SPECIFICATION FOR CRITICAL, HIGH LOAD BEARING ALLOY 718 COMPONENTS PER API 6A 718

Summary:

This document provides a summary of the API6A718 specification requirements for Nickel Base Alloy 718 (UNS N07718) for critical service applications as agreed upon by SARA and end user. Exceptions to API6A 718 include the minimum reduction ratio, approved vendor list and MPQP requirement for large forgings. Material provided in compliance with API6A718 and these exceptions meet the requirements of this specification. Use of this specification shall be approved by SARA Engineering and is applicable to tubing hangers, stems and other critical, high load bearing components.

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Abbreviations	
AOD	Argon Oxygen Decarburization
EF	Electric Furnace
EFR	Electroflux Remelting (same as ESR)
ER	Equivalent Round
ESR	Electro-slag Remelting
QTC	Qualification Test Coupon
VAR	Vacuum Arc Remelting
VIM	Vacuum Induction Melting
VOD	Vacuum Oxygen Decarburization

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1.0 SCOPE

1.1 This document provides a summary of the API6A718 specification requirements for Nickel Base Alloy 718 (UNS N07718) for critical service applications as agreed upon by SARA and end user. Such applications include (but may not be limited to) tubing hangers, stems and associated equipment where the potential embrittlement by deleterious phases should be avoided.

1.2 This specification includes requirements pertaining to detailed process control requirements and detailed testing requirements.

1.3 All microstructural and mechanical testing shall be from either a prolongation (full cross section on thickest end) or sacrificial production part. (see note on large forgings section 2.3.2 for exception)

1.4 SARA requirements in addition to API6A718 can be found in section 2.0. There are no requirements beyond section 2.0 in addition to those of API6A718.

Material provided in compliance with API6A718 and in accordance with section 2.0 meet the requirements of this specification. Use of this specification shall be approved by SARA Engineering.

2.0 ADDITIONAL REQUIREMENTS

2.1 Approved Vendors

2.1.1 The vendors listed below are approved for melting, forging and heat treatment, except as noted:

Foroni	Special Metals Corporation
Thyssen Krupp VDM	Inco Alloys LTD (Hereford)
WASA (melting only)	Allvac
Carpenter	Aubert Duval
Bohler Edelstahl	Firth Rixon Superalloys (FRS)
Villares Metals Brazil	

2.1.2 Material that is to be acquired or processed (forged or heat treated) by any source not listed in section 2.1.1 shall be pre-approved by SARA. The melt source must be one of those listed in 2.1.1, NO EXCEPTIONS. Approval shall consist of (but may not be limited to) pre-approval of a complete Manufacturing Process. The forge and heat treat facilities must be an approved SARA vendor.

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2.2 Forging and Hot Working Requirements

The minimum total hot work reduction ratio shall be 4:1 for all product forms.

2.3 Special Requirements for Forgings and Parts Made From Large Diameter Bar Stock

2.3.1 Components greater than 10 inches (250mm) in diameter and greater than 39 inches (1000mm) in length made from forgings or bar stock require that detailed MPS/Quality Plans for the forging, heat treatment, NDT and machining stages be submitted to SARA for approval prior to production. As a minimum, the plans shall clearly indicate the forging soak temperature and times, forging temperature ranges and the minimum forging temperature. They shall also state when and how the material temperatures will be monitored during the forging, solution annealing, and age hardening stages.

The part report for large API6A718 forging which requires a detailed MPQP should also specify in quality plan. If the part meets the size criteria above for MPQP, and in quality plan was not specified, the supplier is required to provide the MPQP for approval prior to production.

2.3.2 The mechanical testing and microstructural examinations shall be carried out on either sacrificial components or prolongations taken from both ends of the forging or component.

2.3.3 When the requirements of section 2.3.1 are applicable to a given component, the micrographs shall be submitted to SARA prior to acceptance and shipment. This is required unless otherwise waived by SARA in writing.

3.0 APPLICABLE SPECIFICATIONS

API Spec 6A	Specification for Wellhead and Christmas Tree Equipment
API Spec 6A718	Specification of Nickel Base Alloy 718(UNS N07718) for Oil and Gas Drilling and Production Equipment
ASTM A 370	Standard Test Methods and Definitions for Mechanical Testing of Steel Products
ASTM A 604	Standard Test Method for Macroetch Testing of Consumable Electrode Remelted Steel Bars and Billets
ASTM B 880	General Requirements for Chemical Check Analysis Limits for Nickel, Nickel Alloys and Cobalt Alloys
ASTM E 10	Standard Test Method for Brinell Hardness Test of Metallic Materials
ASTM E 18	Standard Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials
ASTM E 112	Standard Test Methods for Determining Average Grain Size
ASTM E 354	Test Methods for Chemical Analysis of High-Temperature Electrical, Magnetic, and Other Similar Iron, Nickel and Cobalt Alloys
ASTM E 1181	Standard Test Methods for Characterizing Duplex Grain Sizes
ASTM E 1473	Test Methods for Chemical Analysis of Nickel, Cobalt, and High-Temperature Alloys
ISO10423	Petroleum and Natural Gas Industries - Drilling and Production Equipment - Wellhead and Christmas Tree Equipment

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4.0 PROCESS CONTROL REQUIREMENTS

4.1 Chemical Composition Requirements

4.1.1 Chemical Composition Limits

The chemical composition shall conform to Table 1 (Values are maximums unless otherwise noted):

Table 1: API6A718

Ni	50.0-55.0	**Ti**	0.80-1.15	**Si**	0.35	**Pb**	10ppm
Cr	17.0-21.0	**Al**	0.40-0.60	**P**	0.010	**Se**	5ppm
Fe*	Balance	**C**	0.045	**S**	0.010	**Bi**	0.5ppm
Nb(Cb) + Ta	4.87-5.20	**Co**	1.00	**B**	60ppm	**Ca****	30ppm
Mo	2.80-3.30	**Mn**	0.35	**Cu**	0.23	**Mg****	60ppm
* Shall be determined arithmetically by difference or by direct measurement.							
** To be determined if intentionally added.							

4.2 Melt Practice Requirements

4.2.1 Acceptable Melt Practices

The alloy shall be melted by one of the following processes (**A or B**):

Table 2: Acceptable Melt Practices

A	B
Step 1 - Basic electric furnace (EF).	Step 1 - Vacuum induction melting (VIM).
Step 2 - Either argon oxygen decarburization (AOD) or vacuum oxygen decarburization (VOD).	Step 2 - Either electroslag remelting (ESR) or electroflux remelting (EFR) or vacuum arc remelting (VAR).
Step 3 - Vacuum arc remelting (VAR).	Optional Step 3 - Electroslag remelting (ESR) or electroflux remelting (EFR) or vacuum arc remelting (VAR).
Step 4 - Additional VAR.	

4.3 Heat Treating Requirements

4.3.1 Solution Annealing and Age Hardening

Material shall be heat treated in accordance with the following procedure:

Solution anneal: 1870°F ± 1925°F (1021°C ± 1052°C) for one hour minimum to two and a half hours maximum.

Cool in air, inert gas, water, polymer or oil to ambient temperature.

Age harden: 1425°F ± 1475°F (774°C ± 802°C) for six to eight

hours. Air cool or faster to ambient temperature.

4.4 Testing Requirements

4.4.1 Macroetch Requirements

4.4.1.1 Test Location, Method and Frequency

4.4.1.2 Macroetch Examination

A macroetch examination shall be performed. The macroetch examination shall be performed on either (a) or (b) as shown below:

a. Full transverse cross-section slices representative of the top and bottom of each final remelt ingot or product thereof.

b. For product not tested by the mill and not identified as to its relative location within the ingot, the macroetch testing shall be performed on a per billet, bar or other raw material product form basis. A full transverse cross-section slice shall be examined from each end. The full cross section slices shall be etched for examination. The acceptable etchants can be found in API 6A 718.

4.4.1.3 Macroetch Examination and Acceptance Criteria

The macrostructure of the slice shall be examined and rated to all four classes in ASTM A 604. The acceptance criteria are as follows:

Class 1 (Freckles) - Severity A or better

Class 2 (White Spots) - Severity A or better

Class 3 (Radial Segregation) - Severity A or better

Class 4 (Ring Pattern) - Severity A or better

4.4.2 Microstructural Analysis Requirement

4.4.2.1 Test Location, Method and Frequency

Material with the same shape and equivalent round from each remelt ingot per heat treat lot shall be sampled and subjected to a microstructural analysis. Samples taken for evaluation shall be a minimum:

¼ in (6 mm) square and oriented longitudinally to the primary axis of grain flow. In the event the product cross section is less than ¼ in. (6 mm), the sample(s) shall be full cross section. The microstructural analysis shall be performed after final heat treatment. Test locations shall be a minimum of 1.25 in. (32 mm) from a heat treated end surface.

The center, ¼ thickness and surface locations or solid shapes shall be evaluated. The mid-wall location and both the inner and outer surfaces or hollow shapes shall be evaluated. The acceptable etchants can be found in API 6A 718.

4.4.2.2 Grain Size Evaluation

4.4.2.2.1 Grain Size

The average grain size shall be determined in accordance with ASTM E 112. The ASTM average grain size shall be predominantly No. 2 or finer.

4.4.2.2.2 Duplex Grain Size

Topological duplex grain size as defined and measured per ASTM E 1181 is not permitted.

4.4.2.2.3 Metallographic Examination for Deleterious Phases

The microstructural samples shall be examined at 100 and 500X for deleterious phases, using optical light microscopy. Microstructural acceptance criteria:

a. The microstructure shall be free from continuous networks of secondary phases along grain boundaries or other unusual microstructural features, except for individual, isolated grains that are not representative of the bulk of the microstructure. The presence of discrete, isolated particles of delta phase or carbides is acceptable.

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b. The microstructure shall be free from acicular delta phase except in individual, isolated grains that are not representative of the bulk of the microstructure. In no case shall any individual grain be surrounded with acicular delta phase.

c. There shall be no laves phase.

Note: Examination of the microstructural samples for laves phase is not required if the original melt source certifies that the material is free from laves phase.

The Reference Photomicrographs in Annex A of API6A718 are examples of acceptable and unacceptable microstructures. Material that is rejected for unacceptable microstructural features may be fully re-heat treated (solution annealed and age hardened) in accordance with 4.3 and re-examined. In the event a heat treat lot is rejected, other pieces within the rejected heat treat lot may be qualified on an per-piece basis. Material containing rejectable locations based on microstructural features may be accepted if the rejectable locations are removed by machining and no longer contained in the finished part.

4.4.3 Tensile and Impact Property Requirements

4.4.3.1 Test Location, Method and Frequency

One tensile test and one set of three Charpy Impact tests shall be performed for each tested QTC. The test frequency shall be one test per remelt ingot per heat treat lot (batch) (as defined in API Spec 6A and ISO 10423) for material of the same size. The QTC shall be either a prolongation (full cross section on thickest end) or sacrificial production part. For solid material, the test specimen shall be removed from a location at ¼ thickness or deeper from the side or outer diameter and at least 1.25 in. (32 mm) from the end. For hollow material, the test specimen shall be removed from a mid-wall location and at least 1.25 in. (32 mm) from the end. Test specimens and test methods shall be in accordance with ASTM A 370.

All Charpy tests shall be performed at or below ±75°F (±60°C) regardless of API Spec 6A or ISO 10423 Temperature Classification or other SARA specification referenced on part DBI. Specimens shall be oriented transverse to the primary direction of grain flow unless the size or geometry of the QTC prevents the usage of transverse specimens (material less than 3 in. [76 mm] in cross section). Longitudinal specimens shall be used for such cases.

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4.4.3.2 Tensile Test Acceptance Criteria

The tensile properties shall meet the acceptance criteria as shown in Table 3.

Table 3 Material Property Requirements

Material Designation	QTC Cross Section Thickness in. (cm)	0.2% Yield Strength min. psi (MPa)	0.2% Yield Strength max. psi (MPa)	Tensile Strength min. psi (MPa)	Elongation in 4D min. %	Reduction of Area min. %
120K	< 10 (25.4)	120,000 (827)	145,000 (1000)	150,000 (1034)	20	35
	> 10(25.4)	120,000 (827)	145,000 (1000)	150,000 (1034)	20	25

4.4.3.3 Charpy V-Notch Acceptance Criteria

The average energy value for a set of three specimens shall meet or exceed the specified average. No more than one of the specimens shall have an energy value below the specified average. No specimens shall have a lateral expansion below the specified value. The adjustment factors for sub-size impact specimens in API Spec 6A shall apply to the absorbed energy values. Lateral expansion shall meet the requirements in Table 4 regardless of specimen size.

Table 4 Charpy V-Notch Impact Toughness Requirements (10 mm X 10 mm)

Temperature		QTC Cross Section Thickness in. (cm)	Minimum Impact Value PSL 1, 2, 3, and 4					
			Transverse Direction			Longitudinal Direction		
API Spec 6A Temp Class	Test Temp °F(°C)		Average Value Ft-lbf (J)	Single Min Value Ft-lbf (J)	Lateral Expansion in. (mm)	Average Value Ft-lbf (J)	Single Min Value Ft-lbf (J)	Lateral Expansion in. (mm)
All	±75 (±60) or below	< 3 (7.6)	Not Applicable	Not Applicable	Not Applicable	50 (68)	45 (61)	0.015 (0.38)
		> < 10 (25.4)	35 (47)	30 (41)	0.015 (0.38)	Not Applicable	Not Applicable	Not Applicable
		> 10 (25.4)	30 (41)	27 (37)	0.015 (0.38)	Not Applicable	Not Applicable	Not Applicable

4.4.4 Hardness Testing

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4.4.4.1 Test Location, Method and Frequency

Following the final heat treatment cycle, the surface or near surface of each piece of production material and each QTC shall be Brinell or Rockwell C hardness tested per ASTM E 10 (10 mm ball, 3000 kgf) or ASTM E 18. Each piece of production material and each QTC shall have a minimum of one hardness test.

4.4.4.2 Hardness Test Acceptance Criteria

The hardness tests shall meet the requirements of Table 5.

Table 5--Hardness Requirements

Material Designation	Minimum Hardness HBW (HRC)	Maximum Hardness HBW (HRC)
120K	298 (32)	363 (40)

5.0 CERTIFICATION

The material supplier shall provide a certified test report containing the following information as a minimum:

5.1 Chemical analysis results

5.2 Melt practice utilized

5.3 Name of melt source

5.4 Name of company performing the hot working operations (if different from melt source)

5.5 Name of company performing the heat treatment (if different from melt source)

5.6 Total hot work reduction ratio

5.7 Actual heat treatment times and temperatures and cooling media

5.8 Name of test laboratory

5.9 Statement that the material complies with the requirements of the macroetch examination

5.10 Predominant grain size

5.11 Statement of compliance with topological duplex grain size testing requirement

5.12 Statement that the material complies with the requirements of the metallographic examination for deleterious phases (note section 2.3.3 requirement when applicable) In addition, a complete set of legible photomicrographs taken at all three referenced locations (at 100X and 500X) is required.

5.13 Tensile test results

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5.14 Impact test temperature, orientation, and results

5.15 Hardness test results

6.0 MARKING

The raw material shall be marked or tagged with identification traceable to the certification.

The material manufacturer or supplier shall maintain copies of the heat treating charts showing the material temperature as measured by the contact surface thermocouple or heat sink for a minimum of 5 years following the date of heat treatment. Likewise, the material manufacturer or supplier shall retain the mounted metallographic specimens for a minimum of 5 years following the date of examination.

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