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1.0 SCOPE

This Engineering Standard defines supplementary requirements for welding, fabrication, heat treatment, NDE and quality control activities for shop and field fabrication of equipment within the scope of API RP5S2. For piping designed in accordance with ASME B31.1 or B313,

The scope of materials covered by this Engineering Standard is as per API RP582 with the following amendments:

- Additional requirements for pressure vessels designed in accordance with API RP934 are specified in Attachment D.
- Additional requirements for duplex steels are specified in Attachment E.
- Additional requirements for equipment with integral cladding or weld overlay are specified in General Specification for Pressure Vessels

2.0 REFERENCES

Add the following references to those in API RP5B2:

2.1 API Standards

Standard 620	:	Design and Construction of Large, Welded, Low-pressure Storage Tanks
RP 934	:	Materials and Fabrication Requirement for 2¼Cr-1Mo & 3Cr-1Mo Steel Heavy Wall Pressure Vessels for High Temperature, High Pressure Hydrogen Service

2.2 ASME Standards

Section V	:	Non-Destructive Examination

2.3 ASNT Standards

ANSI/ASNT CP-189	:	Qualification & Certification of Non-Destructive Testing Personnel
SNT-TC-1A	:	Personnel Qualification & Certification in Non-Destructive Testing

2.4 ASTM Standards

A370	:	Test methods and Definitions for Mechanical Testing of Steel Products
A578	:	Specification for Straight Beam Ultrasonic Examination of Plain and Clad Plates for Special Applications
A956	:	Test Method for Equotip Hardness Testing of Steel Products
E1815	:	Standard Test Method for Classification of Film Systems for Industrial Radiography

2.5 AWS Standards

AWS A2.4	:	Symbols for Welding, Brazing and Non-Destructive Examination
AWS A3.0	:	Standard Welding Terms and Definitions
AWS A5.4	:	Stainless Steel Electrodes for Shielded Metal Arc Welding
AWS A5.01	:	Filler Metal Procurement Guidelines
AWS 5.17	:	Carbon Steel Electrodes and Fluxes for Submerged Arc Welding

2.6 NACE Standards

NACE RPO178	:	Fabrication Details, Surface Finish Requirements, and Proper Design Considerations for Tanks and Vessels to be Lined for Immersion Service.

British Standards

PD5500	:	Specification for Unfired Fusion 'Welded Pressure Vessels

2.7 European Norms (EN)

EN1011-2	:	Welding - Recommendations for Welding of Metallic Materials - Part 2: Arc Welding of Ferritic Steels

2.8 International Standards Organisation (ISO)

ISO1027	:	Radiographic Image Duality Indicators for Non-Destructive Testing - Principles and Identification
ISO9712	:	Non-Destructive Testing - Qualification and Certification of Personnel
ISO10474	:	Steel and Steel Products - Inspection Documents
ISO15614-8	:	Specification and qualification of welding procedures for metallic materials - Welding procedure test - Part S: Welding of tubes to tube-plate joints

2.9 Engineering Equipment A Materials Users Association (EEMUA)

143	:	Recommendations for Tube End Welding: Tubular Heat Transfer Equipment

2.10 Jacobs / IOCL standards as applicable

3.0 DEFINITIONS

Major weld repair : A weld repair shall be considered major when:

- It is made to rectify a leak on pressure testing
- The depth of the repair cavity exceeds 10% of the nominal thickness or 25mm, whichever is smaller
- The extent of the repair cavity exceeds 675cm2
- It is made to rectify laminations in the base material
- It is made to rectify cracks in the weld metal, HAZ or base material.

Major attachment : Attachment welded to the pressure boundary that imposes a stress of 34MPa or greater at the attachment weld.

Elevated temperature service : Equipment with a design temperature more than 454℃ (ferritic steels).

Alkaline Stress corrosion cracking (ASCC) environment : Equipment exposed to service environments containing caustic, amine or carbonates.

Basicity index (BI): Quantitative index for indicating the basic nature of SAW fluxes

calculated as follows:

$$\frac{Ca+MgO+BaO+SrO+Na_2O+K_2O+Li_2O+Ca_2+0.5(MnO+Fe)}{SiO_2+0.5(Al_2O_3+TiO_2+ZrO_2)}$$

4.0 GENERAL WELDING REQUIREMENTS

4.1 in addition to the requirements of API RP582, welding requirements for structural attachments welded directly to the pressure boundary shall meet the requirements of this Engineering Standard.

4.2 The requirements of API RP582 shall be met in full

4.3 In addition to the requirements of API RP582, WPSs and PQRs shall be submitted for Jacobs / IOCL review in accordance with project requirements

4.4 The use of standard welding procedures (SWPSs) in accordance with ASME lit shall be subject to Jacobs / IOCL review.

4.5 In addition to the requirements of the code, the WPS shall include the following details:

- Typical weld deposition sequence
- Weld bevel and fit-up tolerances
- Electrical characteristics for each welding process and consumable diameter
- Oscillation width and frequency and contact tube-to-weld distance for semi-automatic welding process
- Consumable manufacturer and brand designation
- Run-out length (ROL) or run-out ratio (ROR) for manual processes (impact tested WPS only}

4.6 Welding and non-destructive examination (NDE) symbols shall be in accordance with AWS A2.4

4.7 Safety measures for protecting workers involved in welding and cutting operations shall be in accordance with all local and national regulations. Adequate ventilation and fume extraction facilities shall be provided to minimise worker exposure to harmful welding. cutting and NDE consumable fumes.

4.8 All welding processes shall be protected from adverse weather conditions that may affect weld quality. When welding is performed outdoors in adverse weather conditions, temporary shelters shall be erected to completely enclose the work area. Windshields shall always be erected to prevent loss of shielding gas coverage when using gas shielded processes.

4.9 Fabricator shall ensure that procedures are in place to ensure welding parameters specified on the WPS are adhered to during production welding and shall perform regular audits to monitor their implementation.

4.10 All welding equipment, including wire feed or powder feed units, shall be suitably calibrated and shall be checked on a regular basis during production.

5.0 WELDING PROCESSES

5.1 Acceptable Welding Processes

The requirements of API RP5-B2 shall be met in full.

5.2 Automatic Pulsed Gas Tungsten Arc welding (GTAW-P)

in addition to the restrictions in API RP5-82. welding without the addition of filler metal (autogenous welding) shall be subject to Jacobs / IOCL review and agreement. Where this is proposed for austenitic stainless steels and Ni-base alloys, the fabricator shall ensure that suitable heats of steel are identified and welding procedures developed to avoid weld metal penetration problems associated with “cast-to-cast” variations.

5.2.1 Limitations of Fusion Welded Processes

5.2.2 Short Circuiting Gas Metal Arc Welding (GMAW-S)

The requirements of API RP582 shall be met in full.

5.2.3 Pulsed Gas Metal Arc welding (GMAW-P)

The requirements of API RP582 shall be met in full.

5.2.4 Flux Cored Arc welding (FCAW)

5.2.4.1 In addition to the restrictions in API RP582, FCAW-S may be used for either groove or fillet welds on above ground atmospheric storage tanks. All welding procedures shall be qualified with impact testing of the weld metal and HAZ at the lower of 0℃ or minimum design metal temperature (MDMT) in accordance with Section 11. A production test plate (PTP) shall be taken to represent each welding procedure used. The extent and testing requirements for the PTP shall be agreed with Jacobs / IOCL.

5.2.4.2 In addition to the restrictions in API RP582, FCAW-G may be used for either groove or fillet welds for pressure boundary or structural welding subject to the limitations stated in paragraph 5.2.2 when used in the short-circuiting transfer mode.

5.2.5 Electroslag Welding (EGW)

In addition to the restrictions in API RP582, all welding procedures used for welding pressure vessels or storage tanks shall be qualified with impact testing of the weld metal and heat affected zone at the lower of 0℃ or MDMT. A PTP shall be taken to represent each welding procedure used. The extent and testing requirements for the PTP shall be agreed with Jacobs / IOCL.

5.2.6 Submerged Arc welding (SAW)

In addition to the requirements in API RPSSE, SAW procedures shall be re-qualified whenever the welding flux-wire or flux-strip combination, composite-cored electrode or metal powder is changed from one manufacturer's brand or trade name to another. Equivalence under ASME Section II, Part C shall not be considered adequate for substitution without re-qualification.

5.2.7 Gas Tungsten Arc Welding (GTAW)

5.2.7.1 In addition to the restrictions in API RPSSZ all GTAW equipment shall be equipped with arc starting (e.g. high frequency) and crater eliminating devices.

5.2.7.2 in addition to the restrictions in API RP5B2, autogenous welding shall be subject to Jacobs / IOCL review and agreement. Where this is proposed for austenitic stainless steels and Ni-base alloys, the fabricator shall ensure that suitable heats of steel are identified, and welding procedures developed to avoid weld metal penetration problems associated with “cast-to-cast” variations.

5.2.8 Plasma Arc Welding (PAW)

5.2.8.1 PAW using the non-transferred arc mode is not permitted for weld overlay/back cladding or metallic hard facing.

5.2.8.2 Autogenous welding shall be subject to Jacobs / IOCL review and agreement. Where this is proposed for austenitic stainless steels and Ni-base alloys, the fabricator shall ensure that suitable heats of steel are identified and welding procedures developed to avoid weld metal penetration problems associated with “cast-to-cast" variations.

5.2.9 Single-Sided Welded Joints

5.2.9.1 In addition to the requirements in API RP582, flux backing (in-lieu of a backing purge gas) or flux cored GTAW wires shall not be used for root pass welding of austenitic stainless steel and non-ferrous alloys unless slag can be removed from the process side of root passes and the area inspected for complete slag removal.

5.2.10 Combined Welding Processes

The requirements of API RP582 shall be met in full.

5.2.11 Mechanized and Automated Welding Processes

5.2.10.1 In addition to the requirements in API RP582 a change in the type of machine, weld geometry, diameter, direction of welding, base material chemistry, welding consumable manufacturer, thickness and welding variable settings from that stated on the PQR shall be considered essential variables for procedure qualification.

6.0 WELDING CONSUMABLES (FILLER METAL AND FLUX)

6.1 General

In addition to the requirements in API RP582, welding consumables shall be purchased from consumable manufacturers holding approvals by an independent third party unless otherwise agreed with Jacobs / IOCL.

6.1.1 In addition to the requirements of API RP5S2, when the MDMT is below -29°C, including any temperature reduction as permitted by the code, each welding procedure shall be qualified in accordance with section 11 unless otherwise agreed with Jacobs / IOCL.

6.1.2 The requirements of API RP582 shall be met in full.

6.1.3 In addition to the requirements of API RP582, consumables shall be clearly identified with either the national material specification or manufacturers brand designation as applicable, and the identity maintained until consumed. SMAW electrodes and manual GTAW wires shall carry this identification on each individual electrode or wire and reels of wire or strip shall be individually identified. Consumables for which no identification exists shall not be used.

6.1.4 Welding consumables producing low hydrogen deposits shall be used when welding the following base materials:

- P-No.1 Group 1 & 2 materials when the base material thickness exceeds 13mm
- P-No.1 Group 3 materials for all base material thickness
- P-No.3, P-No.4, P-No.5 and P-No.11A materials for all base material thickness
- P-No.9A & 9B materials for all base material thickness.

6.1.5 All consumables shall be used within the primary classification limits specified by the applicable consumable specification and the consumable manufacturers recommendation (e.g. consumables classified for single pass welds shall not be used for multi-pass welds.

consumables classified in the as-welded condition shall not be used where PWHT is a requirement unless suitably qualified in accordance with Section 11).

6.1.6 As a minimum, each batch of consumables shall be certified in accordance with ISO 10474 as follows:

Carbon steel consumables (where impact testing is a requirement)	Type 3.1B
Low alloy steel consumables	
Austenitic stainless-steel consumables (where ferrite testing or additional corrosion testing is a requirement)	
All other consumables	Type 2.2

6.1.7 The original consumable manufacturers certificate shall be supplied for each batch irrespective of whether the consumables are purchased directly from the consumable manufacturer or through an agent or distributor.

6.1.8 When joining base materials with the same nominal chemistry, welding consumable selection shall be based on obtaining weld deposits closely matching the base material chemistry and mechanical properties and that are suitable for the intended service. Proposals to use alternative welding consumables to those stated in Attachment A shall be submitted to Jacobs / IOCL for review.

6.1.9 In addition to the requirements of the code, a welding procedure shall be re-qualified if any of the following changes in welding consumables from that stated on the PDR apply:

a) A change in the nominal chemical composition of deposited weld metal, including change from ASME Section lit OW-442 A-No.1 to A-No.2 or vice versa
b) A change in the consumable manufacturer and brand designation for tubular flux cored or metal cored composite wires for FCAW, SAW or EGW
c) A change between wire chemistry from one AWS classification to another or to wire chemistry not covered by an AWS classification.

6.2 Dissimilar Welding

In addition to the requirements of API RP582, proposals to use alterative welding consumables to those stated in Attachment A shall be submitted to Jacobs / IOCL for review and agreement.

In addition to the requirements of API RF'582, welding consumables depositing a fully austenitic deposit (e.g. Type 310) or that are subject to precipitation hardening during heat treatment (e.g. ERNiCrFe-6) shall not be used.

6.3 Austenitic Stainless-Steel Welding

6.3.1 The requirements of API RP582 shall be met in full.

6.3.2 In addition to the requirements of API RP582, Type 16-8-2 deposited weld metal ferrite number shall be between 2-5FN. Ferrite number shall be determined during welding procedure qualification using either a suitably calibrated magnetic instrument in accordance with AWS A4.2 or by chemical analysis of the weld metal using the WRC-1992 diagram.

6.3.3 In addition to the requirements of API RP582. SMAW consumables shall also have a coating formulation that does not intentionally add bismuth and bismuth in the weld metal shall not exceed 0.002%. The limits on bismuth in SMAW or FCAW weld metal shall also apply if the welds are subject to PWHT above 550°C

6.3.4 When the nominal thickness at the weld is more than 25mm, basic flux coated SMAW

electrodes shall be used.

6.3.5 Addition of principal alloying elements to the weld via the SMAW flux covering (e.g. consumables equivalent to AWS A5.4 E-XXX-25 or 26) is not permitted for pressure retaining welds or attachments welds to pressure retaining components.

6.3.6 When welding Type 304/304H materials in elevated temperature service the following requirements shall be met:

a) Type E16-8-2/ER16-8-2 consumables shall be used for highly stressed welds or as advised by Jacobs / IOCL
b) Type 308l308H consumables may be used for other types of weld and shall meet the following deposited weld metal chemistry:

Carbon (C)	0.04% - 0.08%
Molybdenum (Mo)	0.5% max
Titanium (Ti) + Niobium (Nb)	0.5% max.
Boron (B)	0.005% max.

6.3.7 When welding Types 321/321H or Types 347/347H materials with a nominal thickness at the weld is more than 25mm, the following requirements shall be met:

a) When the first 6mm of deposited weld metal in contact with the process fluid shall be welded with Type 347 consumables in accordance with Table A-2. Thereafter, the weld shall be completed using a more creep ductile consumable such as Type 16-8-2 or Type 308/308L.
b) The capping pass for butt welds shall be ground to a smooth profile to minimise stress raisers at the weld toes. The capping pass for fillet welds and nozzle-to-shell welds shall be ground to a smooth concave profile whilst still maintaining the required weld throat thickness.
c) 100% radiographic testing (RT) and 100% penetrant testing (PT) shall be performed after welding or after PWHT/re-stabilising heat treatment if applicable.
d) Alternative proposals shall be submitted for Jacobs / IOCL review.

In addition to the requirements of the code, where production ferrite determination in accordance with Section 16.2 is specified. a change in the consumable manufacturer or brand designation or position of welding from that stated on the PQR will require re-qualification of the welding procedure (e.g. qualification in the 3G, 5G or 6G position will qualify all positions}.

6.4 Duplex Stainless-Steel Welding

Requirements for duplex stainless steels are covered in Attachment E.

6.5 Submerged Arc Welding

6.5.1 The requirements of API RP582 shall be met in full.

6.5.2 In addition to the requirements of API RP582. addition of principal alloying elements to the weld via the flux (other than to compensate for arc losses} is not permitted. Active fluxes (as defined in AWS A5.17) shall not be used for multi-pass welds.

6.5.3 In addition to the requirements of API RP582, flux that is not fused during welding may be re-cycled providing it is sieved to remove any slag impurities, re-processed in accordance with the manufacturer's recommendation and is mixed with fresh flux (no more than 20% by volume of re-cycled flux) before welding. Re-crushed slag (as defined in AWS A5.17) shall not be used for

pressure retaining welds or attachments welds to pressure retaining components.

6.5.4 A change in the consumable manufacturer and flux-wire or flux-strip combination or a change in the composite-cored electrode or metal powder manufacturer and brand designation from that stated on the PQR will require re-qualification of the welding procedure.

6.5.5 The 'punch-through' technique is permitted providing specifically formulated wires and fluxes are used for the second side "punch-through" welding and the welding procedure is impact tested at the MDMT or 0℃. whichever is lower, in the area of the weld cusp in accordance with Section 11. Any change in the flux-wire combination for production welding from that stated on the PQR will require re-qualification of the welding procedure.

6.5.6 Substantiating data confirming that the flux-wire combination for welding with Nb-containing wire (e.g. EB9, ER347, ERNiCrMo-3} has been specifically formulated to avoid the risk of hot cracking and tightly adherent slag ("tiger stripe") deposits on the weld metal surface.

6.6 Consumable Storage and Handling

6.6.1 The requirements of API RP582 shall be met in full.

6.6.2 Fabricator shall ensure that quality control procedures exist to adequately control the storage. handling. conditioning and issue of welding consumables and shall continuously monitor the implementation of these procedures for effectiveness. Jacobs / IOCL reserves the right to perform periodic audits of fabricators quality control procedures, to ensure proper functioning of the consumable quality control procedures.

6.6.3 Conventional low hydrogen SMAW consumables shall be dried and stored in ovens prior to issue to ensure that they can meet a maximum hydrogen level of 8ml H2/100g weld metal (H8 designation in accordance with AWS classification) prior to commencing welding. Electrodes shall only be issued for use in portable electrode ovens capable of maintaining a temperature of 70℃ minimum. After use. any remaining electrodes shall be re-dried in accordance with the manufacturer's recommendation. Electrodes shall only be re-dried twice before being discarded.

6.6.4 Vacuum packed SMAW electrodes may be used direct from the packaging and shall be handled. used and re-dried strictly in accordance with the consumable manufacturer's recommendation. Electrodes shall only be re-dried twice before being discarded.

6.6.5 FGAW wires shall be stored in accordance with the consumable manufacturer's recommendation to ensure that they can meet a maximum hydrogen level of 8ml H2/100g weld metal prior to commencing welding.

6.6.6 SAW fluxes shall be stored in sealed containers and dried to ensure that the flux-wire combination can meet a maximum hydrogen level of 8ml H2/100g weld metal prior to commencing welding. During welding, flux shall be stored in heated containers and shall be returned to heated storage when welding has ceased for longer than four hours.

6.7 Low Alloy Steels

6.7.1 Consumables shall nominally match the base material chemistry in respect of Cr and Mo. Each PQR shall record the consumable manufacturer and brand designation and results of deposited weld metal chemical analysis.

6.7.2 In addition to the requirements of Table A-1. the use of EXX1Y-BYL or ERXXS-BYL type consumables are not permitted for equipment in elevated temperature service.

6.7.3 When welding 1¼Cr-½Mo. 2¼Cr-1Mo or 3Cr-1Mo equipment with a maximum design temperature within the range 425℃-600℃ and a nominal thickness at the weld in excess of

13mm, the following requirements shall be met:

a) Each batch or heat of welding consumables proposed for use during production welding shall be analysed for P, Sn, Sb. As, Mn, Si and C and recorded on the PQR, preferably by the consumable manufacturer, or on the welding procedure qualification test pieces, and shall meet the following requirements:

Carbon	0.06-0.14%
Phosphorous	0.010% max.
(10P+5Sb+4Sn+As) + 100	15ppm max.
%Mn+%Si (Note 1)	1.2wt% max. (1.4% max. for GTAW and GMAW solid wires only) consistent with good weldability

Note: 1. Applicable for 2¼Cr-1Mo or 3Cr-1Mo only

b) Only basic type fluxes (BI greater than 1.8) shall be permitted for SAW and only basic flux coated electrodes shall be permitted for SMAW

c) The use of FCAW-G shall be subject to Jacobs / IOCL review.

6.8 Nickel Base Alloys

The use of Type ERNiCrMo-3 or ENICrMo-3 consumables shall be limited to the maximum design temperature stated in Table 6.1 of API RP582.

7.0 SHIELDING AND PURGING GASES

7.1 The requirements of API RP582 shall be met in full.

In addition to the requirements of API RP582, there shall be at least ten volume changes of gas in the backing gas enclosure to reduce the oxygen level to approximately 1000ppm before tack welding or root pass welding. An acceptable level shall be confirmed by monitoring the oxygen content with a meter.

7.2 Shielding gases for welding low alloy steels or martensitic stainless steels shall not contain hydrogen.

7.3 In addition to the requirements of the code. deletion or change in composition of a purge gas from that stated on the PQR will require re-qualification of the welding procedure, unless the root pass is ground back to sound metal and re-welded.

8.0 PREHEATING AND INTERPASS TEMPERATURE.

In addition to the requirements of API RP582, preheating shall be applied in accordance with the table below before commencement of all welding (including tack welding) and thermal cutting. When welding dissimilar metal welds having different preheat temperature requirements, the more stringent preheat requirement shall normally be applied.

P-No.	Material Type	Nominal Thickness at Weld (mm)	Minimum Preheat Temperature (°C)[1]	Maximum Interpass Temperature (°C)
1	Carbon steel[2]	t ≤ 13 13 < t ≤ 25 25 < t ≤ 50 t > 50	10[3] 75 100 150	315
3	C-½Mo, Mn-Mo, Mn-Mo-Ni, Mn-Mo-V	t ≤ 13 13 < t ≤ 25 25 < t ≤ 50 t > 50	10[3] 75 100 150	315
4	1Cr-½Mo, 1¼Cr-½Mo	t ≤ 13 13 < t ≤ 25 t > 25	100 125 150	315
5A	2¼Cr-1Mo, 3Cr-1Mo	t ≤ 13 13 < t ≤ 25 t > 25	125 150 175	315
5B	5Cr-½Mo, 9Cr-1Mo			
6 & 7	Ferritic and martensitic stainless steels	All	Per Code[4]	[4]
8	Austenitic stainless steels	All	10[3]	175
9A	2½Ni, 3½Ni	All	125	250
9B	5Ni, 7Ni	All	150	250
11A & 11B	Ni-Cr-Mo, Mn-Mo-Ni, Ni-Cr-Mo-V	t ≤ 13 13 < t ≤ 25 t > 25	125 150 175	315
34-35	Cu-base alloys	All	10[3]	175
41-45	Ni-base alloys	All	10[3]	175

Notes:

1) Preheat temperatures are based on 8ml H_2/100g weld metal hydrogen levels. Alternative preheat temperatures may be calculated in accordance with EN 1011-2. in which case, the WPS and PQR shall show all limiting factors such as combined thickness, CE value, weld metal hydrogen content and heat Input or run-out-length. upon which the preheat level is based.

2) Preheat requirements are based on conventional carbon steel with CE ≤ 0.45 and S > 0.01%. Low sulphur steels (S ≤ 0.01%) may be at higher risk of HAZ hydrogen cold cracking than conventional carbon steels and fabricator shall review the necessity of increasing the preheat temperature or lowering the specified CE value for these steels based on fabricator's experience.

3) Not required other than to remove moisture prior to welding.

4) Preheat temperature for martensitic type steels shall be 200°C minimum but shall not exceed the martensite finish {Mt} temperature to ensure no untransformed austenite is present during PWHT. The maximum inter-pass temperature shall not exceed the preheat temperature by more than 100°C.

8.1 In addition to the requirements of API RP582. preheat may be applied by any suitable method.

Where fuel gas or oil is used, the gas or oil shall be sulphur-free. The fuel/air mixture shall produce a neutral flame to ensure that no carbon deposit is left on the weld area.

8.2 The requirements of API RP582 shall be met in full.

8.3 The maximum recommended inter-pass temperatures are specified in paragraph 8.1.

8.4 Where the specified minimum preheat temperature is 150°C or higher, an intermediate dehydrogenation post weld heat treatment shall be applied in accordance with the table below, or alternatively for equipment subject to PWHT, preheat shall be maintained without interruption until the start of PWHT.

Nominal Thickness at Weld (mm)	Post Heat Temperature
t ≤ 13	Cool under insulation to ambient temperature
13 ≤ t ≤ 25	350°C for 2 hours
25 ≤ t ≤ 50	350°C for 4 hours
t > 50	Intermediate stress relief at 600°C for 2 hours or 650°C for 1 hour (1)

Note 1) Low temperature dehydrogenation at 350°C for 4 hours may be permitted where satisfactory long-term experience can be demonstrated, subject to Jacobs / IOCL review. In this case, only ultra-low hydrogen processes (less than 4ml H2/100g weld metal) shall be acceptable and SAW fluxes shall be non-hygroscopic fused or specially manufactured bonded fluxes. For highly restrained weld joints and for NPS8 and greater self-reinforced nozzle-to-shell set-in weld joints (e.g. ASME VIII. Div.1. UW-16.1(g)), an intermediate stress relief shall be mandatory.

9.0 POSTWELD HEAT TREATMENT (PWHT)

9.1 PWHT used for a PQR shall be in accordance with a procedure based on the requirements of the code and the table below. For production use. the heat treatment procedure shall be submitted for Jacobs / IOCL review.

P-No.	Material Type	Nominal Thickness at Weld (mm)	Holding Temperature (°C)	Time at Holding Temperature (mins.)	
				Per mm	Minimum
1	Carbon steel	Per code[1]	593-640[2][3]	2.5	60[3]
3	C-½Mo, Mn-Mo, Mn-Mo-Ni, Mn-Mo-V	Per code	620-650[2]	2.5	60
4	1Cr-½Mo, 1¼Cr-½Mo	All	680-710[5]	2.5	60
5A	2¼Cr-1Mo, 3Cr-1Mo	All	690-720[5]	2.5	120
5B	5Cr-½Mo, 9Cr-1Mo	All	704-730[5]	2.5	120
				2.5	60
6 & 7	Ferritic and martensitic stainless steels	Per code	Per code[4][7]	2.5	60
8	Austenitic stainless steels	Per code	Per code	Per code	Per code
9A	2½Ni, 3½Ni	Per code	593-620	2.5	60
9B	5Ni, 7Ni				
11A & 11B	Ni-Cr-Mo, Mn-Mo-Ni, Ni-Cr-Mo-V	Per code	Per code[5]	2.5	60
45	800/800H/800HT[8]	All	885 min.[8]		

Notes:

1. In addition to code requirements. PWHT is required for equipment exposed to environments containing the following:
   - Amine (lean and rich)
   - Caustic
   - Carbonates
   - Hydrofluoric acid
   - Sour (wet H2S)
   - Hydrogen service
   - De-aerator storage vessels
2. Where PWHT is not a service requirement. the use of alternative PWHT conditions in accordance with the code is only acceptable for F'-No.1 and F'-l'~lo.3 G-r.1 steels, subject to Jacobs / IOCL review. The reduction in temperature shall be limited to 26℃. an equivalent holding time at temperature to that stated above shall be calculated in accordance with the Tampering Parameter in Section 3 and the hardness requirements in Section 12.6 shall be met as demonstrated on the PQR. The use of alternative PWHT conditions for other materials is not permitted.
3. Minimum PWHT temperature shall be 620℃ for equipment exposed to environments containing amine. caustic. carbonates. sour (wet H_2S) and hydrofluoric acid
4. Double temper heat treatment required for 12Cr-4Ni castings: 577℃ for 2 hours followed by 510℃ for 4 hours

5. Maximum PWHT temperature shall be at least 10℃ below tempering temperature
6. Where specified in Jacobs / IOCL specifications or by Licenser, fabrication welds in Type 321/321H or 347/347H stainless steels shall be subject to a thermal stabilization at 910℃±10℃ for 4 hours
7. Martensitic 400 series stainless steels shall be cooled below the martensite finish temperature (Mf) prior to any PWHT to ensure that no untransformed austenite remains during PWHT which may on final cooling below the Mf temperature, re-transform to martensite
8. For design temperatures more than 650℃. Alternatively. solution heat treatment in accordance with the original material specification is acceptable.

9.2 The requirements of API RP582 shall be met in full.

9.3 In addition to the requirements of API RP582. hardness testing during welding procedure qualification shall meet the requirements of paragraph 12.6.1 of this specification.

Repairs to a post weld heat treated component shall be subject to Jacobs / IOCL review and agreement.

In addition to the requirements in API RP582, where repairs, attachments or additional layers are made to cladding or weld overlay on low alloy steels without subsequent heat treatment, confirmation that no new HAZ is formed with a minimum remaining clad or overlay thickness of 5mm or less shall be demonstrated by a supporting welding procedure qualification.

All P-No.4 and P-No.5 low alloy steels shall be subject to PWHT unless otherwise agreed with Jacobs / IOCL.

Where PWHT is performed in an enclosed furnace. the equipment shall be adequately supported to prevent deformation during the heat treatment. Thermocouples shall be located on both the inside and outside surfaces to monitor the surface temperature and ensure the specified temperature is attained. The final position of thermocouples shall be subject to agreement with Jacobs / IOCL but sufficient thermocouples shall be installed to monitor the minimum and maximum temperatures at both the thickest and thinnest sections (including nozzles), major structural discontinuities [e.g. internal heads} and enclosed areas (e.g. inside support skirts} and also to delineate the maximum temperature gradient.

In addition to the requirements of the code, local PWHT shall meet the following requirements:

a. Local PWHT of circumferential welds shall encompass a complete circumferential band around the equipment weld and shall include the soak, heating and gradient control bands. There shall be no discontinuities such as nozzle connections, structural supports etc. within the circumferential hand but where this is unavoidable the bandwidth shall be extended to include the discontinuity.
b. For nozzle-to-shell connections or major structural support-to-shell attachments, the entire vessel circumference shall be included in the PWHT band. Local spot PWHT over a radial band around nozzle-to-shell connections shall be restricted to spherical pressure vessels or vessel heads and shall be subject to Jacobs / IOCL review.
c. The minimum soak bandwidth measured from the weld toe shall be 50mm. The minimum heating bandwidth shall be a minimum of 6t or 150mm either side of the weld, whichever is greater, or the co-de requirement if this results in a greater heating bandwidth. The gradient control band shall extend a minimum of 250mm beyond the edge of the heating band or the code requirements if this results in a greater insulation width.
d. For flange welds. the entire flange surface. inside and out. shall be insulated.
e. Wherever practical, the inside surface over the area of the heating band shall be

insulated, or if this is not practical, the ends shall be sealed to prevent draughts and minimize convection currents.

f. Thermocouples shall be located as follows:

i. For circumferential welds four thermocouples shall be equally spaced around the weld joint within the soaking band on both the inside and outside surfaces. An additional two monitoring thermocouples shall be placed at the edge of the soak band and at the edge of the heating band to ensure that harmful thermal gradients are avoided. The temperature at the edge of the heating band shall not be less than half the soak band temperature.

ii. For nozzle-to-shell connections one thermocouple shall be placed across the nozzle wall in the thickest section, one at the nozzle-to-shell weld on the inside and outside surfaces and for components of dissimilar thicknesses one at the thickest and thinnest sections and one at the thickness transition.

iii. Where electric resistance elements or induction coils are used for local or partial PWHT, a minimum of one control thermocouple shall be used for each heating circuit to ensure overheating cannot occur.

10.0 CLEANING AND SURFACE PREPARATION

10.1 In addition to the requirements of API RP582. prior to the start of welding, a distance of 50mm from the weld edge shall be thoroughly cleaned of any contaminants (e.g. oil, grease, and NDE materials) which may adversely affect the weld quality. For stainless steels and non-ferrous alloys, the weld area shall be scratch-brushed using a stainless-steel wire brush solely reserved for that material. followed by solvent cleaning. All cleaning fluids, solvents etc. shall be non-injurious to the materials being cleaned.

10.2 Pressure vessels or storage tanks with internal, non-metallic protective coating systems shall meet the following requirements:

10.2.1 The design, fabrication and surface finish shall meet the requirements of NACE Standard RP0178 and any Jacobs / IOCL specified standards.

10.2.2 Surfaces shall have a smooth contour. free from discontinuities. crevices and sharp projections. All sharp projections shall be rounded to a minimum radius of 5mm. All internals shall be fully welded.

10.2.3 All welds on surfaces to be coated shall be continuous with a smooth transition from the weld metal to the base material and shall be completely free from surface or surface-breaking flaws including but not limited to:

- Undercuts and cracks
- Porosity and inclusions
- Excessive reinforcement or penetration
- Root or cap concavity
- Lack-of-fusion

10.3 The requirements of API RP5B2 shall be met in full.

10.4 Surface irregularities, spatter and weld flaws shall be remedied by welding and/or grinding as agreed with Jacobs / IOCL.

10.5 Where any misalignment or differences in wall thickness between two components would prevent correct interpretation of the ultrasound signals and/or cause mode conversion during ultrasonic examination, these shall be corrected by either depositing a weld build-up layer of

matching weld metal or machining the internal and/or external surfaces.

10.6 Where a weld build-up layer of matching weld metal is deposited (e.g. to attach support skirt or to correct misalignment) the finished surface shall be subject to 100% UT, using a compression wave probe, and 100% MT/PT.

10.7 The use of carbon arc-air for gouging shall be subject to the following restrictions:

- Not permitted for use on 300 series stainless steels or non-ferrous alloys.
- The as-gouged surface shall be wire brushed followed by grinding to a bright finish before welding to remove all deposits, dross etc.
- Evidence to confirm that arc-air operators have been property trained and have current experience shall be provided to Jacobs / IOCL on request.

11.0 SPECIAL PROCEDURE QUALIFICATION REQUIREMENTSITESTING

11.1 General

Replace this section of API RP582 in its entirety with the following:

11.1.1 All pressure retaining welds. including fillet welds and nozzle-shell welds shall be qualified using a butt weld test piece with full mechanical testing. For equipment in wet H28 (sour) service, additional fillet-weld test pieces are required to represent any fillet-welded attachments that will not be subject to PWHT with hardness testing in accordance with Section 12.

11.1.2 All welding procedure qualification test pieces shall be subject to visual examination to the same standard applicable for the finished production weld.

11.1.3 Test pieces shall be left for at least 24 hours after welding is completed before NDE and destructive testing is performed.

11.1.4 Welding procedures for materials subject to PWHT shall be qualified with heat treatment equivalent to the maximum PWHT cycle anticipated during fabrication (including any repairs). For carbon steels in excess of 50mm nominal thickness and for low alloy steels in excess of 13mm nominal thickness, one additional PWHT cycle shall be incorporated to simulate field repair or modification.

11.1.5 Welding procedures subject to impact testing in accordance with the code, Jacobs / IOCL or Licensor requirements, shall meet the following requirements:

a. Weld metal and HAZ samples shall be taken to represent each welding process used when the weld test piece thickness exceeds 13mm. If the weld test piece is subject to back gouging or punch-through welding, one set of specimens shall be taken from this area.

b. Impact tests on full-size specimens (10mm along the notch) shall meet the following criteria.

Material	Specified Minimum Tensile Strength (Rm)	Acceptance Criteria
P-N01, P-No.3, P-No.4, P-No.5	Rm<450N/mm^2	27J average /20J min at MDMT
P-N01, P-No.3, P-No.4, P-No.5	Rm>450N/mm^2	40J average /34J min at MDMT

c. Heat input shall be recorded and calculated for each weld run. For manual welding processes. heat input shall be recorded and controlled by measuring the length of weld

deposited per unit length of electrode RDL or ROR. For semi-automatic. automatic or machine welding processes, the heat input shall be recorded by measuring and controlling the amperage, voltage, travel speed and oscillation/maximum bead width and depth.

d. For single sided welds without backing, the root gap shall be measured during procedure qualification and shall not be exceeded by more than 1mm during production welding

e. An increase in the maximum electrode diameter, a reduction in the ROL/ROR, an increase in the inter pass temperature of more than 25℃, a change in the TP of ±0.2 for PWHT or a change in the consumable manufacturer or brand designation from that stated on the PQR will require re-qualification of the welding procedure.

11.1.6 Where step cool screening tests are specified for low alloy base materials, welding procedure qualification shall meet the following requirements:

a. Fabricator shall qualify its own welding procedures, using the same batch/heat of consumables as proposed for production welding. Step cool screening tests performed by the consumable manufacture on the proposed batch of consumables shall not be accepted as a substitute for this procedure qualification.

b. Thickness of test plates for welding procedure qualification tests shall be a minimum of ½t (where t is the production weld thickness) but need not exceed 100mm.

c. Weld metal and HAZ samples shall be taken to represent each welding process used when the weld test piece thickness exceeds 13mm, if the weld test piece is subject to back gouging, one set of samples shall be taken from this area.

d. Impact transition curves shall be determined for both the weld metal and HAZ in accordance with requirements of Section 26 of ASTM A3-T0 and the following:

- A minimum of 18 test specimens shall be taken from both the weld metal and HAZ of test coupons that have undergone the minimum heat treatment cycle anticipated during fabrication. At least one test specimen shall be tested at the upper shelf temperature and one at the lower shelf temperature, with the remainder tested at discrete temperature intervals of no more than 5℃ in the transition region, to establish an accurate 54J transition temperature. Where a rogue impact energy value results {i.e. the value is well off the interpolated curve} an additional test specimen shall be taken to verify the impact energy.
- The same number of test specimens as in the above shall be taken from both the weld and HAZ of the test coupons in a) above alter they have undergone the following additional step cool heat treatment cycle:
  - Heat at 56℃/'hr maximum from 316℃ to 593℃
  - Hold at 593℃ for 1 hour then cool at 6℃/hr. to 538℃
  - Hold at 538℃ for 15 hours then cool at 6℃/hr. to 524℃
  - Hold at 524℃ for 24 hours then cool at 6℃/hr. to 496℃
  - Hold at 496℃ for 60 hours then cool at 3℃/hr. to 468℃
  - Hold at 468℃ for 100 hours then cool at 28℃/hr. to 316℃
  - Cool in still air

e. The shift in the 54J transition temperature between the transition curves before and after step cooling shall meet the following criterion:

$T54 + 2.5\Delta T54 \leq 10℃$

Where: ΔT54 is the 54J transition temperature before the step cool screening test and ΔT54 is the shift in the 54J transition temperature after the step cool screening test

11.1.7 Where intergranular corrosion testing of base materials is specified, the welding procedure qualification shall be subject to the same test. Test specimens shall be full thickness or taken as close to mid-thickness as possible and shall include the weld on the axis of the bend.

11.1.8 When specified by Jacobs / IOCL, mock-ups simulating production conditions shall be performed whenever the accessibility and restraint of the code qualifications fails to simulate production conditions.

11.2 **Tube-to-tubesheet welding**

11.2.1 In addition to the requirements of API RP582, tube-to-tubesheet welds shall be qualified and tested in accordance with ASME Section VIII, Div.2, Article F-3, EEMUA 143 or ISO 15614-8 and the following requirements:

- visual examination
- RT to demonstrate freedom from porosity and cracks
- 100% MT or 100% PT of the completed test piece
- Sectioning of the test piece followed by etching to demonstrate the required weld throat thickness has been met and the weld is free from porosity and cracks
- Hardness testing [when specified in Section 12
- Pull-out strength tests {not required for carbon steels unless stated otherwise

11.2.2 The requirements of API RP 582 shall be met in full

11.2.3 Tube-to-tube sheet welds shall have a minimum of one pass deposited with filler wire unless the proposed design precludes this (e.g. castellated or back face welded joint design).

11.2.4 When specified by Jacobs / IOCL, tube sheet shall be weld overlaid with a non-hardenable material where the root pass of the tube-to-tub-e sheet weld is deposited by autogenous GTAW or where the tube-to-tube sheet weld would require PWHT. PWHT of tube-to-tube sheet welds shall be subject to Jacobs / IOCL review prior to PWHT.

11.2.5 In addition to the requirements of ASME Section VIII, Div.2, Article F-3, EEMUA 143 or ISO 15614-8, a change in the weld joint detail. tube diameter or tube wall thickness from that stated on the PQR will require re-qualification of the welding procedure.

11.2.6 Production tube-tube sheet welds shall be inspected as follows:

- 100% visual examination
- 100% MT/PT of the completed welds
- Gas leak test in accordance with ASME Section V, Article 10, Appendices III to V, after final expansion following welding but prior to pressure testing.

12.0 OTHER ITEMS

12.1 Backing Materials

in addition to the requirements of API RP582, backing materials shall meet the following requirements:

- Permanent metallic backing strips are only permitted for closing welds in refractory-lined piping where access to the root face is not possible. The material of the backing strip shall match the nominal metallurgy of the base material and shall be fused into the

joint for the complete length.

- Single-sided weld with temporary metallic backing strip. if the temporary backing strip is fused into the root pass, it shall match the nominal metallurgy of the base material and be removed after welding is completed.
- Single-sided or double-sided weld with temporary non-metallic backing material. Where this is proposed, the welding procedure shall be qualified with the same type of non-metallic backing material present.

12.2 Peening:

The requirements of API RP582 shall be met in full.

12.3 Weld Overlay and Clad Restoration (Back Cladding)

The requirements for weld overlay and back cladding shall be as specified in project specifications.

12.4 Temporary Attachments

In addition to the requirements of API RP 582, NDE of areas where temporary attachments have been removed shall be performed in accordance with Table 1 or Table 2 as applicable.

12.5 Stud Welding

The requirements of API RP582 shall be met in full.

12.6 Hardness Testing - Weld Procedure Qualification and Production Testing

12.6.1 Welding procedure qualification testing shall be performed as specified below:

P-No.	Material Type	Service Environment	Maximum PQR Hardness Level (HV_{10})[1]
1	Carbon steel	Utility services (air, water, N_2 etc)	300[2]
		General hydrocarbon,	248[2]
		HTHA, Caustic, Carbonate	
		Wet H_2S, Amine/wet H_2S,	248
3	C-½Mo, Mn-Mo, Mn-Mo-Ni, Mn-Mo-V	All	248
4	1Cr-½Mo, 1¼Cr-½Mo		
5A	2¼Cr-1Mo, 3Cr-1Mo		
5B	5Cr-½Mo, 9Cr-1Mo		
6 & 7	Ferritic and martensitic stainless steels	Wet H_2S	248
8	Austenitic stainless steels		
9A	2½Ni, 3½Ni	All	248
9B	5Ni, 7Ni		
11A & 11B	Ni-Cr-Mo, Mn-Mo-Ni, Ni-Cr-Mo-V	All	248

Notes:

1) If Licensor hardness requirements are more stringent, the lower figure shall take precedence

2) Hardness testing of the PQR is not required when following criteria
   - SMAW process with E60YY or E70YY electrodes
   - GTAW or GMAW process with ER70S, ER70S-3, ER70S-4 or ER70S-6
   - SAW process with F7XX-ELX or -EMX

3) The requirements of API RP582 shall be met in full.

4) Acceptance criteria shall meet the requirements of paragraph 12.6.1. Individual hardness readings exceeding the values in paragraph 12.6.1 may be considered acceptable providing no individual reading is greater than 10HV points above the acceptable value and the average of three readings in close proximity do not exceed the permitted value.

12.6.2 Production hardness testing shall be performed as specified below:

P-No.	Material Type	Service Environment	Maximum Production Hardness Level (HB)[1][2]
1	Carbon steel	Utility services (air, water, N_2 etc)	Not required
		General hydrocarbon,	
		HTHA, Caustic, Carbonate	
		Wet H_2S, Amine/wet H_2S,	200
3	C-½Mo, Mn-Mo, Mn-Mo-Ni, Mn-Mo-V	All	225
4	1Cr-½Mo, 1¼Cr-½Mo		225
5A	2¼Cr-1Mo, 3Cr-1Mo	All	241
5B	5Cr-½Mo, 9Cr-1Mo		241
6 & 7	Ferritic and martensitic stainless steels	Wet H_2S	237
8	Austenitic stainless steels		
9A	2½Ni, 3½Ni	All	225
9B	5Ni, 7Ni		
11A & 11B	Ni-Cr-Mo, Mn-Mo-Ni, Ni-Cr-Mo-V	All	241

Notes:

1) If Licensor hardness requirements are more stringent, the lower figure shall take precedence.
2) Where base material is locally heated for bending, distortion control etc., production hardness levels shall meet the lower of specified levels below or the base material specification.

12.6.2.1 The requirements of API RP582 shall be met in full.

12.6.2.2 in addition to the requirements of API RP582, hardness testing using portable hardness testers shall meet the following:

a. Brinell type hardness testing shall be performed in accordance with ASTM A833 and

the equipment manufacturers recommendations. A minimum of three readings shall be taken and reported. with adjacent indents at least three diameters apart.

b. Dynamic or rebound type hardness testing shall be performed in accordance with ASTM A056 and the equipment manufacturers recommendations. The area under test shall be ground or machined flat and shall have a surface finish of 2µm(Re) maximum. The instrument shall be calibrated at the start and end of each batch of tests in the same position as that proposed for production testing. A minimum of five readings shall be taken and the average value reported. Any reading with a value greater than ±15% of the average value shall be disregarded and an additional reading taken. This additional reading must fall within ±15% of the average value to be acceptable. This type of tester is not permitted where the material thickness is less than 13mm nor on small bore piping (NPS2 or smaller}

c. Ultrasonic Contact impedance (UCI) hardness testers shall not be used without Jacobs / IOCL approval.

12.6.2.3 The maximum allowable production hardness for welds shall be in accordance with paragraph 12.6.2.

12.6.2.4 In addition to the requirements of API RP582, production hardness test results and locations shall be recorded in the equipment data book. Operators of portable hardness testers shall have undergone a training programme in their use and records of such training shall be made available to Jacobs / IOCL on request.

12.6.2.5 Where production hardness values exceed those stated in paragraph 12.6.2. two sets of additional tests shall be performed. If these two sets of tests meet the required hardness levels the weld shall be considered acceptable. if the two sets of tests fail to meet the required hardness levels, the weld shall either be heat treated and re-tested or completely removed, re-welded and subsequently re-tested.

13.0 WELDER AND WELDING OPERATOR QUALIFICATION

13.1 General

13.1.1 Welders and welding operators shall be qualified in accordance with the code and this specification.

13.1.2 The acceptance of existing performance qualifications shall depend on documented evidence of satisfactory performance in the 3 months prior to commencing work and shall be subject to meeting the essential variable requirements of the code and this specification. Arc-air operators shall undergo performance tests when required by Jacobs / IOCL to demonstrate their ability to remove metal by gouging in a controlled manner. Jacobs / IOCL reserves right to require additional welder performance qualifications to represent nozzle-shell /head welds that are welded with GMAW or FCAW where doubt exists as to the quality of production welding on these types of weld. The nozzle diameter of the test piece shall represent the smallest diameter used and a minimum of four macrographs shall show no unacceptable flaws. Additional UT of production welds may also be required by Jacobs / IOCL.

13.1.3 Essential Variables

In addition to the requirements of the code, a welder shall be re-qualified if any of the following apply:

- A change from one of the following consumable product forms to another for GMAW or FCAW:
- Flux cored electrode
- Metal cored composite electrode

- Bare solid wire
- A change in the diameter of the SMAW, GMAW or FCAW welding consumable used for the root pass in single-sided weld joints from that used to weld the test piece

14.0 FABRICATIDN

14.1 Forming

14.1.1 In addition to the requirements of the code. carbon and low alloy steel components formed from plate shall meet the following requirements:

- All cold spun heads with a nominal thickness more than 13mm, prior to forming shall be heat-treated after forming in accordance with paragraph 14.1.3, irrespective of the fibre strain induced.
- All cold rolled or cold pressed cylinders, knuckles, cones or knuckle segments of heads or spheres shall be heat-treated after forming in accordance with paragraph 14.1.3 when the fibre strain after forming exceeds 5%.
- If, during any cold forming operation, the fibre strain exceeds 5%. An intermediate heat treatment shall be performed before any subsequent forming operation

14.1.2 In addition to the requirements of the code, carbon and low alloy steel tubular products (e.g. heat exchanger tubes) shall be heat treated after cold forming in accordance with paragraph 14.1.3 for the following conditions:

- Where the tubular products are exposed to wet H2S (sour) or ASCC environment when the fibre strain after forming exceeds 5%.
- For service environments other than those above when the fibre strain after forming exceeds 15%.

14.1.3 Cold formed carbon and low alloy steel components shall be heat treated after forming in accordance with the following:

a. Furnace heat treatment using the original heat treatment as applied to the component at the source of supply (if applicable) e.g. normalizing or a stress relieving heat treatment between 593℃ and the Ac1 transformation temperature, with a hold time of 1hr/25mm, 1 hr. minimum (where the base material is subject to a tempering heat treatment. the maximum stress relieving temperature shall be at least 10℃ below the final tempering temperature)

b. During the final PWHT of the equipment.

c. Electric resistance or induction heating of heat exchanger tubing is acceptable in-lieu of furnace heat treatment, subject to Jacobs / IOCL review and agreement. The bend area plus 250mm straight length shall be included in the heated area and an inert gas purge shall be used during heating and cooling

14.1.4 Hot formed components shall be heat-treated as a separate operation to the forming operation in accordance with the original material heat treatment. Normalizing forming is acceptable only for carbon steels that are not subject to impact testing.

14.1.5 The use of induction bending shall be subject to Jacobs / IOCL review and approval. Contractor shall submit substantiating data to prove that no deterioration in material properties will result during the induction bending operation.

14.1.6 Cold spun or cold formed austenitic stainless steels or non-ferrous alloy components exposed to wet H2S (sour) or ASCC environment shall be heat treated as a separate operation after cold forming when the fibre strain exceeds 15%.

Where electric resistance or induction heating of heat exchanger tubing is performed in-lieu of furnace heat treatment, the bend area plus 250mm straight length shall be included in the heated area and an inert gas purge shall be used during heating and cooling.

14.1.7 Hot forming of austenitic stainless steels or non-ferrous alloy components shall be subject to Jacobs / IOCL review.

14.1.8 A minimum of one thermocouple shall be attached directly to the component during heat treatment to measure the actual surface temperature. For formed heads the thermocouple shall be attached to the surface not directly exposed to the burners. Measurement of the temperature using furnace thermocouples is not acceptable for formed components.

14.1.9 Pre-fabricated components shall be examined as follows:

	Hot Formed Seamless Component	Hot Forming Welded Component	Cold Formed Seamless Component	Cold Formed Welded Component
Re-certification of base material	(1)	(1)	N/A	N/A
RT of welds	N/A	(2)	N/A	(2)
MT or PT of welds	N/A	(3)	N/A	(3)
MT or PT of base material	N/A	N/A	(4)	(4)
Production test plate	N/A	(5)	N/A	(5)
Hardness testing	N/A	(6)	N/A	(6)

Notes:

1) Re-certification of the base material is required in accordance with original material specification/Jacobs / IOCL requirements. The re-certification shall be carried-out on a material test coupon submitted to the same hot forming operation and heat treatment cycle as the base material. Testing shall be performed alter any specified simulated PWHT
2) 100%RT or spot RT required of all welds depending on selected weld efficiency.
3) 100%fvtT or PT of all welds prior to any subsequent fabrication operation
4) 100%MT or PT of the internal and external knuckle areas. Jacobs / IOCL reserves the right to extended MTIPT up to full surface depending on the severity of the forming process. shape and type of base material.
5) Production test plate in accordance with the requirements of Section 15.1.
6) Hardness survey of welds after forming and heat treatment in accordance with Section 12.6.2.

14.1.10 In addition to the requirements of the code. equipment subject to cyclic service or elevated temperature service shall meet the following requirements:

- Axial or circumferential misalignment at weld joints shall not exceed 1.5mm.
- Ovality of cylindrical shells and cones shall not exceed 0.5% and shall meet the following requirements with respect to peaking (inward or outward facing) at any longitudinal weld:

Wall thickness (t)	Max. permitted Peaking

6mm ≤ t < 10mm	3mm
6 > 10mm	t/3mm, 10mm ma.

- Peaking measurements shall be taken using a 20° profile gauge at approximately 250mm centres along the length of the weld to determine the maximum value of peaking.
- Values more than the above shall be subject to Jacobs / IOCL review and approval and Jacobs / IOCL reserves the right to require additional creep/fatigue analysis by fabricator to support acceptance.

14.2 Weld Encroachment

14.2.1 The layout of nozzles and attachments shall minimise the risk of weld encroachment. The minimum distances between welds on pressure vessels shall be as follows:

Description of Weld Type	Minimum Distance Between Weld Toes (whichever is greater)
Longitudinal welds in the same shell strake	120° or √(Dt) or 5t
Longitudinal welds in adjoining shell strakes	120° or √(Dt) or 5t(1)
Nozzle weld (either self-reinforced or with reinforcing pad) and pressure retaining welds (longitudinal, circumferential, meridional, nozzle weld)	100mm or 2t(2)
Longitudinal or circumferential weld and non-pressure retaining attachment weld(4)	100mm or 2t(3)
Nozzle weld (either self-reinforced or with reinforcing pad) and non-pressure retaining attachment weld	50mm or 2t
Non-pressure retaining attachment weld and non-pressure retaining attachment weld	50mm or 2t

Notes:

1) Where these criteria cannot be met due to physical limitations with layout dimensions. each longitudinal weld affected shall be subject to 10-0% RT and 100% MT/PT on the inside and outside surfaces for a distance of 250 mm from the affected end.
2) Where these criteria cannot be met due to physical limitations with the layout dimensions, nozzles may be located on weld joints as follows. Subject to Jacobs / IOCL review:
   - On heads, nozzle shall be self-reinforced type. The meridional weld covered by the nozzle plus an additional 50mm shall be ground flush and subject to 100%RT and 100%MT or PT prior to nozzle installation.
   - On shell strakes, nozzles located on longitudinal welds shall be self-reinforcing type or shall use an insert plate. The weld covered by the nozzle/insert plate/reinforcing pad plus an additional 50-mm shall be ground flush and subject to 100% RT and 100%MT or PT prior to nozzle installation.
3) Where these criteria cannot be met due to physical limitations with the layout dimensions. the attachment weld shall cross the longitudinal or circumferential weld by 50mm or 2t (whichever is greater). The area covered by the attachment weld (and reinforcing pad if applicable) plus an additional 50mm shall be ground flush and subject to 100%RT and 100%MT or PT prior to making the attachment weld.

4) Support skirts or saddles for pressure vessels shall not cover any circumferential welds.

14.2.2 The gap between a reinforcing pad and the shell shall not exceed 0.1t or 1.5mm, whichever is less.

14.2.3 Longitudinal welds shall not be located within the tray down comer area.

14.2.4 Major structural attachment welds shall not be made at the same elevation or orientation on both the inside and outside surfaces of pressure retaining components fabricated from plate. Where this criterion cannot be met on plate thicknesses above 13mm, the plate shall be examined by shear wave UT after the second weld is completed to ensure freedom from lamellar tearing.

15.0 QUALITY CONTROL

15.1 General

15.1.1 Weld inspection. NDE and production tests shall meet the requirements of the code and this specification.

15.1.2 Fabrication inspection and test plans shall be developed detailing all the principal stages of preparation. forming, welding, heat treatment. NDE and production testing and shall be submitted for Jacobs / IOCL review.

15.1.3 All weld joints shall be identified by a unique number. This number shall be identified on a weld map and marked adjacent to the weld joint using a method that is non-injurious to the material. This marking shall be maintained until all inspection and documentation is complete.

15.1.4 Each welder or welding operator shall be allocated a unique identification number or symbol. On completion of a weld, each welder or welding operator shall mark the weld with this number or symbol using a method that is non-injurious to the material. This marking shall be maintained until all inspection and documentation is complete.

15.1.5 Fabricator shall ensure that an adequate quality control system exists to record the complete history of each weld, including WPS(s) used, welder or welding operator. and results of all NDE and production tests. This system shall ensure that any repair and rectification work, including design changes, is recorded and that all necessary NDE and production tests have been performed. Jacobs / IOCL reserves right to perform periodic audits of fabricator to ensure proper functioning of the quality control system.

15.1.6 All tack welds or bridge welds shall be performed by qualified welders or welding operators, using a qualified WPS.

15.2 Non-Destructive Examination (NDE)

15.2.1 NDE shall be in accordance with the requirements of the code and this specification. All pressure retaining components and welds shall be subject to 10D% visual examination for poor workmanship, surface-breaking flaws, fabrication damage and cleanliness after all welding, forming and heat treatment is completed but prior to pressure testing and application of protective coatings or insulation.

15.2.2 In addition to the requirements of the code, full radiography shall be applied when any of the following conditions exist: unless otherwise agreed with Jacobs / IOCL:

- Equipment is designated in cyclic service or elevated temperature service.
- Austenitic stainless-steel welds when the nominal thickness at the weld joint is more than 25mm.

- Field/site-made welds
- Welds in carbon and low alloy steel equipment with an MDMT of -46°C or lower and Ni-alloy steel equipment with an MDMT of -74°C.
- Welds in equipment to be tested pneumatically or by a combination of pneumatic and hydrostatic testing.
- Category D, nozzle-to-shell or nozzle-to-head weld when the nozzle is subject to cyclic service or high, localised thermal stresses.
- Dissimilar metal welds made in accordance with Section 6.2.

15.2.3 The minimum inspection requirements for equipment subject to full radiography are specified in Table 1.

15.2.4 For equipment other than specified in paragraph 15.2.2, the minimum inspection requirements for equipment subject to spot radiography are specified in Table 2.

15.2.5 For atmospheric storage tanks, the minimum inspection requirements shall be in accordance with API B50. For low pressure storage tanks, the minimum inspection requirements shall be in accordance with API 620.

15.2.6 Radiography shall meet the requirements of the code and the following:

- Sensitivity shall be equal to or better than 2% unless the code requires more stringent limits.
- X-ray radiography is preferred. Subject to achieving acceptable sensitivity radiographic film shall fine grain, high contrast type in accordance with ASTM E1815 Type II (e.g. Agfa™, Structurix D7, Fuji or IX100, Kodak™, Industrex AA400) for penetrated weld thickness above 10mm and very fine grain, high contrast type in accordance with ASTM E1815 Type I (e.g. Agfa™, Structurix D5, Fuji IX80 or Kodak™, Industrex M125) for penetrated weld thickness of 10mm and below.
- Gamma radiography may be used in-lieu of lit-ray radiography. Radiographic film shall have very fine grain, high contrast ASTM E1815 Type I for penetrated weld thickness above 19mm and ultra fine grain, very high contrast ASTM E1815 Type i (e.g. Agfa™ Structurix D3, Fuji D150 or Kodak Industrex M100) for penetrated weld thickness of 19mm and below-

15.2.7 At least one image Quality indicator (IQI) shall appear on each separate radiographic film, except for a panoramic technique where a minimum number of three IQIs shall be used, spaced equally around the circumference. wire type IQIs shall be in accordance with ASME V or ISO 1027.

15.2.8 Only lead intensifying screens may be used in conjunction with radiographic film. Fluorescent intensifying screens are not permitted.

15.2.9 Ultrasonic examination shall meet the requirements of the code and the following:

a. The area adjacent to the weld (equivalent to the full skip distance of the maximum probe angle used) shall be scanned by a compression wave probe to check for lamellar flaws prior to scanning the weld itself.
b. For butt welds, examination of the weld for axial flaws shall be performed utilising at least two different angle beam shear wave probes. The weld shall be scanned from both sides and on the inside and outside surfaces, where access permits, to ensure complete coverage of the weld volume.
c. For butt welds, examination of the weld for transverse flaws shall be performed utilising at least two different angle beam shear wave probes. The probe angles shall be chosen

to cover the full weld throat thickness. The weld shall be scanned from both sides, essentially parallel to the weld axis. For nominal thickness greater than 50mm the weld cap shall be dressed flat and flush with the parent material and an additional 45° probe scan performed along the weld axis.

d. For set-on or set-in nozzle welds. examination of the weld shall be performed utilising a combination of at least two different angle beams, shear wave probes and a compression wave probe. The weld shall be scanned from the inside and outside surface of the shell and from the outside surface and internal bore of the nozzle

e. Calibration block shall be of sufficient length to permit a minimum of four signal responses from the artificial reflectors to be used to construct the (Distance Amplitude Correction) DAC curve for all probe angles.

f. The use of tandem probes. mechanised pulse echo equipment with automatic computer enhanced data acquisition capabilities or enhanced UT techniques such as Time-of-Flight-Diffraction (TOFD) or phased array shall be subject to Jacobs / IOCL review and agreement. Where permitted, the proposed technique and operators ability shall be validated by means of demonstrable performance qualification (e.g. ASME Code Case 2235). A detailed procedure shall be submitted for Jacobs / IOCL review.

g. For welds in solid austenitic stainless steel or non-ferrous alloys equipment a procedure, detailing additional measures to overcome the anisotropic nature of the weld metal, and evidence of the operator's ability and experience in the ultrasonic testing of these materials shall be submitted for Jacobs / IOCL review.

15.2.10 Where MT is specified, the following requirements shall be met:

a. The D-C prod method is only permitted for non-impact tested carbon steel equipment that is not subject to PWHT. Any arc strikes resulting from this method shall be dressed out.

b. All other material/service combinations shall use the electromagnetic yoke method.

c. MT of welds shall include a minimum of 25mm of base material either side of the weld centreline.

15.2.11 Where wet fluorescent MT (WFMT) is specified, the weld metal and base material for a distance of 25mm either side of the weld centreline, shall be prepared to a surface finish of SSPC-SP3 minimum, with all mill-scale removed, immediately prior to the examination.

15.2.12 When specified by Jacobs / IOCL. the internal surfaces of equipment fabricated from 300 series stainless steel or non-ferrous alloys shall be subject to random ferroxyl test prior to shipment to ensure no gross contamination with iron is present

15.2.13 NDE procedures shall be submitted for review in accordance with Standard.

15.2.14 NDE operators shall be certified as follows:

- All Level I, Level II and Level III NDE personnel shall be experienced in pressure vessel examination and hold independent certification by a scheme meeting the requirements of ISO 9712 (e.g. PCN (Personnel Certification in Non-Destructive Testing), CSWIP (Certification Scheme for Welding Inspection Personnel) or ACCP (ASNT Central Certification Program)
- Certification by the NDE operator's employer in accordance with a written practice meeting the recommendations in SNT-TC-1A or ANSI/ASNT CP-189 shall be subject to review and agreement by Jacobs / IOCL.
- Re-certification after the second period of validity has elapsed shall be by practical examination for Level I and Level II personnel and by an approved written examination for Level III personnel.
- Jacobs / IOCL reserves the right to require all personnel responsible for performing and

interpreting results from ultrasonic examinations to undertake and pass a practical examination.

- Original "wet copy" certificates attesting to personnel certification shall be made available for review by Jacobs / IOCL. Photocopies of certificates are not acceptable as proof of personnel certification.

16.0 PRODUCTION TESTS

16.1 Production Test Plates

16.1.1 Production test plates (PTPs) shall be produced whenever required by the code and the following:

- Equipment subject to impact testing in accordance with this specification
- Equipment constructed of ferritic materials with tensile properties enhanced by heat treatment.

16.1.2 The number of production test plates to be provided shall be as follows:

- One PTP for each WPS used for each 50m, or part thereof, of longitudinal (Category A) and circumferential (Category B) welds and meridional welds in hot formed heads.
- Large pressure vessels that cannot be heat treated in one heat treatment charge shall be provided with the applicable PTP for each heat treatment charge. The portions of the longitudinal weld that will be subject to two heat treatment cycles shall be represented by separate PTPs that have undergone both heat treatment cycles.

16.1.3 Material for the PTPs shall be from one of the heats of steel used in the fabrication of the equipment. Where the shell is fabricated from a forging and does not contain a longitudinal weld the PTP for the circumferential weld shall be taken from a prolongation of the shell forging.

16.1.4 Inspector shall verify the identity of each PTP and verify that the PTPs are representative of the production weld.

16.1.5 PTP thickness shall qualify production welding within the thickness range $0.75t < 1.25t$, where t is the thickness of the PTP.

16.1.6 PTPs shall be welded by the same welders or welding operators assigned to weld the production welds. PTPs for circumferential welds shall be welded concurrently with the start of production welding.

16.1.7 For equipment subject to impact testing or step cool screening tests. the PTP shall be subject to the same test regime as applied to the welding procedure qualification.

16.1.8 The initial PTP {as required in paragraph 15.1.2) shall be subject to the required testing as early as possible. For equipment subject to PWHT, the PTP shall be subject to a simulated heat treatment prior to testing. A permanent record of the temperature and time of this simulated heat treatment shall be maintained by equipment vendor and included in the production data book. Providing the temperature and time of the final heat treatment does not differ from the simulated heat treatment by a Tempering Parameter of 10.2, the results from the PTP shall be considered valid.

16.1.9 Where more than one production test plate is required in paragraph 15.1.2, the additional test plates shall be placed inside the equipment during any subsequent PWHT and retained for future testing as required by Jacobs / IOCL. If the tolerance in the final heat treatment specified in paragraph 16.1.8 is not met, an additional PTP shall be tested to verify that the production welding is acceptable.

16.1.10 Where the test results do not meet the specified requirements, two additional test specimens may be re-tested to determine compliance. if these two additional test specimens meet the requirements. the weld shall be considered acceptable. If the two test specimens fail to meet the requirements, all further production welding shall be stopped until the cause of failure is established. Once the cause is established. the weld shall either be completely removed and re-welded or, subject to Jacobs / IOCL review and agreement, a fitness-for-service assessment performed to determine its acceptability.

16.2 Ferrite Determination

16.2.1 Ferrite determination is required for austenitic stainless-steel pressure retaining welds subject to elevated temperature service.

16.2.2 This ferrite determination shall be performed prior to PWHT (if applicable) using either a suitably calibrated magnetic instrument in accordance with AWS A42 or by chemical analysis of the weld metal using the WRC-1992 diagram. Each pressure-retaining weld shall be subject to one check per weld for mechanised/automatic welding processes and a minimum of one check per 450mm of weld for manual or semi-automatic welding processes.

16.2.3 Acceptance criteria shall be as specified in paragraph 6.3.3.

16.2.4 Where the ferrite determination fails to meet the requirements in paragraph 16.2.3, two additional tests shall be performed on the failed weld. if these two additional tests meet the requirements, the weld shall be considered acceptable. If the two tests fail to meet the requirements, the weld shall be removed and re-welded.

16.2.5 Where the ferrite determination fails to meet the requirements in paragraph 16.2.3, two additional tests shall be performed on the failed weld. if these two additional tests meet the requirements, the weld shall be considered acceptable. if the two tests fail to meet the requirements, the weld shall be removed and re-welded.

16.3 Hardness Tests

Production hardness tests shall be performed in accordance with Section 12.6.2.

17.0 REPAIRS

17.1 General

17.1.1 Any unacceptable flaws found during NDE shall be repaired in accordance with an approved repair procedure. For major weld repairs, the weld repair procedure shall be submitted.

17.1.2 Wherever possible, unacceptable flaws shall be removed by grinding or machining. Arc-air gouging is permitted subject to the restrictions in Section 10.

17.2 **Inspection**

17.2.1 Where removal of a flaw requires subsequent welding to reinstate the required throat thickness, the repair cavity shall be contoured to permit access for welding followed by 100% MT/PT. A qualified welder using a properly qualified WPS shall perform the repair weld. Normally, only SMAW or GTAW shall be used to make the repair weld.

17.2.2 Following welding, the repair area shall be subject to 100% NDE using the same technique(s) as used to detect the flaw initially. Only two repairs at the same location are permitted, thereafter the complete weld shall be removed, re-welded and re-examined.

17.2.3 All repairs and rectification work shall be fully recorded, and evidence provided for Jacobs / IOCL review and approval that all required NDE and production tests have been performed.

Table 1: Minimum NDE Requirements for Equipment Subject to Full Radiography

Area To Be Inspected	Extent of Inspection[1]			
	Thickness at Weld	Before PWHT	After PWHT	After Pressure Test
Carbon Steels (P-No.1 Gp. 1 & Gp.2)				
Weld preparations	>50mm	MT	-	-
Category A, B, C, D butt welds	≤50mm	RT	[2]	Visual
	>50mm	RT	UT & MT[2]	Visual
Category C, D full penetration corner welds	≤50mm	Spot MT	-	Visual
	>50mm	UT[3]	UT[3] & MT[2]	Visual
Skirt attachment weld	All	MT	-	Visual + MT
Internal head attachment weld	All	MT	[2]	Visual
Major attachment welds (external & internal)	≤25mm	MT	[2]	Visual
	>25mm	-	UT & MT[2]	Visual
Minor attachment welds (external & internal)	All	Spot MT	[2]	Visual
Temporary Attachment welds	>50mm	MT	[2]	Visual
Carbon Steels (P-No.1 Gp.3), Low Alloy Steels (P-No.3, P-No.4, P-No. 5 & P-No.11) & Ni-alloy Steels (P-No.9)				
Weld preparations	>13mm	MT		
Category A, B, C, D butt welds	≤25mm	Spot MT	RT & MT	Visual
	>25mm	MT	UT & MT	Visual
Category C, D full penetration corner welds	≤25mm	Spot MT	MT	Visual
	>25mm	MT	UT[3] & MT	Visual
Skirt attachment weld	All	Spot MT	-	Visual + MT
Internal head attachment weld	All	Spot MT	MT	Visual
Major attachment welds (external & internal)	≤25mm	Spot MT	MT	Visual
	>25mm	MT	UT & MT	Visual
Minor attachment welds (external & internal)	All	-	MT	Visual
Temporary Attachment welds	All	-	MT	Visual
Austenitic Stainless Steels (P-No.8) & Non-Ferrous Alloys[4]				
Weld preparations	>25mm	PT	-	-
Category A, B, C, D butt welds	≤25mm	RT	-	Visual
	>25mm	RT & PT	-	Visual
Category C, D full penetration corner welds	≤25mm	-	-	Visual
	>25mm	UT[3] & PT	-	Visual
Skirt attachment weld	All	PT	-	Visual + PT
Internal head attachment weld	All	PT	-	Visual
Major attachment welds (external & internal)	All	PT	-	Visual
Minor attachment welds (external & internal)	>25mm	PT	-	Visual
Temporary attachment welds	>25mm	PT	-	Visual

Notes:

1. The requirements of the code shall be met in lull. The extent of inspection stated does not preclude fabricator increasing the level of inspection as pan of its in-house QC procedures. 100% visual examination is required during all inspection stages. Unless stated otherwise, all examination specified is for 100% coverage (internal and external) of the complete weld length. Where spot examination is specified, this shall be 5% coverage (internal and external) of the complete weld length.

2. For deaerator storage vessels or equipment exposed to sour (wet H2S) and/or alkaline SCC environments, all internal weld surfaces, including weld repairs and temporary attachment welds. shall be subject to 100% WFMT in accordance with paragraph 15.2.11 after PWHT.

3. Only applicable for nozzles with nominal diameter of NPS4 or greater.

4. Where the code requires PWHT of these materials the requirements stated in the "Before PWHT" column shall he met after PWHT.

Table 2: Minimum NDE Requirements for Equipment Subject to Spot Radiography

Area To Be Inspected	Extent of Inspection[1]			
	Thickness at Weld	Before PWHT	After PWHT	After Pressure Test
Carbon Steels (P-No.1 Gp. 1 & Gp.2)				
Category A, B, C, D butt welds	All	RT	[2]	Visual
Category C, D full penetration corner welds	All	MT	[2]	Visual
Skirt attachment weld	All	MT	-	Visual + MT
Internal head attachment weld	All	MT	[2]	Visual
Major attachment welds (external & internal)	All	MT	[2]	Visual
Minor attachment welds (external & internal)	All	-	[2]	Visual
Temporary Attachment welds	All	MT	[2]	Visual
Carbon Steels (P-No.1 Gp.3), Low Alloy Steels (P-No.3, P-No.4, P-No. 5 & P-No.11) & Ni-alloy Steels (P-No.9)				
Weld preparations	>13mm	MT		
Category A, B, C, D butt welds	All	-	RT & MT	Visual
Category C, D full penetration corner welds	All	-	UT[3] & MT	Visual
Skirt attachment weld	All	MT	-	Visual + MT
Internal head attachment weld	All	-	MT	Visual
Major attachment welds (external & internal)	All	-	MT	Visual
Minor attachment welds (external & internal)	All	-	MT	Visual
Temporary Attachment welds	All	-	MT	Visual
Austenitic Stainless Steels & Non-Ferrous Alloys[4]				
Category A, B, C, D butt welds	All	RT & PT	-	Visual
Category C, D full penetration corner welds	All	PT	-	Visual
Skirt attachment weld	All	PT	-	Visual+PT
Internal head attachment weld	All	PT	-	Visual
Major attachment welds (external & internal)	All	PT	-	Visual
Minor attachment welds (external & internal)	All	PT	-	Visual
Temporary attachment welds	All	PT	-	Visual

Notes:

1. The requirements of the code shall be met in lull. The extent of inspection stated does not preclude fabricator increasing the level of inspection as part of its in-house QC procedures. 100% visual examination is required during all inspection stages. Unless stated otherwise. all examination specified is for a minimum 5% coverage (internal and external) of the complete weld length with the following additional requirements:
   - All longitudinal-circumferential weld junctions shall he inspected as part of the 5% coverage.
   - At least one spot radiograph of each longitudinal weld shall be taken, with a minimum diagnostic film length of 3EIDmm unless restricted by the component geometry.
   - At least one radiograph shall be taken to represent each WPS used and each welder/welding operators work
   - The additional RT specified in Section 14.2 where weld encroachment cannot be avoided shall not be included in the minimum 5% figure.
   - Additional radiographs shall be taken as necessary to satisfy the requirements of ASME Section VIII, Division 1, UW-11(a)5(b)

- Jacobs / IOCL reserves the right to specify where spot radiographs are taken

2. For de-aerator storage vessels or equipment exposed to sour (wet H2S) and/or alkaline SCC environments. all internal weld surfaces, including weld repairs and temporary attachment welds, shall be subject to 100% WFMT in accordance with paragraph 15.2.11 after PWHT.

3. Only applicable for nozzles with nominal diameter of NPS4 or greater

4. Where the code requires PWHT of these materials the requirements stated in the "Before PWHT" column shall be met alter PWHT.

Attachment A: Additional Requirements for Duplex Stainless-Steel welding

A.1 Scope

This Attachment specifies additional requirements for the fabrication of the following Duplex stainless steels:

- Lean 22Cr Duplex steels (e.g. UNS S32304)
- Standard 22Cr Duplex steels (e.g. UNS S31803. UNS S32205)
- High alloy 25Cr duplex steels (e.g. UNS S32550)
- 25Cr Super Duplex steels (e.g. UNS S32750, UNS S32760)

Unless otherwise noted in this attachment, the requirements specified in the main text of this Engineering Standard shall apply in full.

A.2 **References**

Add the following references:

ASTM

E562 : Standard Test Method for Determining Volume Fraction by Systematic Manual Point Count

E1245 : Standard Practice for Determining the Inclusion or Second-Phase Constituent Content of Metals by Automatic Image Analysis

G48 : Standard Test Methods for Pitting and Crevice Corrosion Resistance of Stainless Steels and Related Alloys by Use of Ferric Chloride Solution

A.3 Definitions

Add the following definitions:

PREN : Pitting Resistance Equivalence Number
1 x %Cr + 3.3 (%Mo + 0.5 x %W) + 16 x %N

A.4 General Welding Requirements

The requirements of Section 4 shall be met in full.

A.5 Welding Processes

A.5.1 Acceptable Welding Processes

Acceptable welding processes shall be in accordance with API RP582 with the exception that the EGW process is not permitted.

A.5.2 Limitations of Fusion Welding Processes

A.5.2.1 Automatic Pulsed Gas Tungsten Arc welding (GTAW-P)

in addition to the restrictions in API RP582. welding without the addition of filler metal (autogenous welding} is not permitted.

A.5.3 Flux Cored Arc welding (FCAW)

FCAW-G is not permitted for welding the root pass in single-sided welded joints.

A.5.4 Electrogas Welding (EGW)

The use of EGW is not permitted.

A.5.4.1 Gas Tungsten Arc Welding {GTAW}

In addition to the restrictions in API RP582. welding without the addition of filler metal (autogenous welding_ is not permitted.

A.5.4.2 Plasma Arc Welding (PAW]

Welding without the addition of filler metal (autogenous welding} is not permitted.

A.5.5 Shielded Metal Arc Welding {SMAW)

SMAW is not permitted for welding the root pass in single-sided welded joints.

A.5.6 Single-Sided Welded Joints

In addition to the requirements in API RPEE-2, the use of flux backing (in-lieu of a backing purge gas) or flux cored GTAW wires shall not be used for root pass welding of single-sided welded joints unless slag can be removed from the process side of the root pass and the area inspected for slag removal.

A.6 Welding Consumables (Filler Metal and Flux)

A.6.1 General

A.6.1.1 In addition to the requirements in API RP582. when joining materials with the same nominal chemistry. consumables shall be based on obtaining weld deposits with equivalent mechanical properties and corrosion resistance to that of the base material. Unless otherwise agreed with Jacobs / IOCL, deposited weld metal shall meet the following requirements:

Carbon	0.03% max.
Sulphur	0.01% max.
Phosphorous	0.02% max.
Nitrogen	0.14% min.
PREN	35 min. for 22Cr type consumables (e.g. E2209-XX. ER2209)
	For 25Cr type consumables. PREN shall match the base material as closely as possible but shall not be less than 40
Ferrite	balance 30-65 FN

A.6.1.2 The use of overmatching tiller wires for the root pass shall be subject to Jacobs / IOCL review.

A.6.1.3 Welding consumables producing low hydrogen deposits shall be used when welding all grades of duplex stainless steel. Basic coated SMAW electrodes shall be used when the nominal thickness at the weld joint exceeds 25mm.

A.6.1.4 Each batch of consumables shall be certified in accordance with ISO 10474 Type 3.1B.

A.6.1.5 In addition to the requirements of paragraph 6.1.10. a welding procedure shall be re-qualified if there is a change in the consumable manufacturer and brand designation from that stated on the PQR.

A.6.2 Dissimilar Welding

A.6.2.1 When joining materials of different nominal chemistry, the consumables noted below should be used. Alternative consumable selection shall be submitted to Jacobs / IOCL for review and approval prior to commencement of welding.

Base Material (1)	Carbon and ferritic steels. 300 series stainless steels	Cu-base alloys Ni base alloys
Lean 22Cr duplex	E309L, E309LMo Duplex (e.g. E2209) Ni-base (e.g. ENiCrFe-3, ENiCrMo-3)	Ni-base (e.g. ENiCrFe-3, ENiCrMo-3)
Standard 22Cr duplex		
High alloy 25Cr duplex		
25Cr super duplex		

Note:
1. Above table refers to coated electrodes. For bare wire (SAW, GMAW, GTAW) or FCAW welding, use equivalent AWS electrode classifications

A.7 Shielding Gases

A.7.1 In addition to the requirements of Section 7, a backing purge gas shall be used to prevent oxidation of tacit welds and the root pass in single-sided welded joints. A backing purge gas shall also be used when welding attachments directly to thin-wall components (wall thickness less than or equal to 6.4mm).

Shielding and purge gases shall meet the following requirements:

- Gases shall not contain hydrogen
- Nitrogen and Helium contents shall not exceed 2% and 10% respectively for GTAW
- Moisture content of gases shall not exceed 10ppm.

A.8 Preheating and inter-pass Temperature

A.8.1 Preheating is not required other than to remove moisture from the weld area prior to the commencement of welding.

A.8.2 Inter-pass temperature should be limited to 200℃ for 22Cr and high alloy 25Cr duplex stainless steels and 150℃ for 25Cr super duplex stainless steels. Where the wall thickness is less than or equal to 6.4mm. a maximum inter-pass temperature of 100℃ or lower is recommended. Maximum inter-pass temperatures shall be established during welding procedure qualification.

A.8.3 Temperature indicating crayons shall be certified free from injurious contaminants. such as Sulphur, Bismuth, halides etc.

A.9 Post weld Heat Treatment (PWHT)

Unless otherwise agreed with Jacobs / IOCL, PWHT is not permitted.

A.10 Cleaning and Surface Preparation

A.10.1 In addition to the requirements in Section 10, the following requirements shall be met:

A.10.1.1 All preparation. cutting and welding operations shall be performed in a clean area, segregated from the fabrication of ferrous materials and suitable to produce sound. non-contaminated welds.

A.10.1.2 All tools shall be dedicated to duplex stainless-steel fabrication only and shall not have been

used previously on any ferritic materials. Grinding wheels or discs shall be iron-free and shall not be organic resin bonded.

A.10.1.3 Weld preparations may be cut or profiled by grinding. machining or plasma arc cutting. The HA2 from thermal cutting shall be removed by grinding or machining.

A.10.1.4 Any tack welds shall be made exercising the same care as for root, fill and cap welds. Tack welds shall only be incorporated into the root pass if they are sound and meet the visual inspection requirements.

A.10.1.5 Carbon-arc gouging is not permitted for profiling or back-gouging of welds.

A.11 Special Procedure Qualification Requirements/Testing

A.11.1 General

A.11.1.1 Welding procedures shall be developed to ensure that the weld is essentially free of intermetallic phases (i.e. less than 1%).

A.11.1.2 The root pass for single-sided welded joints shall be welded by depositing a second “cold pass" at approximately ?5% of that used for the root pass.

A.11.1.3 Heat input shall be in accordance with base material manufacturers recommendations and consistent with the base material thickness to obtain adequate fusion and weldment properties. The following limits are recommended but acceptable heat inputs shall be established during procedure qualification:

Lean 22Cr duplex stainless steels	0.51-1.5 J/mm for t ≤ 10mm
22Cr duplex stainless steels	0.5-2.5 J/mm for t > 10mm
High alloy 25Cr duplex stainless steels	
25Cr super duplex stainless steels	0.51-1.5 J/mm for all thicknesses

A.11.1.4 For wall thickness less than or equal to 6.4mm welding procedures shall be qualified using the proposed production wall thickness in order to simulate the actual heat sink effect.

A.11.2 Tube-to-Tubesheet Welding

In addition to the requirements in paragraph 11.2.1, each test sample shall be subject to the following tests:

- Microstructure and ferrite determination
- Hardness determination
- Corrosion testing (where specified)

A.11.3 Welding Procedure Qualification

A.11.3.1 Each welding procedure qualification test piece shall be subject to the following range of tests in addition to the mechanical tests required by the code:

a) Ferrite balance shall be determined on a transverse metallographic specimen in accordance with ASTM E5-52 using the intercept method with a minimum grid size of 25 and maximum accuracy of ±10%. Fields shall be selected randomly and magnification chosen appropriate to the ferrite lathe size (x500-x1000 is preferred). The root. fill and cap of the weld deposit and HA2 shall be sampled separately in addition to the base material. Ferrite levels shall be in the range 45-50% for the base material and

35-65% for weld metal and HAZ. Use of automated analysis in accordance with ASTM E1245 shall be subject to agreement with Jacobs / IOCL.

b) Ferrite content shall be determined on the weld-capping pass in accordance with Section 15.2 for correlation of production ferrite tests. Acceptance criteria shall be 30-BSFN.

c) Macrographic examination for intermetallic phases. The weld metal HAZ and base materials shall be essentially free of intermetallic phases (i.e. less than 5%)

d) Where specified, corrosion testing in accordance with ASTM G43 Method A and the following:

i. At least two samples with a nominal test face size of 50x25mm shall be prepared for testing. Specimen weight shall be sufficiently low to allow measurements to within 11mg. The weld direction shall be approximately parallel to the shorter edge of the test face with the weld positioned equidistant from two ends of the specimen. The weld width should not exceed one third of the specimen length

ii. The sides and ends of each specimen shall be ground to remove any machining marks to produce a 1000-1200 grit finish and all corners shall be rounded. The test face shall be in the as-received condition i.e. “ready for service" with no additional preparation on the surface under test unless otherwise agreed with Jacobs / IOCL

iii. Unless otherwise specified. the test temperature for Type 22Cr duplex stainless steel shall be 22℃ ± 1℃ and 35℃ ± 1℃ for Type 25Cr duplex stainless steel (e.g. lean Type 22Cr steels do not require corrosion testing}.

iv. The test specimen shall be orientated with the test face uppermost and at an angle of approximately 45° to the vertical

v. The test duration shall be 24 hours. thereafter the specimen shall be removed and cleaned to remove any corrosion products.

vi. Acceptance criteria shall be ≤ 1g/m^2 with no visible pitting on the test face under x20 magnification.

e) Impact testing at the MDMT or -40℃, whichever is lower. Samples shall be taken to represent each welding process used when the test piece thickness exceeds 13mm. Acceptance criteria for full sized specimens shall be ≥ 40J ave./28J min.

f) Hardness testing in accordance with Section A.12.6

A.11.3.2 A change in any of the following from that stated on the PQR will require re-qualification of the welding procedure.

- Manufacturer or source of supply for 25Cr base materials
- Type 22Cr base materials to Type 25Cr base materials or vice versa
- A change in thickness of 0.75-1.5 from that recorded on the PQR. For production wall thickness less than or equal to 6.4mm no change in the qualified thickness from that recorded on the PQR is permitted
- Increase in the preheat or inter-pass temperature
- Composition of a shielding or purge gas

A.12 Other Items

A.12.1 Backing Materials

Permanent or temporary backing strips are not permitted

A.12.2 Peening

The requirements of API RPSS2 shall be met in full.

A.12.3 Weld Overlay and Clad Restoration (Back Cladding)

The requirements for weld overlay and back cladding shall be as specified in project specifications.

A.12.4 Temporary Attachments

In addition to the requirements of API RPSS2, NDE of areas where temporary attachments have been removed shall be performed in accordance with paragraph E.15.2.3.

A.12.5 Stud Welding

Stud welding shall only be permitted with approval of the Jacobs / IOCL. When permitted. the welding procedure qualification shall include a hardness survey across the weld and shall meet the acceptance criteria in Section E.12.6.

A.12.6 Hardness Tasting — Wald Procedure Qualification and Production Tasting

A.12.6.1 Each welding procedure shall be hardness tested in accordance with Section 12.6. Acceptance criteria shall be:

Weld Metal	Wet H_2S (sour) service	All other services
Type 22Cr	$310HV_{10}$	$350HV_{10}$
Type 25Cr	$330HV_{10}$	$350HV_{10}$

A.12.6.2 Production hardness testing shall he performed in accordance with Section 12.6. Acceptance criteria shall be:

Weld Metal	Wet H2S (sour) service	All other services
Type 22Cr	260BHN	285BHN
Type 25Cr	270BHN	285BHN

A.13 Welder and Welding Operator Qualification

The requirements in Section 13 shall he met in full.

A.14 Fabrication

A.14.1 Forming

A.14.1.1 In addition to the requirements of the code, all cold spun heads with a nominal thickness more than 13mm, prior to forming, shall be re-solution heat treated, in accordance with the original material heat treatment, after forming irrespective of the fibre strain induced.

A.14.1.2 Pre-fabricated components shall be examined in accordance with paragraph 14.1.3

A.14.1.3 Local flame straightening shall not be permitted without specific Jacobs / IOCL approval. Where permitted. Jacobs / IOCL shall review and approve flame straightening procedures and shall be present during all flame straightening operations.

A.15 Quality Control

A.15.1 General

For single-sided welded joints. the internal root bead shall be inspected for acceptable weld profile (root penetration) and surface condition (i.e. no unacceptable oxidation).

A.15.2 Non-Destructive Examination

A.15.2.1 Welds shall be visually inspected in the as-welded condition for indications of contamination after each pass. Welds shall not be ground, wire brushed or dressed in any way that removes surface discolouration before inspection.

A.15.2.2 A light straw colour discolouration is acceptable. Heavy oxidation, as indicated by a dark brown or blue colour, with possibly a coked weld surface, is unacceptable. Unacceptable oxidation shall be removed by light grinding with 60-35micron grade abrasive paper or by pickling. Fielding procedures shall be submitted for Jacobs / IOCL review.

A.15.2.3 Unless otherwise agreed with Jacobs / IOCL full radiography shall be applied as follows:

Area To Be Inspected	Extent of Inspection[1]		
	Thickness at Weld	Before Pressure Test	After Pressure Test
Weld preparations	>13mm	MT/PT	-
Category A, B, C, D butt welds	All	RT[2] & MT/PT	Visual
Category C, D full penetration corner welds	≤13mm	MT/PT	Visual
	>13mm	UT[3]& MT/PT	Visual
Skirt attachment weld	All	-	Visual + MT
Internal head attachment weld	All	MT/PT	Visual
Major attachment welds (external & internal)	≤13mm	MT/PT	Visual
	>13mm	UT & MT/PT	Visual
Minor attachment welds (external & internal)	All	MT/PT	Visual
Temporary Attachment welds	All	MT/PT	Visual

Notes:

a. The requirements of the code shall be met in full. The extent of inspection stated does not preclude fabricator increasing the level of inspection as part of its in-house QC procedures. 100% visual examination is required during all inspection stages. Unless stated otherwise. all examination specified is for 100% coverage (internal and external) of the complete weld length

b. Where the thickness or design precludes the use of RT, UT may be substituted subject to Jacobs / IOCL review

c. Only applicable for nozzles with nominal diameter > NPS3

A.15.2.4 In addition to the requirements of the code any tacit effusion or penetration at the root face or surface-breaking porosity, either at the root or cap, is not permitted.

A.15.2.5 Ultrasonic examination shall meet the requirements of paragraph 15.2.9 and a procedure, detailing additional measures to overcome the anisotropic nature of the weld metal and evidence of the NDE operator's experience in the UT of these materials shall be submitted for Jacobs / IOCL review.

A.16 Production Tests

A.16.1 Production Test Plates

A.16.1.1 In addition to the requirements in Section 16.1. PTPs shall be produced for each 50m, or part thereof, of longitudinal (Category A) and circumferential (Category B) welds and meridional welds in hot formed heads.

A.16.1.2 PTP shall be subject to the same test regime as applied to the welding procedure qualification unless otherwise agreed with Jacobs / IOCL.

A.16.2 Ferrite Determination

A.16.2.1 Ferrite determination is required for each pressure-retaining weld in accordance with Section 16.2. Acceptance criteria shall be 30-65FN.

A.17 Repairs

A.17.1 General

A.17.1.1 Only one repair at the same location shall be permitted, thereafter the weld shall be completely removed and re-welded.