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CENPES	TITLE: ADDITIONAL REQUIREMENTS FOR H_2 SERVICE		

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INDEX OF REVISIONS

REV.	DESCRIPTION AND/OR REVISED SHEETS
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CHECK	*BRUNO*								
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1 PURPOSE

To establish the minimum requirements to designing, fabrication and inspection of pressure vessels defined as in H_2 (hydrogen) service.

This specification is a part of basic design of the equipments. So this specification presents requirements for the equipments, and its materials. The complete description of the equipment manufacturing will be part of manufacturing design, to be presented by manufacturer to PETROBRAS representative approval.

The requirements outlined in this specification are intended for safety, quality and job records but shall not be considered as preventing the Manufacturer from making additional tests or inspections to set up or improve shop procedures which will result in a satisfactory equipment.

The Manufacturer must show the quality control system which will applied in the manufacture of the equipments, and it must have the applicable stamp of ASME Code Section VIII.

It shall be the responsibility of the equipment Manufacturer to comply with the PETROBRAS regulations as applicable. In no case shall this specification be used to supersede, delete or reduce applicable Code requirements.

Any conflict between this specification, drawings, codes, etc…, shall be brought to the attention of PETROBRAS representative in writing for clarification, prior to any action by the Manufacturer. The more stringent requirements shall govern until written resolution is provided by PETROBRAS.

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2 SUPPLEMENTARY STANDARDS AND ABBREVIATIONS

2.1 – Supplementary Standards

ASME Boiler and Pressure Vessel Code, Sections II, V, VIII and IX

ASTM Material Standards

API standard:

API Publ 941 – Steels for Hydrogen Service at Elevated Temperatures and Pressures in Petroleum Refineries and Petrochemical Plants – 4th ed. – 1990

NACE standard:

RP0472 – Methods and Controls to Prevent In-service Environmental cracking of Carbon Steel Weldments in Corrosive Petroleum Refining Environments

CEN standards:

EN-473 – Qualification and Certification of Nondestructive Testing Personnel – General Principles

EN-45013 – General Criteria for Certification Bodies Operating Certification of Personnel

ISO standard:

ISO 9712 – Nondestructive Testing – Qualification and Certification of Personnel

ABENDE standards:

NA-001 – Personnel Qualification and Certification in Nondestructive Testing – ABENDE Standard No. 01

DC-001 – Personnel Qualification and Certification in Nondestructive Testing – Complementary Document No. 001

2.2 – Abbreviations

ABENDE – Associação Brasileira de Ensaios Não-Destrutivos (Brazilian Association of Nondestructive Testing)

API – American Petroleum Institute

ASME – American Society of Mechanical Engineers

ASTM – American Society for Testing and Materials

CE – Equivalent Carbon

CEN – Comité Européen de Normalisation (European Comitee for Standardization)

ISO – International Organization for Standardization

MT – Magnetic Particle Examination

NACE – National Association of Corrosion Engineers

NDE – Nondestructive Examination

PT – Liquid Penetrant Examination

PWHT – Postweld Heat Treatment

RT – Radiographic Examination

SAW – Submerged Arc Welding

SNQC-END – Sistema Nacional de Qualificação e Certificação de Pessoal em Ensaios Não Destrutivos (Brazilian National System of Qualification and Certification of Personnel in NDE)

UT – Ultrasonic Examination

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2.3 – Definitions of terms

Heat (of steel) - means all necessary events to produce a component that will be used in any part of the equipment (including steelmaking practice, component manufacturing process, etc)

Test coupon - a piece removed from plates (or forging) and used to obtain the test specimen.

Test specimen - a sample removed from the test coupon, for a specific test.

3 MATERIALS

3.1 – Requirements for Carbon Steels

3.1.1 - Process of manufacture:

Plates shall be supplied in fully killed and normalized condition.
The steel shall be vacuum degassed.

3.1.2 - Chemical analysis:

a) Plates:

Referenced materials: ASME SA-515/516 Gr.60 CE = 0.41% (max)
ASME SA-515/516 Gr.70 CE = 0.45% (max)

where Equivalent Carbon:

$$CE = C + Mn/6 + (Cr + Mo + V)/5 + (Cu + Ni)/15$$

The composition and mechanical requirements shall be according to ASME SA-515/516 and ASTM A 20 prescriptions, followed by the additional requirements:

S = 0.005% max
P = 0.020% max (target value = 0.010%)
Al = 0.055% max

b) Forgings, Pipes and Tubes:

According to ASTM SA-105, ASTM SA-106, ASTM SA-234, ASTM SA-266 and ASTM A 20 prescriptions, followed by the additional requirements:

C = 0.30% max
CE = 0.45% max
S = 0.015% max
P = 0.025% max

All forgings shall be manufactured by hot forming, or hot forming and normalized.

3.2 – Requirements for Low Alloy Steels (Cr-Mo)

3.2.1 - Base material: plates for shell

All plates for pressure retaining parts to be used for the fabrication of the equipment shall comply with basic requirements of ASME Sec II SA-387 Gr.22 Cl. 2 or SA-387 Gr.11 Cl.1 or Cl. 2 (where applicable) and shall be specifically manufactured by the steelmaker in order to achieve the following additional requirements.

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a.) – Steelmaking Practice / Heat Treatment

Plates shall be made by vacuum degassed steel process.

With regard to toughness, or guaranteed creep values, accelerated cooling from the austenitizing temperature by air blasting or liquid quenching followed by tempering conform Item 5 from ASTM SA-387, will be permitted, providing that it ensures homogeneous structure through the thickness.

b) – Chemical analysis

Chemical analysis shall conform to ASME SA-387 Gr. 11 or Gr. 22 specifications but, when the operating temperature of components exceeds 350°C, for 2 1/4Cr -1Mo the ***J-***factor shall be verified as follows:

$$\boldsymbol{J} = (Si + Mn)\times(P + Sn)\times 10^4 = 100 \text{ max. (target value: 80)}$$

For 1 1/4Cr – 1/2Mo base material the *J*-factor shall be calculated as below:

$$\boldsymbol{J} = (Si + Mn)\times(P + Sn)\times 10^4 = 220 \text{ max. (target value: 180)}$$

Furthermore nitrogen, oxygen and hydrogen content shall be reported only for information.

All elements mentioned hereabove shall be checked on ladle and on product and clearly recorded in CMTR.

c) – Material properties

The plate manufacturer shall guarantee that the minimum physical properties specified are fully achieved on completion of the equipments. For this purpose, **test coupons shall be removed from most segregate zone of the thickest product/component of each *heat (of steel)* supplied** and be subjected to a simulated heat treatment which shall include all the heat treatments planned during the fabrication of the equipments plus one extra PWHT to anticipate any additional welding repairs on site. This extra PWHT, to be performed by PETROBRAS in future, will have the same requirements (holding time at soaking temperature, etc) of PWHT executed during fabrication. **The Manufacturer shall provide a report showing that material is qualified for all allowed heat treatments (including the extra PWHT)**.
Note: For plate thicknesses above 55mm the most segregated zone is the ½ t. For thicknesses below 55mm, test coupons shall be taken from ¼ t.

In addition to the provisions of the applicable ASME Sec II SA specification material, the following material and mechanical properties shall be required on test coupons having received all simulated heat treatments described above.

Impact tests: for each heat (of steel), one set of three charpy V-notch impact tests, in accordance with ASTM A 370, transverse specimens, shall be done with the fracture plane parallel to the direction of maximum grain flow, at ¼ t for plate thickness below 55mm or at ½ t for plate thickness above 55mm.

The notch orientation, as defined by standard ASTM E-1823, shall be reported.

Tests shall be conducted at -18°C, for 1¼Cr-½Mo, and -30ºC, for 2¼Cr-1Mo, with the average value of 40 ft·lb (54 J) without individual value below 35 ft·lb (47 J). Lateral expansion in mils and per cent shear fracture shall be reported with impact test values.

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Tension tests: tensile properties shall be performed at design temperature and test specimens shall be taken at ¼ t for plate thickness below 55mm or at ½ t for plate thickness above 55mm of the plate thickness, and shall meet the values required by ASME Code Sections VIII and II, at design temperature. Tensile testing shall be carried out in accordance with ASTM A 370.

d) – Nondestructive Examination

All plates shall be ultrasonically tested in accordance with ASTM A 578 Level C and Supplementary Requirement S1.

e) – Marking

Each plate shall be marked in accordance with applicable Code requirements.

f) – Dimensional and Visual Examination

Undertolerance is not acceptable.

Surface finish conditions of plates according to Item 9 of ASTM A 20.

Unless otherwise agreed, repair of plate defects by welding is not allowed.

3.2.2 – Welding consumables

a) – General

Filler metal procurement, reception and acceptance shall be in accordance with the provisions of ASME Code Section II, Part C.

The vendor shall define the condition of treatment, storage, handling, use and control of welding consumables.

Each lot, diameter of covered electrodes and wire/flux combinations, shall be tested per Specifications SFA-5.5, SFA-5.23 and SFA-5.28, from ASME Code Section II, Part C. Dimensions of the test coupons shall be sufficient to allow:

a.1) All tests required by ASME Code Section II, Part C;

b.2) Following supplementary requirements (paragraph 3.2.2.b).

b) – Supplementary Requirements

Chemical analysis

Shall be in accordance with ASME Code Section II, Part C.

Temper embrittlement factor shall not exceed 15 ppm determined by Bruscato parameter relates to impurity elements:

$$X = (10P + 5Sb + 4Sn + As)/100 = 15 \text{ ppm max.}$$

Material properties

Mechanical characteristics shall be verified on test coupons having received all heat treatments and fabrication thermal cycles as described on item **3** (Materials).

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Impact test

For each lot of welding consumables, covered electrodes and wire flux combinations, one set of three charpy V-notch specimens shall be conducted at -18°C, for 1¼Cr-½Mo, and -30ºC, for 2¼Cr-1Mo,.

See Specifications SFA-5.5, SFA-5.23 and SFA-5.28, from ASME Code Section II, Part C, for location specimens for testing.

The average value of three specimens shall not be less than 40 ft·lb (54 J).

No single value of any specimen shall be less than 35 ft·lb (47 J).

4 FABRICATION

Together with the requirements below, all project and construction details from PETROBRAS standard N-1704 are valid.

4.1 – Vessel Connections

a) Threaded connections are prohibited.

b) All flanges shall be welding neck (WN) or long welding neck (LWN) type.

c) Small connections (dia. < 2 in.) shall be long welding neck (LWN) type.

d) Flange face finishings and gaskets: shall be according to correspondent piping specifications.

4.2 – Welding

a) All pressure joints shall be full penetration welds, extending through the entire section at the joint.

b) The weld shall be carried out with low hydrogen welding procedures.

c) Weld deposits (SAW) shall meet the A-No.1 chemical composition shown in Table QW-442 from Section IX of ASME Code.

Other welding processes (including temporary welds) shall meet the requirements of Item 2.2.5 of NACE RP 0472.

4.3 – Postweld Heat Treatment

The equipment shall receive PWHT as required by of ASME Code Section VIII, and applicable Code Cases. All carbon steel vessels shall be PWHT according to ASME Code at 620ºC minimum temperature, but not exceeding a maximum temperature of 640ºC.

The equipment manufacturer shall furnish data showing the total allowed number of hours at intermediate and final PWHT.

The total number of hours spent in all PWHT shall be reported.

This heat treatment procedure shall state:
- Temperature range;

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- Holding time at soaking temperature;
- Heating and cooling rates;
- Number and location of thermocouples;
- Calibration of thermocouple;
- Furnace type;
- Extent of heat treatment/sequences;

The final PWHT must be carry out in only one operation (integral manner).

The extra PWHT to be performed by PETROBRAS in future (if necessary) will have the same procedure of PWHT performed during fabrication.

5 NONDESTRUCTIVE EXAMINATION

5.1 –Qualification

5.1.1 – Procedures

The Manufacturer's NDE procedures shall be qualified by:

- A level 3 inspector, duly qualified by an independent international agency operating in conformity with the standard ISO 9712 (or EN-473) and meeting the requirements of the standard CEN EN-45013 Standard (in this case, the previous approval of PETROBRAS representative is required); **or**,
- A level 3 inspector certified by the SNQC-END of ABENDE.

5.1.2 – Personnel

The Manufacturer's NDE inspectors shall be qualified by

- An independent international agency operating in conformity with the standard ISO 9712 (or CEN EN-473 Standard) and meeting the requirements of the CEN EN-45013 Standard (in this case, the previous approval of PETROBRAS representative is required); **or**,
- The SNQC-END of ABENDE, in conformity with the NA-001 and DC-001 ABENDE standards.
- ASNT (for Level II and Level I personnel only inspectors qualified through the Central Certification Program (ACCP) – CP189)

5.2 –Ultrasonic Examination

a) All (UT) inspections shall be recorded in magnetic or optical means/system, and a copy of all records shall be handed over to PETROBRAS.

b) All plates ½ in. thickness and greater shall be UT tested according to ASTM A 578 with Supplementary Requirements S1 and S2.

c) All forgings 12 in. nominal bore diameter and greater shall be 100% UT, in accordance with ASTM A 388 with straight -beam and angle-beam techniques. For straight-beam examination the sensitivity shall be established by back reflection technique, and for angle-beam by a 60º V-notch. Rejection levels shall be as specified in applicable appendix of ASME Code Section VIII Division 1.

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d) Cold formed heads shall be UT tested when fiber elongation is 5% and greater.

e) All cladded plates shall be UT examined per ASTM A 578 with Supplementary Requirement S7.

f) All nozzles welds shall be UT tested before PWHT.
For nozzles with dia. ≤ 4 in. the Manufacturer shall present a procedure to PETROBRAS approval.
Rejection levels shall be as specified in Article 9-3 of ASME Code Section VIII Division 2, with the additional requirement:

Any group of aligned linear indications shall be considered **unacceptable** if at least one indication of this group has an individual amplitude greater than 50% of reference level and an aggregate length greater than " **t** " in a length of " **12 × t** ", except when the distance between the successive imperfections exceeds " **6 × L** "; where " **t** " is the thickness of the weld and " **L** " is the length of the longest imperfection in the group.

5.3 – Radiographic Examination

All butt welds joints shall be fully radiographed, according to the requirements of Section V from ASME Code. Acceptance criteria shall conform specified in UW-51 of ASME Code, Section VIII, Division 1.

5.4 – Magnetic Particle

After PWHT all welds shall be examined by wet fluorescent magnetic particle, included accessories and jig welds.

For examination of welds of non-magnetic steels, the magnetic particle test shall be changed by PT.

5.5 – Hardness Control of Welds

The minimum number of hardness determinations on completed welds shall be made according to Paragraph 3.5 of NACE RP 0472. Each determination shall be understood as at least one measurement in the weld metal and another one in the heat affected zone. Field hardness testers must be employed, except EQUOTIP.
Weld deposits shall be tested on the side contacted by the process whenever possible. If the access to the process side is impractical, testing shall be done on the opposite side.

- Carbon steel vessels after PWHT: 200 HB.
- Low-alloy steels after PWHT: 225 HB.

If a hardness reading above the maximum value specified is detected, the Manufacturer must:

– Report this hard weld to the purchaser, **and**,
– Perform three additional hardness tests in that area. If any value exceed the specified hardness, the weld must be rejected.

6 SERVICE INDICATION

All documents shall have the indication. **"H_2 SERVICE"**.

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