PETROBRAS	**TECHNICAL SPECIFICATION**	**Nº:**	**I-ET-0000.00-0000-210-P9U-004**
	CLIENT: PETROBRAS		**SHEET:** 1 of 47
	JOB: GENERAL		**CC:**
	AREA: GENERAL		**PROJECT:** --
--	**TITLE:** **WELDING AND NDT OF SUBMARINE RIGID PIPELINE, RISERS, AND PIPELINE COMPONENTS**		EDD/EDR --

INDEX OF REVISIONS

REV.	DESCRIPTION AND/OR REVISED SHEETS
0	ORIGINAL ADAPTED FROM I-ET-0000.00-0000-200-PSQ-001 REV. 0

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1 INTRODUCTION

1.1 SCOPE

This Technical Specification sets forth the technical requirements for welding and non-destructive testing of submarine pipelines, risers and pipeline components during construction and installation of submarine pipeline systems. This specification is not applicable to submarine equipment, except rigid spools or jumpers. This Technical Specification is applicable to all pressure containing parts and/or submitted to differential pressure (for instance half shells of carrier pipes) of the pipeline system and structural items welded directly to pressure containing parts.

This specification is applicable to C-Mn steels (metal group referred within item 5.1 of N-133), low alloy steels (metal group referred within items 5.2 and 5.3 of N-133) and to alloy UNS N06625 (metal group referred within items 5.10) clad, lined, or overlay materials. The code break between girth welds specified as per this Technical Specification and component connections is according to Figure 5-3 of Section 5 of DNV-ST-F101. For welding components within submarine equipment in pressurized parts, such as PLET, PLEM, etc., CONTRACTOR shall refer to I-ET-0000.00-0000-200-PEK-001.

For C-Mn pipelines and riser sections where the fatigue demand exceeds, as per design analyses: F1 S-N curve of DNV-RP-C203 for internal surface, de-rated by the corrosion fatigue penalization applicable to the environment defined by design (if applicable to the specific project); the seawater plus cathodic protection D S-N curve of DNV-RP-C203 for external surface; additional COMPANY requirements may be necessary.

For all clad and lined pipelines sections and for C-Mn pipelines and riser sections specified by project documents, additional COMPANY requirements and full-scale fatigue tests are necessary to validate the required girth weld and CRA layer fatigue endurance, regardless DNV-RP-C203 curve specified. In such cases, APPENDIX A is applicable.

The requirements of DNV-ST-F101 shall be complied with additions (AR), deletions (DR), and modifications (MR) presented herein.

1.2 CONFLICT AND HIERARCHY OF DOCUMENTS

1.2.1 CONTRACTOR shall fully comply with this specification regarding the requirements for welding and non-destructive testing of pipelines, risers and pipeline or riser components during construction and installation of subsea systems.

1.2.2 All works shall be conducted in accordance with DNV-ST-F101, and the requirements stated herein. Should any areas of deviation or conflict between requirements of DNV-ST-F101, this specification, another specification and associated requisition forms or any of the applicable codes and regulations, then this specification shall take precedence.

1.2.3 Should CONTRACTOR's procedures deviate from this specification, written technical query shall be issued and work shall not proceed without COMPANY formal approval of the deviation.

1.2.4 CONTRACTOR shall submit all the welding and NDT documents regarding pipeline, riser, pipeline components or riser components, respecting the contractual time limit for approval. No welding and NDT shall be executed before the formal written approval by COMPANY of all pertinent documents, including and not limited to all NDT Procedure documents, WPS document, PQR document, ECA Report (if applicable), and AUT Acceptance Criteria document.

1.2.5 For the use of this technical specification, all linepipes and pipeline or riser components to be welded in the pipeline or riser construction shall fully comply with the requirements of technical specifications listed in Table 1-2.

1.3 REFERENCES

The revision/edition indicated for following codes, standards, and regulations shall be used with this specification. The use of more recent revision/addenda than mentioned herein of any such document shall be approved by COMPANY; in this case, a written clarification shall be sought before proceeding with the work. The latest issue of the following PETROBRAS specifications shall be used with this specification.

Table 1-1 – Petrobras Standards.

Document Code	Title
N-0133 (N)	Welding
N-1597 (G)	Non-Destructive Testing – Visual Inspection
N-2301 (E)	Elaboration of Technical Documents for Welding
N-2941 (0)	Personal Competencies for Inspection Activities

Table 1-2 – Petrobras Contractual Documents.

Document Code	Title
DCGQ	Diretriz Contratual para Gestão da Qualidade
I-ET-0000.00-0000-200-P9U-005	Alternative Flaw Acceptance Criteria of Submarine Rigid Pipeline and Riser Welds
I-ET-0000.00-0000-211-P9U-001	SAWL Pipes Requirements
I-ET-0000.00-0000-211-P9U-002	Seamless (SMLS) Pipes Requirements
I-ET-0000.00-0000-219-P9U-001	Mechanically Lined Pipe (MLP) Requirements
I-ET-0000.00-0000-219-P9U-002	Clad Pipe Requirements
I-ET-0000.00-0000-200-PEK-001	Welding and NDT Requirements for Subsea Equipment Pressure- Containing Parts

Table 1-3 - American Society of Mechanical Engineers (ASME) Standards.

Document Code	Title
ASME B-31.4 (2019)	Pipeline Transportation Systems for Liquids and Slurries
ASME B-31.8 (2018)	Gas Transmission and Distribution Piping Systems
ASME BPVC.II.C (2019)	Part C - Specification for Welding Rods, Electrodes, and Filler Metal

ASME BPVC.V (2019)	Boiler and Pressure Vessel Code / Section V - Nondestructive Examination
ASME BPVC.IX (2018)	Boiler and Pressure Vessel Code / Section IX – Welding Brazing and Fusing Qualifications

Table 1-4 - American Petroleum Institute (API) Standards.

Document Code	Title
API STD 1104 (2013)	Welding of Pipelines and Related Facilities

Table 1-5 - American Society for Testing and Materials (ASTM) Standards.

Document Code	Title
ASTM E2862 (2018)	Standard Practice for PoD Analysis for Hit/Miss Data
ASTM E407 (2007)	Standard Practice for Microetching Metals and Alloys
ASTM G1 (2017)	Standard Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens

Table 1-6 - American Welding Society (AWS) Standards.

Document Code	Title
AWS A 3.0 (2010)	Standard Welding Terms and Definitions

Table 1-7 - Associação Brasileira de Normas Técnicas (ABNT) Standards.

Document Code	Title
NBR 14842 (2003)	Critérios para a qualificação e certificação de inspetores de soldagem

Table 1-8 - British Standard Institute (BSI) Standards.

Document Code	Title
BS 7910 (2019)	Guide on Methods for Assessing the Acceptability of Flaws in Metallic Structures

Table 1-9 - Det Norske Veritas (DNV) Standards.

Document Code	Title
DNV-ST-F101 (2021)	Submarine pipeline systems
DNV-RP-F118 (2021)	Pipe girth weld automated ultrasonic testing system qualification and project specific procedure validation
DNV-RP-C203 (2021)	Fatigue design of offshore steel structures
DNV-CG-0051 (2022)	Non-destructive testing
DNV-RP-B204 (2021)	Welding of Subsea production system equipment
DNV JIP 2022-4049 Rev. 0	Performance Assessment Based AUT Validation

Table 1-10 - European Committee of Standardization (CEN) Standards.

Document Code	Title
EN 10204 (2004)	Metallic Products – Types of Inspection documents

Table 1-11 - International Organization of Standardization (ISO) Standards.

Document Code	Title
NACE MR0175/ISO-15156 (2015)	Petroleum and natural gas industries – Material for use in H2S containing environments in oil and gas production –Parts 1 and 2
ISO 7539-2 (1995)	Corrosion of metals and alloys – Stress Corrosion Testing - Part 2: Preparation and use of bent-beam specimens
ISO 3690 (2018)	Welding and allied processes - Determination of hydrogen content in arc weld metal
ISO 15653 (2018)	Metallic materials — Method of test for the determination of quasistatic fracture toughness of welds – Second Edition
ISO 17637 (2016)	Non-destructive testing of welds - Visual testing of fusion-welded joints - Second Edition

Table 1-12 - National Association of Corrosion Engineers (NACE) Standards.

Document Code	Title
NACE TM 0177 (2016)	Laboratory Testing of Metals for Resistance to Sulfide Stress Cracking and Stress Corrosion Cracking in H_2S Environments

Table 1-13 – NORSOK Standards.

Document Code	Title
M-601 (2016)	Welding and inspection of piping

1.4 APPLICABLE PETROBRAS WELDING STANDARDS

1.4.1 All welding documents shall be prepared and shall have the content required in PETROBRAS standard N-2301. Specifically, for pipeline and riser welds, the WEII may be waived if all applicable NDT extension and types are included within the respective WPS. See at item 6.6.2 the applicable welding documents that shall comply with N-2301 requirements.

1.4.2 All works shall be carried out in accordance with requirements presented herein this technical specification and PETROBRAS standard N-133 applicable requirements mentioned at Table 1-14. The exceptions mentioned in this item are covered anywhere else in this specification or in DNV-ST-F101, otherwise are not applicable.

Table 1-14- Required N-133 items and exceptions.

Required Items	Related Sub-Items exceptions
4.1	-
4.2	4.2.3, 4.2.4, 4.2.5
4.3	4.3.2, 4.3.6, 4.3.11, 4.3.12
4.4	4.4.1.8, 4.4.1.9, 4.4.2, 4.4.4
4.5	4.5.4, 4.5.11
4.6	4.6.9
4.7	4.7.1, 4.7.3
4.8	-
4.9	4.9.1, 4.9.6
4.10 to 4.16	-
5.1	5.1.3.3, 5.1.3.4, 5.1.4 (and respective sub-items), 5.1.5 (and respective sub-items), 5.1.8.3, 5.1.9, 5.1.10
5.2	5.2.4, 5.2.6, 5.2.9, 5.2.10
5.3	5.3.4.4, 5.3.4.5, 5.3.5.1.b, table 5, 5.3.5.2, table 6, 5.3.6, 5.3.9 to 5.3.12
5.10	5.10.4 (sub-items 5.10.4.2, 5.10.4.3.c, 5.10.4.3.d, 5.10.4.3.e and 5.10.4.5 are applicable), 5.10.4.1, 5.10.4.3.a, 5.10.4.3.b, 5.10.4.4, 5.10.5, 5.10.6, 5.10.9, 5.10.10.1
5.12	5.12.4 to 5.12.7, 5.12.10 e 5.12.11
Annex B	B.2.3

2 CHANGES IN SECTION 1 OF DNV-ST-F101

2.1 VERBAL FORMS

2.1.1 *[Table 1-7]* (MR)

MAY: Verbal form used to indicate a course of action permissible within the limits of this specification, but that requires the formal COMPANY agreement.

SHOULD: Verbal form used to indicate that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others, or that a certain course of action is preferred but not necessarily required. Other possibilities may be applied only under technical query form (TQF) approved by Company. Company reserves the right to reject any proposal.

2.2 TERMS

2.2.1 *[Table 1-8]*:

CONTRACTOR:	The COMPANY responsible for the Engineering, Procurement, Construction, and Installation of the respective contract. (MR)
COMPANY:	PETROBRAS. (AR)
PIPELINE:	see "SUBMARINE PIPELINE" (AR)
SPECIFICATION:	Any or all the sections, paragraphs, appendices, tables, sketches, figures or attachments of this or other referenced specification. (AR)

2.3 ABBREVIATIONS

2.3.1 *[Table 1-9]* (AR)

ABNT:	Associação Brasileira de Normas Técnicas
AYS:	Actual Yield Stress
BTR:	In Process Root Repair or Burn Through Repair
BTRR:	In Process Root Re-repair or Burn Through Re-repair
CEPcm:	Carbon Equivalent, based upon the chemical portion of the Ito-Bessyo carbon equivalent equation (see note 4 of table 7-3 and note 3 of table 7-4 of section 7 of DNV-ST-F101)
CR:	single pass Cap Repair
CRR:	single pass Cap Re-repair
CSWIP:	Certification Scheme for Personal
FCR:	Full Cap Repair
LCW:	List of Qualified Welders and Welding Operators according to PETROBRAS standard N-2301.
MLP:	Mechanically Lined Pipe
MUT:	Manual Ultrasonic Inspection
PAUT:	Phased Array Ultrasonic Testing
PLEM:	Pipeline End Manifold
PLET:	Pipeline End Terminator
PQR:	Welding Procedure Qualification Record according to PETROBRAS standard N-2301
PPR:	Partial Penetration Repair
PPRR:	Partial Penetration Re-repair
PTIR:	Production Test Implementation Record according to PETROBRAS standard N-2301
RM:	Materials Requisition

RMS:	Root Mean Square
RMD:	Regulated Metal Deposition welding process
RSR:	Single pass Root Sealing Repair
SNQC-PS:	Sistema Nacional de Qualificação e Certificação – Profissional de Soldagem
STT:	Surface Tension Transfer welding process
TTR:	Through Thickness Repair
TTRR:	Through Thickness Re-repair
WEII:	Welding Execution and Inspection Instruction
WPC:	Welder or Welding Operator Performance Control
WQR:	Welder and Welding Operator Qualification Record according to PETROBRAS standard N-2301
WPQT:	Welding Procedure Qualification Tests
$\%Cu_{BM}$:	Copper content of base metal
$\%Cu_{WM}$:	Copper content of weld metal
$\%Ni_{BM}$:	Nickel content of base metal
$\%Ni_{WM}$:	Nickel content of weld metal
$\%Cr_{WM}$:	Chromium content of weld metal

3 CHANGES IN SECTION 5 OF DNV-ST-F101

3.1 SYSTEM DESIGN REQUIREMENTS

3.1.1 *[5.2.1.6 bullet 5]* The toe-to-toe distance from other welds shall be minimum 50 mm. In case the nominal thickness is equal or greater than 25 mm, Contractor shall demonstrate that volumetric nondestructive inspection covers 100% of weld volume, otherwise the minimum toe-to-toe distance will be two times the nominal thickness, according to DNV-ST-F101. (MR)

3.1.2 *[5.2.1.8]* Girth welds shall not be covered under doubler rings, clamps, or other items. The requirement to not cover the girth weld is to allow for required NDT, corrosion protection (coating, anodes, or premises for other corrosion evaluations) and leakage detection during FAT testing. For FAT testing based on pressure drop, see [8.7.4], the encircling sleeve is not allowed to constitute a pressure barrier, i.e., pressure built up in the void shall be monitored or avoided. (MR)

4 CHANGES IN SECTION 10 OF DNV-ST-F101

4.1 CONSTRUCTION - OFFSHORE

4.1.1 *[10.5]* Requirements from 10.5.1.1 to 10.5.1.4 are modified according to this technical specification. (AR)

4.1.2 *[10.5.3]* The extend of NDT for attachment welds, such as anode pad welding and doubler sleeves fillet welds, shall be 100% visual examination and 100% MPI of completed welds. (AR)

4.1.3 *[10.5.3.8]* In addition, Visual Examination shall include: (AR)

a) 100% examination of bevel dimensions, fit up and cleanliness of external and internal surfaces before the weld execution.

b) 100% examination of internal surfaces of completed welds for surface flaws, shape, and dimensions where accessible.

4.1.4 *[10.9.2]* For above water tie-in operations, the qualification of the welding procedure shall realistically simulate the same type of line-up clamping to be used in production. The minimum number of weld layers necessary to withstand the tension efforts during the execution of the weld before releasing of line-up clamps shall be calculated. This minimum number of weld layers shall be simulated during the qualification process in addition to the rules of clause C.5.1.7 of DNV-ST-F101. The above water tie-in operation should be planned to be executed during the descending tide, at least up to the completion of a minimum resistant section to avoid plastic collapse or cracking during the weld execution. (AR)

4.1.5 *[10.9.3]* Tie-in operations below water is not acceptable. (DR)

5 CHANGES IN APPENDIX B OF DNV-ST-F101

5.1 MECHANICAL TESTING AND CORROSION TESTING

5.1.1 *[General]* Additional testing is given in: “Guideline for Design and Construction of Lined and Clad Pipelines from JIP Lined and Clad Pipeline Materials” if the liner, clad or weld overlay thickness is included in the design calculation. All requirements regarding the specimens for determining tensile properties for the weld root of girth welds in lined, clad or weld overlay material shall be complied with. (MR)

5.1.2 *[General]* In order to obtain CVN specimens to test the weld overlay as per table C-5 from appendix C of DNV-ST-F101, 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 to obtain the necessary specimen length (55 mm) and the notch at the right position. See clause B.2.4.13 of DNV-ST-F101. (AR)

5.1.3 *[B.2.8]* When the Materials Requisition (RM) and Specific Pipeline or Riser Project Documentation specifies the pipeline or riser according to regions 1, 2, or 3 defined at figure 1 of NACE MR0175/ISO-15156-2 and if an ECA is carried out, the rules of I-ET-0000.00-0000-210-P9U-005 regarding hydrogen charged fracture toughness specimens shall be adopted. The level of hydrogen charging shall be indicated in the Materials Requisition (RM) and Specific Pipeline or Riser Project Documentation. In the absence of this information COMPANY shall be consulted to inform it. (AR)

6 CHANGES IN APPENDIX C OF DNV-ST-F101

6.1 WELDING PROCESS

6.1.1 *[C.1.2.3]* The use of regular SMAW welding process shall be restricted to onshore applications only. Exception is made if all the following conditions are complied with: (AR)

a) Use of hermetically sealed containers, as per AWS 5.02 (or ASME BPVC.II.C, SFA-5.02).

b) Use of extra-low hydrogen coated electrodes (i.e., below 5 ml diffusible hydrogen per 100 g weld metal).

c) Use of low-moisture-absorbing electrodes (i.e., below 0.4 % by weight tested for the maximum allowable atmospheric exposure, but not less than 9 hours).

6.1.2 *[C.1.2.3]* For the purpose of welding clad or lined pipelines or risers, the allowable welding process are: GTAW (process ISO 4063-141), GMAW (process ISO 4063-131), and SAW (process ISO 4063-12, if adopting single wire and heat input parameters below 2.0 KJ/mm). (AR)

6.1.3 *[C.1.2.3]* The WPQT program shall demonstrate the suitability of the internal surface of the respective welds to withstand the predicted fatigue life by means of full-scale fatigue testing, according APPENDIX A, including suitable root profile and reduced number of discontinuities.

6.1.4 *[C.1.2.3]* For CS pipelines design to survive to fatigue life based in curves more stringent than curve F1 of DNV-RP-C203 for internal surface, and all lined and clad pipelines sections, tie -in welds included, remote internal visual inspection is mandatory for detection of root discontinuities such as excess penetration, concavity, undercuts, lack of penetration, etc. All instruments for visual inspection shall be suitably calibrated, and their sizing error shall be considered in the measurement. Remote visual inspection shall be carried out by qualified camera and laser devices. Visual Examination acceptance criteria shall be based in the most stringent between ECA and table D-4 of DNV-ST-F101. (AR)

6.1.5 *[C.1.2.3]* The use of G-FCAW welding process in the root pass, hot pass, and partial repair passes, where the ligament is lesser than 6 mm is not allowed. (AR)

6.1.6 *[C.1.2.5]* CONTRACTOR shall demonstrate previous successful experience applying welding processes in similar conditions, presenting the track records for welding at least 100 kilometers of pipeline projects or 10 kilometers of riser projects where the primary NDT of welding discontinuities shall have been made by AUT. The welding process shall not produce systemic flaws. The qualification program for welding process where Contractor has limited experience or to be used under new conditions, shall additionally include, as a minimum, ten test coupons witnessed by Company. NDT examination, internally and externally on the coupons, shall include 100% UT, 100% RT (X-Ray) 100% PT or MT and 100% visual examination. (AR)

6.2 WELDING EQUIPMENT TOOLS AND PERSONNEL

6.2.1 *[C.2.2]* Welding operators to be hired by CONTRACTOR shall have at least 48 hours of training in the respective welding process, in the same or similar welding procedure, and shall have at least one year of previous experience as welder or welding operator, also respecting the requirements from other parts of the contract, if any. (AR)

6.2.2 *[C.2.2]* CONTRACTOR shall carry out all works of Welding and NDT in accordance with a quality management system in conformity with "DIRETRIZ CONTRATUAL PARA GESTÃO DA QUALIDADE", attached to the contract and the requirements herein. The qualification of all welding and NDT personnel and inspection procedures shall be in accordance with N-2941. The list of all inspectors shall be submitted to COMPANY representatives' evaluation before being engaged in the work. All inspectors are required to demonstrate experience with DNV-ST-F101. It is recommended for all inspectors to have at least two years of experience working with construction and installation of subsea pipelines. A Senior Welding Inspector shall be available during offshore, double joints or spool base welding activities to supervise all Level 1 welding inspectors. Senior Welding Inspectors certification can be covered by (i) Welding Engineers certified in IIW, TWI or equivalent; (ii) Senior Welding Inspector of CSWIP or AWS Scheme; or (iii) Level 2 welding inspector of SNQC-PS certification (DNV-ST-F101, ASME B31.8 or ASME B31.4 standards) with five years of experience in subsea pipeline fabrication. In all cases, the CVs of the personnel involved in the work shall be sent to COMPANY for review and approval.

6.3 WELDING OPERATORS AND WELDERS

6.3.1 *[C.2.2.4]* (DR)

6.3.2 *[C.2.2.5]* Welders/welding operators performing manual, partly mechanized welding, mechanized or automatic welding in pipeline or pipeline components girth welds, shall be qualified for single side butt welds of pipes or plates in the required principal position in accordance with API 1104, for the respective positions, material grades and welding processes. These requirements are also applicable for welders/welding operators performing temporary welds and tack welds. (MR)

6.3.3 *[C.2.2.5]* For the sake of clarity, section 6 of API 1104 shall be utilized for manual and partly mechanized welding process and section 12 of API 1104 shall be utilized for mechanized and automatic welding process only to adopt the respective essential variables (qualification tests are done according to clauses C.2.2.8 and C.2.2.9 of DNV-ST-F101). In case of a multiple welding process procedure, the qualified thickness shall be limited to twice the deposited thickness in the test coupon for each welding process. (AR)

6.3.4 *[C.2.2.5]* The welders and welding operators' qualification tests shall be informed in advance for COMPANY witnessing. Whenever the qualification process occurs overseas, and if no other contractual document establishes the time in advance for

the CONTRACTOR to inform COMPANY about the start of the qualification process, CONTRACTOR is required to provide this information for COMPANY at least 4 weeks before the start. The WQR documents shall be subject to COMPANY's approval before welders and welding operators are allowed to join production. (AR)

6.3.5 *[C.2.2.5]* Welder shall demonstrate the skill to reproduce the qualified heat input range, i.e., failure to reproduce the specified range implies in rejection of the welder. Welding inspector shall orient the welder to perform the right heat input range before the WPQ test. It is not acceptable for the welding inspector to orient the welder to increase the travel speed during part of the circumference section to compensate a lower travel speed performed in the previous circumference sections during qualification and production welds, or vice versa. (AR)

6.3.6 *[C.2.2.5]* The excavation operation shall be considered an essential variable for the welder qualification, if applicable. Only qualified welder shall perform excavation operations of the respective welding procedure during production. (AR)

6.3.7 *[C.2.2.5]* In case AUT is carried out for welders and welding operator qualification, AUT acceptance criteria shall be in accordance with Appendix E, Table E-1 of DNV-ST-F101. Exception is made when ECA criteria are stricter than the AUT acceptance criteria described above and shall be adopted instead. (AR)

6.3.8 *[C.2.2.6]* Welders shall be qualified for single side butt welding of pipes in the required principal position. Welders may be qualified for part of the weld, root, fillers, or cap if primary NDT method is AUT and it is possible to identify the welder responsible for each defect. Welders shall be qualified on each repair WPS according to the essential variables of sections 6 of API 1104. Providing the welding processes and heat input are close (average heat input difference not greater than 20% for the section), welder qualified for PPRR will be considered qualified for PPR and CR. TTR, RSR and BTR shall be qualified apart, if applicable. PPR qualified by PPRR does not need to be mechanically tested. Minimum repair length shall be 300 mm, and the repair shall be performed in the overhead position. (MR)

6.3.9 *[C.2.2.8]* Regarding embedded flaws inspection, the same primary NDT (i.e., RT, MUT or AUT) that is going to be used in production for each WPS shall be used for welders and welding operator's qualification. (AR)

6.4 PERIOD OF VALIDITY

6.4.1 *[C.2.2.13]* The welder or welding operator qualification validity shall be six months (demonstrated by NDT) without an interruption of more than three months (demonstrated as per WPC). NDT demonstration is not applicable to weld overlay welding operators. WPC shall be carried out and it shall be presented biweekly for COMPANY representatives according to N-2301. The required performance shall be as follow: (MR)

a) 2.5% or 75 mm in 3 m of tested welds, when the rate is calculated based in the defect length, the WPC shall start to reject just after which comes first, 3 m of tested welds or 75 mm of rejected length.

b) Independent if the welds will be repaired or cut, the WPC shall be considered necessary. In case Contractor proves that the cause of low performance in automatic or mechanized welds is related to a systematic error of the welding equipment and not due to a specific welding operator skill, the repair length may be excluded from the WPC. A qualification can be cancelled if the welder/welding operator show inadequate skill, knowledge, or performance below the minimum required.

Guidance Note: *the objective of WPC is to keep welders and welding operators focused in produce good welds. In case of deficient performance, their replacement or retraining is benefic to avoid rejected welds and repairs.*

6.5 WELDING CONSUMABLES

General

6.5.1 *[C.3.1]* A welding consumable handle and storage procedure to be complied with for all production welds shall be considered a contractual deliverable. It shall be prepared and submitted for COMPANY approval. Such procedure shall be according to items 4.7.2 to 4.7.22 of N-133 and sub-section C.3 of DNV-ST-F101: appendix C. FCAW coils not in use during continuous 12 hours and GMAW coils not in use during continuous 24 hours shall be collected and re-stored within the consumable's storage compartment in conditions according to N-133 requirements. (AR)

6.5.2 *[C.3.1.1]* Welding consumables shall be suitable for their intended application, giving a weld with the required properties and corrosion resistance in the finally installed condition. Welding consumables with suffix "G" corresponding to AWS specification, or equivalent in CEN standard, are only acceptable if approved by COMPANY. The specification for tensile properties, impact energy and chemical composition, in as-welded condition, shall be presented with the respective welding consumable certificate with the actual values for each batch. (MR)

6.5.3 *[C.3.1.2]* Consumables not specified by AWS (equivalent to ASME BPVC – Section II, Part C) or CEN standards are not acceptable. (AR)

6.5.4 *[C.3.1.3]* CONTRACTOR shall provide welding consumable certificates according to this requirement for all welding process. The welding consumable certificates shall demonstrate that specific diffusible hydrogen tests (for all welding process) and absorbed moisture test (only for coated electrode offshore welding) were carried out (type 3.1 according to EN 10204 or equivalent) and the results shall be explicitly showed in the respective certificates. (AR)

6.5.5 *[C.3.1.8]* Cellulosic coated electrodes are not allowed. (MR)

Chemical Composition

6.5.6 *[C.3.2]* For carbon steel water injection and gas pipelines submitted to the presence of water condensate, welding consumables used for the root and hot pass of girth welds shall be selected to avoid preferential corrosion in weld metal of pipes. The following equation shall be used to determine if the weld metal is cathodic and base metal is not excessively anodic, in comparison with each other:

$\Delta = 3.8 \times (\%Cu_{BM} - \%Cu_{WM}) + 1.1 \times (\%Ni_{BM} - \%Ni_{WM}) + 0.3$

To avoid preferential corrosion, Δ is recommended to be between -0.3 and 0.0%, and it shall not be above +0.3%. Otherwise, COMPANY shall be consulted. (AR)

6.5.7 *[C.3.2]* For carbon steel gas pipelines submitted to the presence of water condensate, welding consumables used for the root of girth welds shall be selected to avoid preferential corrosion in weld metal of pipes. The following two equations shall be used instead:

$\Delta = 3.8 \times (\%Cu_{BM} - \%Cu_{WM}) + 1.1 \times (\%Ni_{BM} - \%Ni_{WM}) + 0.3$

$\varepsilon = 1.71 - 0.58 \times (\%Ni_{BM} - \%Ni_{WM}) - 1.49 \times (\%Cu_{BM} - \%Cu_{WM}) - 1.36 \times (\%Cr_{BM} - \%Cr_{WM})$

To avoid preferential corrosion, parameter Δ should be in the range between -0.63 and +0.95 and parameter ε should be in the range between +1.0 and +2.4. For chemical compositions out of at least one of those ranges, COMPANY shall be consulted for approval. (AR)

6.5.8 In both equations, the chemical composition of $Ni_{weld\ metal}$, $Cr_{weld\ metal}$ and $Cu_{weld\ metal}$, may be obtained from the deposited weld metal, but it is recommended to estimate it, before WPQT. (AR)

Mechanical Properties

6.5.9 *[C.3.3.2]* For girth welds, it shall be considered "undermatch" when the tensile stress-strain curve of the weld filler metal crosses the stress-strain curve of the parent pipe after a strain level of 5%, or the tensile strength of the filler weld metal is not 10% higher than the tensile strength of the parent pipe material. "Undermatch" is not acceptable. (AR)

6.5.10 *[C.3.3.5 and C.3.3.7]* Batch testing is always required. Batch of welding wire tested and approved in a previous Company project and still available for a new project will be considered acceptable in case they comply with the required values for the new project (i.e., average impact test values, transverse all weld tensile values, fracture toughness values, etc.) and only in case they had been tested with the same WPS, respecting the same heat input ranges. (MR)

Batch Testing of Welding Consumables for Pipeline Girth Welds

6.5.11 *[C.3.4.7]* Fracture toughness tests shall be performed as part of batch testing, whenever an ECA is used as basis for establishing acceptance criteria for pipeline girth welds. (AR)

6.5.12 *[C.3.6.2]* In addition, manufacturer's recommendations, and PETROBRAS standard N-133 requirements shall be complied with for solid and flux cored wire handling and storage. The vacuum package opening is only allowed at the presence of COMPANY representative who shall immediately sign off on the package, recording the respective package opening time. Any opened vacuum package shall be discarded after the maximum allowable atmospheric exposure time established by test. Baking/Re-baking are not acceptable. This information shall be included in the consumable handle procedure. Closed vacuum package consumables shall be stored in the storage compartment with the same requirements of other welding consumables. The ratio of new/recycled SAW flux shall not be less than 50/50. (AR)

6.6 WELDING PROCEDURES

General

6.6.1 *[C.4.1]* The "Welding Book" shall be issued including all welding procedures and additional information required in item 6.6.2. All these documents shall be formally submitted for COMPANY approval and be included in the Project Data Book. All welding documents of the "Welding Book" shall be signed off by the "Senior Welding Inspector of CSWIP Scheme", "Level 2 Welding Inspector of SNQC-PS" qualified in DNV-ST-F101 or equivalent. (AR)

6.6.2 *[C.4.1] A* Welding philosophy document shall be issued detailing CONTRACTOR's strategy for WPQT and production. It shall be within the first pack of welding documents issued and it shall refer to all applicable welding and inspection documents. It shall include at least: list of base materials; list of repair types and complete repair strategy; table correlating which PRQ will support each final WPS; list of WPQT tests for each PQR; template of the welding registration report for WPQT; requisition sheet template for mechanical tests; methodology and requirements for temperature control and for heat input control complying with this specification and this standard. The respective pWPS shall be formally released by CONTRACTOR and approved by COMPANY before the WPQT and the approval of the final WPS document. The following content shall be provided in the "Welding Book": (AR)

a) All pWPS: After the approval of these pWPS, as the actual parameters change during the welding procedure qualification process, the pWPS do not need to be re-issued. All applicable content of table C-1, all applicable essential variables of table C-3 and additional production requirements shall be described/included.

b) All final WPS: The WPS shall be according to annex B of PETROBRAS standard N-2301 and shall have all the attachments required in this standard. All applicable content of table C-1, all applicable essential variables of table C-3 and additional production requirements shall be described/included.

c) All PQR: The PQR shall be according to annex C of PETROBRAS standard N-2301 it shall have all the attachments required in this standard, including all

the welding registration report parameters according to annex H of PETROBRAS standard N-2301.

d) All WQR: The WQR shall be according to annex D of PETROBRAS standard N-2301 and shall have all the attachments required in this standard; This item shall be submitted to COMPANY and added to the "Welding Book" before production welds beginning.

e) All PTIR: The PTIR shall be according to annex C of COMPANY' standard N-2301 and shall have all the attachments required in this standard.

f) The LCW, according to annex F of PETROBRAS standard N-2301: It shall have all the attachments required in this standard. This item shall be submitted to COMPANY and added to the "Welding Book" before production welds beginning.

g) All NDT reports (signed off by respective inspectors) including all repair indications, the pos-repair inspection, and all welding registration report of the repairs.

Previously Qualified Welding Procedures

6.6.3 *[C.4.2.4]* Except as limited by C.4.2.3 of this standard, a WPS (or a group of WPS) for new production may be based on a previously qualified WPQR (qualified in previous submarine pipeline, riser, or pipeline component projects). The type and extent of testing and test results for the previously qualified WPQR shall meet the requirements of DNV-ST-F101: appendix C and the requirements herein. A WPS for the new production shall be specified within the essential variables of DNV-ST-F101: appendix C and they shall satisfy the following conditions: (AR)

a) The previous project shall be a rigid submarine pipeline, riser or pipeline component built for other COMPANY project.

b) When the previous COMPANY project is based in a different DNV-ST-F101 edition, all DNV-ST-F101 requirements stated on edition 2017 shall be complied with.

c) CONTRACTOR shall submit all applicable WPS and PQR for COMPANY's evaluation and written approval. The "Welding Book" mentioned herein this specification shall be provided for the new project.

d) The SSC regions (defined in figure 1 of NACE MR0175/ISO-15156-2) specified at Materials Requisition (RM) and Specific Pipeline or Riser Project Documentation (see Table 1-2), qualified in the original welding procedure shall be the same or greater than the ongoing project where they are proposed to be utilized, and the original welding procedure shall have been submitted to the same or to more stringent test requirements than the ongoing project where they are proposed to be utilized.

e) Requirements of item 6.6.6 shall be complied with.

f) Forged components shall comply with the same requirements listed above and with table C-3 of DNV-ST-F101.

g) In case anyone of the above requirements is not complied with, the new proposed welding procedure (s) shall be qualified for the new project.

Welding Procedure Qualification Record

6.6.4 *[C.4.4]* External digital data loggers shall be used during WPQT. The measurement accuracy shall be at least 2.5% for amperage and 1.5% for voltage. Their accuracy shall be verified during the start of WPQT against a resistor bank or non-pulsed welding sources monitored with true RMS clamp meters or digital multimeters. Data logger shall provide pulse data if pulsed modes are used. If the measurements are not taken as close as possible to the torch, the change of welding equipment cable length adopted during the WPQT shall be considered an essential variable. For mechanized welding, internal data loggers are only acceptable if a comparison with an external data logger in at least one weld is included in WPQT Plan. If any inconsistency arise, COMPANY shall be consulted (AR). Data logger raw data shall be provided for COMPANY in a daily basis during WPQT.

Additional Requirements to pWPS for Repair Welding

6.6.5 *[C.4.7.2 – additional bullet]* The maximum length and depth of the repair welding, calculated and provided according to section 10 of DNV-ST-F101, in areas subjected to bending moments / axial stresses or according to clause C.7.5.20 of appendix C of DNV-ST-F101, as applicable. (AR)

Additional Essential Variables for SAWL Linepipes and Multi-torch Welding Process.

6.6.6 *[C.4.8]* When the welding procedure is applicable to girth welds of SAWL linepipes, the linepipe manufacturer shall be considered an essential variable. CONTRACTOR does not need to make all the tests for each linepipe manufacturer. CONTRACTOR may carry out a full qualification in the pipe of one of the manufacturers and at least macro and hardness tests at the seam weld of the non-tested manufacturer linepipe, according to note 11 of Table C-4, and considering the same location for table C-5 of DNV-ST-F101, and applicable fracture toughness tests at the HAZ (in case ECA will be carried out) of the non-tested manufacturer linepipe. When the welding procedure utilizes more than one torch or more than one bug, the maximum number of torches and bugs that consequently will produce the highest interpass temperature shall be fully mechanically tested according to this specification (including requirements of item 6.6.9 or clause C.4.8.7 as applicable). To allow the shutdown of any welding torch in production, one additional test coupon shall be welded with a unique torch, and it shall be submitted to SSC and hardness tests and approved according with item 6.14.4. (AR)

6.6.7 *[C.4.8]* The cleaning tools and degree of cleanness (if slag/silica is completely removed, and for which passes, for instance) used during qualification for the

interpass cleaning shall be recorded in the PQR and repeated in the final WPS as essential variable. Surfaces to be welded by any welding process and the interpass cleaning at SMAW welding process and partly mechanized FCAW welding process shall be made at least by grinding. (AR)

6.6.8 *[C.4.8.4]* Furthermore, regarding welding technique, rolled pipe shall not qualify fixed pipe. For a fixed pipe to qualify a rolled pipe, the welding parameters and essential variables of the equivalent angular position shall be complied with. (AR*)*

6.6.9 *[C.4.8.6]* Multiple test pieces may be required for qualifying a pWPS where the size of the test piece will not allow extraction of test specimens in the correct locations according to Figure C-2. In such cases the maximum heat input variation between the different test pieces shall be as similar as possible. Maximum allowed heat input variations between different test pieces are: (MR)

a) 15% for mechanized and automated welding.

b) 30% for manual and partly mechanized welding.

An average heat input shall be calculated in line with clause C.5.1.7 of appendix C of DNV-ST-F101. Hardness, SSC, impact, and fracture toughness testing shall be taken as follows:

c) hardness and SSC (when applicable) test specimens from the test piece and position welded with the lowest heat input.

d) impact and fracture toughness (when applicable) test specimens from the test piece and position welded with the highest heat input.

Guidance Note: *For manual and partly mechanized welds, the heat input range provided by clause C.4.8.6 generally does not produce a comfortable range for production welds. In those cases, it is preferable to qualify such welding procedures according to clause C.4.8.7.*

6.6.10 *[C.4.8.9]* Artificial heating (boosting) to qualify higher interpass temperatures is only permitted in the following conditions: (i) at least one (first) coupon shall be welded with maximum heat input proposed and without interruption to simulate (but not exceeding) the maximum interpass temperature expected during production; (ii) all next coupons shall achieve the same maximum interpass temperature recorded in the first coupon. It is not allowed to boost the interpass temperature for one pass only. The maximum qualified interpass temperature for carbon steels shall be limited to 315°C for production welds. Exception is made when using solid wires (GMAW or GTAW), in this case, it is acceptable to extend interpass temperature limit to 400ºC for production welds. (MR)

6.6.11 *[C.4.8.9]* For low alloy steels, the maximum interpass temperature for production welds shall be limited according to item 5.2, 5.3 and tables 3 and 7 of N-133. (AR)

6.6.12 *[C.4.8.9]* Only contact thermometer shall be used for measuring pre heat, maximum interpass and accelerated cooling temperatures during the WPQT (for all type of materials), different devices are not acceptable. (AR)

Essential variables for repair welding

6.6.13 *[Table C-3, item 24]* Any increase (no tolerance) in the depth of excavation for partial thickness repair. (AR)

6.7 QUALIFICATION OF WELDING PROCEDURES

General

6.7.1 *[C.5.1]* When required in the respective design basis or any other project document, full scale fatigue testing shall be carried out according to APPENDIX A of this specification and shall be considered part of the WPQT. (AR)

6.7.2 *[C.5.1.1]* CONTRACTOR shall submit all the pWPS and shall provide all the consumables certificates for COMPANY's approval before the beginning of the qualification works. Whenever the qualification works occurs overseas, and if no other contractual document establishes the time in advance for the CONTRACTOR to inform COMPANY about the start of the qualification process, CONTRACTOR is required to provide this information for COMPANY at least six weeks before starting works. The welding procedure qualification process shall be performed and documented by CONTRACTOR and witnessed by COMPANY representatives. CONTRACTOR shall provide the "Welding Book" with the qualification of all pWPS, as prescribed by Appendix C of DNV-ST-F101, at least six weeks before the start of production. No production weld and NDT may be carried out before the formal COMPANY approval. (AR)

6.7.3 *[C.5.1.1]* The configuration of the test joint shall be representative of the actual weld to be performed during production. Charpy V-Notch impact test temperature shall not be higher than that specified in table 7-6 of DNV-ST-F101. T_{min} referred in this table shall be according to the specific project documents, considering also transient temperatures. Test temperature requirements for fracture toughness testing are described in I-ET-0000.00-0000-200-P9U-005. When SSC testing is required as per item 6.14.4, the main welding procedure and all repair welding procedure shall be tested. When SSC tests are exempt as per item 6.14.4 no production repair welding procedure shall be done with a remaining ligament of the excavation lower than the one qualified. (AR)

Qualification Welding

6.7.4 *[C.5.1.7 –bullet 3 of pipeline girth welds]* For welding of pipe with diameter ≥ 20" in fixed positions, the weld circumference shall be divided in appropriate sectors around the circumference. The welding parameters shall be recorded for each pass in each sector and for each welding arc. For all type of welding process, the heat input for a sector shall be recorded as average of all the average heat inputs for the run-out lengths in each pass in that sector. For automatic or mechanized welding, the division in sectors may be disregarded, and in this case the heat input for each pass shall be recorded as average of all the average heat inputs for the run-out lengths in each pass in the pipe circumference. Instrumented data logger shall be used during the WPQT, for all type of welding process, to record amperage, voltage,

and travel speed and to obtain the heat input. Minimum and maximum heat input to be used for each pass to calculate the average heat input of each pass shall be equivalent respectively to the minimum and maximum instantaneous heat input recorded by the data logger (i.e., maximum / minimum heat input regarding amperage, voltage and travel speed that occurred in a unique moment instead to be based in the maximum / minimum individual figures of amperage, voltage, and travel speed of the whole pass). Unsuitable and unrealistic heat input records that may occur during arc opening or arc extinguishing may be disregarded. (MR)

6.7.5 *[C.5.1.7 –bullet 4 of pipeline girth welds]* For welding of pipe with diameter < 20", the heat input shall be recorded for each pass. For all type of welding process, the heat input for each pass shall be recorded as average of all the average heat inputs for the run-out lengths in each pass in the pipe circumference. Instrumented data logger shall be used during the WPQT to record amperage, voltage, and travel speed and to obtain the heat input. Minimum and maximum heat input to be used for each pass to calculate the average heat input of each pass shall be equivalent respectively to the minimum and maximum instantaneous heat input recorded by the data logger (i.e., maximum / minimum heat input regarding amperage, voltage and travel speed that occurred in a unique moment instead to be based in the maximum / minimum individual figures of amperage, voltage, and travel speed of the whole pass). Unsuitable and unrealistic heat input records that may occur during arc opening or arc extinguishing may be disregarded. (MR)

6.7.6 *[C.5.1.7 – Last bullet of pipeline girth welds]* The final temperature after the accelerated weld cooling shall be specified in the pWPS/WPS based on the maximum temperature specified on NDT procedure and shall be simulated and recorded during qualification. The same cooling method adopted during WPQT shall be reproduced for production welds. (AR)

6.7.7 *[C.5.1.7 –pipeline girth welds]* As per above, the heat input parameters shall be recorded for each pass. The heat input range of the final WPS shall also be representative of the respective records of each pass. The average heat input records of each pass may be grouped in order to provide a wider heat input range in the final WPS if the following requirements are complied with: root and hot passes shall not be grouped; cap passes shall not be grouped with fill passes; grouping shall not result in a heat input range wider than the heat input ranges established clauses C.4.8.6 or C.4.8.7 of appendix C of DNV-ST-F101, as applicable. For the welding parameter records, and if diameter is used to calculate the welding pass length, the actual weld deposit depth shall be considered for each diameter figure considered. (AR)

6.7.8 *[C.5.2.1]* In case of PPRR, the test piece shall contain a repair weld of PPR, according to item 6.9.1. It is not necessary to qualify separately the PPR and PPRR weld procedures, once the PPRR will completely remove the weld and HAZ of PPR. In case PPRR is completely tested according to DNV-ST-F101 required mechanical,

macrographic and applicable corrosion and fracture toughness tests, the only necessary tests in the PPR are the Charpy in the original weld metal, the SENT in the HAZ of the original weld metal and the macrographic tests according to item 6.9.1 (when applicable). (MR)

6.8 QUALIFICATION OF GIRTH BUTT WELDS AND COMPONENT LONGITUDINAL WELDS WELDING PROCEDURE

6.8.1 *[C.5.3. Table C-4 note 11 and Table C-5 note 7]* For alloy UNS N06625 welds, pitting corrosion resistant testing according to ASTM G48, Method A and DNV-ST-F101: appendix B requirements shall be carried out. Test temperature shall be 40ºC and test period shall be 24 hours. Acceptance criteria shall be maximum weight loss of 4.0 g/m^2, and no pitting. Maximum iron content in chemical analysis shall be to clause C.6.4.8 of DNV-ST-F101. (AR)

6.9 REPEATED REPAIRS

6.9.1 *[C.5.3.10]* In order to allow the PPRR, i.e., the re-repair in the PPR weld, in carbon steel and low alloy steel, all the following requirements shall be fulfilled during qualification: (AR)

a) During the first repair, the excavation depth shall be measured and registered in the center of the excavation and each 20 mm in both directions (excluding at the final 60 mm of both sides, the measurements and records may be spaced at 60 mm in the remaining space between those 60 mm of both sides).

b) Before the second excavation, the cap width shall be measured and registered in the center of the excavation and each 20 mm in both directions (excluding at the final 60 mm of both sides, the measurements and records may be spaced at 60 mm in the remaining space between those 60 mm of both sides).

c) The excavation area of the second repair shall be in such way that guarantees the complete removal of the first repair weld (HAZ and Weld Metal), removing 3 mm further in depth and in both sides of the width based on the first repair excavation register.

d) The macrographic tests required by DNV-ST-F101 shall demonstrate that PPR weld and HAZ were completely removed during the excavation of PPRR to allow the qualification of PPRR. Each one of both macrographs (one in the seam weld if applicable) of the PPR shall be superimposed with the equivalent macrographs of the PPRR to demonstrate the whole removal of them.

e) If the main weld has a narrow gap, the Charpy test at HAZ of the original weld metal shall be carried out in the PPR weld coupons (one repair attempt). As the second repair attempt shall completely remove the PPR weld, and the depth of the second repair attempt may promote a total removal of the original weld, the Charpy test at HAZ of the original weld metal of the PPR coupon shall be considered valid for the PPRR qualification in this specific location. If the main weld has a wider gap, this bullet shall be disregarded.

f) If the main weld has a narrow gap, and if applicable, the SENT test at HAZ of the original weld metal shall be carried out in the PPR weld coupons (one repair attempt). As the second repair attempt shall completely remove the PPR weld, and the depth of the second repair attempt may promote a total removal of the original weld, the SENT test at HAZ of the original weld metal of the PPR coupon shall be considered valid for the PPRR qualification in this specific location. If the main weld has a wider gap, this bullet shall be disregarded.

6.10 QUALIFICATION OF WELDING PROCEDURES FOR CORROSION RESISTANT OVERLAY WELDING

6.10.1 *[C.5.4]* Welding procedures for corrosion resistant overlay welding, the essential variables of the respective welding process shall be according to ASME BPVC Section IX, with the additional provisions for cladding and buttering in DNV-RP-B204. The qualified range shall be according to that code, and the whole qualification tests and requirements shall be according to sub-sections C.5.4 and C.6.4 of DNV-ST-F101: appendix C added by the requirements of this specification. (AR)

6.10.2 *[C.5.4]* Weld overlay shall be executed in at least two layers to limit the pass height and dilution. If interpass machining is specified, the maximum pass height observed in macro during WPQT shall be reported. (AR)

6.11 QUALIFICATION OF WELDING PROCEDURES

6.11.1 *[C.5.4 Table C-6 note 6)]* For alloy UNS N06625 weld overlay, pitting corrosion resistant testing according to ASTM G48, Method A and DNV-ST-F101: appendix B requirements shall be carried out. Test temperature shall be 40ºC and test period shall be 24 hours. Acceptance criteria shall be maximum weight loss of 4.0 g/m^2, and no pitting. Maximum iron content in chemical analysis shall be according to clause C.6.4.8 of DNV-ST-F101. (AR)

6.12 QUALIFICATION OF PROCEDURES FOR PIN BRAZING AND ALUMINOTHERMIC WELDING OF ANODE LEADS

6.12.1 *[C.5.5.1]* When anode leads are attached to the pipeline or riser by pin brazing or aluminothermic welding, they shall be additionally tied with an external strip, or other device in a suitable way, to avoid them to be electrically disconnected during the laying process or the operation. Fillet weld between the linepipe and doubler sleeves or anode pads shall comply with all requirements of DNV-ST-F101 (see subsections C.5, C.6 and C.8 of DNV-ST-F101). (AR)

6.12.2 *[C.5.6]* Attachment welds, such as anode pad welding, shall be subject to 100% visual and 100% MPI. (AR)

6.13 QUALIFICATION OF WELDING PROCEDURES FOR STRUCTURAL COMPONENTS

6.13.1 *[C.5.7.1]* Welding procedures for structural components, supplied as part of the

pipeline systems and welded directly in the pipeline as per clause C.5.2.1.6 of section 5 of this standard shall be qualified in accordance with AWS D1.1 and PETROBRAS specification N-1852. The requirements shall be appropriate for the structural categorization of the members and stresses in the structure. The extent of tensile, hardness and impact testing and the testing conditions shall comply with this Appendix. (MR)

6.14 EXAMINATION AND TESTING FOR WELDING PROCEDURE QUALIFICATION

Hardness testing

6.14.1 *[C.6.3.12]* The maximum hardness in the HAZ and WM shall be: (AR)

a) 325 HV10 for HAZ in backing steel in clad or lined material if long-term in-service integrity of the CRA layer is demonstrated and documented.

b) 345 HV10 for alloy UNS N06625in clad or lined material.

c) Other bullets as per DNV-ST-F101.

Re-testing

6.14.2 *[C.6.1.6.]* Contractor shall inform to COMPANY the reasons why the specimen failed, and COMPANY shall issue a formal approval before starting any re-test and before accepting any re-test result. (AR)

Tensile testing

6.14.3 *[C.6.3]* The actual weld metal yield strength shall never be lower than SMYS of the base material. The actual weld metal ultimate tensile strength shall never be lower than SMTS of the base material. (AR)

Corrosion Testing

6.14.4 *[C.6.3.15]* In all cases where C-Mn pipelines, risers and pipeline components are designed to withstand to SSC Regions 0, 1, 2 and 3 as defined in figure 1 of NACE MR0175/ISO-15156-2, all welded joints of them shall fully comply with the following requirements, for resistance to SSC. (AR)

a) All welds shall comply with NACE MR 0175/ISO 15156.

b) For all pipelines, risers, and pipeline components, designed to withstand to SSC Regions 1, 2 and 3 as defined in figure 1 of NACE MR0175/ISO-15156-2, all welding procedures and welding repair procedures, except single cap repair procedure and partial repair procedure with ligament size at least equal to 10 mm, shall always include in the qualification process SSC tests. SSC tests shall be performed according to appendix B of DNV-ST-F101, adopting NACE TM 0177 test procedure, except that the test piece shall be in accordance with “four-point bend” of ISO 7539-2 and except per modifications of this specification.

c) Exception for the requirement of SSC tests in the qualification process is made for pipeline components exclusively, except buckle arrestors, J-lay

collars and similar (i.e., significant number of pieces on the project), in case the maximum hardness of the welds are below 250 HV10, their welds may be exempt of the performance of the SSC tests. In this case, hardness tests shall be carried out at weld metal, heat affected zone and parent material of all production welds according to a suitable hardness test procedure. The hardness testing shall be performed according to section B.2.4 of annex B of N-133. Additionally, to exempt pipeline components with hardness below 250 HV10 from SSC tests, internal surface planar discontinuities as overlaps, lack of fusion, lack of penetration, undercuts, etc., are not allowed in the root area of such welding procedures.

d) If during the installation process the pipeline is submitted to total nominal strain in any direction from a single event exceeding 1.0% or accumulated nominal plastic strain exceeding 2.0%, SSC tests shall be done in samples that are removed, strained according to item 7.9.3.6 of section 7 of DNV-ST-F101 requirements and artificially aged at 250°C for one hour before testing in accordance with DNV-ST-F101. Plastic deformation and the cyclic history shall be at least equal to the one introduced during installation process.

e) Hardness profile of all welding procedures shall be according to the maximum values presented in Table 6-1 of this specification (HV10), regarding the respective SSC Regions (from 0 to 3 corresponding to SSC Regions 0, 1, 2 and 3 as defined in figure 1 of NACE MR0175/ISO-15156-2) required for the pipeline/riser/component to withstand. The hardness measurement during the welding procedure qualification shall be done according to figure B-10 of DNV-ST-F101: appendix B.

f) Welding consumables used in the root and hot passes of carbon steel welds shall have their Ni content according to item 6.5.6.

g) SSC test shall be done with base metal with the highest CE_{Pcm} (in case of seam welded linepipes the chemical composition may be obtained by the heat analysis instead of the product analysis). SSC test duration shall last 30 days with continuous gas bubbling pure H_2S purging, using respective solution of Table 6-1 (unless otherwise specified in specific project documents), according to the respective SSC Regions (from 1 to 3 corresponding to SSC Regions 1, 2 and 3 as defined in figure 1 of NACE MR0175/ISO-15156-2) required for the pipeline/riser/component to withstand. The test has to be carried out according to the level of stress and root preparation of Table 6-1, using a four-point bend test according to ISO 7539-2, unless a different test solution is predicted in other project document, when that solution shall replace the one indicated in Table 3.

h) For SSC, each test shall comprise a set of three specimens. All specimens shall be approved in the test. If the test fails, two new set of three samples of the same WPS shall be done. All specimens shall be approved in the re-test, otherwise the WPS shall be rejected.

i) The test pieces of the SSC tests shall be stressed to a fraction of SMYS appropriate for the design pipeline or riser, including stresses induced by buckle, however minimum 80% of the material AYS, that shall be specified in the respective pipeline or riser specification. Strain gauges shall be used in both HAZ to check if the appropriate stress level has been applied. In SSC tests, weld joint internal surface shall be in the as welded condition (no reinforcement or excess penetration removed). The weld reinforcement or excess penetration after the pipe internal surface shall be added to the dimensions of 115 x 15 x 7.5 mm of the 'four-point bend' specimen of SSC, when applicable. Independent of the applied stress, SSC shall last 720 hours. It is not acceptable to interrupt the test and start it again. The acceptance criterion is no cracks or fails (due to SSC) under 10 times magnification inspection, according to DNV-ST-F101. SSC requirements are described in Table 6-1, see it and respective notes for test details that shall be complied with.

Table 6-1- Requirements for Submarine Low Alloy and Carbon Steel Rigid Pipelines, Risers and Pipeline Components operating in presence of H_2S. (AR)

SSC Regions as defined in figure 1 of NACE TM 0175/ ISO 15156-2 regarding operation with H_2S[1]	Requirements to SSC Tests[2]		Requirements to HIC (Pipeline Components) NACE TM 0284[3]		Requirements of Maximum Hardness of Welded Joints (HV10)			Linepipe or forged Specification
	Level of Stress: (ISO 7539-2) % of SMYS in welded joint with root preserved[4]	Test Solution	Criteria	Test Solution	Weld Metal	HAZ - in the lines close to internal side and at mid thickness	HAZ - in the line close to external side	
0	No	No	No	No	325	325	325	API 5L Gr B, X42, X46, X52, X56, X60 and X65 DNV-ST-F101, 245, 290, 360, 415 and 450 Mpa ASTM A707 and A694
1	Yes	B of TM 0284 10% H_2S	CLR Max 15 CTR Max 3 CSR Max 1	B of TM 0284 100% H_2S	300	300	300	
2	Yes	B of TM 0284 100% H_2S	CLR Max 15 CTR Max 5 CSR Max 2	B of TM 0177 100% H_2S	270	270	300	
3	Yes	A of TM 0177 100% H_2S	CLR Max 15 CTR Max 5 CSR Max 2	A of TM 0284 100% H_2S	250	250	275	

1) The respective Pipeline or Riser Specification shall design the steel to withstand to a specific SSC Region as defined in figure 1 of NACE TM 0175/ ISO 15156-2. In the absence of this information COMPANY shall be consulted to inform it.
2) There are exceptions regarding SSC tests in pipeline components as per item 6.14.4 c) and/or referent to class of steel 0. All others shall carry out SSC tests.
3) Requirements to HIC applies only to pipeline components unless specified in other project documents.
4) The test pieces shall be stressed according to item 6.14.4 i).
5) If design basis or another project document specifies a different test solution, this shall be considered.

Guidance Note: *It is worth noting that providing a maximum hardness of 250 HV10 and a grade 450 MPa linepipe is not enough to withstand to SSC. The presence of discontinuities or stress concentrations in the root or close to it, may lead to failure in SSC tests. The use of "preserved internal surface" ("as welded") and tensile stress representative of design conditions brings those tests closer to the actual pipeline design condition. Furthermore, SSC resistance in sour environment may be affected by reeling.*

6.15 WELDING AND PWHT REQUIREMENTS

Production welding, general requirements

6.15.1 *[C.7.2.2]* The tolerances of the bevel preparation in the pWPS shall not be greater than the following values: ±1º for narrow bevels (when the bevel angle, as per AWS 3.0 definition, is equal or lower than 10º); ±2.5º for wide bevels (when the bevel angle, as per AWS 3.0 definition, is greater than 10º); for bevels composed of two different angles, the respective tolerances above shall apply individually. For reference, see ASME B31.8, figures I4 and I5. (AR)

6.15.2 *[C.7.2.6]* The alignment of the abutting ends shall be monitored during production with proper measurement devices and bevel dimension control. CONTRACTOR shall describe within the "welding philosophy" the strategy to be adopted to guarantee production welds complying with the respective internal misalignment criterion. Furthermore: (AR)

a) For welded joints with closed gaps, if the measurement is done from the outer surface the root faces dimensions from both pipes shall be considered (i.e., accounting for the root face size maximum tolerances or applying specific measurements and records of the root faces in equivalent positions before the fit up). For welded joints with opened gaps or for welded joints with closed gaps measured directly from inner surface, such root faces tolerances are not applicable.

b) In case the internal misalignment criterion is according to Table D-4 of DNV-ST-F101 the internal misalignment measurements shall be recorded in at least four points equally distributed around the circumference. The frequency shall be at least in two fitted joints per shift for mechanized or automatic welding process, and all fitted joints for manual or partly mechanized welding process.

c) In case the internal misalignment criterion is based in ECA, and it is more stringent than criterion of Table D-4 of DNV-ST-F101, a specific procedure for measuring the internal misalignment shall be submitted for COMPANY approval. The internal misalignment of all welded joints shall be veri31after the fit up and before welding, in at least four points equally distributed around the circumference. Such figures shall be recorded in at least one in each ten welded joints by the welding inspector.

d) In case there are ECA for the respective WPS, CONTRACTOR shall also verify, control, and record the external misalignment in production welds for those WPS to guarantee that the value of the external misalignment used for the

SCF (stress concentration factor) calculation is not overpassed. The frequency of verification and record shall be the same adopted for internal misalignment.

6.15.3 *[C.7.2.7]* The weld area shall be heated to the minimum preheat temperature specified in the WPS. Pre-heating shall also be performed whenever moisture is present or may condense in the weld area. Specific requirements for preheating in items 4.9.2, 4.9.3, and 4.9.4 of N-133 are mandatory. Both contact thermometer and temperature sticks are acceptable for measuring pre heat and maximum interpass temperatures of production welds, different devices are not acceptable. (MR)

6.15.4 *[C.7.2.12]* Before the beginning of the welding works, the electrical ground system shall be presented to COMPANY representatives when it shall be demonstrated that it is suitable and appropriate to avoid arc burns. (AR)

6.15.5 *[C.7.2.16]* Arc burns shall be repaired by mechanical removal of affected base material followed by NDT to verify absence of cracks and ultrasonic wall thickness measurements to verify that the remaining material thickness is not below the minimum allowed including expected corrosion allowance, according to the respective technical specifications. After grinding, chemical etching with a suitable solution, according to ASTM E407 and capable to confirm the complete removal of the heat affected area shall be carried out. Any affected area shall be removed or otherwise the whole cylinder shall be removed at CONTRACTOR's expenses. (MR)

Repair Welding, General Requirements

6.15.6 *[C.7.3]* The following are applicable regarding repair and re-repair: (AR)

a) Repaired areas shall be examined by the same AUT configuration of the original weld bevel to confirm the removal of the flaw. A second AUT scan shall be done with an adequate configuration for the repair bevel to detect size and evaluate the indications above threshold when ECA criteria are mandatory. Where workmanship is valid, MUT may be performed instead and ToFD shall be used to improve detectability.

b) CR and RSR shall be qualified separately. It is not acceptable to use a qualified CR procedure for internally repairing the internal weld surface. In case of need in production to enter inside a large diameter pipe to make the repair in the internal weld surface, this special position shall be realistically simulated during the welding procedure qualification process.

c) It is not acceptable to make a TTR in the same area of a reproved PPR weld and vice-versa.

d) It is not acceptable to make a PPR in the same area of a reproved TTR weld.

e) It is acceptable to make a PPR in the same area of a reproved CR, only if the CR is completely removed, including all the HAZ, excavating 3 mm further in depth and in both sides of the width, before the PPR.

f) It is acceptable to make a BTR and a CR in the same weld location, unless for lower thickness if they affect each other.

g) If CONTRACTOR intends to use a weld repair type different from those predicted in Table C-8 of Appendix C of this standard, they shall be qualified separately, and CONTRACTOR shall formally submit the complete proposal for COMPANY approval.

h) To allow the PPRR, i.e., the re-repair in the PPR weld, all the following requirements shall be fulfilled during production:

i. During the first repair, the excavation depth shall be measured and registered in the center of the excavation and at least in two other points equally spaced from the center of the excavation in each of both directions. In the absence of the records of the depth of first excavation the second repair is not allowed.

ii. Before the second excavation, the cap width shall be measured and registered in the center of the excavation and at least in two other points equally spaced from the center of the excavation in each of both directions.

iii. The excavation area of the second repair shall be in such way that guarantees the complete removal of the first repair weld (HAZ and Weld Metal), removing 3 mm further in depth and in both sides of the width based on the first repair excavation register.

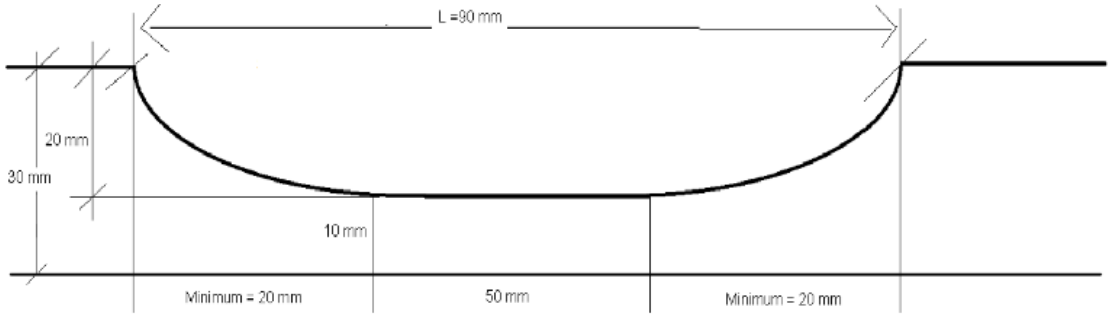
iv. There is no concern about the final excavation length of PPRR compared with the length of the PPR.

i) Regarding the allowed types of weld repairs of Table C-8, for risers, all the weld repair types depending on agreement (i.e., where the table is filled with “if agreed”) shall be considered “not permitted”. For any pipeline or riser, TTRR, CRR and BTRR shall be considered “not permitted”. BTR in clad welds are not permitted.

6.15.7 *[C.7.3.9]* A local weld repair shall be at least 50 mm long or 4 times the material thickness, whichever is longest. In case the resultant length is greater than 100 mm (i.e., for thickness equal or greater than 25 mm), it is acceptable to define the minimum total repair length as the sum of 50 mm in the excavation bottom plus the respective taper lengths, if the taper is made in compliance of clause C.7.3.10 of DNV-ST-F101: appendix C and item 6.15.8 below. A length at the bottom of the excavation of 50 mm is also acceptable if the taper required in C.7.3.10 gives adequate access for welding. As a reminder, for discontinuities longer than 50 mm, the excavation will be greater since the entire defect shall be removed. (MR)

6.15.8 *[C.7.3.10]* Regarding the minimum length of each welding repair excavation, it is acceptable to adopt a minimum length of 50 mm for CR if the entire defect is removed. Arc gouging is not acceptable to make the excavation for CR. For TTR, PPR and PPRR, and as per item 6.15.7, 50mm length at the bottom of excavation is

acceptable, providing tapers are performed with adequate access for welding at both ends of the excavation. Tapers will be considered as adequate access for welding if each taper length is equal or greater than the total equivalent excavation depth, in both sides. See Figure 12-1 just for illustration. (AR)



Base material thickness = 30 mm; excavation depth = 20 mm, minimum taper shall be 20 mm at each side

Figure 12-1 - Minimum repair length.

Production welding

6.15.9 *[C.7.5]* Heat Input of production welds of partly mechanized manual welds shall be monitored, recorded, and controlled as following: heat input of all welds root, hot and reinforcement passes shall be recorded; heat input of at least one pass of each filling layers, strip and cap shall be recorded in case there is no significant width variation between the passes of the respective layer, in case there are passes with different width in the respective layer, then they shall be recorded. The first five production welds and the first production weld for different welders shall be fully recorded. If data loggers are not used for production welds, the welding parameters of the instruments used shall be previously compared with the welding parameters provided by the data loggers used during WPQT. (AR)

6.15.10 *[C.7.5]* Heat Input of production welds of partly mechanized manual welds shall be monitored, recorded and controlled according to item 6.15.9 above independently for each welder side when two or more welders are used in the respective production weld and they are carrying out different sides or parts of the pipe. (AR)

6.15.11 *[C.7.5]* Heat Input of production welds of mechanized or automatic welds shall be monitored, recorded, and controlled as following: the heat input of the first five production welds shall be fully recorded; the heat input at least two girth welds per shift (no longer than 12 hours) shall be fully recorded for all different production lines (i.e., independent double joint lines, AST lines, firelines, mainlines, independent stalk lines, etc.). In case any recorded production weld heat input is out of the qualified range, production shall be stopped, and welding control shall be reevaluated until all parameters are again according to the WPQT and the respective recorded production weld shall be considered rejected. (AR)

6.15.12 *[C.7.5]* After linepipe beveling, the "out of squareness at pipe end" shall be monitored to avoid the introduction of angular misalignment at line-up. The acceptance criteria shall be based on the linepipe dimensional requirements. (AR)

6.15.13 *[C.7.5.10]* Details of line-up clamps to be used shall be included in the welding philosophy document. Clamping method shall be suitable to achieve the required maximum hi-lo. (AR)

6.15.14 *[C.7.5.11]* Internal line-up clamps shall not be removed until the root pass is completed in the whole circumference. (AR)

6.15.15 *[C.7.5.15]* If a pipe is to be cut for any reason, the cut shall be at a minimum distance of 25 mm from the weld toe. It is acceptable to cut less than 25 mm providing a cut procedure is issued and approved by COMPANY (It may be part of the content of the "welding philosophy document), where it shall be established that a scratch all around 360º of the pipe circumference will be carried out, in such a way that this scratch can be only extinguished by mechanical tools (i.e., ink marks are not acceptable). After the cut, the full scratch shall have disappeared, and at least two macrographs, one at 180º from other, shall document that the entire HAZ has been removed. In no circumstance cuts with less than 10 mm from the weld toe will be accepted. (MR)

Repair welding

6.15.16 *[C.7.5.19]* Additionally, it is not allowable to perform a through thickness repair welding procedure in this location. A PPR is permitted but it shall have a remaining ligament size of at least 6.3 mm. (AR)

Production tests

6.15.17 *[C.7.5.25]* For production test of the 2G welding procedure for the J-Lay tower, pup-pieces made from the same pipe may be welded at the same welding station using the same welding equipment, procedure, and consumable batch of the pipeline/riser instead of cutting a production weld. (AR)

6.15.18 *[C.7.5.26]* Production tests are required only for the main welding procedures specifications (including different positions and pipe to buckle arrestor if existent). Production tests shall be done according to the following frequencies and rules: (AR)

a) For pipeline projects where the pipeline extension to be welded with a specific WPS is shorter or equal to 50 kilometers: one complete set of production tests shall be carried out in the first week of production for each applicable specific WPS.

b) For pipeline projects where the pipeline extension to be welded with a specific WPS is longer than 50 kilometers: a first complete set of production tests shall be carried out in the first week of production; a second complete set of production tests shall be carried out between 35% and 45% of completeness of the total pipeline extension. Both sets of production tests shall apply for each applicable specific WPS.

c) For riser projects, one complete set of production tests shall be carried out in the first week of production for each type of riser.

d) Referring to pipeline or riser components, WPS of J-lay collars to pipe and buckle arrestors to pipe shall always be tested. Only assembly welds of pipeline components of reduced number in the pipeline project, i.e.; less than five, may be exempt from production tests.

6.15.19 *[C.7.5.27]* Production tests are not required for tie in welds, flange welds, Tee-piece welds, repair welds, flexible joint first weld, etc. (MR)

Welding and PWHT of pipeline components

6.15.20 *[C.7.6]* When buttering layers are necessary, buttering layers of medium carbon low alloy steels, e.g., AISI 8630/4130 or ASTM A182 F22 steel, shall be made with low carbon low alloy steel filler metal prior to PWHT and girth welding. Buttering using nickel-based alloy filler metal is prohibited to avoid failures under cathodic protection. The following requirements shall be also complied with:

a) Welding Procedure Specification and Qualification Plan, including buttering sequence, weld parameters, and post weld heat treatment parameters shall be submitted to COMPANY for approval.

b) A standard 30° bevel for buttered ends shall be used.

c) Charpy testing is always required. Notch locations for Charpy impact tests shall include low carbon low alloy steel weld metal and fusion line of dissimilar interfaces.

d) Hardness tests shall be performed by using the Vickers method with a load of 10 kgf/cm2 (HV10). Hardness test profiles shall be in accordance with Figure B-10, Appendix B of DNV-ST-F101. Maximum allowed hardness values are: (i) for carbon steel and low alloys subject or not to sour service, maximum hardness shall be limited to 250 HV10 at the root and filler metal and 275 HV10 at the face; (ii) for overlays of nickel-based alloys, maximum acceptable hardness is 345 HV10.

e) The requirements of NACE MR0175/ISO 15156 parts 1 and 2 when the material is designed to withstand to SSC regions 1, 2 and 3 of figure 1 of NACE MR0175/ISO-15156-2.

f) Each specific design regarding the minimum mechanical properties required.

6.16 MATERIAL AND PROCESS SPECIFIC REQUIREMENTS

6.16.1 *[C.8]* For the purpose of welding alloy UNS N06625 clad or lined girth welds, the WPQT program shall have demonstrated, during visual inspection, the absence of inacceptable levels of coloration (according to the acceptance criteria of annexes A and B of Norsok M-601) in the root due to failure in purging system simulating 1000 PPM or more of oxygen content. The respective welding coupon shall be approved in ASTM G48 test and chemical analysis according to the conditions of item 6.8.1. For Production welds maximum oxygen content shall be 1000 ppm, monitored by oxygen analyzer. Alarm level shall be set at 500 ppm and welding shall be interrupted if 1000 ppm is exceeded. Production welds accidentally overpassing

1000 ppm shall be cut out unless oxygen level can be recorded and stays below the level qualified during WPQT (limited to 2000 ppm). Gas purging shall be maintained up to the completion of at least 6.3 mm thickness. (AR)

6.16.2 *[C.8]* For clad, liners and overlay welding, welding consumables shall be according to alloy UNS N06625. It is not allowed to deposit ferritic deposit over austenitic material. The chemical composition of the filler metal shall be selected so that the corrosion resistance of the deposited weld metal matches or exceeds that of the cladding of pipe body. (AR)

6.16.3 *[C.8]* In weld overlays, samples shall be extracted at a distance from the fusion line not greater than the clad/liner minimum thickness minus 0.5 mm. In girth welds, samples shall be extracted at a distance from internal surface after root ground flush of at least 0.5 mm. (AR)

Production

6.16.4 *[C.8.1.6]* Welding of clad/lined carbon steel and duplex stainless steel may be performed by the welding processes listed in item 6.1.2. The welding shall be double sided whenever possible. Welding of the root pass in single sided joints shall require welding with Gas Tungsten Arc Welding (GTAW/141) or Gas Metal Arc Welding (GMAW/135) Welding of the root run of girth welds shall be executed by SCC-GMAW (GMAW with short circuit control) or GTAW welding process, but the use of manual GTAW shall comply with item 6.1.3. (MR)

6.16.5 *[C.8.1.7]* For Welding of CRA parts with alloy UNS N06625, contamination tests shall be conducted in the components to be girth welded in case of suspicious of iron contamination. The contamination tests shall be based in a *Ferroxyl* test as per ASTM A380. In case of iron contamination detected, the contaminated area shall be eliminated by suitable methods, approved by Company. (AR)

6.16.6 *[C.8.1.7]* Provided that Carbon Steel tools shall not be used for CRA parts, CONTRACTOR shall propose material to do not contaminate the CRA layer. The following additional requirements shall be applied to CRA sections, to avoid contamination of CRA layer: (AR)

a) Onshore fabrication of clad, lined or overlay sections 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, lined or overlay sections fabrication, Company will send a team of authorized employees to Contractor fabrication facilities before the start of activities to evaluate the conditions provided by Contractor, to avoid contamination of CRA section with Carbon Steel. Contractor shall, at its own costs, execute any modification required by Company for CRA riser fabrication.

c) Contractor 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 approved by Company. Care shall be taken to avoid C-Mn exposition to pickling, especially the contact zone between CRA and C-Mn layer.

d) When required by this Technical Specification, the pickling solution to be applied shall fulfill the requirements of clause C.6.1, Table A.A1 of ASTM G1.

e) Linepipe ends shall be protected by end cap until the beveling moment. The end cap shall be replaced in linepipe end if the time between beveling and welding be higher than one hour.

6.16.7 *[C.8.1.8]* The weld bevel shall be prepared by milling or other agreed machining methods. The weld bevel and the internal and external pipe surface up to a distance of at least 25 mm from the bevels shall be thoroughly cleaned with an organic solvent. For welding process with gas protection, a minimum of 25 mm at both sides of the bevel, in the internal and in the external surfaces, shall be prepared at white metal (i.e., free from rust and scale). (MR)

6.16.8 *[C.8.1.13]* The interpass temperature shall be measured directly where a weld run will start and terminate. The weld zone shall be kept below the maximum interpass temperature before a welding run is started. The maximum interpass temperature shall not exceed the values of Table 12-2. Acceptance criteria of microstructural analysis shall be as per item C.6.3.17 of DNV-ST-F101: appendix C, no micro cracking at HAZ, fusion line and weld metal are allowed. (MR)

6.16.9 *[C.8.1.14]* Burrs, mechanical damage or laminations on the weld bevel shall be cut and re-beveled. The internal diameter at the re-prepared bevel shall be measured in accordance with procedure previously approved by COMPANY. (AR)

Table 12-2 - Maximum allowable interpass temperature for nickel alloy CRA.

Parent Material	Weld type - consumable	Maximum Interpass Temperature (ºC)
Full thickness nickel alloy CRA - no PWHT and for root and hot pass of girth welds of clad, lined and overlay - no PWHT.	Girth welds – nickel alloy weld consumable	150
Full thickness nickel alloy CRA – with solution annealing and for root and hot pass of girth welds of clad, lined and overlay – with solution annealing	Girth welds – nickel alloy weld consumable	defined during the WPQT
Filling and cap pass of partial thickness nickel alloy CRA. E.g.: nickel alloy based clad or lined linepipes, linepipes with internal nickel alloy weld overlay, forged steel with nickel alloy weld overlay, etc.	Girth welds and longitudinal welds – nickel alloy weld consumable	350 for GTAW and GMAW, 250 for SAW
C-Mn or low alloy steel	Weld Overlay – nickel alloy weld consumable	defined during the WPQT

7 CHANGES IN APPENDIX D OF DNV-ST-F101

7.1 NON-DESTRUCTIVE TESTING

General

7.1.1 *[D.1.1]* COMPANY reserves the right to reject any weld which, in its opinion, lacks good industrial practices. (AR)

Applicability of Requirements

7.1.2 *[D.1.2]* In cases when NDT performance is not made according to COMPANY or code requirements, their result may imply in the approval of rejectable discontinuities. In such cases of doubt or non-confidence in the NDT performance, COMPANY may require, at CONTRACTOR's expenses, additional inspection of welds to assist in discontinuities evaluation NDT performance is under "suspecting". (AR)

Quality Assurance

7.1.3 *[D.1.3]* In addition, requirements of “DIRETRIZ CONTRATUAL PARA GESTÃO DA QUALIDADE” and N-2941 shall be complied with. (AR)

Timing of NDT

7.1.4 *[D.1.6.1]* (DR)

7.1.5 *[D.1.6.2]* NDT of welds fabricated onshore and respective repairs of pipeline components shall not be performed until 24 hours has elapsed since completion of welding, unless those girth welds produced onshore complies with the same requirements of DNV-ST-F101 and this specification, including requirements to avoid cold cracking. (MR)

7.2 MANUAL NON-DESTRUCTIVE TESTING AND VISUAL EXAMINATION OF WELDS

General

7.2.1 *[D.2.1.1]* Visual examination of welds shall be performed in compliance ASME BPVC Sec V and N-133. (MR)

Radiographic Testing of Welds

7.2.2 *[D.2.2.1]* Effective focal spot size of X-Ray systems should be determined according to EN 12543-1 to 5, for the purpose of source-to-object distance calculation. (AR)

7.2.3 *[D.2.2.2]* Whenever possible, panoramic X-ray (single wall single image) shall be adopted for girth welds. Use of radioactive isotopes (gamma rays) requires COMPANY formal approval. In case panoramic exposition is not feasible, SWSI is required. (AR)

Manual Ultrasonic Testing of Welds

7.2.4 [*D.2.3.30]* In addition to straight beam probe minimum three angle probes of 45°, 60° and 70° shall be used for testing regardless of weld thickness and groove type. (MR).

7.2.5 Table D-2 (DR)

Guidance Note: *Ultrasonic tandem technique shall be used for weld bevel angle less than 15°. Two separate angle probes are used, and the most favorable sound beam angle, which covers the area in question, is selected. (Item 6.8.1.1 of DNV-CG-0051).*

7.2.6 *[D.2.3.38]* All indications equal to or exceeding 20% of the reference curve shall be evaluated. The indications shall be investigated by maximizing the echoes by rotating the probes and by using different angle probes with DAC established according to according to [D.2.3.23] and [D.2.3.24]. (MR)

7.2.7 *[D.2.3.39]* The length of an indication shall be determined by 6 dB drop technique performed at the extremities of the discontinuity. (MR)

Reporting

7.2.8 *[D.2.3.41]* Indications exceeding 50% of the reference curve are to be reported with exception of indications having length L > t (thickness) for which a recording level of 20% shall be applied. (AR)

Manual Magnetic Particle Testing of Welds

7.2.9 *[D.2.5]* A tangential magnetic field strength of 1.7 kA/m to 6.5 kA/m (RMS) is required. (AR)

7.2.10 *[D.2.5]* Coating Thickness Measurement: The maximum paint/coating/contrast film thickness permitted is 25 µm. (AR)

7.2.11 *[D.2.5.3]* Magnetic particle testing procedure shall also include the sketches of the testing technique adopted (yoke positioning, pole distance and overlapping). (AR)

Magnetism Equipment

7.2.12 *[D.2.5.8]* Only alternating current (AC) electromagnetic yokes are permitted. (MR)

Manual Liquid Penetrant Testing of Welds

7.2.13 *[D.2.6.1]* In the receiving inspection of liquid penetrant materials, it is required to perform sensitivity tests at a temperature within the range qualified in the procedure to check if the test sensitivity, as defined in the procedure, has been maintained. This sensitivity test shall be performed as stated above in accordance with the parameters described in the procedure. (AR)

7.2.14 *[D.2.6.2]* Liquid penetrant testing shall be applied only in circumstances when there is restricted access to MT, on non-ferromagnetic materials or materials with great variation in magnetic permeability. (MR)

7.2.15 *[D.2.6.4]* The written procedure shall also include: the method of excess PT removal; drying method and time before application of developer; the method and maximum timing for application of developer. (AR)

7.2.16 *[D.2.6.5]* It may be acceptable to carry out PT with penetration time lower than 15 minutes if the applicable range of temperature is qualified for the respective penetration time. The PT performance shall be covered by the tested temperature range for such periods. Any PT temperature out of the tested range or any penetration time lower than the tested period will not be acceptable. (AR)

7.2.17 *[D.2.6.6]* Outside the temperature range from 15°C to 35°C, the performance demonstration of a PT procedure shall be carried out as following. The proposed procedure shall be applied to block "B" after this block and all materials have been cooled and held at the proposed examination lower temperature limit until the comparison is completed. A standard procedure which has previously been demonstrated as suitable for use (required sensitivity level is achieved) shall be applied to block "A" in the specified temperature range: (AR)

a) The indications of cracks shall be compared between blocks "A" and "B." If the indications obtained under the proposed conditions on block "B" are essentially the same as obtained on block "A" during examination at 15°C to 35°C, the proposed procedure shall be considered qualified for use. A procedure qualified at a temperature lower than 10°C shall be qualified from that temperature to 10°C.

b) If the proposed temperature for the examination is above 35°C, block "B" shall be held at this temperature throughout the examination (the comparator block only shall be held at this temperature). The indications of cracks shall

be compared as described above while block "B" is at the proposed temperature and block "A" is at the 15°C to 35°C temperature range.

c) To qualify a procedure for temperatures above 50°C, the upper and lower temperature limits shall be established, and the procedure qualified at these temperatures. As an example, to qualify a procedure for the temperature range 35°C to 93°C, the capability of a penetrant to reveal indications on the comparator shall be demonstrated at both temperatures.

d) As an alternative to the requirements described above, when using color contrast penetrants, it is permissible to use a single comparator block for the standard and nonstandard temperatures and to make the comparison by photography. When the single comparator block and photographic technique is used, the processing details (as applicable) described above apply. The block shall be thoroughly cleaned between the two processing steps. Photographs shall be taken after processing at the nonstandard temperature and then after processing at the standard temperature. The indication of cracks shall be compared between the two photographs. The same criteria for qualification as described above shall apply. Identical photographic techniques shall be used to make the comparison photographs.

e) Procedure Qualification / Performance Demonstration shall fulfill the requirements above and it shall be performed using a PT comparator block in accordance with ISO 3452-3. The minimum sensitivity level shall be the detection of 100% of indications of the 10 µm comparator block for Type I Penetrant Materials - Fluorescent PT or the detection of 100% of indications of the 30 µm comparator block for Type II Penetrant Materials - Visible PT.

Visual Examination of Welds

7.2.18 *[D.2.8.1]* Visual examination of welds shall be performed in accordance with an acceptable Visual Examination Procedure previously submitted for Company and approved, and it shall comply with PETROBRAS standard N-1597 and article 9 of ASME BPVC section V or ISO 17637. The minimum light intensity shall be according to article 9 of ASME BPVC section V. (MR)

7.3 ACCEPTANCE CRITERIA FOR WELDS WITH NOMINAL STRAINS < 0.4% AND NO ECA

7.3.1 *[Table D-4 – bullet referring to Visual Examination of root concavities]* "Length of root concavity shall not to exceed 25% of total length of weld. Depth not to exceed 10% of pipe thickness or 1.5 mm, whichever is the smaller, but at no point shall the weld, including cap reinforcement, be thinner than pipe thickness". (MR)

7.3.2 *[Table D-4 – only for Visual Examination of Root penetration]* For pipelines, pipeline components, risers, risers components, pipeline sections or risers sections designed to survive to fatigue life based in curves more stringent than curve F1 (such as E or D) of DNV-RP-C203 for internal surface or more stringent than curve D for external surface of DNV-RP-C203, the root penetration criteria shall be replaced by: "Not to exceed 3 mm or 0.2t for any length." (AR)

7.3.3 *[Table D-4 – only for Visual Examination of Burn through]* Not permitted for welds in duplex stainless steel, CRAs and clad/lined steel. Burn through will be acceptable for welds in C-Mn and low alloy steels if weld thickness at no point is less than t and: (i) individual length / width equal to 1 mm in any dimension; (ii) accumulated length in any 300 mm length of weld equal to 2 mm (MR)

7.3.4 *[D.2.9.1]* The acceptance criteria given in Table D-4, Table D-5, and Table D-6, are applicable for nondestructive testing of welds exposed to nominal strains < 0.4%, for fatigue non-sensitive welds, and/or for environments that does not promote hydrogen assisted cracking. If it is predicted that an operational corrosion fatigue (H_2S or CO_2 effects in conjunction with fatigue) may invalid those criteria (workmanship criteria) of the respective pipeline, or if it is defined by a specific project document, an ECA shall be carried out according to I-ET-0000.00-0000-200-P9U-005, to establish the girth weld acceptance criteria. When ECA is not a requirement according to this item, CONTRACTOR has the alternative to utilize the ECA, if strictly according to I-ET- 0000.00-0000-200-P9U-005. (MR)

7.3.5 *[D.2.9.1]* Acceptance levels of girth weld discontinuities of Appendix D DNV-ST-F101 are considered valid for all pipeline or riser components not subject to fatigue during installation and operation, neither to nominal strains ≥ 0.4% (AR)

7.3.6 *[D.2.9.3]* For welds where the maximum longitudinal strain is not greater than 0.4%, and radiographic test is the primary NDT and the weld passes are not assumed to be less than 3 mm, clause D.2.9.3 of DNV-ST-F101: appendix D shall be applied in conjunction with computerized ultrasonic inspection for determination of the height sizing. (AR)

7.4 ECA BASED NON-DESTRUCTIVE TESTING ACCEPTANCE CRITERIA FOR PIPELINE GIRTH WELDS

7.4.1 *[D.2.10.2]* All requirements of technical specification I-ET-0000.00-0000-210-P9U-005 shall be complied with in addition to item 5.4.8 of DNV-ST-F101. (AR)

7.4.2 *[D.2.10.3]* If acceptance criteria for weld defects are based on an ECA and hence involves sizing of indication height and lengths, automated ultrasonic testing according to appendix E shall be performed. (MR)

7.5 WELD OVERLAY

7.5.1 *[D.3.3]* For fatigue sensitive sections, weld overlay shall be 100% volumetric NDT for surface and embedded flaws by phased-array ultrasonic testing (PAUT) or film/digital radiographic testing (RT/DRT). Procedure shall be qualified according to APPENDIX B or C, accordingly. (AR)

7.5.2 *[D.3.3]* Internal machining between layers shall be performed if supplier is not able to demonstrate that volumetric NDT can reliably detect and size flaws according to item 7.5.1. After each internal layer machining DPI shall be carried out. DPI acceptance criteria shall be in accordance with item D.8.11.5 of DNV-ST-F101. (AR)

7.5.3 *[D.3.3]* Bonding imperfections may be inspected in conjunction with PAUT. (MR)

8 CHANGES IN APPENDIX E OF DNV-ST-F101

8.1 APPLICABILITY

8.1.1 *[E.1.2.2]* For carbon steel, zonal discrimination technique is preferred. Different approaches may be proposed during tendering phase if there is a substantial amount of data to evaluate AUT system capability for the intended application (pre-qualification).

8.2 BASIC REQUIREMENTS

8.2.1 *[E.2.1.3]* Reflectors shall be distributed along the thickness of calibration block in such a way that no blind spots are left. No gaps are acceptable between cap and fills zones and root and first fill zone. (AR)

8.2.2 *[E.2.1.10]* AUT systems normally have limited accuracy for ligament sizing of near surface embedded flaws due to thickness variations. If ligament sizing error is not considered, embedded flaws detected by surface channel (cap/root) and not detected by the adjacent below channel shall be re-categorized as surface breaking flaw and the equivalent size of the re-categorized flaw shall be equivalent to the smaller between the AUT surface channel zone height and 1.5 times the flaw height. (AR)

8.2.3 *[E.2.1.14]* The signal to noise ratio between evaluation threshold and the structural noise of the CRA material in the weld area shall be minimum 6 dB. In any case the acoustical equivalent noise shall not exceed the smallest allowable defect height (ECA). (MR)

8.3 TRANSDUCERS SET-UP

8.3.1 *[E.2.4.10]* For zonal discrimination, at least 5% of overtrace shall be demonstrated between the last root and first fill zone since hot pass bevel angle normally shift from fusion line. (MR)

8.4 CALIBRATION (REFERENCE) BLOCKS

8.4.1 *[E.2.5.4]* For zone discrimination, additional surface channels may be used to improve ligament sizing of near surface flaws, but surface notches shall lie between 1 and 3mm. Smaller FBH may also be required for improved sensitivity, i.e., stringent acceptance criteria, etc. (AR)

8.4.2 *[E.2.5.10]* Radiographic testing shall be performed on AUT calibration blocks after reference reflectors machining to assist the dimensional verification. (AR)

8.5 OPERATORS

8.5.1 *[E.2.12.2]* AUT operators performing interpretation shall also comply with qualification and certification requirements of N-2941. Additionally, the inspectors shall be qualified and certified by the Level 3 Professional of the CONTRACTOR or

INSPECTION SUB-CONTRACTOR for the specific AUT system that will be used for inspection of production welds. CONTRACTOR or INSPECTION SUB-CONTRACTOR shall provide a qualification and certification procedure for their inspectors and shall maintain evidence of qualification exams and certification of their inspectors. The documents shall be made available for COMPANY before the start of production. (AR)

8.5.2 *[E.2.12.5]* AUT shall be supervised by a Level 3 Professional. Level 3 shall be qualified as per item 8.5.1 of this specification. For offshore activities, Level 3 supervision may be done remotely if a Level 2 supervisor is available (24/7) at the vessel. Level 3 shall issue a bi-weekly report containing the review of AUT files by sampling plus the rejected welds. Sampling shall be agreed based on total number of welds per shift, but it shall not be less than five welds. Systemic misinterpretations shall be corrected in the applicable procedures. AUT files reviewed shall be attached to the report. All AUT reports shall be signed by the Level 2 Supervisor. (AR)

8.6 PROCEDURE

8.6.1 *[E.3.1.2]* The AUT procedure shall be qualified and approved by a Level 3 Professional with documented training/certification in the automated ultrasonic examination technique (e.g., Phased Array, ToFD). (AR)

8.7 THRESHOLD LEVEL

8.7.1 *[E.4.3.1]* Evaluation threshold shall not be set lower than 6dB above the structural noise level to avoid excessive weld cut-out due to false calls. Exception is made for phased array sectorial scans used to improve detection and evaluation of flaws in CRA welds. (AR)

8.7.2 *[E.4.5.6]* It shall be demonstrated an adequate signal-to-noise ratio with the AUT setup selected for inspection. The noise level shall be minimum 6 dB below evaluation threshold at the target area for each channel or focal law, unless a different level is specified (MR)

8.8 FIELD INSPECTION

8.8.1 *[E.5.1.8]* For other types of welds than those listed, the frequency of scan may be reduced to a minimum of 1 scan for each 2 consecutive welds to allow re-scanning before coating if required. (MR)

8.9 WORKMANSHIP ACCEPTANCE CRITERIA

8.9.1 *[E.5.4.1]* If ECA is not required in project documents, weld quality requirements of Tables E-2 shall be adopted. Welds may be considered as “non-fatigue sensitive” if it is demonstrated that the accumulated fatigue crack growth for a 3x25mm flaw is below 0.2 mm for all relevant cyclic loads at a specific zone or for the entire pipeline (risers excluded) during the whole lifetime. In this case, Tables E-1 may be applicable.

8.10 EVALUATION AND REPORT

8.10.1 *[E.7.3.3]* CONTRACTOR shall provide with no expenses three licenses of the most recent viewer software, including activation hard key if not freeware, that is fully compatible with the operational system adopted by COMPANY. The software shall permit viewing and analysis of AUT data files and shall be provided with the user's manual. CONTRACTOR may optionally provide to COMPANY, without any extra cost, free viewer software compatible with the inspection data for further evaluation of the inspection records. Additional training shall not be considered herein with respect to AUT viewer software. (MR)

8.10.2 *[E.7.3.3]* The AUT native files shall be available at any time for retrieval and review. At the end of the project, all AUT 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. (AR)

8.11 QUALIFICATION

8.11.1 *[E.8.1]* AUT system qualification shall be approved by COMPANY. CONTRACTOR shall submit a qualification/validation plan containing the steps to be followed by COMPANY, that shall be notified four weeks in advance to witness the whole process. AUT systems previously qualified without COMPANY witnessing may become acceptable if witnessed and qualified by DNV. In this case, the qualification report shall be submitted for COMPANY review and approval. When a new qualification is required, historical qualification data may be used to reduce the scope of qualification at COMPANY's discretion. (AR)

8.11.2 *[E.8.4]* When ECA derived acceptance criteria is adopted, the smallest allowed height shall be based on the analysis of a full circumferential flaw, or at least long enough to be insensitive to length. Both internal and external surface shall be assessed to validate PoD/PoR. (AR)

8.11.3 *[E.8.7.1]* Machined imperfection techniques are not acceptable. All flaws shall be induced by the welding process itself, artificial flaws induced by for example shims or EDM are not allowable. CONTRACTOR shall submit weld defect maps for COMPANY's approval. (AR)

8.11.4 *[E.8.7.5]* Radiographic testing shall be performed in seeded defective welds. Detection ability and length sizing shall be compared to AUT. (AR)

8.11.5 *[E.8.9.7 third bullet]* To accommodate small positioning and/or machining errors during cross sectioning, at least two measurements not spaced more than 2 mm from each other shall be taken before and after each marked defect peak. Only the highest measurements obtained from the macro sectioning shall be taken for the statistics. (AR)

8.11.6 *[E.8.10.3]* The normality of sizing error shall be assessed. Outliers shall be investigated. (AR)

8.11.7 *[E.8.10.4]* ASTM E2862 shall be considered for preliminary analysis of data, convergence, and informal reliability assessment of PoD/PoR models. (MR)

8.11.8 *[E.8.11.1]* AUT Qualification/Validation report shall be prepared and approved by a level 3 ultrasonic inspector, and shall also include the following (AR):

a) Calibration certificates of AUT unit, probes, and wedges.

b) Calibration blocks dimensional and velocity checks.

c) NDT Written Procedures and inspection reports (RT, MUT and AUT).

d) Previous AUT Qualification Program Report, including reliability data and macro.

e) Comparison between RT, MUT and AUT length sizing.

f) Evaluation of signal-to-noise ratio for each channel/focal law.

g) Resumed reliability data from previous projects (if applicable).

h) Macro sectioning report.

i) Personnel certification and training.

j) Executive summary with a clear indication of PoD/PoR and uncertainty of the AUT system.

8.12 PROJECT SPECIFIC AUT PROCEDURE VALIDATION

8.12.1 *[E.8.1.1]* Project specific AUT procedure validation shall always be performed for previously qualified and approved AUT systems. The minimum number of defects shall not be less than 29 for fatigue sensitive welds and/or girth welds exposed to nominal strains equal or higher than 0.4%, or 12 for girth weld exposed to nominal strain lower than 0.4%. Additional 12 defects are required for the highest and for the lowest thickness when wall thickness variation is large than specified in clause E.2.1.7 of DNV-ST-F101: Appendix E, and/or for different nominal thicknesses. A different strategy may be proposed based on JIP Risk Based AUT Qualification (DNV JIP 2022-4049 Rev. 0), subjected to COMPANY agreement. (MR)

8.12.2 *[E.9.2.3]* If qualification data does not include at least ten observations below the proposed threshold and above noise level, this shall be included in the validation scope and PoD calculation shall be reviewed (AR).

8.12.3 *[E.9.2.5 to 9.2.7]* In addition, the validation shall include: (AR)

a) Temperature sensitivity according to paragraph [E.8.10.2] shall be repeated if hardware is modified (probes, cables, scanner, coupling, etc.).

b) Comparison between AUT x RT x MUT to verify the location and length of the indications and AUT x Macro to verify the height and depth sizing.

8.12.4 *[E.9.2.9]* Sizing error obtained during validation shall not be treated apart from pre-qualified results for the purpose of undersize correction of ECA based acceptance criteria. (AR)

APPENDIX A

REQUIREMENTS FOR FATIGUE FULL SCALE TESTING

A.1. When required in project design basis or any other project document, fatigue full scale testing shall be carried out as part of WPQT of riser welds.

A.2. CONTRACTOR shall fulfill the following minimum number of specimens to be tested: 9 welds per WPS to be qualified, being 3 welds per stress range, with a total of 3 stress ranges tested. For C-Mn and clad pipes, fatigue string may have 3 girth welds positioned along the pipe length. A minimum distance of 500 mm shall be kept between adjacent welded girth joints. For lined pipes, more than one girth weld may be included in the same string if the pup pieces are representative of the MLP ends and are provided by the same MLP supplier.

A.3. Prior to the start of testing, CONTRACTOR shall submit a detailed fatigue testing program for COMPANY approval. The fatigue testing program shall conform to the minimum requirements detailed in this appendix.

A.4. The full-scale fatigue test is considered as a part of WPQT. The WPS shall only be considered qualified if all full-scale specimens are fatigue tested and achieved the required target life. Production welding shall not commence until WPQT is finished.

A.5. The following items shall be considered in full scale fatigue test procedure:

A.5.1 The quality of the girth welds /pieces to be tested (including misalignment close to the acceptance criteria) shall be representative of, but not better than, actual production welds. The specimens shall be tested using the resonance fatigue testing method. The specimen design shall be determined by the girth weld/pipe dimensions and shall be approved by the COMPANY.

A.5.2 All specimens shall be inspected with AUT prior to testing. The test specimens shall meet the proposed AUT acceptance criteria. The AUT acceptance criteria shall be based in ECA analysis or, alternatively, by typical values of similar projects if approved by COMPANY. For testing, it is not permitted to select specimens with smaller acceptable indications or fewer indications than other specimens that meet the weld acceptance criteria. The inspection records for the test specimens shall be submitted to COMPANY for approval prior to testing.

A.5.3 Strain gauges shall be used to measure the nominal mean stress and stress range. The strain gauges shall be placed around the circumference on pipe OD at a minimum of eight positions equally spaced. CONTRACTOR shall mark the 12 o'clock position on the girth weld. The center of the strain gauges shall be located one wall thickness from the toe of the girth weld.

A.5.4 Fatigue tests shall be conducted with either uniaxial tension or internal pressure to induce a constant mean stress during the test. The mean stress shall be either, the average mean stress experienced in service or that due to the operating pressure, whichever is the greater.

A.5.5 Fatigue tests shall be performed at three stress ranges, high, medium, and low. The number of specimens to be tested for each stress range shall be in accordance with specific project documents. Nominal stress ranges should be selected to achieve fatigue lives in the range 10^5 to 10^7 cycles, e.g., 180 MPa, 130 MPa and 80 MPa in ID.

A.5.6 Fatigue tests shall be performed until failure occurs or the specimen achieves the run-out condition (twice the number of cycles required to achieve the target). The number of cycles to failure shall be recorded. "Failure" shall be defined as:

a) through-wall cracking of the pipe or girth weld for C-Mn section.

b) through-wall cracking of the pipe or girth weld for CRA section, when flaws were detected to propagate from the external to internal diameter.

c) entire CRA wall cracking of the pipe or girth weld for CRA section, when flaws were detected to propagate from the internal to external diameter or, in the specific case of lined pipe, from the transition point between liner, C-Mn backing steel and clad weld.

A.5.7 All welds, failed or not, shall be removed from the test specimens allowing a minimum of 200 mm clearance from the girth weld. All welds shall then undergo a postmortem examination. This shall consist of measurements of the wall thickness and internal hi-lo at the strain gauge locations and failure location. These measurements shall be used to calculate the stress concentration factor (SCF) at these locations and allow calculation of the local stress range at the failure.

A.5.8 For risers to be installed by reel-lay method, all the specimens to be tested shall be submitted to full scale bending cycles (representative strain level as specified per design) prior to fatigue full scale tests. The number of simulated reeling/ unreeling cycles shall be representative of reel-lay spooling and installation/contingency methodology.

A.5.9 To calculate the number of cycles required to achieve the target S-N curve, it is necessary to adopt a statistic procedure to guarantee 95% confidence level and 97,7% probability of surveillance (two standard deviations) to define the target number of cycles for each stress range, considering the number of tests. The weld with the lower stresses shall govern the test duration. The statistical procedure to define the target number of cycles for each stress range shall be submitted for PETROBRAS approval. It is recommended to consider TWI Best Practice Guide on Statistical Analysis of Fatigue Data, by Schneider, C. and Maddox, S. (2006) and section E.2.2 of BS-7608. When fatigue design curve is defined using BS-7608, target life shall derive from it, otherwise it shall be derived from DNV-RP-C203.

A.6. When specified in project design basis or any other project document, dependent on the fatigue demand, ground-flush methods are required to remove the weld reinforcement, for all riser production welds or for some specific riser sections, the same ground-flush methods and procedures shall be reproduced in the fatigue string welds to be submitted to full-scale fatigue tests.

APPENDIX B

PAUT PROCEDURE PERFORMANCE DEMONSTRATION FOR WELD OVERLAY

B.1. Inspection of CRA weld overlay is challenging and it was 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.

B.2. PAUT systems shall comply with the requirements of DNV-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 approval. PETROBRAS shall be notified four weeks in advance to witness the whole qualification process.

B.3. 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%l95% or PoR 85%l95%) 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 for lowest and/or highest thickness.

B.4. All test coupons shall be inspected by DPI, MUT and RT (SWSI/film inside). All indications detected by these methods and not detected by PAUT shall be investigated with macro. Radiography shall comply with ISO 17636-1 or 2. At least one additional single wire IQI shall be viewed in addition to the minimum image quality values specified. During production, a length of 100mm on each pipe end shall be inspected by radiography if coverage cannot be demonstrated.

B.5. 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%l95% and/or PoR 85%l95% of the PAUT system.

B.6. 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.

B.7. In addition to personnel certification requirements, all inspectors shall be trained by the Level 3 Professional responsible for the PAUT procedure.