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	CLIENT: PETROBRAS				SHEET: 1 of 18					
	JOB: GENERAL				CC:					
	AREA: RIGID SUBMARINE PIPELINES				PROJECT:					
DPP		TITLE: CLAD BENDS MANUFACTURING REQUIREMENTS				PUBLIC				
						EDD/EDR				


INDEX OF REVISIONS

REV.	DESCRIPTION AND/OR REVISED SHEETS
0	ORIGINAL EMISSION – THIS SPECIFICATION REPLACES I-ET-0000.00-6500-219-P6B-002=0
A	REVISION OF THE HIGHLIGHTED ITEMS 3.3.6, 3.3.7, 3.5.3, TABLE 5-3 AND 7.1.1
B	REVISION OF THE HIGHLIGHTED ITEMS , TABLE 5-2
C	GENERAL REVISION

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DATE	19/02/18	12/07/18	30/04/20	20/10/22					
PROJECT	EISE/EDR	EISE/EDR	EISE/EDR	EDD/EDR					
EXECUTION	CWF8	CWF8	CWF8	CWF8					
CHECK	PNC1	PNC1	PNC1	HXA1					
APPROVAL	CLZ2	CLZ2	CLZ2	CLZ2					

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1. INTRODUCTION

1.1. BEND MANUFACTURING SCOPE

This Technical Specification sets forth the technical requirements for fabricating, inspecting, testing, finishing, marking and shipment of special long radius CRA clad bends.

Bends manufactured according to this specification shall comply with DNV-ST-F101 – Edition August 2021 Amended December 2021 ref [1].

This document shall be read in conjunction with section 8 of ref [1] and ISO 15590-1:2018 ref. [2]. The revised items related to ref. [1] are presented in bold letters between square brackets, while the ones related to ref. [2] are presented in bold letters between slashes. For both the type of revision is highlighted as Addition or Modification, for example **/9.4/ Addition and [8.4.5] Modification**.

The scope of supply includes the provision of all materials (Mother pipes and consumables), services and activities necessary for manufacturing, storage and delivery of CRA clad induction bends.

1.2 - DEFINITIONS AND ABBREVIATIONS

[1.6.1 Table 1-4] 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.

[1.6.2 Table 1-5] Addition - The following terms are applied in this document:

BACKING STEEL - C-Mn outer layer of clad pipe (after the line pipe manufacturing).

PETROBRAS - Including its employees, inspectors and other representatives;


Purchaser - Refers to EPCI contractors, in the occasions where they are responsible for backing steel and mother pipes supply, for fulfil all, or any of, the activities associated with Bend manufacturing in this technical specification.

Supplier - Bend manufacturer;

WELD OVERLAY CLADDING - Deposition of layers of corrosion-resistant alloy by a welding process to provide protection for metallic components to areas at risk of corrosion and wear.

[1.6.3 Table 1-6] Addition - The following Abbreviations are also applied:

CMTR	<i>Certificated Mill Test Report</i>
MDB	<i>Material Data Book</i>
OD	<i>Outside Diameter</i>
PCM	<i>Critical Metal Parameter</i>
QMS	<i>Quality Management System</i>
UNS	<i>Unified Numbering System</i>
WT	<i>Wall Thickness</i>

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2. REFERENCES

2.1 GENERAL

The governing design code for this specification shall be DNV-ST-F101 ref. [1] with additional and modified requirements to ISO 15590-1 ref. [2]. The requirements of this reference shall apply unless otherwise stated in this specification.

The relevant codes, standards and specifications are listed in section 2.1. It shall be taken to mean the latest edition including addenda, supplements or revisions applicable at the date of contract.

2.1.1. The following references shall be considered:

[1] DNV-ST-F101	Submarine Pipeline Systems Edition August 2021 Amended December 2021
[2] ISO 15590-1 (2018)	Petroleum and natural gas industries – Induction bends, fittings and flanges for pipeline transportation systems – part 1: Induction bends
[3] DNV-RP-0034	Steel forgings for subsea applications - technical requirements - Edition November 2020, Amended September 2021
[4] ISO 13628-15	Petroleum and natural gas industries — design and operation of subsea production systems — part 15: Subsea Structures and Manifolds
[5] ISO 15614-7	Specification and qualification of welding procedures for metallic materials - welding procedure test – part 7 – Weld Overlay
[6] I-ET-0000.00-0000-211-P9U-002	Seamless (SMLS) Pipes requirements
[7] I-ET-0000.00-0000-219-P9U-005	CRA weld overlay clad pipe requirements for rigid spools
[8] BS EN ISO/IEC 17024 (July 2012)	Conformity Assessment – General requirements for bodies operating certification of persons
[9] I-ET-0000.00-0000-970-PSQ-001	Procedure and Personnel Qualification and Certification


3. GENERAL REQUIREMENTS

3.1. PURPOSE AND COVERAGE

3.1.1. **1/1 Modification** - The purpose of this specification is to provide supplementary requirements for qualification and production of induction bends IB 450-PSL2 internally clad with UNS N06625 CRA.

3.1.2. **[1.5.1] Modification** - Where there is a conflict between the requirements of this specification, the Material Requirements specification and the referenced DNV, the order of precedence of the documents shall be:

- 1st – Material Requirements (specific for each Riser and Pipeline project);
- 2nd – This Technical Specification;
- 3rd – DNV-ST-F101 ref. [1];
- 4th – ISO 15590-1 ref. [2] and ISO 13628-15 ref. [4].

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3.1.3. **/9.2/ Addition** - Purchaser shall, at his expense, perform all tests mentioned in this technical specification. Supplier shall consider that unless otherwise written agreed, PETROBRAS will not accept historical data in order to waive tests or acceptance criteria. PETROBRAS representatives shall witness all qualification testing activities carried out in Supplier's laboratories and yard.

3.2. MOTHER PIPE REQUIREMENTS

3.2.1. **[8.2.3.2] Addition** – Clad bends shall be produced from CRA Clad mother pipes manufactured according to ref. [7].

3.2.2. **[8.2.3.2] Addition** – Weld overlay clad mother pipes shall be manufactured from DNV SMLS as backing steel pipes [6] or Quenched and Tempered forged pipes manufactured according to ref. [3].

3.2.3. **[8.2.3.2] Addition** – Supplier shall select mother pipe backing carbon steel WT and CRA layer WT in order to respect minimum WT on each point of the bend. After bending, CRA thickness shall not be less than 3.0mm. Wall thinning as a result of the bending process and any eventual grinding or brushing due to NDT inspection requirements shall also be considered.

3.2.4. **[8.2.3.2] Addition** – Mother pipe shall be supplied as bare pipe.


3.2.5. **[8.2.3.2] Addition** – All mother pipes for the same OD bend group shall be manufactured from the same Supplier. Multisourcing of backing steel is not recommended since this is considered an essential variable. Mother pipes for WPQT rings shall be heat treated in the same heat treatment batch of production bends.

3.3. INDUCTION BENDING PROCESS

3.3.1. **[8.2.3] Addition** – The forming (bending) temperature shall be continuously monitored and recorded with, at least, 2 (two) pyrometers located at extrados and intrados to ensure that the temperature difference between readings is not higher than 15°C in the hot bent area. An additional manual pyrometer may also be used to measure the temperature at the neutral line on each 5° during forming.

3.3.2. **[8.2.3.7] Addition** – The following items shall be considered as additional essential variables to the ones given in /table 1/:

- ✓ Mother pipe manufacturing route or supplier;
- ✓ Any change in the heat treatment conditions on clad mother pipe before induction bending;
- ✓ Any change of the CRA clad welding procedure;
- ✓ Any change of CRA chemical composition;
- ✓ Any change in bend radius;

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3.3.3. **/9.3/ Addition** - Clad pipe bending shall be carried out by induction bending process. The following additional requirements shall apply:

- ✓ The mother pipe shall be circumferentially heated at the point of bending in a continuous heating cycle without stops and starts.
- ✓ Attachment of braces or other restraints utilized to prevent warping of bends shall not be welded to the body of the bend.
- ✓ The internal surface of clad mother pipe shall not come into contact with any ferrous metals while hot.
- ✓ Prior to bending, clad mother pipes shall be visually inspected in order to be free of scale, dirt and other foreign materials, if necessary they may be externally blast cleaned in accordance with ISO 8501-1 Sa 2 1/2. The cleaned pipe surfaces shall be protected from moisture, oil and rust.

3.4. MOTHER PIPE AND POST BENDING HEAT TREATMENT


3.4.1. **/9.1/ Addition** – Before induction bending all clad mother pipes shall be subjected to a normalizing heat treatment at the following conditions:

- ✓ Heat rate not higher than 250°C/h;
- ✓ Minimum soaking temperature of 950 °C(+/- 15°C);
- ✓ Soaking time of 40 minutes (-0/+5 minutes);
- ✓ Cooling to room temperature in air.

3.4.2. **/9.4/ Modification** – All bends shall be subjected to a quenching plus tempering post bending heat treatment after completion of the bending process in order to achieve the required mechanical and corrosion properties.

3.4.3. **/9.4/ Addition and [8.4.5] Modification** – During heat treatment furnace temperature shall be continuously recorded on at least three locations. As part of the MPQT, the distribution and accuracy of the temperature measurement shall be demonstrated using additional thermocouples attached to intrados and transition zone extrados. All selected locations shall be clearly defined in the MPS in order to check the hottest and coldest parts of the furnace, as indicated by a current furnace survey. During production at least two contact thermocouples shall be used in bend tangents.

3.4.4. **[8.2.3.8] Addition** – Heat treatment shall be fully traceable.

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3.4.5. **[8.4.5] Addition** – The following requirements shall apply for post bending heat treatment:

- ✓ For tempering operation, minimum allowable temperature shall be 540°C;
- ✓ For each heat-treatment batch, a sketch indicating thermocouples positioning, piece numbers and their relative position inside the furnace shall be issued. This document shall be part of the ITP issued before MPQT;
- ✓ Stacking of pieces is not permitted. A minimum distance of 50mm between each piece shall be ensured;
- ✓ Temperature to be controlled at $\pm 15^{\circ}\text{C}$;
- ✓ Time required for moving the component from the furnace to the quench tank shall not be higher than 60s.

3.5. INFORMATION TO BE SUPPLIED BY PETROBRAS

3.5.1. In order to comply with ISO 15590-1 requirements, PETROBRAS shall provide the following information at the specific project documentation.

- ✓ Minimum design temperature;
- ✓ Maximum design temperature;
- ✓ Minimum wall thickness after bending;
- ✓ Definition of whether or not CRA layer is being considered as having structural performance in pipeline design;
- ✓ Charpy impact temperature;
- ✓ Minimum required weld overlay thickness after induction bending;
- ✓ Hold points for witness and for PETROBRAS approval will be available in PETROBRAS comments on Supplier's ITP.


4. MANUFACTURING PROCEDURES AND QUALIFICATION

4.1. GENERAL REQUIREMENTS

4.1.1. **/9.2 and 10.1/ Modification** – MPS shall be validated by PETROBRAS prior to commencement of production bending. The following requirements shall apply:

- ✓ Purchaser shall submit a specific MPS and ITP according to item 8.2.3 of DNV-ST-F101 and annex A of ISO 15590-1 for PETROBRAS validation;
- ✓ Purchaser shall submit all documentation to PETROBRAS at least 40 days prior to commencement of induction bend qualification trial;
- ✓ Supplier's proposed bend fabrication procedure shall include all operations, in the correct sequence, together with the operating parameters for each pipe bend group.

4.1.2. **[8.2.3.7] Addition** – A change in any of the variables of Purchaser's bend fabrication procedure shall require a full re-qualification of the procedure.

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<p>4.1.3. [8.5.1.1] Modification – During production mechanical testing after induction bending shall be performed on material taken from a prolongation from each test unit, i.e. components of the same size and material, from each heat and heat treatment batch. Number, orientation and location of test specimens to be performed at the prolongation of a tangent section shall be as given in tables 5-1 and 5-2 of this specification.</p> <p>4.1.4. [8.5.1.1] Addition – The prolongation of the bend shall be destructively tested in compliance with table 5-2 of this specification. The prolongation test piece may be fixed on a production piece by welding, if applicable. The test piece or pipe extension shall be clad with the same product parameters.</p> <p>4.1.5. [8.2.3] Addition – Test laboratories shall have a QMS conforming to ISO 17025 or equivalent. If the laboratory is not certified according to ISO/IEC 17025, the QMS shall be approved by the purchaser. All measurement devices shall be calibrated in a laboratory registered in Brazilian calibration network (Rede Brasileira de Calibração (RBC) – INMETRO) or by an equivalent international recognized certifying authority. Additionally, all micrometers shall be checked for calibration at the beginning of each shift.</p> <p>4.2. MANUFACTURING PROCEDURE QUALIFICATION TESTING</p> <p>4.2.1. /9.2/ Addition – One MPQT bend shall be selected from the pipe bend group(s) for test bending. MPQT shall be made on finished test bend of approximately 90° bend angle. The completed test bends shall meet the mechanical properties and dimensional tolerances specified herein. Once the bend fabrication procedure has been qualified and accepted by PETROBRAS, it shall be adhered to in all respects in the fabrication of all production bends. During production, a validation of the requirements shall be performed by testing of prolongation test pieces obtained from each test unit.</p> <p>4.3. RETESTING</p> <p>4.3.1. If a test sample of either mechanical or corrosion test fails to meet the specified requirements, at least two further samples shall be extracted, prepared and tested. All samples shall meet the specified requirements.</p> <p>4.3.2. In case of failure of any retest, the causes shall be investigated and analyzed; corrective actions shall be proposed to PETROBRAS representative. After validation of corrective actions, a new qualification test bend shall be executed.</p>			

5. MECHANICAL PROPERTIES AND ASSOCIATED TEST REQUIREMENTS

5.1. QUALIFICATION TESTING

- 5.1.1. **/10.2.1/ Modification** – One MPQT bend shall be selected from the pipe bend group(s) for test bending.
- 5.1.2. **/10.2.1/ Addition** – At least one finished test bend per bending manufacturing procedure shall be tested for qualification. Table 5-1 defines which tests are applicable for MPQT and production.
- 5.1.3. **/Table 2/ Modification** – Testing and inspection for MPQT and production shall be performed according to requirements defined in table 5.1 of this technical specification. Physical testing performed in production bends are related to prolongation on tangent section. However, NDT and surface hardness test shall be performed not only on prolongation but also on bend full length.
- 5.1.4. **/Table 2/ Modification** – HIC tests and SSC tests shall not be carried out on qualification test bend, as per requirements of ISO 15590-1 annex B. However, ASTM G48 test shall also be performed and the iron content at surface shall not exceed 10% at clad weld.
- 5.1.5. **/Table 3/ Modification** - The number, type and location of tests shall comply with table 5.2. Sampling on backing steel and on cladding /overlay shall be removed from the test specimens as per figure 1 of ISO 15590-1.

Table 5-1 – MPQT and production testing of clad bends

Test		MPQT	Production
Chemical Analysis	Chemical Composition	X	N.A
Physical Tests	Tensile	X	X
	Impact	X	X
	Through-thickness Hardness	X	X
	Surface Hardness	X	X
	Metallography Examination	X	X
	Iron content at surface of the clad weld	X	N.A
	ASTM G48 – Pitting Corrosion	X	N.A.
	CRA thickness check (macro)	X	N.A.
NDT	Visual Inspection	X	X
	Bend Ends (UT and MT)	X	X
	Bend Body (UT, MT and/or PT)	X	X
	Thickness verification	X	X
	Residual magnetism	X	X

Table 5-2 – Location of test pieces and type of test for destructive testing of clad bends

Location	Test
Tangent side A	Tensile (1 specimen) CVN Impact (3 specimens) Through-thickness hardness (1 specimen) Metallography Examination (BM, ZTA and CRA)
Transition zone side A (Initial)	Tensile (1 specimen) CVN Impact (3 specimens) Through-thickness hardness (1 specimen) Surface hardness (3 indentations per quadrant) Metallography Examination (BM, ZTA and CRA) CRA thickness check (macro) ASTM G48 – Pitting Corrosion (1 specimen)
Bend extrados	Tensile (1 specimen) CVN Impact (3 specimens) CVN Impact at mid thickness (3 specimens) Through-thickness hardness (1 specimen) Surface hardness (3 indentations) Metallography Examination (BM, ZTA and CRA) CRA thickness check (macro) ASTM G48 – Pitting Corrosion (1 specimen)
Bend intrados	Tensile (1 specimen) CVN Impact (3 specimens) CVN Impact at mid thickness (3 specimens) Through-thickness hardness (1 specimen) Metallography Examination (BM, ZTA and CRA)
Transition zone side B (Final)	Tensile (1 specimen) CVN Impact (3 specimens) Through-thickness hardness (1 specimen) Surface hardness (3 indentations per quadrant) Metallography Examination (BM, ZTA and CRA) CRA thickness check (macro)
Tangent side B	Tensile (1 specimen) CVN Impact (3 specimens) Through-thickness hardness (1 specimen) Metallography Examination (BM, ZTA and CRA)

Note: All samples shall be obtained from backing steel and from CRA clad layer. When the CRA clad layer is being considered as a part of the design, such mechanical testing of the clad layer are also required.

Table 5-3 – Maximum values for through thickness hardness testing of clad bends

Clad Bends	Methodology	Acceptance criteria
CRA Weld Overlay pipe	Appendix B item B1010	275HV10 on HAZ and base material 345 HV10 on Weld overlay

- 5.1.6. **/10.4.2.2/ Modification** - Tensile testing at ambient temperature shall be carried out in accordance with ASTM A370. Tensile properties shall be in accordance with table H.2 Annex H ISO 3183.
- 5.1.7. **/10.4.3.1/ Modification** - CVN test pieces shall be prepared and tested in accordance with ASTM A370. Testing of CVN impact properties shall, preferably, be performed on transverse test specimens 10 x 10mm. Sub-size samples may be allowed after PETROBRAS written validation.
- 5.1.8. **/10.4.3.3/ and [8.2.3.10] Modification** – Test absorbed energy levels shall be minimum 73J for average value for 3 specimens and 55J for a single value, based on full size specimens. The CVN test temperature shall be informed in the Design basis.
- 5.1.9. **[8.2.3.10] Addition** – Transverse direction CVN test specimens shall be obtained from backing steel outside diameter at no more than 2,0mm from the surface.
- 5.1.10. **[8.2.3.10] Addition** - For MPQT of bends from mother pipes with $t > 25$ mm, one additional set of transverse direction CVN specimens shall be sampled 2 mm above the weld overlay fusion line.
- 5.1.11. **/10.4.4.1/ Modification** - Through-thickness hardness testing shall be performed with the Vickers method in accordance with ASTM E92. Figure 5.1 illustrates Indentation locations for through-thickness hardness testing. Letter “A” – corresponds to HAZ, letter “B” indicates the equally spaced hardness evaluation lines, while letter “C” corresponds to the weld overlay layer.

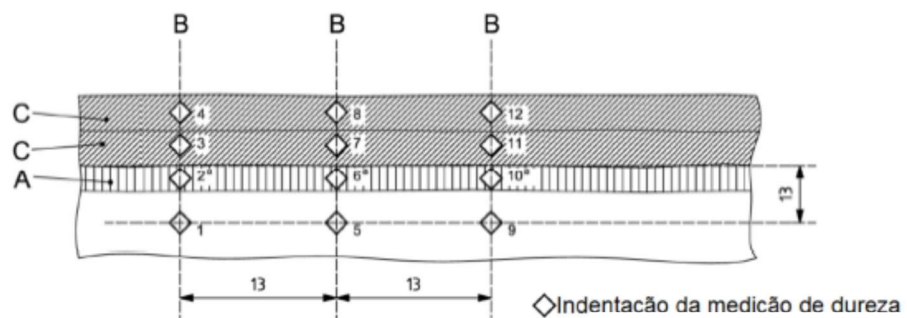




Figure 5-1 –Through thickness hardness testing locations

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<p>5.1.12. /10.4.4.2 and B.4.5.2/ Modification - The hardness levels shall not be greater than values stated in table 5-3.</p> <p>5.1.13. /10.4.5.1/ Modification – Three surface hardness readings using portable equipment shall be performed in each quadrant for each position stated in table 5-2.</p> <p>5.1.14. /10.4.5.2/ Modification - Hardness average variation shall not be greater than 40 HV10 when compared to hardness average values found on the qualification bend for the same location and WPQT ring.</p> <p>5.1.15. /10.4.5.2/ Modification – Surface hardness on bend backing steel may also be reported as HRC or Brinell hardness (HBS/HBW), respecting the limit of 22 HRC.</p> <p>5.1.16. [8.2.3.12] Modification – For metallographic evaluation of clad induction bends, the acceptance criteria shall be in accordance with Section 7.4.7 and 7.4.8 of DNV-ST-F101.</p> <p>5.1.17. /10.4.6.1/ Addition – The Metallography examination at 100x and 400x shall be made at a distance of 2,0 mm from the external and internal surfaces and at a mid-wall position of bends. The minimum average grain size of the backing steel shall be determined and recorded. Acceptance criteria: 7 or higher according to ASTM E112. Regarding CRA layer, the weld metal and HAZ of the CRA layer shall be essentially free from grain boundary and intermetallic phases.</p> <p>5.1.18. [7.4.8.9 and Table 7-15] Modification - Corrosion testing in acc. with ASTM G48 Practice A (50°C, 24h, max. 4g/m²) shall be performed during MPQT. After testing, visible pits shall not be found at 20x magnification. Testing location: Bend Extrados overlay; initial transition zone, final transition zone one Tangent End overlay.</p> <p>5.1.19. [B.2.5.14] Modification - Side bend test shall be performed according to ASME IX, QW-161. Specimen location shall be in accordance with ASME IX, QW-462.5 (c). Acceptance criteria shall be according to ASME IX QW-163.</p> <p>5.1.20. [D.1.5.1, D.1.5.2 and D.8.1.4] Modification – Qualification and certification of NDT inspectors shall be in accordance with [9] I-ET-0000.00-0000-970-PSQ-001.</p> <p>5.1.21. /10.5.9/ Modification – NDT personnel certification according to ASNT SNT-TC-1A is not acceptable.</p>			

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5.2. PRODUCTION TESTING

- 5.2.1. **/9.3/ Modification** - Induction bending shall be carried out in accordance with qualified MPS and ITP.
- 5.2.2. **/10.2.2/ Modification** - The extent of testing and inspection that shall be performed during production is as specified in Table 5-1 of this specification for the CRA clad bends.
- 5.2.3. **/10.2.2/ Addition** - MDB shall be submitted to PETROBRAS validation including all reports and documents stated in clause 14 of this specification.

6. DIMENSIONAL REQUIREMENTS

6.1. INTERNAL DIAMETER


- 6.1.1. **/10.6/ and [8.2.3.14] Addition** - The diameter at both extremities may be verified by caliper rule.
- 6.1.2. **/10.7/ and [8.2.3.15] Modification** - Conformity to specified minimum internal diameter shall be shown by passing of gauge consisting of two gauge plates with a diameter of 95% of the largest nominal inner diameter, or 97% of the minimum inner diameter of the largest nominal inner diameter. The gauge plates shall be rigidly fixed at a distance of $1.5 \times ID$. Each production bend shall be submitted to a drift test using a pig equipped with the two gauge plates described above.

6.2. WALL THICKNESS

- 6.2.1. **/10.6/ and [8.2.3.14] Addition** - Thinning tolerances for pipe bends as a percent of the original nominal wall thickness and shall withstand the minimum thickness defined for the Diverless Rigid Spool design and subsea equipment Specification.
- 6.2.2. **/10.6/ Modification** - Wall thickness measurements shall be performed by ultrasonic methods, in accordance with ASTM E797, at each 300 mm length at pipe quadrants, beginning at 50 mm away from pipe end. The minimum Carbon Steel wall thickness and CRA layer thickness after bending shall be informed by PETROBRAS.
- 6.2.3. **/10.6/ Addition** – Calibration blocks for CRA layer verification may be manufactured from bend sections during MPQT. CRA Weld overlay shall be deposited with the same WPS qualified for the same order of supply and shall be previously tested and approved by other NDT procedures.

6.3. OUT-OF-ROUNDNESS

- 6.3.1. **/10.6/ and [8.2.3.14] Modification** - Out-of-roundness in bend body measured at intervals of one pipe outside diameter along the bend length shall be within $\pm 2,5 \%$ of the nominal outside diameter. Inside diameter Out-of-roundness over a length of 100mm (4") from each end, measured internally shall not exceed $\pm 1,5 \%$ of the nominal internal diameter.

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6.4. OUT OF PLANE

6.4.1. /10.6/ and /Table 4/ Addition - The bend out of plane tolerance shall be 10 mm maximum for 90 degrees and 5 mm maximum for bends less than 90 degrees.

6.5. TANGENT LENGTH

6.5.1. /10.6/ Addition - The minimum tangent length on both ends shall be a minimum of 300 mm, for the bends with angles larger than 20 degrees.

6.6. BEND LENGTH

6.6.1. /10.6/ Addition - The overall bend length including tangents shall be ± 50 mm of the intended length.

7. HYDROSTATIC TESTING

7.1.1. /10.8/ and [8.7] Addition - Hydrostatic testing shall be carried out prior to final inspection on each production bend. If 100% of mother pipes have been hydrostatically tested at the pipe mill, Hydrostatic testing may be performed on one bend of each group of production bends. Group of bends is a classification according to internal diameter (ID), Carbon steel thickness, bend radius and WOL or Clad mother pipe type.


7.1.2. /10.8/ and [8.7] Addition - Induction bends that fail hydrostatic testing shall be rejected and the rest of the bends in that group shall be hydrotested. A full investigation shall be undertaken to determine the failure mechanism. Purchaser shall propose a new bending procedure for PETROBRAS validation, if required.

8. NON-DESTRUCTIVE TESTING

8.1. GENERAL

8.1.1. /10.5.1/ Modification - After final heat treatment and prior to visual or other non-destructive inspection, the entire outside surface of all bends shall be cleaned to a cleanliness grade of ISO 8501-1 Sa 2 1/2.

8.1.2. /10.5.1/ Addition - Each production bend, shall be inspected by non-destructive testing (NDT) in accordance with the NDT testing requirements and acceptance criteria contained in Appendix D of DNV-ST-F101. Purchaser shall submit NDT procedures to PETROBRAS for validation.

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8.2. VISUAL INSPECTION


- 8.2.1. **/10.5.2/ Modification** - After the bends have been fabricated the entire length of each bend shall be 100% internally and externally visually inspected for surface defects with an illuminance of at least 300 lx (28 fc), as per ISO 3183. Any bends having surface anomalies as cracks, wrinkles, arc burns or other evidence of mechanical damage shall be rejected. Minor surface imperfections on the outside surface may be removed by grinding, since the minimum design thickness is maintained. Grinded surfaces for discontinuities removal shall be ultrasonically inspected for thickness measurement. In this case, magnetic particle inspection shall also be performed.
- 8.2.2. **/10.5.2/ Addition** – Internal surface visual inspection shall be performed starting from each pipe end, using high definition (at least 1080 lines) color video camera. The dispositive may be set up with assisted light source. All recordings shall be stored on digital media and will be attached on the MDB.

8.3. INSPECTION OF BEND ENDS

- 8.3.1. **/10.5.4/ Modification** - Ultrasonic inspection for laminar imperfections in accordance with ISO 10893-8 (automated/semi-automated system) shall be performed around the entire outside surface circumference of the bend ends over a minimum distance of 100 mm from the bend end. Manual UT may be performed according to ISO 10893-9.
- 8.3.2. **/10.5.4/ and [D.3.3.4] Addition** - 100% of clad areas shall be ultrasonically tested for bond integrity. The Reference Sensitivity Level (RSL) shall be established by calibration on a 3,0mm flat bottom hole (FBH). In locations through 50 mm from Clad bend end, the RSL shall be established by calibration on a 1,6 mm flat bottom hole.
- 8.3.3. **[8.2.3.13] Addition** – Acceptance level U1 of ISO 10893-8 shall be considered for UT of laminar imperfections.
- 8.3.4. **/10.5.4/ Modification** - For all bends, the bend ends shall be inspected by MT on the outside surface and beveled ends in accordance with ISO 10893-5 and PT on both inside and outside in accordance with ISO 10893-4. Acceptance criteria shall be no cracks.

8.4. INSPECTION OF BEND BODY

- 8.4.1. **/10.5.5/ Modification** - On the inside area PT shall be performed in accordance with ISO 10893-4. Acceptance level shall be according to Item D.3.6.9 of ref. [1].
- 8.4.2. **/10.5.5/ Addition** - MT 100% on the outside surface shall be performed in accordance with ISO 10893-5. Acceptance level shall be according to table D-8 of ref. [1].
- 8.4.3. **[8.2.3.13] Addition** – Acceptance level U1 of ISO 10893-8 shall be considered for UT of laminar imperfections.

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8.4.4. **/10.5.6/ Modification** - 100% of bends shall be inspected for longitudinal and transverse surface imperfections at the bend body over an arc of 180°, 90° each side of the extrados by UT in accordance with ISO 10893-10 (automated/semi-automated system) or in accordance with annex B (manual methods). Acceptance level shall be U2/C.

8.4.5. **/10.5.6/ and [D.3.3.4] Addition** - 100% of clad areas shall be ultrasonically tested for bond integrity. Acceptance criteria shall be as per item D.3.6.10 of ref.[1].

8.5. RESIDUAL MAGNETISM


8.5.1. **/10.5.7/ Modification** - Bends with residual magnetism greater than 20 gauss (2 mT) shall be demagnetized. Residual magnetism shall be measured at each pipe bend end.

8.6. SURFACE DEFECTS

8.6.1. **/10.5.2/ Addition** - The entire external and internal surfaces of the bends shall be visually inspected. The surface shall be free from defects, which may be injurious for the intended services. Bends shall be free of corrugations and indentations on the tangents caused by grips of the bending machine.

8.6.2. **/10.5.8/ Addition** - No repair by welding shall be permitted on any part of the bend. Local buckles (kinks) in the bend are not permitted.

8.6.3. **/10.5.8/ Addition** - Local deviations from the original contour of the pipe shall not exceed 5% of the specified nominal wall thickness, nor shall they extend in any direction greater than 25% of the pipe outside diameter. If item is not followed, pipe bend shall be rejected. Depth of defects less than 5% of the specified nominal wall thickness (minor defects) may be removed by grinding provided the remaining wall thickness is within the specified limits and there is a smooth transition between the ground area and original contour. All repair areas shall be submitted to MT.

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9. INSPECTION ON SUPPLIER'S YARD

9.1. ACCESS

Supplier shall provide PETROBRAS' and Purchaser's representatives free access to all areas of supplier's works when work is being performed concerning this Specification.

Purchaser shall notify PETROBRAS of time and location of qualification testing, bend fabrication, heat treatment, and final inspection at least 40 days before the event. All documentation related to MPQT shall be approved by PETROBRAS before starting activities.

9.2. INSPECTION DOCUMENTS

9.2.1. /11/ **Addition** - The following inspection documents, as applicable, shall be presented to PETROBRAS for review at the time of inspection:

- ✓ Bending procedure and temperature control methods;
- ✓ Heat treatment procedures, charts and certificates;
- ✓ Ultrasonic testing procedures for qualification and production;
- ✓ Dimensional check forms for qualification and production bends;
- ✓ Qualification test forms (Mechanical and corrosion);

9.3. INSPECTION LABEL

Inspection Label shall be put on each bend.

After coating application, traceability shall be kept.

10. FINISHING AND REPAIRS

10.1. COATING


Bends shall be externally coated according to requirements informed by PETROBRAS on the coating assessment issued for a specific project.

10.2. WELDING REPAIRS

Weld repairs to parent pipe metal are not permitted. Weld-on bending aids, but not limited to, braces, brackets and cleats shall not be permitted.

10.3. REJECTED CLAD BENDS

Clad bends that have been rejected by Purchaser or PETROBRAS shall be marked "REJECTED" with the defects noted, and shall be set aside for later disposal.

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11. MARKING

11.1. GENERAL REQUIREMENTS

Supplier shall maintain identification throughout the pipe bending process. If the pipe identification is removed during the heating and bending operations, SUPPLIER shall restore it.

11.2. MARKING OF CLAD BENDS

Marking of clad bends shall be performed using white paint stenciling on a clean surface free of loose mill scale, rust, oil, grease and dirt. The stenciled surface shall be spray covered with a clear durable lacquer. Only paint marking shall be done.

Each clad bend shall be clearly marked by paint stenciling with 20mm letters on the outside surface of the bend at both ends. To ensure traceability during bend manufacturing, marking may be performed on one side of the pipes with a low stress industrial marker with bend supplier internal codes. No steel stamping will be permitted. The paint color shall contrast with the finish bend surface.

The following information shall be applied in English language and metric system:

- ✓ PETROBRAS's Name;
- ✓ Purchase Order number and supplier's name;
- ✓ Outside diameter and minimum Wall thickness;
- ✓ Material grade and weight;
- ✓ Bend radius and bend angle;
- ✓ Unique sequence number,

Markings shall not overlap and shall start 75mm from the end of each bend.

12. HANDLING, PACKAGING AND STORAGE


Purchaser shall submit procedures for handling, stacking during storage and stacking and securing clad bends for shipment for validation by the PETROBRAS.

No welding of temporary attachments for handling, stocking, transporting or securing shall be permitted.

All handling, loading and unloading shall be done in such a manner as to minimize mechanical damage and corrosion. Adequate padding shall be provided when loading bends for transport.

Loading onto or into rail cars, lighters, ship or other transportation means shall be done in accordance with ISO 3183 recommendations.

No on-deck overseas shipment is allowed without prior written validation by PETROBRAS.

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13. QUALITY ASSURANCE / QUALITY CONTROL

Purchaser's Quality Plan shall include QA, QC, testing and inspection systems necessary to ensure that all requirements of this Specification are satisfied. PURCHASER shall ensure that all sub-contractors maintain equivalent QA, QC and inspection systems. Such quality assurance and quality control programs shall follow the requirements of ISO 9001.

14. DOCUMENTATION

A CMTR for each lot of bend(s) shall be submitted to PETROBRAS within two weeks of shipment. The CMTR should be on SUPPLIER's letterhead and shall include the following:

1. PETROBRAS inspection release certificate;
2. Certified test certificates;
3. Mother pipe certificates, including:
 - ✓ MPS, ITP and CRA Clad overlay welding procedure;
 - ✓ Mechanical properties and test reports (original pipe);
 - ✓ Dimensional checks and visual examination;
 - ✓ UT reports of pipe body and pipe ends;
4. Bend control sheets, containing the following information:
 - ✓ Purchase order number;
 - ✓ Mechanical properties and test reports (qualification bend tests);
 - ✓ Chemical analysis (mother pipes and UNS N06625 CRA);
 - ✓ Hardness test reports and Heat treatment records;
 - ✓ Dimensional checks and visual examination;
 - ✓ UT, MP and LP reports of bend body and pipe ends;
 - ✓ Gauge pig passage report.

A complete MDB shall be submitted for PETROBRAS validation with all CMTR for all lots of bends supplied.