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DATE	AUG/28/18	05/06/2020	10/12/2020	April 22nd 2021	Dec 27th 2021	Dec 28th 2021	Jun 14th 2024		
DESIGN	ESUP	ESUP	ESUP	ESUP	ESUP	ESUP	ESUP		
EXECUTION	MARCHON	MARIANO	UQ0O	UQ0O	UQ0O	UQ0O	CSM5		
CHECK	MARIANO	NISGOSKI	CSM5	CSM5	CSM5	US1O	UQ0O		
APPROVAL	JUVENTINO	MEYRELLES	BEX1	BEX1	BEX1	BEX1	BEX1		

SUMMARY

1 INTRODUCTION

This technical specification, in addition to other specifications and codes referred to in Section 2, defines the requirements for all fusion welding operations performed at any part of the Unit, including topside parts and components, hull parts and components, marine systems, as well as any production plant and utilities parts and components. It also includes, but is not limited to, all structures, equipment (both static and dynamic), piping and pipelines, including those supplied as packages.

The requirements herein listed shall be applied along with all the requirements from the applicable Design Codes and IOGP S-705 (welding of pressure containing equipment and piping, supplementary specification to API RP 582 – 2016 Edition), so that the most stringent requirement shall always prevail.

The requirements herein listed are applicable to all players performing such related activities within the scope of the contract, including manufacturers, packagers, main contractor, subcontractors, suppliers, sub suppliers, integrators, constructors, and all technical personnel involved. Within the scope of this document, they are all referred to as being a SELLER.

To establish the inspection of the finished welds is not the purpose of this technical specification.

2 NORMATIVE REFERENCES

The following documents contain requirements that are applicable to the fusion welding operations and shall be followed as applicable.

2.1 CLASSIFICATION SOCIETY RULES

SELLER shall perform the work in accordance with the requirements and rules of the Classification Society (CS).

CS Rules may only be waived upon the formal approval from the CS itself and from BUYER.

2.2 CODES AND STANDARDS

The following codes and standards include provisions which, through reference in this text, constitute provisions of this technical specification. The latest issue of the references shall be used unless otherwise agreed.

Other recognized standards may be used, provided it can be shown that they meet or exceed the requirements of the standards referenced bellow.

- API RP 582 2016 Edition – Welding Guidelines for the Chemical, Oil, and Gas Industries

- ASME B31.3 – Process Piping
- ASME B31.4 – Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids
- ASME B31.8 – Gas Transmission Distribution and Piping Systems
- ASME BPVC Section II Part C – Welding Rods, Electrodes and Filler Metals
- ASME BPVC Section VIII – Rules for Construction of Pressure Vessels
- ASME BPVC Section IX – Welding and Brazing Qualification
- ASTM A262 – Standard Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels
- ASTM A370 – Standard Test Methods and Definitions for Mechanical Testing of Steel Products
- ASTM A380 – Standard Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems
- ASTM A578 – Standard Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications
- ASTM E92 – Standard Test Methods for Vickers Hardness and Knoop Hardness of Metallic Materials
- ASTM E527 – Standard Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)
- AWS A3.0 – Standard Welding Terms and Definitions
- AWS A5.01 – Welding Consumables – Procurement of Filler Metal and Fluxes
- AWS A5.1 – Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding
- AWS A5.4 – Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding
- AWS A5.5 – Specification for Low-Alloy Steel Electrodes for Shielded Metal Arc Welding
- AWS A5.7 – Specification for Copper and Copper-Alloy Bare Welding Rods and Electrodes
- AWS A5.9 – Specification for Bare Stainless Steel Welding Electrodes and Rods
- AWS A5.11 – Specification for Nickel and Nickel-Alloy Welding Electrodes for Shielded Metal Arc Welding
- AWS A5.14 – Specification for Nickel and Nickel-Alloy Bare Welding Electrodes and Rods
- AWS A5.17 – Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding
- AWS A5.18 – Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding
- AWS A5.20 – Specification for Carbon Steel Electrodes for Flux Cored Arc Welding
- AWS A5.23 – Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding
- AWS A5.28 – Specification for Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding
- AWS A5.29 – Specification for Low-Alloy Steel Electrodes for Flux Cored Arc Welding
- AWS A5.34 – Specification for Nickel-Alloy Flux Cored and Metal Cored Welding Electrodes
- AWS D1.1 – Structural Welding Code – Steel

- AWS D10.10 – Recommended Practices for Local Heating of Welds in Piping and Tubing
- ISO 6507-1 – Metallic Materials – Vickers Hardness Test – Part 1: Test Method
- ISO 8501-1 – Preparation of Steel Substrates Before Application of Paints and Related Products – Visual Assessment of Surface Cleanliness
- ISO 15156-1 to 3 – Petroleum and Natural Gas Industries – Materials for use in H2S-Containing Environments in Oil and Gas Production
- ISO 15614-5 – Specification and Qualification of Welding Procedures for Metallic Materials – Welding Procedure Test – Part 5: Arc Welding of Titanium, Zirconium and their Alloys
- ISO 17405 – Non-destructive testing – Ultrasonic Testing – Technique of Testing Claddings Produced by Welding, Rolling and Explosion
- ISO 17781 – Petroleum, Petrochemical and Natural Gas Industries – Test Methods for Quality Control of Microstructure of Ferritic/Austenitic (Duplex) Stainless Steels
- IOGP S-705 – Supplementary Specification to API Recommended Practice 582 for Welding of Pressure Containing Equipment and Piping (version 1.01 of Jun/2021)
- SSPC-SP 10 – Near-White Metal Blast Cleaning
- SSPC-SP 11 – Power-Tool Cleaning to Bare Metal
- WRC 452 – Recommended Practices for Local Heating of Welds in Pressure Vessels

Governmental codes, regulations, ordinances, or rules applicable to the equipment in Brazil shall prevail over the requirements of above specification, including reference codes and standards and/or these engineering specifications, only in those cases where they are more stringent.

2.3 REFERENCE TECHNICAL SPECIFICATIONS

- I-ET-3010.00-1200-970-P4X-003 – REQUIREMENTS FOR PERSONNEL QUALIFICATION AND CERTIFICATION
- I-ET-3010.00-1200-970-P4X-004 – NON-DESTRUCTIVE TESTING REQUIREMENTS FOR METALLIC AND NON-METALLIC MATERIALS
- I-ET-3010.00-1200-200-P4X-115 – REQUIREMENTS FOR PIPING FABRICATION INSPECTION AND COMMISSIONING
- I-ET-3010.00-1200-540-P4X-001 – REQUIREMENTS FOR PRESSURE VESSELS DESIGN AND FABRICATION
- I-ET-3010.00-1200-940-P4X-002 – GENERAL TECHNICAL TERMS

2.4 CONFLICTING REQUIREMENTS

In case of conflicting information between this Technical Specification and the referred applicable standards, the most stringent requirement shall prevail.

The requirements stated in this Technical Specification are intended to be aligned with IOGP S-705 (and API RP 582) or, in some cases, most stringent. Any contradictory requirement between this Technical Specification and IOGP S-705 shall be formally consulted by means of a Technical Query.

In case of conflicting information between this specification and other specific BUYER's Document (Data Sheet or Equipment List), the BUYER technical representative shall be formally consulted through a Technical Query.

Failure to proceed as indicated above may result in repair work at the expenses of the SELLER.

3 DEFINITIONS AND ABBREVIATIONS

3.1 DEFINITIONS

Definitions are in accordance with the technical specification I-ET-3010.00-1200-940-P4X-002 – GENERAL TECHNICAL TERMS, along with the definitions from AWS A3.0 (Standard Welding Terms and Definitions).

Main general terms used throughout this specification that can be added to the definitions are as follows:

Welding Procedure Qualification Record (PQR): The PQR is a record of the welding data and variables used to weld a test coupon and the test results used to qualify the welding procedure. The purpose of the PQR is to establish the properties of the weldment.

Welding Procedure Specification (WPS): The WPS provides direction to the welder while making production welds to applicable code requirements.

Clad: Coating of corrosion resistance alloy (CRA) metallurgically bonded to a less noble base metal (usually carbon steel), to improve its corrosion resistance.

Weld Overlay: A clad coating process that deposits a CRA on the base metal surface by welding.

Heterogeneous Welding: Welding with the application of external filler whose metallurgical composition is substantially different from that of the base metals.

Autogenous Welding: Welding with no additions of filler metal, where the weld pool is composed solely by the fusion and dilution of the base metals.

Dissimilar Welding: Welding which involves the joining together of two metals that possess different chemical or mechanical properties, and so are not necessarily a natural fit for each other.

3.2 ABBREVIATIONS

C	Carbon Steel
CE	Carbon Equivalent
C-Mn	Carbon-Manganese Steel
C-Ni	Nickel Alloy Steel
CRA	Corrosion Resistant Alloy
CS	Classification Society
CVN	Charpy V-Notch
ESW	Electroslag Welding
FCAW	Flux Cored Arc Welding
GMAW	Gas Metal Arc welding
GTAW	Gas Tungsten Arc Welding
HAZ	Heat-Affected Zone
MT	Magnetic Particle Testing
NDT	Non-Destructive Testing
PQR	Procedure Qualification Record
PREN	Pitting Resistance Equivalent Number
PT	Liquid Penetrant Testing (Dye Penetrant Testing)
PWHT	Post-weld Heat Treatment
RT	Radiographic Testing
SAW	Submerged Arc Welding
SMAW	Shielded Metal Arc-Welding
SMYS	Specified Minimum Yield Strength
SWPS	Standard Welding Procedure Specification (according to ASME BPVC Section IX)

TMCP	Thermo-Mechanical Controlled Processing
UNS	Unified Numbering System for Metals and Alloys (according to ASTM E527)
UT	Ultrasonic Testing
VT	Visual Testing
WPS	Welding Procedure Specification
pWPS	Preliminary Welding Procedure Specification

4 GENERAL REQUIREMENTS

4.1 WELDING CONDITIONS

This technical specification shall be used in conjunction with the design, fabrication, assembly, and post fabrication standards, and with standards of additional requirements related to the service conditions of the equipment item or the structure.

Welding shall as a minimum be performed in accordance with IOGP S-705 (and API RP 582) with the additional requirements herein listed.

Where sour service is applicable, all materials and all welding procedures shall also fulfill the requirements of the applicable Part of ISO 15156.

The requirements for welding operation listed in this Section 4 are valid for all of the materials mentioned in Section 5 and all equipment items or structures made from those materials.

Section 5 lists the specific requirements applicable to the various materials mentioned, such as the permitted welding processes, the allowed consumables, preheating, post-heating and heat treatment temperatures, and specific conditions for welding technique of the materials.

All welding requirements which depend on the characteristics of the equipment or structure, such as, for example, details of bevels, joint fit-up, dimensional tolerances, requirements for post weld heat treatment, requirements for inspection, and acceptance criteria of defects, are not replicated in this technical specification. This information is stated in design, fabrication, assembly, and post fabrication standards, as well as within standards of additional requirements related to the service conditions of the equipment item or the structure.

Autogenous welding is not permitted. Dissimilar welding and heterogenous welding may only be performed when approved by OWNER.

Welding is not permitted without the required qualification of welders and welding procedures, according to the applicable design code.

Stainless steel, nickel alloys, copper, copper alloys, and titanium materials shall be stored, handled, and processed completely separated from carbon steel, Cr-Mo steel and Ni steel, in order to avoid the risk of contamination.

4.2 WELDING DOCUMENTS

Welding documents shall be prepared and qualified in accordance with the applicable design, fabrication, and assembly codes.

Prequalified WPSs provided in AWS D1.1 and the standard welding procedure specifications (SWPSs) specified in ASME BPVC Section IX are not acceptable.

Each WPS shall be supported by suitable(s) PQR(s). Each PQR shall have attached on it the following documents, as minimum: base material certificates, consumable certificates, non-destructive testing reports, PWHT reports, laboratory testing reports.

4.3 WELDING PROCEDURE QUALIFICATION

Test specimens for mechanical tests shall undergo dimensional and visual inspection before tests are performed.

When impact testing on heterogeneous welds and dissimilar joints is required, all zones of different chemical composition, such as HAZ and the weld metal, shall be represented by complete set of test specimens with notch located within those zones.

When the design, fabrication or assembly standard requires hardness testing in qualification of welding procedure, the Annex A of this technical specification shall be followed as a minimum. Additional measures may be needed as required by design or service codes and standards.

The application method and brand name of protective varnishes applied to weld bevels shall be evaluated during the qualification of welding procedure, when its removal before welding is not provided.

For pressure containing equipment and piping, the special requirements/testing of Section 11 of IOGP S-705 shall be followed.

Additional requirements regarding the welding procedure qualification are present in Section 5 and in the Annexes of this technical specification.

4.4 PERSONNEL QUALIFICATION AND CERTIFICATION

Personnel qualification and certification for welding and for non-destructive testing shall be in accordance with I-ET-3010.00-1200-970-P4X-003 – REQUIREMENTS FOR PERSONNEL QUALIFICATION AND CERTIFICATION, as applicable to the Project.

Welders Performance Reports shall be issued as required I-ET-3010.00-1200-970-P4X-003 – REQUIREMENTS FOR PERSONNEL QUALIFICATION AND CERTIFICATION.

Qualified welders and welding operators shall bear visible identification including name, the stamp number and qualification (allowed welding process, welding position, etc.).

4.5 WELDING PROCESSES AND EQUIPMENT

Welding shall be performed using processes permitted by the design, fabrication and assembly standards of the equipment or structure, as well as Section 5 of this technical specification.

For pressure containing equipment and piping, the acceptable welding processes listed on Table 7 of IOGP S-705 shall be used with the restrictions in Section 5 of this technical specification.

The measurement instruments existing in welding power sources shall be calibrated and within the expiration date.

Welding power source, cables, clamps, electrode holder, welding guns and torches, wire feeders, control cables, extension cords, refrigeration unit, auxiliary command and control units coupled to equipment, high-frequency drive for GTAW process, and others that have direct interference in the process or are interdependent shall meet the requirements of NEMA (National Electrical Manufacturers Association) or IEC (International Electrotechnical Commission).

For SMAW, GTAW, GMAW, FCAW processes, it is recommended the use of inverter power sources.

The portable ovens for keeping low hydrogen coated electrodes dry shall have electrical resistances to keep the temperature between 80 °C and 150 °C, and to be of exclusive use for each welder. The portable ovens shall be calibrated.

The electric insulation of portable ovens and cables shall be in good conditions, without flaws or unprotected regions, and properly sized for working conditions and personal safety.

The grounding clamps and cables shall be in good conditions (grounding clamps shall not be homemade). The contact surfaces shall be free of rust and painting.

4.6 WELDING TECHNIQUE

The welding arc shall always be struck at the bevel, or at appendix plate used for that purpose.

Joints to be welded shall be free of oil, grease, rust, slag, paint, liquid penetrant testing residues, sand, and soot from gas preheating.

The bevels and edges shall be cleaned to bright metal.

When preparing the bevel, thermal or mechanical cutting irregularities and slag shall be removed.

When gouging by arc-carbon are used, carbon, slag and copper deposits shall be mechanically removed to ensure complete removal of HAZ and contaminants.

Cutting, slag removal and cleaning tools shall be made of materials suitable for each base metal.

Carbon arc cutting and gouging and oxyfuel cutting is not permitted for stainless steel, nickel alloys, copper, copper alloys, and titanium materials. Thermal cutting shall be preferably performed by plasma or laser, and the surface shall be ground in order to remove any signs of oxidation and irregularities. The tools for slag removal, cleaning and cutting shall be used exclusively for these materials and meet the following requirements:

a) Tools for slag removal and cleaning shall be stainless steel or coated with this material.

b) Cutting discs and grinding shall be made of aluminum oxide with soul "Nylon" or fiberglass.

There shall not be any contamination with substances containing chloride, sulfur, lead, zinc, and their compounds.

The welding of socket welds shall be done with GTAW process, with at least two layers (one pass on first layer, two passes on second layer as minimum) and a smooth convex profile.

Slag and flux residues shall be completely removed after welding.

When required in Section 5, back purging in the root shall be maintained until the 3rd layer of weld or 8 mm, whichever is greater. This internal protection is applicable for butt welds, socket welds, sealing welds as well as for any weld performed on the opposite side when thickness of the base material is below 8 mm (e.g. the welding of an external support in a piping requires gas protection internal to the piping). Purging shall ensure the expulsion of all the oxygen in the root zone and no welding is to be started before the oxygen content is equal or less than 500 ppm.

4.7 WELDING CONSUMABLES

The selection of consumables shall be in accordance with the requirements set forth in Section 5 of this specification. For processes not covered by Section 5, the corresponding specification of ASME

BPVC Section II Part C or AWS specification and classification shall be followed. Welding consumables shall be provided with its respective batch certificates.

The packages for coated electrode, rod or rolled wire shall indicate, legibly and without erasures, its brand name, specification, classification, diameter, heat number and manufacturing date.

Filler metals shall present individual identification of its classification. Coated electrodes shall have its identification printed on each one. Rods shall be identified at both ends. The rolled wire shall be identified on the reel.

Irregularities or discontinuities in the coating of coated electrodes, such as localized thickness reduction, cracks, damages at the end, lack of adhesion, as well as dimensional deficiencies in length and eccentricity beyond the limits of the specification and core oxidation signs, are unacceptable.

Bare electrodes or rods with oxidization signs are unacceptable.

The packages of coated electrodes and fluxes shall be free from defects that cause contamination or damage to consumables.

When a consumable is used, it shall present the same conditions of receipt, regarding the absence of defects, identification, and condition of the package.

Coated electrodes and low hydrogen fluxes shall be subjected to drying operations and special handling conditions for keeping them dry. These operations shall be performed as stated by the consumable manufacturers.

For pressure containing equipment and piping, diffusible hydrogen limits for consumables shall not exceed the values stated in Table 8 of IOGP S-705. For duplex and superduplex stainless steels, diffusible hydrogen content shall not exceed 8 ml/100 g of deposited weld metal.

Consumables (wires, rods, and electrodes) shall be properly stored in clean, dry place and always handled with clean gloves.

4.8 ENVIRONMENTAL CONDITIONS

Welding shall not be performed under rain, snow, wind, and dust in general, unless the joint is protected.

For all welding processes, protection means shall be used to prevent the action of air currents and humidity that may change welding conditions.

4.9 PREHEATING, INTERPASS AND POST-HEATING

Preheating and post-heating shall be applied when required by design codes and Section 5 of this technical specification.

For pressure containing equipment and piping, the maximum interpass temperature shall follow the Table 4 of IOGP S-705/API RP 582 with the restrictions in Section 5 of this technical specification.

Preheating, where required, applies to all welding, tack welding, arc gouging and thermal cutting.

When the preheating is required, the temperature shall be maintained until the weld is completed.

Welding shall not be performed when the part surface, in an area of 150 mm centered on the joint to be welded, is wet or below the established preheating temperature for the material, according to specific conditions in Section 5.

If preheating is not required, the temperature of the surface to be welded shall not be below 10 °C. If this happens, the surface shall be preheated at 20 °C, or as otherwise determined in Section 5.

The post-heating, where required, shall be applied immediately after the completion of welding. The temperature shall not fall below the preheating temperature specified in the WPS.

The preheating and post-heating shall be performed preferably by electrical resistance or induction. Manual preheating by blowtorch flame may be used, as long as there is no restriction to its use in Section 5. Professionals responsible for the manual heating by flame shall receive prior training, and also shall be guided about the possible metallurgical damage to the different materials to be welded if this operation is poorly executed. The use of cutting nozzle blowtorch in preheating is not permitted.

The preheating and post-heating temperature shall be measured on the base metal, on all joint members, on the opposite side to the heating source whenever possible, at 75 mm from the weld groove. Preheating and temperature control procedures shall be prepared.

NOTE: If flame heating is used, where the temperature may only be measured from the side of the source, heating shall be interrupted for at least 1 minute for every 25 mm of thickness of the piece before it is measured.

The interpass temperature shall be measured on the weld metal, on the region in which the next pass will be deposited. If using temperature indication stick (crayon), when permitted in Section 5, the measurement shall be made in an adjacent area to avoid contamination of the subsequent pass.

Preheating, interpass and post-heating temperatures shall be checked by means of optical or contact pyrometers, taking care so that the instrument adjustment is correlated with the emissivity of the

material. The temperature indicating sticks may also be used, as long as it does not conflict with Section 5 of this technical specification.

4.10 INSPECTION AND QUALITY CONTROL

All finished welds shall be 100% visually inspected and evaluated by a Welding Inspector or by Visual Welding Inspector, with the acceptance criteria of the applicable standard of manufacture. This visual inspection shall precede the other non-destructive tests. SELLER shall issue a VT report.

The Welding Inspector shall ensure that the welding variables (preheating, heat input, gas flow and composition, welding position, etc.) provided in WPS remains within the qualified limits throughout the production welding.

4.11 WELD REPAIRS

The same inspection requirements needed for welded joints shall be applied to their repairs. Non-destructive testing shall always be performed on 100% of the surface on the excavated area before the release of the repair filling.

The requirements of Annex B for welding repair shall be followed.

NOTE: For pressure containing equipment and piping, see items 11.9 and 12.11 of IOGP S-705.

4.12 POST WELD HEAT TREATMENT (PWHT)

PWHT shall be applied when required by the design or fabrication and assembly codes of equipment or structure and shall comply with the conditions prescribed by those standards.

NOTE: For pressure containing equipment and piping, see item 9 (mainly 9.11 and 9.12) of IOGP S-705.

PWHT shall be performed by electrical heating, induction, or in furnace.

The zone to be heated to PWHT temperature shall cover the temporary weld areas referring to auxiliary assembly devices, even when they have been removed.

When performing PWHT located in the circumferential welds, or in which the component has the freedom of expansion during treatment, the conditions set forth in AWS D10.10 or WRC 452 shall be met.

4.13 AUXILIARY ASSEMBLY DEVICES

Auxiliary assembly devices, when permitted by the fabrication and assembly standard of equipment or structure, shall comply with the requirements of this technical specification and the following conditions:

a) welds of auxiliary assembly devices, tack welds and other temporary welds shall be considered definitive welds for purposes of application of the requirements of this technical specification.

b) chemical composition of the devices shall be similar to the parts being welded, or otherwise be coated with the consumable specified for the welding of base metal in deposits of at least two layers.

c) auxiliary assembly devices shall be removed before any PWHT and prior pressure testing and shall not be removed by impact (e.g. hammering).

d) the area of temporary weld, after it has been removed, the surface shall be ground smooth and inspected with MT or PT and present no undercuts, pores, cracks, thickness reduction or incomplete removal.

4.14 MARKING OF WELDED JOINTS

Welded joints shall be marked with the identification number of the welder or welding operator.

In joints welded by more than one welder or welding operator, the mark shall distinguish who performs each of the passes.

Punch marking is permitted only for carbon steel with nominal thickness greater than 6.4 mm, at a minimum distance of 25 mm from the edge of the weld. All other materials shall be identified by an industrial marker, as long as its composition does not contaminate the material.

For oil and gas pipelines and for hull structural parts, punch marking is not allowed.

4.15 SAFETY IN WELDING

Any welding service shall only be performed if it complies with the safety requirements provided in the applicable Health, Safety, and Environment (HSE) procedures.

In welding services in confined space, an additional assessment shall be made by HSE team regarding the protection of welding team.

5 MATERIALS

5.1 CARBON STEEL (STRUCTURE)

5.1.1 Introduction

For welding of quenched and tempered steels and TMCP steels, the welding procedure qualification shall be performed with test coupons of the same steel supply condition.

For welding procedures qualified with more than one welding process, impact test specimens shall cover all processes.

Unless otherwise specified by the welding qualification code/standard/rules, impact testing temperature on welding procedure qualification shall be equal to or lower than that one required for base metal. For example: -40 °C for EH grades, -20 °C for DH grades and so on.

5.1.2 Welding Technique

Root quality of full penetration welds shall be ensured by back gouging or by use of temporary backing strip, as applicable. The use of permanent backing shall be avoided.

After the use carbon-arc gouging, such as for back gouging, for repair, or for temporary attachments removal, the surface shall be ground in order to remove any carbon contamination.

5.1.3 Welding Processes

Permitted welding processes shall be in accordance with item 4.5 of this technical specification with the following restrictions and notes.

5.1.3.1 SMAW

a) Electrodes AWS classification EXX10, EXX11, EXX12, EXX13, EXX14, EXX24 and EXX27 are not permitted.

5.1.3.2 GTAW

a) No restrictions.

5.1.3.3 GMAW

a) GMAW with conventional short-circuit transfer mode and globular transfer mode is not permitted.

b) GMAW with spray transfer mode is only permitted for tertiary structures.

5.1.3.4 FCAW

a) FCAW-S (self-shielded) is not permitted, except when toughness (impact testing) is not required for the structure.

b) The use of filler metal with specification/classification different from that one applied in the welding procedure qualification is not permitted.

c) The use of filler metal with brand name different from that one applied in the welding procedure qualification is not permitted when toughness (impact testing) is required.

5.1.3.5 SAW

a) The semiautomatic (manually held) process is not permitted.

b) The use of welding flux with brand name different from that one applied in the welding procedure qualification is not permitted.

5.1.3.6 ESW/EGW

a) BUYER's approval is required.

5.1.4 Welding Consumables

Welding consumables shall be according to AWS Specification and Classification.

Welding consumable shall matches/overmatches the mechanical properties of base metal, such as:

a) Base metal with SMYS ≤ 360 MPa: E70XX, ER70X-X, E7XT-X and so on.

b) Base metal with SMYS > 360 MPa: E80XX, ER80X-X, E8XT-X and so on.

For structures with toughness (impact testing) requirement, the welding consumables shall be acquired with impact testing at temperature equal to or lower than that one required in the welding procedure qualification.

Diffusible hydrogen limits for consumables shall not exceed:

a) Base Metal with SMYS ≤ 360 MPa: 16 ml/100 g.

b) Base Metal with SMYS > 360 MPa: 8 ml/100 g.

5.1.5 Preheating and Interpass Temperature

Preheating for welding of metallic structures shall be determined in accordance with AWS D1.1.

Interpass temperature for carbon steel welds shall not exceed 315 °C. For carbon steel welds with toughness (impact testing) requirement, interpass temperature shall not exceed 250 °C.

5.1.6 Post-Heating

It is usually not required, except when there is risk of hydrogen cracking, as for thick plates and high restriction. In this case, approximately 200 °C with baseline time of 1 min/mm of thickness of joint, but no less than 15 minutes shall be applied.

5.1.7 Post Weld Heat Treatment

It is usually not required.

5.1.8 Weld Repair

The same welded area shall not be repaired more than two times.

5.2 CARBON STEEL (PRESSURE CONTAINING EQUIPMENT AND PIPING)

5.2.1 Introduction

The requirements herein stated applies to carbon steels and carbon-manganese steels.

It shall be observed the additional requirements of standards and specifications for quenched e tempered steels, micro-alloyed steels, high strength and low alloy (HSLA) steels, for steels classified under P-Number 1 Group 3 or Group 4, P-Number 10 (except for 10H, 10I, 10J, 10K) and P-Number 11B.

When qualifying weld procedures for high strength pipe components (API 5L X56 and above, as well as the equivalent material specifications for accessories, such as ASTM F694 Grade F56 and above) the qualification test coupon shall use as base material the exact same strength grade as will be used in production welding.

5.2.2 Welding Technique

For high strength steels (tensile strength ≥ 490 MPa), the HAZ formed by thermal cutting processes shall be removed by machining or grinding.

When impact testing is required, the multiple passes welding shall be performed with straight and thin passes, not exceeding three times the diameter of the core of coated electrode for SMAW process or 12 mm for the other welding processes.

5.2.3 Welding Processes

Permitted welding processes shall be in accordance with item 4.5 of this technical specification with the following restrictions and notes.

5.2.3.1 SMAW

a) Electrodes ASME/AWS classification EXX10, EXX11, EXX12, EXX13, EXX14, EXX24 and EXX27 are not permitted.

5.2.3.2 GTAW

a) No restrictions.

5.2.3.3 GMAW

a) GMAW with conventional short-circuit transfer mode and globular transfer mode is not permitted.

5.2.3.4 FCAW

a) The use of filler metal with specification/classification different from that one applied in the welding procedure qualification is not permitted.

b) The use of filler metal with brand name different from that one applied in the welding procedure qualification is not permitted when toughness (impact testing) is required.

5.2.3.5 SAW

a) The use of welding flux with brand name different from that one applied in the welding procedure qualification is not permitted.

5.2.4 Welding Consumables

Welding consumables shall be according to ASME BPVC Section II Part C or AWS Specification and Classification, as applicable.

5.2.5 Preheating and Interpass Temperature

Joints shall be preheated to temperatures equal to or above those indicated in Table 1.

Preheating temperatures of design codes or fabrication standards may be applied, at BUYER's discretion, replacing the values given in Table 1.

Table 1 - Minimum Preheating and Interpass Temperatures for C and C-Mn Steels

Carbon equivalent – CE (1)	Calculated thickness of welded joint (2)		
	e ≤ 20 mm	20 < e ≤ 30 mm	e > 30 mm
$CE_{IIW} \leq 0.41\%$	10 ºC	10 ºC	10 ºC
$0.41\% < CE_{IIW} \leq 0.45\%$	10 ºC	10 ºC	100 ºC
$0.45\% < CE_{IIW} \leq 0.47\%$	10 ºC	100 ºC	125 ºC
$0.47\% < CE_{IIW} \leq 0.50\%$	100 ºC	125 ºC	150 ºC

NOTE 1: The carbon equivalent (CE_{IIW}) shall be calculated according to the following formula, based on the elements content values obtained from mill certificates (chemical analysis) or from laboratory testing.

$$CE_{IIW} = \%C + \frac{\%Mn}{6} + \frac{\%Cr + \%Mo + \%V}{5} + \frac{\%Cu + \%Ni}{15}$$

NOTE 2: The thickness of welded joint shall be calculated according to Figure 1.

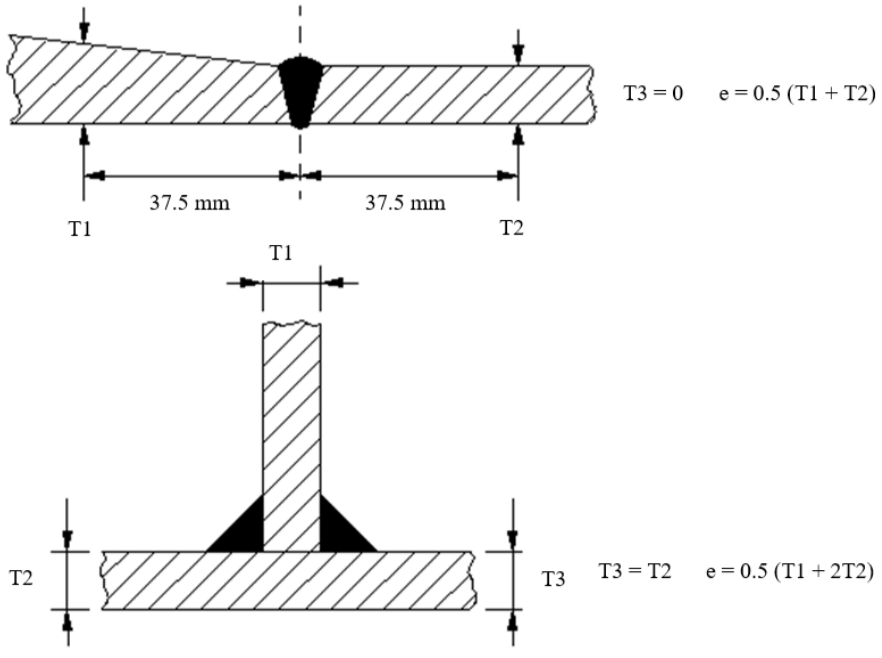


Figure 1 – Details for Determining Weld Thickness

Interpass temperature for carbon steel welds shall not exceed 315 °C. For carbon steel welds with toughness (impact testing) requirement, interpass temperature shall not exceed 250 ºC.

It is recommended that the manual heating by gas flame (blowtorch) is limited in pipes or equipment's shells with thickness up to 25.4 mm and nominal diameter up to 10''.

5.2.6 Post-Heating

It is usually not required, except when there is risk of hydrogen cracking, as for thick plates and high restriction. In this case, approximately 200 °C with baseline time of 1 min/mm of thickness of joint, but no less than 15 minutes shall be applied.

5.2.7 Post Weld Heat Treatment

PWHT shall comply with the applicable design code and/or service standards (e.g. sour service according to ISO 15156).

NOTE: For pressure containing equipment and piping, see items 9.11 and 9.12 of IOGP S-705.

5.2.8 Weld Repair

The same welded area shall not be repaired more than two times.

The repair shall be performed in multiple passes, always trying to promote tempering of the previous passes.

NOTE: For pressure containing equipment and piping, see items 11.9 and 12.11 of IOGP S-705.

5.3 CHROME-MOLYBDENUM STEEL AND MOLYBDENUM STEEL

5.3.1 Introduction

This Section addresses the "P-Numbers" as referred to in ASME BPVC Section IX listed in Table 2. The C-Mo, for familiarity, is included in this subsection.

Table 2 – Designation of "P-Numbers" according to ASME BPVC Section IX

Basic Designation	Basic composition	Grade	UNS	P-Number
C-Mo	C-0,5Mo	1	K12320	3
Cr-Mo	0,5Cr-0,5Mo	1	K11547	3
	1,0Cr-0,5Mo	12	K11562	4
	1,25Cr-0,5Mo	11	K11572 K11597 K11789	4
	2,25Cr-1,0Mo	22	K21590	5A

5.3.2 Welding Technique

The essential supplementary variables of ASME BPVC - Section IX shall be complied with, regardless of the minimum design temperature of the equipment/piping.

If, during welding execution, the welded joint needs to be cooled below the preheating temperature, check the need to perform the DHT according to Item 5.3.6 or the ISR according to Item 5.3.7, before this cooling.

For conventional Cr-Mo steels, if the welded joint inadvertently cools below the preheating temperature, a DHT (dehydrogenation according to Item 5.3.6) shall be carried out immediately, and the weld joint shall be 100% inspected by liquid penetrant before the welding is resumed.

If PWHT is not required by the design code, the final inspection (including all the required NDT) shall be carried out at least 48 hours after welding is completed. When PWHT is required by the design code, the final inspection shall be carried out after the heat treatment.

Back purging is required for 2.25Cr-1Mo steel and shall be performed according to 4.6. Purging with nitrogen during welding is not permitted.

5.3.3 Welding Processes

Permitted welding processes shall be in accordance with item 4.5 of this technical specification with the following restrictions and notes.

5.3.3.1 SMAW

a) SMAW is not permitted for root pass welding of single-sided joints.

5.3.3.2 GTAW

a) No restrictions.

5.3.3.3 GMAW

a) GMAW with spray transfer mode is only permitted for flat position.

b) GMAW is not permitted for branch connections, nozzle-to-shell welds, or socket welds.

c) Shielding gas: argon/CO2 (25% maximum) mixture. Pure CO2 is not permitted.

5.3.3.4 FCAW

a) The use of filler metal with specification/classification different from that one applied in the welding procedure qualification is not permitted.

b) The use of filler metal with brand name different from that one applied in the welding procedure qualification is not permitted when toughness (impact testing) is required.

5.3.3.5 SAW

a) The use of welding flux with brand name different from that one applied in the welding procedure qualification is not permitted.

5.3.4 Welding Consumables

Consumables shall be selected in accordance with Table 3, and meet the requirements listed here:

Table 3 – Consumables for Molybdenum Steels and Cr-Mo Steels

Material	AWS Classification			
	SMAW	GMAW / GTAW	FCAW	SAW
	AWS A5.5	AWS A.28	AWS A.29	AWS A.23
0,5Mo	E7018-A1	ER80S-D2	E8XT1-A1M	EA1
0,5Cr-0,5Mo	E8018-B1	ER80S-G (NOTE)	E8XT1-B1M	EB1
1Cr-0,5Mo / 1,25Cr-0,5Mo	E8018-B2	ER80S-B2	E8XT1-B2M	EB2
2,25Cr–1Mo	E901X-B3	ER90S-B3	E9XT1-B3M	EB3
NOTE: The chemical composition shall be identical to base metal.				

For welding 1.25Cr-0.5Mo and 2.25Cr-1Mo steels, welding consumables shall meet the following requirements:

a) Chemical composition as follows:

The consumable specifications AWS A5.5/A5.5M, AWS A5.23/A.23M, AWS A5.28/A28M and AWS A5.29/A.29M types B2, B2L, B3 e B3L the chemical analysis shall attend Bruscato Factor:

Bruscato Factor (Fator X) = (10P + 5Sb + 4Sn + As) / 100 ≤ 15

As, P, Sb, e Sn in ppm.

b) Impact test: consumables shall be purchased in accordance with AWS A5.01M/A5.01, "Schedule" J and tests carried out according to the following batch classification:

GMAW / GTAW ("Wire"): batch classification S4.

SMAW ("Covered electrodes"): batch classification C5.

FCAW ("Tubular cored electrodes and rods"): batch classification T4.

SAW ("Flux"): batch classification F2.

c) Simulated Post-Weld Heat Treatment, shall be carried out as defined in the design;

d) Tensile Test at Design Temperature ("High Temperature Tension Test") shall be carried out as defined in the design.

When welding between Cr-Mo steels with different "P-Numbers", the consumable used shall be the one with the lowest Cr-Mo content (lowest alloy content) in the joint.

For 2.25Cr-1Mo welding consumables the average impact values at -29°C of three Charpy V-notch test specimens heat treated shall not be less than 40 ft-lb (55 J) with no single value below 35 ft-lb (48 J) unless the design code or the service-related code requires a more stringent toughness requirement.

5.3.5 Preheating and Interpass Temperature

Preheating and interpass temperatures shall be in accordance with Table 4.

Table 4 – Preheating and Interpass Temperature for Molybdenum Steels and Cr-Mo Steels

Material – "P-Number" (PN)	Minimum Preheating Temperature	Maximum Interpass Temperature
C-0,5Mo - (PN 3)	80 °C	300 °C
0,5Cr-0,5Mo - (PN 3)		
1Cr-0,5Mo - (PN 4)	150 °C	
1,25Cr-0,5Mo - (PN 4)		
2,25Cr-1Mo - (PN 5A)	205 °C	

When welding Cr-Mo steels with different "P-Numbers", the minimum preheating and post-heating temperatures shall be those specified for the steel with the highest Cr content.

5.3.6 Dehydrogenation Heat Treatment (DHT)

For thickness (t) ≥ 10 mm, if the welded joint needs to be cooled below the preheating temperature, a DHT shall be performed before cooling.

The DHT shall be in accordance with the manufacturer's welding procedure, as long as it complies with the minimum time and temperature in Table 5.

Table 5 – Dehydrogenation Heat Treatment

Material – "P-Number" (PN)	Temperature	Minimum Duration
C-0,5Mo - (PN 3)	300 °C	1 hour
0,5Cr-0,5Mo - (PN 3)		
1Cr-0,5Mo - (PN 4)		
1,25Cr-0,5Mo - (PN 4)		
2,25Cr-1Mo - (PN 5A)		

When DHT is not required, t < 10 mm, the welded joint shall be protected from rapid cooling through an insulating ceramic blanket.

DHT can also be waived when:

a) The ISR as per 5.3.7 is applied.

b) The PWHT is applied in accordance with 5.3.8.

c) Only the GTAW and GMAW welding processes were applied to the entire welded joint.

NOTE For exemptions from items (a) and (b) above, the joint temperature cannot cool below the preheating temperature, otherwise DHT shall be applied.

5.3.7 Intermediate Stress Relief Heat Treatment (ISR)

For 2¼Cr-1Mo steel with thickness above 50 mm, if the welded joint needs to be cooled below of the preheating temperature, an ISR shall be carried out.

For 2¼Cr-1Mo steel with thickness less than 50 mm, a DHT can be carried out instead of the ISR.

The ISR shall be carried out at 593 ºC for 2 hours.

5.3.8 Post Welding Heat Treatment

The PWHT shall comply with the design code and applicable contractual technical documentation.

The timing, quantity and type of non-destructive tests to be carried out in the manufacture of each equipment shall occur as defined in the equipment or piping design requirements.

When welding Cr-Mo steels with different “P-Numbers”, the minimum PWHT temperature shall be that specified for the steel with the highest Cr content.

5.3.9 Hardness Test

Hardness control is mandatory in welding procedure qualification and production welding joints.

In welding procedure qualification, Vickers hardness traverses of the weld joint shall be made on a weld sample in the minimum PWHT condition.

Hardness measured at production welds shall be limited to the hardness obtained in the welding procedure qualification (10% variation allowed above the maximum).

The hardness in the weld metal and heat-affected zone after PWHT cannot exceed the values required by IOGP S-705.

5.3.10 Welding Repair

The PWHT can be carried out according to the number of PWHT qualified in the welding procedure, as long as 1 (one) PWHT is reserved for PETROBRAS maintenance service. All welding repairs shall be carried out using a qualified welding procedure as specified in item 4.3 of this document.

5.4 AUSTENITIC STAINLESS STEEL

5.4.1 Introduction

This Section includes the austenitic stainless steels with microstructure fully austenitic or austenitic-ferritic, such as:

a) Steels from AISI 3XX Series (304, 316, 317, 321, 347, 310) standard or conventional.

b) Low carbon steels from AISI 3XXL Series, used in corrosive services with carbon content lower than 0.030%.

c) Controlled carbon steels from AISI 3XXH Series, used in services at high temperature, with carbon contents ranging from 0.04% to 0.1%.

d) Casting steels for general use and for use at high temperatures.

5.4.2 Welding Technique

The welding shall be performed with straight passes and low heat input. The heat input shall not exceed 2 kJ/mm. For stabilized austenitic stainless steels (321 and 347 grades), the heat input shall not exceed 1.5 kJ/mm.

Contamination by contact with chloride, sulfur, zinc, copper, tin, lead, among others, may irreversibly compromise the austenitic stainless steels when exposed to high temperature.

Upon completion of welding and before the start of operation, soaps and detergents used in bubble, liquid penetrant and industrial marker residue tests shall be eliminated. Temperature indicating sticks (crayons) shall not be used, the contact or infrared thermometer shall be used for temperature control.

Back purging is required and shall be performed according to 4.6.

The weld root shall be subjected to visual inspection to determine the oxidation level before any non-destructive testing. It is permitted a maximum degree of oxidation according to Table 10 and Annex C of IOGP S-705.

When purging fails to protect the weld root surface, the weld joint shall be internally pickled and passivated.

The pickling and passivation processes shall be according to ASTM A380. Electrolytic weld cleaning may be used in lieu of chemical pickling, but passivation shall always follow.

External oxidation shall also be removed.

Oxidation removal by mechanical processes may only be permitted where the access is feasible.

Back purging with nitrogen during welding is only permitted after previous review and evaluation from BUYER. The ferrite content in base material, gas purity, and risk of hot cracking after welding shall be evaluated.

5.4.3 Welding Processes

Permitted welding processes shall be in accordance with item 4.5 of this technical specification with the following restrictions and notes.

5.4.3.1 SMAW

a) The use of synthetic electrodes is not permitted.

b) For welding of AISI 321 steel, consumable AISI 347 shall be used due to the low transfer of titanium in the process.

c) Whenever the material is exposed to temperature above 538 ºC during fabrication or operation, the consumable shall be acquired according to AWS A5.01 Schedule J, ensuring its bismuth content does not exceed 0.002%.

5.4.3.2 GTAW

a) Shielding gas: pure argon, pure helium, or argon/helium mixture. The use of argon/H2 (1 to 3%) mixture may only be used with previous approval from BUYER.

b) Shielding gas for cored wire for GTAW: pure argon, pure helium, argon/helium mixture, argon/O2 (2% maximum) mixture, or argon/CO2 (5% maximum) mixture. Mixtures with more than 5% of CO2 can be used as long as carburization by CO2 is evaluated in the welding procedure qualification through intergranular corrosion test according to ASTM A262.

5.4.3.3 GMAW

a) GMAW with conventional short-circuit transfer mode and globular transfer mode is not permitted.

b) Shielding gas: pure argon, pure helium, argon/helium mixture, argon/O2 (2% maximum), or argon/CO2 (5% maximum). Mixtures with more than 5% of CO2 can be used as long as carburization by CO2 is evaluated in the welding procedure qualification through intergranular corrosion test according to ASTM A262.

5.4.3.4 FCAW

a) The use of filler metal with specification/classification different from that one applied in the welding procedure qualification is not permitted.

b) Whenever the material is exposed to temperature above 538 ºC during fabrication or operation, the consumable shall be acquired according to AWS A5.01 Schedule J, ensuring its bismuth content does not exceed 0.002%.

c) Shielding gas: pure CO2 (EXXXTX-1), or argon/CO2 mixture (EXXXTX-4). Carburization by CO2 shall be evaluated in the welding procedure qualification through intergranular corrosion test according to ASTM A262.

5.4.3.5 SAW

a) The use of welding flux with brand name different from that one applied in the welding procedure qualification is not permitted.

b) Whenever the material is exposed to temperature above 538 ºC during fabrication or operation, the consumable shall be acquired according to AWS A5.01 Schedule J, ensuring its bismuth content does not exceed 0.002%.

c) The flux shall be neutral or basic.

d) The use of alloyed fluxes is not permitted, except to compensate for loss of alloying elements in the metal transfer.

5.4.4 Welding Consumables

The consumables shall follow the instructions in Table 6. Alternative consumables may only be used with previous approval from BUYER.

Table 6 - Consumables for Austenitic Stainless Steels

Base Material	SMAW (AWS A5.4)		GTAW/SMAW (AWS A5.9)		FCAW-G (AWS 5.22)		SAW (1) (AWS A5.9)	
	1st option	2nd option	1st option	2nd option	1st option	2nd option	1st option	2nd option
304 / CF8	E308	E308L	ER308	ER308L	E308TX-X		ER308	
304L / CF3	E308L	E347	ER308L	ER347	E308LTX-X		ER308L	
304H (2)	E308H	E308 (3)	ER308H	ER308 (3)	E308HTX-X		ER308H	
CH20	E309	E309Mo E309LMo	ER309	ER309Mo ER309LMo				
310 / CK20	E310	E310Nb	ER310	ER310Nb	E310TX-X		ER310	
316	E316	E316L	ER316	ER316L	E316TX-X		ER316	
316L	E316L		ER316L		E316LTX-X		ER316L	
316H (2)	E316H	E316 (3)	ER316H	ER316 (3)	E316HTX-X		ER316H	

CF8M	E308Mo	E316	ER308Mo	ER316				
CF3M	E308LMo	E316L	ER308LMo	ER316L				
317 / CG8M	E317	E385	ER317	ER385	E317LTX-X		ER317	ER317L
317L	E317L	E385	ER317L	ER385	E317LTX-X		ER317L	
321 / 347 / CF8C	E347		ER347		E347TX-X		ER347	
347H (2)	E347 (3)		ER347 (3)		E347HTX-X	E347TX-X (3)	ER347 (3)	

NOTE 1: Only the filler metals present AWS classification, with no similar for the flux.

NOTE 2: E/ER16-8-2 with 1 to 5 FN may be used.

NOTE 3: Filler metal with carbon content 0.04% minimum.

The minimum ferrite content in the weld deposits shall be 3 FN. For classification 347, it shall be 5 FN minimum.

The maximum content of ferrite shall be lower than 9 FN in steels exposed to high temperature (≥ 370 °C) or in those subjected to at least one PWHT cycle (coating/weld overlay) during fabrication. The measurement of ferrite shall be performed before PWHT.

The ferrite content shall be measured in the welding procedure qualification.

5.4.5 Preheating and Interpass Temperature

Preheating is not required.

The interpass temperature shall be kept as low as possible and not exceed 175 °C, except for the AISI 317L steel, which shall not exceed 120 °C.

5.4.6 Post-Heating

Post-heating is not required.

5.4.7 Post Weld Heat Treatment

PWHT is generally not required.

5.4.8 Weld Repair

The same welded area shall not be repaired more than two times.

5.5 DUPLEX AND SUPERDUPLEX STAINLESS STEEL

5.5.1 Introduction

For the purpose of this technical specification, Duplex Stainless Steel (DSS) and Super Duplex Stainless Steel (SDSS) are base material with microstructure composed of about 50% ferrite and 50% austenite and characterized by a Pitting Resistance Equivalent Number (PREN), calculated by the following formula:

$$\mathrm{PREN} = \%\mathrm{Cr} + 3.3\,(\%\mathrm{Mo} + 0.5\,\%\mathrm{W}) + 16\,\%\mathrm{N}$$

DSS is also known as 22Cr Duplex, and the most usual base material specification is:

a) UNS S31803 (EN n° 1.4462), PREN ≥ 30.5

SDSS is also known as 25Cr Duplex, and the most usual base material specifications are:

a) UNS S32750 (EN n° 1.4410), PREN ≥ 37.7

b) UNS S32760 (EN n° 1.4501), PREN ≥ 40 (with W in its chemical composition)

The welding procedure qualification for DSS and SDSS shall consider the additional requirements stated in Section 11 of IOGP S-705 and Annex C of this technical specification.

The welder qualification shall consider the additional requirements of I-ET-3010.00-1200-970-P4X-003 – REQUIREMENTS FOR PERSONNEL QUALIFICATION AND CERTIFICATION.

5.5.2 Welding Technique

Welds of auxiliary assembly devices shall be deposited at least 25 mm away from the edges of the bevel or directly on the faces of the bevel.

The heat input for welding DSS and SDSS weld joints shall be according to IOGP S-705.

Back purging is required and shall be performed according to 4.6.

The weld root shall be subjected to visual inspection to determine the oxidation level before any non-destructive testing. It is permitted a maximum degree of oxidation according to Table 10 and Annex C of IOGP S-705.

When purging fails to protect the weld root surface, the weld joint shall be internally pickled and passivated.

The pickling and passivation processes shall be according to ASTM A380. Electrolytic weld cleaning may be used in lieu of chemical pickling, but passivation shall always follow.

External oxidation shall also be removed.

5.5.3 Welding Processes

Permitted welding processes shall be in accordance with item 4.5 of this technical specification with the following restrictions and notes.

For single-sided joints, root pass and second pass shall be made by the GTAW or PAW process.

5.5.3.1 SMAW

a) The use of synthetic electrodes is not permitted.

5.5.3.2 GTAW

a) Shielding gas: pure argon, pure helium, argon/helium mixture, or argon/N2 (2.5% maximum) mixture.

b) For base materials with nitrogen content ≥ 0.20%, argon/N2 (2.5% maximum) mixture shall be used.

c) Purging gas shall be the same of shielding gas.

5.5.3.3 GMAW

a) GMAW with conventional short-circuit transfer mode and globular transfer mode is not permitted.

b) GMAW is not permitted for root pass and second pass welding of single-sided joints.

c) Shielding gas: pure argon, pure helium, argon/helium mixture, argon/N2 (2.5% maximum) mixture, or argon/CO2 (1% to 2%) mixture.

d) Purging gas shall be the same of shielding gas.

5.5.3.4 FCAW

a) FCAW process is not permitted.

5.5.3.5 SAW

a) The use of welding flux with brand name different from that one applied in the welding procedure qualification is not permitted.

b) The use of alloyed fluxes is not permitted, except to compensate for loss of alloying elements in the metal transfer.

5.5.4 Welding Consumables

Consumables shall follow the requirements of Table 7.

Table 7 - Consumables for DSS and SDSS

Base Material Type	SMAW (AWS A5.4)		GTAW / GMAW / SAW (AWS A5.9)		Filler Metal PREN (IOGP S-705)
	1st option	2nd option	1st option	2nd option	
S31803	E2209	E2594	ER2209	ER2594	34 ≤ PREN ≤ 40
S32750 / S32760	E2594	-	ER2594	-	40 ≤ PREN ≤ 48 40 ≤ PREN ≤ 45 (sour service)

NOTE 1: Additional restrictions about nitrogen, nickel, molybdenum, and sulfur content set forth in Table 3 of IOGP S-704 shall be met.

NOTE 2: The use of consumables with higher Ni content may grant weld metal properties compatible with the base metal. Welding with consumables with a chemical composition that matches the one from the base materials is allowed only when the full welded piece is submitted to a full anneal heat treatment after welding, so that the phase balance is restored in the whole piece.

5.5.5 Preheating and Interpass Temperature

Preheating is not required.

Maximum interpass temperature shall be 150 °C for DSS and 100 °C for SDSS.

5.5.6 Post-Heating

Post-heating is not required.

5.5.7 Post Weld Heat Treatment

PWHT is not required.

5.5.8 Production Parameter Monitoring by Autonomous System

Welds on duplex and superduplex stainless steels with thickness greater than 29 mm shall be performed with continuous monitoring of the welding parameters.

The following parameters should be continuously tracked and registered by an autonomous system:

a) Welding current

b) Welding voltage

c) Welding speed

d) Preheat temperature

e) Maximum interpass temperature

NOTE: Many commercially available monitoring systems do not have the ability to properly track the welding speed and therefore the heat input. In these cases, the missing information may be collected by a qualified welding inspector instead.

Weld parameter monitoring should be applied during the weld procedure qualification, during welder/operator performance qualification, and during production welds.

All data generated during production welds and during welder qualification should be collected and compared to the data collected during procedure qualification.

5.5.9 Weld Repair

The same welded area shall not be repaired more than two times for DSS. For SDSS only one repair is permitted at the same welded area.

NOTE: For pressure containing equipment and piping, see items 11.9 and 12.11 of IOGP S-705.

5.6 NICKEL ALLOY STEEL

5.6.1 Introduction

This item establishes the requirements for welding nickel alloy steels (Ni steels) with nickel content up to 9%, which are usually employed for cryogenic applications (temperatures of -46 ºC and lower).

Since the nickel alloy steels have enough carbon and hardenability to be susceptible to hydrogen-induced cracking, they shall be welded with low-hydrogen consumables and processes.

Nickel alloy steels with nickel content in excess of 1%, when in sour service, shall always be qualified by a Sulfide Stress Corrosion test (laboratory testing) in accordance with ISO 15156-1. This test is applicable for the base materials and for the welding procedures.

5.6.2 Welding Technique

The welding shall be by multiple passes, with straight and slightly convex passes. Passes that have excessive convexity shall be repaired by grinding to avoid lack of fusion. In fillet welds (e.g. socket welds) the finishing passes shall be concave.

The heat input shall be below 2 kJ/mm in homogeneous and 1.5 kJ/mm in heterogeneous welding.

For SAW process, heat input shall be lower than 2.8 kJ/mm in homogeneous and 2.5 kJ/mm heterogeneous welding, except for 9% nickel steel, heat input shall always be limited to 2.0 kJ/mm.

The manual heating by oxyfuel flame (shower-type blowtorch) shall be limited to pieces with thickness below 13 mm and a nominal diameter of up to 10 inches.

Back purging is required and shall be performed according to 4.6. Purging with nitrogen is not permitted.

5.6.3 Welding Processes

Permitted welding processes shall be in accordance with item 4.5 of this technical specification with the following restrictions and notes.

For single-sided joints, root pass and second pass welding shall be done by the GTAW process.

5.6.3.1 SMAW

a) The use of synthetic electrodes is not permitted.

b) SMAW is not permitted for root pass welding of single-sided joints.

c) The oscillation of the electrode shall be such that the pass width does not exceed three times the coated electrode core diameter.

5.6.3.2 GTAW

a) No restrictions.

5.6.3.3 GMAW

a) GMAW with conventional short-circuit transfer mode and globular transfer mode is not permitted.

b) GMAW is not permitted for root pass and second pass welding of single-sided joints.

c) GMAW is not permitted for branch connections, nozzle-to-shell welds, or socket welds.

5.6.3.4 FCAW

a) The use of filler metal with specification/classification different from that one applied in the welding procedure qualification is not permitted.

b) The use of filler metal with brand name different from that one applied in the welding procedure qualification is not permitted when toughness (impact testing) is required.

5.6.3.5 SAW

a) The use of welding flux with brand name different from that one applied in the welding procedure qualification is not permitted.

b) The flux shall be neutral or basic.

c) The use of alloyed fluxes is not permitted.

5.6.4 Welding Consumables

Welding consumables shall be in according with Table 8.

Table 8 - Welding Consumables for Welding C-Ni Steels

Base Material	SMAW (AWS A5.5/A5.11)		GTAW / GMAW (AWS A5.14/A5.28)		FCAW (AWS A5.29/A5.34)		SAW (AWS A5.14/A5.23)	
	1st option	2nd option	1st option	2nd option	1st option	2nd option	1st option	2nd option
1.5% Ni	E801X-C1	-	ER80S-Ni2	-	E8XTX-Ni2	-	EBNi2	-
2.25% Ni	E801X-C1	E801X-C2	ER80S-Ni2	-	E8XTX-Ni2	-	EBNi2	-
3.5% Ni	E801X-C2	ENiCrMo-3 ENiCrFe-2 ENiCrFe-3	ER80S-Ni3	ERNiCr-3	ENiCrMo3T	-	EBNi3	ERNiCr-3
9% Ni	ENiCrMo-3	-	ERNiCrMo-3	-	ENiCrMo3T	-	ERNiCrMo-3	-

5.6.5 Preheating and Interpass Temperature

Preheating and interpass temperature limits shall be in accordance with Table 9.

Table 9 - Preheating and Interpass Temperature for C-Ni Steels

Base Material	Thickness	Preheating (minimum)	Interpass (maximum)
1.5% Ni	≤ 19 mm and C ≤ 0,2%	100 °C	250 °C
	> 19 mm or C > 0,2%	100 °C	
2.25% Ni	≤ 12 mm and C ≤ 0,2%	100 °C	250 °C
	> 12 mm or C > 0,2%	150 °C	
3.5% Ni	≤ 10 mm and C ≤ 0,2%	100 °C	230 °C
	> 10 mm or C > 0,2%	150 °C	
9% Ni	Preheating is not normally required up to thickness of 50 mm		150 °C

5.6.6 Post-Heating

It is not required, unless for thicknesses over 50 mm. In this case, post-heating at 150 °C by 1 minute per mm of thickness is recommended.

5.6.7 Post Weld Heat Treatment

PWHT may be required for welds with high thickness. It shall be performed as required by the design code.

In quenched and tempered materials, the PWHT temperature shall be 30°C lower than the tempering temperature of the base material.

5.6.8 Weld Repair

The same welded area shall not be repaired more than two times.

All weld repairs shall be performed using a specific qualified welding repair procedure, showing that the additional thermal cycle does not affect the toughness and the results in the SSC tests of the joint (the later when sour service is applicable).

The repair shall be performed using multiple passes, looking for the tempering of previous passes, regardless of if the part will be subject to PWHT. The welding shall always look for the tempering of the coarse grain region of previous passes and HAZ.

5.6.9 Additional Requirements for 3.5% Nickel Steel

5.6.9.1 Welding Technique

The welding procedure qualification shall be according to design codes (usually ASME), and the requirements herein listed.

Nickel steels alloys shows a relatively adherent oxide layer which shall be removed before the start of welding.

During welding procedure qualification heat input shall be controlled up to a maximum heat input of 2.0 kJ/mm. SAW welding heat input shall be limited to 2.5 kJ/mm.

In production welds the heat input shall not exceed the range approved on the qualified welding procedure, therefore the heat input shall be monitored during production welding.

Additional care shall be taken for cleaning and preparation of the joint to be welded so as to avoid the presence of contaminants. Slag shall be completely removed during and after welding.

5.6.9.2 Impact Testing

The impact tests (Charpy V-notch) shall meet the energy requirements of the applicable standards. Test temperature shall be -100 °C.

For welding procedure qualification impact tests shall include all welding processes, and the heat affected zone.

5.6.9.3 Post Weld Heat Treatment

Post weld heat treatment shall always be performed on welding procedure qualification and on production welds. PWHT parameters shall be as prescribed in the design code.

Welding procedure qualification shall always include two PWHT conditions, as follows:

a) Minimum PWHT soak time, as predicted in the design code.

b) Maximum PWHT soak time, equivalent to at least twice the soak time predicted in the design code.

Mechanical tests, including hardness, shall be performed on both conditions (minimum and maximum PWHT soak time). Where sour service is applicable, the SSC test shall be performed on the piece with the higher HAZ hardness.

5.7 COPPER AND COPPER ALLOYS

5.7.1 Introduction

For the purpose of this technical specification, besides the commercially pure copper (99.3% Cu), the Copper-Nickel (Cu-Ni with up to 30% Ni) and Copper-Aluminum (Bronze-Aluminum up to 8% Al) alloys are considered, with the following specifications:

a) C10200 deoxidized commercially pure copper (Cu)

b) C70620 alloy 90Cu-10Ni (Cu-Ni-Fe)

c) C71520 alloy 70Cu-30Ni (Cu-Ni-Fe)

d) C61400 bronze-aluminum alloy (Al-Cu-Fe)

All Copper alloy grades shall be of welding quality (e.g., C70620 instead of C70600).

5.7.2 Welding Technique

Back purging is required and shall be performed according to 4.6.

Thermal pencil and industrial marker shall not be used due to the risk of contamination.

5.7.3 Welding Processes

Permitted welding processes shall be in accordance with item 4.5 of this technical specification with the following restrictions and notes.

5.7.3.1 SMAW

a) SMAW is not permitted.

5.7.3.2 GTAW

a) Shielding gas: pure argon, pure helium, or argon/helium mixture.

5.7.3.3 GMAW

a) GMAW with conventional short-circuit transfer mode and globular transfer mode is not permitted.

b) GMAW with spray transfer mode is only permitted for flat position.

c) Shielding gas: pure argon, pure helium, or argon/helium mixture.

5.7.3.4 FCAW

a) FCAW process is not permitted.

5.7.4 Welding Consumables

Welding consumables shall be in according with Table 10.

Table 10 - Rods for Copper and Copper Alloys

Base Material	GTAW / GMAW (AWS A5.7)
C-10200 (Pure Cu)	ERCu
C-70600 (90Cu-10Ni)	ERCuNi
C-71500 (70Cu-30Ni)	ERCuNi
C-61400 (Al-Cu-Fe)	ERCuAL-A2

5.7.5 Preheating and Interpass Temperature

Preheating and interpass temperature shall be in according with Table 11.

Table 11 - Preheating and Interpass Temperature for Copper and Copper Alloys

Base Material	Thickness (t)	Preheating (minimum)	Interpass (maximum)
Pure Cu	t ≤ 3 mm	-	-
	3 < t ≤ 6 mm	100 °C	-
	6 < t ≤ 10 mm	220 °C	-
	t ≥ 10 mm	260 °C to 480 °C	-
Cu-Ni	Any	-	100 °C
Al-Cu-Fe	t ≤ 6 mm	-	-
	t > 6 mm and Al < 10%	-	150 °C

5.7.6 Post-Heating

Post-heating is not required.

5.7.7 Post Weld Heat Treatment

PWHT is not required.

5.7.8 Weld Repair

The same welded area shall not be repaired more than two times.

5.8 NICKEL ALLOYS

5.8.1 Introduction

The requirements herein stated applies to pure nickel and nickel-base alloys hardened by solid solution, such as: UNS N02200, N04400, N06600, N06625, N08800, N08810, N08811, N08825, N06022, N10276.

5.8.2 Welding Technique

The welding shall be performed with low heat input. The input to processes with high density of current shall not exceed 1.8 kJ/mm. For SMAW and GTAW processes, it shall be lower than 1.5 kJ/mm.

The welding of nickel allows shall be performed with straight passes.

Imperfections such as dents, bites, arc strikes, and spatters shall be carefully removed. Slag removal, cleaning and cutting tools shall be compatible with nickel alloys and used only for these materials, not having iron compounds and sulfur (e.g. iron sulfide).

Any signal of contamination with free iron free iron or ferrous oxides shall be investigated as stated in Annex G.

In case of contamination, the surface shall be cleaned by grinding or pickled by controlled etching, and then passivated. Etching and passivation shall comply with ASTM A380.

Contamination by contact with sulfur, zinc, copper, tin and lead irreversibly compromise the nickel alloys when exposed to high temperature. The use of temperature indicating sticks (crayons) based on polymer fusion and industrial markers with these contaminants is not permitted. Cutting oil shall be free of sulfur. Information about detrimental material for nickel alloys is presented on Annex H of this technical specification.

After the welding completion and before the start of operation, soaps and detergents used in bubble and liquid penetrant tests shall be removed, since they may contain elements with low melting point, especially sulfur. Slag and flux residues shall be removed after welding because they compromise the corrosion resistance in operation (fluoride).

Back purging is required and shall be performed according to 4.6.

Thermal pencil and industrial marker shall not be used due to the risk of contamination.

5.8.3 Welding Processes

Permitted welding processes shall be in accordance with item 4.5 of this technical specification with the following restrictions and notes.

5.8.3.1 SMAW

a) The use of synthetic electrodes is not permitted.

b) SMAW is not permitted for root pass welding of single-sided joints.

5.8.3.2 GTAW

a) The filler metals shall be cleaned with acetone before welding.

b) Shielding and purging gas: pure argon, pure helium, or argon/helium mixture.

c) It is recommended to use tungsten electrodes with addition of Cerium or Lanthanum.

5.8.3.3 GMAW

a) GMAW with conventional short-circuit transfer mode and globular transfer mode is not permitted.

b) GMAW is not permitted for root pass and second pass welding of single-sided joints.

c) Shielding and purging gas: pure argon, argon/O2 (2% maximum) mixture, or argon/CO2 (2% maximum). Pure CO2 is not permitted.

5.8.3.4 FCAW

a) FCAW process is not permitted.

5.8.3.5 SAW

a) The use of welding flux with brand name different from that one applied in the welding procedure qualification is not permitted.

b) The flux shall be neutral or basic.

c) The use of alloyed fluxes is not permitted.

5.8.4 Welding Consumables

The consumables shall follow the instructions in Table 12.

Table 12 - Consumables for Nickel Alloys

Base Material	SMAW (AWS A5.11)	GTAW / GMAW / SAW (AWS A5.14)
Inconel 625 (UNS N06625)	ENiCrMo3 (1)	ERNiCrMo3 (1)
NOTE 1: Limited to operation temperature of 540 °C. NOTE 2: For other nickel alloys, Annex B of IOGP S-705/API RP 582 may be used as guide for consumables selection.		

5.8.5 Preheating and Interpass Temperature

Preheating is not required.

The interpass temperature shall be below 175 °C.

5.8.6 Post-Heating

Post-heating is not required.

5.8.7 Post Weld Heat Treatment

PWHT is usually not required. However, it may be required depending on the fluid and according to design specification.

5.8.8 Weld Repair

Only one repair in the same area is permitted.

The welding shall be performed with low heat input using the GTAW process.

5.9 WELD OVERLAY AND CLAD RESTORATION

5.9.1 Introduction

The requirements of item 12.3 and Annex B of IOGP S-705/API RP 582 shall be met.

The other requirements of this technical specification for the specific material shall be followed for both, base material, and clad/weld overlay material.

The minimum thickness of the weld overlay shall be 3 mm, after any grinding or machining, and shall be deposited with a minimum of two layers for all welding process.

The minimum overlap in between weld passes shall be 50% or 3 mm, whichever is lower.

Weld overlay procedures shall be qualified according to design code and the additional requirements of Annex E. Any PWHT shall be performed as required by the applicable design code or service/fabrication standard for the base material.

Back purging is required and shall be performed according to 4.6.

5.9.2 Welding Processes

Permitted welding processes shall be in accordance with item 4.5 of this technical specification.

GTAW-Hot Wire process is also permitted.

5.9.3 Welding Consumables

Consumables for weld overlay of carbon steel base materials shall be according to Table 13.

Table 13 - Consumables for Weld Overlay of Carbon Steels Base Material

Overlay Material	First Layer	Top Layer(s)
316L	E/ER309LMo	E/ER316L
Inconel 625	E/ERNiCrMo-3	E/ERNiCrMo-3
Note: Consumables for other overlay materials shall be according to IOGP S-705/API RP 582 Table B.1.		

AISI 3XX Series weld overlays shall present the chemical composition according to Table B.2 of IOGP S-705/API RP 582.

Inconel® weld overlay shall have a maximum iron (Fe) content of 10%.

When performing a weld overlay of copper alloy over carbon or low alloy steel, a first layer of nickel shall be deposited, over which the copper alloy weld overlay shall be then deposited with additional two layers.

5.9.4 Butt Welds in Overlaid Equipment or Piping

Butt welds of overlaid equipment shall be welded with consumables matching the base material (same chemical composition) and with subsequent internal weld overlay/clad restoration.

Butt welds of overlaid piping shall be welded with the same consumables used for the weld overlay or Inconel weld consumable (heterogeneous welding), provided that the mechanical strength of the base material is met.

For butt welds of overlaid piping (pipe to pipe or pipe to fittings welds), the following is recommended:

a) GTAW process for root pass and second pass.

b) SMAW process for filling/finishing pass.

c) In order to reduce the Fe content in the root pass, buttering may be applied on the bevels using GTAW process. **[Recommend Practice]**

The welding procedures for heterogeneous butt welds of cladded or weld overlaid material shall be qualified using cladded or overlaid materials matching the chemical composition of the production welds. Chemical analysis shall be measured on the root pass.

5.9.5 Pipe End Finish

Pipe ends shall be supplied beveled with weld overlay cladding continuous up to the pipe end.

Pipe ends shall be beveled after weld overlay cladding of internal pipe bore to avoid shrinkage effects and maintain dimensions.

Pipes ends shall be beveled by machining after any buttering applied to the original pipe bevel.

When tapering for thickness transition is required, any removal of the weld overlay shall not affect the minimum required weld overlay thickness (Figure 2). The minimum thickness of 3 mm shall be kept. If necessary, buttering shall be applied for weld overlay thickness restoration (Figure 3).

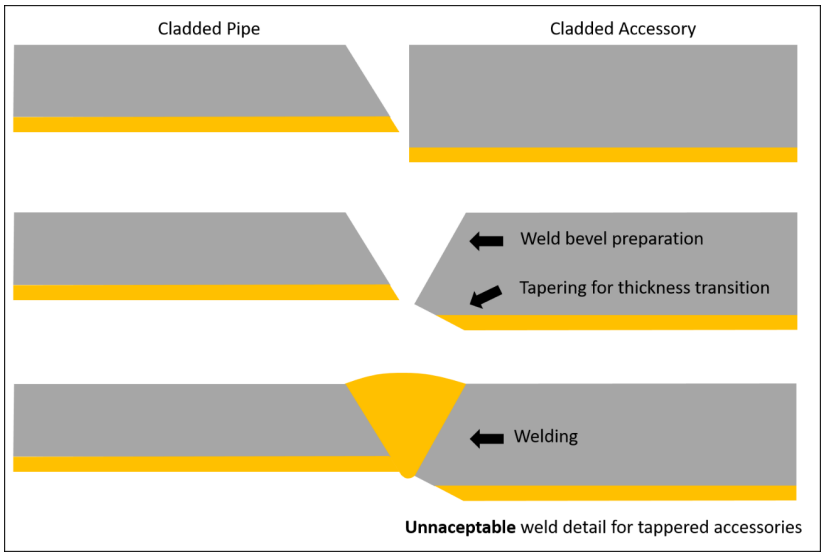


Figure 2 – Unacceptable thickness transition for overlaid piping

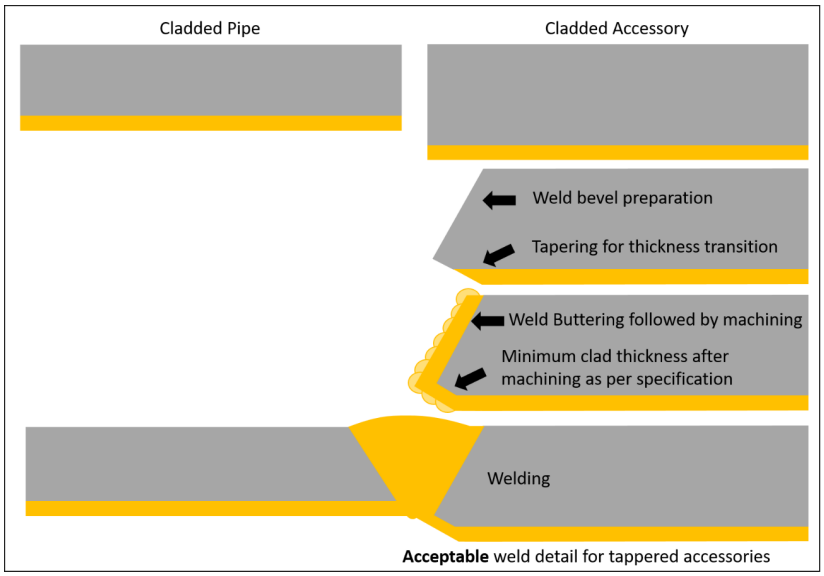


Figure 3 – Acceptable thickness transition for overlaid piping

5.9.6 Set-on Branch Connection on Piping

When performing set-on branch connections on overlaid pieces the following sequence shall be followed:

a) The carbon steel material shall be drilled on the installation point. The drilling diameter shall be at least 6 mm bigger than the internal diameter of the bore of the branch connection (Figure 4).

b) The drilled bore shall be widened in an angle suitable for welding.

c) The opened hole shall than be filled by welding with a qualified welding procedure. The chemical composition of the deposited weld metal shall be equivalent to the internal clad/overlay (Figure 5).

d) After welding the external surface shall be ground flush, and the hole for the branch connection shall be drilled again, this time with the applicable internal diameter (Figure 6).

e) All machined and drilled surfaces shall be 100% checked by PT.

f) The branch connection shall be adjusted over the machined area, and the welding performed as determined by the engineering design (Figure 7).

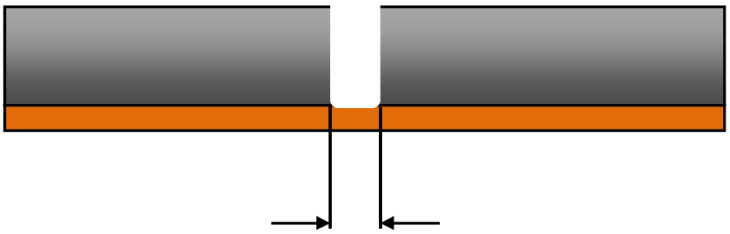


Figure 4 – Drilled bore prior to widening and welding, internal diameter 6 mm bigger than bore of the branch connection

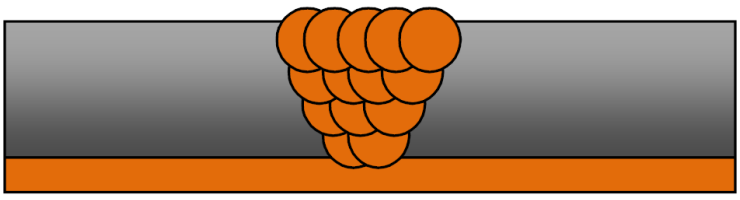


Figure 5 – Opened hole filled by welding, chemical composition equivalent to internal clad/overlay

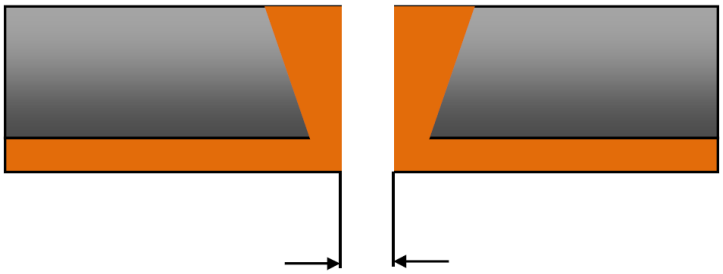


Figure 6 – External surface machined and bore reopened, this time with the correct internal diameter

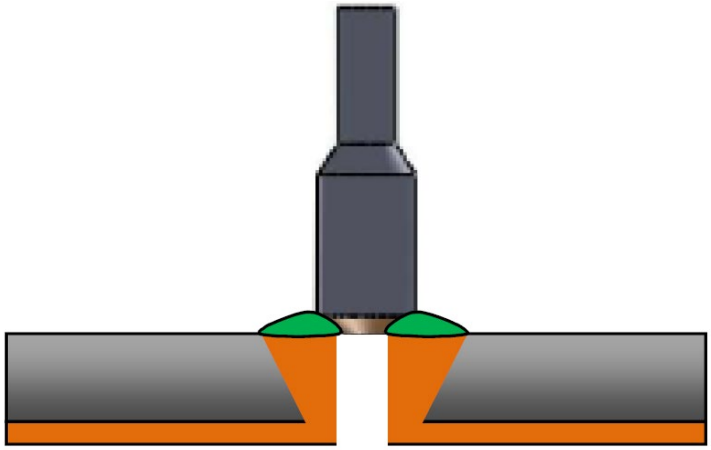


Figure 7 – Set on branch connection adjusted and welded as determined by the engineering design

5.9.7 Preparation and Blasting of Carbon Steel Base Material

Before applying the weld overlay, blasting with carbon steel shot or grit shall be performed on the internal surfaces of carbon steel pipe or equipment to remove loose rust, scale, or varnish. Grinding can also be applied as long as it does not result in the thickness reduction.

After preparation, clean and dry internally all carbon steel pipes shall be performed using dry air.

Visual inspection for cleanliness shall be as per:

a) SSPC-SP 10 or ISO 8501-1 Sa 2½ minimum when applied blasting.

b) SSPC-SP 11 when applied mechanical cleaning (by tools, e.g. grinding).

For piping, random inspection using borescope inspection or similar shall be performed to check full length. If surface scale is visible, pipe shall be re-blasted.

5.9.8 Drying Carbon Steel Base Material

Air drying of carbon steel base material is mandatory before applying the weld overlay. The clean air used for drying shall have a dew point that is at least 4 ºC higher than the ambient air dew point measured locally.

5.10 WELDING OF OTHER METALS AND ALLOYS

The welding of metallic materials other than the ones cited in this technical specification shall follow the applicable requirements of IOGP S-705/API RP 582.

The welding procedure qualification of Titanium shall be as stated in Annex F.

5.11 DISSIMILAR AND HETEROGENEOUS WELDING

Dissimilar joints and heterogeneous welds may lead to the application of different requirements than those herein listed for each specific material.

Before performing any such dissimilar or heterogeneous welding the SELLER shall submit to BUYER all the details for the need of performing such welds, along with the applicable metallurgical details and considerations. The intended supporting weld documents shall be submitted as well (PQR or the intended preliminary WPS).

The following factors, among others, shall be considered when performing dissimilar welds:

- Solubility limits
- Formation of intermetallic compounds
- Weldability
- Thermal Expansion
- Melting temperatures and rates
- Corrosion
- End-service conditions

The requirements of IOGP S-705/API RP 582 shall be met.

NOTE: Item 6.2 and Annex A of IOGP S-705/API RP 582 shall be used as a guide to select the consumables.

For welding procedure qualification of dissimilar joints between Duplex/Superduplex Stainless Steels and Carbon Steel, Annex D of this technical specification shall be followed.

This Section does not apply to weld overlay applications, which shall follow the requirements of the design/service/fabrication code and Section 5 of this technical specification.

ANNEX A – HARDNESS TESTING REQUIREMENTS

A.1 Objective

A.1.1 This Annex establishes the requirements for performance of hardness measurement test in welding procedure qualification and production tests in laboratory.

A.1.2 This Annex does not define the evaluation of deviations regarding the hardness acceptance criteria defined by design, fabrication, construction, and assembly standards.

A.1.3 When the design, fabrication or assembly standard requires a hardness testing, the welding procedure qualification shall be complemented by this test at the weld zone, heat-affected zone, and base metal. Its results shall be consistent with the reference standard.

A.2 Welding Procedure Qualification

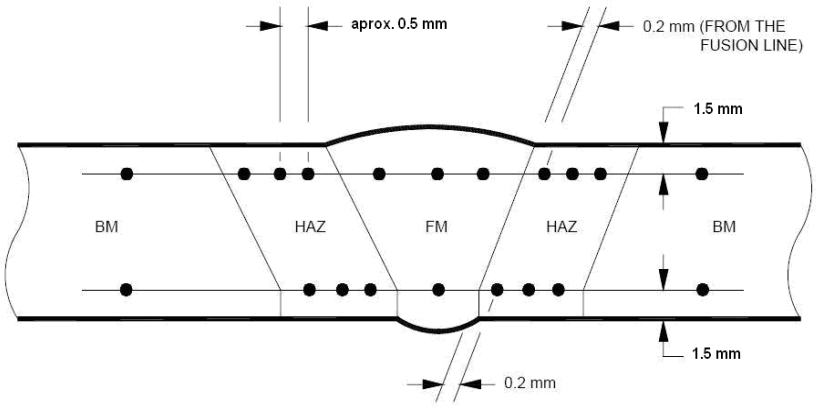
A.2.1 The welding procedure qualification shall be hardness tested by HV10 or HV5 method in accordance with ASTM E92 or ISO 6507-1. The procedure qualification test shall meet the requirements (e.g. PWHT) imposed on production joints. The hardness survey shall be performed on a transverse weld cross section that has been polished and etched to identify the weld metal, fusion line and HAZ.

A.2.2 For material in sour service applications, the hardness requirements of ISO 15156 shall also be met.

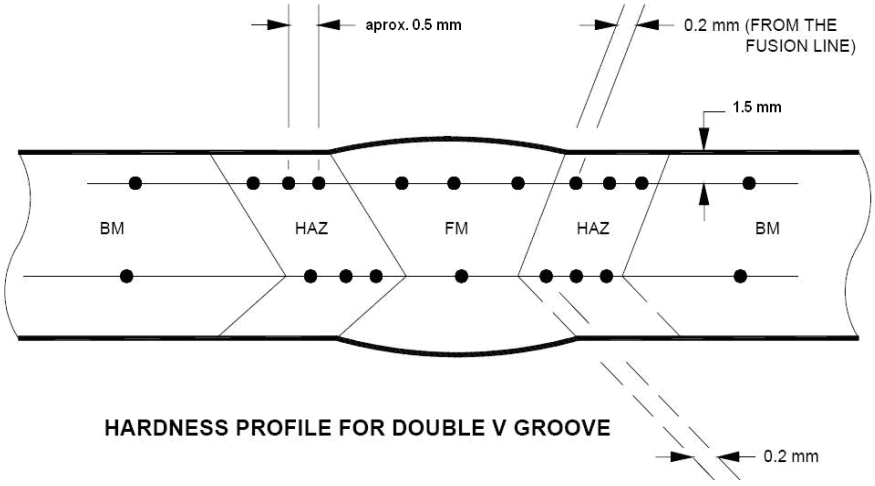
A.2.3 Unless otherwise specified in a specific standard (e.g. ISO 15156), hardness traverses shall be performed according to Figure A.1 (typical single-sided and double-sided welds). The HAZ readings shall include locations as close as possible (approximately 0.2 mm) to the weld fusion line.

A.2.4 Acceptance criteria shall be according to design code, service standard (e.g. ISO 15156) or Table 12 of IOGP S-705, the most stringent criteria shall prevail.

A.2.5 The hardness test results shall be recorded in the PQR.



HARDNESS PROFILE FOR V GROOVE



HARDNESS PROFILE FOR DOUBLE V GROOVE

Note: If necessary, intermediate readings may be slightly dislocated from the horizontal line.

Figure A.1 – Location of Vickers Hardness Indentations

ANNEX B – WELDING REPAIR

B.1 Minor Surface Repairs

B.1.1 Minor surface imperfections or damage on welded joints may be removed by grinding provided that the remaining wall thickness at any point is not less than minimum specified wall thickness.

B.1.2 The ground area shall be carefully dressed to ensure a smooth transition with the surrounding surface, with no notches.

B.1.3 The ground area shall be MT or PT inspected to ensure that the defects have been removed.

B.2 Welding Repairs

B.2.1 Before repair welding, the defect shall be completely removed.

B.2.2 The excavated area shall have smooth transitions to the surface and allow good access for both NDT after excavation and subsequent repair welding. After excavation, complete removal of the defect shall be confirmed by MT or PT.

B.2.3 The excavated groove shall be minimum 50 mm long, measured at defect depth even if the defect itself is smaller.

B.2.4 Defects spaced less than 100 mm shall be repaired as one continuous defect.

B.2.5 Repair welding shall be performed using the same WPS as for the original weld, or a separately qualified welding repair procedure.

B.2.6 All weld-repaired areas shall be ground to a smooth contour with the base material or existing weld. Care shall be taken to ensure that over-grinding does not occur and that the minimum wall thickness is maintained.

B.2.7 After welding repair finished, the repaired area shall be subjected at least to the same NDT specified for the original weld.

B.2.8 Unless otherwise specified, welding repair may only be carried out twice in the same area.

B.2.9 If any welding repair is performed after PWHT and/or hydrostatic test, then the PWHT and/or hydrostatic test shall be repeated.

B.2.10 Any welding repair and welding repair procedure qualification shall also follow the requirements of IOGP S-705.

B.3 Re-Welding

B.3.1 Re-welding (from weld cut-out) shall include complete removal of the original weld metal and HAZ.

B.3.2 Re-welding shall be performed using the same WPS as for the original weld or using a specific WPS for repair proposal.

B.3.3 The re-welded joint shall be subjected at least to the same NDT as specified for the original weld.

ANNEX C – ADDITIONAL REQUIREMENTS FOR WELDING PROCEDURE QUALIFICATION OF DUPLEX/SUPERDUPLEX STAINLESS STEEL

C.1 Additional Essential Variables

C.1.1 The requirements of Section 11 and Table 11 of IOGP S-705 shall be met.

C.2 Requirements for Welding and Preparation of Test Coupons

C.2.1 Welding procedures for duplex stainless steels shall be qualified in accordance with design code and the additional requirements of IOGP S-705 (item 11.3) and this Annex.

C.2.2 The travel speed (TS) and heat input (HI) shall be recorded in the PQR.

C.2.3 Modification of API RP 582 item 11.3.2:

11.3.2 Thickness and Heat Input

11.3.2.1 The minimum and maximum qualified weld thickness (T) shall be as follows:

a) For T < 5/8 in. (16 mm), the minimum qualified thickness shall be the thickness of the qualification test coupon (T) and the maximum qualified thickness shall be 2T, up to a maximum of 1 1/8 in. (29 mm).

b) For T > or = 1 1/8 in. (29 mm), the minimum qualified thickness is T and the maximum qualified thickness shall be 1.2T.

C.3 NDT on Test Coupons

C.3.1 Non-Destructive Testing (NDT) shall be undertaken in the as deposited condition unless clearly stated on the pWPS. In this case the pWPS shall explicit the extent and method of weld cleaning.

C.3.2 The following NDT shall be performed for each welding procedure test coupon:

a) For butt welds: VT, PT and RT (100% for all).

b) For fillet welds: VT and PT (100% for all).

C.4 Laboratory Testing

C.4.1 The tests listed in Table C.1 shall be carried out on an DSS or SDSS welding procedure qualification, additional to the qualification standard/code.

Table C.1 – Additional tests for DSS and SDSS

Test	Extend	Procedure and Reporting	Acceptance Criteria
Chemical Analysis	Weld Metal	-	According to base metal specification
Microstructural Examination	Weld Metal HAZ Base Metal	According to ISO 17781	According to ISO 17781
Ferrite Content Measurement	Weld Metal HAZ Base Metal	According to ISO 17781	According to ISO 17781 for base material and weld metal According to IOGP S-705 for HAZ
CVN Impact Toughness Test	Weld Metal Fusion Line Fusion Line +2 mm	According to ISO 17781 and item C.5.1	Energy values shall be according to ISO 17781 Quality Level II (QL II)
Corrosion Test	Weld Metal HAZ Base Metal	According to ISO 17781 and item C.5.2	According to ISO 17781
Hardness Test	Weld Metal HAZ Base Metal	According to Annex A	The most stringent between ISO 15156-3 and IOGP S-705 Table 12

C.5 Notes

C.5.1 Charpy V-Notch Impact Toughness Test:

a) One set (3 specimens) for each location.

b) Whenever possible, full-size specimens shall be applied.

c) For subsize specimens, the energy reduction factor of ISO 17781 shall be used.

d) CVN impact test is not required for wall thickness lower than 6 mm.

C.5.2 Corrosion test specimens shall be as specified herein:

a) The specimen shall be tested in the as-welded condition, without removal of the reinforcement and the root pass.

b) The test specimen shall have a dimension of full wall thickness x 25 mm along the weld x 50 mm across the weld.

ANNEX D – ADDITIONAL REQUIREMENTS FOR WELDING PROCEDURE QUALIFICATION OF DISSIMILAR JOINTS BETWEEN DUPLEX STAINLESS STEEL AND CARBON STEEL

D.1 Test Coupon

D.1.1 In addition to requirements the applicable code, impact test shall be made using a butt weld joint design to give a full thickness path for crack opening into the HAZ of carbon steel base metal.

D.1.2 Weld joints should be according to Figure D.1.

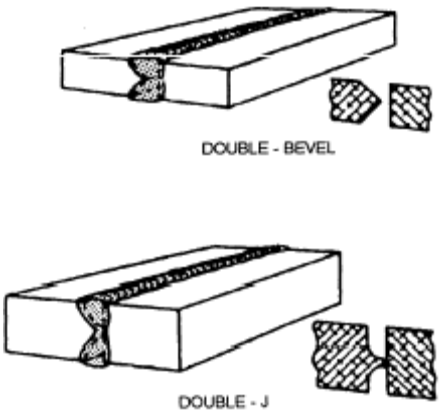


Figure D.1 – Butt Weld Joints Test Coupon

D.2 CVN Specimens

D.2.1 One set of CVN specimens shall be tested according to standard ASTM E370. The specimens shall be cut in order that the V notch goes straight through the HAZ of carbon steel base metal according to Figure D.2.

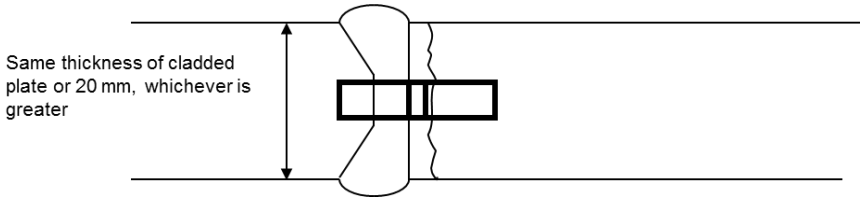


Figure D.2 – Location for removal of CVN specimens from butt weld joints

D.2.2 Acceptance criteria according to design code.

ANNEX E – ADDITIONAL REQUIREMENTS FOR WELDING PROCEDURE QUALIFICATION OF WELD OVERLAY

E.1 Additional Essential Variable

Decrease the number of layers shall be considered as essential variable for welding procedure qualification.

E.2 NDT and Laboratory Testing

The tests required for welding procedure qualification of weld overlay and clad restoration shall be according to Table E.1 (for AISI 3XX Series) or Table E.2 (for Inconel) below.

Table E.1 – Tests for Weld Overlay Procedure Qualification for AISI 3XX Series

Test	Extend	Acceptance Criteria
Visual Testing	100%	According to item 5.8.9
Penetrant Testing	100%	According to ASME BPVC Section IX or Design Code
Ultrasonic Testing	100%	According to item 5.8.9
Side Bend Test	4 specimens	According to ASME BPVC Section IX
Macroscopic Examination	See item E.3.1	According to item E.3.1
Microscopic Examination	See item E.3.2	Grain boundary with no continuous precipitations
Chemical Analysis	See item E.3.3	According to item 5.8.3
Ferrite Content (%) or Ferrite Number (FN)	See item E.3.4	According to item E.3.4
Hardness Testing	See item E.3.5	According to item E.3.5
Intergranular Corrosion Test (when PWHT is required)	1 specimen	According to item E.3.6

Table E.2 – Tests for Weld Overlay Procedure Qualification for Inconel

Test	Extend	Acceptance Criteria
Visual Testing	100%	According to item 5.8.9
Penetrant Testing	100%	According to ASME BPVC Section IX or Design Code
Ultrasonic Testing	100%	According to item 5.8.9
Side Bend Test	4 specimens	According to ASME BPVC Section IX
Macroscopic Examination	See item E.3.1	According to item E.3.1
Microscopic Examination	See item E.3.2	Grain boundary with no continuous precipitations
Chemical Analysis	See item E.3.3	According to item 5.8.3
Hardness Testing	See item E.3.5	According to item E.3.5

E.3 Notes

E.3.1 Macroscopic Examination: Macroscopic examination shall be performed at cross section surface of the test coupon. Cracks and other planar defects are not permitted. Individual pores or clusters of pores exceeding 2 mm are not permitted.

E.3.2 Microscopic Examination: Microscopic examination shall be performed at cross section surface of test coupon and shall include each layer and the interface between base material and weld overlay (fusion line).

E.3.3 Chemical Analysis: Chemical analysis shall be measured on a sample taken from the test coupon. Locations of chemical analysis to shall be at prepared surface and 1.5 mm below prepared surface.

E.3.4 Ferrite Content / Ferrite Number: Ferrite Number shall be measured on the top layer of weld overlay and shall be in the range of 3 to 10 FN for AISI 3XX Series, except for AISI 347 which shall have a range of 5 to 11 FN.

E.3.5 Hardness Testing: Hardness Testing shall be performed according to Annex A. The survey shall be according to Figure E.1. Readings on the HAZ shall be located as close as possible of the fusion line into the base material. A minimum of three readings shall be placed in the HAZ.

Acceptance criteria shall be according to design code, service standard (e.g. ISO 15156, if applicable) or Table 12 of IOGP S-705, the most stringent criteria shall prevail. The hardness for Inconel shall be in the range of 200 to 310 HV10.

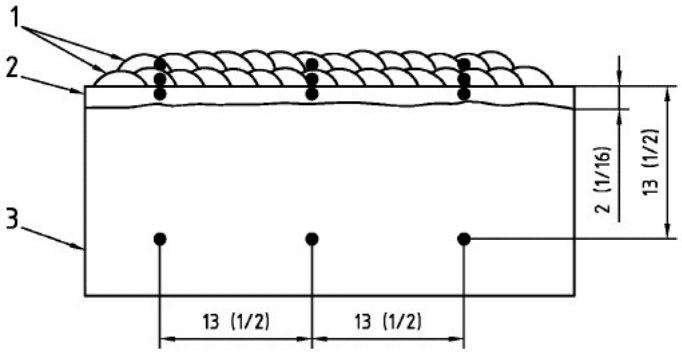


Figure E.1 – Required Hardness Test Locations, (1) Overlay, (2) HAZ, (3) Base Material

E.3.6 Intergranular Corrosion Test: When PWHT is required for base materials with AISI 3XX Series weld overlay, weld procedure qualifications shall include corrosion testing according to ASTM A262 Practice E.

ANNEX F – ADDITIONAL REQUIREMENTS FOR WELDING PROCEDURE QUALIFICATION OF TITANIUM (AND THEIR ALLOYS)

F.1 NDT and Laboratory Testing

The tests required for welding procedure qualification of titanium and their alloys shall be according to Table F.1.

Table F.1 – Examination and Testing of the Test Coupon

Test	Extend	Acceptance Criteria
Visual Testing	100%	According to design code and/or qualification standard
Penetrant Testing	100%	According to design code and/or qualification standard
Radiographic Testing	100%	According to design code and/or qualification standard
Transverse Tensile Test	2 Specimens	According to design code and/or qualification standard
Transverse Bend Test	4 Specimens	According to design code and/or qualification standard
Macro/microscopic Examination	1 Specimen	According to design code and/or qualification standard and according to ISO 15614-5
Hardness Testing	Weld Metal, HAZ, and Base Metal	According to IOGP S-705 (or ISO 15156-3 for sour service applications)

ANNEX G – PASSIVITY TEST FOR NICKEL AND NICKEL ALLOYS

G.1 Scope

This test is intended to reveal the presence of free iron or ferrous oxides on nickel alloy surfaces. Free iron contamination may exist as superficial films or as inclusions.

Two methodologies are accepted to analyze the presence of iron or ferrous oxides on nickel alloy surfaces, as follows.

G.2 Test Procedure with Demineralized Water

The surfaces to be tested shall be sprayed every hour for a period of 12 hours with cold demineralized water without intermediate drying. This period may be reduced to 6 hours if the sprayed drops are sufficiently small to adhere without running down.

A visual examination (using lens with 5x magnification in case of doubt) is performed after the surface is exposed to air for at least 24 hours after water exposure.

G.3 Test Procedure using Ferroxyl

Ferroxyl test shall be according to ASTM A380.

G.4 Acceptance Criteria

The examined surface shall have neither free iron nor iron oxide surface contamination nor iron inclusions or embedded particles.

ANNEX H – PROHIBITED AND DETRIMENTAL MATERIALS FOR NICKEL AND NICKEL ALLOYS

H.1 Prohibited Materials

Lead (Pb), mercury (Hg) and others low melting point elements, their alloys and/or their compounds shall not be added to the consumable products as essential chemical constituents.

Sulfur (S), Lead (Pb) and others low melting point elements, their alloys and/or their compounds shall be prohibited for use in fabrication, testing, shipping, and assembly.

H.2 Detrimental Materials

A detrimental element/compound is one that can have a deleterious effect on performance once it contacts the equipment. Detrimental elements/compounds are classified into seven (7) groups. Each group has allowable maximum concentration limits of detrimental elements/compounds in contact with nickel base alloys at each step of fabrication. Possible sources of detrimental materials are indicated in Table H.1.

H.3 Controlled Products

Controlled products which contain detrimental elements/compounds in excess of the concentration limits as shown in Table H.1 may be used if at least, one of the following conditions is satisfied:

a) No transfer of detrimental elements/compounds to the parts of the equipment occurs.

b) Detrimental elements/compounds shall be removed later with another accepted product prior next fabrication steps.

c) BUYER has specifically authorized the use of the products.

H.4 Acceptable Products

Acceptable products are products listed which satisfy the detrimental elements/compounds concentrations limits of Table H.1.

Table H.1 – Acceptable Products

Detrimental Element/Compound	Concentration (maximum)	Possible Sources	Step of Fabrication
Mercury	0.5 ppm	Chemicals Instrumentation Mercury Lighting	All
Lead	0.5 ppm	Temperature crayons, hammers, cutting oils, paint, plating, wire brushes	All
Cadmium, Magnesium, Tin, Zinc, Antimony, Arsenic, Bismuth, Silver	10 ppm	Hammers, fixtures, lubricants, cutting oils, paint, plating, wire brushes	Final cleaned surfaces or any prior to or during thermal treatment
Aluminum and Copper	250 ppm	Soft pads or hammers, probes, tips, copper chill blocks and electrodes for welding	
Sulfur	100 ppm	Furnace atmosphere, marking materials, lubricants and cutting oils, UT couplants, fluxes	Final cleaned surfaces, prior to or during thermal treatment or machining
Chlorides and Halogens	200 ppm	Human perspiration, lubricants, cutting oils, fluxes, penetrant materials, lagging, UT couplants	
Phosphorous	250 ppm	Furnace atmosphere, marking materials, temperature crayons, lubricants, UT couplant	