni content may be acceptable by agreement, where required for special applications such as low temperatures and/or thick sections. The total Al:N ratio shall not be less than 2:1.			
^a Ca:S ratio shall be a minimum of one (1) for S in the range 0,001 5 % to 0,003 0 %. ^b Carbon equivalent, calculated as follows: $CE = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$ ^c Crack measurement parameter, calculated as follows: $P_{cm} = C + \frac{Si}{30} + \frac{Ni}{60} + \frac{V}{10} + \frac{Mo}{15} + \frac{Cr + Mn + Cu}{20} + 5B$			

9.4.3 Charpy V-notch impact testing

9.4.3.1 Test pieces

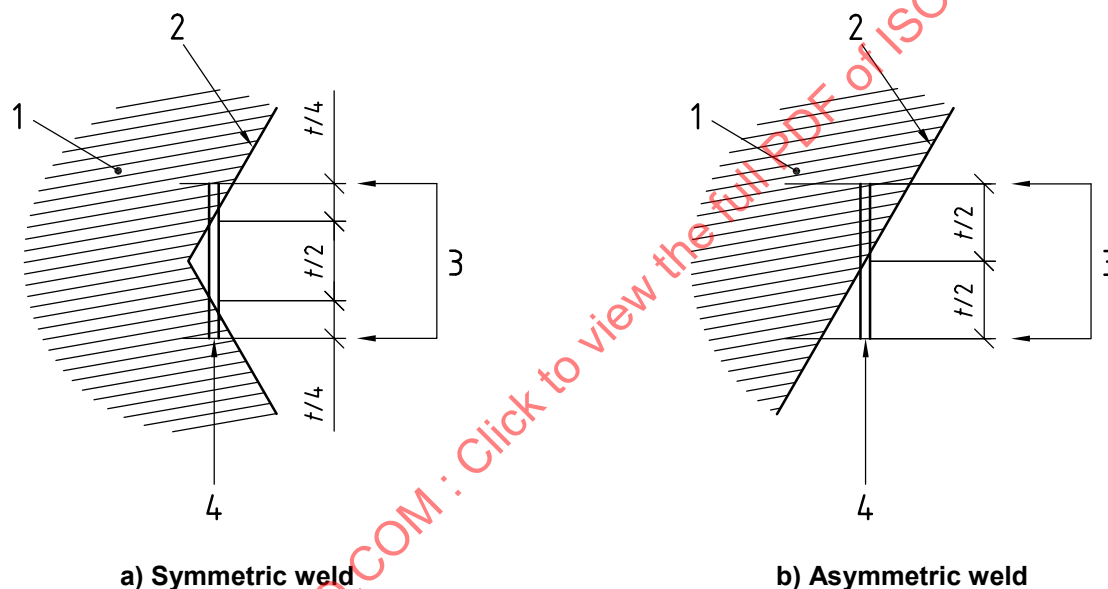
Charpy V-notch test pieces shall be prepared in accordance with ISO 148, with the axis of the notch perpendicular to the fitting surface.

The orientation and size of the test pieces shall be transverse with the greatest possible width between 5 mm and 10 mm. If transverse test pieces with a minimum width of 5 mm are not possible, longitudinal test pieces with the greatest possible width between 5 mm and 10 mm shall be used.

Impact testing is not required if the fitting dimensions are insufficient to extract longitudinal base metal test pieces with a minimum width of 5 mm.

Charpy V-notch test pieces shall be taken from the sample in accordance with ISO 3183-3.

Test pieces for welds shall be taken from the weld centreline. Test pieces of the fusion line should be taken by agreement, in which case the notch location shall be as shown in Figure 2.



Key

- 1 weld
 - 2 fusion line
 - 3 test piece edges
 - 4 Charpy notch
- t is the length of Charpy V-notch

Figure 2 — Location of Charpy V-notch in weld fusion lines

9.4.3.2 Test method

Each set of impact tests shall consist of three adjacent test pieces taken from a single, non-flattened sample.

Charpy V-notch impact testing shall be in accordance with ISO 148. An additional requirement to report shear area of the fracture surface shall be by agreement.

The impact test temperature shall be established in accordance with Table 5.

Table 5 — Maximum Charpy V-notch test temperature

Nominal wall thickness mm	Test temperature °C		
	Class A	Class B	Class C
$t \leq 20$	By agreement	$T_{d, \min}$	$T_{d, \min} - 10$
$20 < t \leq 25$	By agreement	$T_{d, \min}$	$T_{d, \min} - 20$
$t > 25$	By agreement	By agreement	By agreement
In no case shall the test temperature exceed 0 °C.			

9.4.3.3 Requirements

The results of the Charpy V-notch impact tests shall meet the following requirements.

- a) For each set of tests, the minimum average absorbed energy, in joules, in the transverse direction shall be

$$\frac{R_{\text{smys}}}{10}$$

where R_{smys} is the specified minimum yield strength, expressed in megapascals.

For steel grade L245, the minimum average Charpy-V absorbed energy in the transverse direction shall be 27 J.

- b) The minimum individual value in any set of tests shall not be less than 75 % of the minimum required average value.
- c) The minimum average and minimum individual values when testing test pieces taken in the longitudinal direction shall be 1,5 times the values stated for transverse test pieces.
- d) If specified (see 9.4.3.2), the shear area shall be an average of 50 % with a minimum individual value of 40 %.

For subsize test pieces, the minimum required absorbed energy values shall be adjusted in accordance with ISO/TR 7705:1991, Clause 6.

9.4.4 Through-thickness hardness testing

9.4.4.1 Test method

Through-thickness hardness testing shall be performed using the Vickers method in accordance with ISO 6507-1, method HV 10 (i.e. with a test force of 98,07 N).

Hardness indent locations for welded fittings shall be in accordance with Figure 3. For seamless fittings, hardness indent locations shall be made at a distance of 1 mm to 2 mm from the inside and outside surfaces containing four indents spaced at 5 mm arranged similarly to Figure 3.

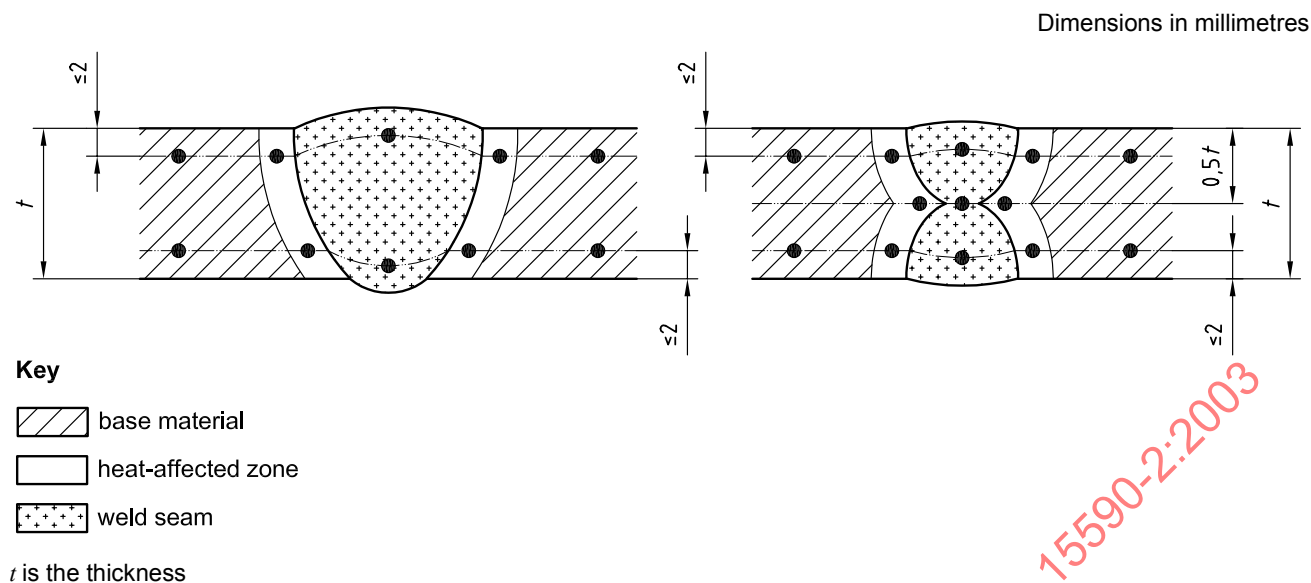


Figure 3 — Hardness indent locations for welded fittings

9.4.4.2 Acceptance criteria

No hardness reading shall exceed

- 300 HV 10 for class A, B and C fittings,
- 250 HV 10 for class CS fittings.

9.4.5 Surface hardness testing

The test method and acceptance criteria shall be established by agreement.

9.4.6 Metallographic examination

9.4.6.1 Test method

The specimens for through-thickness hardness testing shall be examined, prior to hardness testing, at a magnification of not less than $\times 100$. Grain-size measurement shall be performed in accordance with ASTM E 112.

The type of microstructure and actual grain size shall be recorded on the manufacturing procedure qualification test report.

9.4.6.2 Acceptance criteria

The minimum average grain size number shall be 7.

9.4.7 HIC testing

If HIC testing is specified, the test procedures and acceptance criteria shall be in accordance with EFC Publication 16:1995, Annex B.

9.4.8 SSC testing

If SSC testing is specified, test procedures and acceptance criteria shall be in accordance with EFC Publication 16.

9.4.9 CTOD testing

CTOD testing is not required for any fitting class, except by agreement.

Test methods and requirements shall be decided by agreement.

9.4.10 Guided weld bend testing

9.4.10.1 Test pieces

The test pieces shall be in accordance with ISO 7438.

Full-thickness curved-section test pieces are required for fittings with wall thicknesses of 20 mm and above. For fittings with a wall thickness less than 20 mm, the test pieces may be machined to provide a rectangular cross-section with a thickness of 19 mm. The weld reinforcement shall be removed from both faces.

9.4.10.2 Test method

The mandrel dimensions shall be as defined in the corresponding part of ISO 3183 for the grade of fitting.

Both test pieces shall be bent through approximately 180°, one with the root of the weld and the other with the face of the weld directly under the mandrel.

9.4.10.3 Acceptance criteria

The test pieces shall

- a) not fracture completely,
- b) not reveal any crack or rupture in the weld metal greater than 3 mm in length, regardless of depth,
- c) not reveal any crack or rupture in the parent metal, heat-affected zone or fusion line longer than 3 mm and deeper than the wall thickness tolerance of the matching pipe.

Cracks that occur at the edges of the specimen and that are less than 6 mm in length shall not be cause for rejection, regardless of their depth.

If a fracture or crack in a test piece is caused by imperfections, the test piece may be discarded and a new test piece substituted.

9.5 Non-destructive testing

9.5.1 NDT procedures and personnel

All NDT shall be conducted in accordance with documented procedures. If specified by the purchaser, NDT procedures shall be decided by agreement before commencement of fitting manufacture.

All NDT personnel shall be qualified and certified in accordance with ISO 9712 to the appropriate level of competence. The minimum level of competence for UT shall be NDT level 2.

9.5.2 Condition of fittings

Except where radiography of the weld seam of the starting material has been specified (see Table 2), all NDT for acceptance of fittings in accordance with the requirements of this part of ISO 15590 shall be performed after final heat treatment of fittings.

The surface to be examined shall be dry and free of all dirt, grease, lint, scale, welding flux and spatter, oil or other extraneous matter that could interfere with NDT.

Fitting surfaces shall be finished so that surface imperfections can be detected by visual inspection.

9.5.3 Treatment of imperfections

9.5.3.1 Defects

Fittings shall be free of the following defects:

- a) dents with sharp-bottom gouges;
- b) dents, without sharp-bottom gouges, exceeding 3 mm in depth;
- c) peaks exceeding 3 mm in height;
- d) hard spots;
- e) weld reinforcement exceeding 3 mm, for fittings with a wall thickness of 12 mm or less;
- f) weld reinforcement exceeding 4 mm for fittings with a wall thickness greater than 12 mm;
- g) incompletely-filled weld preparations;
- h) radial offset of plate edges, or plate misalignment, exceeding 2 mm, for fittings with a wall thickness of 12 mm or less;
- i) radial offset of plate edges, or plate misalignment, exceeding 3 mm, for fittings with a wall thickness greater than 12 mm;
- j) laps, flats, tears, pulls and similar defects.

NOTE Definitions and visual examples of some of these imperfections can be found in ASM International's Metals Handbook.

9.5.3.2 Treatment of surface imperfections

Imperfections not classified as defects may remain in the fitting without repair. Localized grinding, however, may be performed.

9.5.3.3 Treatment of dressable surface defects

All dressable surface defects shall be dressed out by grinding. Grinding shall be carried out in such a way that the dressed area blends in smoothly with the contour of the pipe. Complete removal of defects shall be verified by local visual inspection, aided if necessary by suitable NDT methods. After grinding, the remaining wall thickness in the dressed area shall be checked for compliance with 9.6.

9.5.3.4 Treatment of non-dressable surface defects

Fittings containing non-dressable defects shall be given one of the following dispositions.

- Weld defects in welded fittings shall be repaired in accordance with 9.5.3.5.
- The fitting shall be rejected.

9.5.3.5 Repair of defects by welding

Repair by welding on weld seams may be performed only by the following processes:

- submerged arc welding;
- manual metal-arc welding;
- metal inert gas/metal active gas welding;
- tungsten inert gas welding.

Weld defects separated by less than 100 mm shall be repaired as a continuous single weld repair.

Each single repair shall be carried out with a minimum of two weld passes over a minimum length of 50 mm.

The weld repair work shall be performed using procedures qualified in accordance with 8.3.2.

After weld repair, the total area of the repaired zone shall be subjected to RT in accordance with 9.5.5.

9.5.4 Fitting ends

The complete end preparation shall be subjected to MT in accordance with ISO 13664, or PT in accordance with ISO 12095. The MT technique should employ fluorescent ink.

For MT and PT, linear indications with a length less than 2 mm shall be acceptable.

For class B and C fittings, a 50-mm wide band at each end shall be inspected for laminar imperfections by UT in accordance with ISO 11496. This 50-mm band shall extend from the intersection of the weld bevel and fitting outside diameter back along the body of the fitting. Laminar imperfections shall not exceed a length of 6 mm in the circumferential direction and their area shall not exceed 100 mm².

9.5.5 Weld seams

Weld seams shall be subjected to RT in accordance with ISO 12096. The image quality class shall be R1. The acceptance criteria shall be in accordance with ISO 12096. Instead of radiographic examination, ultrasonic examination may be substituted by agreement.

9.5.6 Guide bar attachment welds

Guide bar attachment welds shall be subjected to MT in accordance with ASTM E 709.

9.5.7 Fitting body

If specified, the methods and acceptance criteria for fitting body NDT shall be decided by agreement prior to fitting manufacture.

9.5.8 Residual magnetism

The residual magnetic flux density at the fitting ends shall not exceed 3 mT.

9.6 Dimensions

Dimensions and tolerances shall be in accordance with MSS SP-75 and, for nominal sizes less than DN 400, ASME B16.9.

9.7 Gauging

The requirements for gauging, including pigging assessments, shall be decided by agreement.

9.8 Hydrostatic testing

Hydrostatic testing of fittings may be omitted, unless otherwise specified. If hydrostatic testing is omitted, the manufacturer shall certify that the fitting will withstand an internal pressure at least as high as that specified for the mating pipe.

10 Inspection document

The required ISO 10474 designation of inspection document, and any specific requirements for format and content of the document, shall be specified.

11 Marking

One or both ends of each fitting shall be marked with the following information:

- purchase order and item number;
- fitting designation, as defined in Clause 5;
- nominal wall thickness at the fitting ends;
- dimensions;
- heat number or manufacturer's heat identification;
- manufacturer's name or trademark;
- any additional marking specified in the purchase order.

For fittings designed with a lower SMYS than the matching pipe, both the fitting designation and the intended matching pipe grade shall be marked:

Markings shall be made with indelible paint on the inside surface or, if it is not possible to mark on the inside surface (i.e. for smaller diameter fittings), on the outside.

For fittings of DN 100 and larger, markings shall be executed in block capitals of minimum height of 19 mm. For smaller fittings, the character height shall be appropriate. Identification markings shall not be applied on weld bevels.

In addition to paint-marking, the manufacturer's unique fitting identification number shall be die-stamped on a weld bevel of each fitting.

Annex A (normative)

Design calculations

A.1 Elbows

The minimum wall thickness of the extrados shall be equal to t .

The wall thickness of the intrados shall be determined from the following formula:

$$t_i = t \times E$$

where

t_i is the minimum wall thickness required in the elbow intrados;

E is a factor given in Table A.1.

Table A.1 — E -values for intrados wall thickness calculation

R/D^a	E
1 ^b	1,25
1,5 ^c	1,1
3	1,04
Intermediate values may be interpolated.	
^a Elbow centreline radius divided by outside diameter. ^b Known as a short-radius elbow. ^c Known as a long-radius elbow.	

A.2 Caps

Caps shall be ellipsoidal in shape with base radius to depth ratio of 2:1. Approximation of ellipsoidal shape by spherical radii (head $0,9 \times$ base diameter and knuckle $0,17 \times$ base diameter) may be performed. A straight skirt length shall be included in the cap. The minimum wall thickness within the body of the cap, the knuckle, and the straight skirt shall be equal to t .

A.3 Reducers (eccentric or concentric)

A.3.1 Reducers with tangents

Reducers shall consist of a reduction section which is essentially conical, tangents at each end, and knuckle radii joining the conical section to the tangents. The following rules shall apply to the reducer design.

- a) The cone angle shall not exceed 30° .