

	BHEL – Tiruchirappalli - 620014, India. Quality Assurance Department TECHNICAL DELIVERY CONDITIONS	Doc No: TDC:0:409 Rev No: 14 Effective Date: 20/10/2020 Page: 1 of 7
Product: Steel Forgings & Bars for Pressure Controlling Parts of OFE for API-6A & API-16C		

Revisions Record:

Rev: 01:05/03/97: Text written, Tolerance document no. added.
Rev: 02:01/01/01: UT reqt. Altered in CI 8.0 & CI 6.0. NDE for finished items added.
Rev: 03:26/04/02: CI 3.0 Chemistry, UT, Forgings, CI.5.0: Soaking time in title of HT table, modified.
Rev: 04:23/01/03: CI 3.0 Chemistry, UT re-written. CI.5.Heat sink altered.CI.6.0Retest altered. CI 11.0 Melting process in TC restricted to PSL 4.
Rev: 05: Material Inconel UNS N07718 included in CI 1.0 and requirements added in CI2.0, 3.0, 5.0, 6.0 & 8.0
Rev: 06: 30/10/10: Test Requirements in CI 6.0 updated
Rev: 07: 10/04/12: CI 5.0 – Equipment for HT updated. CI 8.0 – Requirements for Wet MPI added for PSL 3, 3G & 4
Rev 08: 24/03/15: Edition numbers for reference standards added. CI 2 – Edition added, Temperature rating R deleted, CI 3 – Restriction on P, S added, CI 6 – Impact test modified, CI 8 – Personnel qualification, exception on test method in UT, MPI added, term '...finished component' removed, CI 11 – modified.
Rev: 09: Dt: 20/10/2015: CI 6.0, 8.0, 11.0 modified.
Rev 10: Dt: 22/12/2015: CI 1, 2, 3, 4, 5, 6, 8, 10, 11 & 12 modified.
Rev:11 Dt: 07/02/2017: CI 1 modified to indicate the use of latest revisions of referred codes, standards, specifications, drawings, procedures, etc; Definitions for relevant, linear and rounded indications provided in CI 8; Table Numbers added in CI 3, 5, 6; CI 5 revised to include HT Furnace calibration procedure; CI 1, 2, 4, 5, 6, 8 & 11 revised to bring better clarity.
Rev:12 Dt: 09/09/2019 - CI 1, 2, 3, 4, 5, 6 & 8 modified as per API 6A 21st Ed Errata 1 and for better clarity.
Rev:13 Dt: 02/07/2020- CI.2- Temperature rating for API 16C updated.CI.3. modified.CI 4 & 8-reference std metric version added.CI5f modified based on API 6A 21st Ed Errata 2
Rev.14 Dt.20/10/2020 – Latest version of the referred Standards/Specifications indicated in TDC; CI.1,2,11 modified

1. MATERIAL SPECIFICATIONS

All the Codes, Standards, Specifications, drawings & procedures, etc., referred in this TDC shall be of latest revision as on the date of Purchase Order, unless specified otherwise.

<i>Product Specifications</i>	: <i>API-6A 21st Ed 2018 Errata 3 Addendum 1, API-16C 2nd Ed 2015 Errata 4 Addendum 1</i>
Carbon Steel (CS)	:AISI 1040:60K, AISI 1042:60K, AISI 1045:60K
Alloy Steel (AS)	:AISI 4130:75K, AISI 4140:75K, AISI 8620;
Martensitic Stainless Steel (SS)	:AISI 410:75K
Inconel Alloy	:API 6ACRA N07718:150K Ed.2015
Additional Requirements	: As listed below (Supplementary to above material specifications/standards)
Size and Quantity	:As per Purchase order & Drawing.

2. APPLICATION

Pressure controlling parts of oil field equipment meeting API-6A 21st Ed 2018 *Errata 3 Addendum 1*; API-16C 2nd Ed 2015 *Errata 4 Addendum 1*; National Oil Well Spec MS 245, 342, 345, 346 & 377; NACE MR0175 Ed.2015 with:

Product Specification Level (PSL)	:	API-6A: 1, 2, 3, 3G & 4; API-16C: 3, 3G & 4
Temperature rating: API-6A	:	P, S, T, U, V, X & Y
API-16C	:	U,V, X & Y
Material Class & Service	:	As per applicable drawing.
Material property designation	:	60K, 75K & 150K

3. CHEMICAL COMPOSITION & PROCESS

Melting Practices (API 6ACRA N07718): Any one of the following methods, Fully killed with Pressure vessel quality.
Basic electric furnace – Either argon oxygen decarburization (AOD) or vacuum oxygen decarburization (VOD) – Vacuum arc melting (VAR) – VAR (or)
Vacuum induction melting (VIM) – either electroslog remelting (ESR), electroflux remelting (EFR) or VAR.

Melting Practices (other materials): Electric furnace or basic oxygen process, Fully killed with Pressure vessel quality.

Ladle and product analysis in mass percentage per heat are given in Table 1 below:



Table 1. Chemical Requirements

Elements	Chemistry for various Material Specifications							
	AISI 1040	AISI 1042	AISI 1045	AISI 4130	AISI 4140	AISI 8620	AISI 410	API 6ACRA N07718
C	0.37-0.44	0.40-0.45	0.43-0.45	0.27-0.35	0.37-0.45	0.18-0.23	0.15 max	0.045 max
Mn	0.60-0.90	0.60-0.90	0.60-1.80	0.40-0.80	0.60-1.00	0.70-0.90	1.00 max	0.35 max
Si	---	---	---	0.15-0.45	0.15-0.45	0.15-0.30	1.00 max.	0.35 max
P	For PSL 1 & 2 – Phosphorous and Sulphur: 0.04% max. each. For PSL 3 & 3G - Phosphorous and Sulphur: 0.025% max. each. For PSL 4 - Phosphorous: 0.015% max. & Sulphur: 0.010% max.							0.010 max
S								0.010 max
Ni*								50.0-55.0
Cr*	---	---	---	0.80-1.30	0.80-1.30	0.40-0.60	11.5-13.5	17.0-21.0
Mo*	---	---	---	0.15-0.35	0.15-0.35	0.15-0.25	---	2.80-3.30
V*	---	---	---	0.30 max	---	0.30 max	---	---
Cu*	0.4 max	0.4 max	0.4 max	---	---	---	---	0.23 max
Others	---	---	---	---	---	---	---	Cb (Nb)+Ta: 4.87-5.20; Co: 1.0 max ^B , Al: 0.40-0.60, Ti: 0.8-1.15, B: 0.006 Max, Pb: 0.001 max, Se:0.0005max Bi: 0.00005 max, Ca: 0.003 max@, Mg: 0.006 max@
Fe	Remainder ^A							

Notes to Table 1:

- * The total of these elements(---) shall not exceed 1% for AISI 1040, 1042, 1045, 410.
- ^A The element shall be determined arithmetically by difference.
- Tolerance for above chemistry shall be as per the applicable material specifications/standards specified in CI 1.
- @ To be determined if intentionally added.

Material shall be Ultrasonic tested (UT) as per method in CI.8b before forging to ensure freedom from defect, if UT is not possible at final stage. Wherever ingots are used, ingot shall be forged to an intermediate billet/bloom & UT tested before forging to final size & shape.

Hot forging: Forging shall be ensured for uniform wrought structure & strength from ingot to finished forging, close to final size and shape with minimum hot working reduction ratio in area: 4:1 for API 6ACRA N07718 and 3:1 for other material specifications. The total hot work ratio for QTC shall not exceed the hot work ratio of the part it qualifies. Grain flow lines shall be parallel to axial length of forging. A forging plan shall be prepared & used indicating stages of forging and reduction ratio at each stage and the final reduction ratio shall be prepared for each type & size of forging.

4. DIMENSIONS AND TOLERANCES

Dimensions & their tolerances shall be as per applicable drawings. For untoleranced dimensions: CS & AS: as per ASTM A 29/A 29M-20; SS: as per ASTM A 484/A 484M-20B.

5. HEAT TREATMENT(HT)

- Equipment/Furnace used for heat treatment shall be qualified as per SIP:OF:01.
- For heat treatment requirements, Table 2 shall be followed.



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- c) For material heat treated in a batch furnace, the QTC shall qualify only material and parts produced from the same heat. For material heat treated in a continuous furnace, the QTC shall qualify only material and parts produced from the same heat and heat-treat lot.
- d) In no case shall the QTC be processed using a melting practice(s) cleaner than that of the material it qualifies. The QTC shall be heat-treated in the same heat-treat furnace and same quench tank as the production parts that it qualifies.
- e) Welding on the QTC is not permitted.
- f) Equivalent Round (ER) (determined as below) of QTC shall be equal to or greater than the dimensions of the part it qualifies.
- ER need not be >63mm (2.5") for PSL 1 & 2 parts and ER need not be > 127mm (5") for PSL 3, 3G parts.
 - For PSL 3 & 3G, for parts that require a yield strength of 75K or greater and where the part's weight during heat treatment is > 454 kg (1000 lb), the QTC ER shall be the same or greater than the part it qualifies but, is not required to exceed 254mm(10").
 - For PSL 4, a prolongation or production part shall only be used. The testing shall use a prolongation or production part for each heat-treat lot. Individual prolongations or production parts corresponding to each quench shall be used for multiple quench batches from the same furnace load.
- g) **Determination of ER** (applicable to PSL 1, 2, 3 & 3G): based on actual part size & shape in "as heat treated condition":
- I) Standard Shapes:
- Round : ER = Diameter
 - Hexagon : ER = 1.1 x Thickness
 - Square : ER = 1.25 x Thickness
 - Rectangle/Plate : ER =1.5xSmallest thickness
 - Hollow shapes : ER = 2xWall thickness
- II) Complex shapes: valve body etc., :
- Internal & external as forged surface within 13 mm of finished surface:ER = 1.25xT.
 - Internal & external as forged surface not within 13 mm of finished surface: ER = 2xT.
- (T = Max. thickness of Flange for flanged component/ Body thickness for flange less component).
- h) **Heat sink for PSL 4:** Temperature levels for PSL 4 to be determined using a heat sink made of same alloy type as the part. ER (determined as above) of the heat sink to be $\geq$ largest ER of any single part in a HT load. A production part may serve as heat sink provided all requirements of this section are met. The temperature sensing tip of the thermocouple shall be within the part or heat sink and shall be no closer than one inch to any external or internal surface.
- i) Temperature of quench media(water/water based - polymer) at start of quenching shall not exceed 38°C. In case of oil, start temperature shall be greater than 40°C.
- j) For bath-type quenching, the temperature of the water or quench media shall not exceed 49°C at any time during the quench cycle.
- k) Heat Treatment temperatures, soaking times and cooling media are given material specification-wise in Table 2 below shall be followed. Tempering temperature range, wherever not provided, to be appropriately chosen to get required Mechanical properties meeting the minimum specified temperature in Table 2.

Table 2. Heat Treatment Requirements

Material Specifications	Heat Treatment Type	Temperature (°C)	Soaking Time: Minutes/inch of max thick of forging	Cooling medium
AISI 1040, 1042 & 1045	Normalising	885-910	30	Air
	Quenching	830-870	30	Quenching in water, oil or polymer
	Tempering	530 (min)	60	Air
AISI 4130	Normalising	885-925	30	Air
	Quenching	830-870	30	Quenching in water, oil or polymer
	Tempering	640 (min)	60	Air



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AISI 4140	Normalising	860-910	30	Air
	Quenching	820-870	30	Quenching in water, oil or polymer
	Tempering	670 (min)	60	Air
AISI 8620	Normalising	870-925	30	Air
AISI 410	Quenching	955-1010	30	Quenching in air, water, oil or polymer
	I Tempering	663 (min)	60	Air
	II Tempering*	621 (min)	60	Air
	*Second tempering temperature shall be less than the first tempering temperature			
API 6ACRA N07718	Solution Annealing	1021-1052	1 to 2.5 hours	Air cool or faster
	Precipitation	718±14	8 hours	Furnace cool to 621±14°C, hold until total hardening precipitation heat treatment time has reached 18 hours; then, Air cool.

6. MECHANICAL TESTS:

- a) Extent of test:** One specimen for each size / heat / HT batch.
- b)** Test specimen shall be removed from acceptable Qualification Test coupon (QTC) forged in similar manner after final QTC heat-treatment cycle as below:
- Solid QTC: longitudinal centre line axis of specimen shall be wholly within the centre core $\frac{1}{4}$ thickness envelope.
 - Hollow QTC: Longitudinal centre line axis of specimen shall be within 3mm of the mid thickness of the thickest section.
 - Tensile specimen gauge length and Charpy V-notch root shall be at least $\frac{1}{4}$ of the thickness from each end of QTC.
 - When actual production part is used as QTC, specimen shall be taken from thickest section of part.
- c) Tensile Test** shall be performed at room temperature (between 4 °C and 50 °C) **as per ASTM A370-19E1**. Acceptance as per below Table 3.

Table 3. Mechanical Property Requirements

Material Specifications	Min. Strength, (min)	Yield psi	Min. Tensile Strength, psi (min)	% Elongation on 2" GL(min)	% Reduction area (min)	Hardness, if not in drg
AISI 1040, 1042 & 1045	60,000		85,000	18	35	174 – 235 HBW
AISI 8620	Not Applicable					160 – 230 HBW
AISI 4130, 4140 & 410	75,000		95,000	17	35	197 – 235 HBW
API 6ACRA N07718	1,50,000 to 1,75,000		1,75,000	20	35% for QTC cross c/s thick* ≤ 254 mm; 25% for QTC c/s thick* > 254 mm	327 – 371 HBW

Note 1. All yield strengths shall be determined using 0.2% offset method of ASTM A370-19E1.

2. * - QTC cross-section thickness at time of heat treatment

Retesting: If results of test do not conform to above requirements, then two more samples (taken from the same QTC without additional heat treatment) to be tested in the same manner. Results of each of these tests shall satisfy the above requirements.

- d) Tensile Tests at Elevated temperatures for materials of X & Y temperature ratings (Refer applicable drawing):**

The elevated-temperature tensile test(s) shall be performed on specimens removed from the same QTC used for room-temperature tensile testing. At least one elevated temperature tensile test shall be performed each at 180°C for X temperature rating and 345°C for Y temperature rating, using the methods of ASTM E21-17E1 and shall meet the requirements of below Table 4.

Table 4. Elevated Temperature Yield & Tensile Strengths

SI No	Material Specifications	Min.YS for X Temp rating (PSI)	Min.YS for Y Temp rating (PSI)	Min.TS for X Temp rating (PSI)	Min.TS for Y Temp rating (PSI)
1	AISI 1040, 1042 & 1045	51,000	45,000	72,250	63,750
2	AISI 4130, 4140 & 410	63,750	56,250	80,750	71,250
3	API 6ACRA N07718	1,42,500 to 1,66,250	1,27,500 to 1,48,750	1,66,250	1,48,750

All yield strengths shall be determined using 0.2% offset method of ASTM A370-19E1.

Retesting: If results of test do not conform to above requirements, then two more samples (taken from the same QTC without additional heat treatment) to be tested in the same manner. Results of each of these tests shall satisfy the above requirements.

e) **Hardness test** as per ASTM E10-18 or E18-20: Min 2 test to be done on test coupon/QTC and on 100% of forgings as per drawing & bars after HT. Hardness acceptance value: as per Table 3.

f) **Impact (Charpy V notch) test as per ASTM A370-19E1: PSL 1, 2, 3, 3G & 4 only:** Min. 3 specimens **shall be** tested at –60°C for API 6ACRA N07718 and for other materials at –29°C.

Acceptance criteria except for API 6ACRA N07718: Min. average: 20 Joules for specimen orientation in transverse direction and 27 Joules for specimen orientation in longitudinal direction. Individual min.: 2/3 of min average. Only one of the three values may go below the minimum average.

Acceptance criteria for API 6ACRA N07718 (Table 5):

Table 5. Acceptance criteria for Impact testing of API 6ACRA-N07718

QTC c/s thick* (mm)	Specimen Orientation	Min. average (J)	Min. single value (J)	Min. Lateral expansion (mm)
<76mm	Longitudinal	68	61	0.38
≥76mm to 254 mm	Transverse	47	41	0.38
>254 mm	Transverse	41	37	0.38

* - QTC cross-section thickness at time of heat treatment

Retesting: If a test fails, then retest 3 additional specimens (from required location within same QTC with no additional heat treatment), each of which to exhibit impact value ≥ min. specified average value.

Note: API-6A & 16C: Sub-size specimens shall not be used for PSL 4.

7. WORKMANSHIP AND FINISH

Items to be machined where required. Bars shall be supplied as forged and ground smooth to enable UT to be conducted on Bars. To be examined visually & to be free from scales & defects like laps, seams, folds, cracks, etc. Forgings to be clean, trimmed of flash & shot blasted to remove scales after HT.

8. NON-DESTRUCTIVE TESTING

NDE personnel qualification: As per ISO 9712 Ed.2012 /ASNT SNT-TC-1A Ed.2020:.

a) Surface NDE:

- CS & AS: 100 % MPI on all accessible wetted surfaces and all accessible sealing surfaces after final heat-treatment and final machining operations,if any.
- SS: 100 % LPI on all accessible wetted surfaces and all accessible sealing surfaces after final heat-treatment and final machining operations,if any.
- Method:** MPI : ASTM E 709-15 for PSL 1 & 2. Prod method is not permitted.
Wet fluorescent MPI: ASTM E709-15 for PSL 3, 3G& 4
LPI : ASTM E 165/ E 165M-18
- linear indication:** Surface NDE indication whose length is equal to or greater than three times its width.

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relevant indication: Surface NDE indication with major dimensions greater than 1.6 mm

rounded indication: Surface NDE indication that is circular or elliptical, having a length less than 3 times its width

v. Acceptance Criteria (MPI):

- 1) Linear indications (like cracks, laps, folds & other injurious defects) are unacceptable.
- 2) no relevant indication with a major dimension equal to or greater than 5 mm;
- 3) no more than ten relevant indications in any continuous 40 cm² area;
- 4) four or more relevant rounded indications in a line separated by less than 1.6 mm (edge to edge) are unacceptable;
- 5) no relevant indications permitted on any pressure contact sealing surface.

vi. Acceptance Criteria (LPI):

- a) Linear indications (like cracks, laps, folds & other injurious defects) are unacceptable.
- b) no relevant rounded indication with a major dimension equal to or greater than 5 mm;
- c) no more than ten relevant rounded indications in any continuous 40 cm² area;
- d) four or more relevant rounded indications in a line separated by less than 1.6 mm (edge to edge) are unacceptable;
- e) no relevant indications permitted on any pressure contact sealing surface.

b) Volumetric NDE:

- 1) PSL 1&2: 100% Ultrasonic test(UT) on bars of Dia $\geq$ 50mm & forgings of thickness $\geq$ 10mm as per ASTM A 388/A 388M-19.

Acceptance Criteria: Item shall be unacceptable if examination result shows one or more reflectors which produce indications accompanied by complete loss of back reflection.

- 2) PSL 3, 3G & 4: 100% UT on all rolled/forged bars and forgings as per flat bottomed hole procedure of ASTM A 388/ A 388M-19 and ASTM E 428-08(Reapproved 2013)/ ASTM E127-19E1. Immersion method shall not be used.

Calibration: Distance amplitude curve (DAC) to be based on maximum 1.6 mm flat bottomed hole (Straight – beam technique) for metal thicknesses upto 38 mm; on a maximum 3.2 mm flat bottomed hole for metal thicknesses from 38 mm to 150 mm and on a maximum 6.4 mm flat bottomed hole for thicknesses exceeding 150 mm.

Acceptance Criteria:

- a) No single indications exceeding reference DAC.
- b) No multiple indication exceeding 50% of the reference DAC. Multiple indications are defined as two or more indications each > 50% of the reference DAC within 13 mm of each other in any direction.
- c) For PSL 4, in addition to above a) & b) - no continuous cluster of indications on the same plane, regardless of amplitude, shall be found over an area twice the diameter of the search unit.

9. REPAIR

Repairs by fusion welding are prohibited. Surface defects can be removed by mechanical means and defective areas smoothly dressed up with the adjacent surface. Minimum thickness after repair shall meet drawing/specification requirements.

10. MARKING AND PACKING

Details of stamping on each item with low stress stamps and border by paint:

(1) Heat number, (2) Material Specification & grade, (3) Size, (4) Maker's emblem/code, (5) Identification details as per drawing.

Items to be coated with a layer of rust preventive coating before despatch. Forgings to be properly packed and despatched to avoid damage during transit.



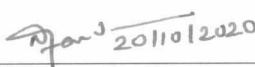
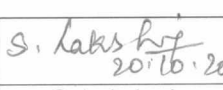
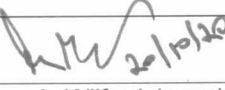
11. INSPECTION AND CERTIFICATION

All tests specified *shall be* carried out by forger and test results *shall be* furnished in the test certificate of type 3.1 or 3.2 as per BS EN 10204. *The applicable versions of the referred Codes, Standards and Specifications shall be reported in the Test Certificates and NDE reports.* Test certificate shall contain the following information in English language only:

1. Purchase Order No.(BHEL),TDC No & its revision no, Test certificate no & date, Part name
2. Material Specification & Grade with year of code, Heat Number, Drawing No.,Quantity & Size
3. Applicable API Specification, PSL, Temperature Class, Material Class & Material Property Designation.
4. Melting process (for PSL 4 only)
5. Forging process, Chemistry with incidental elements- Heat wise ladle & Product analysis.
6. Heat treatment details of the material and test bars like – actual soaking temperature, soaking time, rate of heating & cooling, cooling medium, etc. For PSL 4, actual recorded HT chart shall be submitted.
7. Mechanical test results: Room temperature Tensile Strength, Yield Strength (0.2% offset), %Elongation, %Reduction in Area, Impact, Hardness; Elevated temperature tensile & yield (0.2% offset) strength values, *including the location and orientation of test specimens*, as applicable
8. *NDE reports with NDE Personnel qualification records, all relevant NDE operating parameters and NDE test results with reference & acceptance standard (surface, volumetric).*
9. Repair details if any,
10. Certified copy of TC for starting material.
11. Dimensional reports (for PSL 3, 3G & 4 only).

12. AUDIT CHECKS AT BHEL

BHEL reserves the right to carry out audit checks for chemistry, HT condition, mechanical test and NDT on representative test bars or job. Items found defective during check or subsequent processing at BHEL will be rejected.

 20/10/2020	 20/10/20	 20/10/20	 20/10/20	 20/10/2020
N Nagamuthu Pandian	P. Arunkumar	S. Lakshmi	A. Wilfred Joseph	JVV Aruna Kumar
MGR/QA	DM/Valves Engg	DGM/QA	AGM/Valves/Purchase	SDGM/QA
Prepared By	Reviewed By			Approved By