| PETROBRAS | TECHNICAL SPECIFICATION | N°. I-ET-3010.00-1200-900-P4X-001 |
|---|---|---|
| | CLIENT: | SHEET: 1 of 11 |
| | JOB: | |
| | AREA: | |
| SRGE | TITLE: **ADDITIONAL REQUIREMENTS FOR SOUR SERVICE 3.5% NICKEL STEEL** | INTERNAL |
| | | ESUP |

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| DATE | SEP/22/22 | | | | | | | | |
| DESIGN | EEA | | | | | | | | |
| EXECUTION | ASWG | | | | | | | | |
| CHECK | CJH4 | | | | | | | | |
| APPROVAL | U32N | | | | | | | | |

# SUMMARY

# 1 SCOPE

This specification establishes practices for base metal, welding qualification and production welding of 3.5% nickel steels to be used in offshore oil production units.

# 2 NORMATIVE REFERENCES

All equipment shall comply with the requirements of this technical specification and references stated below. All equipment parts and details not complying with any of these requirements shall be informed on a “Deviation List”. Otherwise, they will be considered as “Agreed”, and so required.

As a general guideline, in case of conflicting requirements between this technical specification and other cited references, the most stringent shall prevail. If necessary, the SELLER may revert to BUYER for clarification.

## 2.1 CLASSIFICATION

SELLER shall perform the work in accordance with the requirements of Classification Society.

SELLER is responsible for submitting to the Classification Society all documentation in compliance with stated Rules.

## 2.2 PETROBRAS

I-ET-3010.00-1200-955-P4X-001
*Welding*

I-ET-3010.00-1200-940-P4X-002
*General Technical Terms*

## 2.3 ASTM – AMERICAN SOCIETY FOR TESTING AND MATERIALS

A203
*Specification for Pressure Vessel Plates, Alloy Steel, Nickel*

A333
*Standard Specification for Seamless and Welded Steel Pipe for Low-Temperature Service and other Applications with Required Notch Toughness*

A420
*Standard Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Low-Temperature Service*

A350
*Specification for Carbon and Low-Alloy Steel Forgings, Requiring Notch Toughness Testing for Piping Components*

A765
*Specification for Carbon Steel and Low-Alloy Steel Pressure-Vessel - Component Forgings with Mandatory Toughness Requirements*

A1038
*Standard Test Method for Portable Hardness Testing by the Ultrasonic Contact Impedance Method*

## 2.4 ASME – AMERICAN SOCIETY OF MECHANICAL ENGINEERS

ASME Boiler and Pressure Vessel Code
*Section IX – Welding and Brazing Qualification*

## 2.5 DIN - DEUTSCHES INSTITUT FÜR NORMUNG

DIN 50159
*Metallic Materials - Hardness Testing with the UCI Method*

## 2.6 AWS – AMERICAN WELDING SOCIETY

AWS A5.5
*Specification for Low-Alloy Steel Electrodes for Shielded Metal Arc Welding*

AWS A5.11
*Specification for Nickel and Nickel-Alloy Welding Electrodes for Shielded Metal Arc Welding*

AWS A5.14
*Specifications for Nickel and Nickel - Alloy Bare Welding Electrodes and Rods*

AWS A5.23
*Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding*

AWS A5.28
*Specification for Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding*

AWS A5.34
*Specification for Nickel-Alloy Flux Cored and Metal Cored Welding Electrodes*

## 2.7 NACE – NATIONAL ASSOCIATION OF CORROSION ENGINEERS

NACE TM 0177
*Laboratory Testing of Metals for Resistance to Sulfide Stress Cracking and Stress Corrosion Cracking in H2S Environments*

## 2.8 ISO – INTERNATIONAL ORGANIZATION FOR STANDARDIZATION

ISO 15156 Parts 1, 2 and 3
*Petroleum and Natural Gas Industries - Materials for Use in H2S Containing Environments in Oil and Gas Production*

ISO 7539-2
*Corrosion of Metals and Alloys – Stress Corrosion Testing – Part 2: Preparation and Use of Bent-beam Specimens*

## 2.9 CONFLICTING REQUIREMENTS

2.9.1 In case of conflicting information between this Specification (ET) and other specific BUYER document (data sheet), the specific BUYER document shall prevail.

2.9.2 In all cases of conflict between this specification and applicable documents listed herein, the more stringent requirements shall prevail. In such cases, SELLER shall inform BUYER of the conflict and seek clarification.

# 3 DEFINITIONS AND ABREVIATIONS

## 3.1 DEFINITIONS

All Terms and definitions are established in the latest revision I-ET-3010.00-1200-940-P4X-002 - GENERAL TECHNICAL TERMS.

## 3.2 ABBREVIATIONS

| | | |
|---|---|---|
| SSC | - | Sulphide Stress Corrosion |
| SMAW | - | Shilded Metal Arc Welding |
| GTAW | - | Gas Tungsten Arc Welding |
| GMAW | - | Gas Metal Arc Welding |
| SAW | - | Submerged Arc Welding |
| FCAW | - | Fluxed-core Arc Welding |
| PTP | - | Production Testing Plans |
| PWHT | - | Post Weld Heat Treatment |
| HAZ | - | Heat Affected Zone |

# 4 GENERAL REQUIREMENTS

## 4.1 BASE METAL

4.1.1 Nickel steels with a nickel content of 3.5 % complying with the material specification indicated by the design standard of the equipment. The material specification shall be as per ASTM A765 Gr.III, ASTM A203 Gr.D, ASTM A350 Gr.LF3, ASTM A333 Gr.3 and ASTM A420 Gr.WPL3. These steels are considered “P number” 9B according to ASME BPVC Section IX. For the supply of these materials, contractor shall perform SSC (Sulphide Stress Corrosion) tests according to ANNEX A of this technical specification. The SSC test is also a requirement to welding qualification joints.

4.1.2 For better welding results, low temperature toughness values and good results in the SSC tests, the chemical composition shall meet the standard requirements, except for the elements given in Table 1, whose contents are more stringent, based in the development expertise for using this material in the presalt project conditions.

**Table 1 – Chemical Composition (wt% - maximum)**

| | C | Mn | P | S | Si |
|---|---|---|---|---|---|
| **ASTM A203 Gr.D** | 0.10 (0.07(1)) | 0.70 | 0.010 | 0.005 | 0.25 |
| **ASTM A333 Gr.3** | | | | | |
| **ASTM A350 Gr.LF3** | | | | | |
| **ASTM A420 Gr.WPL3** | | | | | |
| **ASTM A765 Gr.III** | | | | | |

NOTE (1): Recommended carbon content based on previous project.

4.1.3 Due to the metallurgical properties, this material presents higher capacity of magnetization, compared to carbon steel. Extra care shall be taken during the weld procedures, especially in the root welding. Demagnetization or cancellation of the magnetic field in some cases may be required before welding to prevent magnetic arc blow, especially in small diameter tubes, connections, and small thickness.

4.1.4 When the raw material had been previous tempered, any further post heat treatment shall be performed at least 30 °C lower than the previous tempered temperature of the base material.

## 4.2 IMPACT REQUIREMENTS

4.2.1 The impact tests (Charpy V-notch) shall meet the requirements of the applicable standards, including the minimum temperature at -100°C and impact tests on weld metal and heat affected zone for welded joints.

4.2.2 The minimum individual and the minimum average values of the energy shall be in accordance with the material specification.

## 4.3 WELDING CONSUMABLES

4.3.1 The 3.5% nickel steels are welded using nickel-based welding filler metals and the consumables shall follow the indicated below, according to Table 2.

4.3.2 Consumable brand shall be considered essential variable.

**Table 2 – Electrodes and Rods for 3.5% Nickel Steel**

| Welding Process | AWS Specification | AWS Classification | |
|---|---|---|---|
| | | Preferred | Alternative(1) |
| **SMAW** | A5.5<br>A5.11 | E801X-C2 | ENiCrMo-3<br>ENiCrFe-2<br>ENiCrFe-3 |
| **GMAW / GTAW** | A5.28<br>A5.14 | ER80S-Ni3 | ERNiCr-3 |
| **SAW** | A5.23<br>A5.14 | EBNi3 | ERNiCr-3 |
| **FCAW** | A5.34 | ENiCrMo-3 | |

NOTE (1): These consumables shall be used when the welded joint is subjected to temperatures close to the lower limit allowed for the base material.

## 4.4 WELDING TECHNIQUE

4.4.1 Nickel steels alloys and especially those with high nickel content, such as 3.5% Ni, shows a relatively adherent oxide layer which shall be removed before the start of welding.

4.4.2 For better welding results and good results in the SSC tests, it is recommended to adopt a maximum heat input of 2.0 kJ/mm; with the submerged arc welding process, it should be lower than 2.5 kJ/mm. Additionally, it should not be used low heat input due to temper bead welding.

4.4.3 The heat input shall not exceed the range approved on the qualified welding procedure. The heat input shall be monitored during production welding.

4.4.4 The oscillation of the electrode shall be such that the pass width does not exceed 3 times the covered electrode's core diameter.

4.4.5 Additional care shall be taken for cleaning and preparation of the joint to be welded so as to avoid the presence of contaminants.

4.4.6 Slag shall be completely removed during and after welding.

4.4.7 In order to prevent high hardness at the HAZ, it is recommended to finish the welding pass in the center of the groove, grinding the corners of bead.

4.4.8 Production testing shall be performed for this material, including at least the mechanical tests and hardness measurement. A Production Testing Plans (PTP) shall be elaborate by contractor and approved by BUYER.

## 4.5 APPLICABLE WELDING PROCESSES

4.5.1 The SMAW, GTAW, GMAW, FCAW and SAW processes are permitted. Other processes may be applied upon previous approval of BUYER. All welded joints shall be performed using GTAW process in the root and at least 6.4 mm of the weld metal is completed.

### 4.5.2 SMAW

a) The coating shall be basic and have a maximum diffusible hydrogen of H8;

b) Root welding by SMAW process is not permitted;

c) The oscillation of the electrode shall be such that the pass width does not exceed three times the coated electrode core diameter.

### 4.5.3 GTAW

a) The shielding gas of the purge shall be argon, helium or a mixture of these gases;

b) The purge of the root shall be maintained until the 2nd weld layer or 6.4 mm, whichever is thicker;

c) Only this welding process is allowed for the root passes (roots pass and root reinforcement) up to 6.4 mm.

### 4.5.4 GMAW

a) Additional care shall be taken for overhead position using solid wires due low wettability of the filler metal NiCr-3.

### 4.5.5 SAW

a) The flux shall be neutral or basic, it is not permitted the presence of alloying elements, and it shall contain a level H8 for maximum diffusible hydrogen;

b) Special care shall be given to the flux regarding the contamination risk by dirt and moisture.

### 4.5.6 FCAW

a) The FCAW process is permitted only with shielding gas (FCAW-G);

b) The FCAW-S process (self-shielded, flux-cored) is not permitted;

c) Especial attention shall be taken for toughness results for this welds made with this welding process;

d) The consumable shall be acquired according to AWS A5.01, Schedule J.

### 4.6 PREHEATING AND INTERPASS TEMPERATURE

4.6.1 Preheating and maximum interpass temperatures shall be 150 and 230 °C, respectively.

### 4.7 POST-HEATING

4.7.1 It is not required, unless it involves plates thicker than 50 mm. In this case, it is recommended the post-heating at 150 °C, with 1 minute per mm of thickness.

### 4.8 POST WELD HEAT TREATMENT (PWHT)

4.8.1 PWHT shall always be performed on welding procedure qualification and on production welds. PWHT parameters shall be as prescribed in the design code.

4.8.2 Welding procedure qualification shall always include two PWHT conditions, as follows:

- Minimum PWHT soak time, as predicted in the design code.
- Maximum PWHT soak time, equivalent to at least twice the soak time predicted in the design code.

4.8.3 Mechanical tests, including hardness, shall be performed on both conditions (minimum and maximum PWHT soak time). Where sour service is applicable, the SSC test shall be performed also in both heat treatment conditions.

### 4.9 WELD REPAIR

4.9.1 No more than two repairs shall be done on the same region of the weld metal and HAZ.

4.9.2 All weld repairs shall be performed using a qualified welding procedure, evidencing that the additional thermal cycle, when required, does not affect the toughness and the good results in the SSC tests of the joint.

4.9.3 The repair shall be performed using multiple passes, looking for the tempering of previous passes, regardless if the part will be subject to PWHT. The welding shall always look for the tempering of the coarse grain region of previous passes and HAZ.

### 4.10 WELDING INSPECTION

4.10.1 In addition with the contractual requirements the following stated below shall be performed:

a) The liquid penetrant test shall be performed on root pass in pipe welding;

b) The liquid penetrant testing to the extent specified in the standard of the equipment shall be performed on the outside and inside of the weld when there is access;

c) The visual test shall be performed 100 % on the root pass;

d) Preferably should be used "phased array" ultrassonic method instead in of X-ray.

## 4.11 HARDNESS CONTROL

4.11.1 Hardness control is mandatory in welding qualification and production welding joints. A “qualified welding joint” is one which has been approved by all mechanical tests required by project code, in addition to the SSC tests.

4.11.2 In qualification welding joints, the hardness control must be done in according to ISO 15156:2 (Hardness surveys for welding procedure qualification).

4.11.3 Each qualified WPS will have a respective hardness limit. Due to there is no hardness upper limit defined by project code, this limit depends on the approval mechanical tests and SSC test, i.e., the higher hardness found in qualifying joint (typically in the HAZ of the root and weld cap) is regarded as the upper limit.

4.11.4 In production welding joints, the hardness control shall be done using portable instruments according to the UCI method (Ultrasonic Contact Impedance standardized according to ASTM A 1038 and DIN 50159).

4.11.5 When the root of the production welding is inaccessible, the hardness limit shall be measured externally in HAZ and set as the maximum hardness found on the same region of qualified welding joint plus 5%.

# ANNEX A

Stress Corrosion Cracking test methodology for 3.5% Ni steels material qualification and weld procedure qualification

## A1. Sulfide Stress Corrosion Test Procedure – SSC

A1.1. SSC test is mandatory and shall be carried out in welding procedure qualification and base material qualification.

A1.2. Room temperature during test must be controlled at 25°C during the whole test period.

A1.3. The test solution and conditions shall be as per indicated below in Table 3.

**Table 3 – The test solution and conditions**

| Description | Reference |
|---|---|
| Total pressure | 100 bara |
| Temperature | 40°C |
| CO2 content | 99.9% |
| H2S content | 0.1% |
| Estimated pH | 3.05 |
| fH2S | 45 mbara (0.65 psia) |

Notes:
(1) Deionized water with 1 g/L NaCl (only)
(2) It is important that the test is performed with continuous bubbling, because the corrosion processes consume H2S in aqueous solution, which is a very reactive species

A1.4. For welding procedure qualification, the SSC test shall be carried out according to NACE TM0316.

A1.5. Preferably, test specimens for longitudinal welds in seam pipes must be in accordance with NACE TM0177 type C. Four-point bend specimens (FPB) can be used according to NACE TM0316, subject to BUYER Surveyors' approval (recommended at least one inch thickness or full thickness of the pipe sample).

A1.6. For girth welds, the samples must be four-point bend specimens (FPB) according to NACE TM0316 (recommended at least five millimeters thickness or full thickness of the sample).

A1.7. For forged materials, the testing must be carried out using tensile test specimens (UT) according to NACE TM0177 type A (Table 4). Standard tensile specimen size is recommended.

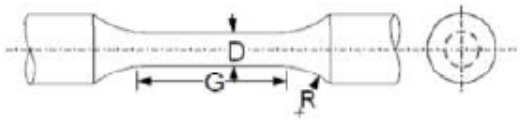
A1.8. The test shall be carried out using load stress of the 80% SMYS (Specified Minimum Yield Strength) of the base material. For this procedure, may be considered as Specified Minimum Yield Strength the requirement of respective materials standards.

A1.9. For girth welds samples, the FBP samples shall be machined removing the weld root from the internal surface of the weld joint, until obtain surface parallel in the sample. No more than 1mm should be machined from the internal surface of the sample.

A1.10. It is recommended to soft grind the edges of the samples to avoid the stress concentration.

**Table 4 – Dimensions for tensile test specimens**

| Dimension | Standard tensile test specimen | Subsize tensile test specimen |
|---|---|---|
| D | 6,35 ± 0,13mm (0,250 ± 0,005in) | 3,81 ± 0,05mm (0,150 ± 0.002in) |
| G | 25,4mm (1,00in) | 15mm (0,60in) |
| R (min.) | 15mm (0,60in) | 15mm (0,60in) |




A1.11. Recommended specimen's dimensions for the FPB samples: 115 mm x 15 mm x 5 mm (minimum for FPB specimens), as shown in Figure 1.

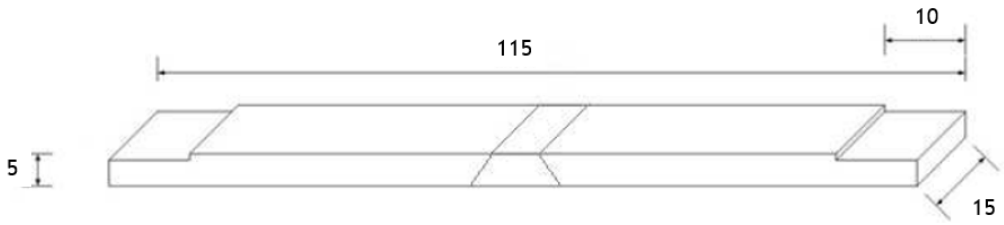



**Figure 1 – Recommended four-point bend (FPB) specimens**

A1.12. All SSC test must be carried out using three (3) specimens for each WPQ or material qualification.

A1.13. A visual survey with 10X magnification must be carried out at the end of the test (720h). No cracks are allowed in any specimen for the test to be approved.

A1.14. When just one specimen fails, retest is allowed using two (2) other specimens from the same WPQR welded joint or material batch. If both retested samples are approved in visual according the previous criteria, then SSC test can be considered approved.

A1.15. Only one retest is allowed per test qualification.