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	CLIENT:	PETROBRAS	SHEET: 1 of 18
	JOB:	GENERAL	CC:
	AREA:	RIGID SUBMARINE PIPELINES	PROJECT:
DDP	TITLE: <b>CRA WELD OVERLAY CLAD PIPE REQUIREMENTS</b>		PUBLIC
EDR			


INDEX OF REVISIONS

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0	ORIGINAL EMISSION
A	GENERAL REVISION – ITEMS REVISED WERE HIGHLIGHTED IN YELLOW
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EXECUTION	CWF8	CWF8	CWF8	CWF8	HXA1				
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## 1 TECHNICAL SPECIFICATION SCOPE

1.1 The objective of this technical specification is to define the technical requirements for full weld overlay clad pipes. **WELD OVERLAY CLAD pipes fabricated according to this Technical Specification shall be in compliance with all requirements of DNVGL-ST-F101 (2017).** This document shall be read in conjunction with DNVGL-ST-F101 and other standards mentioned in item 2 of this technical specification. All additional and modified requirements are mentioned in this technical specification. The DNVGL-ST-F101 paragraph number is given in square brackets.

1.2 **[7.1.2 Section 7] Addition** - This technical specification is applicable to the following limits:

- a) Outside diameter: from 6" to 16";
- b) Backing steel grade: SMYS shall be equal to 415MPa or 450MPa;
- c) CRA weld overlay cladding covered by this specification is based on the deposition of Alloy 625 in a thickness range of 3.5 to 8 mm. The chemical composition shall be in line with "ASTM B443 Alloy 625", UNS N06625 [5].
- d) Installation Methods: J-lay, S-lay and Towing;

NOTE: This technical specification may be adopted for reel-lay installation method provided that the additional requirement AR R is fulfilled (see Appendix A) as a Research and Development case only.

- e) Coating: Application temperature for parent and field joint coating not exceeding 260°C;
- f) Thickness transitions design demand: equal or smoother than 1:7 transition;

NOTE: The part responsible for design shall establish a smoother transition, if required by one specific project.

- g) Weld Overlay clad pipes requirements intended to be used for rigid spool application shall be in accordance with [11].


1.3 **[7.1.1.3 Section 7] Addition** - The fatigue resistance of girth welds is not included in the scope of this document. This technical specification is exclusively dedicated to the Weld Overlay Clad pipe.

NOTE: This technical specification presents general requirements for full weld overlay clad pipe manufacturing. It is responsibility of the team in charge of the design, to insert additional or modified requirements, if judged necessary, to guarantee the integrity of risers during design life.

1.4 **[1.7.1 Section 1] Addition** - Where there is a conflict between the requirements of this specification, the Pipeline Project Design Basis, the referenced DNVGL and other specific standards, the order of precedence of the documents shall be:

- 1st – Design Basis (specific for Riser and Pipeline project);
- 2nd – This Technical Specification;
- 3rd - DNVGL-ST-F101 (2017)
- 4th – Other specific standards (see references in item 2)

1.5 The Appendix B of this specification presents the necessary information to be informed in the purchase order by PETROBRAS or purchaser for full weld overlay clad pipe supply.

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## 2 REFERENCES

2.1 [1.7 Section 1] **Addition** - The latest revision of the following documents applies:

- [1] DNVGL-ST-F101 - Submarine Pipeline Systems - Revision Oct 2017;
- [2] DNVGL-RP-C203 (2016) - Fatigue design of offshore steel structures;
- [3] API STD 2RD - Dynamic Risers for Floating Production Systems;
- [4] ASTM E2862 (2018) - Standard Practice for Probability of Detection Analysis for Hit/Miss Data;
- [5] 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;
- [6] ASTM G1 (2017) – Standard Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens;
- [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] DNVGL Report - JIP Lined and Clad Pipeline Materials, Phase 4 –Guideline for Design and Construction of Lined and Clad Pipelines - Report No.: 2017-3114, Rev. 1.
- [11] I-ET-0000.00-0000-219-P9U-005 - CRA Weld Overlay Clad Pipe requirements for rigid spools.


## 3 DEFINITIONS

3.1 [1.8.1 Section 1] **Modification** - The following verbal forms are applied:

- SHALL - Indicates a mandatory requirement (When related to SUPPLIER).
- SHOULD - Indicates a preferred course of action.
- MAY - Indicates a possible course of action.

3.2 [1.8.2 Section 1] **Modification** - The following definitions are applied in this document:

- PETROBRAS including its employees, inspectors and other authorized representatives;
- Purchaser – Refers to EPCI contractors, when they are responsible for full weld overlay clad pipe supply;
- SUPPLIER – Weld overlay Clad pipe manufacturer;
- BACKING STEEL – The C-Mn pipe in which an internal weld overlay is to be applied;
- BACKING STEEL SUPPLIER – Backing steel pipe manufacturer;
- CRA WELD OVERLAY CLAD PIPE – C-Mn Pipe to be used in offshore applications with internal (Corrosion Resistant Alloy) layer where the bond between backing steel and cladding material is metallurgical, deposited by welding;
- 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;

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**3.3 [1.8.3 Section 1] Addition** - The following Abbreviations are also applied:

- EDX – **Energy** Dispersive X-ray
- GTAW – Gas Tungsten Arc Welding;
- PFMECA – Process Failure Modes, Effects and Criticality Analysis
- QMS – Quality Management System;
- WPQR – Welding Procedure Qualification Report;
- QTS - Qualification Test Sample

## **4 TECHNICAL REQUIREMENTS**

### **4.1 GENERAL REQUIREMENTS:**

- 4.1.1 SUPPLIER shall fulfill all the requirements stated in [1] related to **weld overlay clad** pipes, as well as the supplementary requirements listed below:
- a) General Full Weld Overlay Clad pipe **DNVGL** Supplementary Requirements;
  - b) Supplementary Qualification Testing;

4.1.1.1 The “General Full Weld Overlay Clad pipe **DNVGL** 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 full weld overlay clad pipe.

The Appendix A of this specification presents additional requirements. These additional requirements shall only be fulfilled by SUPPLIER if required by PETROBRAS or purchasers in the purchase order.


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

- 4.1.2 **[7.1.7.2 - Section 7] Modification** - Target chemical composition including applicable tolerances, ranges for deliberately added elements and maximum for other elements.
- 4.1.3 **[7.1.8.7 Section 7] Modification** - The validity of the MPQT shall be limited to the steelmaking, rolling, and manufacturing/ fabrication facilities used during the qualification of backing material, weld overlay clad pipe and welding procedure specifications based on approved WPQR.

## **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 or equivalent documents validated by PETROBRAS.
- 5.1.2 During production, the supplier shall make available upon request all material certificates to PETROBRAS and purchaser. All materials shall be certified according to BS EN 10204 Inspection certificate 3.1 “type 3.1” [7].

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## 5.2 MANUFACTURING PROCEDURE:

5.2.1 Before MPQT, the following documentation shall be submitted for PETROBRAS evaluation:

- ✓ Quality Plan;
- ✓ Manufacture Procedure Specification (MPS) and Inspection Test Plan (ITP) for full weld overlay clad pipe, including test requirements and acceptance criteria;
- ✓ Manufacturing procedures;
- ✓ Preliminary Welding procedures specifications (pWPS) for weld overlay, including procedures for repair welding;
- ✓ Non-destructive testing procedures, including defective weld map reference;

5.2.2 **[7.1.4 Section 7] Modification** – The following requirements related to manufacturing procedure shall be considered:

- ✓ Weld overlay clad pipes shall be manufactured from internally deposition of CRA overlay clad on C-Mn backing steel pipe. Weld overlay shall be executed in at least, two welding layers;
- ✓ The weld overlay clad pipes shall be manufactured exclusively by welding.

5.2.3 **[7.4.3.1 Section 7] Addition** – The following shall be included in the MPS:

*For full weld overlay clad pipes*

- ✓ The mating and surface preparation procedure of backing steel before weld overlay;
- ✓ Additional mechanical tests regarding the additional requirements of Appendix A (if applicable in accordance with **Material Requirements**);
- ✓ Weldability testing matrix (if applicable);

5.2.4 **[7.4.3.1 Section 7] Addition** – SUPPLIER shall submit the detailed MPS of the manufacturing of the full weld overlay clad pipe. MPS shall be subjected to CONTRACTOR validation and shall cover all metallurgical aspects, fabrication tolerances, weld and NDT requirements, dimensional control before and after nickel alloy weld overlay application.

## 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].

## 6 GENERAL WELD OVERLAY CLAD PIPE DNVGL SUPPLEMENTARY REQUIREMENTS

### 6.1 BACKING STEEL REQUIREMENTS:

6.1.1 **[7.1.4.3 and 7.4.1.2 Section 7] Modification** – The backing steel of the full weld overlay clad pipe shall comply with [8].


6.1.2 **[7.1.5 Section 7] Modification** – The applicable supplementary requirements given in subsection I of [1] are listed in [8]. The project specific conditions will be defined by PETROBRAS or purchaser (see Appendix **B**).

NOTE: Supplementary Requirement "P" is automatically required if AR R is required (see Appendix A).

6.1.3 **[7.1.5 Section 7] Addition** – Additional requirements **AR RL, AR HL and AR UE** of [8] may be selected depending on the project specific conditions.

6.1.4 **[7.2.3.39 Section 7] Addition** - The ID pipe roughness shall be checked in backing steel supplier facility prior to shipping. Acceptance criteria shall be in the Backing steel MPS.

6.1.5 **[7.4.1.2 Section 7] Addition** – No repair of the backing steel by weld overlay is permitted.

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## 6.2 WELD OVERLAY CLAD PIPE MANUFACTURING REQUIREMENTS

6.2.1 **[7.4.2 Section 7] Addition** - In addition to the designation of the backing material (see [7.1.4]) Weld overlay clad pipe shall be designated with:

- WO, for Weld overlay;
- UNS N06625 (for Alloy 625 as cladding material).

6.2.2 **[7.4.4 Section 7] Addition** - Overlay welding shall be performed according to qualified welding procedures meeting the requirements of Appendix C of DNVGL-ST-F101 [1].

6.2.3 **[C.5.4.1 Appendix C] Modification** – Weld overlay shall be performed with pulsed **GTAW mechanized process** or **GMAW mechanized** process.

6.2.4 **[C.8 Appendix C] Addition** - For full weld overlay clad pipes using Alloy 625 as CRA, welding consumables shall be in accordance with **UNS N06625**.

6.2.5 **[C.5.4 Appendix C] Addition** - The qualification of welding procedures, **including the whole qualification tests and requirements**, for full weld overlay clad pipes shall be in accordance with sub-sections C.5.4 and C.6.4 of [1] added by the requirements of this specification. The essential variables of the respective welding process from ASME BPVC Section IX shall be complied with. **The qualified range shall be according to that code**.

6.2.6 **[C.5.4 Appendix C] Addition** - The clad weld shall be executed in several welding passes in order to limit an eventual flaw height **and weld metal dilution**. At least, two welding layers are required. After final pass, a machining shall be executed.

6.2.7 **[7.4.7 Section 7] Addition** - Mechanical and Corrosion Testing shall, at least, comply with DNVGL-ST-F101 requirements of Appendix B, C and D. Exceptions to the stated requirements may be provided on this Technical Specification or in a Design Basis.


6.2.8 **[7.2.3.39 Section 7] Addition** – Internal **machining between layers** shall be performed if supplier is not able to carry out volumetric NDT in order to detect and to size (height, length and depth) flaws, such as **porosities and lack of fusion**, on weld overlay layers. After each internal layer machining DPI shall be carried out. DPI acceptance criteria shall be in accordance with item D.8.11.5.

6.2.9 **[7.2.3.39 Section 7] Modification** - Before the execution of any machining step, the weld overlay pipe shall be carefully fixed in order to not create a conical machining (i.e. the machining axis not parallel to pipe axis). The procedure to avoid conical machining shall be submitted for PETROBRAS validation.

6.2.10 **[7.2.3.39 Section 7] Modification** – Internal pipe machining shall be carried out to achieve the required pipe inside diameter tolerances. The **machining length** of the pipe shall be as specified in the purchase order. Internal machining procedure shall **be submitted to PETROBRAS validation**.

6.2.11 **[C.6.4 Appendix C] Addition** - The inner surface to be in contact with the conveyed fluid shall have an **RzDIN roughness** (mean peak-to-valley height) not higher than 50µm. The test frequency shall be one for every 50 (fifty) fabricated pipes. The acceptance criteria for roughness are requested to be fulfilled in overall surface condition. After final machining, the weld profile (weld bead) shall not be visible and the surface shall be free from any kind of grooves or any other stress concentration areas, **as steps due to Start / stop and repairs**

6.2.12 **[7.4.4.1 Section 7] Addition** – **Pickling** shall be performed. The pickling solution to be applied shall fulfill the requirements of Item C.6.1, Table A1.1 of ASTM G1 [7]. Subsequent rinsing shall be performed using water with low chloride content.

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6.2.13 [7.4.4.1 Section 7 and C.8.1.7 Appendix C] **Modification** - Provided that Carbon Steel tools shall not be used for CRA parts, Purchaser shall propose material in order to do not contaminate the CRA layer. The following additional requirements shall be applied to CRA sections, in order to avoid contamination of CRA layer:

(a) Fabrication of clad overlay pipes shall be performed in a workshop, or part thereof, which is reserved exclusively for this type of material. During all stages of manufacturing, contamination of CRA layer with carbon steel and zinc shall not be permitted. Direct contact of the CRA layer with carbon steel or galvanized handling equipment (e.g. hooks, belts, rolls, etc.) shall not be permitted. Tools such as earthing clamps, brushes etc., shall be stainless steel suitable for working on type of material in question and not previously used for carbon steel. Contamination of weld bevels and surrounding areas with iron and low melting point metals such as copper, zinc, etc. is not acceptable. The grinding wheels shall not have previously been used for carbon steel. Parts of internal line-up clamps that are in contact with the CRA layer shall be non-metallic or of a similar alloy as the internal pipe surface.

(b) In the occasion of clad overlay pipes fabrication, PETROBRAS will send a team of authorized employees to Supplier fabrication facilities before the start of activities in order to evaluate the conditions provided, in order to avoid contamination of CRA section with Carbon Steel. Purchaser shall, at its own costs, execute any modification required by Petrobras for CRA riser fabrication.

(c) Supplier shall have in its facilities pickling equipment in case of accidental contamination of internal CRA layer, or a suitable equipment to suitably remove the contamination by a procedure previously validated by PETROBRAS. Care shall be taken to avoid C-Mn exposition to pickling, especially the contact zone between CRA and C-Mn layer.

(d) Pipe ends shall be protected by end cap until the beveling moment for girth weld execution.

### 6.3 CORROSION RESISTANCE REQUIREMENTS

6.3.1 [7.4.7.8 Section 7 and C.6.4.7 Appendix C] **Addition** - The minimum and maximum PRE values shall conform to UNS N06625. Figure 1 presents the PRE values for UNS06625.

$$\begin{aligned}
 & \text{N06625} \\
 & \% \text{ Cr} = 20.0 - 23.0 \\
 & \% \text{ Mo} = 8.0 - 10.0 \\
 & \% \text{ N}_2 = 0.0 \\
 & \text{PRE}_{\text{min}} = 20.0 + (3.3 \times 8.0) + (16.0 \times 0.0) = \mathbf{46.4} \\
 & \text{PRE}_{\text{max}} = 23.0 + (3.3 \times 10.0) + (16.0 \times 0.0) = \mathbf{56.0}
 \end{aligned}$$

Figure 1 - PRE values for UNS06625.

6.3.2 [C.6.4.8 and C.8 Appendix C] **Modification** – Iron (Fe) dilution shall be measured using semi quantitative EDX technique. After final machining, the iron content at inner surface shall not exceed 10% (Fe% ≤ 10).

6.3.3 [7.4.8.9 Section 7 and C.6.4.7 Appendix C] **Addition** – Pitting corrosion resistance of weld overlay shall be validated by testing during MPQT in accordance with ASTM G48 Method A. The maximum weight loss shall not exceed 4.0 g/m<sup>2</sup> when tested at 50°C for 24 hours. After testing, visible pits shall not be found at 20x magnification.

6.3.4 [C.6.4.17 Appendix C] **Modification** - Corrosion testing and microstructure examination of UNS06625 weld overlay shall be performed during MPQT. During production microstructure examination of weld overlay and backing steel interface shall be performed at least once per production shift.





## 6.4 SMALL SCALE SUPPLEMENTARY TESTING REQUIREMENTS

- 6.4.1 [7.1.8.6 Section 7] Addition – Weldability tests shall be executed unless SUPPLIER presents a track record supplying successfully DNVGL 450 WO UNS N06625. If the testing is deemed necessary, a testing matrix shall be proposed by SUPPLIER for PETROBRAS validation. The testing matrix shall prove that full weld overlay clad pipes may be welded without any special resources or welding methods. Pipes shall be able to be welded using at least GTAW and GMAW methods.
- 6.4.2 [7.4.7.3 Section 7 and C.6.4.6 Appendix C] Addition – Hardness - The maximum hardness of the CRA layer shall be limited to 345 HV10.
- 6.4.3 [C.6.4.5 Appendix C] Modification – The macro sections shall be documented by photographs (magnification of at least 10X). The macro section shall show a sound weld merging smoothly into the base material and meeting Quality level B of ISO 5817.

## 6.5 NDT REQUIREMENTS:

6.5.1 [Table 7-16 Section 7] Addition – Type and extent of non-destructive testing for full weld-overlay shall be equivalent to clad welds in lined pipe with the following additional requirements.

6.5.2 [Table 7-16 Section 7] Addition – After final machining, weld overlay shall be 100% volumetric inspected for surface and embedded flaws by phased-array ultrasonic testing (PAUT). PAUT shall be capable of detect and reject planar flaws not higher than 1 mm height x 10 mm length. Volumetric flaws shall be judged according to radiographic testing acceptance criteria. Exception is made when a fatigue demand higher than E curve of DNVGL-RP-C203 is specified. In this case, critical flaw sizes shall be specified according to DNVGL-RP-F108. Inspection of CRA weld overlay is challenging and it is still scope of a R&D project conducted by PRCI. Apparently, there is not a single technique, which completely fulfills the desired capabilities. SUPPLIER may propose a range of standard and advanced ultrasonic techniques, including imaging techniques such as TFM/FMC. PAUT system may consist in a combination of both mechanized/automated and manual PAUT for better detection ability and sizing accuracy.

The PAUT system shall comply with the requirements of DNVGL-ST-F101 App. D and E. Since there is not a standard procedure for weld overlay inspection, a specific PAUT procedure and qualification plan shall be submitted for COMPANY validation.

PETROBRAS shall be notified four weeks in advance to witness the whole qualification process. Reliability tests shall include reference destructive testing (macro sectioning) in a sufficient number of weld defects to derive reliable estimates of detection or rejection ability (PoD 90%|95% or PoR 85%|95%) and sizing accuracies. In no case, it shall be less than 29 defects. Natural induced defects are preferred, but artificial reflectors (EDM) may be included to a limit of 50% of the samples. If there is more than one thickness/diameter to be qualified, additional 12 defects shall be included each lowest and/or highest. All test coupons shall be inspected by DPI and RT according to the requirements described herein. All indications detected by these methods and not detected by PAUT shall be investigated with destructive testing. In addition to personnel certification requirements, all inspectors shall be qualified by the Level 3 Professional responsible for the PAUT procedure.

PAUT qualification report shall have the following minimum content: personnel certification; calibration certificates for equipment, probes, wedges and calibration blocks;

PAUT reports; macro sectioning report; comparison between macro sizing x PAUT sizing; methodology adopted for PoD/PoR calculation; statistical analysis for AUT sizing error; and a final conclusion with a clear indication of the under sizing error and PoD 90%|95% and/or PoR 85%|95% of the PAUT system.



PAUT native files and viewer software shall be made available at any time for review. At the end of the Project, all PAUT native files shall be provided in their original digital acquisition version, compatible with the viewer software provided, and organized to permit the traceability and recovery of information related to the inspected joint.

**6.5.3 [Table 7-16 Section 7] Addition** – After final machining, a length of 100mm on each pipe end shall be inspected by digital radiography if automated or manual PAUT coverage cannot be demonstrated. Digital radiography shall comply with ISO 17636-2 and DNVGL-ST-F101. SUPPLIER shall issue a comparative report between Digital X-ray and conventional radiography in terms of sensitivity and detection for PETROBRAS validation. All data utilized for double checking the evaluation of equivalence between methods shall be available for review. The detection ability of radiographic tests shall be established according to NORDTEST NT TECHN REPORT 394 or ASTM E2862 Ed. 2012. The probability of detection of DRT shall be equivalent to those specified for PAUT in item 6.5.2. The samples size shall be statistically representative, but never less than 29 defects. DRT procedure and qualification plan shall be submitted for Purchaser approval. PETROBRAS shall be notified four weeks in advance to witness the whole qualification process. The same coupon used to qualify PAUT may be used for DRT qualification. Both wire and duplex IQIs shall be adopted to evaluate sensitivity and out of sharpness. If the sensitivity of the IQI is better than the minimum required in ISO 17636-2, the sensitivity (wire number) obtained during procedure qualification shall become the essential wire in production. The test matrix for qualification purpose shall be submitted for PETROBRAS validation. The acceptance criteria shall be as follows:

- a) Enclosed volumetric indications like for example pores or inclusions with a  $\varnothing \leq 1.0\text{mm}$  are permissible. Enclosed volumetric indications with a  $\varnothing > 1.0\text{mm}$  are not acceptable;
- b) The distance between single pores or volumetric inclusions shall be 3 mm minimum;
- c) There are a maximum of 10 pores or volumetric inclusions permitted within a weld length of 150 mm;
- d) Accumulated diameters of round indications in any 100 mm length shall not exceed 6mm;
- e) Cluster porosity is not acceptable;
- f) Elongated, linear or crack like indications are not acceptable.

**6.5.4 [Table 7-16 Section 7] Modification** – For inspection of backing steel material, the acceptance criteria for laminar imperfection in ultrasonic testing shall be as per sour service in table D-12.

**6.5.5 [Table 7-16 Section 7] Modification** – For surface testing of clad welds, liquid penetrant testing shall be performed according to D.3.3.2 of appendix D in [1] on 100% of inner surface of weld overlay.

**6.5.6 [Table 7-16 Section 7] Modification** – For bonding imperfection in clad welds, ultrasonic testing shall be performed according to D.3.3.4 and reports in accordance with D.3.3.5 of appendix D in [1] on 100% of the interface between backing material and weld overlay. Alternatively, it may be done in conjunction with PAUT inspection.

## 6.6 DIMENSIONAL REQUIREMENTS:

**6.6.1 [7.7.2.3 Section 7] Addition** – Minimum 95% of the total quantity per Item shall be supplied in length of 12,1 m  $\pm 0,2$  m and maximum 5% in length of minimum 11,0 m. The target average pipe length shall be minimum 12,1 m. Jointers are not allowed.

**6.6.2 [Table 7-22 Section 7] Addition** - The total deviation from a straight line, over the entire linepipe length, shall be  $\leq 0.15\%$  of the whole pipe length and any local deviation shall be  $< 3\text{mm}$  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 PETROBRAS approval and a minimum of three measurements per shift shall be recorded.



6.6.3 **[Table 7-20 Section 7] Modification** - The overall wall thickness tolerance at the pipe ends shall not exceed  $\pm 2.0$  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.

6.6.4 **[7.7.2.1 and 7.7.2.2 Section 7] Addition** – The following requirements shall apply:

Wall thickness (pipe ends and pipe body):

- ✓ The weld overlay clad pipes manufactured in accordance with this technical specification shall have a CRA over thickness to allow for a pipe end inside diameter machining, to achieve the required pipe end tolerances. The wall thickness of the weld overlay layer shall be  $-0/+2,0$  mm.
- ✓ An ultrasonic wall thickness measurement shall be performed in approximately 1,0 m length for each pipe.
- ✓ Wall thickness measurement shall be carried out in 12 locations as follows ( $0^\circ$ ;  $30^\circ$ ;  $45^\circ$ ;  $90^\circ$ ;  $120^\circ$ ;  $135^\circ$ ;  $180^\circ$ ;  $225^\circ$ ;  $240^\circ$ ;  $270^\circ$ ;  $315^\circ$  and  $345^\circ$ ).
- ✓ During MPQT weld overlay wall thickness measurements shall be performed in approximately 1.0 m length for one pipe. Recordings shall be carried out by macrographs.

Internal diameter, external diameter and hi-lo:

- ✓ All pipes shall be supplied with a pipe end actual inside diameter tolerance of  $\pm 0,25$  mm incl. OoR. The machining shall be executed in such a way that a girth weld between any of the supplied linepipe will be able to provide an internal hi-lo equal or lower than 0.5mm without the demand of pipe sorting/pipe matching activities.
- ✓ The inside diameter may be fixed by the pipe manufacturer after the completion of the first 25 pipes. The tolerance shall be based on the actual fixed inside diameter and shall apply over the length of the pipe end inside machining. However, once established the “actual inside diameter”, this actual diameter shall be applied for the whole production (all lots manufactured).


NOTE: If a long term agreement is signed related to a certain standardized pipe dimension (characterized for its diameter and thickness), the “actual diameter” shall be kept constant along all contract validity.

- ✓ The pipe end inside diameter measurement shall be performed by means of a laser dispositive.
- ✓ The inside diameter shall be calculated as an average out of the measured ID values and the OoR shall be calculated under consideration of the minimum and maximum measured value.
- ✓ The pipe inside diameter measurement shall be performed in 100% of pipe ends, at a distance of 20 mm from the pipe end and at a distance as specified in the purchase order, i.e. the specified length of the inside machining.
- ✓ The pipe end OD tolerance shall be based on an actual OD which shall be fixed after start of production as the ID is mandatory. OD tolerance:  $\pm 0.5$  mm (max.)

Pipe end surface requirements:

- ✓ Visual inspection in 100% of pipe ends, in order to verify the existence of grooves, scars or any other stress concentrator. The buffing extension beyond the taper length shall be verified.
- ✓ The roughness in 100% of pipe ends shall be measured and compared to the acceptance criteria.

NOTE 1: All measurement devices shall be calibrated in a laboratory registered in Brazilian Calibration Network - RBC (Rede Brasileira de Calibração – INMETRO) or by an equivalent international recognized certifying authority. Additionally, all micrometers shall be checked for calibration at the beginning of each shift.

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6.6.5 **[Table 7-23 Section 7] Modification** - The pipe end wall thickness, inside diameter and out of roundness shall be measured and reported for each pipe end.

## 7 SUPPLEMENTARY FULL SCALE QUALIFICATION TESTING

### 7.1 GENERAL INFORMATION

7.1.1 **[7.9 Section 7] Addition:** The supplementary qualification tests are: Full scale bending test, Fatigue full scale testing and Non Destructive Testing for full weld overlay clad pipe evaluation.

7.1.2 During BID phase, SUPPLIER shall submit for PETROBRAS validation the results of previous tests performed by PETROBRAS or by other recognized Operators and/or by EPCI contractors. Requirements of Appendix D of this specification shall be fulfilled. As a guideline to issue the qualification / industrialization proposal the following topics shall be considered: how to perform material validation, full weld overlay clad pipe fabrication process, internal quality controls and product validation (including simulated installation and service testing).

### 7.2 FULL SCALE BENDING TESTING [7.9.3 Section 7] Addition :

7.2.1 Full weld overlay clad pipes to be installed by J-Lay or Reel Lay 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. For this test, volumetric inspection shall be performed before and after in order to verify any crack propagation, which may be caused by installation and operational loads.

7.2.2 In order to check any disbondment of weld overlay, conventional UT shall be performed, before and after bending test.

7.2.3 PETROBRAS reserves the right to request to SUPPLIER, at SUPPLIER cost, 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 carried out by institutions or companies. Reports / certificates issued by the selected institution shall be previously submitted for PETROBRAS validation.

### 7.3 QUALIFICATION TEST DESCRIPTION:

7.3.1 **[7.4.8.11 Section 7] Modification** - Two bare full weld overlay clad pipes manufactured with the qualified WPS shall be submitted to a simulated coating application (heated during 10 minutes to at least 260°C and left to cool in air). The full weld overlay clad pipes shall have at least 12m, unless otherwise formally agreed with PETROBRAS. At least 1 start stop shall be done on each 6m of pipe. Purchaser shall propose location on full scale testing proposal. Location of start stop shall be clearly identified.

7.3.2 After the simulated coating application, one of the pipes shall be cut in the middle and the two pipe mill ends girth welded together.

NOTE: The girth welding **procedures don't need to be** qualified. The objective of the girth welds is just to allow the test execution. Their eventual failure does not implicate in test failure.

7.3.3 After the girth welding of one pipe, a volumetric inspection by UT phased array technique shall be performed at HAZ and at start stop locations to be compared with indications after bending simulation trial. Imaging technique may be used to verify any indication of crack propagation. The proposed imaging technique shall be validated by PETROBRAS.

7.3.4 After the NDT inspection, the full overlay clad pipes shall be bent in a full scale bending machine.

- 7.3.5 The test bending apparatus shall be designed to impose at least 0.5% strain at compression.
- 7.3.6 The full scale bending testing shall compose 2 cycles (first bending, allowed to relax and second bending, allowed to relax). After the testing, the inner surface shall be carefully inspected and measured once again.
- 7.3.7 Acceptance criteria: no volumetric indication using UT phased array + imaging technique higher than critical defect height calculated for pipeline loading.

**7.3.8 VALIDITY OF FULL SCALE BENDING QUALIFICATION TESTS:**

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

- a) Backing steel manufacturer and CRA clad wire supplier;
- b) Outer diameter: Any increase of pipe outer diameter requires a new qualification;
- c) Backing steel grade: Change from SMYS=415 to 450 MPa requires new qualification. Change from SMYS=450 to 415MPa does not require new qualification;
- d) Weld overlay: Any modification in welding procedure specification, including number of welding passes, change in machining requirements, requires a new qualification;

**7.4 FULL SCALE FATIGUE TESTING:**

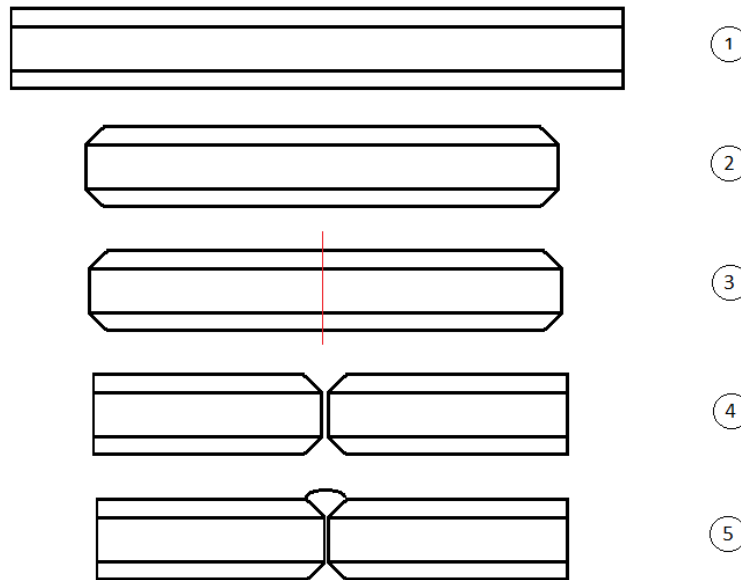
7.4.1 Full weld overlay clad pipes submitted to any installation method covered by this specification shall be submitted to qualification tests beyond the ones stated in [1]. The following items describe the supplementary qualification tests:

**7.4.2 QUALIFICATION TEST DESCRIPTION:**

7.4.2.1 Twelve (12) full weld overlay clad pipe ends shall be tested in fatigue full scale testing resonance machine in a frequency between 25 and 30Hz. The full weld overlay pipe ends used on testing shall be manufactured using **average** heat input in WPS.

7.4.2.2 The prepared weld overlay clad 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 is highly recommended in order to avoid prematurely stop of the test.




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Figure 4 – Steps for samples manufacturing for full scale fatigue testing. Step 1 – Weld overlay clad pipe “as fabricated”; Step 2 – Cut-out to turn their lengths 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;

7.4.2.3 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.

7.4.2.4 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 **DNVGL** E curve “in air” in the inner surface as per [2].

7.4.2.5 The calculation of the target number of cycles shall be submitted for PETROBRAS validation.

7.4.3 After the end of the target number of cycles, test shall be stopped and a DPI shall be executed on the inner surface of the weld overlay clad pipe. No signs of crack shall be present, unless it shall be demonstrated by dissection that the backing steel is not exposed.

#### 7.4.4 VALIDITY OF FATIGUE FULL SCALE QUALIFICATION TESTS:

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

- a) Backing steel manufacturer **and** CRA clad wire supplier;
- b) Outer diameter: Any increase of pipe outer diameter requires a new qualification;
- c) Weld overlay thickness: Any reduction in **CRA layer** thickness requires a new qualification;
- d) Total thickness: Any increase in total thickness will require a new qualification;
- e) Weld overlay Clad: Any modification in welding procedure specification, including, number of welding passes, change in machining requirements, requires a new qualification;

### 8 DELIVERY CONDITIONS

8.1.1 **[7.8.2 Section 7] Addition** - Weld overlay Clad pipes shall be supplied with square cut – non beveled ends.

8.1.2 **[7.8.3 Section 7] Addition** - All pipe ends shall be closed with non-hook able plastic end caps to avoid impacts able to damage pipe end and to avoid dust ingress into the weld overlay clad pipe. The plastic protections provided shall be able to be installed and re-installed manually in pipe end during coating application.

### 9 DOCUMENTATION AND RECORDS


9.1.1 **[7.8.4 Section 7 and 12.3.1.1 Section 12] Addition** - The documentation to be submitted for review prior to start or during start-up of manufacturing shall be submitted for PETROBRAS evaluation by SUPPLIER two months before the date schedule for MPQT.

Note 1: PETROBRAS will release comments 14 days after the submission of documentation for PETROBRAS 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 PETROBRAS and/or purchaser are implemented by SUPPLIER.

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

Note 3: Before production commences, SUPPLIER shall release the resting of the documents stated in item 12.3.1.1 section 12 of plus the Inspection Test Plan (ITP) for PETROBRAS or purchaser appreciation. The revision cycle deadline presented in Note 1 above is still applicable for production purposes.


Note 4: PETROBRAS 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.

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9.1.2 **[12.3.1.2 Section 12] 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 Section 12] 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 and in DVD format. All files shall be clearly presented in folders in a logical index to be proposed by SUPPLIER and submitted to PETROBRAS or purchaser validation.



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## APPENDIX A – ADDITIONAL REQUIREMENTS:

### A.1 GENERAL

A.1.1 This appendix presents the additional requirements for manufacturing and testing of full weld overlay clad pipes. These additional requirements are applicable if required by PETROBRAS or the Purchaser on the purchase order.

A.1.2 The following additional requirements are envisaged in this appendix:

AR R: This additional requirement is necessary when full weld overlay clad 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 take into account the strengthening effects of CRA weld overlay layer on riser/ pipeline design;

AR DYN: This additional requirement is applicable when designer intends to use full weld overlay clad pipes in riser locations where the fatigue demand exceeds DNVGL S-N E curve "in air" in the inner surface;

### A.2 - AR R – ADDITIONAL REQUIREMENT FOR REEL-LAY INSTALLATION

The additional requirement AR R defines the requirements for testing in a development and research programme of full weld overlay clad pipes for risers or pipelines installed by reel-lay method, under the following limit in addition to section 1.2.

- e) Reel-lay drum and aligner radius: Equal or higher than 7.5m; (Additional requirement)

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

Item 6.1.2 – Additional requirement:

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

Item 6.3– Additional requirement:

Pre-strained and aged samples shall be used in case of reel-lay installation for corrosion tests (including pitting test).


Item 6.4.4 – Additional requirement:

CTOD specimens for reel-lay installation method shall be pre-strained considering 4 reeling cycles referring to a minimum bending radius of 7.5m and aged at 250°C for 1 hour before testing.

Items 7.2.3.5 and 7.2.3.6 – 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 a radius of 7.5m. 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 PETROBRAS;

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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 a radius of 7.5m. 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 PETROBRAS;

### **A.3 - AR SE – ADDITIONAL REQUIREMENT FOR THE DOCUMENTATION OF THE STRENGTHENING EFFECTS OF FULL WELD OVERLAY PIPE.**

A.3.1 The additional requirement AR SE allows the consideration of the structural contribution of the **CRA layer of full weld overlay clad pipe** or pipeline and riser design, considering the limitations and limit states stated in the DNVGL Report for JIP Lined and Clad Pipeline Materials, Phase 4 – Guideline for Design and Construction of Lined and Clad Pipelines [10].

A.3.2 **[C.6.4.12 and 6.4.14 Appendix C] Modification** - All-weld tensile testing and Charpy-V-notch testing shall be performed.

A.3.3 **[B.2.4.13 Appendix B and C.6.4.14 Appendix C] Addition** - In order to obtain CVN specimens to test the weld overlay as per table C-5 of [1], the CVN notch position shall be parallel to the surface, in the areas described at note 4 of this table. Additional weld overlay deposition may be necessary in order to obtain the necessary specimen length (55 mm) and the notch at the right position.

A.3.4 **[C.6.4.15 Appendix C] Addition** - Testing temperature shall be in accordance with item 7.8.1, Table 5 of API STD 2RD [3].

A.3.5 **[C.6.4.16 Appendix C] Addition** - The average and single Charpy V-notch toughness at each position shall not be less than specified for the base material (90J as average value and 80J as minimum individual value). Charpy V-notch testing shall exhibit a minimum of 50 % shear fracture appearance at the specified temperature.

Besides the acceptance criteria stated herein regarding the minimum and average absorbed energy, the shear area of each specimen extracted from backing steel (FL+5mm) shall not be lower than 85%, at tests executed at the impact testing temperature, as per item 7.8.1, Table 5 of API STD 2RD [3].

NOTE: The additional criterion reflects the criticism related to the establishment of the energy as a sole acceptance criterion for Charpy V notch testing. In the recent years, new materials and refined manufacturing processes could manufacture steels with high impact energies on charpy V notch testing, even in temperatures near the lower shelf of the ductile - brittle transition curve. In other words, the line pipe material could present a brittle behavior even if the impact energy is high.

Besides, there are several questions about the validity of CVN in the necessity to guarantee the occurrence of ductile behavior in case of fracture. The establishment of a minimum shear area aims to take advantage of the knowledge developed during drop weight tear testing development. See the article of Coshaw et al Journal of Pipeline Engineering – June 2010 Vol9, no 2.

### **A.4 - AR DYN – ADDITIONAL REQUIREMENT FOR THE UTILIZATION ON FATIGUE SENSITIVITY LOCATIONS ON RIGID RISERS**

The additional requirement AR DYN allows that the **weld overlay clad pipes** manufactured present fatigue resistance of at least equal to **DNVGL S-N curve D** in the outside diameter and **DNVGL S-N curve C** in the inside diameter, in order to allow the utilization of full weld overlay clad 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 6.5.2 – Additional requirement**

**Acceptance criteria shall be specified according to DNVGL-RP-F108.**

Item 6.6.4.11 b) – Modified requirement:

After machining the nominal internal diameter tolerance shall not exceed  $\pm 0.25\text{mm}$ . The 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  $0.5\text{mm}$  and  $\delta m \leq 1.0\text{ mm}$ . Purchaser may consider the use of pipe sorting/pipe matching activities.

Item 7.3.2.4 – 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 **the DNVGL proposed S-N curve** “in air” in the inner diameter of full weld overlay clad pipe as per [2].



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**APPENDIX B – ADDITIONAL INFORMATION TO ALLOW FULL WELD OVERLAY CLAD PIPE SUPPLY:**

This technical specification shall be supplemented by PETROBRAS or purchaser in order to allow full weld overlay clad pipe supply. The following additional information shall be supplied:

Type and quantity data:

- Clad pipe diameter;
- Total nominal thickness;
- CRA nominal thickness;
- Backing steel nominal thickness;
- Specified Minimum Yield Strength of Backing steel and CRA layer;
- 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;
- Supplementary Requirements “U” and/or “P” of [1];

Process:

- Minimum design temperature;

Commercial:

- Delivery point;

Third Party Inspection:

- Third party inspection coverage (if applicable);