INDEX OF REVISIONS

REV.	DESCRIPTION AND/OR REVISED SHEETS
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	REV. 0	REV. A	REV. B	REV. C	REV. D	REV. E	REV. F	REV. G	REV. H
DATE	05/08/2021								
DESIGN	EES								
EXECUTION	CX4H								
CHECK	BH8F								
APPROVAL	UP65								

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1 INTRODUCTION

1.1 OBJECTIVE

The purpose of this technical specification is to set minimum requirements for fabrication, inspection, testing, and procurement of MTL as ref. [6]. Appendix 9 brings alternative designs and materials for MTL components.

1.2 SCOPE

This technical specification covers high-strength low-alloy steel and copper-beryllium alloy for subsea applications and subjected to cathodic protection, and shall be applied on all components, to be delivered to PETROBRAS.

1.3 TERMS, DEFINITIONS AND ABBREVIATED TERMS

QTC - Qualification Test Coupon

ITP – Inspection and test Plan

Mill – manufacturer of raw material

MPS – Manufacturer procedure specification

T – “Thickness”

Equipment Manufacturer – Manufacturer of MTL

2 REFERENCE DOCUMENTS

[1] SAE AMS6346 - Steel Bars 0.95Cr - 0.20Mo (0.28 to 0.33C) (SAE 4130) Hardened and Tempered, 125 Ksi (862 MPa) Tensile Strength;

[2] ASME BPVC.II.A-2019 - SA–540 Grade B23 (E-4340-H)

[3] ASTM A370 Mechanical Testing of Steel Products

[4] ASTM B196 - Standard Specification for Copper-Beryllium Alloy Rod and Bar

[5] ASTM B570 Copper-Beryllium Alloy - Forgings and extrusions

[6] I-DE-3010.00-1300-279-PEK-006 – MTL DRAWING

[7] API 6A 2018 – Wellhead Christmas Tree Equipment

[8] ASTM A322 - Standard Specification for Steel Bars, Alloy, Standard Grades

[9] ET-3000.00-1500-251-PEK-001

[10] ET-3000.00-1500-251-PEK-002

[11] ET-3000.00-1500-29B-PMU-001

3 GENERAL REQUIREMENTS

Raw material shall be supplied as per reference [8].

Machining process for assembly its acceptable.

For the raw material certificate, one tension test and one set of impact test consisting of three specimens shall be made for each diameter of each heat represented in each tempering charge.

3.1 Decarburization

Components shall be free from decarburization on the ground, turned, or polished surfaces.

3.1.1 Qualification test coupons

The properties exhibited by the QTCs shall represent the properties of the thermal response of the material comprising the production parts it qualifies.
A single QTC may be used to represent the impact and/or tensile properties of the part(s) produced from the same heat,

The QTC shall be from the same specified material and heat-treatment batch/processing as the part(s) it qualifies.

Prolongation may be applied for QTC. Sacrifice piece shall also be acceptable.

Tensile and/or impact test specimens shall be removed from a QTC after the final QTC heat treatment cycle.

At least one Rockwell or Brinell hardness test shall be performed on the QTC(s) after the final heat-treatment cycle.

4 MATERIALS SPECIFIC REQUIREMENTS

4.1 SAE 4130

Parts of MTL specified to be manufactured with SAE 4130 shall be supplied finished with quenched and tempered condition with properties and requirements complying with 4.1.1 through 4.1.5. If the results of the mechanical tests of any test lot do not conform to the requirements specified, the manufacturer shall retreat such lot not more than twice.

A MPS shall be issued but the manufacturer.

The material grade shall be as per reference [8].

4.1.1 Heat treatment

The manufacturer shall submit a detailed heat treatment procedure for approval by PETROBRAS, which must be attached to the MPS as per item 4. Quenching and tempering are mandatory heat treatment cycles to guarantee the specific requirements of mechanical properties required by this specification. Operations must be carried out to return to a temperature above the recrystallization of the grain. A temperature range should be 1650°F (899°C) to 2350°F (1288°C).

Time from the components are leaving the furnace until being immersed in the quenchant shall not exceed 90 seconds.

The volume of quenchant shall be sufficient and shall be heavily agitated, preferably by cross flow to ensure adequate cooling rate. The maximum temperature of the quenchant shall never exceed 40°C. Temperature measurements of the quenchant shall be performed

The minimum tempering temperature required is 580 °C. The parts must be machined prior to heat treatment with the aim of removing imperfections or surface inclusion, including high temperature decarburization. The heat treatment procedure must contain the minimum information required by reference [8], which is shown below:

• List of tracking and monitoring equipment to control and record charts;
• The calibration certificate of the heat treatment furnaces must be demonstrated. Oven and calibration equipment must comply with API 6A / 17D standards. Calibration frequency should be at least once a year. The maximum variation allowed in the temperature of the equipment, throughout its entire volume, is a maximum of ± 10 °C;
• Drawings with loading arrangements and position in the furnace;
• Heating and cooling rates;
• Maximum and minimum fluid soak temperature;
• Temperature gradients;
• Maximum time to move the pieces from the furnace to the cooling tank;
• Cooling rates (conditions);
• Type of cooling fluid (water, oil, etc...);

4.1.2 Composition

Chemical composition shall conform to the percentages by weight shown in Table 1, determined in accordance with ASTM A751 or by other analytical methods acceptable to purchaser

Table 1 - SAE 4130 Composition

Element	Min	Max
Carbon	0,28	0,33
Manganese	0,40	0,60
Silicon	0,15	0,35
Phosphorus	-	0,03
Sulfur	-	0,040
Chromium	0,80	1,10
Molybdenum	0,15	0,25
Nickel	-	-

4.1.3 Tensile Properties

Sampling for mechanical test shall be performed after final heat treatment, i.e. in the final condition.
One (1) tensile test shall be made at the T/4x T/4 position in the longitudinal direction from the greatest thickness;
The testing shall be performed in accordance with ref. [3]. Yield Strength, tensile strength Elongation and Reduction of Area shall conform to the requirements prescribed in Table 2

Table 2 - Longitudinal tensile properties, minimum [1]

Yield strength at 0,2% Offset:	685MPa (100 ksi)
Tensile strength:	841MPa (125 ksi)
Elongation in 4D	17%
Reduction of Area	55%

4.1.4 Hardness

The hardness of the accessible surfaces of the component shall be tested. The hardness of the accessible surfaces of the components shall be tested. The acceptance criteria is defined in Table 3.

Table 3 hardness limits

Minimum hardness	26 HRC (258 HB)
Maximum hardness	35 HRC (327 HB)

4.1.5 Impact

Impact tests are required. Charpy “V” notch Impact testing shall be performed on sets of three specimens with the test temperature -20°C

One (1) set (3 specimens) of “Charpy V-Notch” impact test shall be made at the T/4x T/4 position in the transverse direction from the greatest thickness;

The test specimens shall be removed from the QTC after the final heat treatment cycle. Impact properties shall meet the requirements as given in Table 4.

Table 4 - Impact Energy Absorption Requirements

Size of Specimen, mm	Minimum Impact Value Required for Average of Each Set of Three Specimens, ft·lbf [J]	Minimum Impact Value Permitted for One Specimen Only of a Set, ft·lbf [J]
10 by 10	20 [27]	15 [20]
10 by 7.5	16 [22]	12 [16]

4.2 SAE 4340 (alternative do ASTL A320 gr L7)

4.2.1 Heat treatment

Components shall be rough machined to near final dimensions prior to heat treatment.
Heat at 830°C for 1 hour per inch (25.4mm) of thickness with minimum of 1h then quench in water. Time from the components are leaving the furnace until being immersed in the quenchant shall not exceed 90 seconds.
The volume of quenchant shall be sufficient and shall be heavily agitated, preferably by cross flow to ensure adequate cooling rate. The maximum temperature of the quenchant shall never exceed 40°C. Temperature measurements of the quenchant shall be performed

Temper at 620°C and hold for not less than 1 hour per inch (25.4mm) of maximum thickness.

The material grade shall be as per reference [8].

4.2.2 Composition

Chemical composition shall conform to the percentages by weight shown in, determined in accordance with ASTM A751 or by other analytical methods acceptable to purchaser

Table 5 – SAE 4340 Composition

Element	Min	Max
Carbon	0,38	0,43
Manganese	0,60	0,80
Silicon	0,15	0,35

Phosphorus	-	0,03
Sulfur	-	0,040
Chromium	0,70	0,90
Molybdenum	0,2	0,3
Nickel	1,65	2

4.2.3 Tensile Properties

Sampling for mechanical shall be performed after final heat treatment, i.e. in the final condition.

One (1) tensile test shall be made at the T/4x T/4 position in the longitudinal direction from the greatest thickness;

The testing shall be performed in accordance with ref. [3]. Yield Strength, tensile strength Elongation and Reduction of Area shall conform to the requirements prescribed in Table 6.

Table 6 - Longitudinal tensile properties, minimum

Yield strength at 0,2% Offset:	725 MPa (105 ksi)
Tensile strength:	825 MPa (125 ksi)
Elongation in 4D	15%
Reduction of Area	50%

4.2.4 Hardness

The hardness of the accessible surfaces of the component shall be tested. The acceptance criteria is defined in Table 7

Table 7 hardness

Minimum hardness	26 HRC (258 HB)
Maximum hardness	35 HRC (327 HB)

4.2.5 Impact

Impact tests are required. Charpy “V” notch Impact testing shall be performed on sets of three specimens with the test temperature -20°C

One (1) set (3 specimens) of “Charpy V-Notch” impact test shall be made at the T/4x T/4 position in the transverse direction from the greatest thickness;

The test specimens shall be removed from the QTC after the final heat treatment cycle. . Impact properties shall meet the requirements as given in Table 8.

Table 8 - Impact Energy Absorption Requirements

Size of Specimen, mm	Minimum Impact Value Required for Average of Each Set of Three Specimens, ft·lbf [J]	Minimum Impact Value Permitted for One Specimen Only of a Set, ft·lbf [J]
10 by 10	20 [27]	15 [20]
10 by 7.5	16 [22]	12 [16]

4.3 UNS C17200

Components specified with UNS C17200 may be manufactured with rod as ref.[4] or forged as [5] .

Temper designation as TF00 (AT), TD04 (H), TF00 (AT) next to UNS as defined in [4] means:

- Solution heat-treated TB00 (A)
- cold-drawn hard TD04 (H)
- precipitation heat treated TF00 (AT)

Temper designation specified in [6] refers to finished condition of components manufactured with UNS C17200. This means that equipment manufacturer may obtain raw material in TB00 (A) condition and to be precipitation heat treated after machined or get already precipitation heat treated by mill.

Mechanical requirements defined in paragraphs 4.3.2 through 4.3.3 shall be met at finished component after machining to its final dimensions. Mechanical requirements may be accomplished by MTL manufacturer heat treatment or at delivered by mill condition.

4.3.1 Composition

The material shall conform to the chemical composition requirements prescribed in Table 9

Table 9 - UNS C17200 chemical composition ref.

Element	Min	Max
Beryllium	1,8	2
Nickel + cobalt, min	0.20	
Nickel + cobalt + iron, max		0.6
Aluminum, max		0.20
Silicon, max		0.20
Copper		remainder

4.3.2 Tensile Properties

Copper-Beryllium Alloy Rod and Bar C17200 shall meet the tensile properties defined in Table 10.

Table 10 - Copper-Beryllium Alloy Rod and Bar Requirements ref. [4]

ASTM	ASTM B196	ASTM B196	ASTM B196	ASTM B196
Temper Designation	TB00 (A)	TD04 (H)	TF00	TF00
Diameter or Maximum Distance Between Parallel Surfaces	all sizes	over 1 to 3, incl.	over 3	up to 3, incl.
Minimum Yield strength at 0,2% Offset:	140 MPa (20 ksi)	520 MPa (75 ksi)	900 MPa (130 ksi)	1000 MPa (145 ksi)
Maximum Tensile strength:	590MPa (85 ksi)	830MPa (120 ksi)	1380MPa (200 ksi)	1380MPa (200 ksi)
Minimum Tensile strength:	410MPa (60 ksi)	590MPa (85 ksi)	1140MPa (165 ksi)	1140MPa (165 ksi)

Elongation in 4D	20%	8%	3%	4%

Copper-Beryllium Alloy C17200 Forgings and Extrusions shall comply with Table 11 requirements.

Table 11 - Copper-Beryllium Alloy Forgings and Extrusions

ASTM	ASTM B590	ASTM B590	ASTM B590
Temper Designation	TF00	TF00	TF00
Diameter or Maximum Distance Between Parallel Surfaces	Up to 8, incl	Over 8 to 12, incl.,	Over 12
Minimum Yield strength at 0,2% Offset:	890 MPa (130 ksi)	890 MPa (130 ksi)	860 MPa (125 ksi)
Maximum Tensile strength:	1380MPa (200 ksi)	1310MPa (190 ksi)	1240MPa (180 ksi)
Minimum Tensile strength:	1140MPa (165 ksi)	1070MPa (155 ksi)	1000MPa (145 ksi)
Elongation in 4D	3%	3%	3%

4.3.3 Hardness

Copper-Beryllium Alloy Rod and Bar C17200 shall meet the hardness limits defined in Table 12

Table 12 - Hardness limits ref. [4]

ASTM	ASTM B196	ASTM B196	ASTM B196	ASTM B196
Temper Designation	TB00 (A)	TD04 (H)	TF00	TF00
Diameter or Maximum Distance Between Parallel Surfaces	all sizes	over 1 to 3, incl.	over 3	up to 3, incl.
Rockwell Hardness, B Scale, MAX	85	101	-	-
Rockwell Hardness, B Scale, MIN	45	88	-	-
Rockwell Hardness, C Scale, MAX	-	-	42	42
Rockwell Hardness, C Scale, MIN	-	-	36	36

Copper-Beryllium Alloy C17200 Forgings and Extrusions shall comply with Table 11 requirements.

Table 13 - Hardness limits ref.[5]

ASTM	ASTM B590	ASTM B590	ASTM B590

Temper Designation	TF00	TF00	TF00
Diameter or Maximum Distance Between Parallel Surfaces	Up to 8, incl	Over 8 to 12, incl.,	Over 12
Rockwell Hardness, C Scale, MAX	42	40	40
Rockwell Hardness, C Scale, MIN	36	34	36

5 NDT

This specification provides the minimum NDT requirements; however, other NDT methods can be used in combination with those specified here to complement the limitation of some of the techniques described herein and properly identify some type of defect.

NDT methods not described here must comply with the requirements of the API 6A reference [7] level PSL 3G. The procedures must be sanctioned by an NDT inspector ABNT NBR ISO 9712 level III. The interpretation of the results can be done by an ABNT NBR ISO 9712 level II or level III inspector.

All NDT personnel must be qualified in accordance with the minimum requirements required by API 6A level PSL 3G. NDT personnel must be qualified by the ABNT NBR ISO 9712 standard and approved by an ABNT NBR ISO 9712 level III inspector.

Before starting any NDT activity, the contractor must issue the procedures for PETROBRAS' comments. All NDT procedures must be approved by the SUPPLIER and by PETROBRAS before their execution.

5.1 Visual inspection

Components shall be visually inspected by the manufacturer on 100% of the surface in accordance with the procedure listed in API 6A PSL 3G [7].

5.2 UT – ultrasonic test

After machining and before sending it to PETROBRAS, the entire volume must be 100% inspected by the ultrasonic technique in accordance with API 6A level PSL 3G standard by the manufacturer. The acceptance criteria must be in accordance with the API 6A level PSL 3G standard [7].

Note: If it is not possible to inspect 100% of the part by ultrasonic due to geometry and or configuration, radiographic analysis according to API 6A level PSL 3G should be performed as a supplementary procedure.

5.3 MPT – Magnetic Particles test

After machining and surface finishing of the parts making them suitable for visual inspection, each part must be 100% inspected by the manufacturer through the magnetic particles procedure in

accordance with API 6A level PSL 3G standard. The acceptance criteria must be in accordance with the API 6A level PSL 3G standard [7].

5.4 Repair

Superficial defects must be removed by grinding and/or scraping. In no case is it allowed that the wall thickness after grinding and/or scraping decreases below the minimum specified in the drawing and design tolerance. The components shall be able to be welded in pup-pieces and/or other forgings of similar grade material and/or laminated tubes according to item 4 of this specification, consequently the welded joints must be able to meet the mechanical requirements required by this specification.

Repair by welding of components is not allowed.

6 MPS AND QUALITY CONTROL

Before starting production, the supplier must submit for PETROBRAS' evaluation a detailed manufacturing plan containing the requirements as per item 4. The MPS must demonstrate how the properties specified here will be achieved, as well as include the manufacturing route of the component, including all factors that may influence the reliability and quality of the final product. The MPS must contain the following items:

- Information about the supplier of the material (ingot). Material traceability certificates, date of manufacture and chemical composition.
- Detailed heat treatment procedure and furnace loading arrangements;
- Drawings of components with the respective extension or sacrifice piece, according to item 4 of this specification, containing the respective positions from which the specimens (CP'S) will be removed
- Description of the mechanical tests that will be performed, according to item 4 of this specification
- Description of non-destructive tests (END) that will be performed, according to item 5 of this specification
- Traceability and registration plan
- Stocking and storage plan

Supplier shall operate a quality system compatible with the ISO 9001 system. Supplier shall prepare a quality plan and test monitoring and disclosure (ITP) for all activities that comprise the scope of work. This procedure shall be issued for review and approval by PETROBRAS before beginning any work.
All test equipment shall be certified and its calibration certificates issued for PETROBRAS evaluation.
A final dimensional disclosure report for all components shall be issued for analysis and approval by PETROBRAS. Reports of all END tests performed must be issued for PETROBRAS evaluation.

7 REGISTRY, TRACKING AND STORING

Components/pieces shall be registered and tracked according to their run and production batch. Components shall have an identification number (serial number) and shall be identified in the Manufacturing Databook with its respective identification plate (tag) for each part. This plate, in turn, shall remain in the equipment and be located on the outside in a position for easy and legible viewing. Flange marking must occur in a way that does not form any stress concentrator that reduces the integrity of the equipment.

It is recommended to store it indoors to avoid exposing the equipment to the atmosphere. Materials shall be stored in such a way as to avoid possible damage and deterioration. Components/pieces shall be packed in wooden boxes. It is not admitted that pieces are directly in contact with the ground. The faces and holes must be protected from possible shocks using elastomers or foam. Flange faces shall be lined with casings, and these must be secured so that they do not fall off during storage, storage and transport.

Materials shall be stored in such a way that the possibility of damage due to impact, loading or local kneading is avoided. If it is necessary to remove any of the protections to facilitate transport, it must be immediately replaced in the original position it was in right after the end of the operation.

8 DIMENSIONAL REPORT

Full dimensional report shall be issued for each component manufactured according to this technical specification

9 HYDROSTATIC TESTING

Each actuator shall be subjected to hydrostatic pressure at factory at 5500 psi.

10 DATA BOOK

Manufacturing and quality control data book shall be issued including full traceability of materials used. Each hydraulic actuator shall be low stress stamped with serial number linked with tests and material certificates.

11 APPENDIX

11.1 Alternative design for piston

Due to dificulties reported to find copper-beryllium alloy rods over 9 inch equipment manufacturers may propose alternative design by combining high strength inox steel (blue part) with original copper-beryllium alloy (orange part) as shown in Figure 1 subject to Petrobras approval.

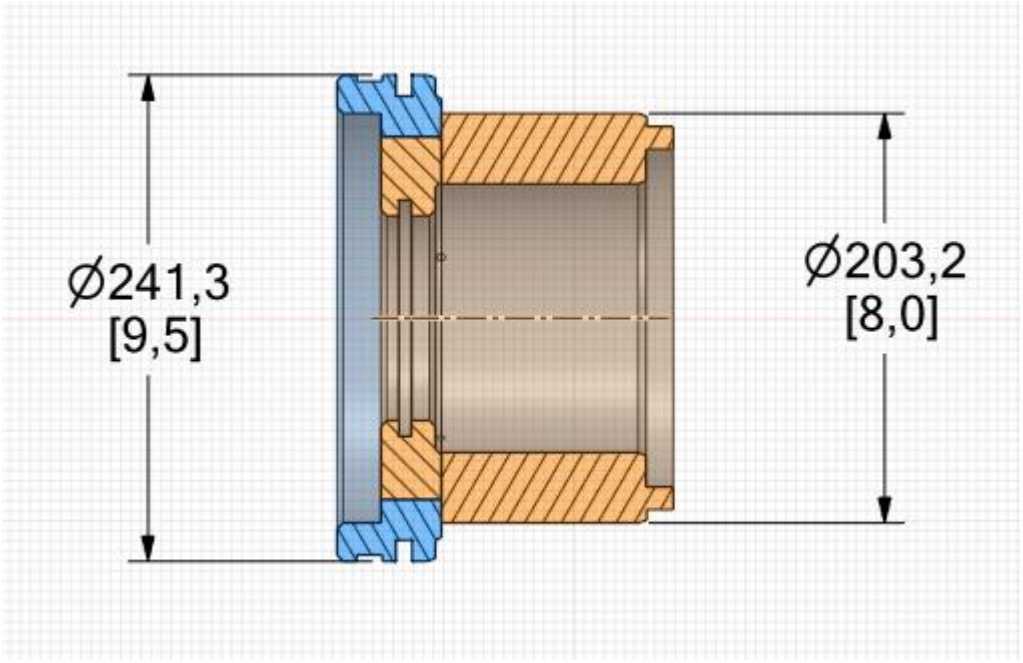

Figure 1 – alternative design for piston

11.2 Load ring

Load ring material specified in ref. [6] can be supplied in original ASTM A 320 gr L7 or alternative 4340 as defined in 4.2 in this technical specification