International Association of Oil & Gas Producers

SPECIFICATION
S-616

JANUARY
2019

Supplementary Specification to API Specification 5L and ISO 3183 Line Pipe

Revision history

VERSION	DATE	AMENDMENTS
1.0	January 2019	Issued for publication

Acknowledgements

This IOGP Specification was prepared by a Joint Industry Project 33 Standardization of Equipment Specifications for Procurement organized by IOGP with support by the World Economic Forum (WEF).

Foreword

This specification was prepared under a Joint Industry Project 33 (JIP33) "Standardization of Equipment Specifications for Procurement" organized by the International Oil & Gas Producers Association (IOGP) with the support from the World Economic Forum (WEF). Ten key oil and gas companies from the IOGP membership participated in developing this specification under JIP33 Phase 2 with the objective to leverage and improve industry level standardization for projects globally in the oil and gas sector. The work has developed a minimized set of supplementary requirements for procurement, with life cycle cost in mind, based on the ten participating members' company specifications, resulting in a common and jointly approved specification, and building on recognized industry and international standards.

This specification has been developed in consultation with a broad user and supplier base to promote the opportunity to realize benefits from standardization and achieve significant cost reductions for upstream project costs. The JIP33 work groups performed their activities in accordance with IOGP's Competition Law Guidelines (November 2014).

Recent trends in oil and gas projects have demonstrated substantial budget and schedule overruns. The Oil and Gas Community within the World Economic Forum (WEF) has implemented a Capital Project Complexity (CPC) initiative which seeks to drive a structural reduction in upstream project costs with a focus on industry-wide, non-competitive collaboration and standardization. The vision from the CPC industry is to standardize specifications for global procurement for equipment and packages, facilitating improved standardization of major projects across the globe. While individual oil and gas companies have been improving standardization within their own businesses, this has limited value potential and the industry lags behind other industries and has eroded value by creating bespoke components in projects.

This specification aims to significantly reduce this waste, decrease project costs and improve schedule through pre-competitive collaboration on standardization. This document defines the supplementary requirements to recognized industry standard API Specification 5L 46th Edition, 2018 including Errata 1 2018, Line Pipe and ISO 3183, 4th Edition[1], 2019, Steel pipe for pipeline transportation systems, which are indispensable for the application of this specification.

Following agreement of the relevant JIP33 work group and approval by the JIP33 Steering Committee, the IOGP Management Committee has agreed to the publication of this specification by IOGP. Where adopted by the individual operating companies, this specification and associated documentation aims to supersede existing company documentation for the purpose of industry-harmonized standardization.

[1] At the time of publishing IOGP S-616, this 4th edition of ISO 3183 is not yet published.

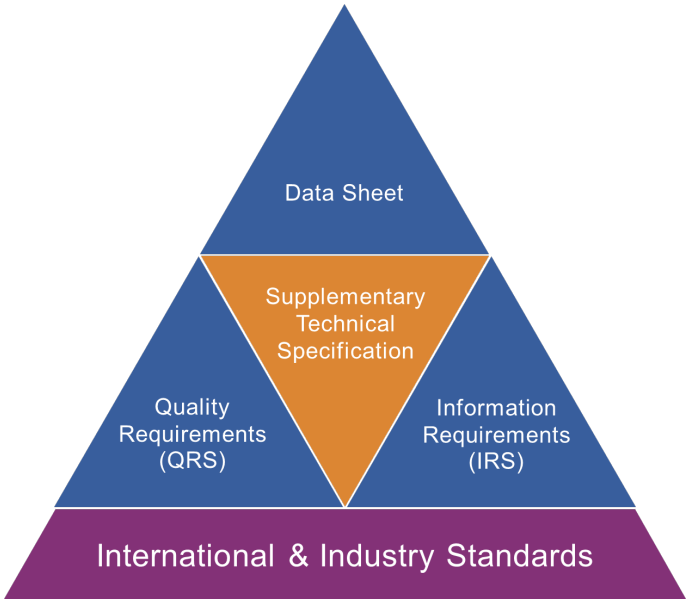
Table of Contents

Introduction

The purpose of this specification is to define a minimum common set of supplementary requirements for procurement of line pipe to API Specification 5L 46th Edition 2018 including Errata 1 2018 and ISO 3183 4th Edition 2019 for application in the petroleum and natural gas industries.

This specification may also be applied to line pipe manufacturing for pipelines designed according to other design standards. It is the responsibility of the manufacturer to comply with the manufacturing requirements of the selected design code and this specification.

This JIP33 standardized procurement specification follows a common document structure comprising the four documents as shown below, which together with the purchase order define the overall technical specification for procurement.



JIP33 Specification for Procurement Documents
Supplementary Technical Requirement

It is required to use all of these documents in conjunction with each other when applying this specification, as follows:

IOGP S-616: **Supplementary specification to API Specification 5L and ISO 3183 Line Pipe**

This specification is written as an overlay to API 5L, following the clause structure of the parent standard (API 5L), to assist in cross-referencing the requirements. Where clauses from the parent standard are not covered in this specification, there are no supplementary requirements or modifications to the respective clause. The terminology used within this specification follows that of the parent standard and otherwise is in accordance with ISO/IEC Directives, Part 2.

Modifications to the parent standard defined in this specification are identified as *Add* (add to clause or add new clause), *Replace* (part of or entire clause) or *Delete*.

IOGP S-616D: **Line Pipe Material Data Sheet (LPMDS) for IOGP S-616**

This document provides project specific requirements where the supplementary specification and its parent standard require the purchaser to define an application specific requirement. It follows the clause structure of the parent standard and this specification. It also includes information required by the purchaser for technical evaluation. Additional purchaser supplied

documents are also listed in the data sheet, to define scope and technical requirements for enquiry and purchase of the equipment.

IOGP S-616L: Information requirements (IRS) for Line Pipe

This document defines the information requirements, including format, timing and purpose, for information to be provided by the manufacturer. It also defines the specific conditions which must be met for conditional information requirements to become mandatory. The information requirements listed in the IRS have references to the source of the requirement.

IOGP S-616Q: Quality requirements (QRS) for Line Pipe

This document includes a conformity assessment system (CAS) which specifies standardized purchaser interventions against quality management activities at four different levels. The applicable CAS level is specified by the purchaser in the datasheet.

The LPMDS and IRS are published as editable documents for the purchaser to specify application specific requirements. The supplementary specification and QRS are fixed documents.

Unless defined otherwise in the requisition, the order of precedence (highest authority listed first) of the documents shall be:

a) regulatory requirements;

b) contract documentation (e.g. purchase order);

c) user defined requirements (LPMDS, IRS, QRS);

d) this specification;

e) the parent standard.

1 Scope

1.1 Coverage

Replace section with

This supplementary specification is limited to seamless pipes and single seam welded pipes manufactured in accordance with product specification level 2 (PSL 2).

Any section within API 5L or ISO 3183 that specifically relate to PSL1 line pipe, double seam welded pipes, jointers, intermediate grades, couplings and end welds are not relevant to the application of this specification and shall be considered as not applicable.

If line pipe is ordered to ISO 3183, the applicability of ISO 3183, Annex A for PSL 2 pipe ordered for European onshore natural gas transmission pipelines shall be specified in the LPMDS.

2 Normative References

Add to section

API Specification 5L:2018	Line Pipe
ISO 3183:2019	Petroleum and natural gas industries - Steel pipe for pipeline transportation systems NOTE At the time of publishing IOGP S-616, this 4th edition of ISO 3183 is not yet published. In the meantime, ISO DIS 3183:2018 may be used.
EFC Publication 16	Guidelines on Materials Requirements for Carbon and Low Alloy Steels for H_2S-Containing Environments in Oil and Gas Production
API RP 5L1	Recommended Practice for Railroad Transportation of Line Pipe
API RP 5LT	Recommended Practice for Truck Transportation of Line Pipe
API RP 5LW	Recommended Practice for Transportation of Line Pipe on Barges and Marine Vessels
ASME BPVC Section II Part C	Boiler and Pressure Vessel Code
ASME BPVC Section VIII	Rules for construction of pressure vessel
ASTM E9	Standard Test Methods of Compression Testing of Metallic Materials at Room Temperature
ASTM E45	Standard Test Methods for Determining the Inclusion Content of Steel
ASTM E112	Standard Test Methods for Determining Average Grain Size
ASTM E384	Standard Test Method for Knoop and Vickers Hardness of Materials
ASTM E1928	Standard Practice for Estimating the Approximate Residual Circumferential Stress in Straight Thin-walled Tubing
AWS A4.4M	Standard Procedures for Determination of Moisture Content of Welding Fluxes and Welding Electrode Flux Coverings
AWS A5.01/A5.01M	Filler metal – Procurement guidelines
AWS A5.1/A5.1M	Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding
AWS A5.5/A5.5M	Specification for Low Alloy Steel Covered Arc Welding Electrodes
AWS A5.17/A5.17M	Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding

AWS A5.18/A5.18M	Specification for Carbon Steel Filler Metal for Gas Shielded Arc Welding
AWS A5.23/A5.23M	Specification for Low Alloy Steel Electrodes and Fluxes for Submerged Arc Welding
AWS A5.28/A5.28M	Specification for Low Alloy Steel Filler Metal for Gas Shielded Arc Welding
AWS A5.32/A5.32M	Specification for Welding Shielded Gases
BS 8701	Full ring ovalization test for determining the susceptibility to cracking of linepipe steels in sour service - Test method
DNVGL-ST -F101	Submarine Pipelines Systems
ISO 3690	Welding and allied processes - Determination of hydrogen content in arc weld metal
ISO 5817	Welding — Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded) — Quality levels for imperfections
ISO 14732	Welding personnel - Qualification testing of welding operators and weld setters for mechanized and automatic welding of metallic materials
ISO 17637	Non-destructive testing of welds - Visual testing of fusion-welded joints
ISO 17639	Destructive tests on welds in metallic materials - Macroscopic and microscopic examination of welds
ISO 17640	Non-destructive testing of welds - Ultrasonic testing - Techniques, testing levels, and assessment
NACE MR0175/ ISO 15156-1	Petroleum and natural gas industries - Materials for use in H2Scontaining environments in oil and gas production - Part 1: General principles for selection of cracking-resistant materials
NACE MR0175/ ISO 15156-2	Petroleum and natural gas industries - Materials for use in H2Scontaining environments in oil and gas production - Part 2: Cracking-resistant carbon and low-alloy steels, and the use of cast irons
NACE TM0316	Four-Point Bend Testing of Materials for Oil and Gas Applications

3 Terms, Definitions, Symbols, and Abbreviations

3.1 Terms and Definitions

Add to section

3.1.66
inspector
The purchaser's representatives or members from an inspection agency duly appointed by the purchaser and thus notified to the manufacturer, and shall be referred to herein as the "inspector".

3.1.67
contract
The purchase order together with all material requisitions, specifications, etc. issued by the purchaser and attached to the contract or the purchase order shall be referred to herein as the "contract".

3.1.68
acceptance
Authorization given in writing by the purchaser to the manufacturer on a procedure or to proceed with the performance of a specific part of the work without releasing in any way the manufacturer from any of its obligations to conform to the technical specifications, requisitions, etc. "Accept", "accepted" and "acceptance" shall be construed accordingly. Acceptance of a deviation may override the technical requirement from the specification.

3.1.69
integrated mills
A steelworks which manufactures not only final pipe products but also their material of billets/slabs and starting material of plates/coils used for the pipe products.

3.1.70
systematic imperfections
Imperfections that are not classified as defects but that are repeatedly distributed in the weld over the weld length to be examined.

3.1.71
coarse grain
Area affected by welding exhibiting a grain growth.

3.2 Symbols

Add to section

α_{fab}	fabrication factor
M	mean value
T_O	test temperature
T_{min}	minimum design temperature
Sd	standard deviation (of wall thickness)

3.3 Abbreviations

Add to section

AUT	automatic ultrasonic testing
AWMT	all weld metal tensile test
CAR	crack area ratio
CGHAZ	coarse grain heat-affected zone
CO	cut-off
CR	computed radiography
CCW	counterclockwise
CW	clockwise
DAC	distance amplitude curve
DBTT	ductile brittle transition temperature
DDA	digital detector array
DHC	delayed hydrogen cracks
DR	digital radiography
EMAT	electro magnetic acoustic transducer
EMI	electromagnetic inspection
FBE	fusion bonded epoxy
FBH	flat bottom hole

FL	fusion line
FL2	fusion line + 2 mm (0.08 in.)
FSH	full screen height
LPMDS	line pipe material datasheet (see IOGP S-616D)
MPfB	mother pipe for bends
MPQT	manufacturing process qualification testing
MPS	manufacturing procedure specification
MUT	manual ultrasonic testing
NCR	nonconformance request
PRG	primary reference gain
PQR	procedure qualification record
PRL	primary reference level
PWHT	post-weld heat treatment
pWPS	preliminary welding procedure specification
RCA	root cause analysis
RDH	radially-drilled hole
RT	radiographic testing
SAUT	semi-automated ultrasonic testing
SCR	steel catenary riser
SDH	side-drilled hole
SOHIC	stress orientated hydrogen induced cracking
S/N	signal/noise ratio
SS	scanning sensitivity
TC	transfer correction
TCG	time-corrected gain
ToFD	time of flight diffraction
UEL	uniform elongation

5 Compliance to this Standard

5.1 Quality

Replace section with

The manufacturer shall be previously audited or accepted by the purchaser.

All sub-contractors (e.g. raw material supplier, NDT supplier, etc.) shall be clearly identified at the bid stage and accepted by the purchaser.

Quality plans and inspection and test plans, developed as outputs to operational planning and control for the products and services, shall define the specific controls to be implemented by the manufacturer and when applicable sub-manufacturers to ensure conformance with the specified requirements.

Controls shall address both internally and externally sourced processes products and services.

Quality plans and inspection and test plans shall include provisions for:

a) PSL 2 in accordance with this specification and the LPMDS;

b) CAS as specified in IOGP S-616Q and the LPDMS.

5.3 References to Annexes

Add to section

The following normative appendices address aspects not covered within the parent standard main sections or annexes;

- welding consumables, see Appendix 1;
- weldability test, see Appendix 2;
- qualification of NDT at plate/coil and pipe mill, see Appendix 3;
- NDT procedure minimum content, see Appendix 4.

Pipe ordered for onshore and offshore fatigue service shall comply with Annex J.

NOTE For fatigue service, the purchaser shall consider premium pipe dimension tolerances as per Annex J and surface condition requirements from N.5.

Add new section

5.4 Minimum Inspection Requirements

The manufacturer shall notify the purchaser and inspector with a sufficient notice period to enable their attendance at qualification tests, and at all other tests or stages of manufacture which are subject to acceptance in accordance with this specification. The notice period for intervention points shall be agreed at the kick-off meeting.

The manufacturer shall ensure that the purchaser and the inspector have full and free access to all parts of the mill during all manufacturing and inspection stages, without interfering with normal mill production.

Free access to records from the mill's computerized system shall be made available to the inspector.

Where the mill country language is not English, all procedure required for review and all tests certificates shall be written in two languages, i.e. the native language of the country in which the mill is located and English.

If during the main production more than 10 % of the pipes are rejected in any single day's production or re-routed for repairs or re-processing, the purchaser or inspector shall have the right to instruct the manufacturer to increase his quality control program to an appropriate level, and to maintain it at that level until the causes of the defective quality are identified and eliminated. A corrective action request will be sent by the inspector to the manufacturer. Production will not be accepted until a response with positive results is accepted by inspector.

If the above reaches 15 %, the purchaser or inspector may require the main production to be stopped. In such a case, the purchaser is entitled to require a program of investigation to determine the root cause of the defective quality. This program will be established in mutual agreement between the purchaser and the manufacturer. The rest of production shall be put on hold until the investigations are concluded and the purchaser has accepted that production can be resumed.

NOTE An indication found but later cleared by additional NDT checks shall not be part of the above repair rate ratio.

Add new section

5.5 Technical Queries, Concession Requests and Nonconformance Reports

After contract award, any manufacturer's requests for clarifications or deviations to specifications shall be submitted to the purchaser only through technical queries or concession requests, the format of which shall have prior acceptance by the purchaser.

Acceptance given by the purchaser to any manufacturer's work procedures, specifications, equipment, etc. shall not release the manufacturer in any way from their obligation to meet the specifications of the contract.

Any work performance or test result not in conformance with the purchaser's specifications or agreed procedure shall be subject to a nonconformance request (NCR), to be issued by the manufacturer for the purchaser's acceptance. Each NCR report shall state the corrective action proposed by the manufacturer. An NCR process including lead times for issue and response shall be agreed at contract award.

6 Pipe Grades and Steel Grades, and Delivery Condition

6.2 Delivery Condition

Add to section

NOTE Pipes fabricated from thermomechanical rolled material may not be suitable for hot (induction) bending unless the chemistry is modified to increase strength, or specific post bend heat treatments are undertaken.

7 Information to Be Supplied by the Purchaser

Add to section

Information to be supplied by the purchaser and options within this specification are covered in Table 28, Table 29 and the LPMDS.

7.2 Additional Information

Replace section with

Add new table

Table 28 – Items that Apply as Prescribed, Unless Otherwise Agreed

API 5L, 7.2 Item Number	Apply as Prescribed, Unless Otherwise Agreed	API 5L Section or Table Number	Purchaser Requirements (per this specification, as referenced below)
b) 1)	Range of sizing for cold-expanded pipe	8.9.2	8.9.2
b) 2)	Equation for sizing ratio	8.9.3	Sizing ratio shall be derived using API 5L Equation 1 in 8.9.3
b) 4)	Chemical composition limits for PSL 2 pipe	Table 5, footnotes c, e, f, g, h, i, k and l	9.2 (Table J.1 and LPMDS)
b) 11)	Product analysis method	10.2.4.1	Product analysis method shall be specified in MPS by the manufacturer
b) 12)	Alternate method for diameter measurement for D ≥ 508 mm (20.000 in.)	10.2.8.1	10.2.8.1
b) 15)	Repairs in cold-expanded pipe	C.4.2	C.4.2

Add new table

Table 29 – Items that Apply, if Agreed

API 5L, 7.2 Item Number	Items that Apply, if Agreed	API 5L Section or Table Number	Purchaser Requirements (per this specification, as referenced below)
c) 10)	CVN impact test of the longitudinal seam weld of PSL 2 HFW pipe	9.8.3 and Table 18	9.8.3 and Table 18
c) 23)	Use of an alternative to macrographic examination	10.2.5.2	Not applicable
c) 39)	Multiple grade marking	11.4.1	Not allowed
c) 43)	Manufacturing procedure qualification for PSL 2 pipe, in which case Annex B shall apply	B1.1	Annex B
c) 44)	Radiographic inspection of SAW seam or coil/plate end weld	Table E.1	E.1
c) 46)	NDT of EW seam welds after hydrotest	E.3.1.3 b)	E.3.1.3
c) 47)	Ultrasonic inspection of welded pipe for laminar imperfections at pipe ends	E.3.2.3	E.3.2.3
c) 48)	Ultrasonic inspection of SMLS pipe for laminar imperfections at pipe ends	E.3.3.2	E.3.3.2
c) 50)	Use of both holes and notches in ultrasonic reference standard	Table E.7	Tables E.7.1, E.7.2, E.7.3 and E.7.4
c) 51)	Alternative re-inspection technique for COW seams	E.5.5.5	E.5.6
c) 52)	Ultrasonic inspection for laminar imperfections in the pipe body of EW, SAW or COW pipe	E.8	E.8
c) 53)	Ultrasonic inspection for laminar imperfections along the coil/plate edges or the weld seam of EW, SAW or COW pipe	E.9	E.9

8 Manufacturing

8.2 Processes Requiring Validation

Replace section with

Any change to the essential manufacturing process parameters beyond the limit qualification of the MPQT shall require requalification (see Annex B).

8.3 Starting Material

8.3.2

Delete item c)

8.3.3

Add to section

The manufacturer shall demonstrate that clean steel making practices are used and specific treatment to control inclusions size, shape and distribution are employed to produce the quality steel required to manufacture the pipes according to this specification.

If specified in the LPMDS, inclusion content shall be tested on the first and last heat of each casting sequence.

For HFW pipes, inclusion control with respect to content, distribution and shape shall be performed by desulfurizing, degassing, and either calcium injection or rare earth metal treatment.

If steel scrap is used, a procedure for scrap management shall be issued. External scraps deliveries shall be checked for radioactivity.

Hydrogen control practice for billets and slabs shall be applied (see 9.2.6).

The manufacturer shall record details of the casting sequences (e.g. casting strand, number of heats, tons, scrapping lengths). These parameters shall be available for inspector review, if requested.

8.3.5

Add to section

The width of the strip after edge machining or milling shall be continuously monitored and recorded.

The practice for cropping of the strip end shall be detailed in the manufacturing procedure qualification (MPS) and the minimum crop length shall be qualified.

Rolling mill edges shall be removed before welding. Plate or strip shall be cut to the required width and the weld bevel prepared by milling or machining before forming.

Rotary shearing is not permitted with the exception of, for pipe of 8 mm (0.315 in.) wall thickness or less, with a pipe diameter of 273 mm (10 in.) or less, and with a pipeline design temperature of not less than -10 °C, unless specified otherwise in the LPMDS.

If slitting is performed, the details of slitting, including precautions taken to address adverse effects of segregations (e.g. additional metallographic investigation, macros, hardness including frequency), shall be included in the MPS and agreed between the purchaser and the manufacturer.

Replace 8.3.6 with

8.3.6 Any lubricant or contamination on the weld bevel or the surrounding areas [minimum 100 mm (3.94 in.)] shall be removed before making the seam welds (tack weld and SAW weld). The weld bevel shall be clean and completely dry.

Add new section

8.3.10 Inspection documents for plate/coils: except for integrated mills, the manufacturer shall issue a 3.1 inspection certificate in accordance with ISO 10474 or EN 10204.

Alternatively, if specified in the LPMDS, a 3.2 inspection certificate in accordance with ISO 10474 or EN 10204 shall be issued.

In all cases (integrated or non-integrated mills), reports of all tests and inspections carried out on plates and coils in accordance with this specification shall be prepared. The reports shall include results of the following:

a) heat and product analyses;

b) mechanical tests;

c) through thickness metallographic examination;

d) visual inspection;

e) thickness measurements;

f) ultrasonic inspection.

Format of mill certificates shall be agreed between the purchaser and the manufacturer prior to the start of production.

The mill certificates shall identify the heat and slab from which each plate or coil was produced. Mill certificates shall clearly indicate the as-delivered condition of plates (e.g. normalized, controlled rolled with accelerated cooling).

8.4 Tack Welds

8.4.1

Add to section

Tack welding shall be continuous and performed by an automatic welding process.

Manual welding is allowed but shall be restricted to pipe ends.

The tack welding process and the maximum thickness of the tack weld shall be specified within the welding procedure specification (WPS).

Tack welding shall be performed in accordance with the purchaser's accepted WPS.

Add new section

8.4.3 Repair of a tack weld by manual welding is permitted provided that the weld is ground down to the thickness of the automatic pass.

Repair of a tack weld (excluding the manual weld at pipe ends) shall be recorded, and a dedicated repair ratio maintained and reported to the purchaser.

8.6 Weld Seams in SAW Pipe

Replace section with

For the production of weld seams in SAW pipe, the first pass shall be made on the inside of the pipe and at least one submerged-arc welding pass shall be made on the outside of the pipe.

Unless otherwise agreed by the purchaser, run-on and run-off tabs shall always be used. Run-on and run-off tabs shall be grooved to match the seam weld groove geometry. If not grooved, the pipe ends shall be cropped off.

Tabs length shall be sufficient to establish the arc regime and ensure completion of welding outside the pipe seam. The minimum tab length shall be reported in the MPS and qualified during MPQT.

After completion of the longitudinal seam weld, the run-on and run-off tabs shall be removed. Mechanical breaking of tabs is not allowed.

Welding:

- Tolerances shall be in accordance with Annex B.

SAW:

- Welding equipment shall include a weld seam tracking system to ensure complete interpenetration and overlap of the inside and outside welds (see 9.13.3).

Flux coverage:

- Flux coverage of all arcs is mandatory. Visible arcs are not permitted.
- The flux shall meet the requirements specified in Appendix 1.

8.8 Treatment of Weld Seams in EW and LW

8.8.2 LW Pipe and PSL 2 HFW Pipe

Replace section with

For each grade which is not subjected to quench and temper processing, the full thickness of the weld seam and HAZ shall be normalized above the upper critical transformation temperature of the steel.

The heat treatment area shall be extended to the base metal by the lesser of 30 mm (1.18 in.) or twice the pipe wall thickness measured on the internal surface.

Cooling by water is permitted when this area has a temperature of 250 °C (482 °F) or below, unless qualified to allow a higher temperature prior to water cooling.

Weld seam heat-treating equipment shall include a weld seam tracking system to ensure full coverage of the weld:

a) This system shall be reviewed and accepted by the purchaser.

b) Heat treatment temperature shall be continuously monitored and recorded.

c) The records shall be available for review by the third-party inspector during production and until the order is shipped.

Alternate ways of ensuring adequate heat treatment and seam inspection may be proposed, but shall be reviewed and accepted by the purchaser.

Failure or abnormal operation of the seam heat treatment equipment, including the seam tracking and heating elements, shall trigger an alarm and automatic pipe marking.

If the seam heat treatment temperature does not meet the control range, such portions shall be discarded.

8.9 Cold Sizing and Cold Expansion

8.9.1

Add to section

The sizing ratio shall be recorded for three pipes per shift (at the beginning, middle and end of shift) or every 20 pipes per shift, whichever is greater and also on the MPQT pipe used for qualification of the MPS.

Replace 8.9.2 with

8.9.2 The sizing ratio for cold-expanded pipe shall not be less than 0.003 or greater than 0.015.

The sizing ratio shall be recorded for three pipes per shift (at the beginning, middle and end of shift) or every 20 pipes per shift, whichever is greater, and also on MPQT pipe used for qualification of the MPS.

Unless otherwise agreed by the purchaser, non-expanded pipes manufactured by press or roll bending processes are not acceptable unless full body heat treatment is performed.

NOTE Cold expansion of 0.8 % to 1.2 % has been found effective in controlling pipe dimensional and roundness tolerances, and in minimizing residual stresses resulted from pipe forming and welding operation.

8.12 Heat Treatment

Add to section

Furnace surveys shall be done at least once per year in accordance with an industry recognized standard e.g. NORSOK, ISO, API, ASTM, etc.:

- For austenitizing furnaces, temperature uniformity shall be ±14 °C (±25 °F).
- For tempering furnaces, temperature uniformity shall be ±8 °C (±15 °F).

Furnaces shall be equipped with recording sensors that are calibrated at least quarterly.

For quenching facilities, the coolant temperature shall be continuously monitored and remain below 40 °C (104 °F).

Essential variables including nozzle size, water flow rate and quenching conveyor speed shall be controlled for each production size.

Pipe with $\frac{D}{t} \leq 20$ shall be subject to stress relief heat treatment. Otherwise, an ageing test shall be carried out (see B.5.2.6).

MPQT shall be performed in the stress relief condition.

NOTE 1 Stress relief heat treatment should be performed by heating the pipe in accordance with the following:
- 20 °C (68 °F) lower than the mill tempering temperature for pipe with delivery condition QT or NT;
- The temperature should not be above 595 °C (1103 °F) for pipe with delivery condition M.

NOTE 2 See API 5L, 3.1.61.
NOTE 3 See ASME Section VIII UCS-56 for details of stress relieve heat treatment variables and tolerances.
NOTE 4 For sour service and demanding applications, quenching by spraying is not recommended.

8.13 Traceability

Add to section

Unless otherwise agreed, the manufacturer shall record the following heat identity properties, as applicable:

- date of production;
- casting sequence number;
- heat number;
- casting strand number;
- billet/slab sequence number;
- mother billet/slab;
- daughter billet/slab;
- mother pipe/plate;

– test unit identity.

The pipe numbering shall be agreed with the purchaser.

Add new section

8.14 Mother Pipes for Bends

Mother pipes should be from the same source and manufacturing procedure as the line pipes. Alternative sources or manufacturing methods of mother pipes shall be subject to the purchaser's acceptance.

If bend supply is under the responsibility of the manufacturer, the chemical composition and the mother pipe wall thickness and MPS shall be accepted by the bend fabricator.

NOTE If the bend supply is not within the manufacturer's scope, it is recommended that the purchaser validates the chemical composition and mother pipe MPS and wall thickness with the bend fabricator or by reviewing historical data.

9 Acceptance Criteria

9.1 General

Replace 9.1.2 with

9.1.2 Substitution of the ordered specific grade by another grade is not allowed.

9.2 Chemical Composition

Replace 9.2.2 with

9.2.2 For PSL 2 pipe with $t \leq 25.0$ mm (0.984 in.), the chemical composition for standard grades shall be as specified in API 5L, Table J.1.

9.2.3

Replace 9.2.3 with

For PSL 2 pipe with $t > 25.0$ mm (0.984 in.), the chemical composition shall be agreed with the purchaser, with the requirements of API 5L, Table J.1.being amended as appropriate.

Add new section

9.2.6 The manufacturer shall declare the target chemical composition and proposed range prior to order placement.

Permissible ranges are stated in Table 30, however in no case shall the chemical composition be outwith the limitations of API 5L, Table J.1.

Elements not intentionally added shall be declared.

After order placement, any change shall be subject to the purchaser's acceptance.

The chemical composition of the MPQT and the product analysis shall be within the target composition declared by the manufacturer. The manufacturer shall control the listed chemical elements even if the elements are considered as not intentionally added.

Where any of the elements in Table 30 are not intentionally added, the manufacturer may propose maximum values for approval by the purchaser.

The intentionally added elements that are not specified in Table 30 and API 5L, Table J.1 are not permitted.

Product analysis shall be performed under the responsibility of the pipe manufacturer.

Add new table

Table 30 – Chemical Composition Allowable Range (Weight Percentage)

Element	Allowable Range	Element	Allowable Range
C	0.040	**V**	0.030
Mn	0.200	**Nb**	0.020
P	N/A	**Ti**	0.014
S	N/A	**Al**	0.040
Ca	N/A	**N**	N/A
Si	0.300	**O**	N/A
Ni	0.100	**B**	N/A
Cr	0.100	**H**	N/A
Mo	0.100	**CE_{IIW}** [b]	0.060
Cu	0.060	**CE_{Pcm}** [b]	0.040
		CEN [a]	Info

a CEN shall be calculated for information

$$CEN = C + A(C)\left[\frac{Mn}{6} + \frac{Si}{24} + \frac{Cr + Mo + V}{5} + \frac{Cu}{15} + \frac{Ni}{20} + \frac{Nb}{5} + 5B\right]$$

$$A(C) = 0.75 + 0.25 \tanh [20(C - 0.12)]$$

b For CE_{IIW} and CE_{Pcm} the range shall be split equally around the agreed target value (allowable range: Target CE_{IIW} ± 0.030 and CE_{Pcm} ± 0.020)

9.3 Tensile Properties

Replace 9.3.2 with

9.3.2 For PSL 2 pipe, the tensile properties shall be as given in API 5L, Table J.2.

Unless otherwise specified in the LPMDS, the maximum $R_{t0.5}/R_m$ ratio specified in API 5L, Table J.2 applies.

When longitudinal tensile testing is specified in the LPMDS, the $R_{t0.5}/R_m$ in the longitudinal direction shall not exceed 0.95.

When specified in the LPMDS, tensile testing shall be performed at maximum design temperature and the acceptance criteria shall be in accordance with that given in the LPMDS and the design code.

During cross weld tensile testing, the test piece shall break in the base metal.

NOTE For temperatures above 50 °C (122 °F), it is advised to require elevated temperature tensile testing to confirm temperature de-rating.

9.4 Hydrostatic Test

Replace 9.4.1 with

9.4.1 The pipe shall withstand the hydrostatic test without leakage through the weld seam or the pipe body.

In case of failure:

a) Pipes that fail the hydrotest shall be quarantined until examined by the purchaser's inspector.

b) Failed pipes shall be removed from the hydrotest area and quarantined to a location where an investigation can be conducted to determine the cause of failure.

c) Results of the failure investigation shall be made available to the purchaser.

9.6 Flattening Test

Replace section with

Acceptance criteria for flattening tests shall be as follows:

a) No cracks or breaks shall occur in either weld or parent metal during flattening of the test specimen to 50 % of the original outside diameter.

b) The specimen shall be further flattened to 33 % of original outside diameter without cracks or breaks, other than in the weld.

9.8 CVN Impact Test for PSL 2 Pipe

9.8.2 Pipe Body Tests

Replace 9.8.2.1 with

9.8.2.1 For a set of three test pieces, the minimum average absorbed energy for each pipe body test shall be as given in Table 8, based upon full-size test pieces and a test temperature as specified in Table 31.

Replace Table 8 with

Table 8 – CVN Absorbed Energy Requirements for Pipe Body of PSL 2 Pipe

Specified Outside Diameter D mm (in.)	**Full-size CVN Absorbed Energy,** min K_V J (ft·lbf)						
	Grade						
	≤ L415 or X60	> L415 or X60 to ≤ L450 or X65	> L450 or X65 to ≤ L485 or X70	> L485 or X70 to ≤ L555 or X80	> L555 or X80 to ≤ L625 or X90	> L625 or X90 to ≤ L690 or X100	> L690 or X100 to ≤ L830 or X120
≤ 508 (20.000)	54 (40)	60 (44)	60 (44)	60 (44)	60 (44)	60 (44)	60 (44)
> 508 (20.000) to 762 (30.000)	54 (40)	60 (44)	60 (44)	60 (44)	60 (44)	60 (44)	60 (44)
> 762 (30.000) to 914 (36.000)	54 (40)	60 (44)	60 (44)	60 (44)	60 (44)	60 (44)	60 (44)
> 914 (36.000) to 1219 (48.000)	54 (40)	60 (44)	60 (44)	60 (44)	60 (44)	60 (44)	68 (50)
> 1219 (48.000) to 1422 (56.000)	54 (40)	60 (44)	60 (44)	60 (44)	60 (44)	68 (50)	81 (60)
> 1422 (56.000) to 2134 (84.000)	54 (40)	68 (50)	68 (50)	68 (50)	81 (60)	95 (70)	108 (80)

NOTE Only one test piece is allowed to have an individual value less than the minimum average value.

Add new table

Table 31 − CVN Impact Testing Temperature T_O (°C) as a Function of T_{min} (°C)

Specified Wall Thickness, *t* (mm)	**Pipelines and Risers**
$t \leq 20.0$	$T_O = T_{min}$
$20.0 < t \leq 30.0$	$T_O = T_{min} - 10$
$30 < t$	$T_O = T_{min} - 20$
NOTE A lower test temperature may be specified for gas service not covered by Annex G. This will be specified in the LPMDS.	

Replace 9.8.2.2 with

9.8.2.2 If specified in the LPMDS, for a set of three test pieces, the minimum average and individual shear fracture area for each test shall be at least 85 % and 75 % respectively, at the test temperature specified in Table 31.

9.8.3 Pipe Weld and HAZ Tests

Replace section with

For a set of three test pieces, the minimum average absorbed energy for each pipe weld and HAZ test shall be as specified in Table 8, based upon full-size test pieces and a test temperature as specified in Table 31.

If specified in the LPMDS, for a set of three test pieces, the minimum average and individual shear fracture area for each test shall be at least 75 % in the HAZ, at the test temperature specified in Table 31.

Replace section heading with

9.9 DWT Test for PSL 2 Pipe

Replace 9.9.1 with

9.9.1 If specified in the LPMDS, DWT testing shall be performed on seamless and welded pipes with $D \geq 406$ mm (16 in.).

The test shall be performed at the minimum design temperature specified in the LPMDS for a full thickness specimen.

For a reduced thickness specimen, test temperature shall be as per API RP 5L3.

DWT temperature reduction for a specimen with a thickness greater than 39.7 mm (1.56 in.) shall be by agreement with the purchaser.

The minimum average shear area of a set of two test pieces shall be 85 %.

9.10 Surface Conditions, Imperfections and Defects

9.10.1 General

9.10.1.1

Add to section

The external surface of all seamless pipes shall be free from scabs, laps, shells, slivers, burrs, metallurgical tears and sharp edged discontinuities that may interfere with the application of thin film [e.g. fusion bonded epoxy (FBE)] coatings, and multi-layer coatings where FBE forms the first layer.

Prior to manufacturing procedure qualification, the manufacturer shall propose the acceptance criteria for the surface condition of all seamless pipe, together with historic evidence of the successful FBE coating of such pipe without excessive remedial work.

Add new section

9.10.1.4 The pipe shall be substantially free of loose scale as assessed by the inspector.

9.10.2 Undercuts

Add to list

d) Undercuts which are coincident at the inside and outside welds are not permitted.

Replace section heading with

9.10.3 Arc Burns (Welded Pipes)

9.10.3.2

Add to section

If specified in the LPMDS, arc burns caused by arcing between copper-based materials (e.g. electrode holder, contact tip) shall be classified as defects and treated in accordance with API 5L, C.3 b) or C.3 c).

9.10.4 Laminations

Replace first sentence with

Any laminations or inclusions extending into the face or bevel of the pipe shall be classified as a defect.

9.10.5 Geometric Deviations

Replace 9.10.5.1 with

9.10.5.1 Other than for dents, geometric deviations from the normal cylindrical contour of the pipe (e.g. flat spots and peaks) that occur as a result of the pipe forming process or manufacturing operations, shall be considered defects and treated in accordance with API 5L, C.3 b) or C.3 c). This applies only to those deviations that exceed:

- 3.2 mm (0.125 in.) in depth (measured as the gap between the extreme point of the deviation and the prolongation of the normal contour of the pipe); or

- 25 % of pipe diameter or 300 mm (12 in.) in any direction whichever is smaller.

Replace 9.10.5.2 with

9.10.5.2 For dents, the length in any direction shall be ≤ 25 % of the pipe diameter with a maximum length of 300 mm (12 in.). The depth, measured as the gap between the extreme point of the dent and the prolongation of the normal contour of the pipe, shall be in accordance with the following:

a) No sharp-bottom dents are acceptable. For sharp bottom gouges, see 9.10.7.

b) Cold formed dents without sharp bottom gouges are acceptable to a maximum depth of 3.2 mm (0.125 in.).

c) Dents > 1.6 mm (0.0625 in.) are not acceptable at the pipe ends i.e. within a length of 100 mm (4 in.) at each of the pipe extremities.

Dents that exceed the specified limits shall be considered defects and shall be treated in accordance with API 5L, C.3 b) or C.3 c).

9.10.6 Hard Spots

Replace first sentence with

Any hard spot larger than 50 mm (2.0 in.) in any direction shall be classified as a defect if its hardness exceeds:

a) for grade X70 and below, 275Hv10;

b) for grade X80 and above, 325Hv10.

9.10.7 Other Surface Imperfections

Replace in item a)

"depth ≤ 0.125*t* " with "depth ≤ 0.05*t* "

Replace in item b)

"depth ≤ 0.125*t* " with "depth ≤ 0.05*t* "

Add to list

d) Any sharp bottom gouge shall be considered as a defect and treated in accordance with API 5L, C.3 b) or C.3 c).

9.11 Dimensions, Mass and Tolerances

9.11.3 Tolerances for Diameter, Wall Thickness, Length, and Straightness

9.11.3.1

Add to section

If specified in the LPMDS, tighter tolerances as per Table J.9 or API 5L, Table J.3 shall apply.

NOTE This may typically be required if automatic welding is required during fabrication.

9.11.3.4 Straightness

Replace in item a)

"0.2 %" with "0.15 %"

9.12 Finish of Pipe Ends

9.12.5 Plain Ends

9.12.5.2

Add to section

Beveling shall be carried out by machining only.

Any repair by grinding on the bevel edge, further to machine beveling, shall require full re-beveling.

Add new section

9.12.5.6 With the exception of weld reinforcement grinding (covered in 9.13.2), internal machining or grinding shall not be undertaken unless accepted by the purchaser. When accepted it shall be limited to the 200 mm (7.87 in.) at pipe ends, unless a longer length is specified in the LPMDS.

A procedure describing the remaining wall thickness check at pipe ends after machining shall be subject to acceptance by the purchaser.

Outside and inside burrs shall be removed by filing within 2 mm (0.08 in.), provided that the root face is not altered, to the satisfaction of the inspector.

9.13 Tolerances for the Weld Seam

9.13.1 Radial Offset of Strip/Plate Edges

Replace API 5L Table 14 with

API 5L, Table J.5.

9.13.2 Height of the Flash or Weld Bead/Reinforcement

Replace 9.13.2.1 with

9.13.2.1 The external flash shall be trimmed essentially flush with the pipe surface, with no visually noticeable radial step.

The internal flash shall not extend above the contour of the pipe by more than 0.3 mm (0.01 in.) + 0.05*t* [max 1.5 mm (0.06 in.)].

The trimming shall not reduce the wall thickness to below t_{min} .The groove resulting from the trimming shall have a smooth transition to the base material without notches, with a maximum depth of 0.05*t*.

Replace 9.13.2.2 with

9.13.2.2

a) Welds shall have a regular finish, merge smoothly into the base material and shall not extend beyond the original joint preparation by more than 8 mm (0.31 in.).

- For SAW and COW, the cap profile shall be subject to acceptance by the purchaser at the MPS stage.

- For SAWH/COWH weld beads, the weld cap profile shall exhibit minimal concavity.

- A sample of the weld cross section macro shall be retained as a standard sample of acceptable cap profile.

b) For a distance of at least 100 mm (4.0 in.) from each pipe end, the inside weld bead shall be ground flush to -0.0 mm, +0.5 mm (0.02 in.) from the original contour of the pipe. For the remainder of the pipe, the weld bead height above the prolongation of the original surface of the pipe, shall be within 0.5 mm (0.02 in.) and 3.5 mm (0.14 in.), irrespective of wall thickness.

c) If specified in the LPMDS, for a distance of at least 150 mm (6.0 in.) from each pipe end, the outside weld bead shall be ground to a height -0.0 mm, +0.5 mm (0.02 in.) from the original contour of the pipe. Longer distances may be specified in the LPMDS.

d) For the remainder of the pipe, the outside weld bead height above the prolongation of the original surface of the pipe shall be within 0.5 mm (0.02 in.) and 3.5 mm (0.14 in.), regardless of the wall thickness.

e) When grinding seams, the transition between the base material to the pipe body shall be smooth without a visually noticeable step. The outside pipe diameter contour shall be maintained, avoiding grinding flat.

Removal of pipe ends outside and inside weld beads using grinding wheels may be carried out after expansion, however shall be carried out before hydrostatic testing.

9.13.3 Misalignment of the Weld Beads of SAW and COW Pipe

Replace section with

Misalignment of the weld beads of SAW pipe [see API 5L, Figure 4 d)] and COW pipe [see API 5L, Figure 4 e)] shall not be cause for rejection if it is within the limits specified in this section, and provided that complete penetration and complete fusion have been achieved as indicated by nondestructive examination and as demonstrated by macro examination.

The maximum misalignment of the weld beads shall not exceed 3 mm (0.1 in.) for pipe with specified wall thickness $t \leq 20$ mm (0.8 in.) or 4 mm (0.16 in.) for pipe with specified wall thickness $t > 20$ mm (0.8 in.).

For SAW pipes, the width of overlap, measured with a straight line perpendicular to the radial direction, shall be minimum $\frac{1}{4}t$ or 5 mm (0.2 in.), whichever is less.

If specified in the LPMDS, when the seam tracking system associated with the welding equipment is deemed insufficient to follow the pipe rotation, the weld penetration shall be visually checked at both pipe ends on every pipe, by chemical etching on the machined weld sections.

Add new section

9.13.4 Peaking

Peaking of the pipe at the weld location shall not deviate by more than 1.5 mm (0.06 in.) from the theoretical form, when measured transverse to pipe axis using inspector accepted inside and outside templates (minimum 200 mm (7.87 in.) in length or 0.25D whichever is greater) / dial gauge.

If agreed with the purchaser, peaking up to 2.5 mm (0.1 in.) may be allowed for SAWH pipes.

NOTE See API 5L, 10.2.8.4 for template.

Add new section

9.13.5 Weld Toe Angle

The weld toe angle for both OD and inner diameter ID welds shall not exceed 40°. It shall be measured from the tangent line of the base metal - weld metal crossing point to the curvature of the weld bead.

Add new section

9.13.6 Welding related imperfections, visual examination

Arc burns, cracks, start/stop craters, poor restart and surface porosity are not permitted.

Add new section

9.13.7 Systematic Imperfections

Systematic imperfections shall be reported. The source of the imperfections shall be investigated and corrected to ensure they do not lead to defects in subsequent production.

9.15 Weldability of PSL 2 pipe

Add to section

If specified in the LPMDS, weldability tests shall be performed in accordance with Appendix 2.

When weldability tests are not specified in the LPMDS, the manufacturer may be required to submit, to the satisfaction of the purchaser, comprehensive documentation to support the weldability of the finished pipe.

If specified in the LPMDS, the purchaser recognized independent third party shall endorse such a report.

If specified in the LPMDS, simulated post weld heat treatment (PWHT) shall be conducted during MPQT.

NOTE Simulated PWHT should be 590 ºC (1094 °F) - 610 ºC (1130 °F) for one hour per inch of wall thickness.

Add new section

9.16 Fracture Toughness

CTOD value at the minimum design temperature shall be specified in the LPMDS.

Add new section

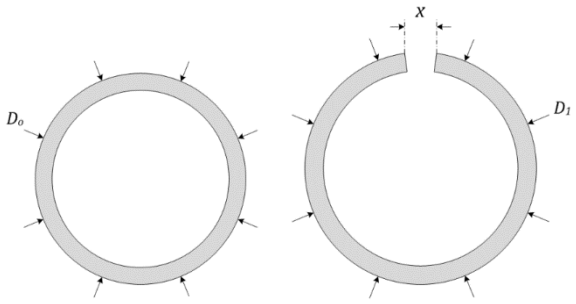
9.17 Spring-back Ring Test

SAWH and COWH pipes shall be subject to spring-back ring testing.

If specified in the LPMDS, other manufacturing line pipe methods such as HFW shall be tested.

The residual stress, as defined in Figure 10, shall not exceed ±10 % of the specified minimum yield strength of the pipe.

Add new figure



$$\sigma = \frac{Et}{1-\mu^2}\left(\frac{1}{D_o} - \frac{1}{D_1}\right)$$

Measured using diameter differences

[SOURCE: ASTM E1928]

$$\sigma = \frac{Et}{1-\mu^2}\left(\frac{1}{D_o} - \frac{1}{\left[\frac{x}{\pi} + D_o\right]}\right)$$

Measured using the opening x

Where

σ is the residual stress;

μ is Poisson's ratio;

E is modulus of elasticity;

*D*o is average outside diameter before splitting; and

D_1 is average outside diameter after splitting.

Figure 10 − Spring-back Ring Test

Add new section

9.18 Hardness Survey

Finished pipes shall have a hardness level (HV10) not exceeding the values specified in Table 32.

Add new table

Table 32 – Acceptance Criteria for Hardness Survey

Steel Grade	Base Metal	Weld & HAZ	Cap area
≤ L450 or X65	250	250	275
> L450 or X65	270	300	300

Add new section

9.19 Macrographic and Metallographic Examination

The macro and metallographic examination shall be documented by macro and micrographs at sufficient magnification (e.g. X10, X100, and X400) and resolution to demonstrate that the base metal, if required in the LPMDS, and the weld metal quality meet the requirements of this specification.

The macro section on an SAW/COW seam shall show the weld merging smoothly into the base material without weld defects, in accordance with ISO 5817 level C.

For SAW seam and HAZ areas, any untempered martensite found shall be brought to the attention of the purchaser for evaluation.

Additional requirements specific to HFW pipes are as follows:

a) Metallographic examination of the HFW seam shall demonstrate that no detrimental oxides, inclusions and untempered martensite from the welding process are present.

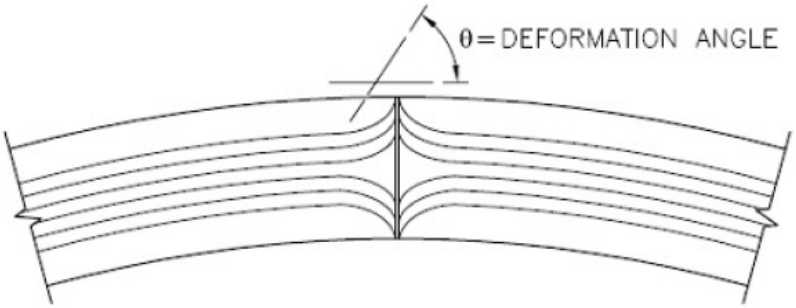
b) The manufacturer shall record the following information:

- Width of heat treated zone (unless full body heat treatment carried out);
- Grain size (refer to ASTM E112) and microstructure of heat treated weld area;
- Deformation angle (i.e. the angle by which the material adjacent to the weld is displaced from the horizontal) or other means of assessment of deformation or squeeze pressure during welding, as agreed with the purchaser.

c) The manufacturer shall produce acceptance criteria, subject to acceptance by the purchaser, based on the results of the manufacturing qualification test:

- These acceptance criteria shall be applied in production and shall demonstrate that the entire weld heat affected zone has been heat treated over the full wall thickness and is free of defects.
- The acceptance criteria shall include assessment of the grain size, and general microstructure.
- Metallographic examination shall include an assessment of the level of deformation achieved during the welding operation, e.g. deformation angle (see Figure 11).

Add new figure



NOTE 1 Various techniques can be used for revealing and measuring metal flow distortion.

NOTE 2 Some methods that have proven successful individually or in combination include:

- saturated picric acid etchant in distilled water;
- specimens taken from a small pipe sample in which the seam has not been heat-treated;
- use of an optical comparator or profile projector.

Figure 11 − Deformation Angle

10 Inspection

10.1 Types of Inspection and Inspection Documents

10.1.3 Inspection Documents for PSL 2 Pipe

10.1.3.1

Add to section

Final inspection reports shall be supplied as per the LPMDS and as a minimum shall be supplied in searchable electronic format e.g. PDF.

If specified in the LPMDS, testing in which data curves are developed (e.g. tensile tests, compressive stress strain, CTOD) shall be supplied in native data formats that can be imported into a spreadsheet file. These data shall be provided at a frequency specified in the LPMDS.

10.2 Specific Inspection

10.2.1 Inspection Frequency

Replace section with

The inspection frequency shall be as given in Table 18.

Inspections and tests required by API 5L / ISO 3183 and this specification shall be performed concurrently with the line pipe production process as an ongoing manufacturing quality control check.

Macrographic, metallographic and mechanical tests results shall be available to the purchaser or the purchaser's inspector no later than three days after the test unit was processed.

In case of test failure, the test specimen and the remaining part of tested pipes shall be stored by the manufacturer until root cause analysis (RCA) is completed to the satisfaction of the purchaser.

A test specimen may be discarded if testing is confirmed successful.

Replace Table 18 with

Table 18 – Inspection Frequency for PSL 2

Item No	Type of Inspection	Type of Pipe	Frequency of Inspection
1	Heat analysis	All pipes	One analysis per heat of steel
2	Product analysis	All pipes	Two analyses per heat of steel (taken from separate product items)
3	Tensile testing of the pipe body	All pipes	Once per test unit of pipes with the same cold-expansion ratio [a c]
3a	If specified in the LPMDS, tensile testing of the pipe body in the longitudinal direction (if not already performed as per API 5L, Table 20)	All pipes	Test shall be performed as part of MPQT. If required in the LPMDS, production test frequency shall be the same as transverse tensile test (item 3).
4	If specified in the LPMDS, tensile testing at elevated temperature	All pipes	Test shall be performed as part of MPQT. If required in the LPMDS, production test frequency shall be the same as transverse tensile test (item 3).
5	Tensile testing of the seam weld of welded pipe	HFW, SAW, COW	Once per test unit of pipes with the same cold-expansion ratio [a b c]
6	Macrographic and metallographic testing on of pipe body	All pipes	If specified in the LPMDS, MPQT
6a	Macrographic and metallographic testing of the of the seam weld of welded pipe	SAW, COW	Once per test unit of pipe with the same cold-expansion ratio [a b c]
6b	Macrographic and metallographic testing of the seam weld of welded pipe	HFW	Once per test unit of pipe with the same cold-expansion ratio [a b c] and at least once per shift.
6c	If specified in the LPMDS, macro hardness testing of the seam weld of welded pipe	HFW, SAW and COW	Once per test unit of pipe with the same cold-expansion ratio [a b c]
6d	If specified in the LPMDS, macro hardness testing of the pipe body	All pipes	Once per test unit of pipe with the same cold-expansion ratio [a c]
7	CVN impact testing of the pipe body of pipe with specified outside diameter and specified wall thickness as given in API 5L, Table 22 [d]	All pipes	Once per test unit of pipes with the same cold-expansion ratio [a c]
7a	Longitudinal CVN impact testing of the pipe body	All pipes	MPQT pipes
8	CVN impact testing of the seam weld of welded pipe with specified outside diameter and specified wall thickness as given in API 5L, Table 22 [d]	SAW, COW	Once per test unit of pipe with the same cold-expansion ratio [a b c]
8a	CVN impact testing of the seam weld of welded pipe with specified outside diameter and specified wall thickness as given in API 5L, Table 22 [d]	HFW	Once per test unit of pipe with the same cold-expansion ratio [a b c] and at least once per shift.
9	Spring–back test	SAWH, COWH	MPQT pipe
10	If specified in the LPMDS, DWT testing	All pipes	Once per test unit of pipes with the same cold-expansion ratio [a c]

Item No	Type of Inspection	Type of Pipe	Frequency of Inspection
11	Guided-bend testing of the seam weld of welded pipe	SAW, HFW, COW	Once per test unit of not more than 50 lengths of pipes with the same cold-expansion ratio [a] [b]
12	If specified in the LPMDS CTOD of weld metal, HAZ and base material	All pipes	MPQT pipes
13	Flattening test of welded pipe	HFW	As per API 5L, Figure 6
14	Hardness testing of hard spots in cold-formed welded pipe	HFW, SAW, COW	Any hard spot exceeding 50 mm (2.0 in.) in any direction
15	Hydrostatic testing	All pipes	Each pipe
16	Visual inspection	All pipes	Each pipe
17	Pipe diameter and out-of-roundness	All pipes	First 10 pipes, then once every 20 pipes but no less than once per 4 hours operating shift plus whenever any change of pipe size occurs during the operating shift
18	Wall thickness measurement	All pipes	Each pipe (see API 5L, 10.2.8.5)
19	Other dimensional testing	All pipes	At least once per 4 h per operating shift plus whenever any change of pipe size occurs during the operating shift
20	Weighing of pipe	All pipes	Each pipe
21	Length	All pipes	Each length of pipe
22	Non-destructive inspection	All pipes	In accordance with Annex E or Annex K as specified in the LPMDS
23	Etching of the longitudinal seam weld of welded pipe	SAWL, COWL	If specified in the LPMDS, each pipe shall be monitored and 5 pipes per shift shall be recorded (qualitatively)

[a] The cold-expansion ratio (if applicable) is designated by the manufacturer, and is derived using the designated before-expansion outside diameter or circumference and the after-expansion outside diameter or circumference. An increase or decrease in the cold-expansion ratio of more than 0.002 requires the creation of a new test unit.

[b] Pipe produced by each welding machine shall be tested at least once per week.

[c] Unless specified otherwise in the LPMDS, test unit is defined as a pipe lot coming from same size, same heat number, and consist of:

− Max. 200 pipes for D ≤ 114.3 mm (4.5 in.).

− Max. 100 pipes for 114.3 mm < D < 508.0 mm (4.5 in. < D < 20 in.).

− Max. 50 pipes for D ≥ 508.0 mm (20 in.).

For design temperature below -10 °C (50 °F): max 50 pipes whatever the diameter.

Unless stated otherwise all values shall be recorded.

[d] The purchaser shall be consulted for Charpy tests specimen for sizes not covered by API 5L, Table 22.

10.2.3 Sample and Test Pieces for Mechanical Tests

10.2.3.1 General

Add to section

All mechanical test specimens shall be taken from pipe in the final condition, i.e. after heat treatment and cold expansion. A specimen may be sampled before cold end sizing.

Each specimen shall be prepared in a manner that does not intentionally enhance their mechanical properties.

10.2.3.2 Test pieces for Tensile Test

Add to section

Transverse yield strength may be determined using either transverse flattened rectangular specimens or round bar specimens, provided that the same method is used for all pipe of a given wall thickness and grade. Limitation on pipe diameter / wall thickness combination shall be as per API 5L.

NOTE Pipe diameter / wall thickness combination applies to all tensile testing specified, including in the annexes and appendices of this specification and API 5L.

10.2.3.3 Test Pieces for the CVN Impact Test

Add new section

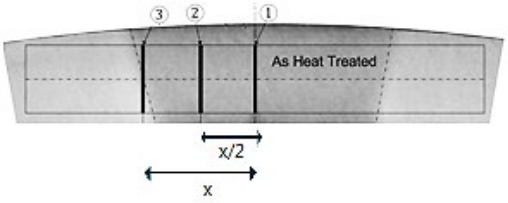
10.2.3.3.1 Welded Pipes

The axis of the notch shall be taken as close as practicable to the weld metal, the fusion line (FL) that consists of 50 % weld metal and 50 % HAZ, and the fusion line + 2 mm (0.08 in.) (FL2). The specimen shall be taken as close as practicable to the OD surface of the pipe, i.e. within 2 mm (0.08 in.) of the outer surface of the pipe.

For SAW and COW pipe with wall thickness equal to or greater than 25 mm (1 in.), additional testing [weld metal, fusion line and fusion line +2 mm (0.08 in.)] shall be done as close as practicable to the ID surface of the pipe, i.e. within 2 mm (0.08 in.) of the inner surface of the pipe.

For HFW during MPQT Charpy testing shall be sampled in positions 1, 2 and 3 as shown in Figure 12.

In production, only positions 1 and 2 shall be sampled.



Key

① On the weld line (±0.25 mm (0.01 in.))

② On the midway of heat treated area

③ On the transition between base metal and heat-treated area after seam weld heat treatment

Figure 12 − CVN Testing of HFW Weld Seam

10.2.3.3.2 Seamless Pipes

For test pieces taken from seamless pipes, the specimen's axis shall be aligned with the mid-thickness of the pipe.

For seamless line pipe with wall thickness greater than 20 mm (0.79 in.), Charpy impact testing shall be done on specimens taken from the ID and OD.

For seamless line pipe with wall thickness greater than 35 mm (1.38 in.), Charpy impact testing shall be done on specimens taken from ID, mid-wall and OD.

Coupons/specimens shall not be flattened.

Add new section

10.2.3.8 Test Pieces for Fracture Toughness Test

Test pieces for a CTOD test shall meet the requirements below:

a) Test pieces shall be taken from the weld metal, the HAZ and the parent metal.

b) Test pieces shall be prepared in accordance with ISO 12135, ISO 15653 or BS 7448-1.

c) Test pieces shall be Bx2B through thickness notched specimens.

d) For weld metal testing, the notch axis shall be located on the weld center line.

e) For HAZ specimens, the notch axis shall be located so as to sample the fusion line.

f) The central 50 % portion of the specimen shall sample the HAZ.

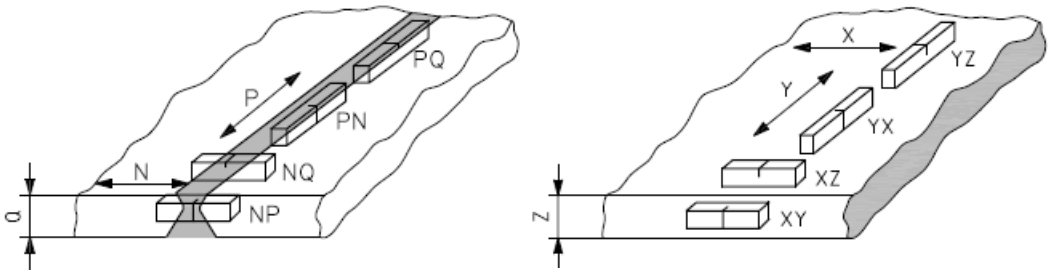
g) The outer portions of the specimen shall sample weld metal.

h) Test pieces for base metal shall be taken at location 180° from the weld seam and have position YX, per Figure 13.

i) Test pieces for weld metal and HAZ area shall be taken from position NP, per Figure 13.

The number of valid CTOD tests for each location shall be a minimum three.

Add new figure



Key

X parallel to rolling direction
Y transverse to rolling direction
N normal to weld direction
P parallel to weld direction
Z weld thickness direction
Q weld thickness direction

Figure 13 − CTOD Orientation

Add new section

10.2.3.9 Test Piece for Spring-back Test

The length of the sample piece of tube should be at least three times the outside diameter and a minimum 150 mm (5.90 in.) long, to avoid significant end effects.

Add new section

10.2.3.10 Test Pieces for Hardness, Macro and Metallographic Examination

Sampling for macro hardness testing shall be as below:

a) For seamless pipe, two test pieces, 180° apart shall be taken from finished pipe.

b) For welded pipe, test pieces (three) shall be taken from the seam weld, and 90° and 180° from the seam weld.

The test pieces shall be prepared according to ISO 17639. The surface to be examined shall be perpendicular to the pipe axis.

10.2.4 Test Methods

Add new section

10.2.4.9 Spring-back Test

Spring-back testing method shall be in accordance with ASTM E1928.

Add new section

10.2.4.10 Fracture Toughness Test

CTOD testing shall be performed in accordance with ISO 12135, ISO 15653 or BS 7448-1.

10.2.5 Macrographic and Metallographic Tests

10.2.5.3

Add to section

For HFW pipe, metallographic examination of the weld seam shall be carried out at a magnification of at least X200.

Add new section

10.2.5.5 Macro hardness testing shall be performed as per API 5L, Figure J.1.

If specified in the LPMDS, hardness testing shall be performed as per Figures 14, 15 and 16 as applicable.

Macro hardness testing using the Vickers test shall be in accordance with ISO 6507-1 or ASTM E384.

For base metal (i.e. at 90° and 180°), a minimum of 12 indentations shall be made for below ID and OD surfaces, and at mid-wall thickness, as shown in Figure 14.

Add new figure

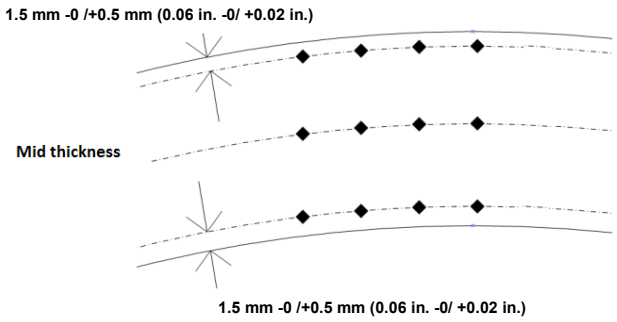
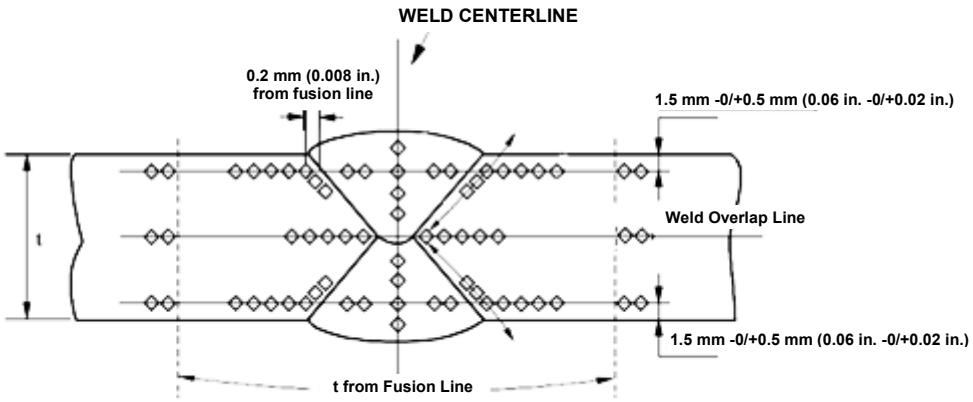


Figure 14 − Base Material (typical)

Add new figure



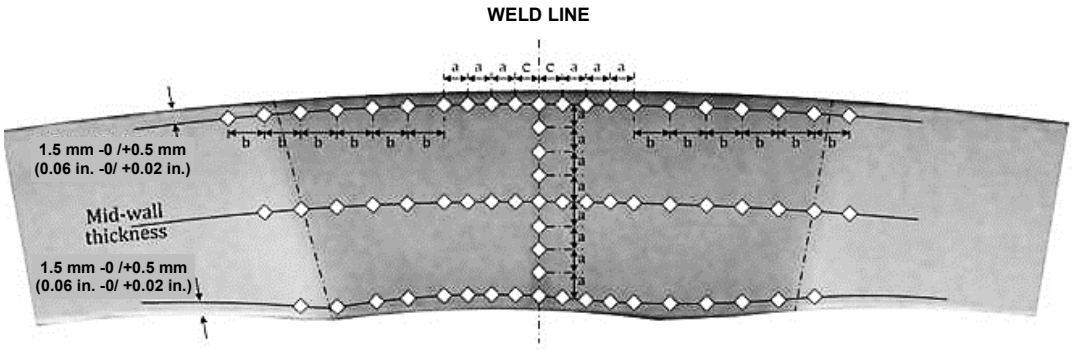
Notes

Base material indents spacing: 2.0 mm +/- 0.1 mm (0.08 in. +/-0.004 in.)

HAZ indents spacing: 0.5 mm -0 / +0.1 mm (0.02 in. +/-0.004 in.)

Weld metal indents spacing: 1.0 mm +/- 0.1 mm (0.04 in. +/-0.004 in.)

Figure 15 − SAW and COW Welds



Key

a = 1.0 +/- 0.1 mm (0.04 in. +/-0.004 in.)

b = 2.0 +/- 0.1 mm (0.08 in. +/-0.004 in.)

c = 5.0 +/- 0.1 mm (0.02 in. +/-0.004 in.)

Figure 16 − HFW Welds

10.2.6. Hydrostatic Tests

Replace 10.2.6.1 with

10.2.6.1 Each length of pipe shall be hydrostatically tested for a duration of not less than 10 seconds.

The hydrostatic test shall be conducted after all manufacturing processes (including repairs and heat treatments) are completed. See C.2 and E.3.1.3.

The water for testing should be clean and free from any suspended or dissolved substance that can be harmful to the line pipe material.

10.2.6.2

Add to section

The test configuration shall permit bleeding of trapped air prior to pressurization of the pipe. The equipment shall be capable of measuring a pressure variation of a minimum of 2 % of the applied pressure.

Mill hydrostatic test pressure records shall show clearly the pipe number, date of test, applied test pressure and test duration for each pipe.

Paper or electronic copies of pressure records shall be available for conformance check at the mill.

In no case shall the actual pressure lead to stress in excess of the specified minimum yield strength.

Add new section

10.2.6.8 Other test pressures may apply if specified in the LPMDS.

10.2.7 Visual Inspection

Replace 10.2.7.1 with

10.2.7.1 Each pipe seam weld shall be visually inspected according to ISO 17637, with an illuminance of at least 350 lx. Such inspection shall be over the entire external surface and shall cover as much of the internal surface as is practical.

For pipe with *D* ≥ 609.6 mm (24 in.), the entire internal surface shall be visually inspected.

10.2.8 Dimensional Testing

10.2.8.1

Replace last sentence with

For *D* ≥ 508 mm (20.00 in.), measurements made by circumferential tape shall govern in case of dispute.

10.2.8.2

Add to section

A bar gauge, a caliper or a device that measures actual maximum and minimum diameters shall be used for measuring out-of-roundness of pipe ends. The absolute maximum and minimum OD shall be measured to determine the out-of-roundness.

Add new section

10.2.8.8 Straightness measurements shall be taken using a taut string or wire from end to end along the pipe, measuring the greatest deviation. Other equivalent methods may be used, including optical and automatic systems.

The length of each pipe shall be measured with tape or another automatic measuring device.

10.2.11 Reprocessing

Add to section

The pipes subject to any reprocessing shall be treated as a new test unit.

For HFW pipes, reprocessing is not allowed. In case the retest fails, the entire test unit shall be rejected.

10.2.12 Retesting

Add new section

10.2.12.0 General

Where one specimen fails to conform to the specified requirements, the manufacturer may elect to perform retesting in accordance with API 5L,10.2.12.1 to 10.2.12.8 as applicable.

If increased retesting frequency is specified in the LPMDS, a retest on four pipes from the same test unit and same cold-expansion ratio (if applicable) shall be carried out.

If any test specimen fails due to some defect in the material, it may be substituted by another test specimen, with prior acceptance of the purchaser's representative. The nature of the defect shall be made clear and the inspector shall specify additional nondestructive testing to ensure that the defect is an isolated case.

11 Marking

11.2 Pipe Markings

11.2.1

Add to section

The purchaser should consider adding to the marking requirement of API 5L:

- purchaser's name;
- order number;
- pipe number;
- heat number; and
- length.

Both pipe ends may not need to be marked with the full information. Reduced stenciling should be considered for one pipe end (e.g. pipe number and length only).

11.2.3

Add to section

a) If required by the purchaser, the inspector shall finalize the pipe inspection by the application of a specific stamp (or indelible paint marking if so previously agreed with the purchaser).

b) The quality of the paint employed and its application shall be designed to provide inscriptions that shall be perfectly readable for at least a year, for pipes exposed to outdoor weather conditions.

c) Unique pipe numbers shall be allocated sequentially.

11.2.5

Add to section

If specified in the LPMDS, varnish type coating (hard drying) shall be used.

If a temporary protective coating (see API 5L, 12.1.2) is applied, the markings shall be legible after such coating.

13 Retention of Records

Add to section

If specified in the LPMDS, the manufacturer shall keep the manufacturing data and inspection records for the period defined.

14 Pipe Loading

Add new section heading before first paragraph

14.1 General

Add to section

Unless otherwise specified in the LPMDS, all pipes shall be fitted with bevel protectors. Bevel protector details shall be submitted to the purchaser at the bid stage.

Pipe shall be bare and free of oil, grease, lacquer, antifreeze (from UT couplant) and other contaminants, such as chlorides, that adversely affect coating adhesion.

All pipe shall be handled, loaded and shipped in accordance with API RP 5L1, API RP 5LT and API RP 5LW, as applicable.

A procedure for handling, transport and storage detailing the proposed methods of handling, stacking during storage, method of preservation, and stacking and securing pipes for transportation and shipment shall be submitted to the purchaser for review and acceptance.

Add new section

14.2 Shipping

The manufacturer shall submit with the shipping procedures a written method to prevent salt contamination of the pipe at the receiving facility.

For transoceanic shipping, the ship's log shall be made available to the purchaser for review when the pipe is unloaded.

At least eight weeks prior to shipment, the manufacturer shall submit loading instructions and diagrams for review and comment, for all pipe shipped by truck or vessel.

When the manufacturer is responsible for handling or shipping, the purchaser's review and comment of these loading instructions shall not relieve the manufacturer of responsibility for any damage during shipment. If in-transit fatigue cracks are detected after shipment, the purchaser shall reserve the right to reject the entire shipment until an absence of fatigue cracking is proven on the entire shipment, by an agreed-upon NDT method.

Add new section

14.3 Handling

Unless hookable end caps are fitted, hooks shall not be used for handling of pipe.

Handling devices that contain copper or copper alloys shall not be used.

Add new section

14.4 Storage

No overstowage or deck loads shall be permitted.

The storage of pipe shall be elevated off the ground, sloped and not in contact with other pipe.

Pipe shall not be nested one diameter inside another.

All handling, loading and unloading shall be carried out in such a way as to avoid magnetization, mechanical damage and prevent stresses which result in dents or out-of-roundness.

All dimensional tolerances and pipe surface conditions specified within this specification and API 5L shall apply to the pipe condition as received by the purchaser at the shipping destination. The manufacturer shall be responsible for any permanent deformations subsequent to mill acceptance and resulting from loading, storing, stacking, transportation or shipping, provided that these operations are within the scope of the manufacturer.

Annex B
(normative)
Manufacturing Procedure Qualification for PSL 2 Pipe

B.1 Introduction

Replace B.1.3 with

B.1.3 Verification of the manufacturing procedure shall be by qualification in accordance with B.3, B.4 and B.5. The MPQT shall be completed prior to the start of production.

If accepted by the purchaser, the MPQT requirement may be performed as first day production testing.

In specific cases, other means of verification of the manufacturing procedure may be proposed by the manufacturer, for agreement with the purchaser.

B.2 Additional Information to be Supplied by the Purchaser

Replace section with

a) The manufacturer shall submit a comprehensive manufacturing procedure specification (as per B.3) and an inspection and test plan (as per B.4), for the purchaser's acceptance prior to the start of production.

b) A manufacturing procedure qualification test in accordance with B.5 shall be carried out.

B.3 Characteristics of the Manufacturing Procedure Specification

Replace first paragraph with

The MPS shall be prepared for each mill to cover each type of pipe, delivery condition, nominal pipe diameter, grade and specified wall thickness.

The required information may be included within the MPS or provided as standalone document, at the manufacturer's discretion.

Before production commences, the manufacturer shall supply the purchaser with summary information or identification of the control documents as applicable, on the main characteristics of the manufacturing procedure. This shall include a plan and process flow description/diagram and at least the following information:

Replace item a) 2) with

a) 2) equipment and process description including steelmaking method, heat size, deoxidation practice, control of slag physicochemical properties and slag removal, secondary/ladle refining, degassing and stirring practice, inclusion shape control practice, and casting method;

Replace item a) 3) with

a) 3) control of chemical composition, based on target chemical composition (to be agreed prior to start up);

Replace item a) 5) with

a) 5) hydrogen control practice;

Replace item a) 7) with

a) 7) product reprocessing/retesting/release controls for nonconformances to the manufacturer's documented practices and this specification;

Replace item a) 8) with

a) 8) steelmaking and casting methods used to mitigate segregation and inclusions during the continuous casting process. The documentation shall include a description of the processes, quality control steps and tests to assure adequate quality of the final pipe. Control of steel cleanliness and centerline segregation, including the acceptance criteria;

Add new item a) 9)

a) 9) control of steel scrap;

Add new item a) 10)

a) 10) billets and slabs visual inspection and associated acceptance criteria.

Replace item b) 3) with

b) 3) hydrostatic testing practices including calibration of equipment and records of the test;

Replace item b) 4) with

b) 4) non-destructive inspection methods and practices including calibration practice and records of the test;

Replace item b) 8) with

b) 8) pipe marking process and details (including freehand marking limitation, lettering height, distance from pipe ends, painted colored band);

Replace item b) 10) with

b) 10) product reprocessing/retesting/release controls for nonconformances to the manufacturer's documented practices and this specification;

Replace item b) 11) with

b) 11) pipe storage, handling (including pipe end protection), loading and shipping practices.

Add new item b) 12)

b) 12) method for cold expansion/reduction/sizing/finishing, target and maximum sizing ratio;

Add new item b) 13)

b) 13) control of intermediate heat treatment process if any (e.g. quenching or normalizing);

Add new item b) 14)

b) 14) control of final heat treatment process;

Add new item b) 15)

b) 15) heat treatment procedure including a sketch of the heat treatment facilities layout, showing furnaces and quenching bath relative to each other;

Add new item b) 16)

b) 16) type, identification of furnaces and sketch of furnaces showing, overall dimensions, working zone and location of heat elements;

Add new item b) 17)

b) 17) location and identification of thermal sensors in the furnace. Sensors for temperature regulation and sensors for temperature control shall be clearly distinguished. Method of heating and fuel (if applicable);

Add new item b) 18)

b) 18) calibration frequency of the thermocouples;

Add new item b) 19)

b) 19) maximum operating temperature of furnaces;

Add new item b) 20)

b) 20) loading temperature, heating and cooling rate, soaking temperature set-up and soaking time with associated tolerances and maximum transfer time;

Add new item b) 21)

b) 21) for continuous and semi-continuous furnaces: travel speed and minimum soaking time as function of size (e.g. thickness, diameter, cross section, etc.) for products to be heat-treated and other relevant parameters.

Add new item b) 22)

b) 22) arrangement of pipes inside the furnaces including minimum distance between pipes, number of pipe layers in the furnace and location of the weld seam;

Add new item b) 23)

b) 23) identification and control of individual pipes throughout the heat treatment cycle.

Replace item c) 2) with

c) 2) equipment and process description including slab reheating practices, minimum temperature and soaking time at slab reheating stage, rolling schedule and cooling practices;

Add new item c) 11)

c) 11) plate cutting practice (including plate/coil slitting).

Add new item e) 5)

e) 5) preliminary welding procedure specification (pWPS) or previously qualified WPS (if available) including all essential variables from Table B.5 and Table B.6;

Add new item e) 6)

e) 6) welding equipment, including weld tracking system.

Add new item f) 3)

f) 3) equipment and process description including billet reheating practices, minimum temperature and soaking time at billet reheating stage, tube manufacturing stage and finishing stage;

Add new item f) 4)

f) 4) control of process parameters for reheating, tube manufacturing and finishing stage;

Add new item f) 5)

f) 5) end cropping practices.

Replace section heading with

B.4. Characteristics of the Inspection and Test Plan (ITP)

Add to section

j) each inspection activity and reference to the procedure for that activity.

Replace section heading with

B.5 Manufacturing Procedure Qualification Tests (MPQT)

Add new section

B.5.0 The MPS shall be validated through MPQT as described herein.

If one or more tests in the MPQT fail, the MPS shall be reviewed and modified accordingly, and a complete re-qualification performed. Retesting may be allowed subject to agreement by purchaser. In the specific case of SAW failed fusion line CVN tests (with reference to local brittle zone), retesting of a further two sets removed from the failed MPQT pipe (at the same position relative to wall thickness) is permitted, prior to declaring the MPQT as having failed.

In cases where the qualification test results do not comply with the requirements of this specification, the pipe tested, as well as all preceding pipes, shall be rejected.

Replace B.5.1 with

B.5.1 For qualification of the manufacturing procedure, the mandatory tests specified in Table 18, selected annexes and appendices (in accordance with the LPMDS) and the additional destructive tests specified in B.5.2 shall be carried out.

Replace B.5.2 with

B.5.2 Unless otherwise specified in the LPMDS, the MPQT pipes shall comprise one pipe from two different heats (total of two pipes) from the first pipes produced in each size (each diameter and each wall thickness), grade and steel source (first shift production). All MPQT pipes shall be subject to all the applicable inspections and tests. If the entire production is limited to one heat, then MPQT may be carried out on one single pipe from that heat. The MPQT pipes shall be selected by the inspector.

Add new section

B.5.2.1 Macrographic, Micrographic and Segregation Analysis on Slabs

For HFW, the first, middle and last slab from the first heat shall be subject to macrographic, micrographic and segregation analysis. The analysis procedure shall be subject to agreement with the purchaser:

a) macrographic methods may be by macroetch (hot acid etch test) and magnetic particle testing;

b) micrographic methods shall be by optical microscope on the polished sample. A procedure shall be submitted for the purchaser's review and acceptance;

c) segregation analysis shall be carried out by cross-section chemical analysis at the surface of the slab, ¼ slab thickness and ½ slab thicknesses (see Figure B.1). The chemical composition shall be within the tolerance of target chemical composition.

Add new figure

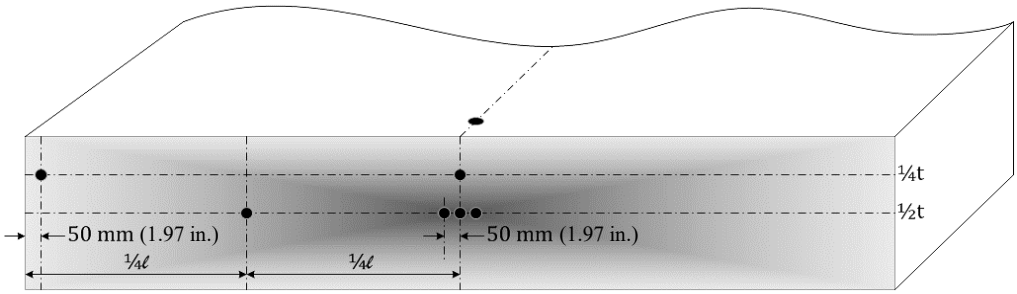


Figure B.1 − Slab Macrographic, Micrographic Analysis Sampling

Add new section

B.5.2.2 Charpy Impact Tests

If specified in the LPMDS, a ductile brittle transition temperature (DBTT) curve, (in terms of energy, shear area and lateral expansion) shall be developed from a Charpy impact test, with test temperature 10 °C (18 °F) and 20 °C (36 °F) above routine test temperature, and 10 °C (18 °F), 20 °C (36 °F) and 30 °C (54 °F) below routine test temperature at the following location:

a) seamless: DBTT shall be performed within the pipe body.

b) HFW: DBTT shall be performed within the parent material and along the weld centerline within 0.25 mm (0.01 in.) from the fusion line).

c) SAW and COW: DBTT shall be performed within the parent material at 90° from the weld seam, along the weld centerline and on the fusion line.

The temperature range for testing shall be extended when necessary to get sufficient data for representing fully a transition curve showing the transition area.

The tests at temperatures below the routine test temperature will be for information only.

If specified in the LPMDS, the transition curve shall be generated for both finished pipe and in the aged condition.

Ageing shall be done by heating the specimen to a temperature of 250 °C (492 °F) with one hour soaking time.

DBTT in terms of shear area is not required to be performed in the weld metal location, but is required for HAZ, in line with the requirements specified in 9.8.3.

Add new section

B.5.2.3 Tensile Tests

Parent material tensile test and all weld metal tensile tests (at ambient and elevated temperature if specified in the LPMDS) shall be conducted to record the full stress-strain curve up to maximum load.

If specified in the LPMDS, data shall be supplied in native data formats that can be imported into a spreadsheet file.

Two round bar all-weld tensile tests (one from inside and one from outside the weld bead) shall be performed.

The yield strength and tensile strength shall meet the requirements of the pipe base material. Elongation shall be a minimum of 18 %. Reduction of area, $R_{t0.5}/R_m$ ratio and uniform elongation shall be reported for information only.

If specified in the LPMDS, elevated temperature tensile tests shall be made in the longitudinal direction for all pipe sizes and the transverse direction for pipes with an outside diameter greater than 219.1 mm (8.63 in.). See API 5L, Table 20.

Acceptance criteria shall be as specified in the LPMDS.

Add new section

B.5.2.4 Macrographic, Metallograpic and Hardness Tests on Pipes

Tests shall be performed at both ends of the MPQT pipes for up to three cross-sections to be sampled for micrography and hardness:

- at 0° (weld seam);
- and if specified in the LPMDS at 90° and 180°.

They shall be polished and etched to show the metallurgical microstructure.

Photographs of the microstructure shall be supplied at three locations minimum, i.e. at below the ID and OD surfaces, and at mid-thickness.

The inclusion rating shall be performed in accordance with ASTM E45 (Method d) and shall not be higher than severity 2.

If not evaluated on the slab (see B.5.2.1), the carbon/carbide segregation level shall be assessed and qualified.

Add new section

B.5.2.5 Guided Bend Test

For HFW, one additional root guided bend test shall be performed in order to test both pipe ends.

Add new section

B.5.2.6 Ageing Tests

Charpy, tensile and hardness testing shall also be performed in the aged condition if cold forming during manufacturing of C-Mn steel exceeds 5 % strain after heat treatment. The cold forming shall take into account

all operations on the steel, including but not limited to, levelling of plate, pipe forming and expansion. The tests shall be performed on the actual pipe without any straightening or additional deformation.

NOTE In most cases cold forming strain is less than 5 %. In exceptional cases where the *D*/*t* ratio is below 20, the requirement above applies only where no heat treatment is performed after final forming.

Add new section

B.5.2.7 Non-destructive Testing

In addition to standard production requirements:

a) The weld seams of all SAW and COW pipes shall be radiographically examined throughout their full length.

b) The weld seam shall be subjected to liquid penetrant or magnetic particle testing to check for surface defects in the weld, externally and internally along the accessible length.

Add new section

B.5.2.8 Surface Condition Test – Seamless Pipe

If required in the LPMDS, a surface condition test shall be carried out according to the following:

a) In the absence of historic data, seamless pipe shall undergo blast cleaning and examination of three pipes during the manufacturing procedure qualification.

b) The pipes shall be selected at random and heated to a minimum of 70 °C (160 °F).

c) The outside surface of the pipe shall be blast cleaned to a surface finish of SA2½ and the pipe then re-heated to 250 °C (482 °F).

d) Each pipe shall be examined visually over its entire surface for imperfections that could interfere with the FBE coating process. The surface condition of the pipes shall be such that a coating supplier using a grit blasting system can achieve a blast profile of 50 µm – 100 µm (0.002 in. − 0.004 in.).

e) If a seamless pipe is rejected, the remaining pipes from the test unit and one pipe from each subsequent test unit shall be blast cleaned and examined.

B.5.3

Add to section

Reference is made to tables B.1 and B.2 for changes in essential variables that require new qualification.

Replace B.5.4 with

B.5.4 Weldability test requirements shall be in accordance with 9.15.

Subject to the purchaser's acceptance, weldability tests may be undertaken separately to the MPQT.

Replace B.5.6 with

B.5.6 Any change to the essential variables listed in B.5.7 shall require a new MPQT.

Add new section

B.5.7

Add new section

B.5.7.1 Welding Essential Variables

If requested by the purchaser in the IRS, a preliminary welding procedure shall be submitted.

Qualification of the welding procedure specification shall be carried out for each production before commencing the fabrication. Prequalified procedures may be accepted at the purchaser's discretion.

The WPS and supporting procedure qualification record (PQR) shall be submitted to the purchaser for acceptance.

During production, changes of any welding parameters defined as essential variables, outside the ranges specified in the WPS, will require requalification of the WPS. If other manufacturing essential parameters remain unchanged, requalification shall be limited to the WPS.

The manufacturer shall provide details, subject to the purchaser's acceptance, of how the parameters detailed in B.5.7 are to be monitored and recorded.

For HFW, the mill shall operate a welding system where the control parameters are used to adjust the welding process automatically. The system shall monitor, as a minimum, the voltage, current, welding power, travel speed, weld fusion point temperature (if available), frequency and squeeze roll pressure or load. These parameters shall be recorded at least every 10 milliseconds.

Welding records shall be available for review by the third-party inspector during production and until the order is shipped.

As a minimum, all information required in ASME IX WPS format shall be listed.

Add new table

Table B.1 − Welding Essential Variable for SAW and COW Pipes

Essential variables	Changes that require new qualification	
	GMAW	SAW
1) Base metal	A change in API 5L steel grade.	
	An increase in CEPCM greater than 0.02 as an essential variable.	
	An increase in CEIIW greater than 0.03 as an essential variable.	
	A change in pipe delivery condition.	
	A change in specified wall thickness by more than −10 % / +5 %.	
2) Bevel shape, angle	A change in bevel shape / groove type.	
	A change in root face by more than −1.5 mm / +1.5 mm (±0.06 in.).	
	A change in root gap by more than −1.0 mm / +1.0 mm (±0.04 in.).	
	A change in angle by more than −5° / +5°.	
3) Filler metal	A change in number of wires.	
	A change in nominal wire diameter.	
	Any change in brand name.	
	A change in wire classification.	A change from one flux–wire classification to any other flux–wire classification.
	A change in wire manufacturer.	A change in flux or wire manufacturer.
4) Position of welding point (for SAWH pipe)	A change in location and distance between strip–pipe meeting point to ID welding point.	A change in location and distance between strip–pipe meeting point to ID welding point.
		A change in location for OD welding.
5) Preheat / interpass temperature	Methods to be used for heating strip edges.	
	Decrease in qualified minimum preheating and/or interpass temperature.	
	Increase of qualified maximum preheating and/or interpass temperature by > 50 °C (122 °F).	
6) Equipment	Any change in make, type and model of welding equipment.	
7) Electrical characteristics	A change in welding position, type of current and polarity.	
	A change of ±10 % in voltage, amperage, and wire feed speed for each wire.	
	A change of ±10 % in travel speed.	
	A change of ±7 % in welding heat input.	
	A change from Constant Voltage to Constant Current output.	A change of > 5 mm (0.2 in.) in longitudinal or lateral spacing of the arcs.
	A change in the mode of transfer.	
8) Weld pass	A change in number of weld passes.	
9) Shielding gas	A change in gas composition.	
	Decrease in gas flowrate.	
	Increase in gas flow rate by more than 10 %.	
10) Postweld heat treatment	Addition or deletion of PWHT.	
	A change in the PWHT temperature by more than ±10 °C (50 °F).	
	A change of ≥ 10 % in soaking time.	

Add new table

Table B.2 − Welding Essential Variables for HFW Pipes

Essential variables	Changes that require new qualification
1) Base metal	A change in API 5L steel grade.
	An increase in CE_{PCM} greater than 0.02 as an essential variable.
	An increase in CE_{IIW} greater than 0.03 as an essential variable.
	A change in pipe delivery condition.
	A change in nominal wall thickness.
	A change in nominal pipe diameter.
	A change in the source of coil.
2) Transfer of welding current and the use of impeder	A change in welding current transfer mechanism (either by induction coils or contact tips).
	A change in dimension of induction coils/contact tip, material, coolant type and the contact tip force.
	A change in the use, dimension, material and location of impeder.
3) Equipment	Any change in make, type and model of welding equipment.
	Methods to be used for heating strip edges.
	Method to control and monitor power input in relation to the temperature of the pipe surface and the speed of the pipe.
4) Induction coil configuration (HFW only)	Any change.
5) Impeder configuration (HFW only)	Any change.
6) Electrical characteristics	A change of ±5 % in qualified frequency (frequency shall be ≥ 150KHz).
	A change of ±5 % in welding heat coefficient, Q = (amps × volts) / (travel speed × thickness).
7) Roll pressure on welding/squeezing point, squeeze–out and metal flow angle	A change in roll pressure location.
	A change of > 5 % in roll pressure.
	Decrease in minimum qualified squeeze–out [squeeze–out shall be > 4 mm (0.16 in.)].
	The metal flow angle shall be within the range 45° - 60°.
8) Shielding gas and coverage area	A change in gas composition.
	Decrease in gas flowrate.
	Decrease in coverage area (as minimum beveled areas after induction coils/contact tip shall be protected).
9) Weld seam heat treatment and cooling system	A change of > 5 % in qualified frequency.
	Decrease in soaking time.
	Decrease in qualified exit temperature by > 10 °C (50 °F).
	A change in cooling system.

Annex C
(normative)
Treatment of Surface Imperfections and Defects

C.2 Treatment of Dressable Surface Defects

C.2.2

Add to section

The acceptable grinding processes are listed in Table C.1.

Add new table

Table C.1 – Acceptable Grinding Processes

Manufacturing Stage	SMLS Pipe	Welded Pipe [b]
Before hydrostatic pressure	Grinding wheel or flap wheel	-
After hydrostatic pressure	Only flap wheels (cosmetic grinding [a])	-
Before expansion	-	Grinding wheel or flap wheel
After expansion	-	Only flap wheels (cosmetic grinding)

[a] Cosmetic grinding i.e. grain size disk # 100 or flap wheels. Wall thickness check is not required after cosmetic grinding.

[b] Repairs to HFW weld line: external light grinding is permitted.
Internal light grinding shall be limited to removing weld flash only.
Wall thickness shall be checked after light grinding.

C.2.3

Replace section with

After grinding, complete removal of defects shall be verified by wet or dry MT as per ASTM E709 or ISO 10893-5, and by the NDT method which detected the defect i.e. automatic UT (AUT) or electromagnetic inspection (EMI).

Following ID grinding, MT or liquid penetrant shall be used to verify complete removal of defects:

a) If MT or liquid penetrant cannot be performed on the ID, manual or automatic UT (and EMI as applicable) may be used to ensure complete defect removal.

b) Any UT procedure for verification of removal of defects by ID grinding shall be submitted to the purchaser for review and acceptance.

Wall thickness measurements shall be made by UT in the ground areas and the results shall be recorded. The wall thickness in the ground area shall be in accordance with API 5L, 9.11.3.2; however, the minus tolerances for diameter and out-of-roundness (see 9.11.3.1) shall not apply in the ground area.

C.4 Repair of Defects by Welding

C.4.1

Add to section

Repair of a weld area previously repaired shall be performed in accordance with a dedicated welding procedure qualification and WPS. Multiple repairs shall be limited to a maximum of two consecutive repairs.

Back-to-back repairs are not permitted unless otherwise agreed with the purchaser.

Repairs due to welding process failures (e.g. burn-through during tack-welding, flux stop and/or wire stop during SAW) inducing base metal repair are not permitted. Flux and wire stops which permit a restart area that does not alter the final SAW weld size are permitted, subject to specific procedure / method statement acceptance by the purchaser.

Weld seams containing cracks shall not be weld repaired. The section of pipe containing cracks shall be cut off. Acceptability of the remaining pipe shall subsequently be based on length requirements.

Inside pipe is considered as a confined space and repairs inside the pipe may only be permitted when safe access procedures are in place. Inside repairs shall be followed by visual inspection.

Inside arc stop/restart repairs for SAW may be allowed if visual inspection (and dressing if required) can be safely performed.

Repair of HFW pipe weld seams by welding is not permitted.

C.4.2

Add to section

All repairs shall be carried out before cold expansion (if any) and hydrostatic testing.

C.4.3

Add to section after first sentence

Weld repairs shall be limited to a maximum of four per pipe with a maximum length of 350 mm (13.8 in.) each.

Replace C.4.4 with

C.4.4 Repairs shall be separated by at least 200 mm (7.9 in.).

Each repair shall be carried out with a minimum of two layers/passes over a length of at least 50 mm (2.0 in.)

No welding repair is permitted over a length of 254 mm (10.0 in.) from each pipe end.

C.4.5

Add to section

The properties of the weld repair shall meet the specification requirements of the longitudinal seam weld.

Replace C.4.6 with

C.4.6 The external surface of the repair weld shall be subject to grinding to obtain a uniform appearance and to merge smoothly into the base material.

Each repaired area shall be 100 % examined by ultrasonic and MT testing. Additional radiographic testing shall be performed if specified in the LPMDS.

Replace C.4.7 with

C.4.7 Complete removal of the defect shall be confirmed by magnetic particle inspection before the weld repair. If arc-air gouging is used for defect removal, grinding shall be carried out for the removal of the decarburized zone.

Annex D
(normative)
Repair Welding Procedure

D.1. General

D.1.2

Delete item b)

Replace D.1.4 with

D.1.4 Test welds shall be made on pipe.

D.2 Repair Welding Procedure Qualification

D.2.1 General

D.2.1.1

Add to section

Unless otherwise agreed with the purchaser, WPS for repair welding shall be qualified as follows:

a) one partial repair (minimum of ⅔*t* repair), simulating a defect located on the fusion line;

b) one shallow repair with two weld passes minimum, simulating a defect located at the weld toe;

c) multiple repairs.

Through thickness repairs are not allowed.

Repair welding shall be qualified in a manner realistically simulating the repair situation to be qualified. All repairs shall include a minimum preheating of 100 °C (212 °F), unless the qualification test has shown that a higher temperature is necessary.

Defects in the weld seam may be removed by grinding and repaired by welding carried out by qualified welders, using a previously qualified welding procedure.

D.2.2 Essential Variables

Add to section

c) 7) if it is agreed to have electrode under matching with respect to the strength of the base material: change in batch number of the electrode (each batch shall be individually tested).

D.2.3 Mechanical Testing

D.2.3.4 Charpy (CVN) Impact Test

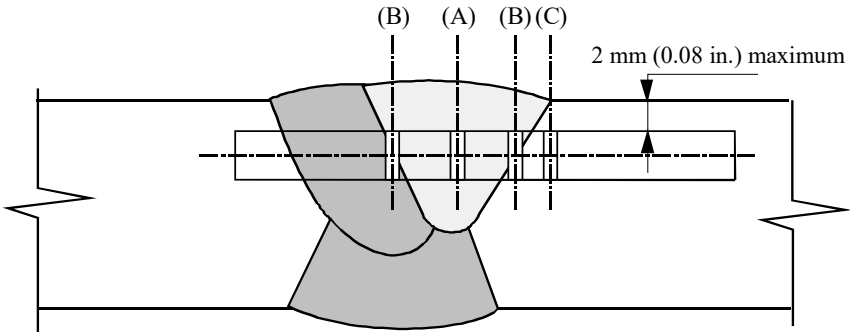
Add new section

D.2.3.4.5 Sampling of CVN specimens shall be performed in accordance with Figure D.2 for a partial thickness repair.

Minor changes in the sampling location may be accepted by the purchaser.

The test temperature and acceptance criteria shall be the same as those required for unrepaired pipe weld and HAZ (see 9.8).

Add new figure



Key

A Weld metal center line

B Fusion line of repair weld to base metal and fusion line of repair to original weld

C Fusion line + 2 mm (0.08 in.)

Figure D.2 − Partial Repair Charpy Sampling Location

Add new section

D.2.3.5 Hardness Testing

If hardness testing (HV10) is specified for the longitudinal weld, hardness testing shall also be performed on any repairs to the longitudinal weld.

The typical number and position of the indentations shall be as shown in Figure D.3.

Acceptance criteria shall be as per 9.19 or applicable annexes and appendices as specified in LPMDS.

Add new figure

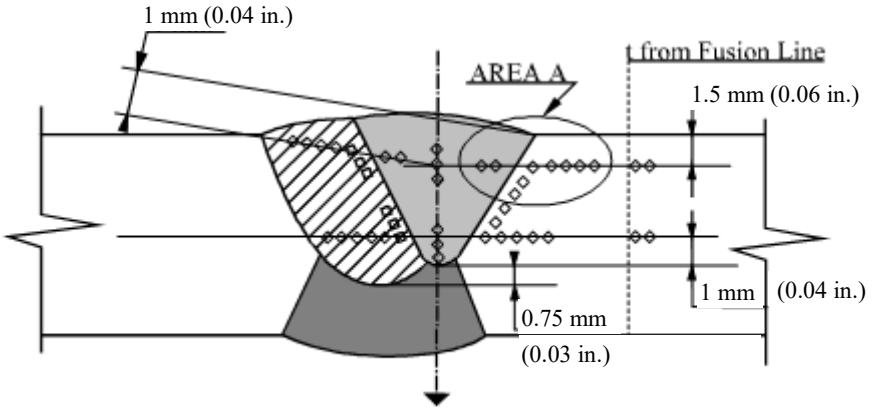


Figure D.3 − Partial repair Hardness Indentation Location

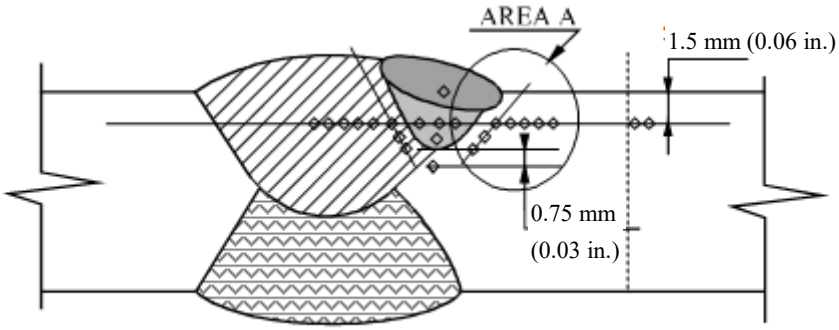


Figure D.4 − Cap Repair Hardness Indentation Location

Add new section

D.2.3.6 CTOD Testing

If CTOD testing is specified in the LPMDS or required by an annex selected in the LPMDS, the qualification of a repaired weld shall be subject to the same CTOD testing, except that surface notched specimens shall be used to sample the weld metal and both HAZs (repair/parent material and repair weld/original weld).

An alternative notch specimen may be proposed by the manufacturer.

NOTE Figures representing the repaired area are not to scale.

As per API 5L, C.4.2, the rim of the cavity shall not extend by more than 3.2 mm (0.126 in.). See API 5L, Figure C.1.

D.3. Welding Personnel Performance Qualification

D.3.1 Qualification

D.3.1.1 General

Add to section

Welding operators performing automatic welding may also be qualified according to ISO 14732.

Annex E
(normative)
Nondestructive Inspection for Pipe Not Required to Meet Annex H, J or N

E.1 Qualification of Personnel

E.1.1

Add to section

Level 2 personnel shall possess a minimum of one year experience. Qualification for personnel responsible for visual inspection shall be either NDT VT level 2 or International Welding Inspection Personnel level comprehensive (IWIP-C).

NDT personnel shall be requalified for any method previously qualified if they have not performed nondestructive inspection in that method for a period exceeding six months.

When required, the manufacturer shall supply the purchaser or the inspector with a list of NDT personnel working on the job, showing the scope and dates of their qualifications.

In addition, the following may be specified by the purchaser in the LPMDS:

a) if the qualifications of personnel performing NDT are to be subject to acceptance by the purchaser;

b) if any restriction is to be placed by the purchaser on certification schemes for NDT personnel.

Replace E.1.3 with

E.1.3 The manufacturer shall have Level 3 personnel responsible for all NDT activities.

The NDT UT Level 3 personnel shall be available on call during manufacture.

All of the manufacturer/supplier NDT specifications and procedures shall clearly demonstrate the approval of the NDT Level 3 showing an approval date.

When required, the manufacturer shall supply the purchaser or the inspector, the qualification number and the expiry date of the NDT Level 3 individual.

Evaluations of indications shall be performed by a Level 2 or Level 3 personnel only.

E.3 Methods of Inspection

E.3.1 General

Replace E.3.1.1 with

E.3.1.1 The weld seams and HAZs of welded pipes shall be inspected over 100 % of the length for longitudinal imperfections, for the entire thickness and width, as specified in Table E.1 and as follows.

UT shall be performed in accordance with ISO 10893-11, as amended or supplemented by this annex.

UT shall be performed using automated equipment with “conventional” or phased array techniques. UT procedures using time of flight diffraction (ToFD) and electro magnetic acoustic transducer (EMAT) equipment shall only be used with the specific written acceptance of the purchaser and on the basis of a specific qualification program accepted by the purchaser.

Unless otherwise accepted by the purchaser, manual UT (MUT) shall not be permitted as a substitute or replacement for AUT.

If specified in the LPMDS, full X-ray supplemented by MUT may be allowed for seam weld inspection.

Unless otherwise accepted by the purchaser, real-time (dynamic) radiography is not acceptable.

Acceptance levels shall be in accordance with Table E.8.1 and Table E.8.2.

Replace Table E.1 with

Table E.1 – Pipe Weld Seam NDT

Weld seam type	NDT Method [a]		
	EMI [b]	UT	RT
HFW for t < 6.4 mm (0.25 in.)	One method or a combination of methods is required		Not applicable
HFW for t ≥ 6.4 mm (0.25 in)	Not applicable	Required	Not applicable
SAW and COW	Not applicable	Required	Required [c]

[a] The weld seam at the pipe ends might require additional inspection (see E.3.2).

[b] Acceptable EMI method shall be as per the LPMDS.

[c] Required as a minimum on pipe ends.

Replace E.3.1.2 with

E.3.1.2 All SMLS pipe shall be subject to automated NDT over 100 % of the length and circumference as stated in Table E.2. The applicable codes for testing are:

- ISO 10893-2, Automated Eddy Current Testing;
- ISO 10893-5, Magnetic Particle Inspection; and
- ISO 10893-10, Automated UT for longitudinal and transverse imperfections.

Replace Table E.2 with

Table E.2 – SMLS Pipe Body NDT

Item	Thickness mm (in.)	NDT Method		
		EMI	UT	MT
PSL 2 pipe, any grade	≤ 6.4 mm (0.25 in.)	Either EMI or UT as specified in the LPMDS		Not required unless specified in the LPMDS
	≥ 6.4 mm (0.25 in.)	If specified in the LPMDS	Required	

Replace E.3.1.3 with

E.3.1.3

a) For seamless pipe, if required, NDT shall be performed after hydrotesting.

b) For welded pipe, NDT shall be completed after hydrostatic testing.

c) For SAW pipe, NDT shall be done after hydrostatic testing and any sizing practice.

E.3.2 Pipe End Inspection – Welded Pipe

Add title to E.3.2.1

E.3.2.1 Non-inspected Ends

Replace section with

For the weld seam at the pipe ends, if an AUT or EMI inspection is applied to meet the requirements of E.3.1.1, the lengths of weld at the pipe ends that are not covered by the automated inspection, up to a maximum of 305 mm (12 in.), shall be inspected for defects using the same inspection parameters as specified in E.3.1.1, by:

- UT using an alternative AUT system or semi-automated UT (SAUT) system; or
- manual UT (MUT).

MUT shall only be used to inspect the untested ends of weld seams if prior written acceptance has been obtained from the purchaser. Scanning shall be performed in both circumferential directions using adequate shear wave probes. The shear wave probe angle shall be selected to ensure full weld and HAZ coverage.

Alternatively, the non-AUT-inspected pipe ends shall be cut off, with the following conditions:

a) Non-AUT-inspected weld ends shall not exceed 305 mm (12 in.).

b) Removal of non-AUT-inspected pipe ends does not remove the manufacturer's obligation to perform radiographic testing (RT) of the weld ends (see E.3.2.2).

c) Removal of non-AUT-inspected pipe ends does not remove the manufacturer's obligation to perform UT of the pipe ends (see E.3.2.3 and E.3.2.4).

d) Where more critical UT acceptance criteria applies to pipe ends than applies to the rest of the pipe, the more critical acceptance criteria shall be applicable to new pipe ends, after non-AUT-inspected pipe ends have been cut off.

Add title to E.3.2.2

E.3.2.2 RT of Welds at Pipe Ends

Add to section

The same area subject to RT shall also be inspected using UT (see E.3.2.1), which shall be taken as the prime inspection method.

If a defect is detected by any NDT method, it shall be considered rejected.

The final acceptance shall be by UT. RT shall not be used to accept defects detected by UT.

NOTE RT inspection shall be X-ray unless otherwise accepted by the purchaser

Add title to E.3.2.3

E.3.2.3 UT for Lamination Check

Replace section with

UT shall be carried out in accordance with ISO 10893-8 or an agreed equivalent to verify that the whole circumference of both pipe ends is free from laminar imperfections exceeding the limits stated in Table E.8.1.

Scanning shall be carried out over a distance of [3.5*t* + 25 mm (0.98 in.)] or 50 mm (2.0 in.), whichever is greater, from the point where the outside surface meets the pipe end face or bevel.

Pipe end UT shall be undertaken from the outside surface and be inspected before beveling.

Longer scanning distance may be specified in the LPMDS.

If specified in the LPMDS, pipe end lamination check may be performed using MUT.

Add new section

E.3.2.4 SAW & COW Pipe End Circumference

UT shall be carried out to verify that the 50 mm (2 in.) zone at each pipe end is free of axially-aligned through-thickness cracking. Scanning shall be performed in both circumferential directions using 45° shear wave probes. Axially-aligned N5 notches on the inside and outside surfaces shall be used to set the reference and acceptance levels.

No cracks shall be allowed.

Add new section

E.3.2.5 MT of End Face

If specified in the LPMDS, the end face (beveled or square cut) at each pipe end shall be magnetic particle inspected for the detection of laminar imperfections, in accordance with ISO 10893-5 or ASTM E709.

The end face shall be free of indications.

NOTE This should only be performed on beveled ends.

E.3.3 Pipe End Inspection – SMLS Pipe

Add title to E.3.3.1

E.3.3.1 Non-inspected Ends

Replace section with

The lengths of the pipe ends that are not inspected during AUT of the pipe body (see E.3.1.2), up to a maximum of 305 mm (12 in.), shall be inspected for defects by an alternative AUT system or SAUT system using angle beam probes, and the same inspection parameters as specified in E.3.1.2. Scanning shall be performed in both circumferential directions using 45° shear wave probes.

Alternatively, the non-AUT-inspected pipe ends shall be cut off, with the following conditions:

a) Non-AUT-inspected pipe ends shall be defined and confirmed by a demonstration by the manufacturer.

b) Where more critical UT acceptance criteria applies to the pipe ends than applies to the rest of the pipe body, the more critical acceptance criteria shall be applicable to the new pipe ends, after non-AUT-inspected pipe ends have been cut off.

Add title to E.3.3.2

E.3.3.2 UT for Lamination Check

Replace section with

UT shall be carried out in accordance with ISO 10893-8 to verify that the whole circumference of both pipe ends is free from laminar imperfections exceeding the limits stated in Table E.8.1.

Scanning shall be carried out over a distance of [3.5*t* + 25 mm (0.98 in.)] or 50 mm (2.0 in.), whichever is greater, from the point where the outside surface meets the pipe end face or bevel.

Pipe end UT shall be undertaken from the outside surface and be inspected before beveling.

A longer scanning distance may be specified in the LPMDS.

Add new section

E.3.3.3 MT of End Face

If specified in the LPMDS, the end face (beveled or square cut) at each pipe end shall be magnetic particle inspected for the detection of laminar imperfections, in accordance with ISO 10893-5 or ASTM E709.

The end face shall be free of indications.

NOTE This should only be performed on beveled ends.

E.4 Radiographic Inspection of Weld Seams

E.4.2 Radiographic Inspection Equipment

Replace E.4.2.2 with

E.4.2.2 The radiographic films used shall be in accordance with ISO 11699-1, class C4 and shall be used with lead screens.

Replace E.4.2.3 with

E.4.2.3 The density of the radiograph shall be between 2.0 and 3.0 in the weld seam and between 2.0 and 3.5 in the parent metal. Film viewers (illuminator) shall be certified for the applicable density ranges.

Add new section

E.4.2.4 Where digital imaging methods (CR, DDA or DR) are used, the grey values and contrast achieved shall be controlled within limits specified in the procedures, and shall be sufficient to enable the required radiographic sensitivity to be achieved.

E.4.6 Defects Found by Radiographic Inspection

Add to section

Where suspect indications have been recorded by UT but have not been detected during retesting by RT, the area shall be subjected to further UT. If the repeat UT confirms the indication as true and relevant (i.e. not due to geometrical features or coupling conditions), the UT indication shall be classed as a defect and rejected.

Add new section

E.4.8 Use of Filmless, Computed or Digital Radiography

If accepted, the conventional RT film of the body weld seam and the weld seam at the pipe ends may be replaced by digital imaging methods, in accordance with ISO 10893-7, provided that the standard of the CR, DDA or DR is at least equal to the requirements for RT specified in this document.

The image quality during CR, DDA and DR shall comply with ISO 10893-7 Class B.

If a defect is detected by any NDT method, it shall be considered rejected.

The final acceptance shall be by UT. RT shall not be used to accept defects detected by UT.

E.5 Ultrasonic and Electromagnetic Inspection

E.5.1 Equipment

Add title to E.5.1.1

E.5.1.1 Characteristics

Add to section

AUT equipment shall be used to inspect weld seams and pipe bodies for the detection and recording of indications. AUT equipment shall have facilities with the following characteristics.

Add new section

E.5.1.1.1 General

a) The system shall be qualified in accordance with Appendix 3.

b) The NDT system shall be capable of revealing the discontinuities specified in the LPMDS and in general, capable of revealing axial and circumferential imperfections (as applicable) in the internal surface, external surface and inner material of pipe, including laminations and segregations.

c) If specified in the LPMDS or whenever specified in the annexes, the NDT system shall have capability for oblique imperfection detection.

d) All automated systems shall be equipped with robust (firm and stable) scanning systems.

e) Registration/recording of indications on paper or on a retrievable medium shall be without any intervention from the ultrasonic operator. Any indication above the recording level shall be automatically recorded.

f) Any indication above 50 % (-6 dB) of the primary reference level shall be recorded for investigation. The primary reference level shall be below saturation level, and below 100 % full screen height (FSH) on systems capable of measuring amplitude up to 100 %.

g) Coupling shall be monitored for all probes, by use of consistent and reliable reference signals, e.g. the backwall echo, a through-transmitted signal (for probes arranged in pitch-catch) or the signal from the ultrasound entry surface. The coupling monitor gate shall be set at 10 dB below the reference signal peak. The reference signals and monitor gates shall be established and checked dynamically during equipment standardization.

h) Loss of coupling shall be recorded, and clear automatic audible and acoustic warnings activated. Areas identified with acoustic coupling loss during AUT inspection shall be evaluated manually including the areas equal to one skip distance adjacent to the area identified as coupling loss for angle beam inspection.

i) UT equipment shall satisfy the requirement for the signal/noise ratio (at least 12 dB).

j) Equipment shall be capable of automatic paint spray marking of defects or, if agreed with the purchaser, systems that record defect positioning with inspection maps may be accepted.

k) Every four hours, each paint spray, including those of coupling failure, shall be activated in order to clean out the spray nozzle.

Add new section

E.5.1.1.2 Plate/Coil

If required in the LPMDS:

a) scanning systems for AUT of plate or coil shall enable 100 % coverage of the plate/coil area, and coverage of the full thickness of the plate or coil (see E.5.1.4); and

b) any indication above the recording level shall be presented in C-Scan format.

Add new section

E.5.1.1.3 Pipe Weld Seam and Pipe Body

a) Scanning systems for AUT of the pipe weld seam or pipe body shall enable 100 % coverage in one continuous pass. Coverage shall include the full depth and width of the seam and HAZs of welded pipe (HAZs shall be considered to be at least 3.0 mm (0.12 in.) wide).

NOTE Multiple carriages may be used together or separately

b) For seamless pipes, coverage shall include the inside and outside surfaces and full thickness of the pipe.

c) For welded pipe, an automated weld tracking system for correct positioning of the probes with respect to the weld centerline shall be used, capable of a positional accuracy of ±2 mm (0.08 in.) or better.

d) Any indication above the recording level shall be automatically marked on the pipe surface (see Table E.9).

e) UT equipment shall produce consistent responses within ±25 % amplitude (or equivalent dB values as decided by the purchaser) from identical reference reflectors at both ends and the center of pipes or weld seams (as applicable).

NOTE If the plate or coil body has been 100 % inspected at the plate or pipe mill in accordance with this specification, inspection may not be required on the pipe body.

Add new section

E.5.1.1.4 Manual UT

MUT equipment shall only be used to:

a) inspect non-AUT-inspected plate edges and plate ends;

b) inspect non-AUT-inspected pipe ends or weld ends, if prior written acceptance has been obtained from the purchaser;

c) verify indications recorded by AUT; and

d) confirm the rejection or acceptance of indications.

Recording levels used during MUT shall be equivalent to those used during AUT. The MUT scanning speed shall not exceed 150 mm/s (5.91 in./s).

MUT for detection of laminar imperfections shall be performed in accordance with ISO 10893-9, Annex A. Dual transducer probes shall be used.

The extent of laminar imperfection size shall be determined with the -6 dB method, or in case the beam size is bigger than the imperfection size, the -20 dB method shall be used.

Add title to E.5.1.2

E.5.1.2 Weld seam coverage

Replace section with

For welded pipe, the equipment shall be capable of testing the entire length of the weld seam (except for weld ends subject to separate AUT, SAUT or MUT, as applicable) and the entire thickness of the weld seam as follows:

a) for EW and LW seams, the weld line plus at least 1.6 mm (0.063 in.) of adjacent parent metal on each side of the weld line (the HAZs);

b) for SAW and COW seams, the weld seam plus at least 1.6 mm (0.063 in.) of adjacent parent metal on each side of the seam (the HAZs).

The precision of the weld tracking device shall be taken into account.

Add new section

E.5.1.3 Probes Used for AUT

Probes used for AUT shall:

a) enable the sensitivity and scanning coverage required;

b) be provided with probe data sheets demonstrating the manufacturer, type, beam angle, dimensions, frequency distribution and focusing;

c) for angle beam probes used for UT of weld seams, be provided with data sheets that illustrate the vertical -6 dB beam profile; and

d) for normal (0°) beam probes, be provided with data sheets that illustrate the lateral -6 dB beam profile.

Add new section

E.5.1.4 AUT Systems for Inspection of Plate/Coil and Pipe

For AUT systems used to detect laminar imperfections in plate/coil and pipe, the capability of the UT systems to record and reject the minimum sizes of defects required by the acceptance criteria, shall be demonstrated for all probe types to be used:

a) Plate/coil: over the full body, at the plate edges and at the plate ends, 3 mm (0.12 in.) below the top surface and 3 mm (0.12 in.) above the bottom surface of the substrate.

b) Pipe: over the full body and at the pipe ends, 3 mm (0.12 in.) below the top surface and 3 mm (0.12 in.) above the bottom surface.

c) Weld edges: across the full area including at the pipe ends, 3 mm (0.12 in.) below the top surface and 3 mm (0.12 in.) above the bottom surface.

E.5.2 Ultrasonic and Electromagnetic Inspection Reference Standards

E.5.2.1

Add to section

a) The reference standards shall be of the same material grade, wall thickness of the plate/coil or pipe to be tested and taken from the same order, unless otherwise agreed with the purchaser.

b) Unless otherwise agreed, reference standards used to demonstrate the consistency and accuracy of weld tracking systems during the qualification of AUT of HFW seams and SAW seams shall be full production length and may be of similar diameter and any wall thickness.

c) Reference standards for seamless or welded pipe shall include sufficient lengths for run-on and run-off, where applicable.

d) The design of reference standards shall be agreed with the purchaser, prior to use.

Replace E.5.2.2 with

E.5.2.2 Unless otherwise specified in the LPMDS, reference standards used for dynamic demonstration and repeatability testing shall be full production length.

Replace E.5.2.3 with

E.5.2.3 Reference standards shall, as applicable, contain as a minimum, the reference reflectors stated in the following tables of this specification:

a) HFW Seam: Table E.7.1

b) SAW Seam: Table E.7.2

c) SMLS pipe: Table E.7.3

d) Plate/coil: Table E.7.4

Alternative or additional reflectors may be added in the LPMDS.

The surface profile of all scanning surfaces shall be within a tolerance of ±1.0 mm (0.04 in.) in 50 mm (1.97 in.) of the nominal straightness, flatness and circumference (as applicable) of the reference standard, unless otherwise agreed with the purchaser.

A certification sheet shall be prepared for each test standard, to document and certify the reference defects. Data shall include the following information:

a) mechanical dimensions of each test notch, hole, and wall reduction (depth, length and width and/or diameter);

b) acoustical characteristics for each flaw including drilled holes, being a maximum variation of 2 dB for production reference standards and 1 dB for AUT qualification reference standards (see Appendix 5), unless otherwise agreed with the purchaser;

c) test notch replicas or molds;

d) remaining thickness, measured by manual ultrasonic testing or micrometer.

E.5.2.4

Replace note with

NOTE The term “reference reflector” is used in this annex to mean “reference indicator”, “artificial defect” or “reference defect", e.g. flat bottom hole (FBH), radially-drilled hole (RDH), side-drilled hole (SDH) and N5 Notch.

E.5.2.5

Add to section

Visual and dimensional inspection shall be carried out on each reference standard and the results shall be included in a formal report or certificate, demonstrating compliance with the requirements of this specification and the applicable design. NDT methods may be used to provide additional information. The following shall be included as a minimum requirement:

a) report identification, date, purchaser name, authorizing name and signature;

b) reference standard: identification, length, diameter, thickness, material, weld procedure and weld profile (as appropriate), scanning surface profile, and reference reflector locations;

c) N5 notches: length, width, depth, angle and cross-section;

d) FBH (weld): diameter, drilled depth, depth below surface, location of end relative to fusion line, angles in two perpendicular planes, and confirmation of flatness and perpendicularity of end;

e) FBH (plate/coil): diameter, drilled depth, depth below surface, angles in two perpendicular planes, and confirmation of flatness and perpendicularity of end;

f) SDH: diameter, drilled length, depth below surface, location, angles in two planes; and

g) RDH: diameter, location, angles in two perpendicular planes.

Replace Table E.7. with Tables E.7.1, E.7.2, E.7.3 and E.7.4

Table E.7.1 − HFW Seam: Reference Reflectors

NOMINAL THICKNESS *t* mm (in.)	REFERENCE REFLECTORS [a, b, c, i]				
	WELD BODY N5 NOTCHES [d]		FBH [e]	RDH (SEAM) [f]	WELD END N5 NOTCHES [d, g]
	OD [h]	ID			
t < 12 (0.47)	One	One	n/a	One	Two at each end (OD and ID)
12 (0.47) ≤ *t* ≤ 18 (0.7)			One pair centered at 50 % of *t*		
18 (0.7) < *t* ≤ 24 (0.94)			Two pairs centered at 40 % and 60 % of *t*		
t > 24 (0.94)	To be agreed with the purchaser in advance of NDT				

a Reference reflectors shall be located on the weld fusion line. If required in the LPMDS, additional reflector shall be placed to detect lamination in the HAZ and/or parent metal to satisfy the requirements of E.9.

b Reference reflectors shall be sufficiently separated from each other and from any joints or edges in the reference standard such that indications from the reference reflectors can be properly identified, resolved and measured ultrasonically.

c Drilled hole dimensions are based upon standard drill-bit sizes.

d All notches shall be N5, rectangular section. Longitudinal, at and parallel to the weld axis.

− Depth: 5 %*t*; not necessarily less than 0.3 mm (0.012 in.); tolerance ±15 % of depth or ±0.05 mm (0.012 in.), whichever is greater.

− Length at full depth: maximum 50 mm (2.0 in.). Alternative notch length may be specified in the LPMDS.

− Width: maximum 1 mm (0.04 in.).

− The weld body OD and ID notches shall be as close to the pipe center as practicable.[h].

e FBH: all 3 mm (0.012 in.) diameter, drilled perpendicular to the weld fusion line (within ±1° of the normal to the fusion line), end faces at the weld fusion line; one of each pair facing clockwise, one of each pair facing counterclockwise.

f RDH - Seam: 1.6 mm (0.06 in.) diameter drilled through and perpendicular to the weld fusion line (within ±1° of the normal to the fusion line axis). For EMI only.

g N5 Notches at pipe ends: OD [h], to represent the maximum extent of automated NDT coverage of the length of the seam (also see E.3.2.1).

RDH 1.6 mm (0.06 in.) [200 mm (7.87 in.) from each pipe end and at mid length] and RDH 3.2 mm (0.126 in.) [3.2 mm (0.126 in.) from weld centerline] may be used in lieu of N5 end notches.

h OD N5 notches shall also be used to demonstrate the accuracy and consistency of the alignment of the automated weld tracking system.

i If required in the LPMDS, lamination check shall be performed with a 6 mm (0.24 in.) diameter FBH, drilled in radial direction located in the HAZ area with a depth of 50 % wall thickness.

Table E.7.2 − SAW Seam: Reference Reflectors

Pipe Nominal Thickness *t* mm (in.)	REFERENCE REFLECTORS [a, b, i]							
	N5 NOTCHES [c]				FBH [f]		SDH [j]	RDH [k]
	Longitudinal [d]		Transverse [e]		Longitudinal [g]	Transverse [i]	Longitudinal	Vertical
	OD	ID	OD	ID	Embedded			
t < 12 (0.47)	3	3	1	1	Not applicable	Not applicable	Not applicable	5
t ≥ 12 (0.47)					Pairs of FBH at depths according to Footnote h	1 pair	Pairs of SDH at depths according to Footnote h	

a Reference reflectors shall be sufficiently separated from each other and from any joints or edges in the reference standard such that indications from the reference reflectors can be properly identified, resolved and measured ultrasonically.

b Drilled hole dimensions are based upon standard drill-bit sizes

c All notches shall be N5, rectangular section:

− Depth: 5 %*t*; not necessarily less than 0.3 mm (0.012 in.), maximum 2.0 mm (0.08 in.); tolerance ±15 % of depth or ±0.05 mm (0.002 in.), whichever is greater.

− Length at full depth: maximum 50 mm (2.0 in.). Alternative notch length may be specified in the LPMDS.

− Width: maximum 1 mm (0.04 in.).

d N5 Notches, longitudinal, located in the HAZs, parallel to the weld axis, one on each side of the weld and on weld centerline.

e N5 Notches - Transverse – perpendicular to the weld, centered on the weld centerline. Applicable only to Annex K, Sour or Offshore service. If the weld is capped, the manufacturer may elect to grind both the internal and external weld reinforcements to match the pipe contour in the immediate area and on both sides of the notches.

f FBH: all 3 mm (0.12 in.) diameter

g FBH drilled perpendicular to the fusion face (within ±1° of the normal to the fusion face in two perpendicular planes), end faces parallel to and at the fusion face; one of each pair facing clockwise, one of each pair facing counterclockwise.

h Number of pairs of reference reflectors, N = ((*t*/8)-1) ↑ (rounded up); evenly distributed through the weld depth. Depths are measured from pipe outer surface to FBH centerline at end/SDH centerline. For example:

− Pipe Thickness, *t* = 12 mm (0.47 in.), Number of Pairs, N = 1, Depth = 6 mm (0.24 in.).

− Pipe Thickness, *t* = 20 mm (0.79 in.), Number of Pairs, N = 2, Depths = 6.7 mm (0.26 in.) and 13.3 mm (0.52 in.).

− Pipe Thickness, *t* = 30 mm (1.18 in.), Number of Pairs, N = 3, Depths = 7.5 mm (0.30 in.), 15.0 mm (and 22.5 mm.

i FBH drilled from the ID at 45˚ to the weld axis (within ±1° in the radial/axial plane); one facing forward, one backwards. Drilled to 0.5 *t* depth. Applicable to Annex K, sour or offshore service or as specified for the project.

j SDH: all 3 mm (0.12 in.) diameter, longitudinal, located on both sides of the weld, 5 mm (0.20 in.) from the weld toes, drilled parallel to the weld axis within ±1°.For setting defect gate lengths/assuring coverage.

k RDH: 3.2 mm (0.13 in.) diameter, drilled through weld centerline, (within ±1° of the axial/radial and circumferential/radial planes). One as close as practicable to the mid-length position and one at each pipe end, representing the maximum extent of automated NDT coverage of the length of the seam. These shall also be used to demonstrate the accuracy and consistency of the alignment of the automated weld seam tracking system.

l If required in the LPMDS, lamination check shall be performed with FBH diameter 152 mm (6 in.) radial direction located in the HAZ area with a depth of 50 % wall thickness.

Table E.7.3 − SMLS Pipe: Reference Reflectors

PIPE NOMINAL THICKNESS *t* mm (in.)	Reference Reflectors [a, i]					
	N5 Pipe Body Notches [b]				RDH [d]	Longitudinal Pipe End N5 Notches [b, e, g]
	Longitudinal [c]		Transverse			
	OD	ID	OD	ID		
All	3	3	1	1	1	2

a Reference reflectors shall be sufficiently separated from each other and from any joints or edges in the reference standard such that indications from the reference reflectors can be properly identified, resolved and measured ultrasonically.

b All notches shall be N5, rectangular section:

− Depth: 5%*t*; not necessarily less than 0.3 mm (0.012 in.); tolerance ±15 % of depth or ±0.05 mm (0.002 in.), whichever is greater.

− Length at full depth: maximum 50 mm (2.0 in.). Alternative notch length may be specified in the LPMDS.

− Width: maximum 1 mm (0.04 in.).

Angular tolerance: within ±0.5° of the angle specified Footnote c.

c For OD and ID longitudinal pipe body N5 notches, three of each shall be included as follows:

1) One parallel to the pipe axis (axial) (Footnote f)

2) One inclined to the pipe axis by +5˚ (Footnote h) (oblique)

3) One inclined to the pipe axis by -5˚ (Footnote h) (oblique)

d RDH: 1.6 mm (0.06 in.) diameter drilled through the pipe (within ±1° of the axial/radial and circumferential/radial planes). For EMI only. Drilled hole dimensions are based upon standard drill-bit size.

e One OD N5 Notch, at each pipe end, parallel to the pipe axis (axial), representing the maximum extent of automated NDT coverage of the length of the pipe.

f The OD axial N5 notch (Footnote g) shall be as close as practicable to the center of the pipe length.

g The three axial OD N5 Notches (one at pipe center, two at pipe ends) shall be used to demonstrate the consistency of the automated scanning system along the pipe length.

h These oblique angles shall apply unless otherwise stated by the purchaser for specific projects and/or mills. If specified in the LPMDS, the oblique angle shall be determined using notched billet.

i The pipe shall also contain an area of known/specified thickness [tolerance ±0.01 mm (0.0003 in.)] for the calibration of pipe wall thickness measurement (where this is applicable).

Table E.7.4 − Plate/Coil: Reference Reflectors

THICKNESS *t* mm (in.)	REFERENCE REFLECTORS [a]				
	FBH [b]	DEPTHS (mm) [c]	EACH EDGE ZONE [d]	EACH END ZONE [e]	BODY ZONE [f]
All	Diameter: 6 mm (0.24 in.)	3	2 [g k]	2 [h k]	4 [l j]
		t/2	2 [g k]	2 [h k]	4 [l j]
		(*t*-3)	2 [g k]	2 [h k]	4 [l j]

a Reference reflectors shall be sufficiently separated from each other and from any joints or edges in the reference standard such that indications from the reference reflectors can be properly identified, resolved and measured ultrasonically.

b FBH shall be drilled from the back surface, opposite the scanning surface, perpendicular to the surface within ±1°. Drilled hole diameter shall be stated as the standard drill bit diameter.

c Depths are given as those below the UT scanning surface. Tolerance ± 0.5 mm (0.02 in.).

d Each of the two edge zones shall run the full length of the plate/coil and from the line of the final cut edge to a distance [3.5*t* + 25 mm (0.98 in.)] or 50 mm (2.0 in.), whichever is greater, inside this.

e Each of the two end zones shall run the full width of the plate/coil and from the line of the final cut end to a distance of [3.5*t* + 25 mm (0.98 in.)] or 50 mm (2.0 in.), whichever is greater, inside this.

Longer scanning distance may be specified in the LPMDS.

For continuous coil subject to in-line AUT before cutting to length, the end zone requirement may be omitted.

f The body zone shall be located inside the edge zones and end zones.

g One drilled 5 mm (0.2 in.) from the line of the final cut edge and one drilled [3.5*t* + 25 mm (0.98 in.)] or 50 mm (2.0 in.), whichever is greater, from the line of the final cut edge (distances to FBH centerlines).

h One drilled 5 mm (0.2 in.) from the line of the final cut end and one drilled [3.5*t* + 25 mm (0.98 in.)] or 50 mm (2.0 in.), whichever is greater, from the line of the final cut end (distances to FBH centerlines).

i One drilled as close as practicable to the center of the body zone.

j Where scanning is performed in the axial direction only, using multiple fixed probes, only one single body zone shall apply and the number of FBH at each depth shall be equal to the number of ultrasonic probes, the FBH locations coinciding with the probe centerlines.

k Where MUT is used to examine edge and/or end zones, at least three 6 mm (0.24 in.) diameter FBH shall be used, with depths as stated.

1 Reference standards for plate shall be of any convenient width (subject to compliance with this specification) if scanned with an X/Y scanner but still wide enough to comply with Footnote j.

2 Reference standards for coil/strip shall be full production width.

3 Alternative arrangements shall only be permitted if agreed in writing by the purchaser at tender stage.

4 For HFW manufacturing, full-body ultrasonic testing for laminar imperfections is acceptable if coil edge ultrasonic inspection is unavailable.

5 Where AUT is performed on HFW pipe body instead of coil, the same criteria as above shall apply (also see Table E.8.1).

E.5.3 Instrument Standardization

Replace E.5.3.1 with

E.5.3.1 The manufacturer shall use a documented procedure to achieve 100 % coverage of the application and to establish sensitivity and the recording and reject thresholds for UT or EMI (as applicable).

The reference reflectors given in Tables E.7.1 through E.7.4 (as applicable) shall be used to ensure full coverage of the pipe.

Reference reflectors shall be used to establish sensitivity and be detected under normal NDT operating conditions. Such capability shall be demonstrated dynamically on-line using the same equipment as used for

production inspection, the same relative speeds between pipe and probe and the same scanning directions as used for the production pipe.

Responses from each of the reference reflectors shall be recorded. No individual channel or transducer shall produce a saturated response from any of the reference reflectors

Replace E.5.3.2 with

E.5.3.2 For an automated NDT system, standardization shall be performed as follows.

Add new section

E.5.3.2.1 Static Calibration

Static calibration shall be performed once at the beginning of the operating shift.

The amplitudes of indications from each reference reflector shall be adjusted to 80 % FSH ±5 %.

Add new section

E.5.3.2.2 Dynamic Calibration

Dynamic calibration shall be performed at the following periods:

a) at the beginning of the operating shift;

b) every four hours;

c) at the end of the operating shift;

d) whenever there is an equipment operator change-over; and

e) whenever there is an electrical interruption (e.g. black-out).

NOTE End of shift calibration may be combined with the start of next shift calibration if both operators' shifts overlap.

On each occasion, dynamic calibration shall be performed at least three times and the amplitudes of indications from each reference reflector shall be adjusted to 80 % FSH ±5 %.

If, for any channel:

- The signal amplitude has drifted by > + 2 dB (amplitude increase), static calibration shall be repeated.
- The signal amplitude has drifted by > - 2 dB (amplitude decrease), static calibration shall be repeated and all pipes tested since the last satisfactory dynamic calibration shall be retested.

Add new section

E.5.3.5 For UT and EMI, the adequacy of coverage of the application shall be demonstrated for all applicable scans by the detection of all applicable reference reflectors.

Record of calibrations and indications exceeding the threshold level shall be available onsite for the inspector's review.

If required by the purchaser, these records shall be compiled and be part of production dossier.

The NDT procedures shall be submitted for the purchaser's review and acceptance.

Add new section

E.5.3.6 Sensitivity for automated UT and EMI shall be established by use of the reference reflectors contained in the reference standard (see E.5.3.1 and Table E.9).

For AUT:

- Primary reference gain (PRG) shall be the calibrated gain setting (in dB) used to establish an 80 % (±5 %) FSH indication from the applicable reference reflector. Where two or more reference reflectors are used, a distance amplitude curve (DAC), time-corrected gain (TCG) or equivalent shall be used to establish PRG. The DAC or TCG shall be sufficiently long to detect all relevant reference reflectors.

- A transfer correction (TC) shall be determined for each probe/scan, to adjust for any differences > 2 dB between the reference standard and production plate/pipe.

- Primary reference level (PRL) = PRG + TC.

- Scanning sensitivity (SS) shall be as specified in Table E.9.

- Recording level = PRL – 6 dB, i.e. 50 % PRL.

- The coupling monitor gates shall be set to trigger at any loss of coupling in excess of 10 dB from the good coupling situation. Good coupling refers to the consistent reference signal, achieved in a defect-free area (see 5.1.1.1).

- Signal/noise ratio (S/N) shall be at least 12 dB, i.e. noise shall not exceed 25 % PRL.

For EMI:

- PRG = gain setting used to establish an indication from the applicable reference reflector at an appropriate amplitude.

- Recording level = PRG = scanning sensitivity.

E.5.5 Acceptance limits

Replace E.5.5.1 with

E.5.5.1 The acceptance limit for indications produced by reference indicators shall be as given in Table E.8.1 and Table E.8.2.

For HFW, alternative acceptance criteria may be specified in the LPMDS.

Replace Table E.8 with Table E.8.1 and Table E.8.2

Table E.8.1 − Acceptance Limit for Laminar Imperfections - UT Normal (0˚) Beam Scans

Process	Plate/Coil		Pipe	
	Area/Zone	Limits	Area/Zone	Limits
HFW & SAW	BODY	Table K.1 [a]	Body	Table K.1 [a]
	EDGES	ISO 10893-9 Level U1	Weld Edges	ISO 10893-8 Level U1
	ENDS	< 6.4 mm (0.25 in.) in any direction ≤ 6.4 mm (0.25 in.) FBH-equivalent amplitude	Ends	< 6.4 mm (0.25 in.) in any direction ≤ 6.4 mm (0.25 in.) FBH-equivalent amplitude
SMLS	n/a		Body	ISO 10893-8 Level U1
			Ends	< 6.4 mm (0.25 in.) in any direction ≤ 6.4 mm (0.25 in.) FBH-equivalent amplitude

NOTE For laminar inspection of HFW pipe, if it is not possible to disassociate the different areas for body, edges and ends, then the most stringent criteria applies.

[a] Acceptance criteria level shall be specified in the LPMDS.

Table E.8.2 − Acceptance Limit, EMI, and UT Angled Beam Scans

Application	Acceptance Limit [a]		
	N5 NOTCH	3 mm (0.12 in) FBH	RDH [b]
HFW SEAM & HAZs	100 % PRL	100 % PRL	100 % PRL (1.6 mm (0.06 in.) RDH)
SAW SEAM& HAZs	100 % PRL	100 % PRL	n/a
SMLS PIPE	100 % PRL	Not applicable	100 % PRL (1.6 mm (0.06 in.) RDH)
All	Cracks are unacceptable, irrespective of amplitude		

[a] Expressed as a percentage of PRL established using the applicable reference reflector.

[b] EMI only.

E.5.6 Disposition of defects found by Ultrasonic and Electromagnetic Inspection

Add to section

For SAWL/COW pipe seams, all indications exceeding the recording level (see Table E.9) shall be evaluated in accordance with the flowchart in Figure E.2.

Add new table

Table E.9 − UT Sensitivities

Technique	Application	Scans	Reference Reflector	PRG	PRL	SS	RL [a]
AUT	Plate/Coil, Pipe for laminations	Normal (0°)	6 mm (0.24 in.) diameter FBH	100 % DAC/TCG	PRG+ TC	PRL	PRL-6dB (50 % PRL)
	HFW & SAW Seam & HAZs	Angled Beam [b]	N5 Notch				
			3 mm (0.12 in) FBH				
	SMLS Pipe	Angled Beam	N5 Notch				
MUT	All	All	All as above			PRL+ 6 dB [c]	

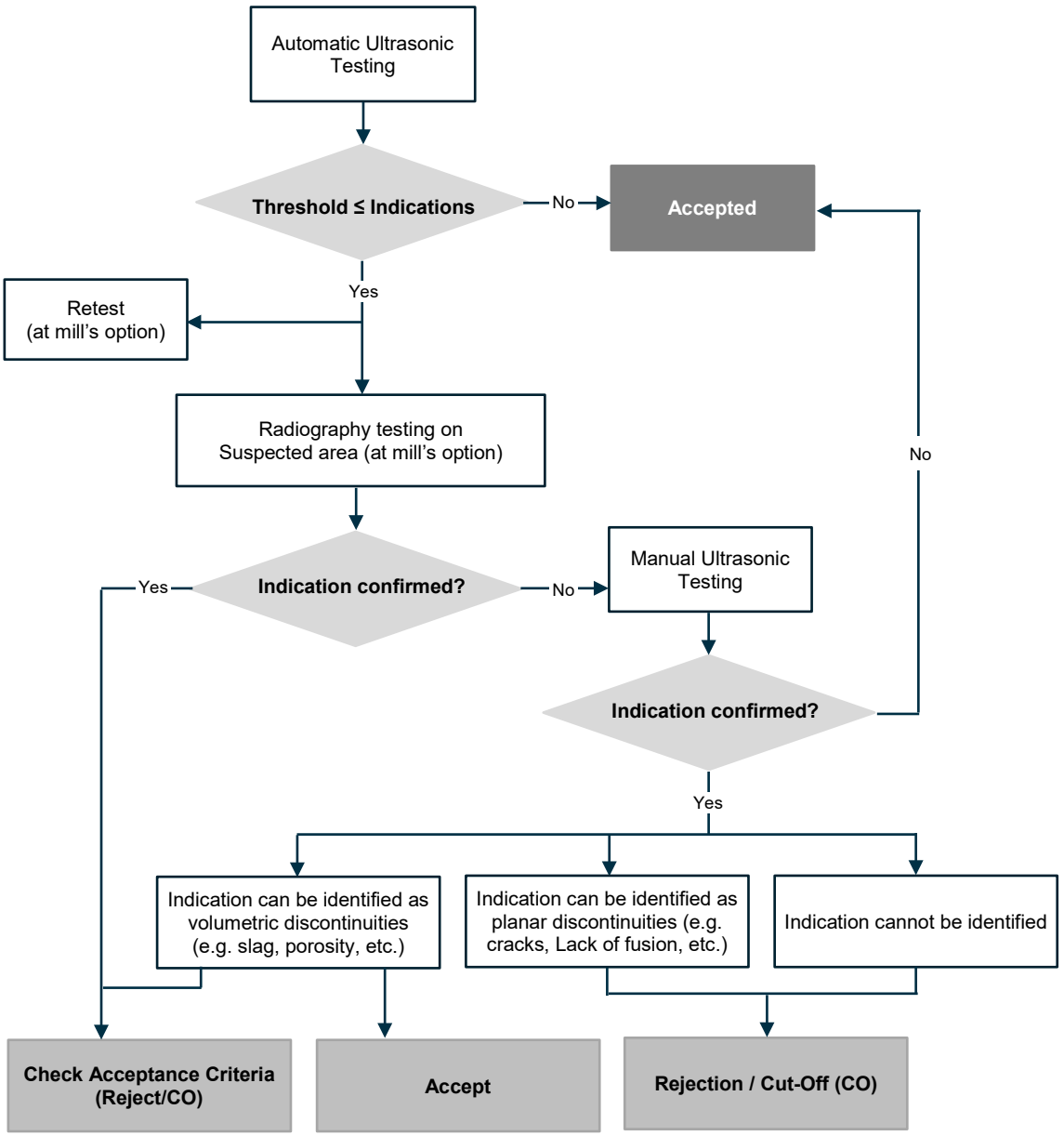
[a] All relevant recordable indications shall be evaluated against the acceptance limits (see E.5.5).

[b] N5 notches and 3 mm FBH shall be used to establish sensitivity. For some scans, it might be necessary to establish the DAC/TCG using both types of reflector.

[c] For MUT, 6 dB shall be added for scanning but should be removed prior to evaluation of indications against the acceptance criteria. This requirement does not apply to 5.9.

Footnotes a, b and c shall apply unless otherwise specified in the LPMDS.

Add new figure



Note

Retest, if performed, shall consist of at least three scans and if the indication is detected by two out of three scans, it shall be considered confirmed.

Figure E.1 − Longitudinal Weld Seam Inspection Decision Tree

Add new section

E.5.8 Scanning

Scanning shall be carried out in accordance with the following tables in this specification:

a) HFW Seam: Table E.10

b) SAW Seam: Table E.11

c) SMLS pipe: Table E.12

Add new table

Table E.10 − HFW Seam: UT Scanning Requirements

Nominal Thickness *t* mm (in.)	Minimum Requirement For Probes/Scans [a]			
	OD [b]	ID [b]	Embedded Defects [c]	
			Either Option A or B	
			Option A	Option B
t < 12 (0.47)	45° Pulse-Echo [d] 1 probe in each direction	45° Pulse-Echo [d] 1 probe in each direction	N/A	
12 (0.47) ≤ *t* ≤ 18 (0.7)			45° Tandem – 1 pair in each direction, centered on the 50 % t FBH	Single Pulse-Echo probe, in each direction, with beam axis centered on the 50 %t FBH and perpendicular to the end of the FBH within ±3°
18 (0.71) < *t* ≤ 24 (0.94)			45° Tandem – 2 pairs in each direction, respectively centered on the 40 %T and 60 %T FBH	Two Pulse-Echo probes, in each direction, with beam axes respectively centered on the 40 %T and 60 %T FBH and perpendicular to the ends of the FBH within ±3°

a Scanning shall be carried out in both circumferential directions [clockwise (CW), counterclockwise (CCW)].

b Scanning of the inside and outside diameters may be combined using a single probe in each scanning direction (0.5 to 1.0 skip or equivalent) where satisfactory sensitivity and coverage can be demonstrated using the applicable reference standard.

c 100 % coverage of the weld thickness shall be achieved by a combination of overlapping scans and beam profiles, as applicable. *t* = nominal pipe wall thickness.

d 45° is the probe angle of refraction at the scanning surface.

Add new table

Table E.11 − SAW Seam: UT Scanning Requirements

Nominal Thickness *t* mm (in.)	Minimum Requirement For Probes/Scans [a, b, h]			
	Parent Metal Scans [c]	Angled Beam Scans Of Weld And HAZ For Longitudinal Defects [d]		
		ID [e]	Embedded Defects	OD [e]
t < 12 (0.47)	≥ 1 probe, 0°, 4-5MHz, compression wave	≥ 1 probe, Pulse-Echo, in each direction [f]	n/a	≥ 1 probe, Pulse-Echo, in each direction [f]
t ≥ 12 (0.47)			≥ 1 probe as required [g]	

a 100 % coverage of the weld thickness, width and depth, including HAZs, shall be achieved by a combination of overlapping scans and beam profiles, as applicable.

b Gate widths shall collectively include the whole of the weld volume, including HAZs.

c Parent metal scans may be omitted if the material has been subject to 100 % UT prior to welding. The strips shall be (3.5*t* + 25 mm (0.98 in.)) or 50 mm (2.0 in.), whichever is greater, from the point where the outside surface meets the pipe end face or bevel.

d Scanning shall be carried out in both circumferential directions (CW, CCW) using shear wave probes.

e Scanning of the inside and outside diameters may be combined using a single probe in each scanning direction where satisfactory coverage and sensitivity can be demonstrated using the applicable reference standard.

f Beam angle(s) dependent on cap width and offset distance: typically 45° to 70°.

g The number of scans and beam angles for embedded defects shall be determined as Footnote a and as follows:

1 Each area of the weld volume (seam + HAZs) shall be covered by at least one beam angle from each side of the weld.

2 Gate lengths may be adjusted to prevent non-relevant indications from weld cap and toes.

3 The original weld preparation locations shall be scanned as follows:

i The beam centerline(s) shall be perpendicular to the original weld preparation ±3° at each FBH location.

ii Areas of the original weld preparation that are less than 15° from the vertical shall be scanned using two-off shear wave probes arranged in tandem (beam angles chosen to suit; 45° probes shall be used in tandem for vertical weld preparations). Alternatively, one or more single-crystal shear wave probe(s) in pulse-echo as per Footnote g 3 i.

h Where the presence of the weld cap prevents 100 % scanning coverage as required above, the cap shall be dressed flush.

Add new table

Table E.12 − SMLS Pipe: UT Scanning Requirements

Nominal Thickness *t* mm (in.)	Minimum Requirement For Probes/Scans [a, b]			
	Scanning For Longitudinal Defects [c]		Scanning For Transverse Defects	
	OD	ID	OD	ID
All	45° Pulse-Echo [d]	45° Pulse-Echo [d]	45° Pulse-Echo [d]	45° Pulse-Echo [d]

a Scanning shall be carried out in both circumferential directions (CW, CCW) and both axial directions. (For = forward, Rev = reverse).

b Scanning of the inside and outside diameters may be combined using a single probe in each scanning direction (0.5 to 1.0 skip or equivalent) where satisfactory coverage and sensitivity can be demonstrated using the applicable reference standard.

c When scanning for oblique defects (see Table E.7.3 footnotes c 2 and c 3, either additional probes shall be used or additional gain shall be used to compensate for the defect angles.

d 45° is the probe angle of refraction at the scanning surface, ±3°.

Add new section

E.5.9 Special Requirements for MUT Inspection for Delayed Hydrogen Cracks (Chevron Cracking) Detection

If required in the LPMDS, MUT inspection for delayed hydrogen cracking (DHC) shall be performed as specified below. AUT may be applied when agreed with the purchaser. AUT procedures and reference pipes shall also be agreed with the purchaser.

When AUT is applied, adequate reference flaws shall be added to the reference standard, to assure 100 % coverage of the weld.

The inspection is limited to SAWH and SAWL pipes.

Add new section

E.5.9.1 Coverage of the Inspection

One pipe per shift shall be selected or 2 % of produced pipes per day, whichever is greater. 100 % of the weld seams shall be tested 48 hours after hydrotest.

The DHC testing shall sample equally, all welding lines.

The procedure for DHC detection shall also be applied on any indication detected by the AUT transverse channels.

Add new section

E.5.9.2 Probe Arrangements

45° probes shall be used. When agreed with the purchaser or specified in the LPMDS, an alternative scanning technique to that illustrated in Figure E.2 may be utilized when UT from the weld cap is not practicable due to profile or roughness.

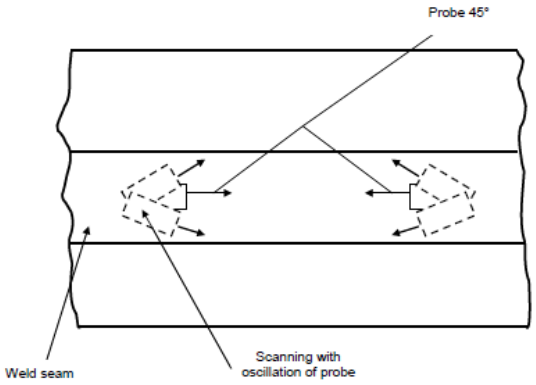


Figure E.2 – MUT Probe Arrangements

Add new section

E.5.9.3 Calibration

Calibration shall be carried out on a minimum of three side drilled holes of 1.6 mm (0.06 in.) in diameter covering the pipe wall thickness: mid-thickness and 4 mm (0.16 in.) [remaining ligament of 2 mm (0.08 in.)] from the ID and the OD.

The reference level for calibration shall be 80 %FSH.

For detection, 12 dB shall be added.

The UT procedure shall be in accordance with ISO 17640.

Add new section

E.5.9.4 Discontinuities Evaluation and Recording Criteria

All indications ≥ 25 % of the DAC reference curve shall evaluated.

All indications that exceed 50 % of the DAC reference curve shall be recorded.

All indications between 25 % and 50 % of the DAC reference curve shall be re-checked by a different level 2 inspector. If an agreement is not achieved, the indication shall be checked by an NDT level 3 inspector.

Add new section

E.5.9.5 Discontinuities Rejection Criteria

Indications with amplitude above 50 % of the DAC curve and classified as DHC, shall be rejected.

Indications not classified as DHC will be disregarded.

Add new section

E.5.9.6 Repairs

Indications classified as DHC shall be communicated immediately to the purchaser's representative.

The welded joint shall be rejected.

All pipes manufactured during the same shift as the defective pipes, as well as those manufactured during the previous shift and the following shift, shall be inspected for DHC detection.

NOTE Expected location and orientation of DHC in the SAW weld seam location and orientation of DHC in the SAW weld seam are described in Figure E.3.

E.6 Magnetic Particle Inspection

E.6.2 Equipment

Add to section

Magnetization shall be carried out in two perpendicular directions for pipe bodies and in at least one direction (for circumferential defects) for pipe end bevels. The magnetic field strength shall be in the range from 2.0 to 4.8k A/m, measured using a tangential field meter. Magnetizing conditions shall be confirmed in each magnetizing direction using an appropriate shim-type flux indicator.

Add new figure

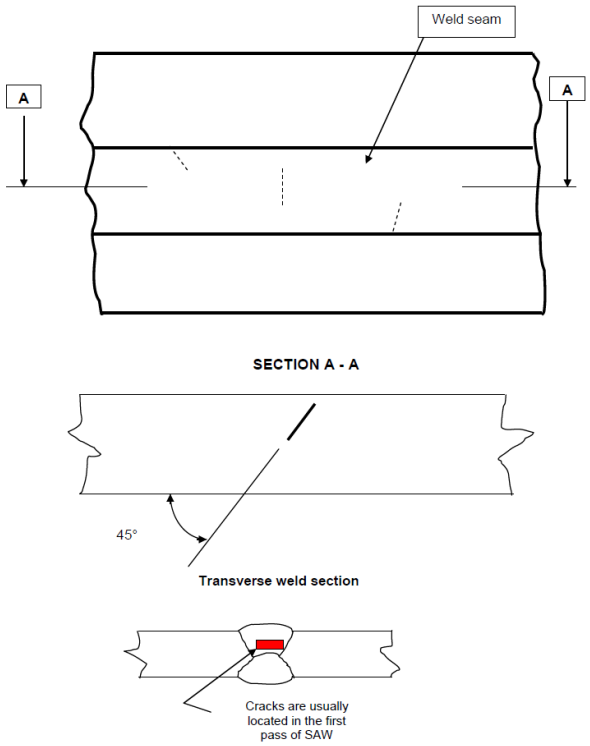


Figure E.3 – Expected DHC Locations and Orientations

Add new section

E.6.4 SAWH and SAWL MT of Long Seam

Magnetic particle testing shall be performed in accordance with ASTM E709.

The full seam weld of SAWL and SAWH MPQT pipes, of one pipe per shift shall be inspected 48 hours minimum after welding. For pipe with D ≥ 609.6 mm (24 in.), the entire internal weld shall be MT inspected.

Indications > 3.2 mm (0.125 in.) in any direction shall be classified as defects. Cracks are not acceptable.

E.7 Residual Magnetism

E.7.5

Add to section

If specified in the LPMDS, residual magnetism shall be checked.

Replace E.7.6 with

E.7.6 Four readings shall be taken approximately 90° apart around the circumference at each end of the pipe. The average of the four readings shall be ≤ 1.5 mT (15 Gs), and no single reading shall exceed 2.0 mT (20 Gs).

E.8 Laminar Imperfections in the Pipe Body of EW, SAW and COW pipes

Replace E.8.1 with

E.8.1 For HFW pipe, UT shall be used to verify that the plate/coil or pipe body is free of laminar imperfections. UT shall be performed in accordance with E.5.1 and E.5.2 (as applicable) and:

a) ISO 10893-9, if such inspection is performed prior to pipe forming; or

b) ISO 10893-8, if such inspection is performed after seam welding.

The acceptance criteria shall be in accordance with Table E.8.1.

The scanning coverage shall be 50 % of the area of the plate/coil or pipe body.

Replace E.8.2 with

E.8.2 For SAW and COW pipe, UT shall be used to verify that the plate or pipe body is free of laminar imperfections. UT shall be performed in accordance with E.5.1 and E.5.2 (as applicable) and:

a) ISO 10893-9, if such inspection is performed prior to pipe forming; or

b) ISO 10893-8, if such inspection is performed after seam welding.

The acceptance criteria shall be in accordance with Table E.8.1.

The scanning coverage shall be 50 % of the area of the plate or pipe body.

E.9 Laminar Imperfections Along the Strip/Plate Edges or Pipe Weld Seam of EW, SAW, and COW Pipe

Replace section with

For HFW, SAW and COW pipes, UT shall be used to verify that the zone along each side of the plate/coil edges or along each side of the weld seam is free of laminar imperfections.

Inspection shall be performed up to a distance from the edge or the edge of the weld seam, as applicable, of [3.5t + 25 mm (0.98 in.)] or 50 mm (2.0 in.), whichever is greater.

UT shall be performed in accordance with E.5.1 and E.5.2 (as applicable) and:

a) ISO 10893-9, if such inspection is performed prior to pipe forming; or

b) ISO 10893-8, if such inspection is performed after seam welding.

The acceptance criteria shall be in accordance with Table E.8.1.

The scanning coverage shall be 100 % of the area.

If specified in the LPMDS for SAWL pipes, UT for detection of laminar imperfections shall be performed on both the plate and along the pipe weld seam.

Add new section

E.11 Laminar Imperfections in the Pipe Body of SMLS Pipe

If specified in the LPMDS for SMLS pipes, UT shall be used to verify that the pipe body is free of laminar defects. UT shall be performed in accordance with E.5.1 and E.5.2 (as applicable) and ISO 10893-8.

The acceptance criteria shall be in accordance with Table E.8.1.

The scanning coverage shall be at least 50 % of the area of the pipe and sufficient to ensure detection of the minimum individual sizes required by acceptance level U1.

Add new section

E.12 Thickness Measurement

Add new section

E.12.1 Seamless Pipes

For SMLS pipes, ultrasonic thickness measurements shall be carried out in accordance with ISO 10893-12. Scanning coverage shall be at least 25 % of the area of the pipe.

The accuracy of measurements and records shall be to one decimal place.

If required in the LPMDS, pipe suitable for AUT inspection (girth weld) shall be checked as follows.

a) The wall thickness shall be automatically measured over 100 mm (3.94 in.) of each pipe end on the whole circumference area. The minimum and the maximum thickness measured at each end shall be recorded and traceable in regard to pipe number and end side.

b) The measured wall thickness versus the pipe numbers and the end sides shall be traceable. The records shall be made available to the purchaser or pipe laying contractor for review and shall be included in the final documentation as a native file, in a native data format that can be imported into a spreadsheet file.

c) The standard deviation (*Sd*) of wall thickness records for all measurement results, irrespective of the pipe number, shall be calculated. *Sd* shall be conventionally calculated in accordance with Equation (E.1):

$$Sd = \frac{t_{max} - t_{min}}{6} \quad \text{(E.1)}$$

The following data shall be transmitted to the purchaser and the contractor within five days, after the automatic measurement has been carried out:

- maximum wall thickness;
- minimum wall thickness;
- wall thickness mean value (*M*);
- STD value;
- pipe numbers and end sides with $t = M + 2\ Sd$;
- pipe numbers and end sides with $t = M - 2\ Sd$.

Add new section

E.12.2 Welded Pipes

Add new section

E.12.2.1 Steel Plate Wall Thickness Measurement

If specified in the LPMDS, wall thickness checks shall be performed, as a minimum, on every five plates in the middle and edges of the plate.

Steel plate thickness measurements shall be such that the specified minimum and maximum wall thickness of finished pipes are met.

The manufacturer shall provide histograms with detail of the minimum/maximum range, the mean value (*M*) and the standard deviation (*Sd*) of wall thickness records for all measurements results, irrespective of the measurement location. *Sd* shall be conventionally calculated in accordance with Equation (E.1).

Add new section

E.12.2.2 Pipe Wall Thickness Measurement

If specified in the LPMDS, pipe suitable for AUT inspection (girth weld) shall be checked as follows.

a) When the pipe item wall thickness standard deviation (*Sd*) has been found in plate mill in excess of 0.25 mm (0.001 in.), see 6.8.2, the following shall apply:

   - wall thickness shall be measured and recorded on 100 % of pipe ends, at two locations at each end, approximately 20 mm (0.79 in.) from one weld toe and on the opposite side to the weld (i.e. four measurements on each pipe);
   - measurements shall not be carried out on ground areas;
   - a dial micro-meter shall be used for measurement. Its fingers (jaws) shall be sharp or round ended for a proper touch on the internal pipe surface;
   - the accuracy of measurements and records shall be to one decimal place;
   - the results shall be presented on a histogram and shall indicate the mean value (*M*) and the standard deviation (*Sd*).

b) The measured wall thickness versus the pipe numbers and the end sides shall be traceable. The records shall be made available to the purchaser or pipe laying contractor for review and shall be included in the final documentation as a native file, that can be imported into a spreadsheet.

Add new section

E.13 Calibrations, Control Checks and Maintenance

NDT equipment, facilities, consumables and processes shall be subject to a documented system of routine calibrations, control checks and maintenance.

Add new section

E.14 Qualification of Mill NDT

NDT performed by plate/coil and pipe mills shall be subject to qualification in accordance with Appendix 3.

Annex G
(normative)
PSL 2 Pipe with Resistance to Ductile Fracture Propagation

G.1 Introduction

G.1.1

Add to section

NOTE 3 The Charpy test requirements given in 9.8 are based on crack initiation principles. Typically, for rich gas transmission and two phase pipe lines, higher absorbed energy requirements may be specified to avoid the risk of running fractures. In this case, one of the approaches in this annex would be used to determine the required absorbed energy. This shall be performed by the purchaser and the outcome requirements included in the LPMDS.

If specified in the LPMDS, additional Charpy impact testing shall be performed on the pipe body.

G.2 Additional Information to be Supplied by the Purchaser

Replace G.2.1 with

G.2.1 The CVN minimum average absorbed energy value (based on full-size test pieces) shall be applicable for each test.

Replace G.2.2with

G.2.2 The CVN impact test temperature shall be the minimum design temperature (refer to the LPMDS).

The DWT test temperature shall be as per 9.9.

NOTE If CVN and DWT testing conducted in accordance with 9.8 and 10.2, meet the requirement of this annex, CVN testing is not required to be repeated.

G.6 Guidance for Determining CVN Absorbed Energy Values in Buried Onshore Gas Pipelines

Add to section

Absorbed energy values shall be as specified in 9.8.2.1, or as stated in the LPMDS.

Add new section

G.12 PIPEDFRAC - Approach 6

The Charpy energy shall as a minimum meet the requirements specified in API 5L, Table G.1.

These values are based on PIPEDFRAC (PRCI) analysis. They shall be checked and confirmed by the purchaser for each project.

Table G.4 specifies the Charpy energy requirements and is valid for thicknesses up to 30 mm (1.8 in.).

The equivalent yield stress to be used in pipeline design shall be between 40 % and 80 % of the specified minimum yield strength minus the de-rating value due to temperature.

Add new table

Table G.4 – Charpy Energy Requirements

Steel Grade	Base material Minimum Average / Single Value (Joules) [a]	
	D ≤ 813 (32 in.)	813 (32 in.) < D ≤ 1118 (44 in.)
L360 or X52	65 / 52	75 / 60
L415 or X60	80 / 65	95 / 76
L450 or X65	90 / 72	100 / 80
L485 or X70	100 / 80	125 / 100

[a] The values obtained in the longitudinal direction, when tested, shall be at least 50 % higher than the values required in the transverse direction.

Annex H
(normative)
Pipe Ordered for Sour Service

H.1 Introduction

Add to section

General sour service requirements are specified in this annex. For purchaser specific applications, see H.4.8.

Material supplied according to this annex shall also comply with NACE MR0175/ISO 15156. Where conflicting requirements arise, the most stringent requirement shall apply.

Pipe that has not been intentionally manufactured to be HIC resistant steel shall not be used, even if it has passed subsequent HIC tests.

H.2 Additional Information to be Supplied by the Purchaser

Replace section with

Information to be supplied by the purchaser and options within this specification are covered in Table H.5 and in the LPMDS.

Table H.5 – Additional Information to be Supplier by the Purchaser

API 5L, H.2 Item Number	Information Required	API 5L Section or Table Number	Purchaser Requirements - (per this specification, as referenced below)
b)	Ultrasonic inspection of strip or plate for laminar imperfections	H.3.3.2.4	H.3.3.2.4
g)	Frequency of hardness testing of the longitudinal seam weld of EW or SAW pipe	Table H.3	Table H.3
j)	Photomicrographs of reportable HIC cracks	H.7.3.1.4	H.7.3.1.4
l)	Deviation from hardness test	H.7.3.3.2 and H.7.3.3.3	As per Figures 14, 15 and 16 or as per LPMDS
m)	Deviation from 4 hardness impressions	H.7.3.3.2 c)	As per Figures 14, 15 and 16 or as per LPMDS
n)	For pipe with $t \geq 5.0$ mm (0.197 in.), ultrasonic inspection for laminar imperfections within extended length of 100 mm (4.0 in.) at the pipe ends	K.2.1.3	K.2.1.3
o)	Supplementary end NDT lamination criteria	K.2.1.3 and K.2.1.4	K.2.1.3 and LPMDS
q)	Verification of lamination size/density	K.3.2.2	K.3.2.2
t)	Ultrasonic inspection of SMLS pipe for the detection of transverse imperfections	K.3.4.1	K.3.1
y)	Acceptance level U2/U2H for non-destructive inspection of the weld seam of HFW pipe	K.4.1	K.4.1
z)	Alternate ISO 10893-10 HFW weld seam UT acceptance criteria	K.4.1 b)	K.4.1
aa)	Ultrasonic inspection of the pipe body of HFW pipe for laminar imperfections	K.4.2	K.4.2
bb)	Ultrasonic inspection of the strip/plate edges or areas adjacent to the weld for laminar imperfections	K.4.3	K.4.3
dd)	Use of fixed depth notches for equipment standardization	K.5.1.1 c)	Not applicable
ee)	Radiographic inspection of pipe ends (noninspected ends) and repaired areas	K.5.3 a)	K.5.3

H.3 Manufacturing

H.3.1 Manufacturing Procedure

Replace section with

H.3.1.1 General

All pipes shall be manufactured in accordance with a manufacturing procedure that has been qualified to the requirements of Annex B, supplemented with additional testing (refer to API 5L, Table H.3).

Add new section heading

H.3.1.2 MPQT

Add new section

H.3.1.2.1 Macrographic, Micrographic and Segregation Analysis on Slabs

Testing according to B.5.2.1 shall be performed on SAWL and HFW pipes.

Add new section

H.3.1.2.2 Macrographic, Metallograpic Analysis on Pipes

The base metal shall be examined for a banded structure (i.e. ferrite or pearlite/martensite). The acceptance criteria shall be agreed between the manufacturer and the purchaser.

H.3.2 Steelmaking

Replace H.3.2.2 with

H.3.2.2 Vacuum degassing or an alternative process to reduce the gas content of the steel shall be applied and reported in the material certificates.

H.3.3 Pipe Manufacturing

H.3.3.1 SMLS Pipe

Replace section with

SMLS pipe shall be manufactured from continuously cast (strand cast) or ingot steel if accepted by the purchaser. If the process of cold finishing is used, this shall be stated in the inspection document.

H.3.3.2 Welded Pipe

Replace H.3.3.2.1 with

H.3.3.2.1 Unless otherwise agreed, plate used for the manufacture of welded pipe shall be rolled from continuously cast (strand cast) or pressure cast slabs.

The pipe shall be SAWL or HFW.

All SAWL pipe for sour service shall be expanded unless otherwise agreed.

Replace H.3.3.2.2 with

H.3.3.2.2 For HFW pipe, the abutting edges of coil or plate shall be machined or milled.

Shearing is not permitted.

See 8.3.5 for center slitting. The manufacturer shall obtain written acceptance to use center slit coils.

Replace H.3.3.2.4 with

H.3.3.2.4 Coil and plate shall be inspected ultrasonically for laminar imperfections or mechanical damage in accordance with Annex K.

Alternatively, full body UT of HFW pipe after forming is permitted.

Replace H.3.3.2.6 with

H.3.3.2.6 Intermittent tack welding of the SAWL groove shall not be permitted.

Add new section

H.3.3.2.7 Welding consumables shall comply with Appendix 1.

Add new section

H.3.4 Cold Sizing and Cold Expansion

The sizing ratio shall be recorded for ten pipes per shift (evenly distributed throughout production) or every 10 pipes per shift, whichever is greater, and also on MPQT pipe used for qualification of the MPS.

H.4 Acceptance Criteria

H.4.1 Chemical Composition

Replace H.4.1.1 with

H.4.1.1 For pipe with $t \leq 25.0$ mm (0.984 in.), the chemical composition shall be in accordance with the values specified in API 5L, Table H.1, and modified by Table H.6.

The pipe designation shall be as given in API 5L, Table H.1 and consist of an alpha or alphanumeric designation that identifies the grade, followed by a suffix that consists of a letter (N, Q or M) that identifies the delivery condition, and a second letter (S) that identifies the service condition.

Replace H.4.1.2 with

H.4.1.2 For pipe with $t > 25.0$ mm (0.984 in.), the chemical composition shall be as agreed with the requirements given in API 5L, Table H1 and modified by Table H.6, being amended as appropriate.

The chemical composition recorded for the pipes used in first-day production testing shall set the datum CE_{IIW}.

The maximum percentages of residual elements shall be as follows:

a) Sn ≤ 0.0150 %;

b) Sb ≤ 0.010 %;

c) Bi ≤ 0.005 %;

d) Pb ≤ 0.005 %;

e) As ≤ 0.0150 %.

Residual elements shall be tested for on the finished product, unless a ladle analysis has been performed and certification has been issued.

Add new table

Table H.6 – Chemical Composition for Pipe Ordered for Sour Service

	Weight Percentage	
Element	**Seamless pipes**	**Welded pipes**
Carbon (C)	0.040 - 0.110	0.040 - 0.110
Phosphorus (P)	0.0180 max	0.0120 max
Sulfur (S)	/	0.0030 max
Niobium (Nb)	0.010 max	0.040 max
Titanium (Ti)	0.0250 max	0.0250 max
Manganese (Mn)	1.65 max	/
Vanadium (V)	0.020 – 0.060 or API 5L Table H.1, whichever is lower	0.080 max or API 5L Table H.1, whichever is lower
CE_{Pcm}	0.190 max	0.210 max or API 5L Table H.1, whichever is lower
Other	The following alternative composition limits for niobium and vanadium are allowed: Nb: 0.035 % max. V: 0.010 % max. Higher limits may be proposed if there is a corresponding reduction in carbon equivalent.	Nb + Ti + V : 0.10 max
NOTE Weld procedures for offshore sour service are required to be qualified on the highest CE_{Pcm} that will be used for production.		

Add new section

H.4.1.3 Maximum deviations from the target chemical composition stated in the agreed MPS shall comply with Table H.7.

Add new table

Table H.7 – Chemical Composition Allowable Range for Pipe Ordered for Sour Service

Element	Allowable Range Percentage	
	Welded pipes	Seamless pipes
C	0.02	0.02
Mn	0.15	0.2
Si	0.1	0.15
Ni	0.1	0.05
Cr	0.1	0.05
Mo	0.05	0.05
Cu	0.1	0.05
V	0.015	0.02
Nb	0.01	0.02
Ti	0.01	0.01
CE_{Pcm}	0.020 [a]	0.020 [a]

[a] For CE_{Pcm} the range shall be split equally around the agreed target value (Allowable range: Target CE_{Pcm} ±0.010)

H.4.2 Tensile Properties

Replace section with

The tensile properties shall be in accordance with 9.3 and API 5L, Table H.2, with the following additional requirements:

a) Maximum yield strength shall be the specified minimum yield strength + 120 MPa;

b) The minimum uniform elongation in the longitudinal direction for seamless and welded pipes shall be 8 % and 6 % respectively.

H.4.3 HIC/SWC Test

Add to section

If specified in the LPMDS:

- crack sensitivity ratio, crack length ratio and crack thickness ratio limits shall apply to each section of pipe;
- alternative acceptance criteria (to be specified by the purchaser in the LPMDS) shall apply;
- crack area ratio (CAR) = 5 % maximum of the specimen area, per specimen. The CAR shall include all cracks and all laminations whether they are associated with cracks or not.

Damage due to hydrogen pressure induced cracking related features such as blistering, straight and stepwise cracks shall be measured and reported.

H.4.4 Hardness Test

Replace section with

Pipes ordered for sour service applications shall satisfy the hardness requirements as given in the Table H.8.

Hardness limits shall be uniform.

Add new table

Table H.8 − Acceptance Criteria for Hardness Test

Grade	Hardness on Pipe and Welded Seam (HV10)
All	230 for Base Material 245 for HAZ and Weld metal/Weld line

H.4.5 SSC Test

Replace section with

Test results shall be assessed as per NACE TM 0316, Section 9.

The metallurgical features shall be documented with photomicrographs.

If specified in the LPMDS, after removal from the solution, the specimen shall be stressed to more than the actual yield strength. The specimen shall not break and no cracks shall be visible at X100 magnification.

No cracks (or rupture) shall be accepted in any of the tested specimens within the 30 day period, for any of the tests carried out.

Only SSC or stress orientated hydrogen induced cracking (SOHIC) cracks shall be considered for evaluation.

Unbroken samples containing clearly identified welding defects that may have generated cracks with a length not exceeding 0.2 mm (0.008 in.) in the through thickness direction are acceptable.

Add new section

H.4.6 Fracture Toughness

If specified in the LPMDS, additional CTOD testing shall be performed in the environment also defined in the LPMDS.

The manufacturer shall submit a CTOD testing procedure for review and approval by the purchaser.

Add new section

H.4.7 Macrographic and Metallographic Examination

The macro and metallographic examination shall be documented by macro and micrographs at sufficient magnification (e.g. X10, X100, and X400) and resolution to demonstrate that the base metal and weld quality meet the requirements of this specification and ISO 5817 level C.

If specified in the LPMDS, the base metal macrograph shall have inclusion ratings in accordance with ASTM E45 method D. The severity level shall be based on the service condition.

NOTE Severity level ½ or 1 should be considered.

If specified in the LPMDS, metallographic examination shall be performed as below:

a) The mid-thickness area of the base metal and the weld area (i.e. centerline of the weld and fusion lines between the base metal and weld metal and between passes) shall not show any indication of centerline segregation, more severe then qualified.

b) The base metal at location *¼t* and *½t* shall be examined for a banded structure (i.e. ferrite or pearlite/martensite). Acceptance criteria shall be agreed between the manufacturer and the purchaser.

Add new section

H.4.8 User Specific Sour Requirements (informative)

User specific sour requirements (if any) will be specified by the purchaser in the LPMDS and may include the following (the list is not exhaustive):

a) Chemical composition: a different chemical composition may be specified (with no changes to the limits on CE_{IIW} / CE_{Pcm} of this specification).

b) Hardness: maximum value may be reduced and different HV load and indentations path may be specified.

c) Corrosion testing: different testing methods, testing environment and/or more stringent acceptance criteria for HIC and SSC test may be specified (see H.7.3.1.3 and H.7.3.2.2) including:

   1) Full ring test may be required (see H.7.2.3.2).

   2) Additional SSC tests may be requested to be performed during qualification at simulated operating conditions if the maximum expected partial pressure of H_2S is higher than 1 bar (14.5 psi).

   3) Test method: 4 points bend according to NACE TM0177 Method B or TM0316.

d) NDT: In case of pipes with delivery condition M (thermomechanical rolled or thermomechanical formed) it may be requested that plate surface is entirely inspected with suitable scanning tools for the detection of local surface areas with increased hardness according to the provisions of H.5.2.

H.5 Surface conditions, Imperfections and Defects

H.5.2

Add to section

If specified in the LPMDS, NDT of plate surface hardness shall be performed in accordance with the provision of K.6.

H.7 Inspection

H.7.1 Specific Inspection

Replace section with

The frequency of inspection shall be as given in Table 18, except as specifically modified in Table H.3.

The test unit definition of Table 18 shall be amended to: “Unless specified otherwise in the LPMDS, test unit is defined as a pipe lot coming from same size, same heat number, and consists of a max. 50 pipes”.

Replace Table H.3 with

Table H.3 − Inspection Frequency

Item No	Type of Inspection	Type of Pipe	Frequency of Inspection [b]
1	Hardness testing	SMLS, SAWL, HFW	Once per test unit of not more than 50 lengths of pipe with the same cold-expansion ratio [a].
2	Hardness testing of hard spots in welded pipe	SAWL, HFW	Each hard spot found on the internal or external surface of the pipe.
3	If specified in the LPMDS, hard spot / local surface areas with increased hardness inspection	SAWL	Each pipe, plate Full surface
5	Hardness testing of the longitudinal weld of welded pipe	SAWL, HFW	Once per test unit of not more than 50 lengths of pipe with the same cold-expansion ratio [a c].
6	Pipe diameter and out-of-roundness for pipe	SMLS, SAWL, HFW	First 10 pipes, then once per test unit of no more than 20 pipes but no less than once per 4 hour operating shift plus whenever any change of pipe size occurs during the operating shift.
7	Non-destructive inspection	SMLS, SAWL, HFW	In accordance with Annex K
8	HIC tests	SMLS, SAWL, HFW	Unless otherwise specified in the LPMDS: one test for each of the first three heats; thereafter, not less than one test per each ten heats of steel.
9	If agreed, SSC tests	SMLS, SAWL, HFW	If specified in the LPMDS, test shall be performed as part of MPQT testing. If specified in the LPMDS, one test for each of the first three heats; thereafter, not less than one test per each ten heats of steel.

[a] The cold-expansion ratio is designated by the manufacturer and is derived using the designated before-expansion outside diameter or circumference and the after-expansion outside diameter or circumference; an increase or decrease in the cold-expansion ratio of more than 0.002 requires the creation of a new test unit.

[b] Unless noted otherwise all values/data shall be recorded.

[c] Pipe produced by each welding machine shall be tested at least once a week.

H.7.2 Samples and Test Pieces for Mechanical and Technological Tests

H.7.2.1 General

Add new section

H.7.2.1.3 For HIC and SSC testing, detailed drawings of test specimens sampling for MPQT and production tests shall be issued by the manufacturer and submitted (in PDF format) for the purchaser's approval, as part of the MPS.

These drawings shall:

a) precisely define the specimen location (along the length, around the circumference and in the pipe wall thickness); and

b) give a unique identification number for each test specimen.

H.7.2.2 Samples for HIC/SWC Tests

Add to section

If specified in the LPMDS, for SMLS pipes, three sets of three specimens shall be taken from each test pipe as follows: one set cut in the base material in a direction parallel to the rolling direction at each of the three 120° location (i.e. 120° x 3 equally spaced = 9 specimens).

If specified in the LPMDS, for welded pipes, three sets of specimens shall be taken from each test pipe as follows:

a) One set of three specimens cut transverse to the longitudinal weld.

   For HFW, the set shall be sampled parallel to the weld for the weld area of HFW line pipe. The weld shall be approximately on the centerline of the test specimens.

b) Two sets cut in base material in a direction parallel to the rolling direction: one at 90º and one at 180º from the weld.

c) For MPQT testing, an additional two sets: one at each pipe end (head and tail of the mother plate) shall be tested.

H.7.2.3 Samples and Test Pieces for SSC Tests

H.7.2.3.1

Add to section

If specified in the LPMDS for SMLS pipes, three sets of three specimens shall be taken from each test pipe as follows: one set cut in the base material in a direction parallel to the rolling direction at each of the three 120° location (i.e. 120° x 3 equally spaced = 9 specimens).

If specified in the LPMDS for welded pipes, three sets of specimens shall be taken from each test pipe as follows:

a) One set of three specimens cut transverse to the longitudinal weld.

   For HFW, the set shall be sampled parallel to the weld for the weld area of HFW line pipe. The weld shall be approximately on the centerline of the test specimens.

b) Two sets cut in the base material in a direction parallel to the rolling direction: one at 90º and one at 180º from the weld; and

c) For MPQT testing, an additional two sets: one at each pipe end (head and tail of the mother plate) shall be tested.

H.7.2.3.2

Add to section

Unless otherwise specified in the LPMDS, each specimen shall have the following dimensions: 115 mm (4.53 in.) to 140 mm (5.51 in.) long, 15 mm wide (0.59 in.) and 5 mm (0.20 in.) thick.

Only samples free of defects shall be used. Regardless of the pipe wall thickness *t*, the set of specimens shall be cut as close as possible to the surface in contact with the effluent containing H_2S (inside or outside), with a minimum depth of machining to obtain flat surfaces.

Unless otherwise specified in the LPMDS, all surfaces shall be polished to 600 grit after machining.

Samples identification shall be performed on each specimen by an accepted method.

If requested by the purchaser, test specimens shall have the surface in contact with effluent in the original condition with no subsequent surface preparation (refer to NACE TM 0316).

If a full ring test is specified in the LPMDS, test sample and specimen reference shall be made to BS 8701.

Note An alternative width of 20 mm (0.79 in.) and thickness of 15 mm (0.6 in.) or full wall thickness whichever is the lesser may be considered. Reference and guidance may be found in NACE TM 0316.

H.7.2.4 Samples for Hardness Tests

Replace section with

Samples for hardness tests shall be taken from the end of selected pipes.

Replace Table H.4 with

Table H.4 − Number, Orientation and Location of Test Pieces per Sample for Hardness Tests

Type of pipe	Sample location	Number, Orientation and location of Tests Pieces [ab]	
		Specified Outside Diameter *D* mm (in.)	
		< 508 (20.000)	≥ 508 (20.000)
SMLS	Pipe body	4T	4T
SAWL/HFW	Pipe weld	1W	1W
	Pipe body	3T	3T

[a] Test Piece shall be spaced by 90° (all four quadrants of the selected pipe).

[b] Refer to API 5L, Figure 5 for an explanation of the symbols used to designate orientation and location.

H.7.3 Test Methods

H.7.3.1 HIC/SWC Test

Replace H.7.3.1.2 with

H.7.3.1.2 Except as allowed by H.7.3.1.3, HIC and SWC tests shall be conducted in a medium complying with NACE TM0284, Solution A.

The manufacturer shall prepare a detailed HIC test procedure, if not included as part of the MPS, and submit it to the purchaser for prior acceptance. The procedure shall include as a minimum:

a) a description of the HIC testing setup/apparatus (schematic required) to be used;

b) the purity of the utilized salts and H_2S for the test solution;

c) a detailed procedure describing the testing;

d) metallographic preparation and evaluation of HIC specimens.

HIC tests are not required on mother pipes for bends.

Replace H.7.3.1.3 with

H.7.3.1.3 If agreed with the purchaser, HIC and SWC tests may be conducted:

a) in an alternative medium, as per ISO 15156-2:2003, Table B.3 or other to be specified in the LPMDS, including NACE TM0284, Solution B;

b) with a partial pressure of H_2S appropriate to the intended application; and

c) with acceptance criteria that are equal to or more stringent than those specified in H.4.3.

H.7.3.1.4

Add to section

In addition to the requirements of NACE TM 0284, the following data shall be provided in the manufacturer's report for each heat tested, for the purchaser's acceptance:

a) the CAR percentage result for each specimen (If UT testing is specified in the LPMDS);

b) locations and dimensions of specimens in tested pipe;

c) all pertinent explanations (where needed) and concluding comments; and

d) photographs of etched and un-etched sections, of any reportable crack, at a suitable magnification.

Any failure shall be analyzed by the manufacturer and the cause of failure made clear to the purchaser.

Add new section

H.7.3.1.5 If specified in the LPMDS, prior sectioning (i.e. after testing, scale and deposits removal), the test piece shall be tested using immersion AUT technique, in accordance with NACE TM0284, Appendix A. Unless otherwise agreed with the purchaser, all narrow and wide faces shall be scanned. The CAR of each scanned surfaces shall be calculated and reported.

Additional sectioning shall be performed at the largest AUT indication. Photographs shall be provided in the report, as required in H.7.3.1.4.

Crack sensitivity ratio, crack length ratio and crack thickness ratio shall be reported for each section. The acceptance criteria shall also be applicable to this additional sectioning.

The manufacturer shall submit a detailed HIC test procedure and AUT procedure for the purchaser's acceptance.

Add new section

H.7.3.1.6 Laboratory facilities for testing shall be accepted by the purchaser.

H.7.3.2 SSC Test

Replace H.7.3.2.1 with

H.7.3.2.1 Except as allowed by API 5L, H.7.3.2.2, SSC tests shall be performed in accordance with H.7.3.2.1.1 to H.7.3.2.1.5.

Add new section

H.7.3.2.1.1 General

Sulfide stress cracking tests shall be performed using the 4 point bending test method (method B of EFC Publication 16 or NACE TM 0316).

With the exception of the type of specimen (no holes) and the bending method (4-point bending), all the provisions regarding method B of NACE TM0177 shall apply.

The manufacturer shall prepare a fully detailed test procedure proposal based upon this specification and submit it to the purchaser for prior approval.

SSC tests are not required on mother pipes for bends.

Add new section

H.7.3.2.1.2 Test Required

Round bar tensile specimens shall be machined as per ASTM A370 in the base metal and parallel to the pipe axis. The tensile test specimen shall be sampled as close as possible to the place where SSC specimens are sampled.

A tensile test shall subsequently be carried out and the yield strength (0.5 % proof stress) and ultimate tensile strength shall be recorded.

The lowest yield strength value shall be taken as the reference for the actual yield strength.

The actual yield strength of the base material shall be the reference for calculating the stress level of the SSC tests. The measurement of applied stress shall be made using either electrical strain gauges or the deflection method. If the deflection method is used, it shall be measured using a dial gauge with an accuracy of 0.01 mm (0.0004 in.).

Spare test specimens shall also be cut out and shall be available for additional testing (in case of test failure).

Add new section

H.7.3.2.1.3 Test Set-up

Test arrangements and loading of specimens shall be in accordance with Appendix 2 of EFC Publication 16 :2009 or ASTM G39 or ISO 7539-2.

The outer and inner rollers shall be made using materials which do not creep when subjected to the sustained loads (e.g. glass and ceramic rods) and avoiding galvanic coupling with the specimen.

Stress applied to specimens shall be adjusted in accordance with H.7.3.2.1.4.

Add new section

H.7.3.2.1.4 Test Conditions

The test solution shall be the NACE test solution “A” (refer to NACE TM0177).

The manufacturer shall ensure that saturation is obtained within one hour.

Hydrogen sulfide concentration in the solution shall be measured by the iodine titration method at the start and at the end of the test.

The pH of the solution shall be recorded at the start and at the end of the test.

Partial pressure of H_2S shall be 1 bar.

The test pieces shall be stressed to a minimum of 80 % the actual yield strength of the pipe.

If specified in the LPMDS, additional SSC tests shall be performed at 90 % of actual yield strength. The results of the tests shall be described and reported as pass or fail, for information only.

Tests shall have a minimum duration of 30 days (720 hours).

Add new section

H.7.3.2.1.5 Reporting

At the end of the test, the manufacturer shall provide a test report giving the following information:

a) measurement of the actual applied stress (strain gauges, etc.);

b) individual results for each specimen tested per set, with photographs and photomicrographs (when applicable);

c) type of solution used for the tests. pH of solution at the start and at the end of the test and during the test, for EFC Publication 16 solutions. H_2S concentration at the start and at the end of the test;

d) location and dimensions of specimens;

e) mill certificates of materials tested showing full chemical analysis and mechanical properties;

f) testing procedure specification; and

h) conclusions and pertinent explanations (where needed), or concluding information.

Any test failure shall be analyzed by the manufacturer and the cause of failure explained in the report.

H.7.3.3 Hardness Test

H.7.3.3.1

Add to section

Hardness testing on the parent metal, HAZ and weld metal / weld line shall be performed using the Vickers test in accordance with ISO 6507-1 or ASTM E92.

An additional hardness indentation line is required close to the surface in contact with the sour process fluid, for pipes formed from thermomechanically controlled processed plates and coils. This shall be done using Hv0.5 (500 g), 0.25 mm (0.01 in.) from the surface. Acceptance criteria shall be as per H.4.4.

No individual readings shall exceed the acceptance criteria specified in H.4.4.

If specified in the LPMDS, the hardness indentation shall be as per Figure 14, Figure 15 and Figure 16.

H.7.5 HIC/SWC Retests

Replace section with

Add new section

H.7.5.1

If any HIC/SWC fails during production, the pipe shall be rejected. Retesting shall be as follows, unless otherwise agreed:

a) one retest shall be taken on two different pipes from the same test unit;

b) providing both these tests give acceptable results, the test unit shall be considered acceptable;

c) if either or both pipes fail during retest, the test unit shall be rejected.

Add new section

H.7.5.2

The pipes manufactured before and after the discarded test units shall be tested per test units or heats, depending of the result of the RCA specified in H.7.3.1.4.

a) Two pipes from every preceding consecutive test unit/heat shall be tested, until two pipes pass for three consecutive test units/heats.

b) For pipes manufactured after the discarded test units, two pipes from each subsequent test unit/heat shall be tested until two pipes pass for three consecutive test units/heats.

If applicable, reprocessing shall be as defined in 10.2.11.

NOTE If the RCA points to a raw material issue, retest frequency based on heat may be more appropriate.

Add new section

H.7.6 SSC Retests

If SSC has been specified as a production test (see Table H.3), retesting according to the following procedure and criteria applies:

a) if any SSC test fails, the pipe shall be rejected and one retest taken on two different pipes from the same test unit;

b) if both tests pass, the entire test unit may be accepted with the purchaser's review and acceptance;

c) if the SSC test fails on either or both pipes during retest, all pipes produced prior to the failed SSC test and after the last successful test shall be rejected.

In case of failure, RCA shall be performed by means of microstructure/metallographic examination. The affected slab shall be identified and pipe manufactured from the slab, produced before and after the test unit, shall be tested in order to release production. This shall also apply to H.7.5.

Annex J
(normative)
PSL 2 Pipe Ordered for Offshore Service

J.2 Additional Information to be Supplied by the Purchaser

Replace section with

Information to be supplied by the purchaser and options within this specification are covered in Tables J.8 and in the LPMDS.

Add new table

Table J.8 – Additional Information to be Provided by Purchaser – Offshore Pipe

API 5L, J.2 Item Number	Information Required	API 5L Section or Table Number	Purchaser Requirements (per this specification, as referenced below)
b)	Ultrasonic inspection of strip or plate for laminar imperfections	J.3.3.2.4	J.3.3.2.4
m)	Hardness test of the pipe body seam weld and HAZ of EW and SAW pipe	Table J.7	Table J.7
n)	Hardness testing of pipe body for SMLS pipe	Table J.6	Table J.6
o)	CTOD testing	J.8.2.2 and Table J.6	Table J.6 (Table 18)
q)	Additional longitudinal tensile testing for deep-water pipelay	Table J.6, footnote d	Table J.6 and J.4.2.1.1
r)	Deviation from hardness test	J.8.3.2.2 c) and J.8.3.2.3	As per Figures 14, 15 and 16 or as per LPMDS
s)	Deviation from location of hardness test	J.8.3.2.2.c)	As per Figures 14, 15 and 16 or as per LPMDS
t)	For pipe with $t \geq 5.0$ mm (0.197 in.), ultrasonic inspection for laminar imperfections within extended length of 100 mm (4.0 in.) at the pipe ends	K.2.1.3	K.2.1.3
u)	Supplementary end NDT lamination criteria	K.2.1.3 and K.2.1.4	K.2.1.3 and LPMDS
x)	Verification of lamination size/density	K.3.2.2	K.3.2.2
aa)	Ultrasonic inspection of SMLS pipe for the detection of transverse imperfections	K.3.4.1	K.3.1
ee)	Acceptance Level U2/U2H for non-destructive inspection of the weld seam of HFW pipe	K.4.1	K.4.1
ff)	Alternate ISO 10893-10 HFW weld seam UT acceptance criteria	K.4.1 b)	K.4.1
gg)	Ultrasonic inspection of the pipe body of HFW pipe for laminar imperfections	K.4.2	K.4.2
hh)	Ultrasonic inspection of the strip/plate edges or areas adjacent to the weld for laminar imperfections	K.4.3	K.4.3
jj)	Use of fixed-depth notches for equipment standardization	K.5.1.1 c)	Not applicable
kk)	Radiographic inspection of the pipe ends (non-inspected pipe ends) and repaired areas	K.5.3 a)	K.5.3
mm)	For grades L625QO or X90QO, and L690QO or X100QO, a lower $R_{t0.5}/R_m$	Table J.2	J.4.2

J.3 Manufacturing

J.3.3 Pipe Manufacturing

J.3.3.1 SMLS Pipe

Replace first sentence with

SMLS pipe shall be manufactured from continuously (strand) cast or ingot steel, as specified in the LPMDS.

Replace J.3.3.2.2 with

J.3.3.2.2 The edges of the coil shall be milled or planed. Shearing is not permitted.

Replace J.3.3.2.4 with

J.3.3.2.4 Coil and plate shall be inspected ultrasonically for laminar imperfections or mechanical damage in accordance with Annex K.

Alternatively, full body UT of HFW pipe after forming is permitted.

Replace J.3.3.2.6 with

J.3.3.2.6 Tack welding shall be in accordance with 8.4.

J.4 Acceptance Criteria

J.4.1 Chemical Composition

Add footnotes j, k and l to Table J.1

j	The aluminum shall be analyzed for acid soluble aluminum (Al_{sol}) and aluminum total (Al_{tot}). The difference between the two shall not exceed 0.0040 % ($\lvert Al_{tot} - Al_{sol} \rvert \leq 0.0040\%$) In all cases, Al/N ≥ 2. Al/N is not applicable to titanium killed steel.
k	A maximum of 0.08 % vanadium shall be required unless a lower threshold is set per API 5L Table J.1, regardless of wall thickness.
l	Hydrogen content shall be limited to 2 ppm (parts per million).

J.4.2 Tensile Properties

J.4.2.1

Replace section with

J.4.2.1.1 The tensile properties shall be in accordance with API 5L, Table J.2, with the following amendments:

a) maximum yield to tensile ($R_{t0.5}/R_m$) ratio in the transverse direction shall be 0.90 for grades up to X56, and 0.92 for grades X60/L415 and above, unless otherwise stated on the purchase order;

b) ($R_{t0.5}/R_m$) ratio in the longitudinal direction shall not exceed 0.93 unless otherwise agreed;

c) a tensile test shall be performed in the transverse direction (whenever pipe size allows it) and longitudinal direction;

d) maximum yield strength shall be the specified minimum yield strength + 120 MPa;

e) actual yield strength shall be ≤ 100 MPa;

f) tensile properties in the longitudinal direction shall be guaranteed to be the same as those in the transverse direction, except that the minimum longitudinal tensile strength can be 95 % of the transverse tensile strength. The test frequency shall be same as the transversal test (see table J.6);

g) the minimum uniform elongation in the longitudinal direction for seamless and welded pipes shall be 8 % and 6 % respectively.

Unless otherwise specified in the LPMDS, a stress-strain curve shall be produced for the first five heats. If specified in the LPMDS, these data shall be supplied in native data formats that can be imported into a spreadsheet file.

The full stress-strain curve shall be reported.

Add new section

J.4.2.1.2 If specified in the LPMDS, a circumferential compression test as per ASTM E9 shall be performed to assess or confirm the α_{fab} value (refer to DNVGL-ST-F101:2017, 5.3.3.7). Testing shall be performed during MPQT and if required, as a production test with the same frequency as the tensile test production test.

a) A compressive stress-strain curve shall be developed.

b) The units used on each axis of each compressive stress-strain curve shall be clearly identified.

c) The compressive stress-strain curves shall cover a range of at least -2.0 % strain.

J.4.3 Hardness Test

Replace section with

Acceptance criteria shall be in accordance with 9.18.

J.6 Tolerances for Diameter, Wall Thickness, Length and Straightness

Replace J.6.1 with

J.6.1 Diameter and out-of-roundness shall be within the tolerances given in Table J.3.

If level A or level B is specified in the LPMDS, Table J.9 shall apply.

If specified in the LPMDS the following requirements shall apply:

a) Out-of-roundness and pipe end diameter shall be measured against the ID instead of OD;

b) The OD out-of-roundness requirements at pipe ends shall be maintained.

Replace J.6.2 with

J.6.2 The wall thickness shall be within the tolerances given in Table J.4.

If specified in the LPMDS, Table J.10 additional restrictions shall apply.

Replace Table J.3 with

Table J.3 − Tolerances for Diameter and Out-of-roundness

Specified outside diameter *D* mm (in.)	**Diameter** mm (in.)				**Out-of-roundness mm (in.)**	
	Pipe body [a]		**Pipe end** [b,c,e]		**Pipe body**	**Pipe end** [b,c,d,e]
	SMLS	**Welded pipes**	**SMLS**	**Welded pipes**		
< 60.3 (2.37)	±0.5 (0.02) or ±0.0075 D, whichever is greater	±0.5 (0.02) or ±0.0075 D, whichever is greater, but max. ± 3.2 (0.125)	±0.5 (0.02) or ±0.005 D, whichever is greater, but max. ±1.6 (0.063)		Included in the diameter tolerance	
60.3 (2.37) ≤ D ≤ 610 (24.02)					0.015 D	0.01 D
610 (24.02) < D ≤ 1422 (55.98)	± 0.01 D	±0.005 D, but max. ±4.0 (0.156)	±1.6 (0.063)		0.01 D but max. 8 (0.31) [f]	0.0075 D but max. 5 (0.20) [f]
> 1422 (55.98)	To be agreed					

a Dimensions of pipe body to be measured approximately in the middle of the pipe length.

b For SMLS pipe, the tolerances apply for $t \leq 25.0$ mm (0.98 in.), and the tolerances for heavier wall pipe shall be agreed with the purchaser.

c The pipe end includes a length of 100 mm (3.94 in.) at each of the pipe extremities.

d For welded pipes, the out-of-roundness shall include the peaking effect.

e For expanded pipe with D ≥ 219.1 mm (8.625 in.) and for non-expanded pipe, the diameter tolerance and the out-of-roundness tolerance may be determined using the calculated inside diameter (the specified outside diameter minus two times the specified wall thickness) or measured inside diameter rather than the specified outside diameter (see API 5L, 10.2.8.3).

f For pipe with both D> 610 mm (24 in.) and D/t >75, the tolerances shall be agreed between the manufacturer and the purchaser.

Add new table

Table J.9 − Premium Tolerances for Diameter and Out-of-roundness

Specified Outside Diameter *D* mm (in.)	Diameter mm (in.)				Out-of-roundness [d] mm (in.)	
	Pipe body [a]		Pipe end [b,c]		Pipe body [b]	Pipe end [c]
	SMLS	Welded pipes	SMLS	Welded pipes		
< 60.3 (2.37)					Included in the diameter tolerance	
60.3 (2.37) ≤ D ≤ 610 (24.02)	±0.5 (0.02) or ±0.0075 D, whichever is greater	±0.5 (0.02) or ±0.0075 D, whichever is greater, but max. ±3.2 (0.125)	Level A [g] ±0.5 (0.02) Level B ±0.5 (0.02) or ±0.005 D, whichever is greater, but max. ±1.2 (0.048) for SAW pipes ±1.0 (0.040) for SMLS and HFW pipes		Level A 0.0075D max 4 (0.156) Seamless pipes: 0.012D Level B 0.015 D but max. 8 (0.31) [f]	Level A [g] Welded pipe: 0.005D max 2.0 (0.079) Seamless pipes: Max 1 (0.040) Level B Welded pipes: 0.01 D but max. 4.5 (0.177) [f] Seamless pipes : 2 (0.079)
610 (24.02) < D ≤ 1422 (55.98)	±0.01 D	±0.005 D, but max. ±4.0 (0.156)	Level A [g)] ±0.5 (0.02) Level B ±1.2 (0.048) for SAW pipes ±1.0 (0.040) for SMLS and HFW pipes		0.01 D but max. 8 (0.31) [f]	0.0075 D but max. 5 (0.20) [f]
> 1422 (55.98)	To be agreed					

a Dimensions of pipe body to be measured approximately in the middle of the pipe length.

b For SMLS pipe, the tolerances apply for t ≤ 25.0 mm (0.98 in.), and the tolerances for heavier wall pipe shall be as agreed with the purchaser.

c The pipe end includes a length of 100 mm (3.94 in.) at each of the pipe extremities

d For welded pipes, the out of roundness shall include the peaking effect.

e For expanded pipe with *D* ≥ 219.1 mm (8.625 in.) and for non-expanded pipe, the diameter tolerance and the out-of-roundness tolerance may be determined using the calculated inside diameter (the specified outside diameter minus two times the specified wall thickness) or measured inside diameter rather than the specified outside diameter (refer to API 5L, 10.2.8.3).

f For pipe with both *D* > 610 mm (24 in.) and D/t >75, the tolerances shall be agreed between the manufacturer and the purchaser.

g Level A: Machining to achieve tolerances is acceptable.

If pipe end machining is required, DNVGL-ST-F101:2019, 7.2.3.39 requirements shall be applied.

Pipe end rectification may be applied to achieve diameter and out-of-roundness tolerance, subject to review and acceptance of the rectification procedure by the purchaser.

NOTE Premium level tolerances are recognized to be stringent and generally specified for critical applications such as, fatigue sensitive risers and flowlines and deep water pipe lines.

Replace Table J.4 with

Table J.4 − Tolerances for Wall Thickness

Wall Thickness t mm (in.)	Tolerances [a] mm (in.)
SMLS Pipe	
< 4.0 (0.157)	+0.6 (0.024) −0.5 (0.020)
4.0 (0.157) to < 10.0 (0.394)	+0.15t −0.1t
10.0 (0.394) to < 25.0 (0.984)	+0.125t −0.1t
≥ 25.0 (0.984)	+3.7 (0.146) or +0.1t, whichever is the greater −3.0 (0.120) or −0.1t, whichever is the greater
HFW Pipe [b,c]	
≤ 6.0 (0.236)	±0.4 (0.016)
> 6.0 (0.236) to 15.0 (0.591)	±0.7 (0.028)
> 15.0 (0.591)	±1.0 (0.039)
SAW Pipe [b,c]	
≤ 6.0 (0.236)	±0.5 (0.020)
> 6.0 (0.236) to 10.0 (0.394)	±0.7 (0.028)
> 10.0 (0.394) to 20.0 (0.787)	±1.0 (0.039)
> 20.0 (0.787)	+1.5 (0.060) −1.0 (0.039)

[a] If the purchase order specifies a minus tolerance for wall thickness smaller than the applicable value given in this table, the plus tolerance for wall thickness shall be increased by an amount sufficient to maintain the applicable tolerance range.

[b] The plus tolerance for wall thickness does not apply to the weld area.

[c] See 9.13.2 and refer to API 5L, J.7.2 for additional restrictions.

Add new table

Table J.10 – Premium Tolerances for Wall Thickness

Wall Thickness t mm (in.)	Tolerances level C mm (in.)
SMLS Pipe	
≥ 25.0 (0.984)	+3.0 (0.120) −3.0 (0.120)
SAW Pipe	
> 6.0 (0.236) to 10.0 (0.394)	±0.6 (0.028)
> 10.0 (0.394)	±1.0 (0.039)

Add new section

J.6.5

There shall be no pitting greater than 0.5 mm (0.001 in.) in depth, in the outer surface of the pipe, for a distance of 200 mm (8 in.) from each pipe end.

The visual surface finish of the pipe measured during the MPQT shall be the agreed surface finish for all production pipes.

J.7 Tolerances for the Weld Seam

J.7.1 Radial Offset of Strip/Plate Edges

Replace Table J.5 with

Table J.5 − Maximum Permissible Radial Offset for SAW Pipe

Specified Wall Thickness *t* mm (in.)	**Maximum Permissible Radial Offset** mm (in.)
≤ 15.0 (0.512)	1.3 (0.051)
> 15 (0.512)	1.5 (0.059)

J.8 Inspection

J.8.1 Specific Inspection

Replace section with

The frequency of inspection shall be as given in Table 18, except as specifically modified in Table J.6.

The test unit definition of Table 18 shall be amended to: “Unless specified otherwise in the LPMDS, a test unit is defined as a pipe lot coming from same size, same heat number and consist of a maximum of 50 pipes”.

Replace Table J.6 with

Table J.6 − Inspection Frequency

Item No	Type of Inspection	Type of Pipe	Frequency of Inspection
1	Tensile testing of the pipe body	All pipes	Once per test unit of pipes with the same cold-expansion ratio [a]
2	Tensile testing of the longitudinal or helical-seam weld of welded pipe	Welded pipes	Once per test unit of pipes with the same cold-expansion ratio [a, b]
3	CVN impact testing of the pipe body	All pipes	Once per test unit of pipes with the same cold-expansion ratio [a]
4	CVN impact testing of the longitudinal or helical-seam weld of welded pipe	Welded pipes	Once per test unit of pipes with the same cold-expansion ratio [a, b]
5	Hardness testing of pipe body and of the longitudinal or helical-seam weld and HAZ of welded pipe	All pipes	Once per test unit of pipes with the same cold-expansion ratio [a, b]
6	Non-destructive inspection	All pipes	As per Annex K
7	Pipe diameter and out of roundness	All pipes	First 10 pipes, then once per test unit of no more than 20 pipes but no less than once per 4 hour operating shift plus whenever any change of pipe size occurs during the operating shift If specified in LPMDS, each pipes end shall be measured If specified in the LPMDS, each pipe end measurement shall be recorded.
8	Wall thickness measurement	All pipes	Each pipe If specified in the LPMDS, each pipe end measurement shall be recorded.
9	Pipe body dimensional testing, squareness, magnetism	All pipes	5 pipes per shift (recorded)
10	Straightness	All pipes	5 pipes per shift (recorded) If specified for fatigue services, straightness shall be measured and recorded on 100 % of pipes

[a] An increase or decrease in the cold-expansion ratio of more than 0.002 requires the creation of a new test unit.

[b] In addition, pipe produced by each welding machine shall be tested at least once per week.

Add to section J.8.1

For HFW pipes, a higher frequency of inspection may be specified in the LPMDS.

J.8.3 Test Methods

J.8.3.1 CTOD Testing

Add to section

CTOD testing shall be in accordance with 10.2.3.8 and 10.2.4.10.

J.8.3.2 Hardness Test

Add to section

Hardness testing shall be in accordance with 10.2.5.5

Replace Table J.7 with

Table J.7 − Number, Orientation, and Location of Test Pieces per Sample for Mechanical Tests

Type of Pipe	Sample Location	Type of Test	Number, Orientation, and Location of Test Pieces per Sample [a]		
			Specified Outside Diameter D mm (in.)		
			< 219.1 (8.625)	≥ 219.1 (8.625) to < 508 (20.000)	≥ 508 (20.000)
SMLS, not cold-expanded [see API 5L, Figure 5 a)]	Pipe body	Tensile	1L [b]	1L + 1T	1L + 1T
		CVN	3T	3T	3T
		Hardness	3T	3T	3T
SMLS, cold-expanded [see API 5L, Figure 5 a)]	Pipe body	Tensile	1L [b]	1L + 1T	1L + 1T
		CVN	3T	3T	3T
		Hardness	3T	3T	3T
HFW [see API 5L, Figure 5 b)]	Pipe body	Tensile	1L90 [b]	1L + 1T180	1L + 1T180
		CVN	3T90	3T90	3T90
		Hardness	1T90 + 1T180	1T90 + 1T180	1T90 + 1T180
	Seam weld	Tensile	—	1W	1W
		CVN	3W + 3HAZ	3W + 3HAZ	3W + 3HAZ
		Hardness	1W	1W	1W
	Pipe body and weld	Flattening	As shown in API 5L, Figure 6		
SAWL [see API 5L, Figure 5 b)]	Pipe body	Tensile	1L90 [b]	1L + 1T180	1L + 1T180
		CVN	3T90	3T90	3T90
		Hardness	1T90 + 1T180	1T90 + 1T180	1T90 + 1T180
	Seam weld	Tensile	—	1W	1W
		CVN [c]	3W + 6 HAZ	3W + 6 HAZ	3W + 6 HAZ
		Guided-bend	2W	2W	2W
		Hardness	1W	1W	1W
SAWH [see API 5L, Figure 5 c)]	Pipe body	Tensile	1L[b]	1L + 1T	1L + 1T
		CVN	3T	3T	3T
		Hardness	1T90 + 1T180	1T90 + 1T180	1T90 + 1T180
	Seam weld	Tensile	—	1W	1W
		CVN [c]	3W + 6 HAZ	3W + 6 HAZ	3W + 6 HAZ
		Guided-bend	2W	2W	2W
		Hardness	1W	1W	1W
		CVN	3WS and 3HAZ	3WS and 3HAZ	3WS and 3HAZ

[a] Refer to API 5L, Figure 5 for an explanation of the symbols used to designate orientation and location.

[b] Full-section longitudinal test pieces shall be used as far as possible.

[c] Charpy HAZ testing to be as per 10.2.3.3 (HAZ= 1 set FL and 1 set FL2 with additional set for t > 25 mm (0.98 in.)).

Annex K
(normative)
Nondestructive Inspection for Pipe Ordered for Sour Service, Offshore

K.1 Introduction

Replace section with

This annex applies to pipe that is ordered for sour service, offshore service, service requiring longitudinal plastic strain capacity and pipe ordered for fatigue service.

For such pipe, the nondestructive inspection provisions of Annex E shall apply, except as specifically modified by the provisions in this annex. In case of conflict between requirements, the most stringent requirement shall be applied.

K.2 General Nondestructive Testing Requirements and Acceptance Criteria

K.2.1 Laminar Imperfections at the Pipe Ends

K.2.1.1

Add to section

If specified in the LPMDS, laminar imperfections > 3.2 mm (0.125 in.) in any direction shall be classified as a defect.

Delete section **K.2.1.2**

Replace K.2.1.3 with

K.2.1.3 For pipe with $t \geq 5.0$ mm (0.197 in.), UT shall be carried out at the pipe ends, in accordance with ISO 10893-8, to verify freedom from laminar defects. Scanning shall be performed over a distance of [3.5t + 25 mm (0.98 in.)] or 50 mm (3.94 in.), whichever is greater, from the point where the outside surface meets the pipe end face or bevel.

Pipe end UT shall be undertaken from the outside surface and be inspected before beveling.

A longer scanning distance may be specified in the LPMDS.

K.2.1.4

Replace section *with*

If specified in the LPMDS, the end face/bevel at each pipe end shall be magnetic particle inspected, in accordance with ISO 10893-5 or ASTM E709, for the detection of laminar imperfections.

The end face/bevel shall be free of indications.

K.2.2 Suspect Pipe

Replace K.2.2.4 with

K.2.2.4 When dressing is carried out, complete removal of defects shall be verified by local visual inspection and by an NDT method in accordance with C.2.3.

K.3 Nondestructive Inspection of SMLS pipe

Replace section heading with

K.3.1 UT for Longitudinal and Transverse Imperfections

Replace section with

All SMLS pipe shall be subject to 100 % AUT in accordance with Table E.2 and ISO 10893-10.

K.3.2 Laminar Imperfections in the Pipe Body

Replace K.3.2.1 with

K.3.2.1 For sour service, UT shall be used to verify that the pipe body is free of laminar imperfections. UT shall be performed in accordance with E.5.1, E.5.2 (as applicable) and ISO 10893-8.

Scanning coverage shall be 100 % of the area of the pipe.

Individual laminations or lamination densities exceeding the specified acceptance limits for sour service in Table K.1 shall be classified as defects. Level 2 or Level 3 shall be specified in the LPMDS

Replace K.3.2.2 with

K.3.2.2 For offshore service requiring longitudinal plastic strain capacity and fatigue service, UT shall be used to verify that the pipe body is free of laminar imperfections. UT shall be performed in accordance with E.5.1, E.5.2 (as applicable) and ISO 10893-8.

Scanning coverage shall be 100 % of the area of the pipe.

Individual laminations or lamination densities exceeding the specified acceptance limits for offshore service in Table K.1 shall be classified as defects.

Alternative acceptance criteria (Table K.1, Level 2 or Level 3) may be specified in the LPMDS.

Replace Table K.1 with

Table K.1 − Acceptance Criteria for Laminar Imperfections

Service Condition	Maximum Individual Imperfection		Minimum Imperfection Size Considered			Maximum Population Density [a]
	Area mm^2 (in.^{2})	Length mm (in.)	Area mm^2 (in.^{2})	Length mm (in.)	Width mm (in.)	
Pipe Body (or strip/plate body)						
Level 1 : Offshore and longitudinal plastic strain capacity	1000 (1.6)	Not specified	300 (0.5)	35 (1.4)	8 (0.3)	10 [per 1.0 m (3.3 ft) × 1.0 m (3.3 ft) square] [b]
Level 2 : Sour	500 (0.8)		150 (0.2)	15 (0.6)	8 (0.3)	10 [per 500 mm (1.6 ft) × 500 mm (1.6 ft) square] [c]
Level 3 : Sour, if agreed	50		30 (0.05)	5 (0.2)	5 (0.2)	5 [per 500 mm (1.6 ft) × 500 mm (1.6 ft) square] [c]
Strip/Plate Edges or Areas Adjacent to the Weld Seam [d]						
Sour, fatigue, offshore or longitudinal plastic strain capacity	32	6.4	—	6.4	—	3 [per 1.0 m (3.3 ft) length]

NOTE 1 For an imperfection to be larger than the minimum imperfection size, each of the minimum area, minimum length and minimum width given for the pipe body (or strip/plate body) have to be exceeded.

NOTE 2 For the purpose of determining the extent of a suspect area, adjacent suspect areas separated by less than the smaller of two minor axes of the areas shall be considered as one area.

[a] Number of imperfections smaller than the maximum and greater than the minimum imperfection size.

[b] For pipe with $D < 323.9$ mm (12.375 in.) or strip/plate widths less than 1000 mm (39.4 in.), the maximum population density is referred to 1.0 m^2 (10.8 ft^2).

[c] For pipe with $D < 168.3$ mm (6.625 in.) or strip/plate widths less than 500 mm (19.7 in.), the maximum population density is referred to 0.25 m^2 (2.7 ft^2).

[d] The maximum imperfection area of edges is the product of the maximum imperfection length, where length is the dimension parallel to the material edge and the transverse dimension. An imperfection is considered to be larger than the maximum imperfection size if either the length or the transverse dimension is exceeded.

K.4 Nondestructive Inspection of HFW Pipe

K.4.1 Nondestructive Inspection of the Weld Seam

Replace section with

All HFW weld seams shall be subject to 100 % UT in accordance with Annex E (relevant sections), with the acceptance limits being in accordance with Table E.8.1 and Table E.8.2

K.4.2 Laminar Imperfections in the Pipe Body

Replace section with

UT shall be carried out in accordance with E.8.1, except that scanning coverage shall be 100 % of the area of the plate/coil or pipe body.

Replace section heading with

K.4.3 Laminar Imperfections on the Plate/Coil Edges or Areas Adjacent to the Weld Seam

Replace section with

For HFW pipes, UT shall be used to verify that the zone along each side of the plate/coil edges or along each side of the weld seam is free of laminar imperfections.

Inspection shall be done up to a distance from the edge, or the edge of the weld seam as applicable, of [3.5*t* + 25 mm (0.98 in.)] or 50 mm (1.97 in.), whichever is greater.

UT shall be performed in accordance with E.5.1, E.5.2 (as applicable) and with:

a) ISO 10893-9, if such inspection is performed prior to pipe forming; or

b) ISO 10893-8, if such inspection is performed after seam welding.

Acceptance criteria shall be in accordance with Table K.1. Level 1, Level 2 or Level 3 shall be specified in the LPMDS.

Scanning coverage shall be 100 % of the area of the pipe.

For HFW manufacturing, full-body ultrasonic testing for laminar imperfections is acceptable if coil edge ultrasonic inspection is unavailable.

Where AUT is performed on HFW pipe body instead of coil, the same criteria as above shall apply (see also Table K.1).

K.5 Nondestructive Inspection of SAW Pipe

K.5.1 Ultrasonic Inspection for Longitudinal and Transverse Imperfections in Seam Welds

K.5.1.1

Add to section

UT shall be carried out in accordance with E.3.1.1, with the following exceptions:

a) Scanning shall be performed for the detection of longitudinal and transverse imperfections.

b) Scanning for longitudinal imperfections shall be in accordance with Annex E.

c) Scanning for transverse imperfections shall be in accordance with Table K.2.

d) The acceptance level shall be in accordance with Table E.8.2.

e) The manufacturer shall apply the provisions of E.5.6 to retest suspect areas.

Add new table

Table K.2 − SAW Seam: UT Scanning Requirements for Transverse Imperfections

PIPE NOMINAL THICKNESS *t* mm (in.)	Minimum Requirement For Probes/Scans [a, b]		
	Angled Beam Scans Of Weld And HAZ For Transverse Defects [c, d]		
	ID [e]	Embedded Defects [f]	OD [e]
t < 12	≥ 1 probe, Pulse-Echo, in each direction [g]	n/a	≥ 1 probe, Pulse-Echo, in each direction [g]
t ≥ 12		≥ 1 probe as required [g]	

a 100 % coverage of the weld thickness, width and depth, including HAZs, shall be achieved using AUT.

b Gate widths shall collectively include the whole of the weld volume.

c Scanning shall be carried out in both axial directions (For = Forward, Rev = Reverse) using shear wave probes or as agreed with the purchaser

d Scanning shall normally be carried out from the weld cap. Where the roughness or profile of the weld cap prevents this, scanning may be carried out from the parent metal using probes in K or X configuration. Where the presence of the weld cap prevents 100 % scanning coverage as required above, the cap shall be dressed flush.

e Scanning of the inside and outside diameters may be combined using a single probe in each scanning direction (0 to 1 skip) where satisfactory coverage and sensitivity can be demonstrated using the applicable reference standard. Beam angle(s) typically 45° to 70°.

f Beam angle(s) typically 45° ±3°.

g The number of scans for embedded defects shall be determined to comply with Footnote a, dependent on weld thickness and probe focussing.

K.5.2 Laminar Imperfections in the Pipe Body and on the Strip Edges

Replace K.5.2.1 with

K.5.2.1 The pipe or plate/coil body shall be UT'd in accordance with E.8.1, except that scanning coverage shall be 100 % of the area of the plate/coil or pipe body. Acceptance criteria shall be in accordance with Table K.1.

Replace K.5.2.2 with

K.5.2.2 The plate/coil/strip edges or the areas adjacent to the weld seam shall be UT'd in accordance with E.9, except that the acceptance limits given in Table K.1 apply.

K.5.3 Nondestructive Inspection of the Weld Seam at the Pipe Ends/Repaired Areas

Replace section with

The length of the weld seam at the pipe ends that cannot be inspected by the automated UT equipment and repaired areas of the weld seam (see C.4) shall be subjected to the following inspections:

a) AUT, SAUT or MUT as agreed with the purchaser, for the detection of longitudinal and transverse imperfections using the same inspection sensitivity and parameters as specified in K.5.1.1.

b) RT in accordance with E.4.

See E.5.6 for disposition of defects found by ultrasonic testing.

Add new section

K.5.5 Laminar Imperfections on the Plate/Coil Edges or Areas Adjacent to the Weld Seam

For SAW pipes, UT shall be used to verify that the zone along each side of the plate/coil edges or along each side of the weld seam is free of laminar imperfections.

Inspection shall be done up to a distance from the edge, or the edge of the weld seam as applicable, of [3.5*t* + 25 mm (0.98 in.)] or 50 mm (1.97 in.), whichever is greater.

UT shall be performed in accordance with E.5.1, E.5.2 (as applicable) and with:

a) ISO 10893-9, if such inspection is performed prior to pipe forming; or

b) ISO 10893-8, if such inspection is performed after seam welding.

Acceptance criteria shall be in accordance with Table K.1. Level 1, 2 or 3 shall be specified in the LPMDS.

Scanning coverage shall be 100 % of the area of the pipe.

If specified in the LPMDS, for SAWL pipes, ultrasonic testing for detection of laminar imperfections shall be performed on both the plate, and along the pipe weld seam.

Add new section

K.6 Plate Surface Inspection for Hard Surface Layer

If specified in the LPMDS, the surface of thermomechanically rolled plates which will be in contact with the sour effluent, shall be inspected for the detection of possible surface hard layers.

The NDT procedure, verification of the NDT technique and procedure qualification shall be subject to the purchaser's acceptance.

The equipment (e.g. eddy current technique) shall be subject to the purchaser's approval.

Unless otherwise agreed, any blind zone shall be inspected by portable hardness tester following a grid pattern. Grid dimensions are to be agreed upon at bid stage. Alternatively, blind zones shall be cropped.

The manufacturer shall submit details of the inspection technique employed, including inspection and evaluation of blind zones.

A hardness increase due to cold forming and ageing, if applicable, shall be considered. This hardness increase shall be documented by the manufacturer and may be used to define the plate maximum acceptable hardness value. This surface hardness value measured on the plate surface shall not exceed 220Hv.

Annex N
(normative)
PSL 2 Pipe Ordered for Applications Requiring Longitudinal Plastic Strain Capacity

N.1 General

Add to section

This annex specifies additional requirements for pipes ordered for applications with designs requiring longitudinal plastic strain capacity (resulting from single high strain event or accumulated strain) and reeled installations, or if specified in the LPMDS.

These conditions apply to all pipelines subjected to high strain, whether onshore or offshore.

These requirements are additional to those specified for PSL 2 pipe for offshore service defined by ISO 3183, API 5L, Annex J and this specification.

N.2 Additional Information to be Supplied by the Purchaser

Replace section with

Information to be supplied by the purchaser and options within this specification are covered in Table N.8 and in the LPMDS.

Add new table

Table N.8 – Additional Information to be Provided by Purchaser, Longitudinal Plastic Strain Capacity

API 5L, N.2 Item Number	Information Required	API 5L Section or Table Number	Purchaser Requirements (per this specification, as referenced below)
b)	Ultrasonic inspection of strip or plate for laminar imperfections	N.3.3.2.4	N.3.3.2.4
h)	Requirements for longitudinal tensile properties	N.4.2.2	N.4.2.2
i)	Ageing conditions for longitudinal tensile test pieces and method of heating the sample	N.4.2.3	N.4.2.3
l)	Limit on the difference between the maximum and minimum values of actual longitudinal yield strength	N.4.2.6	N.4.2.6
p)	Use of inside diameter to determine diameter and out-of-roundness tolerances with D ≥ 219.1 mm (8.625 in.)	Table N.2, Footnote c	N.6.1
q)	Hardness test of the pipe body of seamless, EW and SAW pipe and of the seam weld and HAZ of EW and SAW pipe	Table N.6	Table N.6 (ref Table J.6)
r)	CTOD testing	N.8.2.2 and Table N.6	J.8.3.1 (ref 10.2.3.8 and 10.2.4.10) and Table N.6 (ref Table 18)
t)	Alternatives to full-thickness strip test pieces for longitudinal testing of welded pipe	N.8.3.1	N.8.3.1
u)	The use of three hardness impressions at each through-thickness location	N.8.3.2.2 c)	As per Figures 14, 15 and 16 or LPMDS
v)	The use of an alternative distance from the weld line for parent metal hardness impressions for welded pipe	N.8.3.2.3 c)	As per Figures 14, 15 and 16 or LPMDS
w)	For pipe with t ≥ 5.0 mm (0.197 in.), ultrasonic inspection for laminar imperfections within extended length of 100 mm (4.0 in.) at the pipe ends	K.2.1.3	K.2.1.3
y)	Ultrasonic inspection to verify conformance with the applicable requirements given in Table K.1	K.3.2.2	K.3.2.2
bb)	Acceptance Level L2/C or L2 for non-destructive inspection of the weld seam of HFW pipe	K.4.1	K.4.1
cc)	Ultrasonic inspection of the pipe body of HFW pipe for laminar imperfections	K.4.2	K.4.2
dd)	Ultrasonic inspection of the strip/plate edges or areas adjacent to the weld for laminar imperfections	K.4.3	K.4.3
ff)	Use of fixed-depth notches for equipment standardization	K.5.1.1 c)	Not applicable
gg)	Radiographic inspection of the pipe ends (non-inspected pipe ends and repaired areas	K.5.3 a)	K.5.3

N.3 Manufacturing

N.3.1 Manufacturing Procedure

Replace section with

All pipe shall be manufactured in accordance with a manufacturing procedure that has been qualified in accordance with Annex B, with supplementary testing specific to the intended application required in this annex.

Add new section

N.3.1.1 Weldability Test

If specified in the LPMDS, weldability testing shall also include suitable toughness tests of the heat affected zone of girth welds.

NOTE The purchaser should consider girth weld HAZ testing after strain and ageing.

Add new section

N.3.1.2 Delivery Condition M

For delivery condition M, the manufacturing procedure qualification test shall include longitudinal tensile and Charpy impact tests in both the as-received condition, and after a heat treatment simulating thin-film coating.

The heat treatment shall consist of holding the temperature at 250 °C (480 °F) for a minimum of 10 minutes, unless otherwise specified by the purchaser.

At the purchaser's discretion and depending on MPQT results, all production longitudinal tensile and Charpy impact tests shall undergo the same heat treatment prior to testing.

Add new section

N.3.1.3 Strain Cycle Simulation – Application Other than Reeling

For all applications other than reeling, testing including small-scale, medium-scale or full-scale testing, to qualify tensile and compressive strain capacity of the pipe, shall be performed as a part of the qualification. Test conditions shall be specified in the LPMDS to be representative of the installation and operation scenario.

The samples shall then be artificially aged at 250 °C (480 °F) for one hour prior to testing.

Add new section

N.3.1.4 Strain Cycle Simulation – Reeling

For reeling applications, unless specified otherwise in the LPMDS, accumulated straining simulation requirements shall be as follows:

a) strain level 1: two cycles with ±2.5 % plastic strain giving a total accumulated plastic strain of 10.0 %;

b) strain level 2: two additional cycles, giving a total accumulated plastic strain of 20.0 %.

Two scenarios shall be tested independently. The first straining cycle (strain level 1 + 2) shall start in tension and end in compression. The second straining cycle (strain level 1 + 2) shall start in compression and end in tension.

The samples shall then be artificially aged at 250 °C (480 °F) for one hour prior to testing.

Simulation of reeling cycles shall be performed on full scale samples, or small scale specimens as specified in the LPMDS. A detailed procedure shall be submitted to the purchaser for acceptance.

Add new section

N.3.1.5 Additional Testing per MPQT Pipe

The following tests are applicable only for MPQT.

Add new section

N.3.1.5.1 Tensile Testing

One longitudinal and one transverse specimen shall be taken from each end of the pipe. Samples shall be extracted from alternating ends and elongation shall be recorded up to 8 % minimum on the stress-strain curve.

Welding consumables for SAW pipes ordered for applications requiring longitudinal plastic strain capacity, shall have the deposited weld metal overmatching the maximum specified or actual yield strength of the base metal.

The weld metal uniform elongation shall be 5 % minimum.

Elongation shall be a minimum of 18 %.

Add new section

N.3.1.5.2 Hardness Testing

One ring shall be extracted from each pipe end.

Hardness profile testing shall be done on each quadrant of each ring.

Add new section

N.3.1.6 MPQT additional testing after strain and ageing simulation (see N.3.1.3 and N.3.1.4).

The following tests are applicable only for MPQT.

Add new section

N.3.1.6.1 Tensile Testing

One all weld metal tensile test (AWMT) and two longitudinal tests shall be performed. Longitudinal tensile test samples shall be extracted from alternating ends.

For base material testing:

- minimum yield strength and minimum and maximum tensile strength shall be as per API 5L, Annex J.4.2;
- the $R_{t0.5}/R_m$ ratio shall be ≤ 0.98;
- elongation shall be 15 % minimum and uniform elongation 5 % minimum.

For AWMT testing:

- weld metal uniform elongation shall be minimum of 5 % and $R_m > R_{t0.5}$;
- elongation shall be 15 % minimum.

Note Subject to agreement with the purchaser, a lower UEL for the strained and aged condition can be applied. A lower UEL should conservatively reflect the strain level in the pipeline in operation, and should not be lower than 2.5 %.

Add new section

N.3.1.6.2 Charpy Testing

Samples for longitudinal Charpy testing in the pipe body shall be extracted from alternating ends.

The seam weld shall be sampled as follows: one set in the weld metal (weld metal / weld line), one set on the FL and one set on the FL2.

Test temperature and acceptance criteria shall be as per the unstrained tests (see 9.8).

In the longitudinal direction, acceptance criteria shall be 50 % higher than the specified criteria in the transverse direction.

The shear area shall be recorded for information.

Add new section

N.3.1.6.3 Hardness Testing

In case of full scale testing, one ring shall be extracted from each pipe end. Hardness profile testing shall be done on each quadrant of each ring, including the weld seam area.

In case of small scale testing, hardness testing shall be performed on both the body and weld seam samples at four locations, spaced at 90° apart.

Acceptance criteria shall be as per Table N.9.

Add new table

Table N.9 − Hardness Test Acceptance Criteria in Strained and Aged Condition

Steel Grade	Base Metal, Weld & HAZ	Cap area
≤ L450 or X65	270	300
> L450 or X65	300	300
NOTE For sour service, Annex H is applicable		

Add new section

N.3.1.6.4 SSC and HIC Tests

If specified in the LPMDS, SSC and HIC testing shall be performed in accordance with Annex H.

Add new section

N.3.1.6.5 Fracture Toughness Test

If specified in the LPMDS, CTOD testing shall be performed in accordance with 10.2.3.8 and 10.2.4.10.

Add new section

N.3.1.6.6 Weld Seam Repairs

Repair welds as defined in Annex D shall be qualified in the strained and aged condition. Mechanical tests acceptance criteria as defined in this annex for the original weld shall apply.

N.3.3 Pipe Manufacturing

N.3.3.2 Welded Pipe

Replace N.3.3.2.2 with

N.3.3.2.2 For HFW pipe, the abutting edges of the strip or plate shall be milled or machined immediately before welding.

Replace N.3.3.2.4 with

N.3.3.2.4 Coil and plate shall be inspected ultrasonically for laminar imperfections or mechanical damage in accordance with Annex K.

Alternatively, full body UT of HFW pipe after forming is permitted.

Replace N.3.3.2.5 with

N.3.3.2.5 Intermittent tack welding of the SAWL groove shall not be permitted.

Add new section

N.3.3.2.6 If specified in the LPMDS, HFW pipe intended for reeling shall be subjected to one of the following heat treatments:

a) full body quench and temper; or

b) weld seam online quench followed by full body temper.

N.4 Acceptance Criteria

N.4.1 Chemical Composition

Add to section

See 9.2 for amendments to Table N.1.

N.4.2 Tensile Properties

Add to section

The tensile properties requirements for PSL 2 pipe as defined in 9.3, shall apply for the tensile tests. This annex specifies additional requirements for longitudinal tensile properties.

Replace N.4.2.2 with

N.4.2.2 Unless specified otherwise in the LPMDS, additional requirements for longitudinal tensile properties shall be as follows:

a) the maximum yield strength shall be the specified minimum yield strength + 120 MPa;

b) the maximum tensile strength shall be the specified minimum tensile strength + 150 MPa;

c) the maximum ratio of $R_{t0.5}/R_m$ in the longitudinal direction shall not exceed 0.90.

Replace N.4.2.3 with

N.4.2.3 See N.3.1.3 and N.3.1.4 for requirements for the MPQT.

Replace N.4.2.6 with

N.4.2.6 The difference between the maximum and minimum values of actual longitudinal yield strength of produced pipe shall not exceed 100 MPa (14.5 ksi).

N.4.3 Hardness Test

Replace section with

The maximum hardness in the pipe body, weld and HAZ shall be as per requirement of 9.18 for non-sour service or of Annex H for sour service.

Add new section

N.4.4 CVN Impact Test

The test temperature and acceptance criteria shall be as per unstrained tests (see 9.8).

In the longitudinal direction, the acceptance criteria shall be 50 % higher than the specified criteria in the transverse direction.

Add new section

N.4.5 Fracture Toughness

Unless otherwise specified in the LPMDS, the pipes shall as a minimum have a CTOD value of 0.30 mm (0.01 in.) for the base metal, weld area, and HAZ area, tested at the minimum design temperature.

N.5 Other Surface Imperfections

Add new section heading before first paragraph

N.5.1 General

Add new section

N.5.2 Outer Diameter Grinding

a) Grinding shall be performed in accordance with procedures reviewed and accepted by the purchaser. A maximum of 15 % of the pipe order may be repaired by stone wheel grinding. Cosmetic repairs shall not be included in the repair percentage calculation.

b) Ground areas shall:

   1) not exceed more than 45 % of the circumference of a cross-sectional plane.

   2) be smoothly contoured to the surface of the pipe at a minimum 4:1 slope.

3) not exceed an area of 10 % of the total surface area of each pipe. After grinding, the remaining wall thickness shall conform to the thickness tolerance requirements of this specification.

4) have the final wall thickness measured by UT and shall be recorded (i.e. wall thickness and joint number).

5) not interfere with nondestructive testing at the pipe mill.

6) at pipe ends, comply with the requirements of API 5L, E.2.2.2.

7) shall not result in loss-of-signal or otherwise impede inspection verification required by C.2.3.

c) Pipe ends shall not be internally or externally machined nor ground by stone, without prior review and acceptance by the purchaser.

d) Pipes that are repaired by grinding shall be identified with a green paint band (or other color agreed with the purchaser), die stamped with the letter “R” on square cut face, and noted on the pipe tally list.

Add new section

N.5.3 Dents

a) Pipes shall contain no dents on the outside surface that cause visible distortion of the inside surface, or vice versa.

b) Pipe shall contain no dents on the outside surface exceeding 2 mm (0.08 in.) for the pipe body, or exceeding 1 mm (0.04 in.) within 150 mm (5.91 in.) from either pipe end.

Add new section

N.5.4 Surface condition

After review and evidence of the billet and/or pipe surface quality, the purchaser may require that all billets be scarfed or peeled prior to rolling.

N.6 Tolerances for Diameter, Wall Thickness, and Straightness

Replace N.6.1 with

N.6.1 The diameter and out-of-roundness shall be within the tolerances specified in Table J.3 or Table J.9 for “premium” level A or B, as specified in the LPMDS.

The tolerance shall refer to the internal diameter. Actual nominal ID shall be established, with measurements on the first 100 production pipes.

ID and OD tolerances shall be measured and verified with calipers or a laser.

Replace N.6.2 with

N.6.2 The wall thickness shall be within the tolerances specified in Table J.4 or Table J.10 for “premium” tolerances, as specified in the LPMDS.

Replace N.6.3 with

N.6.3 Geometric deviations from the normal cylindrical contour of the pipe (e.g. flat spots and peaks), that occur as a result of the pipe forming process or manufacturing operations, which exceed the lesser of 0.005*D* or 2.0 mm (0.080 in.) measured as the gap between the extreme point of the deviation and the prolongation

of the normal contour of the pipe, or that exceed 25 % of pipe diameter in any direction with a maximum length of 300 mm (11.8 in.), shall be considered defects and shall be treated in accordance with API 5L, C.3 b) or C.3 c).

Replace N.6.4 with

N.6.4 The tolerances for straightness shall be as per 9.11.3.4.

Replace N.6.5 with

N.6.5 For seamless pipes, the eccentricity for pipe ends shall be as follows:

a) allowable eccentricity tolerance less than or equal to 18 %;

b) measurements to be made around the full circumference on the same cross-sectional plane, using calipers, laser or by other equivalent methods;

c) eccentricity within 152 mm (6 in.) of each end defined as follows:

$$Eccentricity = \frac{t_{max} - t_{min}}{t_{max}} \times 100$$

where

t_{max} is maximum wall thickness

t_{min} is minimum wall thickness

N.8 Inspection

N.8.1 Specific Inspection

Replace section with

The frequency of inspection shall be as given in Table J.6, except as specifically modified in Table N.6.

Replace Table N.6 with

Table N.6 − Inspection Frequency

No	Type of Inspection	Type of Pipe	Frequency of Inspection
1	Longitudinal CVN impact testing of the pipe body	All pipes	Once per test unit of pipe with the same cold-expansion ratio [a]
2	Pipe end eccentricity	SMLS	Each pipe Record frequency: 1 pipe at beginning of the shift then every 4 hours and 1 pipe at the end of the shift
NOTE When specified on the LPMDS, the frequency for HFW shall be one every 5 joints of pipe			

[a] The cold-expansion ratio is designated by the manufacturer and is derived using the designated before-expansion outside diameter or circumference and the after-expansion outside diameter or circumference; an increase or decrease in the cold-expansion ratio of more than 0.002 requires the creation of a new test unit.

N.8.2 Samples and Test Pieces for Mechanical and Technological Tests

N.8.2.3 Samples for Hardness Tests

Replace section with

For the hardness testing, one ring shall be extracted from alternating ends. The hardness profile testing shall be done on each quadrant of each ring (one including the seam weld for welded pipes).

Add new section

N.8.2.4 Samples for Charpy Tests

Samples for Charpy testing shall be extracted from alternating ends.

The sample location shall be in accordance with 10.2.3.3.

Replace Table N.7 with

Table N.7 − Number, Orientation and Location of Test Pieces per Sample for Mechanical Tests

Type of Pipe	Sample Location	Type of Test	Number, Orientation, and Location of Test Pieces per Sample [a]		
			Specified Outside Diameter *D* mm (in.)		
			< 219.1 (8.625)	≥ 219.1 (8.625) to < 508 (20.000)	≥ 508 (20.000)
SMLS, not cold-expanded [see API 5L, Figure 5 a)]	Pipe body	Tensile	1L [b]	1T + 1L	1T + 1L
		CVN [c]	3T + 3L	3T + 3L	3T + 3L
		Hardness	4T	4T	4T
HFW [see API 5L, Figure 5 b)]	Pipe body	Tensile	1L90 [b]	1L90 and 1T180	1L90 and 1T180
		CVN [c]	3T90 + 3L90	3T90 + 3L90	3T90 + 3L90
		Hardness	3T	3T	3T
	Seam weld	Tensile	—	2W	2W
		CVN [c]	3W + 3HAZ	3W + 3HAZ	3W + 3HAZ
		Hardness	1W	1W	1W
	Pipe body and weld	Flattening	As shown in Figure 6		
SAWL [see API 5L, Figure 5 b)]	Pipe body	Tensile	1L90 b	1L90 and 1T180	1L90 and 1T180
		CVN [c]	3T90 + 3L90	3T90 + 3L90	3T90 + 3L90
		Hardness	3T	3T	3T
	Seam weld	Tensile	—	2W	2W
		CVN [c]	3W and 6HAZ	3W and 6HAZ	3W and 6HAZ
		Guided-bend	2W	2W	2W
		Hardness	1W	1W	1W
SAWH [see API 5L, Figure 5 c)]	Pipe body	Tensile	1L [b]	1L and 1T	1L and 1T
		CVN [c]	3T + 3L	3T + 3L	3T + 3L
		Hardness	3T	3T	3T
	Seam weld	Tensile	—	2W	2W
		CVN [c]	3W and 6HAZ	3W and 6HAZ	3W and 6HAZ
		Guided-bend	2W	2W	2W
		Hardness	1W	1W	1W

[a] See API 5L, Figure 5 for an explanation of the symbols used to designate orientation and location.

[b] Full-section longitudinal test pieces may be used at the option of the manufacturer.

[c] Charpy HAZ testing to be as per 10.2.3.3 (additional set required depending on wall thickness).

N.8.3 Test Methods

N.8.3.2 Hardness Test

Replace N.8.3.2.2 with

N.8.3.2.2 Hardness test indent locations shall be in accordance with 10.2.5.5.

N.8.3.3 Longitudinal Tensile Tests

Add to section

The LPMDS shall specify the tensile test specimen type.

For non-proportional tensile specimens, 50 mm (2 in.) gauge length should be used.

For the proportional type (in accordance with ISO 6892-1), the gauge length shall be equal to $5.65\sqrt{S0}$, where S0 is the original cross-sectional area of the specimen.

Appendix 1
Welding Consumables

AP1.1 General

The manufacturer's procedures concerning storing, handling, drying, recycling and traceability of consumables is subject to the purchaser's review and acceptance. The manufacturer shall provide evidence of long and successful use of the proposed combination of welding consumables on similar applications, to the satisfaction of the purchaser.

Welding consumables shall be stored and handled in accordance with the supplier's written recommendations.

The welding consumables shall be procured according to AWS A5.01 or ASME BPVC Section II Part C SFA A5.01 and be supplied by a supplier accepted by the purchaser.

The level of testing shall be in accordance with Schedule I as specified in AWS A5.01.

Unless otherwise specified in the LPMDS, all welding consumables shall be individually marked and supplied with an inspection certificate type 3.1 according to EN 10204, obtained for the same batch.

Deposited weld metal shall not have diffusible hydrogen content higher than 5 ml per 100 g weld metal under production conditions, tested in accordance with ISO 3690. The hydrogen content test shall be done during the packing and the actual value shall be specified in the certified material test report.

If specified in the LPMDS, welding consumables and procedures that produce a weld deposit containing more than 1 % mass fraction nickel are not acceptable.

Weld deposits shall be in compliance with ISO 15156 for welding consumables for SAW pipes ordered for sour service applications.

AP1.2 Consumables for GMAW

The solid electrode shall conform to the requirements of either AWS A5.18 or AWS A5.28 and produced according to Lot Class S3 of AWS A5.01.

The gas shielding shall conform to the requirements of AWS A5.32.

AP1.3 Consumables for SAW

The SAW consumables shall conform to the requirements of either AWS A5.17 or AWS A5.23 and produced according to Lot Class S3 and Lot Class F2 of AWS A5.01 for solid electrode and flux, respectively.

The manufacturer shall issue a dedicated procedure for flux management. This procedure shall cover all steps from flux purchasing to the "ready-to-use" step (welding heads).

This procedure shall be submitted to the purchaser for review.

AP1.3.1 Procurement of flux

At the time of packing the flux, the diffusible hydrogen content in the SAW weld deposit shall be lower than 5 ml/100 g of weld deposit, taken from a sample of the batch of flux.

Flux grain size shall be checked per batch when the flux is first received. The recorded grain size shall comply with the recommendation of the flux supplier. Should any deviation be recorded, the flux shall be rejected.

Acceptable packing shall be:

- metallic / stiff plastic drums with a rubber gasket for top tightness;
- double polymer top welded bags;
- PEHD-aluminium-PEHD top welded bags.

The packing shall be designed to guarantee no significant humidity absorption during storage for a minimum of one year.

AP1.3.2 Diffusible Hydrogen, Moisture Content Test

Diffusible hydrogen assessment may be done through moisture content measurement, when evidence of correlation for the flux intended to be used, can be provided by the flux supplier (previously established data is acceptable).

This correlation curve shall be based on previous comparative tests of diffusible hydrogen versus flux moisture content.

The maximum moisture content shall be 0.03 % unless a higher figure can be justified via the correlation curves.

AP1.3.2.1 Test Condition

The moisture content shall be measured as per AWS A4.4M by the “Karl Fisher” method, or by using equivalent equipment subject to the purchaser’s acceptance.

For diffusible hydrogen testing or for moisture measurement, neither pre-drying nor any pre-heating of the flux sample shall be carried out before testing, regardless of applicable standard guidance.

The moisture measurement test shall be carried out at 982 °C (1800 °F) minimum. The carrier gas shall contain 10 % minimum of oxygen.

AP1.3.2.2 Test Results

Results of diffusible hydrogen or moisture measurement shall be reported on the 3.1 flux certificate for each batch. The testing conditions as per this appendix shall be confirmed on the certificate.

AP1.3.3 Flux Storage

Flux shall be stored in a room with controlled hygrometry and temperature.

The resulting relative hygrometry and temperature values shall be permanently maintained such that the resulting absolute hygrometry is as per the supplier’s recommendation.

The maximum duration of storage shall be one year after the date of packing. After one year of storage, a spot check of the diffusible hydrogen / moisture content shall be required.

Flux that has been wet or damp shall not be used.

AP1.3.4 Flux Handling and Transfer System

Drums/bags shall be checked before using the flux and be undamaged.

All flux shall be dried before use and poured in the welding machine hopper. The temperature of the hopper shall be maintained between 120 ºC (248 ºF) and 150 °C (302 ºF).

Flux feeding from the hopper shall be by gravity. If pressurized air is used for flux conveying, the air shall be dried and made oil-free.

The manufacturer shall explain the flux management philosophy in case of an interruption or pause in welding.

Unless the manufacturer can justify otherwise, in case of welding interruption:

a) of more than two hours, the system of feeding downstream of the hoppers shall be drained off before recommencing welding;

b) of more than 12 hours, the remaining flux stored in the hoppers shall be scrapped.

NOTE Flux is often stored in an intermediate oven at 150 °C (302 ºF) to avoid a reduction of the flux temperature in the welding machine hopper during charging of the new flux.

AP1.3.5 Flux Recycling

AP1.3.5.1 Flux Recycling

When recycling flux, the manufacturer shall demonstrate that the mill has an appropriate flux recycling system:

a) As a minimum, the flux recovery system shall be equipped with vacuum suction to collect the excess unfused flux from the weld seam.

b) The recovered flux shall be processed with sieving and a magnetic separator.

c) The size distribution of recovered flux shall be within a tolerance ±5 % of the fresh batch.

d) The frequency of flux size testing shall be aligned with the moisture content check.

e) The use of crushed or recycled slag, or blending crushed or recycled slag with fresh flux is not permitted

AP1.3.5.2 Moisture Content Check

In case of flux recycling, the manufacturer shall demonstrate that the flux management system will guarantee dry flux at the welding point:

a) Flux shall be sampled at the welding point and checked at the start of production and then once per shift for both inside and outside welding. All welding lines shall be sequentially tested.

b) The inspector may impose the timing for sampling.

c) The test procedure and results shall comply with AP1.3.2.

d) The procedure shall include a scheme of flux management and shall specify the temperature of the ovens used for re-drying.

AP1.4 Consumables for SMAW

The covered electrodes shall conform to the requirements of either AWS A5.1 or AWS A5.5, produced according to Lot Class C5 of AWS A5.01 and shall be supplied in hermetically sealed containers. Cellulose coated electrodes shall not be used.

Appendix 2
Weldability Test

AP2.1 Introduction

The intent of the weldability test is to verify acceptable properties in the girth weld HAZ. The manufacturer should note that the weldability tests are acceptance tests for the pipes, and that pipes cannot be accepted until these tests have been successfully completed.

Weldability tests shall be performed by the pipe manufacturer or by an accepted supplier under their responsibility.

Where the purchaser allows data from previous weldability trials in lieu of testing, material used in the previous weldability trials shall be identical in grade and manufacturing procedure to the pipe to be supplied, and be of similar diameter, wall thickness and chemical composition (within the limits of applicable chemical composition and associated tolerances).

AP2.2 Material for Weldability Test

The pipe material shall be qualified in accordance with the manufacturing procedure qualification (see Annex B) and within the limits specified (see B.5.).

Weldability tests shall be conducted for each steel grade, pipe size and steel source on pipes produced at an early production stage.

Pipe size grouping of dimensions may be allowed, subject to the purchaser's approval, however as a minimum, those with the greatest wall thickness shall be tested.

The material shall be taken from finished production pipes.

Pipes shall be selected from the high end of the chemical composition range, e.g. no less than 0.02 % less than the maximum carbon content, CE_{IIW}, CE_{Pcm}.

The purchaser shall accepted the heat analysis of steel or pipes to be used for the weldability tests.

AP2.3 Welding Procedure Specification (WPS)

Prior to welding, the manufacturer shall submit a pWPS including as a minimum:

a) details of welding consumables, type of process, welding parameters, etc.;

b) proposals on the pipe ring dimensions (length) so as to represent realistic welding conditions;

c) full details of weld bevel geometries. The proposed groove profile shall be such that the welding will result in a straight HAZ on one side of the bevel (i.e. half–V bevel or narrow gap bevel shall be used);

d) the welds shall be single sided from the outer surface of pipe;

e) welding positions, heat input range;

f) tests rings for weldability tests to be sampled from pipe ends.

No welding test shall be carried out until the manufacturer's proposals have been accepted by the purchaser.

AP2.3.1 Test Welds

At least one full butt weld shall be produced for each trial.

The welding processes for weldability tests shall be proposed by the manufacturer in accordance with the method for pipe laying (e.g. P-GTAW, P-GMAW, m-GMAW, STT, CMT, SMAW and SAW).

Test coupons shall be prepared with a single V-groove. Test coupons shall have one side with 0° bevel angle. The tests shall be carried out with two welding heat inputs as follows:

a) low welding heat inputs (0.45 KJ/mm ≤ HI ≤ 0.75 KJ/mm) with a maximum preheat temperature of 50 °C (122 °F) and an inter-pass temperature not exceeding 250 °C (482 °F);

b) high welding heat inputs (1.5 KJ/mm ≤ HI ≤ 3 KJ/mm) with a preheat temperature and inter-pass temperature not lower than 250 °C (482 °F).

The HAZ shall be considered sufficiently straight when scribed marks for the machining of fracture toughness specimen notches sample at least 75 % of the scribe length in the central two thirds of the specimen thickness within 0.5 mm (0.02 in.) of the fusion line.

NOTE 1 The 75 % of the scribe length need not be continuous. The fusion line shall be considered part of the weld metal and not be included in the determination of % HAZ sampled.

The time lapse between the root and hot pass shall be 15 minutes without maintaining preheating during that time.

NOTE 2 Weld bead placement techniques should be utilized such that within the central 60 % of the section thickness, 25 % of the weld metal adjacent to the fusion line on the square edge side of the weld grove is unrefined-columnar weld metal.

AP2.3.2 Testing and Inspection

AP2.3.2.1 Nondestructive Testing

The test weld shall be inspected by visual, magnetic particle and UT or X–ray radiography testing.

The weld shall satisfy the acceptance criteria of the specific project fabrication code prior to being sent for sampling.

The project fabrication code shall be specified in the LPMDS.

AP2.3.2.2 Mechanical Testing

The test specimen failing due to welding defects shall be declared as invalid and retesting is permitted upon the purchaser’s acceptance.

AP2.3.2.2.1 Tensile Testing

A cross weld tensile test shall be carried out for information.

NOTE A failure located in the weld metal shall not be considered relevant. The intent of the test is to gather information on HAZ performance.

AP2.3.2.2.2 Charpy Testing

For welding in position 5G, a set of specimens shall be cut at the 12 o’clock, 3 o’clock and 6 o’clock positions, transverse to the weld direction. For other welding position (i.e. 1G or 2G), a sample of specimens shall be taken from two opposite locations.

Each set shall consist of three specimens.

The notches shall be located at mid-thickness of the welded side with 0° bevel as per Figure AP2.1.

Additionally, for welded pipes, a set of Charpy specimens shall be taken from the intersection of the longitudinal and circumferential weld seam and the notch location shall be extended into the longitudinal seam side.

The impact test temperature and acceptance criteria shall be as defined in 9.8 or the relevant annex/appendix. Alternative test conditions and acceptance criteria may be specified in the LPMDS.

If specified in the LPMDS, a transition curve shall be performed for each test location.

AP2.3.2.2.3 CTOD Test

CTOD specimens shall be taken from both low and high welding heat input test coupons.

A set of specimens shall be cut at the 12 o'clock and 6 o'clock positions for the 5G welding position and shall be located at mid-thickness. For each set, three specimens shall be cut and tested. For other welding positions (i.e. 1G or 2G), a sample of CTOD specimens shall be taken from one location only.

SENB B*2B specimens shall be used. The notches shall be located on the welded side with 0° bevel as follows:

a) in the coarse grain HAZ (CGHAZ) – to be determined by metallography;

b) at 2 mm (0.08 in.) from the fusion line – to be determined by metallography.

Sectioning of CTOD samples should be made following testing, to ensure sampling of the required areas. Pre and post-testing macrographs shall be supplied to show that sampling requirements have been met.

CTOD testing shall be carried out in accordance with ISO 15653 and ISO 12135.

The CTOD test temperature and acceptance criteria shall be defined in the relevant annex/appendix or in the LPMDS.

AP2.3.2.2.4 Macrography and Vickers Hardness Survey

Three specimens shall be extracted, one at each of the 12 o'clock, 3 o'clock and 6 o'clock positions for the 5G welding position.

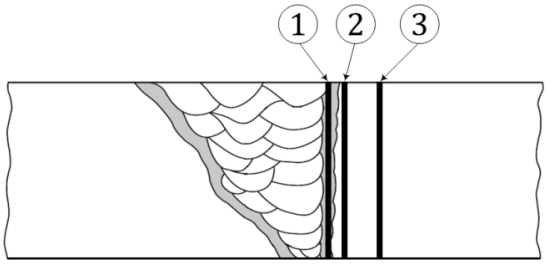
For other welding positions (i.e. 1G or 2G), a sample of macrography specimens shall be taken from two locations:

a) 180° apart for pipe; and

b) a minimum distance of 300 mm (12 in.) apart for plate.

For the above macrographic cross-sections, an HV10 hardness survey shall be conducted as per Figure AP2.2.

If not specified in the LPMDS, the acceptance criteria shall be as per the applicable annex/appendix.



Key

① In the Coarse Grain HAZ (CGHAZ) – to be determined by metallography
② At 2 mm from the Fusion Line
③ At 5 mm from the Fusion Line

Figure AP2.1 – Charpy Testing Locations

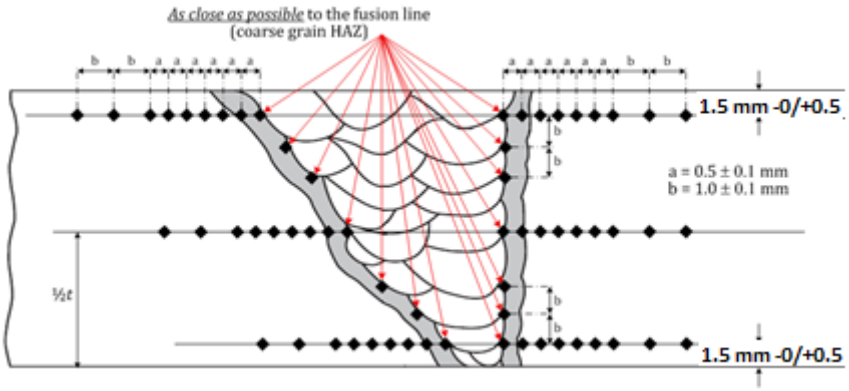


Figure AP2.2 – Hardness Indents Location

AP2.4 Reporting

Following completion of the test program, the results and a final report from the manufacturer shall be submitted to the purchaser.

The final report shall include, as a minimum, the following:

a) welding procedure specifications;

b) procedure qualification records;

c) mill certificates of pipe materials used;

d) NDT and mechanical test results (including any failures);

e) any other testing agreed with the purchaser;

f) any necessary photographs, macrographs and micrographs (if any); and

g) the interpretation of the results and the conclusions of the manufacturer, including the recommendations for welding the pipes at the installation site.

Appendix 3
Qualification of NDT at Plate/Coil and Pipe Mills

Qualification shall be subject to demonstration of the capability of the mill to satisfy the requirements of this specification, and all standards referenced herein.

The qualification shall remain valid for a period of four years unless there is a change to the equipment, including structural components, software or hardware.

The purchaser may require repeating the qualification for a specific project. This shall be specified in the LPMDS.

The process for the qualification of pipe mill NDT equipment and practices shall be as follows.

AP3.1 Prior to the Qualification Audit

The mill shall submit the following information to the purchaser for review and agreement prior to the audit:

a) Scope of the qualification required, as follows:

   1) Renewal of existing scope of qualification, extension to scope or new qualification;

   2) Service: whether “conventional”, sour or offshore or multiple services, the audit shall be based on the most stringent requirement, based on the mill’s capability;

   3) Pipe types (manufacturing methods e.g. SAW, HFW, SMLS), materials, grades;

   4) For each pipe type: ranges of pipe diameter and thickness for which qualification is sought;

   5) For plate/coil: materials, grades, and ranges of length, width and thickness;

   6) Applicable NDT methods, techniques and documented threshold settings.

b) Written procedures for NDT including applicable methods, compliant with Appendix 6 and applicable to the scope (and for UT and EMI: reference standards) of the audit;

c) Design of UT and/or EMI reference standards, compliant with E.5.2;

d) Report of visual and dimensional inspection for UT and EMI reference standards, demonstrating compliance with AP3.1 c);

e) Detailed description of the equipment design and any capability studies that the mill may have performed on the equipment.

AP3.2 NDT Method-specific Requirements During the Qualification Audit

AP3.2.1 General Requirements

The qualification audit shall include (but not necessarily be limited to):

a) Practical demonstration of each applicable NDT method and technique, performed on welds, pipes, plates/coils (as applicable).

b) Calibrations, control checks and maintenance;

c) Qualification and certification of NDT personnel; and

d) Elements of the quality system/business management system related to NDT.

AP3.2.2 Practical Demonstrations

Inspection parameters shall be qualified on an individual basis. This means that for systems using more than one configuration, each transducer array shall be qualified individually and documented in a scan plan and standard operating procedures.

For HFW mills that perform full-body AUT, the coil edge AUT system is exempt from qualification.

AP3.2.2.1 AUT of Plate/Coil

The practical demonstration shall be carried out on one or more reference standards (as agreed with the purchaser) covering the manufacturing thickness range capability and shall include:

a) Equipment set-up;

b) Static and dynamic standardization;

c) Gate positions for defects and coupling, S/N ratio;

d) Extent of coverage;

e) Detection of all required reference reflectors;

f) Repeatability trial; and

g) Documented threshold settings.

In addition, at least one production plate shall be scanned at production settings to demonstrate achievement of 100 % scanning coverage.

AP.3.2.2.1.1 Repeatability trials

a) The repeatability trial shall be carried out dynamically, using the same conveyor assembly and at the maximum scanning speed(s) (travel and/or cross-head) to be used during production;

b) Indications from all reference reflectors shall be set at a suitable amplitude to enable recording and subsequent height measurement, typically 80 % FSH ± 5% (i.e. where an AUT system can only measure amplitudes up to 100 % FSH, any indication greater than 100 % shall be invalid);

c) Ten test runs shall be carried out;

d) The results of a repeatability trial shall be considered acceptable when no reference reflector indication amplitude deviates from the average value by more than ±25 % (or equivalent dB tolerance(s) as determined by the purchaser).

e) The following data shall be recorded:

    1) Written procedure;

    2) Reference standard details and dimensions;

    3) Equipment used, including probe types, frequencies and dimensions;

    4) C-scan record, either paper or digital – as applicable;

5) For each channel: the probes used, scanning direction, reference reflector identities and locations, indication amplitudes (digitally recorded);

6) Indication amplitudes for all reference reflectors shall be recorded as percentage of screen height or as percentage chart height (as applicable), or decibels, using an automated digital method such as a digital export feature, to at least one decimal point (e.g. 81.6 %, not rounded up to 82 %); and

7) Indication amplitudes for all channels and all reference reflectors shall be entered into a spreadsheet supplied by the auditor for the calculation of the average values and the minimum and maximum deviations from the average values.

AP3.2.2.2 AUT of HFW, SAW and SMLS Pipe

The practical demonstration shall be carried out on one or more reference covering the manufacturing thickness and diameter range capability and shall include:

a) Equipment set-up;

b) Static (if practicable) and dynamic standardization;

c) Gate positions for defects and coupling, S/N ratio;

d) Detection of all reference reflectors (as per Annex E Table E.7.1, Table E.7.2 and Table E.7.3);

e) Repeatability trial;

f) Extent of coverage;

g) Accuracy and consistency of seam tracking system;

h) Documented threshold settings.

AP3.2.2.2.1

The number and dimensions of reference standard/pipe shall be determined as follows:

a) For wall thickness ≤ 12 mm (0.47 in.): one reference standard having the lowest wall thickness and smallest diameter to be qualified;

b) For wall thickness > 12 mm (0.47 in.): one reference standard having the highest wall thickness and largest diameter to be qualified.

AP3.2.2.2.2

For the repeatability trial, the following shall apply:

a) The repeatability trial shall be carried out dynamically, using the same conveyor assembly and at the maximum scanning speeds (travel and/or cross-head) to be used during production.

b) Indications from all reference reflectors shall be set at a suitable amplitude to enable recording and subsequent height measurement, typically 80 % FSH ±5 % (i.e. where an AUT system can only measure amplitudes up to 100 % FSH, any indication greater than 100 % shall be invalid)

c) Ten uninterrupted test runs, in the forward direction, without any adjustment of equipment or settings. Any interruption or adjustment shall invalidate the results.

d) When specified in the LPMDS by the purchaser, ten uninterrupted test runs, in the reverse direction (after turning the reference standard end-to-end), without any adjustment of equipment or settings. Any interruption or adjustment shall invalidate the results.

e) For equipment with rotating head assemblies, 20 runs shall be completed in total, consisting of five runs at each pipe angular position (0°, 90°, 180° and 270°), the pipe being rotated after each series of five runs.

f) The results of a repeatability trial shall be considered acceptable when no reference reflector indication amplitude deviates from the average value by more than ±25 % (or equivalent dB tolerances as determined by the purchaser).

g) The following data shall be recorded:

1) Written procedure;

2) Reference standard details and dimensions;

3) Equipment used, including probe types, frequencies and dimensions;

4) Chart record, either paper or digital – as applicable;

5) For each scan number: the channel, probes used, scanning direction, reference reflector identities and locations, indication amplitudes (digitally recorded);

6) Indication amplitudes for all reference reflectors shall be recorded as percentage of screen height or as percentage chart height (as applicable), or decibels, using an automated digital method such as a digital export feature, to at least one decimal point (e.g. 81.6 %, not rounded up to 82 %); and

7) Indication amplitudes for all channels and all reference reflectors shall be entered into a spreadsheet supplied by the auditor for the calculation of the average values and the minimum and maximum deviations from the average values.

AP3.2.2.3 EMI of Welded or SMLS Pipe

The practical demonstration shall be carried out on one or more reference standards (as agreed with the purchaser) and shall include:

a) Equipment set-up;

b) Static (if practicable) and dynamic standardization;

c) Gate positions for defects, S/N ratio;

d) Detection of all reference reflectors;

e) Extent of coverage;

f) Repeatability trial;

g) Application to one or more production pipes, or suitable substitute, to be determined by the purchaser;

h) Documented threshold settings.

AP3.2.2.3.1

The number and dimensions of reference standard/pipe shall be determined as follows:

- One reference standard representative of the diameter and thickness range to be qualified, as agreed with the purchaser.

AP3.2.2.3.2

For the repeatability trial, the following apply in one direction of the reference standard:

a) Carried out dynamically, using the same conveyor assembly and at the maximum scanning speed(s) (travel and/or cross-head) to be used during production.

b) Indications from all reference reflectors shall be set at a suitable amplitude to enable recording and subsequent height measurement, typically 80 % FSH ±5 % (i.e. where an EMI system can only measure amplitudes up to 100 % FSH, any indication greater than 100 % shall be invalid).

c) Ten uninterrupted test runs, without any adjustment of equipment or settings. Any interruption or adjustment shall invalidate the results.

d) The results of a repeatability trial shall be considered acceptable when no reference reflector indication amplitude deviates from the average value by more than ±25 % (or equivalent dB tolerances).

e) The following data shall be recorded:

1) Written procedure;

2) Reference standard details and dimensions;

3) Equipment used, including probe types, frequencies and dimensions;

4) Chart record, either paper or digital – as applicable;

5) For each scan number: the channel, probes used, scanning direction, reference reflector identities and locations, indication amplitudes (digitally recorded);

6) Indication amplitudes for all reference reflectors shall be recorded as percentage of screen height or as percentage of chart height (as applicable), using a consistent method, to at least one decimal point (e.g. 81.6 %, not rounded up to 82 %); and

7) Indication amplitudes for all channels and all reference reflectors shall be entered into a spreadsheet supplied by the auditor for the calculation of the average values and the minimum and maximum deviations from the average values.

Appendix 4
Procedure Requirements for NDT

The manufacturer shall provide a procedure for each NDT technique, describing the inspection equipment and processes to be applied. Multiple NDT techniques shall not be combined within one procedure. The procedures shall contain as a minimum, the details stated in the tables included in this appendix and shall be submitted to the purchaser in English, for review and acceptance prior to qualification or requalification of the mill NDT or production NDT.

Table AP4.1 − Ultrasonic Testing (UT)

Scope (application)	Product form (e.g. plate/coil, pipe, pipe end, weld, etc.)
	Material grade and specification
	Dimensions (plate/coil: length, width, thickness; pipe: length, diameter, thickness)
	Coverage required; coverage limits
	Weld process (as applicable)
	Weld preparation (drawing showing weld preparation dimensions and angles)
	Reference to this specification and related standards
Personnel	Qualification requirements
	Performance demonstration - if required
Stage of Manufacture	Stage at which UT is to be performed e.g. for longitudinally welded pipe seams - after hydrotest
Surface Condition	Condition and surface preparation of scanning surfaces
	Profile of scanning surfaces
Inspection techniques	Whether automated, semi-automated or manual
	Contact-, gap- or immersion-scanning
Equipment	Instrument/System: manufacturer type and designation, number of channels, computerized programme identification and revision.
	Scanning frames descriptions and illustrations, with probe arrangement (layout and scanning directions)
	Probes: quantity, manufacturer, types, beam angles, frequencies, single- or twin-crystal, element dimensions, number and arrangement of elements in probes. Focusing. Probe data sheets.
	Reference standards: Identification, description, and plan and sectional drawings showing all dimensions and reference reflectors (types, dimensions, locations in plan and depth). Inspection certificates for the same. Acoustical properties of the reference reflectors
	Calibration blocks
	Couplant and method of irrigation
	Weld seam tracking
Calibration	Calibrations, control checks and maintenance
Standardization	Range calibration
	Setting of sensitivity (PRG, transfer correction, PRL, scanning sensitivity)
	S: N ratio
	Recording levels (defect gate heights, start points and lengths
	Method of monitoring coupling (with coupling gate heights, start points, lengths
	Weld seam tracking and accuracy
Inspection parameters	Description of operation
	Guiding principle
	Scanning directions with respect to product axis
	Maximum permitted product travel speeds and probe traverse speeds
	Scan plans
	For HFW and SAW seams: scan plans for individual scans showing -6dB beam profile and probe offsets from datum – relative to reference reflector locations. Overall scan plan showing combination of scans. Scan plans shall be prepared using proprietary software and shall clearly demonstrate how 100 % coverage of depth and width is achieved.
Reference Table	Table coordinating:
	Scan and channel numbers
	Probe identifications, types and scan directions
	Reference reflector types, identifications and locations
Acceptance Criteria	Interpretation, evaluation and acceptance criteria
Reporting	Report shall include at least the following items:
	Procedure identification and revision
	Application: Identification, description and dimensions (see above)

	All equipment used
	Result: accept or reject
	For all scans, the primary reference level used
	Position, depth and size of all discontinuities exceeding the recording level and all defects
	Date and time of inspection
	Name of operator responsible for performing UT

Table AP4.2 − Penetrant Testing (PT)

Scope (application)	Product form (e.g. weld, pipe end bevel, etc.)
	Material grade and specification
	Dimensions (pipe: length, diameter, thickness)
	Coverage required
	Weld process (as applicable)
	Reference to this specification and related standards
Personnel	Qualification requirements,
	Performance demonstration - if required
Stage of Manufacture	Stage at which PT is to be performed
Surface Condition	Condition and surface preparation of surfaces requiring inspection
Inspection techniques	Method for cleaning
	Method of applying penetrant
	Method of removing excess penetrant
	Method of drying the surface
	Method of applying developer
	Whether color contrast or fluorescent
Equipment and consumables	Manufacturer type and designation of consumables (cleaner, penetrant, remover and developer).
	Requirement for certification of compliance for consumables (limits for sulfur and halogens)
	Light/UV-A meter, timers, sensitivity test blocks, timer, etc.
	Performance demonstration block – if required
Calibration	Calibrations, control checks and maintenance
Inspection parameters	Description of process
	Permitted time periods for process stages
	Light or UV-A intensity ranges (for UV-A, also include background white light)
	Applicable temperature limits
	Adjustments to stage durations if lower or upper temperature limits are exceeded
Acceptance Criteria	Interpretation, evaluation and acceptance criteria
Reporting	Report shall include at least the following items:
	Procedure identification and revision
	Application: Identification, description and dimensions (see above)
	All equipment and consumables used
	Result: accept or reject
	Position and size of all defects
	Date and time of inspection
	Name of operator responsible for performing PT

Table AP4.3 − Magnetic Particle Testing (MT)

Scope (application)	Product form (e.g. weld, pipe end bevel, etc.)
	Material grade and specification
	Dimensions (pipe: length, diameter, thickness)
	Coverage required
	Weld process (if applicable)
	Reference to this specification and related standards
Personnel	Qualification requirements,
	Performance demonstration - if required
Stage of Manufacture	Stage at which MT is to be performed.
Surface Condition	Condition and surface preparation of surfaces requiring inspection.
Inspection techniques	Magnetizing techniques and magnetizing directions (with illustration showing these)
	Type/waveform and amperage of magnetizing current
	Whether color contrast or fluorescent
Equipment and consumables	Manufacturer, type and designation of magnetic field generator (DC Yokes are not permitted)
	Manufacturer, type and designation of consumables (cleaning liquid, magnetic particles (wet or dry) and contrast medium)
	Light/UV-A meter, tangential field meter, flux indicator and residual field meter
	Lift block for AC Yoke
	Performance demonstration block – if required
Calibration	Calibrations, control checks and maintenance
Inspection parameters	Description of process
	Fill factors for rigid encircling coils
	Method for cleaning
	Method of magnetization and method of applying magnetic particles - and whether “continuous” or “residual”
	Light or UV-A intensity ranges (for UV-A, also include background white light)
	Tangential field strength range required (kA/m) - minimum and maximum
	Ink concentration range
	Applicable temperature limits
	Adjustments to stage times if temperature limits are exceeded
Acceptance Criteria	Interpretation, evaluation and acceptance criteria
Reporting	Report shall include at least the following items:
	Procedure identification and revision
	Application: Identification, description and dimensions (see above)
	All equipment and consumables used
	Result: accept or reject
	Position and size of all defects
	Date and time of inspection
	Name of operator responsible for performing MT

Table AP4.4 − Electromagnetic Inspection (EMI)

Scope (application)	Product form (e.g. SMLS pipe, HFW pipe, HFW weld seam),
	Material grade and specification
	Dimensions (pipe: length, diameter, thickness)
	Coverage required; coverage limits
	Weld process (if applicable)
	Reference to this specification and related standards
Personnel	Qualification requirements,
	Performance demonstration - if required
Stage of Manufacture	Stage at which EMI is to be performed
Surface Condition	Condition and surface preparation of surfaces requiring inspection
Inspection techniques	Mode of inspection: differential or absolute or combination
	Scanning mode: automated, manual
Equipment	Manufacturer, type and designation of EMI instrument and scanner
	Probe manufacturer, types, designations, sizes and arrangements)
	Reference standards: identification, description, illustration, including all reference reflectors
Calibration	Calibrations, control checks and maintenance
Standardization	Setting of sensitivity
	Recording levels (defect gate heights, start points and lengths)
Inspection parameters	Description of process
	Scanning direction with respect to product axis
	Frequencies, drive voltages and gain settings
	Minimum digitization rate
	Maximum permitted product travel speed and probe traverse speed
Acceptance Criteria	Interpretation, evaluation and acceptance criteria
Reporting	Report shall include at least the following items:
	Procedure identification and revision
	Application: Identification, description and dimensions (see above)
	All equipment used
	Result: accept or reject
	Scanning direction with respect to product axis
	Position and size of all defects
	Date and time of inspection
	Name of operator responsible for performing EMI

Table AP4.5 − Radiographic Inspection (RT)

Scope (application)	Product form (e.g. pipe longitudinal weld seam; pipe weld seam ends)
	Material grade and specification
	Dimensions (pipe: length, diameter, thickness; weld thickness including root and cap)
	Coverage required
	Weld process
	Weld preparation (drawing showing weld preparation dimensions and angles)
	Reference to this specification and related Standards
Personnel	Qualification requirements
	Performance demonstration - if required
Stage of Manufacture	Stage at which RT is to be performed e.g. for longitudinally welded pipe seams - after hydrotest.
Surface Condition	Condition and surface preparation of weld surfaces
Inspection techniques	Conventional film RT or digital (e.g. DR, DDA, CR)
	Single-wall/double-wall; source inside/outside; film/detector outside/inside
	Film processing: automated or manual
	Arrangement of equipment – description, with illustration
Equipment	X-ray set: manufacturer, type and designation. Maximum kV and amperage. Focal spot size(s)
	X-ray generator: manufacturer, type and designation. Maximum kV.
	Film: brand, designation and sizes
	Film processor: manufacturer, type and designation
	Source/film/detector manipulation system
	Intensifying screens
	Digital detector: manufacturer, type and designation, dimensions, number of pixels
	Imaging plate (IP): types, dimensions, resolution
	Imaging plate scanner: manufacturer, type and designation. Resolution
	Film viewer: Sizes, maximum readable densities
	Digital viewers/monitors: manufacturer, type, designation, size. Capabilities in terms of brightness, shades of grey, light intensity ratio, number of pixels
	Image quality indicators
Calibration	Calibrations, control checks and maintenance
	For digital RT: as required by ISO 10893-7, plus routine checking of image archiving
Inspection parameters	Source-film/detector distance, object-film/detector distance, geometric unsharpness (Ug)
	Angle of beam centerline relative to weld centerline
	Maximum kV permitted relative to penetrated thickness
	Overlap of consecutive exposures
	Location of film/detector/IP, IQIs, identification letters
	For digital RT: image quality class; permitted ranges for grey values and contrast; requirements for basic spatial resolution and signal-to-noise ratio
	IQI location and sensitivity
	Storage conditions for unexposed and exposed films. Digital image archiving
Acceptance Criteria	Interpretation, evaluation and acceptance criteria
Reporting	Report shall include at least the following items:
	Procedure identification and revision
	Application: Identification, description and dimensions (see above)
	All equipment used
	Result: accept or reject
	Position and size of all defects
	Date and time of inspection
	Name of operator responsible for performing RT/interpreting images

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