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	CLIENT: E&P		**SHEET:** 1 of 28
	JOB: E&P PRODUCTION		–
	AREA: SUBSEA INSTALLATIONS		NO SCALE / A4
SUB/ES	**TITLE:** **HIGH-STRENGTH LOW-ALLOY STEEL FASTENERS FOR SUBSEA APPLICATIONS**		PUBLIC
			EECE/EES

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REV.	DESCRIPTION AND/OR REVISED SHEET
0	This document is the English translation of the technical specification “ET-3000.00-1500-251-PEK-001_A” (Fixadores em aço baixa liga de alta resistência para aplicação submarina).
A	Included the definition of “exposed bolting” and the ASTM A453 Gr. 660D material in section 2.2.12. Revised reference documents in sections 3.2 and 3.3; and adjusted ‘Hydrogen Embrittlement Relief’ term in section 4.5.8. Included Annex II with additional requirements for “exposed boltings”.

	REV. 0	REV. A	REV. B	REV. C	REV. D	REV. E	REV. F	REV. G	REV. H
DATE	29/05/2020	16/01/2023							
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CHECK	U3DA	U3DA							
APPROVAL	UP65	UP65							

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1. INTRODUCTION

1.1. OBJECTIVE

1.1.1. The purpose of this Technical Specification is to establish minimum requirements for fabrication, inspection, testing, and procurement of high-strength low-alloy steel fasteners for subsea applications and subjected to cathodic protection.

1.1.2. This technical specification complements the requirements of ASTM A320 for fasteners, bolts, studs, and threaded bars, and the requirements of ASTM A194 for nuts.

1.2. SCOPE

1.2.1. This technical specification covers high-strength low-alloy steel fasteners (with yield strength equal or higher than 105 ksi) for subsea applications and subjected to cathodic protection, and shall be applied on all components, whether or not they assume pressure containment function, either to components to be delivered to PETROBRAS or to components necessary to execute any part relating to the scope of supply of the project.

1.2.2. This technical specification also shall be integrally applied to fasteners installed on the top connection of subsea risers (rigid, flexible and/or umbilical) with the Production Unit, even if the connection is located on a non-submerged region.

1.2.3. Fasteners to be installed on components and/or pieces of equipment with temporary use, and that are not part of the scope of supply contracted by PETROBRAS, and/or will not be supplied by PETROBRAS, are not covered by this technical specification. In this case, the high-strength low-alloy steel fasteners to be installed on these applications shall be supplied as per API SPEC 20E level BSL 2, and considering specifications ASTM A193 B7, ASTM A320 L7 or L43.

1.2.4. Fasteners in the “exposed bolting” design situation shall be made with alloy of the type CRA - ASTM A453 Grade 660 Class D, which shall follow the requirements of API SPEC 20F level BSL-3. The use of ASTM A320 L7M alloy fastener on components under thermal insulation/buried/confined will not be allowed. Annex II of this specification has additional mandatory requirements for exposed bolting fasteners as per ASTM A453.

1.3. GENERAL REQUIREMENTS

1.3.1. Alternatively to the requirements set forth throughout this technical specification, it is allowed to supply fasteners in accordance with API SPEC 20E level BSL-2, considering material specifications ASTM A320 Gr. L7 and Gr. L43, and ASTM 194 Gr. 4 and Gr. 7, provided that the additional requirements presented in Annex I have been complied accordingly.

1.3.2. CONTRACTOR shall assure the requirements listed in this technical specification will be followed by all parties involved in the procurement process of fasteners and/or components and pieces of equipment that include them.

2. TERMS AND DEFINITIONS

2.1. VERBAL FORMS

2.1.1. Following meanings shall be considered for the verbal forms used throughout this technical specification:

Shall: Mandatory requirement;
Should: Preferred requirement;
May: A permissible course of action;
Must not: Prohibited requirement.

2.2. DEFINITIONS

2.2.1. **High-strength low-alloy steel:** Low-alloy steel assuming specified minimum yield strength equal or higher than 105 ksi.

2.2.2. **Certification:** Third-party of a statement, based on a decision following review, that fulfillment of specified requirements related to products, processes, systems or personal has been demonstrated.

2.2.3. **CONTRACTOR:** Company directly awarded by PETROBRAS to supply components, pieces of equipment and/or full subsea installations. Provided that foreseen in the contract, the CONTRACTOR may award SUB-SUPPLIERS to deliver part of the contract scope. Depending on the situation, CONTRACTOR and SUB-SUPPLIER (or even the MANUFACTURER) may be the same entity.

2.2.4. **Temporary-use components:** Components or devices that are designated for use in the same campaign of installation and will be removed before the system starts operation, not remaining submerged.

2.2.5. **Third Party Certification:** Accredited independent organization that certifies and declares a product, service, person or system is in compliance with technical requirements specified.

2.2.6. **MANUFACTURER:** Company that fabricates fasteners and is responsible for the acquisition and traceability of the raw material, as well as the manufacture of threads.

2.2.7. **PURCHASER:** Company that purchases the fasteners and install them in their components, pieces of equipment and/or subsea installation.

2.2.8. **Fastener:** Generic name given to the set of bolts, studs and nuts. In this technical specification, the term fastener also includes threaded bars (such as trunnions for latching of subsea clamp connectors).

2.2.9. **Manufacturing batch:** Batch of fasteners from the same raw-material and manufactured with the same diameter and heat treatment regardless of the Purchase Order.

2.2.10. **Purchase Order:** Material supply request firmed between two (or more) of the following entities: PETROBRAS, CONTRACTOR, PURCHASER and MANUFACTURER.

2.2.11. **Material Requisition:** Document issued by PETROBRAS to define the scope of supply of components, pieces of equipment, installations and/or projects.

2.2.12. **Exposed Bolting:** are defined as bolts/fasteners capable of maintaining the tightness of internally pressurized equipment (pressure containing bolts/fasteners). These are bolts that can become “exposed” to a leak event from a pressurized connection under the following conditions: a) directly exposed to fluids (from production or injection) containing brines and

incoming gases (H_2S and/or CO_2); b) buried or immersed in marine mud (subsea mud); c) covered by thermal insulation or external seals. The presence of insulation, which will cover the sealing face of the connection, defines the condition of the fastener as “Exposed Bolting”. Pressure containing bolts that are close to the insulation and which inadvertently become covered by the insulation should also be considered “Exposed Bolting”.

2.3. ABBREVIATIONS

BSL	Bolting Specification Levels
CRA	*Corrosion Resistant Alloy*
TS	Test Specimen
NDT	Non-Destructive Testing
ET	Technical Specification
FAT	Factory Acceptance Tests
INMETRO	Brazilian National Institute of Metrology, Quality and Technology
LPI	Liquid Penetrant Inspection
MPS	Manufacturing Procedure Specification
NQA	Nível de Qualidade Aceitável “Acceptance Quality Level”
ITP	Inspection and Testing Plan
MPI	Magnetic Particle Inspection
RBC	Brazilian Calibration Network
RM	Material Requisition
MRR	Material Release Report
MDR	Material Discard Report

3. REFERENCE DOCUMENTS

3.1. REFERENCE DOCUMENTS AND DIVERGENCES

3.1.1. Reference documents listed on section 3.2 are mandatory for the application of this technical specification. Documents listed on section 3.3 are complementary.

3.1.2. For listed reference documents with specific edition and/or year of publication, only the version mentioned is applicable. For listed reference documents without edition and/or year of publication, the latest edition (including amendments) at the date of signature of the supply agreement shall be considered as applicable.

3.1.3. In case of divergence regarding the requirements established in this technical specification and the reference documents listed on it, the technical specification prevails.

3.1.4. If any technical deviation regarding this technical specification and/or the reference documents listed on it has been noted, it need to be submitted to PETROBRAS for formal clarification.

3.2. APPLICABLE REFERENCE STANDARDS AND CODES

Ref.	Standard/Code	Title	Ed.	Year
1	ABNT NBR 5426	*Planos de Amostragem e Procedimentos na Inspeção por Atributos*		
2	ABNT NBR ISO 9001	*Sistemas de Gestão da Qualidade – Requisitos*		
3	API SPEC 6A ISO 10423	Specification for Wellhead and Christmas Tree Equipment		
4	API SPEC 20E	Alloy and Carbon Steel Bolting for Use in the Petroleum and Natural Gas Industries		
5	ASME B18.2 series	Square and Hexagon Bolts and Nuts (inch and metric series)		
6	ASME B18.3 series	Socket Cap, Shoulder, and Set Screws, Hex and Spline Keys (inch and metric series)		
7	ASTM A194/ A194M	Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both		
8	ASTM A320/ A320M	Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for Low-Temperature Service		
9	ASTM A370	Standard Test Methods and Definitions for Mechanical Testing of Steel Products		
10	ASTM A751	Standard Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products		
11	ASTM A962/ A962M	Standard Specification for Common Requirements for Steel Fasteners or Fastener Materials, or Both, Intended for Use at Any Temperature from Cryogenic to the Creep Range		
12	ASTM B117	Standard Practice for Operating Salt Spray (Fog) Apparatus		
13	ASTM B201	Standard Practice for Testing Chromate Coatings on Zinc and Cadmium Surfaces		
14	ASTM B602	Standard Test Method for Attribute Sampling of Metallic and Inorganic Coatings		
15	ASTM B766	Standard Specification for Electrodeposited Coatings of Cadmium		
16	ASTM B841	Standard Specification for Electrodeposited Coatings of Zinc Nickel Alloy Deposits		
17	ASTM B850	Standard Guide for Post-Coating Treatments of Steel for Reducing Risk of Hydrogen Embrittlement		
18	ASTM D5894	Standard Practice for Cyclic Salt Fog/UV Exposure of Painted Metal, (Alternating Exposures in a Fog/Dry Cabinet and a UV/Condensation Cabinet)		

Ref.	Standard/Code	Title	Ed.	Year
19	ASTM D610	Standard Test Method for Evaluating Degree of Rusting on Painted Steel Surfaces		
20	ASTM E3	Standard Guide for Preparation of Metallographic Specimens		
21	ASTM E7	Standard Terminology Relating to Metallography		
22	ASTM E8	Standard Test Methods for Tension Testing of Metallic Materials		
23	ASTM E10	Standard Test Method for Brinell Hardness of Metallic Materials		
24	ASTM E18	Standard Test Methods for Rockwell Hardness of Metallic Materials		
25	ASTM E23	Standard Test Methods for Notched Bar Impact Testing of Metallic Materials		
26	ASTM E45	Standard Test Methods for Determining the Inclusion Content of Steel		
27	ASTM E112	Standard Test Methods for Determining Average Grain Size		
28	ASTM E140	Standard Hardness Conversion Tables for Metals Relationship Among Brinell Hardness, Vickers Hardness, Rockwell Hardness, Superficial Hardness, Knoop Hardness, and Scleroscope Hardness		
29	ASTM E381	Standard Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings		
30	ASTM E384	Standard Test Method for Microindentation Hardness of Materials		
31	ASTM E407	Standard Practice for Microetching Metals and Alloys		
32	ASTM E1268	Standard Practice for Assessing Degree of Banding or Orientation of Microstructure		
33	ASTM E1417/ E1417M	Standard Practice for Liquid Penetrant Testing		
34	ASTM E1444	Standard Practice for Magnetic Particle Testing		
35	ASTM F788	Standard Specification for Surface Discontinuities of Bolts, Screws, and Studs, Inch and Metric Series		
36	ASTM F812	Standard Specification for Surface Discontinuities of Nuts, Inch and Metric Series		
37	ASTM F2328	Standard Test Method for Determining Decarburization and Carburization in Hardened and Tempered Threaded Steel Bolts, Screws, Studs, and Nuts		
38	ISO 898-1	Mechanical Properties of Fasteners Made of Carbon Steel and Alloy Steel		

Ref.	Standard/Code	Title	Ed.	Year
39	ISO 2859-1	Sampling Procedures for Inspection by Attributes – Part 1: Sampling Schemes Indexed by Acceptance Quality Limit (AQL) for Lot-by-Lot Inspection		
40	ISO 9001	Quality Management Systems – Requirements		
41	ISO 17024	Conformity Assessment – General Requirements for Bodies Operating Certification of Persons		
42	ISO 17025	Conformity Assessment – General requirements for the competence of testing and calibration laboratories		

3.3. COMPLEMENTARY REFERENCE STANDARDS AND CODES

Ref.	Standard/Code	Title	Ed.	Year
43	ASTM E1823	Standard Terminology Relating to Fatigue and Fracture Testing		
44	API RP 17A/ ISO 13628-1	Design and Operation of Subsea Production Systems – General Requirements and Recommendations		
45	API SPEC 17D ISO 13628-4	Design and Operation of Subsea Production Systems – Subsea Wellhead and Christmas Tree Equipment		
46	API SPEC 17E ISO 13628-5	Specification for Subsea Umbilicals		
47	API SPEC 17J	Specification for Unbonded Flexible Pipe		
48	API RP 17P ISO 13628-15	Design and Operation of Subsea Production Systems – Subsea Structures and Manifolds		
49	ISO 17000	Conformity Assessment – Vocabulary and General Principles		
50	ET-0000.00-0000-972-1AL-001	Requisito Geral da qualidade de bens		
51	API SPEC 20F	Corrosion Resistant Bolting for Use in the Petroleum and Natural Gas Industries		

4. REQUIREMENTS FOR BOLTS, STUDS AND THREADED BARS

4.1. RAW-MATERIAL

4.1.1. Raw-material to be used for manufacturing of bolts, studs and threaded bars shall comply with the requirements of ASTM A320.

4.1.2. The minimum reduction ratio during the manufacturing process for forged or rolled steel shall be 4:1.

4.2. MECHANICAL PROPERTIES

4.2.1. Additionally to the requirements of specification ASTM A320, the fasteners material shall comply with the requirements presented in Table 1.

4.2.2. Other specifications of low-alloy steel proposed by the client engineering may be submitted for prior approval of PETROBRAS, provided that they meet the minimum requirements presented in Table 1.

4.3. MANUFACTURING

4.3.1. Prior to the manufacturing of the threads, the body of bolts, studs and threaded bars cannot be manufactured by cold forming.

4.3.2. Threads shall be manufactured by machining or rolling.

4.3.3. For bolts and studs in which the thread is made by rolling, the MANUFACTURER shall demonstrate to the PURCHASER that the manufacturing process is controlled and will not generate defects such as delamination and cracks, and excessive hardness, according to limits defined in Table 1.

4.3.4. Materials shall not be submitted to shear cutting, oxyacetylene cutting, laser or graphite electrode cutting.

4.3.5. Remanufacturing, reprocessing or complementary heat treatment are not permitted for fasteners that have been already manufactured.

Table 1: Material specifications for bolts, studs and threaded bars

Property	Diameter up to 2 ½" (65 mm)	Diameter up to 4" (100 mm)	Reference specification for testing
Class and Material Grade	Gr. L7 or Gr. L43	Gr. L43	ASTM A320
Chemical Composition	Maximum Phosphorus and Sulfur: 0.025%, as per API 20E class BSL-2		ASTM A751
Impact Testing	Average absorbed energy: 27 J (20 lbf.ft); and Individual minimum energy: 20 J (15 lbf.ft), tested at -101ºC		ASTM A370 ASTM A320
Specified Yield Strength (Tensile Testing)	Minimum: 105 ksi (725 MPa) Maximum: 138 ksi (950 MPa)		ASTM E8
Hardness Limits	Minimum: 26 HRC (258 HB) Maximum: 32 HRC (301 HB)		ASTM E10 ASTM E18
Microhardness in segregation bands (section 6.2.6)	Maximum: 450 HV0.05 or 470 HK0.05		ASTM E384
Macrostructure	No laps, cracks, voids or large structural heterogeneities. ASTM E381 S1, R1, C2 (Plate I)		ASTM E381

Property	Diameter up to 2 ½" (65 mm)	Diameter up to 4" (100 mm)	Reference specification for testing
Segregation bands	Heavily banding microstructures are not permitted as per ASTM E1268 Figure A1.20		ASTM E1268
Microstructure	Homogeneous microstructure, fine grain (ASTM 5 or greater), only tempered martensite is allowed. Maximum inclusion level according to ASTM E45, method "A": equal to 2 for fine inclusion A/B/C/D; and 1.5 for coarse inclusion A/B/C/D.		ASTM E3 ASTM E7 ASTM E45 ASTM E112

4.4. HEAT TREATMENT

4.4.1. Fasteners shall be submitted to a double tempering process with a minimum temperature of 593ºC for both cycles. The temperature of the second cycle or any subsequent thermal cycles (even without tempering purpose) shall not be higher than the temperature of the first tempering cycle.

4.4.2. Minimum time at the tempering temperature shall be one hour per inch of fastener thickness or thirty minutes, whichever is longer.

4.4.3. Cooling inside furnace after tempering is not permitted and the cooling medium adopted shall be reported.

4.4.4. After performing the heat treatment, the fasteners shall be free of non-tempered martensite in the microstructure. Figure 1 illustrates examples of microstructures with and without patterns of non-tempered martensite.

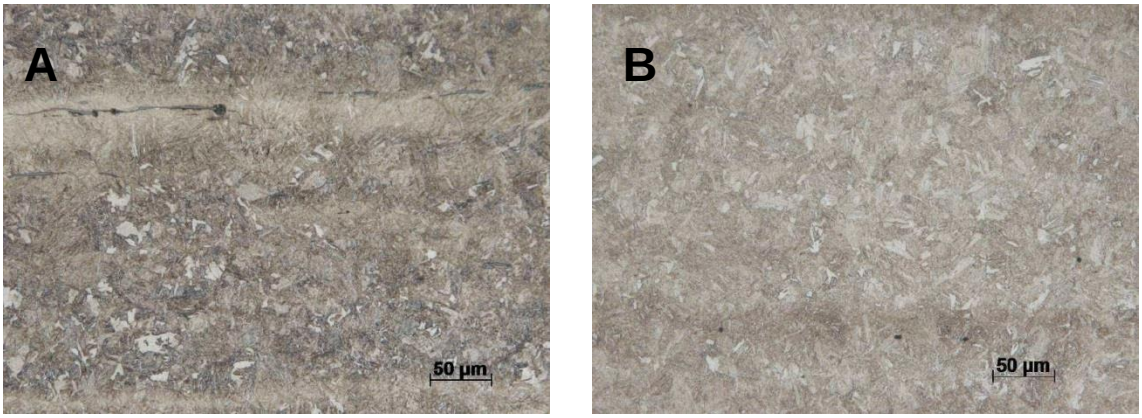

Figure 1: Image (A) shows a microstructure with the presence of non-tempered martensite (clear lines), while image (B) shows a microstructure without the presence of non-tempered martensite.

4.4.5. Metallography tests according to section 6.2.5 shall be performed on specimens from each heat treatment batch in order to identify the presence of non-tempered martensite. Microhardness tests according to section 6.2.6 shall be performed on the segregation bands of the metallography specimens in order to characterize the microstructure.

4.4.6. For bolts, studs, and threaded bars in which the execution of the thread is made by rolling after the second cycle of heat treatment of the material, a stress relieving process shall be

carried out at a temperature above 550ºC but not above temperature related to the last tempering cycle.

4.4.7. The stress relieving process may be disregarded if the last tempering cycle is performed after the thread rolling and since it meets the requirements presented in sections 4.4.1, 4.4.2 and 4.4.3.

4.4.8. Heat treatment details such as cycles of time and temperature shall be fully registered in charts and heat treatment schematics of the fasteners manufacturer (including the holding time).

4.4.9. The arrangement of the bolts, studs, nuts and threaded bars among themselves inside the furnace shall not affect the soaking quality of the tempering. The arrangement of the pieces by stacking is not permitted.

4.4.10. The heat treatment furnaces shall be submitted to an annual calibration. The recording instruments and the thermocouples shall be calibrated every 3 months, according to API SPEC 6A, Appendix M.

4.4.11. The tempering shall not be performed after the application of the anticorrosive metallic coating due to the risk of solid/liquid metal embrittlement.

4.4.12. For induction heat treatments, if temperatures above 700ºC are used, specimens shall be removed for the hardness testing, with samples as according to ASTM A320 for batch testing of heat-treated bars. A Rockwell C hardness profile shall be made from the outside diameter to the center of the bar. All hardness measures shall be within the specified limits of table 1 and with a maximum difference of 3 HRC from each other.

4.4.13. DECARBURIZATION

4.4.13.1. During heat treatment, the decarburization of the material is not accepted.

4.4.13.2. A decarburization test shall be performed in accordance with ISO 898 or ASTM A962 section 14 and supplemental requirement S54.3 and meet the acceptance criteria as per ISO 898-1 or ASTM F2328 Table 2. The test frequency shall be in accordance with ASTM A962 section 14 and S54.3.

4.4.13.3. No decarburization test is required if the difference between the diameter of the part after the heat treatment and the diameter of the final part after the machining process be higher than 1.5 mm.

4.5. COATINGS

4.5.1. As per section 8.2.1, MPS of the fasteners shall include the coating specification which shall contain, at least, the information detailed in section 8.2.2.

4.5.2. The process of coating application shall have the scope of tests performed by an independent laboratory certified in accordance with ISO 17025. The homologation shall be as according to criteria of ASTM coating standards.

4.5.3. PURCHASER shall ensure that the range of friction coefficients of the specified coatings is adequate to get the preload specified by the Calculation memory for the joint, according to the designated tightening method. A Calculation Memory or a normative reference for the determination of the applied torque shall be added to the Manual or Project Report of the equipment or installations.

4.5.4. Fasteners shall be supplied with one of the following metallic coatings:

- Cadmium double chrome-coated, as per ASTM B766, Class 12 and Type II; or,
- Nickel-Zinc, as per ASTM B841, Class 1 Gr. 10 and Type B/E.

4.5.5. Coatings shall be qualified by salt spray corrosion testing as per ASTM B117 and exposure time of 1000 hours. The acceptance criterion is absence of red corrosion. The corrosion test is considered destructive and shall be repeated whenever the coating process changes. Test coupons shall be used and they need to be in accordance with ASTM B766. The number of coupons to be tested shall be determined by sampling as per ASTM B602 Level III.

4.5.6. A chronological report, including logs of date and hour of the entrance and exit of material batches from the coating plant (and also from the Hydrogen embrittlement relief treatment furnace as per section 4.5.8 below) shall be prepared by the MANUFACTURER, and attached to Databook.

4.5.7. Tests for composition quality control, thickness, color, adhesion and abrasion shall be performed in accordance with ASTM B766 or ASTM B841, depending on the specified coating.

4.5.8. HYDROGEN EMBRITTLEMENT RELIEF

4.5.8.1. After the application of coating, regardless their mechanical strength, fasteners shall be subjected to hydrogen embrittlement relief heat treatment in accordance with ASTM B850 class ER 9 (190ºC to 220ºC for at least 8 hours).

4.5.8.2. Hydrogen embrittlement relief shall be conducted prior to the chromate treatment as per ASTM B850.

4.5.8.3. The arrangement of the parts inside the furnace shall not affect the homogeneity quality at the tempering temperature. Parts shall not be arranged by stacking.

4.5.8.4. Hydrogen embrittlement relief shall be registered by means of charts (temperature vs time) on a chart recorder. The chart shall be attached to Databook.

4.5.8.5. Date and hour related to the entrance and exit of material batches from the hydrogen embrittlement relief treatment furnace shall be registered and included on the chronological report mentioned in section 4.5.6.

4.5.9. OTHER COATINGS

4.5.9.1. Other specifications relative to anodic or non-metallic coatings may be proposed for prior analysis and approval by PETROBRAS, provided that requirements established in this technical specification has been demonstrated accordingly.

4.5.9.2. Specifically for non-metallic coatings, the electrical continuity through two different components shall be checked by PURCHASER in the FAT tests of the equipment that received the fasteners or after the field connection.

4.5.9.3. Organic coatings shall be qualified by salt spray corrosion testing as per ASTM D5894 and exposure time of 1000 hours. The acceptance criterion is absence of red corrosion as in accordance with ASTM D 610. This test shall be conducted in the pilot batch of supply and repeated whenever there is a change in the coating process. The number of coupons to be tested shall be determined by sampling as per ASTM B602 Level III.

5. REQUIREMENTS FOR NUTS

5.1. RAW-MATERIAL AND MECHANICAL PROPERTIES

5.1.1. Nuts material shall meet the requirements of ASTM A194 plus the requirements presented in Table 2, after the conduction of the forming process and final heat treatment.

Table 2: Material specification for nuts

Property	Reference Values	Reference specification for testing
Class and Material Grade	Gr. 4 or Gr. 7	ASTM A194
Impact Toughness	Average energy: 27 J (20 lbf.ft); and Individual minimum energy: 20 J (15 lbf.ft), tested at -101°C	ASTM A370 ASTM A320
Hardness Limits	Minimum: 24 HRC (247 HBW) Maximum: 32 HRC (301 HBW)	ASTM E10 ASTM E18

5.1.2. Nuts shall be submitted to Charpy V-Notch impact testing as per ASTM A320 requirements. The area for extraction of the test specimens shall comply with the criterion set forth in ASTM A962. Test shall be conducted after all heat treatment be performed and the acceptance criterion shall be the same as for the bolts, studs and threaded bars.

5.1.3. Other material specifications may be proposed to PETROBRAS for prior analysis and approval, provided that they meet the requirements presented in Table 2, regardless the material class and grade.

5.2. MANUFACTURING PROCESS

5.2.1. Manufacturing process shall meet the requirements of ASTM A194 for the specified material grades.

5.3. HEAT TREATMENT

5.3.1. Heat treatment shall meet the requirements of ASTM A194 for the specified material grades.

5.3.2. Heat treatment details of fasteners, such as cycles of time and temperature, shall be fully recorded in charts and operation plans.

5.4. COATING

5.4.1. Coating shall meet the requirements defined in section 4.5 of this technical specification.

6. QUALITY CONTROL

6.1. CERTIFICATION

6.1.1. MANUFACTURER shall be certificated by ISO 9001 or either by ABNT NBR ISO 9001.

6.1.2. The following requirements shall be met whenever the equipment that include the fasteners that will be supplied is subjected to certification:

6.1.2.1. CONTRACTOR shall assure that the inspector of the Third Party Certification follow the whole process of inspection of the fasteners as detailed in Table 3;

6.1.2.2. Fasteners shall be certified by the Third Party Certification, ensuring compliance with the requirements of this technical specification, considering the set of certifications relating to the equipment/installation to be provided by CONTRACTOR.

6.2. INSPECTIONS CONDUCTED BY THE MANUFACTURER

6.2.1. Table 3 summarizes the mandatory inspection activities to be conducted by the MANUFACTURER.

6.2.2. All tests shall be conducted by qualified professionals regardless of their location (own laboratory or Third Party Certification).

Table 3: Minimum scope for the mandatory testing to be conducted by the MANUFACTURER /

Applicable to	Testing	Samplings per batch	Acceptance Criteria		Testing conducted in a Third Party Certification
			Other than nuts	Nuts	
Raw-material	Chemical analysis, macrography and inclusion level analysis	At least 1 TS	Table 1	Table 2	Mandatory
Fastener material throughout its manufacturing[A]	Metallography	At least 3 TS	Table 1 and 6.2.5	Not applicable	Mandatory
	Microhardness	All TS of metallography	6.2.6	Not applicable	
	Toughness	At least 3 TS	Table 1 and 6.2.7	Not applicable	
	Tensile	At least 3 TS	6.2.8	Not applicable	
	Hardness [B]	100% of batch	Table 1 and 6.2.9	Table 2 e 6.2.9	Acc to MANUFACTURER[C]
Final Product	Visual	100% of batch	6.2.10	6.2.10	
	Dimensional	100% of batch	6.2.11	6.2.11	
	Penetrant Testing or Magnetic Particle Inspection	100% of batch Nuts: see section 6.2.12.2	6.2.12	6.2.12	

NOTE A See section 6.2.4.6.
NOTE B See sections 6.2.4.3, 6.2.4.7 and 6.3.6.
NOTE C See sections 6.2.4.3, 6.2.4.4 and 6.2.4.5.

6.2.3. RAW-MATERIAL TESTING

6.2.3.1. Besides the tests and certificates provided by the manufacturer of raw-material, the MANUFACTURER of fasteners shall perform an additional chemical analysis, macrography and inclusion level analysis for the raw-material acceptance. The acceptance criteria shall be those presented in Table 1 and Table 2, considering respective material class and grade, chemical composition, macrostructure and microstructure.

6.2.3.2. Raw-material tests shall be conducted by a Third Party Certification that is accredited by INMETRO to perform the necessary tests or, in case of the laboratories are not located in Brazil, tests shall be conducted by a Third Party Certification accredited by a metrological authority that complies with ISO 17025.

6.2.3.3. Reports of raw-material tests shall be submitted to the PURCHASER inspector.

6.2.4. PRODUCT TESTING

6.2.4.1. For each manufacturing batch shall be carried out at least the tests described in Table 3, for which the sampling and acceptance criteria informed therein shall be followed accordingly.

6.2.4.2. Testing of product throughout its manufacturing (except macro hardness testing) shall be conducted by a Third Party Certification that is accredited by INMETRO to carry out the necessary tests or, in case of laboratories that are not located in Brazil, testing shall be conducted by a Third Party Certification by a metrological authority that complies with ISO 17025.

6.2.4.3. For macro-hardness, it is up to the MANUFACTURER to conduct tests in its own laboratory or in a Third Party Certification (however, requirements specified in section 6.3.3 shall be met).

6.2.4.4. For other NDT (visual, dimensional and LPI or MPI), it is up to the MANUFACTURER to carry out the tests by their own professionals (duly qualified), by a Third Party Certification or by an external qualified professional (however, requirements specified in sections 6.3.3 and 6.3.4 shall be met).

6.2.4.5. In case of direct purchase of fasteners by PETROBRAS (i.e., PETROBRAS is the PURCHASER), it is mandatory the macro hardness tests and other NDT to be executed by the MANUFACTURER in a Third Party Certification.

6.2.4.6. Hardness, metallography, microhardness, impact toughness and tensile tests shall be carried out after all heat treatment cycles of material have been concluded.

6.2.4.7. The hardness test may be carried out on the final product. In this case, however, requirements specified in section 6.2.9.5 shall be met, and batch rework as specified in section 6.2.13.2 is not accepted in case of non-compliance has been identified.

6.2.4.8. All technical documents shall be submitted for analysis of the PURCHASER inspector, following the requirements specified in this technical specification.

6.2.4.9. Sections 6.2.5 to 6.2.12 include additional requirements and information regarding the specified tests.

6.2.4.10. In case of rejection of any fastener due to non-compliance with the acceptance criteria, the criteria specified in section 6.2.13 for rejection of the manufacturing batch shall be met.

6.2.5. METALLOGRAPHIC TESTING

6.2.5.1. Metallographic testing shall be carried out on a finished bolt, stud or threaded bar, in their longitudinal section and at half-diameter according to sampling specified in Table 3 and as per ASTM E3 and ASTM E7 methods.

6.2.5.2. The acceptance criteria for metallographic testing are specified in Table 1.

6.2.5.3. Specimens of metallographic testing shall be kept by the MANUFACTURER for at least 5 years and kept available for future verification, and duly traceable to their respective reports.

6.2.5.4. For metallographic attacks it is recommended to use Nital etchant solution (as per ASTM E407).

6.2.5.5. Metallographic testing is not applicable for nuts.

6.2.6. MICROHARDNESS TESTING

6.2.6.1. Vickers or Knoop microhardness testing as per ASTM E384 shall be performed in the segregation bands at half-diameter of all specimens used in the metallographic testing (section 6.2.5) to check the presence of non-tempered martensite in the microstructure of the material (non-tempered martensite segregation bands are clear-colored after Nital metallographic attack, as per ASTM E407).

6.2.6.2. All microhardness testers shall be calibrated with standards traceable to the Brazilian Calibration Network (RBC) or similar entity when the component is not manufactured in Brazil.

6.2.6.3. Microhardness testing shall be carried out with 0.05 kilogram-force load and the printed area shall be completely included in the band (see Figure).

6.2.6.4. At least 5 indentations shall be made per clear-colored band where it is identified the possibility of non-tempered martensite.

6.2.6.5. If non-tempered martensite bands are not identified by the metallographic attack, at least 5 indentations shall be carried out on a segregation band with darker coloration, on a specimen extracted from a position at half-diameter.

6.2.6.6. For the cases described in sections 6.2.6.4 and 6.2.6.5, the hardness of each indentation shall not exceed 450 HV0.05 or 470 HK0.05.

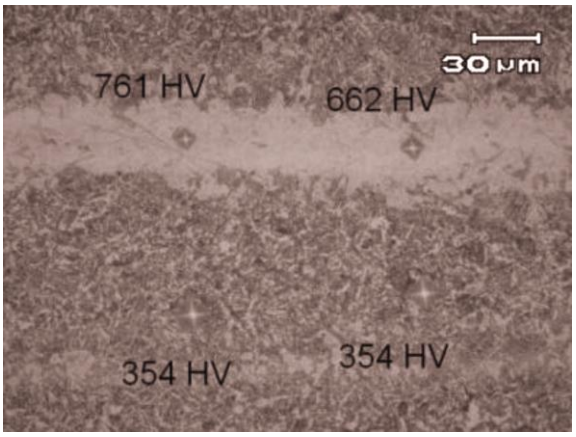

Figure 2: Image illustrating the hardness measures done in a non-tempered martensite band (clear-colored area) and in a tempered martensite band (darker coloration)

6.2.6.7. Microhardness test specimens shall be stored and kept available as per section 6.2.5.3.

6.2.6.8. Microhardness testing is not applicable to nuts.

6.2.7. IMPACT TESTING

6.2.7.1. Impact toughness testing shall be carried out using Charpy V-notch technique, according to the procedures specified in ASTM A370, criteria defined in this technical specification and Table 1.

6.2.7.2. Test specimens shall be taken at half diameter for diameters including 25 mm and smaller and at half radius for diameters higher than 25 mm as per ASTM A320.

6.2.7.3. It is required one impact test (three test specimens) for each manufacturing batch.

6.2.8. TENSILE TESTING

6.2.8.1. Tensile testing shall meet the requirements of yield strength, tensile strength, elongation and longitudinal area reduction specified in Table 1 and ASTM A320 Gr. L7 or Gr. L43.

6.2.8.2. Test specimens shall be extracted at half diameter for pieces with diameters up to 38 mm and at half radius for larger diameters in accordance with ASTM A370.

6.2.8.3. The number of tests per manufacturing batch shall be defined as according to table 3 and ASTM A962, and this also include batchs with less than 50 pieces.

6.2.8.4. Specimens failed during the tensile testings shall be stored by the MANUFACTURER for at least 5 years and kept available for future verification, duly traceable to their respective reports.

6.2.8.5. Tensile testings are not applicable to nuts.

6.2.8.6. Specified minimum yield strength of material shall be determined using the offset method specified in ASTM A370. Extensometer to be used shall be qualified as class B2.

6.2.9. HARDNESS TESTING

6.2.9.1. Brinell or Rockwell C hardness testing shall be performed on all fasteners of the manufacturing batch, according to the requirements of ASTM E10 or ASTM E18 respectively.

6.2.9.2. All durometers shall be calibrated in accordance with standards traceable to the Brazilian Calibration Network (RBC) or similar entity if the component is not manufactured in Brazil.

6.2.9.3. Acceptable hardness levels shall be according to Table 1 for bolts, studs and threaded bars, and according to Table 2 for nuts.

6.2.9.4. Measurements of hardness testing may be converted between Brinell and Rockwell C scales according to ASTM E140.

6.2.9.5. If the coating is removed for executing the hardness testing, the uncoated area of the fastener shall be painted using saltwater resistant coating, suitable for application over non-blasted surfaces.

6.2.10. VISUAL TESTING

6.2.10.1. Specifications ASTM F788 and ASTM F812 shall be fully complied.

6.2.10.2. All fasteners surfaces shall be free of laps, seams, protrusions, cracks and other surface defects.

6.2.11. DIMENSIONAL TESTING

6.2.11.1. All fasteners shall be dimensional checked.

6.2.11.2. Dimensional testing shall meet the dimensions and tolerances established in the geometry standards specified by PURCHASER.

6.2.11.3. Threads shall be checked using calibrators in a good condition, certified by a Third Party Certification (in Brazil, by the Brazilian Calibration Network, RBC).

6.2.12. LIQUID PENETRANT INSPECTION OR MAGNETIC PARTICLE INSPECTION

6.2.12.1. Fasteners shall be inspected by magnetic particles (MPI), according to ASTM E1444. If it is unable to perform the magnetic particle inspection, the fasteners shall be inspected by liquid penetrant (LPI), in accordance with ASTM E1417.

6.2.12.2. For bolts, studs, and threaded bars, the sampling shall be done on the entire (100%) manufacturing batch. For nuts, the sampling shall be in accordance with NBR 5426. Alternatively, ISO 2859-1 may be used instead of NBR 5426, provided that the same parameters as above are used.

6.2.12.3. As acceptance criteria, the presence of any discontinuity is not acceptable.

6.2.13. ACCEPTANCE CRITERIA OF MANUFACTURING BATCH FOR TESTING CONDUCTED BY THE MANUFACTURER

6.2.13.1. Rejection of any fastener from a manufacturing batch implies the MANUFACTURER (and/or the PURCHASER) to reject the entire manufacturing batch.

6.2.13.2. To avoid the rejection of the manufacturing batch, the batch may be reworked only once according to the requirements specified in sections 6.2.13.3, 6.2.13.4 and 6.2.13.5.

6.2.13.3. Fasteners rejected by testing conducted in the entire manufacturing batch may be segregated from the other fasteners and the approved fasteners may be accepted. Fasteners that are rejected in hardness testing may be reworked (once) or permanently discarded according to MANUFACTURER criteria. The set of segregated and reworked fasteners will set up a new manufacturing batch. Fasteners rejected for visual, dimensional and/or LPI / MPI inspection shall be not reworked, only segregated and permanently discarded.

6.2.13.4. The manufacturing batch that includes, for the first time, one or more specimens rejected in the sample tests (Table 3) shall either be entirely reworked or discarded according to MANUFACTURER criteria.

6.2.13.5. All quality assurance testing specified in Table 3 (except raw-material testing) shall be repeated for the reworked manufacturing batch. In case of failure in any fastener of the reworked manufacturing batch, the entire batch shall be permanently discarded according to MANUFACTURER criteria.

6.2.13.6. A Material Discard Report (MDR) shall be issued for all discarded manufacturing batches (permanently or not).

6.2.13.7. The fasteners manufacturing batch that is permanently discarded by this technical specification shall be appropriately identified in a manner that it shall be recognized as unsuitable for subsea applications.

6.2.13.8. If there is no fastener rejection according to inspection conducted by the MANUFACTURER, the PURCHASER or Third Party Certification, the manufacturing batch may be accepted. In this case, the corresponding Material Release Report (MRR) shall be issued.

6.3. INSPECTION CONDUCTED BY THE PURCHASER

6.3.1. Table 4 summarizes the mandatory inspection activities to be conducted by the PURCHASER.

6.3.2. The PURCHASER shall conduct, under its responsibility and in a Third Party Certification accredited by INMETRO (or accredited by a metrological body that meets ISO 17025, in the case of laboratories not located in Brazil), hardness tests, visual and dimensional inspection according to sampling specified in NBR 5426, complying with NQA 0.040. Alternatively, ISO 2859-1 may be used instead of NBR 5426, provided that the same parameters listed above are used. Any rejected piece rejects the entire manufacturing batch. Visual and dimensional inspections may be performed at the PURCHASER location by an independent qualified professional as an alternative to the accredited Third Party Certification.

Table 4: Summary of mandatory inspection activities conducted by the PURCHASER

Testing / Requirements	Sampling	Acceptance Criteria
Hardness	NBR 5426 complying with NQA 0.040. Any rejected piece rejects the entire manufacturing batch[D]	Fasteners, excluding nuts: Table 1 and section 6.2.9; Nuts: Table 2 and section 6.2.9.
Visual		Section 6.2.10
Dimensional		Section 6.2.11
Evaluation of MANUFACTURER technical documents (Databook)	All documentation	Any deviations from the requirements specified in this technical specification and applicable standards are not accepted.

NOTE D See section 6.3.6.

6.3.3. If macrohardness testing either visual and either dimensional inspections to be conducted by the MANUFACTURER, as specified in section 6.2, are performed by a Third Party Certification (see sections 6.2.4.3 and 6.2.4.4), the respective testing specified in Table 4 (and section 6.3.2) are no longer required (already performed in a Third Party Certification).

6.3.4. If visual either dimensional inspections to be conducted by the MANUFACTURER, as specified in section 6.2, are performed by an independent qualified professional (see section 6.2.4.4), it is not required to repeat the inspections already performed, provided that the PURCHASER had witnessed the MANUFACTURER inspections at a sampling level equivalent to that indicated in Table 4.

6.3.5. Excluding sampling, the hardness, visual and dimensional testing shall follow the requirements specified in sections 6.2.9, 6.2.10 and 6.2.11 respectively.

6.3.6. In order to prevent the rejection of the entire manufacturing batch due to any non-conformity found in the visual and dimensional inspection (as per section 6.3.2), the PURCHASER

may perform a full (100%) inspection of the batch and, in this case, discard only rejected fasteners. This waive to prevent rejection of the entire batch is not valid for the macrohardness testing as any fastener rejected at PURCHASER inspection indicates that the MANUFACTURER laboratory does not have sufficient quality assurance to identify and segregate rejected products.

6.3.7. At the end of the inspection phase, the PURCHASER shall evaluate the technical documents issued by the MANUFACTURER (Databook). Any non-conformity identified in the documents without proper treatment and without the approval of the PURCHASER, implies the rejection of the entire manufacturing batch.

6.3.8. At the end of the inspection phase, the PURCHASER shall issue an Inspection Report consolidating the inspection results, as per section 8.3.3.

6.3.9. For those cases where PETROBRAS is responsible for the acquisition of the high-strength low-alloy steel fasteners for subsea applications, the inspection shall be executed by the own MANUFACTURER inspection area, as according to reference 50.

6.4. TRACEABILITY

6.4.1. MANUFACTURER shall have a procedure describing the fasteners identification process and shall ensure traceability control by any manufacturing batch until the final release and delivery.

6.4.2. Fasteners shall be individually marked according to requirements specified in section 7.1. Packaging shall be identified in accordance with the requirements of section 7.2.6.

6.4.3. Specimens ruptured during the tensile and metallographic testing as specified in section 6.2, shall be identified, properly traceable to their respective testing reports, and kept available at least for 5 (five) years (see section 6.2.5.3).

7. MARKING AND PACKAGING FOR SHIPPING

7.1. MARKING

7.1.1. All fasteners shall be marked with the MANUFACTURER logo and material grade, which shall be made on the face with the larger length of the thread for studs and threaded bars, and in accordance with ASTM A962 for all other types of fasteners.

7.1.2. All fasteners with 3/4-inch nominal diameter or larger shall be additionally marked with the manufacturing batch identification.

7.2. PACKAGING

7.2.1. Fasteners shall be arranged inside boxes of appropriate material and protected in a manner to avoid contact each other during shipping.

7.2.2. Packaging shall protect fasteners against shipping damage and corrosion.

7.2.3. Boxes shall be designed with sufficient strength to protect fasteners during the period of storage in the PURCHASER warehouse.

7.2.4. Each box shall storage only fasteners from the same manufacturing batch.

7.2.5. Boxes shall be designed for forklift handling if they cannot be lifted and handled by one person.

7.2.6. Boxes shall be appropriately identified with the information included in the fasteners data sheet (according to section 8.4, except that the quantity and total weight information is relative to the contents of the box and not to the manufacturing batch).

8. DOCUMENTATION

8.1. REQUIRED TECHNICAL DOCUMENTATION

8.1.1. The following documents relating to the fasteners manufacturing process shall be issued and submitted by the MANUFACTURER to PETROBRAS for approval:

1. ISO 9001 Certification;
2. Manufacturing Procedure Specification (MPS);
3. Inspection and Test Plan (ITP);
4. Procedure describing the systematic used for fastener marking and traceability control (as per section 6.4.1);
5. Databook;
6. Quality Certificate for the fasteners (as per section 6.1.2, subsection 6.1.2.2);
7. Datasheet (as per section 8.4).

8.1.2. PURCHASER shall submit for prior approval of PETROBRAS its own Inspection Reports, and include them in its Databook, as per section 8.3.3.

8.1.3. PURCHASER and/or CONTRACTOR shall include a Calculation Memorandum or normative reference for determining the fastener tightening torque in the Manual or Design Report of the equipment, to be issued as per section 4.5.3.

8.2. MANUFACTURING PROCEDURE SPECIFICATION (MPS)

8.2.1. The minimum information shall be included in the Manufacturing Procedure Specification (MPS) of the fasteners:

1. Material specification, including chemical composition with respective tolerances and required mechanical properties;
2. Material qualification;
3. List of all SUB-SUPPLIERS that perform or participate in the execution of any stage of supply, starting from the raw material supply to the final inspection and release, duly evaluated and recorded in the Vendor List;
4. Method used for steel manufacturing, including ingoting;
5. Method used for forming of steel bars;
6. Method used for fasteners manufacturing, including forming process;

7. Heat treatment procedure including thermal cycle, description of practices adopted for normalization, quenching and tempering (including cooling medium), temperatures with tolerances, heating curves, cooling and tempering temperature;
8. Coating specification (according to section 8.2.2); and,
9. Non-destructive testing (NDT) requirements;

8.2.2. The Coating Specification shall include, at least, the following information:

1. Coating type;
2. Coating application process;
3. Thickness range;
4. Coating qualification test, including corrosion tests;
5. Inspection and Test Plan; and,
6. List of applicable Standards.

8.3. DATABOOKS

8.3.1. Both MANUFACTURER and PURCHASER shall issue their own Databooks.

8.3.2. Databook to be issued by the MANUFACTURER shall include the minimum information:

1. Material Certificates;
2. Heat treatment charts, including hydrogen embrittlement relief (see sections 4.4.8, 4.5.8.4 and 5.3.2);
3. Chronological report of the manufacturing process of the material and pieces, according to sections 4.5.6 and 4.5.8.5;
4. Procedures;
5. Qualification Reports;
6. Inspection Plan;
7. Inspection Reports;
8. Testing reports including the results, informing places of test specimen removal;
9. Testing results on reworked fasteners (see section 6.2.13.5).
10. List of Material Discard Report (MDR) and Material Release Report (MRR) issued (see sections 6.2.13.6 and 6.2.13.8).

8.3.3. Databook to be issued by the PURCHASER at the minimum shall include:

1. Reports of all testing executed by the PURCHASER;
2. Certificate attesting that the Databook issued by the MANUFACTURER and relating to the manufacturing batches of interest was evaluated. The Certificate also shall include the conclusion of the evaluation;
3. Inspection Reports, including the testing results (see section 6.3.8);

8.4. DATASHEET

8.4.1. For each manufacturing batch a datasheet shall be issued, including at the minimum the information:

Item.	Description	Value and Unit	Notes
1	Application	"FOR SUBSEA APPLICATION"	As per I-ET-3000.00-1500-251-PEK-001
2	Fastener designation (dimensions)		
3	Quantity		
4	Total weight		
5	MANUFACTURER Name		
6	Manufacturing Batch Code		
7	Date of supply		
8	Invoice number		
9	Purchase Order Number		
10	Purchase Order Section Number		
11	PURCHASER Part Number		
12	Material Specification Code		
13	Coating Specification Code		
14	Manufacturing Procedure Specification (MPS)		
15	MANUFACTURER Databook Code		

NOTE: Documents codes shall be informed including their revision number.

ANNEX I API SPEC 20E BSL-2

AI.1. GENERAL REQUIREMENTS

AI.1.1. Due to the similarities of requirements and in order to facilitate the procurement and understanding of this technical specification, it is permitted to specify fasteners according to API SPEC 20E level BSL 2 for material specifications ASTM A320 Gr. L7 and Gr .L43 and ASTM 194 Gr.4 and Gr.7 plus the mandatory additional requirements described below.

AI.1.2. These mandatory additional requirements shall be included in the PURCHASER specification, which shall be submitted to prior approval of PETROBRAS.

AI.2. MATERIAL

AI.2.1. Maximum yield strength shall be limited to 138 ksi (950 MPa).

AI.2.2. Minimum and maximum hardness values specified for fasteners (excluding nuts) shall be limited to the range of 26 HRC and 32 HRC;

AI.2.3. Minimum and maximum hardness values specified for nuts shall be limited to the range of 24 HRC and 32 HRC.

AI.2.4. The impact testing shall be performed at a temperature of -101ºC according to ASTM A320.

AI.2.5. Vickers or Knoop microhardness testing shall be performed in the segregation bands at half-thickness in a longitudinal section in order to check non-tempered martensite, according to section 6.2.6.

AI.3. MANUFACTURING AND HEAT TREATMENT

AI.3.1. Materials shall not be submitted to shear, oxyfuel, graphite electrode or laser cutting.

AI.3.2. All material grades (ASTM A320 Gr. L43 and Gr. L7) shall be double tempered.

AI.3.3. For bolts, studs and threaded bars which thread is fabricated by rolling, a stress relieving process shall be carried out at a temperature between 550ºC and the temperature used on the last tempering cycle performed. The stress relieving shall be made only after the second tempering cycle.

AI.3.4. Stress relieving treatment may be disregarded if the last tempering cycle is performed after thread rolling and provided that it meets the specifications of section 4.4.1.

AI.3.5. Furnace cooling is not permitted. The selected cooling medium shall be reported.

AI.3.6. Tempering heat treatment shall not be performed after anti-corrosion metal coating due to risk of embrittlement of the material.

AI.3.7. All requirements specified in section 4.4.13 (decarburization) of this technical specification shall be complied with.

AI.4. COATING

AI.4.1. Coating shall comply with the requirements of section 4.5 of this technical specification, including hydrogen embrittlement relief heat treatment, as per ASTM B850 Class ER-9.

AI.5. SAMPLING AND INSPECTION

AI.5.1. Inspection and monitoring requirements for mechanical, metallographic and non-destructive testing shall comply with the requirements of Table 4 of this technical specification.

AI.5.2. Sampling for mechanical, metallographic and NDT testing shall comply with the requirements of Table 3 of this technical specification.

AI.5.3. The NDT testing frequency shall comply with the requirements of item 6.2.12 of this technical specification (100% inspection) instead the criteria specified in API SPEC 20E level BSL 2.

AI.6. TRACEABILITY

AI.6.1. Traceability shall comply with the requirements of section 6.4 of this technical specification.

ANNEX II SPECIFICATION API SPEC 20F BSL-3 FOR "EXPOSED BOLTING"

AII.1. GERAL

AII.1. a) According to item 1.2.4, for fasteners in the project situation of ("exposed bolting"), material according to specification ASTM A453 Gr.660D API SPEC 20F shall be adopted.

AII.1. b) All requirements of API SPEC 20F level BSL-3 apply, except as modified by the text of this annex.

AII.1. c) The use of ASTM A320 L7M low-alloy steel fasteners or any other low-alloy steel on fasteners under the "exposed bolting" situation will not be allowed.

AII.1. d) The additional requirements contained in this Annex II shall be part of the CONTRACTOR specification, which must be submitted to PETROBRAS for approval.

AII.2. MATERIAL

AII.2. a) The heat treatment of the base material shall be as per standard ASTM A453 Ed. 2017, table 4.

AII.2. b) The manufacturing process shall avoid the introduction of stress concentrators, such as tool and machining marks. Threads can be machined or rolled.

AII.2. c) Materials cannot be subjected to shear, oxyfuel, graphite electrode or laser cutting.

AII.3. MECHANICAL TESTS

AII.3. a) Mechanical tests shall be performed after all heat treatments, including precipitation hardening.

AII.3. b) In case of mechanical tests were performed by the supplier of the raw material, the MANUFACTURER of the fastener shall perform new tests.

AII.3. c) The tests shall be performed in each manufacturing batch as according to table 3.

AII.3. d) Mechanical properties shall comply with table 5 ASTM A453 Ed. 2017 for Grade 660 and Class D.

AII.3. e) The failure of any mechanical test and/or of items AII.3 (f) and (g) results in the rejection of the entire lot, which may undergo a new cycle of heat treatment for adequacy once.

AII.3. f) The macrohardness test shall be performed on 100% of the fasteners and nuts. The minimum and maximum hardness values are limited to 24 HRC and 35 HRC respectively.

AII.3. g) Vickers or Knoop microhardness tests shall be performed from the bottom of the screw threads, about 2 mm deep from the thread, with 200 µm of distance between the measurement points. The microhardness shall be performed with a load of 100 grams. The acceptance criterion is a maximum hardness of up to 450 HV or 470 HK. Batches that have specimens with microhardness above this value shall be rejected. Figure 3 has the details.

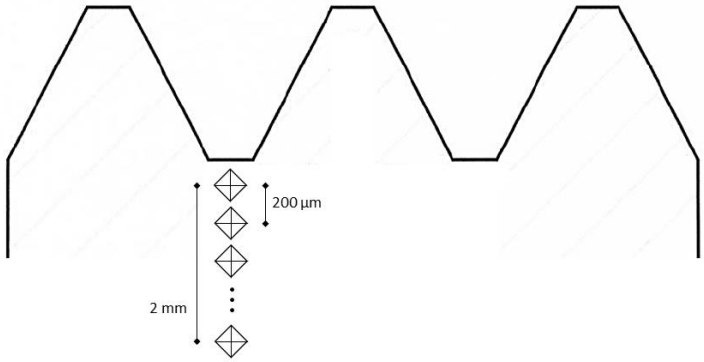

Figure AII-1: Image illustrating the hardness measurement points as a function of the thread profile.

AII.4. COATING

AII.4. a) If non-metallic and non-conductive coatings are adopted (Ex: PTFE base), the electrical continuity test shall be performed after the installation of the fasteners. Additionally, indication of the measurements shall be included in the databook.

AII.5. SAMPLING AND INSPECTION

AII.5. a) The sampling frequency for mechanical, metallographic, and non-destructive tests (END) shall be in accordance with API 20F level BSL-3.

AII.5. b) Volumetric non-destructive tests (ultrasonic) shall be performed on 100% of the fasteners (any diameter). Acceptance criteria must be in accordance with API 20F level BSL-3.

AII.6. DIMENSIONAL, VISUAL AND PMI

AII.6. a) For visual and dimensional inspection, API 20F level BSL-3 requirements apply, with inspection and verification of all parts (100% of the lot).

AII.6. b) For verification by Positive Material Identification (PMI), the requirements of API 20F level BSL-3 apply, with inspection and verification of all parts of the lot (100% of the lot).