PETROBRAS	**TECHNICAL SPECIFICATION**	**N°:**	**I-ET-0000.00-0000-219-P9U-001**
	CLIENT: PETROBRAS		**SHEET:** 1 of 30
	JOB: GENERAL		**CC:**
	AREA: RIGID SUBMARINE PIPELINES		**PROJECT:**
DDP	**TITLE:** **MECHANICALLY LINED PIPE (MLP) REQUIREMENTS**		PUBLIC EDR

INDEX OF REVISIONS

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1 SPECIFICATION SCOPE

1.1 The objective of this technical specification is to define the technical requirements for Mechanically Lined (MLP) pipes. **MLP pipes fabricated according to this Technical Specification shall be in compliance with all requirements of DNV-ST-F101 – Edition August 2021 Amended December 2021 ref. [1]]**.

1.2 This document shall be read in conjunction with ref.[1]. The revised items are presented in bold letters between square brackets, and the type of revision is highlighted as Addition or Modification, for example **[7.1.2] Addition.**

1.3 **[7.1.2] Addition** - This technical specification is applicable to the following limits:

a) Outside diameter: From 6” to 16”.
b) Host pipe grade: SMYS shall be equal to 415MPa or 450MPa.
c) Host pipe: Only quenched and tempered seamless pipes are envisaged.
d) CRA Liner material: Only alloys UNS N06625. For alternative material as UNS N08825, UNS N08904 and Super austenitic Stainless Steel (SASS) type 6Mo (e.g., UNS S31254 and UNS N08367) see additional requirement AR ALM in appendix A of this specification.

   NOTE: This technical specification is not applicable for polymeric liners.

e) CRA Liner seam weld consumable and clad weld consumable: UNS N06625 consumable is envisaged (e.g., ER--NiCrMo3).

   Note: Other nickel-based alloy consumables without Niobium, superior to ER-NiCrMo3NiCrMo3 in terms of weldability, may be considered for deposition of deposition of welding beads in the interface liner/seal weld at the triple point root, in order to minimize second phases formation and reducing the solidification temperature interval, but shall be by agreement between the purchaser and manufacturer and approved by COMPANY.

f) Liner thickness: From 2.5 to 9.0 mm.

   Note: MLP with liner thickness lower than 3.0mm shall not be used at bend sections susceptible to erosion, at riser Top, TDP and other fatigue sensitive sections as defined according to item 4.3 of [B9]

g) CRA Liner bevel on triple point shall not be higher than 15º.
h) Installation Methods: J-lay, S-lay and Towing. For Reel-lay see additional requirement AR R in Appendix A of this specification.
i) Coating: Application temperature for parent and field joint coating not exceeding 260ºC.

1.3.1 The lined pipes manufactured in accordance with this technical specification present some application constrains that shall not be violated:

a) The lined pipes shall only be utilized in pipelines or risers in locations/sections where the fatigue demand does not exceed the fatigue damage allowed by DNV-RP-C203 F1 curve for inside surface and D curve for outside surface.

   NOTE: The team responsible for design is also responsible to define the design curve to be used based on test results. Corrections in transition point and due to corrosion fatigue shall be envisaged during design.

b) The lined pipes shall only be utilized in pipelines or risers in locations where the load-controlled criterion of DNV-ST-F101 ref. [1] is fulfilled.

   b.1) The only accepted exception is the submission of lined pipe section to reel-lay drum, aligner, and straightener during installation phase, in case of reel-lay method utilization. In these cases, the load-controlled criterion may be violated provided that the displacement-controlled limit state DNV-ST-F101 ref. [1] is fulfilled and the additional requirement AR R is also fulfilled (see Appendix A).

c) The lined pipes shall not be used in locations submitted to low cycle fatigue (e.g., lateral buckling) unless the feasibility is demonstrated through ECA.

d) The structural contribution of CRA layer may be considered on design if the additional requirement AR SE is required (see appendix A).

1.4 **[7.1.1.3] Addition** - The fatigue resistance of girth welds is not included in the scope of this document. This specification is exclusively dedicated to Mechanically Lined Pipe.

NOTE: This technical specification presents general requirements for lined pipes manufacturing. It is responsibility of the team responsible for design to insert additional or modified requirements if judged necessary to guarantee the integrity of riser/pipeline during design life.

1.5 **[7.1.1.3] Addition** - The fatigue limit may be extended, provided that the additional requirement AR DYN is fulfilled (see Appendix A for further information).

1.6 **[1.5] Addition -** Where there is a conflict between the requirements of this specification, the Pipeline Project Design Basis and the referenced standards, the order of precedence of the documents shall be:

1st – Material Requirements and Quality guideline (documents issued for each Riser and Flowline project).

2nd – This Technical Specification.

3rd – DNV-ST-F101.

4th - Other international standards referred.

2 REFERENCES

2.1 **[1.5] Addition -** The latest revision of the following documents applies:

[1] DNV-ST-F101 Submarine Pipeline Systems - Revision DEC 2021
[2] DNVGL-RP-C203 (2016) Fatigue design of offshore steel structures.
[3] API 5LC: Specification for CRA Line Pipe.
[4] API 5LD: Specification of CRA Clad or Lined Steel Pipe.
[5] ASTM D4285 - Standard Test Method for Indicating Oil or Water in Compressed Air.
[6] BS-7910 Guide to methods for assessing the acceptability of flaws in metallic structures: 2013+A1:2015 Incorporating Corrigenda Nos. 1 and 2.
[7] BS EN 10204 – Metallic Products – Types of Inspection Documents.
[8] I-ET-0000.00-0000-211-P9U-002 – Seamless (SMLS) Pipes Requirements.
[9] I-ET-0000.00-0000-970-PSQ-001 - Procedure and personnel qualification and certification.
[10] ISO 8501: Preparation of steel substrate- Visual assessment of surface cleanness part-1.
[11] ISO 15156-3: Materials for use in H2S environment in Oil & Gas Production-Cracking resistance CRA and other alloys.
[12] I-ET-0000.00-0000-210-P9U-005 – Alternative Flaw Acceptance Criteria of Submarine Rigid Pipeline and Riser Welds.
[13] I. J. Munns & C. R. A. Schneider (1999, July) The Reliability of Radiography of Thick Section Welds, July 1999.
[14] ASTM E2862 - Standard Practice for Probability of Detection Analysis for Hit/Miss Data.
[15] ASTM B-443 - Standard Specification for Nickel-Chromium-Molybdenum-Columbium Alloy (UNS N06625) and Nickel-Chromium-Molybdenum-Silicon Alloy (UNS N06219) Plate, Sheet, and Strip.
[16] ASME BPVC.IX-2019 - ASME Boiler and Pressure Vessel Code an International Code - SECTION IX Welding, Brazing, and Fusing Qualifications. Qualification Standard for Welding, Brazing, and Fusing Procedures; Welders; Brazers and Welding, Brazing, and Fusing Operators.
[17] I-MD-0000.00-1519-940-P9U-006 - Pre-qualification plan – CRA liner alternative alloys for MLP.
[18] DNV-RP-B204 - Welding of subsea production system equipment (2021).

3 DEFINITIONS

3.1 **[1.6.1 Table 1-4] Modification -** The following verbal forms are applied:

SHALL – verbal form used to indicate requirements strictly to be followed in order to conform to the document.
SHOULD - verbal form used to indicate that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others.
MAY - verbal form used to indicate a course of action permissible within the limits of the document that requires the formal COMPANY agreement.

Other possibilities may be adopted if approved by Company through a technical query form (TQF). Company reserves the right to reject any proposal.

3.2 **[1.6.2] Modification -** The following definitions are applied:

COMPANY – PETROBRAS including its employees, agents, inspectors, and other authorized representatives.

Purchaser – Refers to EPCI contractors, in the occasions where they are responsible for pipes supply.

SUPPLIER – Lined pipe manufacturer.

CRA Layer – When referred herein means the liner and clad welds.

Host pipe – CMn pipe which forms the outer part of a bi-metallic pipe system.

Clad overlay (WoL) – Circumferential CRA weld overlay metallurgically deposited at both lined pipe extremities to fix the liner within the host pipe. **Where initial weld pass(es) is deposited the term seal weld can also be used.** The clad overlay length shall allow automated ultrasound testing in girth welds.

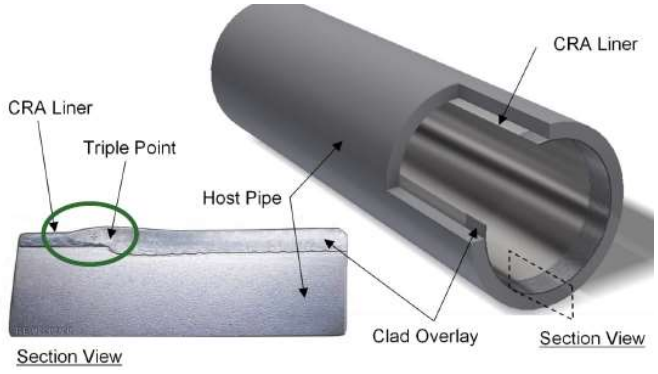


Figure 1 – Bimetallic lined pipe schematic with regions of interest.

CRA Liner – CRA pipe section which forms the inner part of a bi-metallic pipe system. The liner is responsible to provide corrosion resistance to the lined pipe and does not contribute to the structural resistance of lined pipe.

Lined pipe (L): Bimetallic pipe with internal (corrosion resistant) liner where the bond between host pipe and cladding material is mechanical. The lined pipe is composed by host pipe, CRACRA liner and Weld overlay.

Line pipe – Pipes utilized for pipeline / risers' construction.

Reeling Cycle – When referred herein, a reeling cycle consists in one bending step followed by a reverse bending step. Each example below characterizes one reeling cycle:

- Wound and unwound in reeling drum.
- The passage through the aligner.
- The passage through the straightener.

Triple point – Point of intersection between host pipe, liner and clad weld (see figure 1).

HAZ - Non-melted area of liner / host pipe which has undergone changes in material properties as a result of being exposed to the high temperature of WOL.

Triple Point Zone, TPZ - Circumferential area in region of Triple Point which is directly diluted by clad overlay (WoL) and the adjacent HAZ. This area is subjected to specific Triple Point ECA Criteria.

Gap - The circumferential "linear void" between host pipe and liner.

Weld repair (Cut back) - Part / all of the original WoL is removed by internal machining and the internal area prepared for re-welding as per original. Typically, this will mean extending beyond the original Triple Point by 20-30mm. This repair procedure is only possible on the clad overlay (Wo) area.

Weld repair (Cut out) - The MLP pipe end is cut and liner cutback to produce a new prep area. The seal weld and WoL is performed as per original. Typically, "wet" cutting methods will be employed when the WoL is being cut. Whilst "dry" cutting methods will be employed where the liner has to be cut.

3.3 **[1.6.3] Addition -** The following abbreviations are applied:

MDR – Master Document Register.
FSBT – Full Scale Bend Test
FSFT - Full Scale Fatigue Test
GTAW – Gas Tungsten Arc Welding.
QMS – Quality Management System.
PFMECA – Process Failure, Effects and Criticality Analysis

4 TECHNICAL REQUIREMENTS

4.1 GENERAL REQUIREMENTS:

4.1.1 SUPPLIER shall fulfill all the requirements stated in [1] related to Lined pipes, as well as the supplementary requirements listed below:

a) General Lined pipe DNV Supplementary Requirements.
b) Supplementary Full-Scale Qualification Testing (FSBT and FSFT).

4.1.1.1 The "General Lined pipe DNV Supplementary Requirements" are presented in section 6 of this technical specification. The "Supplementary Qualification Testing" is presented in section 7 of this technical specification.

NOTE: The main body of this technical specification presents additional and modified requirements in relation to [1]. In all the referred requirements presented in sections 6 and 7, the intention is to present more stringent requirements in relation to [1] in order to cope with the lessons learnt from previous projects, as well as update the traditional requirements in accordance with recent research related to lined pipe.

4.1.1.2 The Appendix A presents additional requirements. The additional requirements AR R, AR SE, AR DYN and AR ALM shall only be fulfilled if required by COMPANY or Purchaser.

4.1.1.3 The Appendix B presents some waivers in relation to [1] accepted by COMPANY. SUPPLIER may consider these waivers as valid for pipe manufacturing purpose.

4.1.1.4 The Appendix C presents the necessary information to be informed in material requisition by Purchaser in order to complement this technical specification, allowing pipe supply.

4.1.1.5 The Appendix D presents the requirements for RT/DRT procedure performance demonstration.

4.1.1.6 The Material Requirements document of each subsea project shall present supplementary requirements and testing for liner selection of CRAs different than UNS N06625, if applicable.

5 QUALITY ASSURANCE AND QUALITY CONTROL

5.1 GENERAL

5.1.1 All activities to be performed by the supplier or sub-supplier(s) shall be planned, managed and performed under a Quality Management System (QMS) certified to be in compliance with ISO 9001.

5.1.2 All reports, certificates and inspection plans related to quality assurance and control shall follow the requirements stated at Quality guideline issued for the project.

5.1.3 During production, the supplier shall make available upon request all material certificates to COMPANY and purchaser.

5.1.4 During liner and MLP manufacturing, SUPPLIER should maintain a Manufacturing Review Board in order to check all production and repairs rates (in process repair, WoL repair, cutback, cut-out). The Manufacturing Review Board shall be constituted from members of all relevant Departments (Quality, Technical, NDE and Production).

5.2 MANUFACTURING PROCEDURE:

5.2.1 Two months before the date schedule for MPQT, the following documentation shall be submitted by SUPPLIER for COMPANY evaluation:

- Manufacture Procedure Specification (MPS) and Inspection Test Plan (ITP) for liner and lined pipe, including test requirements and acceptance criteria.
- Manufacturing procedures, including heat treatment.
- Preliminary Welding procedures specifications (pWPS) for liner and lined pipe, including procedures for repair welding.
- Non-destructive testing procedures, including defective weld map reference.

5.3 INSPECTION REQUIREMENTS

5.3.1 The inspector employed by SUPPLIER for quality control and quality assurance shall have at least the qualifications as per [9].

5.3.2 SUPPLIER shall consider that COMPANY may require at any time full access of the lined pipe manufacture to COMPANY representatives. This includes access to samples preparation, MPQT and production testing. SUPPLIER shall not deny access to COMPANY representatives.

5.3.3 ASNT certification to complement the ISO 9712 where ISO do not have the specific method, for example, dimensional control may be accepted. In this case, a detailed training plan shall be presented to COMPANY regarding dimension control inspectors.

5.3.4 NDT reports shall consider at least the minimum information of D.2.14 and D.2.15 of ref. [1] and specific testing standard procedure reporting requirements.

5.4 TRACEABILITY

5.4.1 During MPQT traceability of heat number, heat treatment batch and test unit (pipe) number shall be recorded and demonstrated. The validated traceability system shall be used during production. All records from the required tests, inspections and dimensional reports shall be able to be matched to individual pipe (including individual host pipe and CRA liner) numbers.

5.5 TECHNICAL QUERIES

5.5.1 After contract award, any manufacturer's requests for clarifications or deviations to specifications shall be submitted to the purchaser only through technical queries (TQ) or deviation requests (DR), the format of which shall have prior approval by the purchaser.

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

5.6 NON-CONFORMANCE REPORTS

5.6.1 Any part of the supply not in conformance with the requirements of this specification shall be listed in a Non-Conformance Report (NCR) prepared by the supplier and sent to COMPANY validation. This NCR shall contain, as a minimum, causes and major concerns, the proposed remedial and mitigation actions with impacts on quality, performance and delivery schedule. The reason for the failure/quality deviation of any test shall be established and the appropriate corrective actions to prevent re-occurrence shall be presented in the NCR. The adequate evidence confirming treatment shall be available and attached to NCR.

5.6.2 Any procedure mentioned shall have the codification used in the MDR, especially when subcontractors' procedures are mentioned during root cause analysis and corrective actions.

5.6.3 As NCR contains several attachments, navigation and itemization system must be created using the .pdf file markers, separating them by the items to transmit a better sequence of the steps performed and their evidence documentation.

5.6.4 The requirements related to non-conformance reports stated at Quality guideline issued for the project shall be followed.

6 GENERAL LINE PIPE DNV SUPPLEMENTARY REQUIREMENTS

6.1 LINER REQUIREMENTS:

6.1.1 [**7.4.1.5 and 7.4.6.1] Addition** – CRA liner of lined pipe shall be manufactured and tested in accordance with API 5LC. Liner shall be fabricated using CRA coil. Liner shall have a single longitudinal weld. Jointers are not allowed.

6.1.2 **[7.4.1.5] Modification** – The CRA liner thickness should be typically 0.2 to 0.3mm higher than the minimum CRA liner thickness required for MLP by purchaser. Coil thickness tolerance shall consider any thickness reduction related to coil manufacturing, decoiling, liner and MLP manufacturing.

6.1.3 **[7.4.1.5] Addition** – The nominal liner thickness shall be as specified in purchaser order. The applicable tolerance of CRA coil thickness should be +0.2/-0.0mm in respect to the minimum value required in the purchase order.

NOTE: In order to respect the minimum clad weld thickness, the liner thickness shall be higher than the nominal value to allow machining and reeling if AR R and AR DYN are specified.

6.1.4 **[7.4.8.4] Addition** – The test frequency for the following tests shall be one in each liner production lot within a heat, with a minimum of one set per heat: Tensile test (longitudinal at base metal, Tensile test (transversal) CRA Weld, face and root guided bend test, hardness test, macro and micrography (including weld), corrosion test, product analysis on base metal and weld. Quantity of pipes per lot to be defined as 50 or 100 pipes by supplier and purchaser.

6.1.5 **[7.4.8.7] Addition** – YS of CRA liner shall be 276 MPa minimum and maximum of 414 MPa after expansion process.

6.1.6 **[7.4.6.6] Addition** – The weld cap and root reinforcement of liner shall not exceed 0.5mm in height for CRA liner thickness $\leq$ 3.5mm. For higher CRA liner thickness maximum values may be proposed by purchaser for COMPANY approval.

6.1.7 **[7.6.2] Addition** – In case of a fully MLP integrated mill. MPQT of liner may be waived. During start of liner manufacturing the internal and external surface of longitudinal seam weld shall be submitted to DPI and DRT on at least 5 liner pipe lengths.

6.1.8 **[Table 7-16 and D.8.10] Addition** – RT shall be performed in 100% of the CRA liner pipe longitudinal seam weld, in case of it is not 100% EC tested. DRT shall be performed for any indication detected by EC in order to confirm and evaluate it according to the given acceptance criteria. If the indication is already rejected by Visual Testing the DRT may be performed only after the repair. Digital Radiographic Testing (DRT) may be used since it provides, at least, the same level of sensitivity and detection as conventional X-ray. DRT shall be carried out in accordance with ISO 10893-7, class B, radiographic technique with enhanced sensitivity. A maximum of two wires may be added to sensitivity (IQI) in order to compensate poor basic spatial resolution.

6.1.9 **[D.7.5.1] Addition** – Demonstration of Digital radiographic inspection shall be performed using naturally induced defects only. Defect types shall be typical for the selected welding processes and shall be validated by purchaser and COMPANY.

6.1.10 **[C.5.3.7] Addition** – Liner repair welding of the following areas and defects is not permitted:

- Pipe body.
- Seam weld within 150 mm of pipe ends.
- Repair weld length higher than 500mm.

6.1.11 **[C.5.3.7] Addition** – Repaired Liner pipes shall be identified and clearly marked. For through thickness repair, the weld root shall have the same finishing of the original weld (a-GTAW dressing may be used). A visual inspection guide with acceptable and non-acceptable welds shall be prepared by supplier and validated by purchaser and COMPANY.

6.1.12 **[C.5.3.7] Addition –** Liner partial thickness manual repair welding may be permitted, considering the following limitations during pWPS qualification:

- The minimum remaining ligament shall be equal or greater than 1mm after excavation.
- The maximum partial repair length shall be limited to 150 mm; Maximum accumulated length of any type of repair shall be 500 mm.
- Excavation depth and actual thickness shall be measured and reported. Excavation shall be witnessed by all parties involved.
- Specific qualification of the welder in the type of repair, including to prepare the excavation area.
- DPI shall be performed on 100% of the excavation area before repair execution.
- Low heat input procedure shall be used in order to avoid distortion.
- The start and stop points of cap reinforcement of the partial repair shall be ground flush to be merged smoothly to the original weld cap profile. Thickness measurement to be done on any ground flush area.
- The test coupons shall pass be DPI, RT, dimensional and visual tested after the repairs have been carried out. If a heat treatment (annealing) is considered as PWHT, it shall also be performed for the repaired liners.
- The purge conditions must be representative of the conditions of the production repairs. A “no purge” test must be added to the qualification tests, passing the ASTM G48 tests.

6.1.13 **[C.5.3.7] Addition –** Liner partial thickness manual repair welding may be permitted, considering the following test plan for pWPS qualification shall be sent for analysis:

- Tensile test - (TWT).
- Bend test (Face bend & Root bend).
- HV10 hardness.
- Macrography (10x) and micrograph (100x and 500x)
- Chemical analysis and corrosion ASTM G48.

Note: The macrography must show that the repair was performed with complete fusion, absence of cracks and that does not affect the geometry of the internal surface (root).

6.1.14 **[C.5.3.7] Addition –** The following shall be considered during execution of the qualified liner partial thickness manual repair WPS:

- Excavation depth and actual thickness shall be measured and reported.
- DPI shall be performed on 100% of the excavation area before repair execution.
- Strict control of the Heat Input of production repairs, with 100% registration of the passes of all repairs, with no higher tolerance (i.e., + 0%).
- The start and stop points of cap reinforcement of the partial repair may be ground flush to be merged smoothly to the original weld cap profile. Thickness measurement to be done on any ground flush area.

Note: Hold point measures should be taken to measure excavation and welding of 100% of partial repairs, for all parties involved

6.1.15 **[C.5.3.7] Addition –** Internal liner manual repair welding may be permitted, considering the following limitations during pWPS qualification:

- The maximum internal repair length shall be limited to 150 mm; Accumulated length of any type of repair shall not be higher than 500 mm.
- Excavation depth and actual thickness shall be measured and reported. Excavation shall be witnessed by all parties involved.
- Specific qualification of the welder in the type of repair, including to prepare the excavation area.
- DPI shall be performed on 100% of the excavation area before repair execution.
- Low heat input procedure shall be used in order to avoid distortion.

6.2 HOST PIPE REQUIREMENTS:

6.2.1 **[7.1.4.3 and 7.4.1.2] Modification** – Host pipe of lined pipe shall comply with [8]. The min YS may be increased by supplier.

6.2.2 **[7.1.5.1] Addition** – The applicable supplementary requirements given in subsection 7.9 of [1] are listed in [8]. The project specific conditions will be defined by COMPANY or purchaser (see Appendix C).

6.2.3 **[7.1.5] Addition** – Additional requirements AR SS, AR RL, AR HL and AR UE of [8] may be selected depending on the project specific conditions.

6.2.4 **[7.4.6] Addition** – SMLS pipes to be used as host pipe may be submitted to full length drifting inspection or only at pipe ends area, depending on MLP supplier´s decision. Drift diameter will determine what size of CRA liner can be run through the SMLS pipe, i.e., to assure insertion of CRA liner without damages.

6.2.5 **[7.9.4] Addition** – As the host pipe is an intermediate product, the dimensional requirements of ref. [8] can be relaxed (e.g., ID and ID out-of-roundness tolerances at pipe ends) provided that the final MLP dimensions comply with Material requirements, purchaser MLP specification and the requirements within this document.

6.3 LINED PIPE MANUFACTURING REQUIREMENTS:

6.3.1 **[7.4.6.2] Modification** – The internal surface of host pipe shall be blast cleaned to a surface cleanliness of ISO 8501-1 Sa 2 ½ along the complete length of the pipe prior to fabrication of lined pipe. The external surface of the liner pipe shall be blast cleaned as specified or pickled.

6.3.1.1 **[7.4.6.3] Addition** – The external surface of CRA liner and the internal surface of the host pipe shall be cleaned and completely dry prior to assembly. The air used to dry both surfaces shall be tested once per shift according to ASTM D4285 [5].

6.3.2 **[7.4.6.5] Addition** – The strain imposed during liner expansion process shall be defined during MPQT and maintained during MLP production. Expansion pressure shall be recorded for each MLP.

6.3.3 **[7.4.6.5] Addition** – Inspection of sizing ratio after expansion shall be carried out at 3 locations minimum on selected pipe (both ends and middle) with frequency of 1 pipe per shift during production.

6.3.4 **[7.4.6.5] Addition** – In case of pipe end calibration is performed, inspection of sizing ratio shall also be done and recorded before and after at the following locations during MPQT 50mm,100mm,150mm and 200mm of pipe end. During production pipe end calibration record should be done, once per shift, at 50mm and 100mm.

6.4 CLAD OVERLAY

6.4.1 **[7.4.6.7] Addition** - Only clad overlay is allowed in pipe extremities. Fillet welds do not allow girth weld AUT and therefore are not permitted. Clad overlay welding procedures shall be developed in such a way that gaps do not appear due to heat distortion. Such procedure shall be submitted for COMPANY validation. Weld overlay procedure shall be in such way that a minimum overlap between beads is assured.

Note: At triple point area, optimization of welding sequence, bead shape, number of reinforcing passes, maximum heat input/interpass temperature/iron dilution, liner clamping device to control gap (below 0,1 mm), etc. shall be carefully evaluated in order to avoid appearance of micro cracks at the triple point regions.

6.4.2 **[7.4.6.7] Addition** – The essential variables for corrosion resistant weld overlay welding process shall be according to ASME BPVC Section IX ref. [16], supplemented by additional variables of DNV-RP-B204 ref. [18], table 5.1.

6.4.3 **[7.4.6] Addition** – The clad overlay shall be executed in at least, two welding passes. The first pass of weld overlay shall only be applied after a visual verification that shows no visible gap between liner and host pipe. At seam weld location, it is acceptable to have a gap not greater than 0.1mm, measured by a filler gauge. Supplier shall have a qualified volumetric NDT on weld overlay layer and triple point area, according to item 6.6.4.6 and appendix D of this technical specification.

6.4.4 **[7.4.6] Addition** – In process repairs on weld overlay shall be individually logged and endorsed on the In Process Repair Report (IPRR). Pre-repair defect description (location along pipe i.e., length and circumference relative to A0) shall be recorded. A0 is defined as end A of pipe, zero-degree axis.

6.4.5 **[7.4.6] Addition** – MLP shall be supplied with weld overlay length of minimum 75 mm. After the AUT inspection of girth welds, cut-outs may be allowed if the remaining weld overlay section of MLP is equal or greater than 50 mm after the allowed cut-outs.

6.5 MACHINING

6.5.1.1 Internal surface machining shall be performed on 100% pipe ends. The final machining shall be executed in such a way that a girth weld between any of the supplied pipe will be able to provide an internal hi-lo equal to the one defined at purchaser design.

6.5.1.2 In addition, the shape of the transition between weld overlay of clad weld and host pipe shall be even in order to not jeopardize the AUT performance during girth weld inspection.

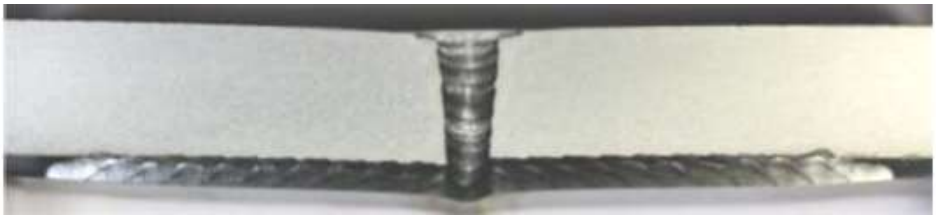


Figure 2 – Example of acceptable transition shape (extracted from OTC 23096).

6.5.2 Machining steps shall be detailed in the MPS and ITP. Liner tracking system or surface teaching may be proposed for liner cut-back and final machining. Machining devices shall be checked for dimensional accuracy at least once per shift.

6.5.3 Before the execution of each machining step, the pipe shall be carefully fixed in order to not create a conical or off-centered machining. A smooth transition between the machined section and the “as manufactured” liner shall be ensured. No sharp edges shall be kept (transition step shall not be higher than 0.5mm). In addition, the maximum taper angle at the transition shall be proposed by supplier and validated by COMPANY and purchaser.

6.5.4 Final machining shall provide Ra roughness lower than 3.2µm and maximum Rt of 50µm.

6.5.5 After final machining, the transition between weld overlay and liner shall be buffed by grinder using only a finish enhancing buffing wheel. The amount of material to be removed by grinding shall be kept at minimum. The buffed area length shall be limited on the ITP.

6.5.5.1 After final machining, the weld overlay thickness shall not be lower than the nominal liner thickness. The tolerance of weld overlay thickness shall be +2.0/-0.0mm.

6.5.5.2 After final machining, the liner thickness shall not be lower than the minimum specified. Any transition in pipe ID due to out of roundness or different CRA thicknesses shall not reduce the liner thickness beyond the minimum specified.

6.5.5.3 After final machining pipe ends calibration using hydraulic expander are permitted.

6.6 NDT REQUIREMENTS

6.6.1 **[D.8.11 and 7.7.2] Addition** - The inspection of machined section shall be made considering at least the testing expressed below:

a) Visual inspection in 100% of pipe ends with back light, in order to verify the existence of grooves, dents, scratches or any other stress concentration points. The buffing extension beyond the taper length shall be verified.

b) Internal diameter inspection in 100% of pipe ends, including at least 8 diameter measurements points equally spaced along the circumference. The inspection shall be done by micrometer, dial vernier caliper or laser system. ID will be measured at 10mm and 50 mm from of each pipe.

c) After final machining the nominal internal diameter tolerance shall not exceed ±0.5mm. The machining should be executed in such a way that a girth weld between any of the supplied pipe will be able to provide a hi-lo equal or lower than 1.0mm without the demand of pipe sorting/pipe matching activities.

> Note: It is possible to negotiate that the ID tolerance be related to an actual diameter to be defined during production instead of nominal diameter. However, once established the “actual diameter”, this actual diameter shall be applied for the whole production (all lots manufactured).

d) Wall thickness measurements at triple point and adjacent area are mandatory, whenever machining or any other process that involves material removal could reduce the CRA thickness, below the minimum specified. Other cases that it becomes mandatory includes: MPQT, FSBT/FSFT pipes, short MLPs and cut-outs beyond pipe end sizing/pre-machining. CRA thickness shall be measured by PAUT immersion technique using a water-wedge or similar. The results in 100% of circumference shall be recorded. Linear seam weld shall be visible at start and stop of the scan to demonstrate full coverage and overlap. PAUT shall be complemented by manual UT A-Scan, whenever loss of coupling or missing data cannot be sorted out. CRA thickness measurement procedures in the transition and weld overlay areas shall be qualified for the range of thickness of interest with a 5% oversizing tolerance. The acceptance criteria for minimum CRA thickness shall be adjusted if the procedure does not meet this requirement. Triple point zone, liner and seam weld shall be judged apart. COMPANY shall receive all scan files in the original ODT format along with any exported C-Scan that was used to judge pipe conformity.

e) The roughness in 100% of pipe ends shall be measured and compared to the acceptance criteria defined in item 6.5.4. The roughness verification procedure shall be submitted for COMPANY validation.

f) All measurement devices shall be calibrated as required in item 6.10.3.

6.6.2 **[D.8.11.4] Modification -** The triple point and clad welds at pipe ends shall be subject to manual liquid penetrant testing according to (D.2.6 Appendix D) [1], including a distance of at least 50 mm past the seal weld. Therefore, the total area to be inspected shall consider clad overlay length and triple point plus 50mm.

6.6.3 [**D.8.11.5] Modification** –

- ✓ No round indications with diameter above 1 mm and no elongated indications.
- ✓ Indications separated by a distance less than the diameter or length of the smallest indication, shall be considered as one indication.
- ✓ Accumulated diameters of round indication in any 100 mm length of seal weld shall not exceed 6 mm and accumulated diameters of round indications in any 100 × 100 mm of weld overlay shall not exceed 10 mm.

6.6.4 **[Table 7-16] Addition** – After final machining, radiographic testing shall be performed in 100% of triple point and clad weld pipe ends in accordance with Class B requirements of ISO 17636-1 for film radiography (RT) or ISO 17636-2 for digital radiography (DRT), and the following additional requirements:

6.6.4.1 Radiographic testing shall be performed by use of X-ray and Single Wall Single Image (SWSI) technique. Use of radiographic isotopes (gamma rays) and/or Double Wall Single Image (DWSI) is not permitted. The angle between radiation beam and triple point bevel preparation or any cross section of the pipe end shall not exceed 10 degrees. If needed, radiography shall be taken from more than one axial position to improve incidence.

6.6.4.2 Each radiographic procedure and the consumables used shall be qualified. Procedure will be considered qualified if it demonstrates an acceptable calibration (DRT only), the minimum sensitivity requirements (including SRb and SNRn for DRT) and a successful performance demonstration according to appendix D of this specification.

6.6.4.3 For film radiography, a film system class better than C4 according to ISO 17636, Table 3, shall be used. The average density shall lie between 2.3 and 4.0 in the region of interest.

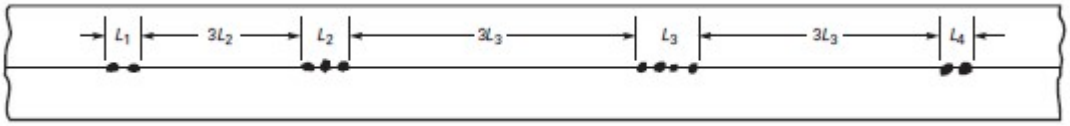
6.6.4.4 For digital radiography, only system with digital detector array (DDA) are allowed. Computed Radiography (CR) is not permitted. The calibration of DDA shall be performed in a production MLP without any weld overlay or other feature (long seam, dent, gouge, etc.) at the pipe end. Gain shall be calibrated at three different grey levels in order to accommodate thickness variation.

6.6.4.5 Radiographic sensitivity required for production shall meet the same result observed in procedure qualification, but it shall at least exceed the requirements of ISO 17636-1/2 by one visible wire. IQI shall be positioned on liner side, as close as possible to triple point.

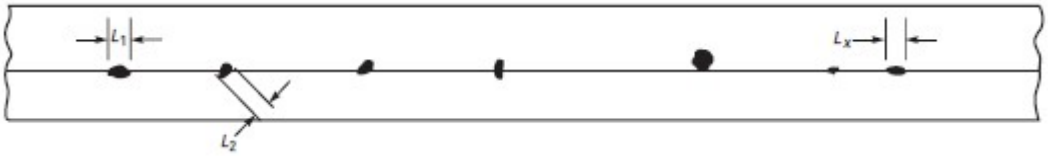
6.6.4.6 The acceptance criteria shall be as follows:

a. Definition:
   i. Rounded indication: the highest dimension is less than 3 times the smallest dimension.
   ii. Linear indication: the highest dimension is equal or higher than 3 times the smallest dimension.
   Triple point: Interface between liner and weld overlay, including the first passes of each layer of the seal weld.

b. Acceptance level:
   i. Round indications with the highest dimension equal or below one tenth of CRA liner thickness (t/10) are considered acceptable and do not need to be reported.
   ii. Round indications in triple point with the highest dimension equal or below one sixth of CRA liner thickness (t/6) are considered acceptable.
   iii. Round indications in weld overlay with the highest dimension equal or below one third of CRA liner thickness (t/3) or 1.0 mm, whichever is lower, are considered acceptable.
   iv. Indications separated by a distance less than the highest dimension of the smallest indication shall be considered as one indication.
   v. Indications separated by a distance less than 3 mm shall be considered as grouped.
   vi. Grouped rounded indications with length greater than 6 mm is not acceptable. Minimum spacing shall be three times the length of the longest adjacent group being evaluated.



   vii. Accumulated dimension of round indications in any 100 mm length of weld shall not exceed 6 mm, limited to 10 indications (regardless of size) in any 150 mm length of weld.



   viii. Clustered porosity is not acceptable.
   ix. Tungsten inclusions greater than one sixth of CRA liner thickness (t/6) are not acceptable.
   x. Linear or crack like indications are not acceptable.

6.6.4.7 The report shall inform details about defect classification (single pore, porosity, inclusion, lack of fusion, crack), location (axial/circumferential) and dimension (individual, cumulated).

6.6.4.8 Radiographic films shall be digitized using methods giving a resolution comparable to digital radiography. The procedure to be used shall be comply with ASME Section V, Article 2, Appendix VI.

6.6.4.9 Digital radiographies shall be identified through an exclusive code, not duplicated, but generated by the user, allowing traceability with each pipe end. DICONDE protocol (“Digital Imaging and Communication in Non-Destructive Evaluation”) shall be used for image storing.

6.6.4.10 COMPANY shall receive all digital images in the original TIFF/DCM format in a weekly basis, maximum, for audit purposes. At the end, an electronic copy of all files shall be provided along with the databook.

6.7 CORROSION RESISTANCE REQUIREMENTS

6.7.1 **[7.4.8.8] Addition** – UNS N06625 composition of liner and clad overlay shall be as defined in API 5LD or ASTM B443. The hardness of the UNS N06625 layer shall not exceed 325HV10. The hardness limit shall be considered for all manufacturing steps (including qualification, production, and raw material fabrication).

6.7.1.1 **[7.4.7] Addition** – Liner and clad overlay shall fulfill the requirements of ISO 15156-3 [11] for sour service applications. Liner and clad overlay shall withstand to a sour service environment compatible with the figure 1 of ISO 15156-2 class 3 or specific environment presented in Materials Requirements document when a CRA liner different than UNS N06625 is selected.

6.7.1.2 **[7.4.8.9] Modification** – Pitting corrosion resistance of liner and clad overlay shall be validated by testing during MPQT in accordance with ASTM G48 Method A. The maximum weight loss for both clad weld and liner shall not exceed 4.0 g/m^2 when tested at 50°C for 24 hours. After testing, visible pits shall not be found at 20x magnification.

6.7.1.3 **[C.6.4.8] Modification -** After final machining, the iron content at surface shall not exceed 10% at clad weld. The PRE and chemical composition of weld overlay shall still be able to be classified as UNS N06625. The minimum PRE to be considered for UNS N06625 shall be 46.4.

6.8 SMALL SCALE SUPPLEMENTARY TESTING

6.8.1 **[7.2.4.8] Addition** – **Hardness testing** shall be executed during MPQT and for each fifty (50) pipes manufactured for each heat. The HV10 hardness testing shall include the points presented in Figure 2. Tests shall be executed after liner expansion. The distance between readings shall be between 0.5-1.0mm. In addition, hardness survey shall be performed at CRA liner (adjacent to weld overlay – 2mm) in order to obtain measurements on the seal weld and CRA liner.

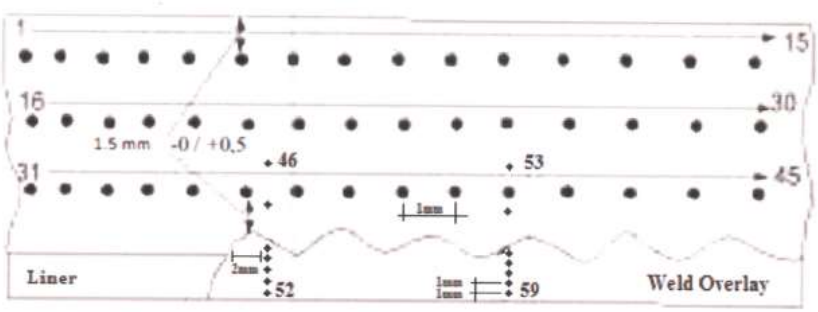


Figure 3 – Hardness measurement points

6.8.2 **[7.2.4.9] Addition** – Charpy V notch testing shall be performed on MPQT and production: besides the acceptance criteria stated in [8] regarding the minimum and average absorbed energy, the shear area of each specimen extracted from host pipe shall not be lower than 85%, at tests executed at the impact testing temperature, as per Table 7-6 of [1].

6.8.3 **[7.2.4.15] Addition** – CTOD testing shall be executed in host pipe during MPQT at the minimum design temperature at a location submitted previously to clad weld application. The CTOD shall be higher than 0.40mm. The samples shall be based on SENB specimens with X-Y plane orientation (through-thickness notch) and with rectangular-section dimensions of W=2B, as per ISO 15653. It is acceptable that CTOD samples be extracted from host pipe, before expansion.

6.8.4 **[Table 7-14] Addition –** Guided Bend Test shall be executed during MPQT according to B2.5 Appendix B of [1]. Four (4) bend test samples shall be obtained from:

a) Fusion line between CRA liner and Weld overlay (Face and root Bend).

b) Fusion line between Host pipe and weld overlay (side bend), including triple point plus 20 mm of liner.

NOTE 1: For tests required in a), in order to guarantee the adequate removal of C-Mn, sample preparation shall be performed by intermediate cycles of machining and etching followed by slight grinding.
NOTE 2: Side Bend tests of the triple point region shall be performed in order to look for eventual growing of micro cracks and discontinuities. Evaluation method to be proposed and detailed by purchaser.

6.8.5 **[7.4.7.10 and 7.4.8.10] Addition** – The gripping force testing shall be executed not only in MPQT, but also in production in the following frequency: two tests for every 100 MLPs produced and after the first 200 MLPs produced with satisfactory results, the frequency may change to two for every 500 MLPs. The minimum gripping force shall be verified in accordance with the following acceptance criteria: The gripping force shall be equal or higher than 25kN, considering a friction length of 250mm (250mm of contact length between host pipe and liner). In case of failure, a root cause analysis shall be performed and two sequential MLP (one before and other after the suspected pipe) shall be tested. Samples shall be obtained from opposite sides. Both tests shall achieve the minimum criteria.

NOTE 1: The gripping force is important to delay the wrinkle formation, especially when the riser/pipeline installation is not executed with internal pressure.
NOTE 2: The gripping force shall be performed during MPQT in as manufactured condition and after simulation of coating application as recommended in API 5LD.Coating simulation may be performed by induction coil or furnace and shall be detailed on MPS and ITP. The measured minimum force after coating simulation may be considered for information only and for design optimization by purchaser.

6.8.6 **[7.4.6] Addition** – CRA liner surface to be in contact with the conveyed fluid shall have RzDIN **roughness** (mean peak-to-valley height) not higher than 50µm. It shall be checked coil manufacturer facility prior to shipping. The test frequency shall be one per coil.

6.8.6.1 **[7.4.6] Addition** – The acceptance criteria for roughness are requested to be fulfilled in overall surface condition. It means that it is acceptable that local deviations such as scratches, forming marks, etc. present roughness higher than the specified above without compromise the desired properties. However, the surface acceptance criteria of Appendix D of [1] are still applicable.

6.8.7 **[7.4.7.10] Addition and [C.6.3.17] modification -** Micro examination testing shall be executed in at least 2 pipe ends during MPQT, including a more extensive evaluation of microcracks and flaws at the triple point region, including EDX, SEM examination. In a minimum of eight locations microscopy analysis, including one at the liner seam weld shall be performed. The acceptance criteria shall be micro cracking at the fusion line and triple point are not permitted. Essentially, free implies that the grain boundary carbides, nitrides and intermetallic phases, including Laves phases, within one field of vision (at 400X magnification) shall be limited to 1.0%.

6.8.8 **[Table 7-14] Modification –** Macrographic examination of seal weld shall include thickness and lift-off measurements at TP, TP+10mm, TP+20mm and TP+30mm. Macrographic examination shall be performed at seam weld and three (3) other positions along the circumference.

6.8.9 **[7.7.3] Addition –** The gap between host pipe and liner at triple point shall be checked during MPQT after clad overlay and machining. One pipe end shall be sectioned in four (4) pieces (separated by 90 degrees). The gap shall not exceed 0.2mm and average shall not be higher than 0.1mm. An appropriate measurement procedure shall be submitted for COMPANY approval.

6.9 REPAIR WELDING REQUIREMENTS

6.9.1 Partial/full CRA thickness repair at triple point is not acceptable. Cut back or cut-out of triple point shall be done, and clad overlay shall be redone in case of an indication higher than the DRT acceptance criteria is detected.

6.9.2 **[C.5.4] Addition –** Partial/full CRA thickness repair at weld overlay area due to lack of bonding, DPI or DRT indication locate at least 8mm of triple point may be performed if WPS is qualified according to table C-5 of ref. [1].

6.9.3 **[C.5.4] Addition –** The following shall be considered during execution of the qualified weld overlay manual partial thickness repair WPS:

- Excavation depth and actual thickness shall be measured and reported.
- DPI shall be performed on 100% of the excavation area before repair execution.
- Proper cleaning of NDE residues shall be performed. Remove any loose impediments from the bore, then perform post clean camera/visual check.
- Reinstate both/all layers as per original approved WPS.
- Strict control of the Heat Input of production repairs, with 100% registration of the passes of all repairs, with no higher tolerance (i.e., + 0%).
- Submit for NDE on reworked area (DPI, UT, clad thickness and DRT) and report.

6.9.4 [C.5.4] Addition – Preliminary welding procedure (pWPS) shall be issued for COMPANY and purchaser approval consisting of the following:

6.10 DIMENSIONAL CONTROL

6.10.1 **[7.7.3.10] Modification -** The total deviation from a straight line, over the entire pipe length, shall be $\leq$ 0.15% of the whole pipe length and any local deviation shall be <3mm within any 1m of pipe length. The end straightness shall be measured in, at least, two perpendicular planes. The method of determining straightness shall be subject to COMPANY validation and a minimum of three measurements per shift shall be recorded.

6.10.2 **[Table 7-20] Modification -** The total wall thickness tolerance (including clad welds) at the pipe ends shall not exceed ±2.0 mm. Furthermore, the eccentricity at the pipe ends, i.e., the difference between the maximum and minimum overall wall thickness in one cross-sectional plane shall be limited to 2.0 mm.

6.10.3 All measurement devices shall be calibrated in a laboratory registered in RBC (*Rede Brasileira de Calibração – Inmetro*) or by an internationally recognized equivalent institute (ILAC – International Laboratory Accreditation Cooperation) and shall have calibration certificates according to ISO 17025.

7 SUPPLEMENTARY FULL SCALE QUALIFICATION TESTING

7.1 GENERAL INFORMATION

7.1.1 **[7.9] Addition**: The supplementary qualification tests shall be performed as part of MPQT. The following tests shall be done: FSBT, FSFT and NDT validation for Clad overlay and triple point evaluation.

7.2 FULL SCALE BENDING TESTING:

7.2.1 Lined pipes submitted to any installation method shall be submitted to full scale bending qualification tests. The intention of the test is to guarantee that no indications higher than the maximum residual allowable imperfection height are verified. These indications measured as the gap between the highest point of the imperfection and a prolongation of the original contour of the liner pipe may be caused by installation and operational loads.

NOTE: This test is necessary because depending on the manufacturing process, materials used, installation method, pipe diameter and liner thickness, the liner may be induced to wrinkles even with a very small strain. See OMAE2014-23577 and OMAE2013-11139 for further information.

7.2.2 COMPANY reserves the right to request to purchaser the execution of finite element analysis (FEA) to check the capability of the manufactured pipe prior to full scale bending testing execution, based on the supplier track record and tradition. The finite element model and analysis shall be calibrated in accordance with full scale bending test results. Reports / certificates issued shall be submitted for COMPANY validation.

7.2.2.1 FEA shall consider gripping force equals to zero to ensure conservativeness.

NOTE: SUPPLIER shall not rely on gripping force to delay the wrinkle. The gripping force depends on several variables which cannot be duly controlled.

7.2.3 FULL SCALE BENDING TEST DETAILMENT:

7.2.3.1 The bending capacity of mechanically lined pipes (MLP) shall be demonstrated via a bending trial with the acceptance criteria defined as a maximum difference between the pre and post-bend liner topology of 0.5 mm, where the liner topology is measured with a laser tool. Alternatively, purchaser may propose for COMPANY´s approval an approach according to DNVGL report for “JIP LINED AND CLAD PIPELINE MATERIALS - PHASE 4”.

7.2.3.2 Two bare (without coating) lined pipes shall be used on the bending trials. The lined pipes shall be submitted to a simulated coating application, which may be performed by passing the lined pipes through an induction coil and cooling system representative to external coating parameters defined at Coating assessment specification issued for the project or heated in a furnace for 10 minutes to at least 260ºC and left to cool in air). The lined pipes shall have at least 12m, unless otherwise formally agreed with COMPANY.

7.2.3.3 After the simulated coating application, one of the pipes shall be cut in the middle and the two factory ends girth welded together. The use of more than one (1) joint per string may be proposed for COMPANY approval.

7.2.3.4 After the girth welding of one pipe, a dimensional inspection shall be done in the inner surface of both pipes in a way to establish a liner surface mapping “before testing”. Unless otherwise agreed, a laser profiling and camera shall be used. At least, 720 measurements shall be executed around the circumference in every 10mm increment in pipe axial direction. The measurement accuracy shall be proposed by purchaser and validated by COMPANY.

7.2.3.5 After the measurements, the lined pipes shall be submitted to full-scale bending.

7.2.3.6 The test bending apparatus shall be designed to impose at least 0.5% axial strain at compression.

7.2.3.7 FSBT shall compose the representative cycles to be used by purchaser for the project. After the testing, the inner surface shall be carefully inspected and measured once again.

7.3 FULL SCALE FATIGUE TESTING:

7.3.1 Lined pipes submitted to any installation method shall be submitted to qualification tests beyond the ones stated in [1]. The following items describe the supplementary qualification tests:

7.3.2 QUALIFICATION TEST DESCRIPTION:

7.3.2.1 Twelve (12) lined steel pipe ends shall be tested in fatigue full scale testing resonance machine in a frequency between 25 and 30Hz. The lined pipe ends used on testing shall be manufactured using pipes manufactured with the lowest strain imposed during liner expansion allowed in manufacturing procedure specification.

7.3.2.1.1 Before girth weld execution, the clad welds of each pipe end shall be reduced up to 50mm or a lower value to be validated by COMPANY in order to simulate the girth weld repair/cut-out during pipeline/riser construction. The minimum length for AUT shall also be considered. In order to do so, pipe ends shall be cut off up to the referred length and rebevelled to allow the girth welding.

7.3.2.2 The prepared lined pipe ends (12 off) shall be used to form six (6) girth welds. These girth welds will be tested, 2 welds per value, at the following stress range values: 80, 130 and 180 MPa (reference: pipe inner surface).

NOTE: The girth welds don´t need to be qualified. The objective of the girth welds is just to allow the test execution. Its failure does not implicate in test failure. However, cap ground flush and NDT inspection (ST and / or UT) are highly recommended in order to avoid prematurely stop of the test.

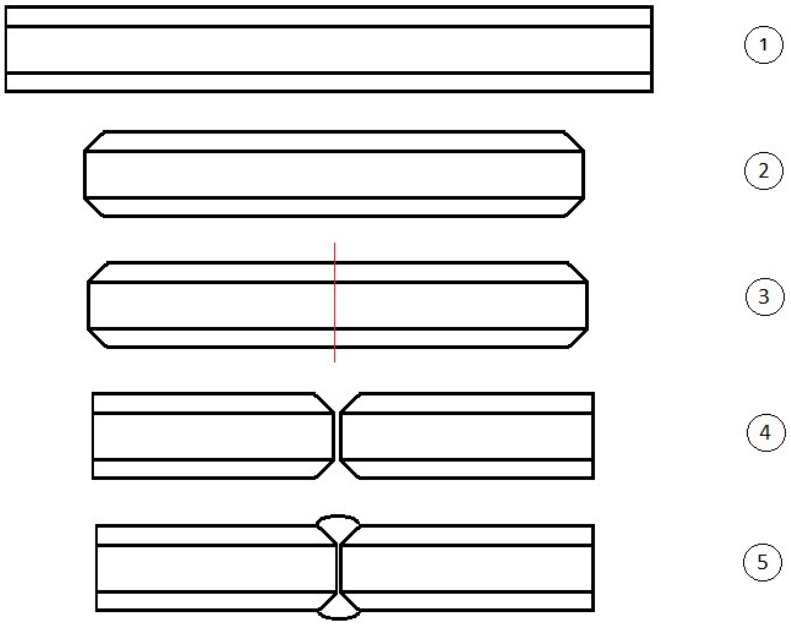


Figure 4 – Steps for samples manufacturing for full scale fatigue testing. Step 1 – Lined pipe “as fabricated”; Step 2 – Cut-out of clad welds in order to turn their lengths adjusted to 50mm +0 – 10mm (see 7.3.2.1.1) and subsequent beveling for girth weld; Step 3 and 4 – Cut pipe in two halves and turn lengths; Step 5 – Girth welding of both halves.

7.3.2.3 Tests shall be executed with internal pressure to simulate axial load. Unless otherwise agreed, at least 100 MPa shall be imposed in axial direction by the pressure containment. Nevertheless, the loading ratio (minimum stress applied divided by the maximum stress applied) shall be higher than zero.

7.3.2.4 The testing shall be run up to the following target number of cycles: The number of cycles enough to guarantee with 95% confidence level the performance of DNV F1 curve “in air” in the inner diameter of lined pipe as per [2].

7.3.2.5 The calculation of the target number of cycles shall be submitted for COMPANY validation.

7.3.3 Once the target number of cycles is achieved, a dye penetrant inspection shall be executed on the inner surface of lined pipe in the whole extension of clad weld, including transition between weld overlay and liner (triple point projection) and vicinities. SUPPLIER may propose to stop test for inspection considering a number of cycles higher than the calculated target life.

7.3.3.1 No signs of crack shall be present. If an indication is detected, it shall be demonstrated by dissection that the host pipe is not exposed/ reached.

7.3.3.2 In each triple point transition area, at least four (4) equally spaced positions around the pipe circumference shall be sampled, sectioned, and evaluated by a longitudinal macrography containing the triple point. The very spot with higher strain gauging records in these points must be considered, even it is adjacent to the 3, 6, 9 and 12 o’clock positions. Purchaser may propose additional locations for macrographic analyses.

7.3.3.3 No sign of a crack defect in the CRA layer thickness exposing the host pipe is allowed in these macrographic analyses.

7.4 VALIDITY OF FSBT and FSFT):

7.4.1 The following limits in the essential variables shall be considered by SUPPLIER:

a) CRA Liner supplier: any change.
b) Host pipe SMYS and liner Grade: Any increase of Host pipe grade or CRA or CRA liner grade requires new qualification.
c) Outer diameter: Any increase of pipe outer diameter higher than 10% requires new qualification.
d) Liner thickness: Any reduction in liner thickness, which results a higher Liner D/t requires a new qualification.
e) Total thickness: Any increase of total thickness higher than 15% requires new qualification.
f) Expansion process: Variation of expansion pressure outside the range of -15%/+15% requires new qualification.
g) Initial manufacturing gap: Any increase in initial manufacturing gap (the nominal distance between host pipe internal diameter and the liner external diameter before expansion process) requires a new qualification.
h) Clad overlay: Any change in welding process, change in welding procedure related to chamfer angle, heat input increase higher than 10%, recovery or repair welding procedure in the triple point zone, any reduction of clad overlay length any change in machining steps requirements, requires a new qualification.
i) Liner CRA: For modification in CRA see AR ALM in appendix A.

8 DELIVERY CONDITIONS

8.1 GENERAL

8.1.1 **[7.8.2] Addition -** After final manufacturing steps (including mill test), the lined pipe shall be internally pickled and passivated. For the MLP final condition of integrated supplier (CRA liner + MLP) internal pickling and passivation may be performed on pipe ends only, if full body pickling and passivation of the CRA Liner is performed prior to insertion into the carbon steel backing pipe. it shall be guaranteed that no potential contamination will occur after liner insertion.

8.1.2 Unless otherwise agreed with COMPANY, at least 95% of supplied pipes length shall be between to 12.2 ± 0.2m. The average of 12.2m shall be targeted by SUPPLIER. Jointers are not allowed.

8.1.2.1 It is acceptable that up to 5% of the supplied lined pipe quantity present lengths between 11 and 12m.

8.1.3 Pipes shall be delivered with the bevel in “square cut” shape.

8.1.3.1 Pipes shall be delivered with plastic protections to avoid impacts able to damage pipe end and to avoid dust ingress to the pipe. The plastic protections provided shall be able to be installed and re-installed manually in pipe end during coating application.

8.2 HANDLING, TRANSPORTATION AND STORAGE

8.2.1 **[7.8.3] Addition -** All pipes shall be handled, loaded and shipped in accordance with API RP 5L1 and API RP 5LW as applicable. Pipes shipped using marine vessels shall be delivered without salt contamination. The ship's log, for transoceanic shipping, shall be made available to COMPANY for review when the pipe is unloaded.

8.2.2 **[7.8.3] Addition -** SUPPLIER shall submit 8 weeks prior to initial loadout, for review and validation by COMPANY or purchaser, loading instructions and diagrams for all pipe shipped by truck or vessel. Careful consideration to facilitate unloading shall be incorporated into procedures.

8.2.3 **[7.8.3] Addition -** All dimensional tolerances and pipe surface conditions specified herein shall apply to the pipe condition as received at the shipping destination.

9 DOCUMENTATION AND RECORDS

9.1 GENERAL

9.1.1 **[7.8.4 and 12.3.1] Addition** - The documentation to be submitted for review prior to start or during start-up of manufacturing shall be submitted for COMPANY evaluation by SUPPLIER two months before the date schedule for MPQT.

Note 1: COMPANY will release comments 14 days after the submission of documentation for COMPANY evaluation. SUPPLIER shall resubmit the document with the implemented comments up to 14 days after the comments release. The revision cycle will only be finished when all comments made by COMPANY and/or purchaser are implemented by SUPPLIER.

Note 2: MPQT shall not begin until all documents are approved by COMPANY and purchaser.

Note 3: Before production commences, SUPPLIER shall release the other documents stated in item 12.3.1 of [1] plus the Inspection Test Plan (ITP) for COMPANY and purchaser appreciation. The revision cycle deadline presented in Note 1 above is still applicable for production purposes.

Note 4: The quality of documentation shall allow COMPANY or purchaser validation. COMPANY or purchaser reserve the right to reject the documentation in case of lack of clarity, poor quality documentation, deviation to this technical specification and the absence of the information requested in this section.

9.1.2 **[12.3.1.2] Addition** - The “complete statistics of chemical composition, mechanical properties and dimension for the quantity delivered” shall be released per batch manufactured, one month after each batch manufactured. Information of measured properties such as chemical composition, yield and ultimate strength and wall thickness shall be clearly presented for each batch.

9.1.3 **[12.3.1.2] Addition** - All documentation shall be available in electronic data files one month after manufacture ends. All electronic data files shall be delivered in PDF type, spreadsheet (XSL) and TIFF/DCM, where applicable. All files shall be clearly presented in folders in a logical index to be proposed by SUPPLIER and submitted to COMPANY or purchaser validation.

APPENDIX A – ADDITIONAL REQUIREMENTS:

GENERAL

This appendix presents the additional requirements for manufacturing and testing of lined pipes. These additional requirements are applicable if required by COMPANY or the purchaser on Purchase Order.

The following additional requirements are envisaged in this appendix:

AR R: This additional requirement is necessary when lined pipes manufactured are intended to constitute risers or pipelines installed by reel-lay method.

AR SE: This additional requirement is applicable when designer intends to consider the strengthening effects of liner and clad weld on riser/ pipeline design.

AR DYN: This additional requirement is applicable when designer intends to use lined pipes in riser locations where the fatigue demand exceeds DNV F1 curve (see section 1.1.2a of this technical specification).

AR ALM: This additional requirement is applicable when designer intends to consider alternative CRA liner material.

AR R – ADDITIONAL REQUIREMENT FOR REEL-LAY INSTALLATION

The additional requirement AR R allows the utilization of lined pipes for risers or pipelines installed by reel-lay method, under the following limit in addition to section 1.1.1.

a) Reel-lay drum and aligner radius: Equal or higher than 7.5m.

The following amendments are applicable for AR R fulfillment in this technical specification main body:

Item 6.2.2 – Additional requirement:

Supplementary Requirement “P” shall be fulfilled for reel-lay installation method.

Items 6.7 and 6.8 – Additional requirement:

Pre-strained and aged samples for mechanical and corrosion tests of liner seam weld, liner body and clad overlay shall be performed as part of MPQT and WPQT.

Items 7.2.3.6 and 7.2.3.7 – Modified requirements:

The procedure established in item 7.2.3 shall be amended as follows:

a) The bending full-scale apparatus shall be designed in a way that the “reel” side presents the representative radius of the vessel intended to be used. If any value is proposed, a radius of 7.5m should be considered. The “straightener” side radius shall be designed in accordance with Bauschinger effect.
b) The full-scale bending test shall comprise at least 3 reeling cycles (considering conservatively each “cycle” to be simulated in accordance with the following sequence: Bending in reel radius, allowed to relax, bending in the straightener radius, allowed to relax).
c) In case of additional cycles are intended to be used depending on CONTRACTOR strategy of reverse reeling, this condition shall be simulated during full scale bending testing. The proposed additional cycles shall be validated by COMPANY.
d) The testing shall be executed with pressurized water in the inner diameter.

d.1) The test pressure shall be proposed by SUPPLIER based on finite element analyses. Unless otherwise agreed with COMPANY, calculated values higher than 30 bar derived from finite element analyses are not allowed due to safety concerns.

NOTE: 30 bar is a value considered to be numerically adequate in accordance with some studies (see OTC 23932). One should bear in mind that the actual pressure during installation shall be higher in order to take into account the pressure reduction due to bending and the vessel dynamics.

d.2) For each reeling cycle, once the pipe string is fully in contact with the “reel side”, the pressure shall be reduced to atmospheric pressure and re-pressurized to the test pressure again before the test proceeds.

NOTE: This requirement intends to allow depressurization during static conditions (i.e., wound or unwound NOT occurring in reel drum), since depressurization may be necessary during installation (ex: tie-in welding).

d.3) SUPPLIER and/or purchaser may propose for COMPANY validation to not utilize internal pressure. In this case, it is still necessary that the liner does not present wrinkles under the strains imposed per bullets a) and b). It is acceptable as well that SUPPLIER and/or purchaser propose the increase of liner nominal thickness to avoid internal pressure demand. In both cases, the proposition shall be based on finite element analyses and tests previously executed.

Item 7.3.2 – Additional requirement:

A full-scale bending strain shall be imposed on test strings prior to fatigue full scale. The following requirements shall apply:

a) The bending full-scale apparatus shall be designed in a way that the reel side presents the representative radius of the vessel intended to be used. If no value is proposed, a radius of 7.5m should be considered. The straightener side radius shall be designed in accordance with Bauschinger effect.
b) The full-scale bending test shall comprise at least 3 reeling cycles.
c) In case of additional cycles are intended to be used depending on purchaser strategy of reverse reeling, this condition shall be simulated during full scale bending testing. The proposed additional cycles shall be validated by COMPANY.

AR SE – ADDITIONAL REQUIREMENT FOR THE DOCUMENTATION OF THE STRENGHNENING EFFECTS OF LINER AND CLAD WELD.

The additional requirement AR SE allows the consideration of the structural contribution of the liner and clad weld or pipeline and riser design, considering the limitations and limit states stated in “DNVGL report for “JIP LINED AND CLAD PIPELINE MATERIALS - PHASE 4”.

NOTE: If this additional requirement is not specified, design process shall not take into consideration any possible benefit of liner and clad weld on the riser/pipeline design (e.g., pressure containment limit state shall not consider liner and clad weld thickness for bursting resistance purpose).

Item 6.1.4 - Modified requirement:
The specified minimum yield strength of UNS 06625 shall be 414 MPa or 276MPa, to be defined in Purchase Order.

NOTE: It is recommended for designer to use 276MPa as much as possible, only requiring 414MPa if really necessary, since this increase in specified minimum yield strength could impact the gripping force.

NOTE: The specified minimum yield strength of liner and clad weld at ambient temperature is assured by the tests required in this additional requirement. However, a de-rating rule shall be applied for temperatures higher than 40ºC for design purposes.

The following amendments in this technical specification main body are applicable:

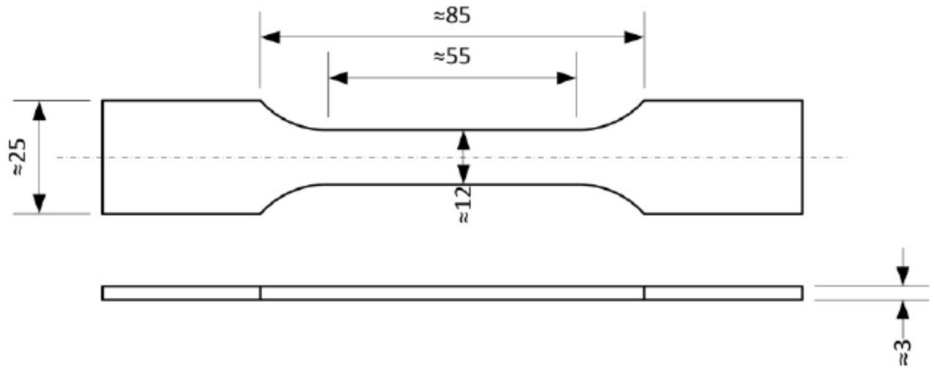
Item 6.8 - Additional requirement **[Table C-5] Addition:**

In order to guarantee that the liner and clad weld will contribute structurally to the resistance, the additional testing presented in Table A.2.1 shall be executed by SUPPLIER:

Table A.2.1 – Additional Tests for LINED pipes utilizing the strength of the CRA layer

Number	Type of Test	Extent of Testing	Standard	Acceptance Criteria	Remarks (Note 1)
MPQT frequency: 2 pipes from different heats except if the entire production is limited to one (1) heat					
#Q.1	Tensile Test of liner (after cold expansion)	1 tensile per each MPQT pipe	API 5LC / Specimen as per Note 1	YS min: and TS min: (Note 4) Elongation at break: 30%	(Note 1) (Note 2) (Note 4)
#Q.2	WPQT for pipe end clad weld	1 WPQT	[1] - Appendix C	[1] - Appendix C	One set of tests stated in Table C-5 of [1] shall be envisaged. (Note 3). (Note 5)
#Q.3	WPQT of liner longitudinal welding	1 WPQT	API 5LC	API 5LC	One set of tests shall be envisaged. (Note 3)
#Q.4	Chemical analysis of the pipe end clad weld	Once per filler material used on WPQT	API 5LD / ASTM B443	As per datasheet filler	-
PRODUCTION TESTS					
#P.1	Tensile Test of liner (after cold expansion)	Once per test unit, but not more than 100 pipes	API 5LC / Specimen as per Note 1	Same as #Q.1 test.	Performed on a rectangular test specimen in longitudinal direction in acc. with API 5LC at Room temperature.
#P.2	Batch test of the pipe end clad weld	Once per filler material batch NOT used during WPQT	[1]	[1] - Appendix C	Performed on a specimen in accordance with Note 1.
#P.3	Chemical analysis of the pipe end clad weld	Once per filler material batch NOT used during WPQT	API 5LD / ASTM B443	As per datasheet filler	-

Note 1: The rectangular tensile testing sample to be tested in longitudinal direction at room temperature shall follow the general dimensions presented below:



Note 2: Test to be performed also on the following temperatures: 40ºC / 60ºC/ 80ºC/ 125ºC. The YS and TS measured shall be documented for information only

Note 3: If reel-lay method is also envisaged (and consequently the AR R is demanded), an additional set of tests in pre-strained shall be executed as per [1]. At least four reeling cycles shall be envisaged, referring to a minimum radius of 7.5m.

Note 4: For YS min of 276MPa, the minimum TS shall be 690MPa. For YS min of 414 MPa, the minimum TS shall be 827MPa.

Note 5: All weld tensile and Charpy V-notch Impact tests are necessary as per note 2 of Table C-5 of [1].

It is relevant to note in Table A.2.1 that tests #Q.2 and #Q.3 present in “remarks” column additional tests if the additional requirement AR R is specified together with AR SE.

In addition to Table A.2.1, SUPPLIER shall submit every pipe manufactured to mill test. The hydrostatic pressure used on test shall be in accordance with the formula [2]:

$$p_{b\_lc} = \frac{2\,(t_1 . f_{cb} + t_{lc} . f_{cb_{lc}})}{D - t_1 - t_{lc}} . 0.96 \qquad [2]$$

Where,

p_{b_lc} is the test pressure
$f_{cb_{lc}}$ is the minimum specified yield strength of CRA layer (UNS 06625).
t_{lc} is the liner minimum thickness (considering less tolerance).

The other symbols are already defined in [1].

AR DYN – ADDITIONAL REQUIREMENT FOR THE UTILIZATION ON FATIGUE SENSITIVITY LOCATIONS ON RIGID RISERS

The additional requirement AR DYN allows that the lined pipes manufactured present fatigue resistance of at least equal to DNV D curve in the outside diameter and DNV E curve in the inside diameter, in order to allow the utilization of lined pipes for “dynamic application”.

NOTE: The team responsible for design is also responsible to define the design curve to be used as target on fatigue test. Corrections in transition point and due to corrosion fatigue shall be envisaged during design, if applicable.

“Dynamics applications” referred in this additional requirement are related exclusively to the fatigue consumption due to high cycle fatigue on rigid risers. The fatigue consumption derived from wave fatigue, vortex induced vibration and slugging imposed on risers is included in this classification, provided that the load-controlled criterion of [1] is fulfilled.

Resistance to low cycle fatigue phenomena is not included in the scope of this additional requirement.

The following amendments in this technical specification main body are applicable:

Item 6.6.1 c) – Modified requirement:

After final machining, visual inspection and execution of any cosmetic repair, the nominal internal diameter tolerance shall not exceed **±0.25mm**. The final machining shall be executed in such a way that a girth weld between any of the supplied pipe will be able to provide an internal hi-lo equal or lower than **0.5mm and δm $\leq$ 1.0 mm**. Purchaser may consider the use of pipe sorting/pipe matching activities. PAUT technique may also be included in this evaluation.

Note: Weld overlay thickness upper tolerance may be disregarded if dimensional requirements proposed (i.e., WT, ID, Hi-lo and SCF) comply with Design Basis (specific for Riser and Pipeline project) issued by purchaser.

Item 6.7 – Additional requirement

Final thickness at triple point (TPZ) and liner transition should be measured by Phased Array by qualified procedure by immersion probes to allow 100% recording of sanded area. In the points of coupling loss (e.g., seam weld) it is acceptable to measure the thickness by A-Scan ultrasonic technique for process control and thickness check. Contractor shall make available for COMPANY representatives all reports and files containing thickness measurements,

Final configuration shall be validated by ECA of triple point and reeling analysis.

Item 7.3.2.5 – Modified requirement:

The acceptance criteria of fatigue full scale testing shall be modified as follows: The testing shall be run up to the following target number of cycles: The number of cycles enough to guarantee with 95% confidence level the performance of DNV E curve “in air” in the inner diameter of lined pipe as per [2].

AR ALM – ADDITIONAL REQUIREMENT FOR ALTERNATIVE CRA LINER MATERIALS

The additional requirement AR ALM shall be followed when the utilization of lined pipes for risers or pipelines with liner CRAs other than alloy 625 are intended for project optimization. If permitted, a list of alternative materials and constraints for usage will be provided in the material requirements on and may include Alloys 825, 6Mo or 904L.

Weldability of alternative CRA liner materials shall be considered in the evaluation. Requirements presented in item 4 of ref. [17] shall be fulfilled.

APPENDIX B – ACCEPTED DEVIATION TO DNV-OS-F101 REQUIREMENTS:

[7.5] Addition – Hydrostatic testing of MLP may be disregarded if the full compliance with the inspection requirements of DNV-ST-F101 and this specification for CRA liner pipe longitudinal seam weld, the triple point zone and weld overlay area, is confirmed.

APPENDIX C – ADDITIONAL INFORMATION TO ALLOW LINED PIPE SUPPLY:

This technical specification shall be supplemented by COMPANY or purchaser in order to allow lined pipe supply. The following additional information shall be supplied:

Type and quantity data:

- Lined pipe diameter.
- Total nominal thickness.
- CRA minimum and nominal thickness.
- Host pipe nominal thickness.
- Specified Minimum Yield Strength of host pipe.
- Length.

  NOTE: In order to determine length to be acquired, bear in mind to include contingency and the amount necessary to execute installation, welding, NDT and coating tests.

Additional requirements (If applicable):

- AR R.
- AR SE (including specified minimum yield strength for CRA layer).
- AR DYN.
- Range of mechanical properties according to supplementary requirement U of [1].

Process:

- Minimum design temperature.

Commercial:

- Delivery point.

Third Party Inspection:

- Third party inspection coverage (if applicable).

APPENDIX D – RT/DRT PROCEDURE PERFORMANCE DEMONSTRATION

COMPANY approach to fatigue and fracture limit state of MLP on high strain, high fatigue load and/or hard to inspect pipelines and riser applications relies on radiographic testing (RT) as alternative to PAUT for the inspection of pipe end triple point and weld overlay during fabrication. The main reason is due to the limitations imposed to PAUT for detection of planar flaws in CRA weld overlay and triple point: anisotropy, reduced thickness, liner interface, lack of coverage at pipe extremities and difficult to interpret results in large scale production. Digital radiography (DRT) with DDA (Digital Detector Array) is the preferred method. PAUT may be employed to aid planar flaw detection and sizing, but it shall not be used to substitute RT until it can be proved to reliably detect and size planar flaws during full scale production in comparison with radiography.

Radiographic testing is limited to flaw detection and length sizing. Linear indications shall not be acceptable. The detection ability of planar flaws in mostly influenced by contrast sensitivity. X-ray sources are required for better image quality. Radiographic sensitivity level shall be verified on each film or image by IQI - Image Quality Indicators. The sensitivity in CRA is reduced with the increase of carbon steel thickness in MLP. Table 3 shows different levels of sensitivity for a MLP with 25.4 + 3 mm of wall thickness as a function of the IQI visible wire diameter (d).

TABLE 1: RADIOGRAPHIC SENSITIVITY LEVELS

Visible Wire	Wire Diameter	Radiographic Sensitivity (Full thickness)	Radiographic Sensitivity (CRA only)
12	0.25 mm	0.88 %	8.33%
13	0.20 mm	0.70 %	6.67%
14	0.16 mm	0.56 %	5.33%

Besides that, the detectability of planar flaws in radiography is also a function of total unsharpness (UT), flaw height (a), width (w) and beam orientation (α), BS-7910 ref. [6] refers to a modified Pollitt model ref. [13] for the assessment of planar flaws detectability in RT, where an index of detectability (I) greater than one (1.0) denotes a high detectability. Table 4 exemplify the use of Pollitt model to estimate the detectability of a flaw with 1.0 mm height and 0.1 mm width.

TABLE 2: DETECTABILITY VERSUS BEAM ORIENTATION.

Visible Wire	Index of Detectability			
	0º	5º	10º	15º
12	1.16	0.88	0.66	0.48
13	1.48	1.19	0.98	0.80
14	1.81	1.52	1.31	1.13

A certain level of flaw misorientation could be compensated by an increased sensitivity, but the triple point and weld overlay may require separate shots depending on the liner bevel preparation angle, weld overlay length and the technique used (ex. panoramic). For smaller diameter (4-8 inches ID), a panoramic exposure is normally not feasible due the required source-to-object distance that is required by ISO 17636. Single wall single image (SWSI) with source outside and film/detector inside should be adopted instead. This would require several radial exposures, which makes digital radiography (DRT) highly recommended due to the reduced exposure time.

However, the flaw detectability on DRT will not depend only in contrast sensitivity as specified in Pollitt model, but also in detector spatial resolution and image signal to noise ratio. Procedure qualification shall also include a full performance demonstration according to ASME BPVC Sec V Art 14 (High Rigor) or NORDTEST NT TECHN REPORT 394. The standard binomial detection test is the preferred approach. From table T-1472 of article 14 of ASME BPVC Section V, a minimum sample size of 29 detected defects out of 29 existing defects is required to obtain a probability of detection of 90% with a level of confidence of 95% (PoD 90|95%). i.e., no misses.

A group of planar flaws with dimensions less than or equal to the required PoD 90%|95% shall be natural induced on both triple point and weld overlay . A map with the location of induced defects shall be kept confidential for the blind test. Normally, it is difficult to induce defects with controlled height by welding. In addition to the proper setting of welding parameters (low heat input/cold wire, high travel/wire speed) and slight changes of torch positioning, manual autogenous GTAW can be used to aid height control. To be considered planar, flaw gape must be at least three times smaller than flaw height. Macros shall be taken in order to confirm defect height, shape and orientation. The proposed locations for macro sectioning shall be submitted for COMPANY approval. The defects shall be marked/hard stamped in the internal surface, and the radiographic testing shall be repeated in order to confirm the macro location.

In this process, small defects (less than 1 mm) may be generated and some of them may be barely detected. In case of dispute, a blind test with three or more interpreters shall be performed. From table T-1472.1 of article 14 of ASME BPVC Section V, it can be seen that the number of samples required for obtaining a PoD 90%|95% increases very fast, if one or more misses are observed. In case of more than one “miss” is obtained, a Hit-miss approach to derive a PoD curve should be used. Hit/Miss procedure requires misses, i.e., small defects induced by welding but not detected by DRT/RT or barely visible. It is acceptable to augment the data increasing the number of macros at defect edges and considering as misses the macros took from the positions where the image of the defect starts to fade. A first estimate of PoD curve can be done with ±30 well distributed indications, but high confidence intervals normally require more (50+).

NOTE: A PoD curve approach based NORDTEST NT TECHN REPORT 394 or ASTM E2862 Ed. 2012 (Hit-miss) is not recommended for DRT/RT unless repeated blind inspection is performed and or signal to noise ratio is determined from digital radiography. In this case, the number of testing samples shall be statistically representative. COMPANY shall be consulted.

Performance demonstration shall be split between the minimum and maximum thicknesses to be qualified for the procedure. Any change beyond the following limits will require a new performance demonstration:

a) Equipment/software: any change in the equipment and technique used, including film/detector, filters, intensifying screens and image processing steps.
b) Procedure: any change in execution tables outside the qualified thickness range.
c) Sensitivity: any decrease in essential wire observed during qualification.
d) Weld Overlay: any change in welding procedure specification, including clad overlay length, number of welding passes and liner bevel angle.
e) Material: any change in type of material, thickness range and diameter.

A reduced scope may be proposed to extend the range of validity but in no case the number of induced planar flaws for performance demonstration shall be less than 12. The modified Pollitt model may be used to adjust PoD where there is a small change in one of the essential variables above. In any case, a technical justification shall be submitted for Company approval.

The required PoD 90%|95% shall be based on ECA of a full circumferential flaw at triple point according to I-ET-0000.00-0000-210-P9U-005. Whenever ECA is not required and the SN curve considered in fatigue design for triple point is F1 or worst (DNV-RP-C203), the performance demonstration may be omitted for single wall / single image technique if it can be demonstrated, during qualification and production, that at least two additional single wires can be viewed in addition to the minimum image quality values of ISO 17636-1 and 2, and the maximum image unsharpness (duplex wire) requirement can be achieved without any compensation (DRT only).