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LNG PLANT

WELDING REQUIREMENTS FOR EQUIPMENT AND PIPING

QUALITY PAGE

CHANGES LOG

REVISIONS LOG

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REFERENCE DOCUMENTS

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BS 7910
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EN 1600
[Welding consumables - Covered electrodes for manual metal arc welding of stainless

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EN 12072
[Welding consumables - Wire electrodes, wires and rods for arc welding of stainless and heat resisting steels – Classification]

DIN 8555
[Filler metals used surfacing]

ISO/TR 15608:2005
[Welding. Guidelines for a metallic material grouping system]

1.0 SCOPE

This specification outlines the requirements for welding, backcladding, overlay, tube to tubesheet welding, preheat and postweld heat treatment of vessels, heat exchangers, piping and piping components, heater tubing and other equipment, including tanks.

Except as supplemented in this specification, welding and inherent works shall conform to the requirements of the latest edition and revision including all addenda, officially issued as of the data of purchase order award of:

Pressure Equipment Directive 97/23/EC

ELOT EN 13445

ELOT EN 1594

ELOT EN 10208-2

ELOT EN 13480

All other Standards and Codes referred to therein or in Material Requisition or Purchaser's drawings.

Any conflict between this specification and other Owner drawings, specifications, standards, codes, etc., shall be brought to the attention of Owner in writing for clarification.

The more stringent requirements shall govern until written resolution is provided by Owner.

1.1 RIGHT OF ACCESS

Representatives of Owner, the Accredited Inspection Body and the Owner or his Representative shall have access to the Vendor's facilities and equipment for the purpose of inspection and audit of work and materials.

The Owner Representative shall have free entry, at all times while work on this Contract is being performed, and to all parts of the Contractor's works that concern the fabrication, assembly and/or installation.

The Contractor shall afford the Inspector all reasonable facilities to satisfy him that the work is being furnished in accordance with the Contract. All inspections shall be conducted so as not to interfere unnecessarily with the operation of the works.

1.2 SUBCONTRACTING

Use of Subcontractors by the Contractor for any operations required for the execution of this contract is prohibited without prior permission and approval by Owner.

All the requirements of this document, including all the herein referenced documents, codes, standards, specifications, procedures, etc, are applicable to the Subcontract and are to be included in Contractor's purchase orders to Subcontractor.

2.0 WELDING PROCEDURES

Contractor shall prepare and qualify welding procedures to cover all welding situations. Welding procedure qualification shall be performed in accordance with **ELOT EN 15614-1.**

Contractor shall qualify all welders and/or welding operators.

The complete set of Welding Procedure Specifications (WPS) and Procedure Qualification Records (PQR) shall be submitted together with the preliminary outline drawings as requested by subsequent paragraphs of this specification.

All welding procedures shall be identified by number and all welds shall be referenced to WPS identifying number on fabrication drawings. Contractor shall submit an index of all weld procedures required for the job, including referenced Procedure Qualification Records.

No welding shall be performed until written acceptance has been received by the Owner for the reviewed Welding Procedures.

Any comment/acceptance does not relieve Vendor from his responsibility. Owner can issue further comments if deviation from Codes, Standards, specifications and engineering practice, etc. are formed.

Welding procedures shall be prepared as required by **ELOT EN 13480-4** and **ELOT EN ISO 15609-1.** The applicable information shall be recorded as recommended in Forms, Annex A, **ELOT EN ISO 15609-1**.

Although exact duplication of these forms is not mandatory, all the information indicated shall be included.

Specific information that must be included in Contractor's weld procedures and/or restrictions which must be complied with **ELOT EN 13480-4** and the relevant **ELOT EN ISO.**

Information / restrictions listed in **TABLES 1** and **2** of this standard.

Definite minimum preheat and interpass temperature and, if necessary, corresponding maximum temperatures.

(Maximum interpass temperature limits must be specified for stainless steels and non-ferrous materials).

Definite range of holding temperature, holding time, and maximum heating and cooling rates for post weld heat treatment.

The qualification of welding procedures and of welders/welding operators shall be in accordance with **ELOT EN 287-1.**

Welder and Welding Operator Qualification Test Record shall be available for evaluation by Owner Inspector at all times.

Welding procedures shall be submitted to Owner for review for any one of the following conditions:

- Items which receive postweld heat treatment for either

process reasons or per Standard requirements.

- Materials or material combinations, i.e. low alloy, high alloy, non- ferrous materials, as per applicable **ENs** and carbon steel materials having thickness equal to 50 mm or more.
- Design pressure greater than 80 bar.
- Design temperature greater than 400°C or less than -29°C.
- Tube to tube sheet strength welds.
- Welding of studs used to secure refractory materials.
- Repairs of pressure containing castings.

3.0 PREHEAT

3.1 GENERAL REQUIREMENTS

3.1.1 When, before welding, the base metal temperature is below 0°C, the base metal shall be preheated to at least 20°C, and this minimum temperature shall be maintained during welding unless a greater temperature is specified in the following paragraphs.

3.1.2 When ambient temperature is below 0° C, welding may be done in accordance with the requirements of the applicable standards, taking all the necessary precautions. Welding activities in no case shall be performed at temperatures lower than -10° C.

3.1.3 Welding shall not be performed when condensation occur on the metal surfaces, appropriate heating shall be provided.

3.1.4 In all cases, except of 3.1.1 here in above, the minimum preheat shall not be less than 10 °C.

3.2 FERRITIC STEELS

The minimum preheat temperature for carbon and alloy steels shall be:

- For equipment and vessels - as given in **ELOT EN 13445 series,** as a minimum, with the following specific requirements:
  1. All carbon steel in excess of 32 mm shall be preheated to 80°C minimum. A preheat of 100°C shall be used if carbon steel material of thickness over 32 mm but not exceeding 38 mm is used without post weld heat treatment (P.W.H.T.).
  2. All Mn-Mo materials in excess of 16 mm shall be preheated to 120°C minimum.
- For piping and piping components - as given in **ELOT EN 13480.**

The above temperatures must be intended as a minimum, in dependence of a lot of favorable combinations.

The Contractor is requested, under its full responsibility, to establish

the minimum preheat temperatures related to: chemical analysis, thickness, welding process and heat input, restraint of the parts being joined, etc.

It shall be ascertained that specified preheat, if required, prevails throughout thickness of parts being welded and not just at the surfaces.

Neither welding, even of temporary attachments, nor stricking of arcs are permitted without the specified preheat.

3.3 AUSTENITIC STAINLESS STEELS AND HIGH NICKEL ALLOYS

For all thicknesses of austenitic stainless steel and high nickel alloys, preheat shall be at least 20°C, preheat and maximum interpass temperature shall not exceed 175°C.

3.4 ALUMINIUM AND ALUMINIUM ALLOYS

In gas-shielded arc welding of aluminum and aluminum alloys, preheating of parts to be welded is only required:

- When the temperature of the parts is below 10°C or,
- For gas tungsten-arc welding of parts thicker than 5 mm with alternating current or,
- For gas metal-arc welding of parts thicker than 25 mm.

When preheating is required, a preheating temperature in the range of 65° to 95 °C shall be used. A higher preheating temperature shall not be used, unless otherwise authorized in writing by Owner.

3.5 WELDING DISSIMILAR METALS OR THICKNESSES

For welding material combinations of dissimilar metals or of different thicknesses, the minimum required preheat temperature shall be that for the material requiring the higher preheat unless otherwise approved in writing by Owner, except for ferritic steel to austenitic or non-ferrous metals where the austenitic or non-ferrous side of the joint shall not be preheated.

3.6 ARC CUTTING

Specified preheating is also required prior to electric arc cutting operations used for cutting or grooving plates, for back gouging double welded joints and for gouging to remove defects.

3.7 PREHEAT MAINTENANCE FOR CIRCUMFERENTIAL BUTT JOINTS

For circumferential butt joints for which required preheat temperature is less than 120°C, the welding and also preheat may be interrupted provided the weld deposit thickness is at least 25% of the joint thickness or 10 mm, whichever is greater. The weld shall be allowed to cool slowly to room temperature.

Prior to resumption of welding, preheat shall be restored.

For circumferential butt joints and highly restrained joints of ferritic alloys normally requiring a preheat of 120°C or higher, such as shell welds and nozzles to vessel or nozzles to header welds, respectively, preheat shall be maintained without interruption until the commencement of post weld heat treatment, unless either a 200 °C preheat or a post weld soak a 200°C for two (2) hours is used and the weld is insulated and allowed to cool slowly after welding.

4.0 WELDING

4.1 GENERAL

The welding processes listed in TABLE 1 "Acceptable Welding Processes" of this specification are acceptable for fabrication subject to the limitations stated therein.

Request to use any other welding process shall be submitted to Owner for approval.

Unless otherwise allowed in writing by Owner all butt joints which are accessible from both sides shall be back gouged or ground to sound metal after welding the first side and then back welded on the reverse side.

Where access or wall thickness precludes the use of double welded butt joints, single welded joints shall be made using a root pass deposited by the TIG or MIG/MAG (Short Arc) process, except that for carbon steel piping the use of E 35 3 C 25, **EN ISO 2560** electrodes for root pass welding by MMA (SMAW) is also acceptable.

The use of consumable insert rings for TIG is an exception.

Permanent back rings shall not be used, unless specifically allowed in writing by Owner.

Temporary back rings shall have the same chemical composition as the base materials to be joined and shall be removed after welding.

Consumable inserts are acceptable for piping welds and shall have the same chemical composition as the base metal or as the filler metal.

All welds of nozzles, man ways and their reinforcement to equipment shell, heads, skirt and/or piping shall be full penetration.

All welds shall be regarded as requiring at least as much care as main seams. This includes welds for items such as fit-up clips, insulation rings, ladder and pipe clips, etc.

Proper application of qualified procedures by qualified welders using the appropriate preheat is essential, preheat shall not be less than that used for main seams.

For any equipment constructed of Carbon and Carbon-Manganese steels, the Vanadium content shall not exceed 0.07% and the maximum Carbon equivalent shall be as per applicable **ENs**.

The Carbon equivalent and Vanadium content shall be defined on

the material certificates.

4.2 BASE METAL PREPARATION

Joint preparation for welding may be performed by machining, grinding, thermal cutting, or combination there of. See relevant paragraph for preheating restrictions.

Excessively deep or sharp irregularities in joint edges shall be removed by machining or by grinding. Joint edges shall be crack and lamination free prior to welding.

When thermal cutting or carbon-arc gouging is utilized on ferritic or high alloy steels, the beveled surfaces shall be ground approximately 1.5 mm to remove any hardened or sensitized zone prior to welding.

Prior to welding, all oil, grease, dirt, rust and excessively thick or loose scale shall be removed from the surface of the joint and the adjacent base metal within 25 mm form the edge of the joint. Oil and grease shall not be removed by heating with a torch.

It is very important when welding ferritic steel components which are internally lined with high chrome or nickel-chrome materials, to remove the high alloy material prior to any cutting or welding operation.

To ensure complete removal of residual cladding and high chrome filler metal from previously clad surfaces, all surfaces shall be etched with an 8% nitric acid solution or similar solution approved by Owner.

Acid etching and grinding shall be repeated as required until high alloy material is completely removed prior to welding or cutting. For other clad materials consult Owner for appropriate test procedures.

4.3 WELDING ITEMS IN HYDROGEN OR AQUEOUS HYDROGEN SULFIDE SERVICE

For items or equipment, vessels, piping and piping components in hydrogen service having a hydrogen partial pressure above 7 bar or as noted on Owner drawings or requisitions, all welds in contact with the process fluid shall be full penetration.

Socket welds are permitted.

For items or equipment, vessels, piping and piping components in hydrogen aqueous sulfide service the hardness of welds and heat affected zone shall not exceed 200 BHN.

4.4 WELDING ITEMS COATED WITH LOW MELTING METALS AND PROPRIETARY ITEMS

For all vessels, parts painted with zinc rich paints or hot dip galvanized shall not be welded to the vessel, unless the zinc in the area odjacent to the zone to be welded is completely removed by sand blasting, grinding or taping prior to welding. Removal of the zinc rich areas by burning is not permitted.

Cadmium plated materials shall not be welded to carbon or stainless steel.

Welding of property items such as Alonized pipe, etc, is not permitted without prior written approval from Owner.

4.5 HEAT EXCHANGER TUBE TO TUBE SHEET WELDS

Seal welds are required when specified on the Material Requisitions or Job Specifications.

Strength welds are required in case of any of the following conditions:

a. When specified on the Material Requisition or Job Specification.

b. When the design pressure (shell and/or tube side) is greater than 80 bar.

c. When the differential design temperature (between tube and shell side) is greater than 400°C.

d. For waste heat exchangers.

e. Hydrogen service (i.e. where the hydrogen partial pressure exceeds 7 bar).

For exchangers in aqueous hydrogen sulfide service, carbon steel tube sheets shall have 0.21% C maximum and carbon steel tubes 0.18% C maximum. Hardness of welds and heat affected zone (HAZ) shall not exceed 200 BHN.

Tube to tube sheet mock-up samples shall be submitted to Owner for any of the following conditions:

a. When specified on the Requisition.

b. Non ferrous material.

c. When strength welds are specified.

Qualification of welding procedure shall be carried out according to **ELOT EN 15614-8**.

Mock-up samples shall be constructed using actual production welders, materials and procedures for the piece of equipment involved.

Mock-up samples shall have a minimum of six (6) tubes 75 mm in length from the backside of the tubesheet, using the same pitch arrangement as the piece of equipment involved.

4.6 STORAGE TANKS

Welding of storage tanks shall conform to pertinent paragraphs of this specification and to provisions regarding to welding of **EN 14620**. In addition, the vertical joints of shell courses shall be executed using MMA (SMAW) process, unless otherwise allowed in writing by Owner.

4.7 STRIP LINED CONNECTIONS

The inside surface of base material shall be cleaned to remove rust, mill, scale, dirt, weld spatter, e.t.c., and weld reinforcement shall be ground flush with the inside surface.

Acceptable welding processes are manual TIG and MMA (SMAW).
Acceptable filler materials are the same as those used for clad restoring.

4.8 WELDING CLAD/OVERLAY MATERIALS

The following requirements apply to equipment made of internally clad/overlaid steel plate:

The overlay welding procedure shall be developed and qualified in accordance with the requirements of **ELOT EN 1011-5**, **ELOT EN ISO 9692-4** and **ELOT EN ISO 15614-7**.

The procedure qualification record shall contain the following information as minimum.

- Results of liquid penetrant test on first and last passes.
- Results of guided bend tests.
- Ferrite content of the overlay, where applicable.
- Ferricyanide test, where applicable.
- Chemical analysis.

Elements to be included in the chemical analysis of the weld metal overlay shall include carbon, Cb/C ratio if applicable, plus all other elements contained in the filler metal in excess of one percent.

Sample material for chemical analysis shall be taken at least 2.5 mm into the overlay. The depth at which these samples were taken shall be indicated on the procedure qualification record.

The overlay surface shall be relatively smooth (waving is permissible but without notches, undercuts, etc., that would serve as stress risers). The interface between base metal and overlay shall be prepared by grinding where necessary to eliminate pockets, sharp notches, and other flaws which would prevent full bonding of the overlay material.

Qualification weld test specimens shall be subjected to P.W.H.T., if required, equivalent to that anticipated for fabrication, including aggregate time at temperature, with appropriate allowance for repairs.

Clad/Overlaid carbon steel or alloy steel components shall be welded using the following sequence of welding, and the filler metals specified in TABLES 3 and 7.

4.8.1 SEQUENCE OF WELDING

Strip of grind back clad/overlay material at least 6 mm from the root of the base material.

The stripped area shall be acid etched to ensure complete removal of the Clad / overlaid material.

Tack weld joint from base material side.

Weld the base material completely from the non-clad/overlaid side of the joint using the appropriate filler metal indicated in TABLE 3.

Back grind to sound metal the root of the base material (clad/overlaid side) and back weld the joint with the same filler metal used in step 3 flush with the base material surface.

Filler metal shall not come in contact with the clad/overlaid material.

Overlay the joint between the clad/overlaid materials with the appropriate filler

metals indicated in TABLE 7.

Overlay surface shall blend with the clad/overlaid surfaces. Dye check overlay surfaces to assure that they are crack free.

Undercutting: minimum base material thickness shall not include the thickness that will be removed to prepare the surface for back-cladding.

Unless otherwise indicated on the Owner drawings, the top 2.5 mm of all overlay shall meet the full chemical requirements for specified filler metal type. This type of overlay will be considered to be the corrosion allowance.

Excess thickness in the overlay necessary to obtain the 2.5 mm minimum will not be considered in strength calculations. Maximum overlay thickness shall not exceed 10 mm, unless specifically indicated in Material requisitions or drawings. Minimum overlay thickness shall be 3 mm.

The surface of weld overlay shall be left in the "as deposited" condition except for gasket surfaces or other surfaces requiring machining or grinding to meet requirements stipulated in the purchase order on the equipment drawings.

Samples for chemical analysis shall be taken using either a chipping or a drilling technique and shall be removed from the overlay starting at a depth of at least 2.5 mm from the surface.

All areas from which samples have been removed for chemical analysis shall be repaired by the fabricator using already qualified Welding Procedure Specification and qualified welder.

Chemical analysis checks shall be conducted per the following:

-For equipment which is clad and requires that seams be overlaid, at least one (1) chemical analysis shall be made on each circumferential and longitudinal overlaid shell and head welds.

-For equipment which is entirely overlaid, at least one (1) chemical check shall be made on each shell course and each head (minimum of five (5) checks per vessel) for both automatic and manual weld applications.

-Nozzle and piping which have been overlaid require that the deposited overlaid material have a chemical analysis taken on weldments made for each welder, each welding process, and each lot of weld wire and/or flux, with a minimum of one (1) chemical check for every four (4) nozzles, unless otherwise specified in writing by Owner.

Chemical analysis samples shall be taken at locations designated by the Owner Representative.

The Inspector shall consider those locations containing visual weld abnormalities or where weld process, weld wire and/or welders have been changed in addition to those others representative of normal conditions.

For situation where a clad (or overlaid) component is welded to corresponding base material with a continuous full fillet weld.

Consult Owner for determination of the appropriate filler metal for each joint in question.

Indication of overlap between adjacent passes is to be indicated on WPS.

All P.W.H.T. procedures for P.W.H.T. of clad piping or equipment are to be submitted to Owner for approval.

Equipment and Piping involving austenitic stainless steel overlays or clad restorings shall conform to the requirements below, unless otherwise indicated by Owner drawings or requisitions.

CHROMIUM CONTENT of overlay	FERRITE	Cb/C
Up to 20%, Incl. 20% to 22%, Incl. Greater than 22%	4-10 4-9 4-9	35 Max. 25 Max. 15 Max.

Frequency and location of measurements shall be the same as those required for chemical analysis.

Ferrite numbers may be determined by use of the Severn Gauge, Fisher Ferrite meter, or Delong diagram and shall be measured before P.W.H.T.

The magnetic gage shall be calibrated before measurement by the Vendor on at least two standards (calibration test blocks) having of ferrite content in the range 3 - 10 and with a minimum spread of five (5) numbers, the standards shall be either primary or secondary weld metal standards.

Equipment not complying with the chemical and/or ferrite requirements shall be reported to the Owner for resolution.

Ferricyanide test shall be reported on PQR and applied to all finished welds in 70 Ni 30 Cu cladding or overlay to ascertain the absence of iron pick-up.

Ferricyanide test shall be carried out as follows:

a. Clean welds and adjacent surfaces with hydrochloric acid.

b. Check weld deposits for cracks and repair, if any.

c. Clean again as per point a.

d. Check for iron pick-up or porosity with a 4% solution of potassium ferricyanide $K_5 Fe (Cn)_6$.

A blue color will indicate the presence of iron.

4.9 HARDFACING

Hardfacing deposits shall be qualified according to **ELOT EN ISO 15614-7** and according to following restrictions, before production welds are commenced.

A buffer layer shall be deposited on ferritic steels, using ENi6082 (ELOT EN ISO 14172) or SNi6082 (ELOT EN ISO 18274) materials, in order to provide suitable base material for hard facing unless otherwise indicated on Owner drawings.

Hardfacing material shall be E20-UM-45-CRTZ (DIN 8555), unless otherwise indicated by Owner drawings or requisitions.

4.9.1 HARDFACING QUALIFICATION SPECIAL REQUIREMENTS :

- The maximum acceptable width of hairline cracks shall not exceed 0.8 mm.
- Cracks shall not reach the base material.

- Hardness tests on Cobalt base deposited material shall be 40 HRC minimum.
- Hardness on H.A.Z. of ferritic base material shall be in accordance with what required in this Specification for the subject steel.

4.9.2 PRODUCTION TESTS:

- The maximum acceptable width of hairline cracks shall not exceed 0.8 mm.
- Cracks shall not show evidence that they reach base material.
- Hardness test to be 40 HRC minimum.

5.0 WELDING FILLER METALS

Electrodes and/or filler metals shall be selected such that:

a. The strength of deposited weld metal shall be at least equal to the specified minimum tensile strengths of the material being welded.

b. When joining similar materials the chemical composition of the deposited weld metal shall match that of the base material as closely as possible.

However, this shall not preclude the use of welding materials containing alloying elements of different types or in different amounts than those in the base materials provided there is evidence that such elements are not harmful and are the only way to achieve desirable weld metal properties, such as adequate tensile strength after post weld heat treatment or adequate impact strength at low temperatures. In any case a written approval by Owner shall be obtained before production commence.

5.1 FERRITIC STEELS

Unless otherwise authorized in writing by Owner filler metals for similar and dissimilar welds in ferritic steels shall meet with requirements of **TABLE 3** "Guide for Welding Ferritic Steels", of this specification.

For carbon-molybdenum and chromium-molybdenum materials, the chromium and molybdenum content of deposited weld metal shall be verified by chemical analysis of the weld deposit on the procedure qualification test plates.

It shall be checked further by chemical analysis of chips or drilling taken from the welds in the vessel during fabrication.

Sample drilling or chips shall be obtained from one location for each longitudinal joint between neighbouring circumferential joints, one for each circumferential joint and one for each nozzle joint. Owner shall designate the locations at which drilling or chips are to be taken.

Analysis of these samples shall be performed by a qualified, independent laboratory, and results shall be approved by Owner.

Should any of these samples have a molybdenum or chromium content not in the same range as the base metal, two additional samples shall be taken at nearby locations in the deficient weld and analyzed. If one of the additional samples fails to meet requirements, the entire weld shall be removed and replaced.

5.2 AUSTENITIC STAINLESS STEEL AND HIGH NICKEL ALLOYS

Unless otherwise authorized in writing by the Owner, filler metals for joining similar and dissimilar stainless steels and high nickel alloys shall meet with requirements of **TABLE 6,** "Acceptable Filler Metals for Joining Austenitic Stainless Steels and

High Nickel Alloys", of this specification. Additional requirements of the weld deposit are outlined in the notes of **TABLE 6.**

5.3 ALUMINIUM AND ALUMINIUM ALLOYS

Unless otherwise authorized in writing by the Owner, filler metals for joining similar and dissimilar aluminium and aluminium alloys shall meet with the requirements of **TABLE 8,** "Acceptable Filler Metals for Joining Aluminium and Aluminium Alloys" of this specification.

5.4 FERRITIC STEELS TO AUSTENITIC STAINLESS STEELS AND TO HIGH NICKEL ALLOYS

For Carbon and Low Alloys steels welded to Austenitic stainless steels (**ELOT EN 10088**) with operating temperatures below 370°C and in the absence of thermal cycling and P.W.H.T. requirements, Stainless Steel filler metal shall be used.

For these dissimilar base metal combinations with operating temperatures above 370°C, Inconel welding electrode 182 (ENi6082, ELOT EN ISO 14172) or Inconel filler metal 82 (SNi6082, ELOT EN ISO 18274) or Incoweld A (ENi6092, ELOT EN ISO 14172) shall be used.

These filler metals are also an acceptable alternate to stainless steel for lower temperature, except where the environment contains sulphur.

If the environment contains sulphur above 370°C, or thermal cycling conditions are anticipated and/or P.W.H.T. is required, consult Owner for further requirements.

For carbon and low alloy steels welded to Inconel or Incoloy and in the absence of thermal cycling and of P.W.H.T. requirements, use Inconel welding electrode 182 (ENi6082, EN ISO 14172) or Inconel filler metal 82 (SNi6082, ELOT EN ISO 18274) or Incoweld A (ENi6092, ELOT EN ISO 14172) shall be used.

If post weld heat treatment and/or thermal cycling are involved, consult Owner for further requirements.

For carbon and low alloy steels welded to Monel and in the absence of thermal cycling and of P.W.H.T. requirements, use Monel welding electrode 190 (ENi4060, ELOT EN ISO 14172) or Monel 60 (ENiCr30Fe9Nb) or nickel filler metal 61(SNi2061, ELOT EN ISO 18274).

If post weld heat treatment and/or thermal cycling are involved, consult Owner for further requirements.

5.5 CRYOGENIC STEELS WITH NICKEL CONTENTS FROM 1.5% to 9%

Cryogenic steels with nickel contents from 1.5% to 9% are suitable for use at temperatures as low as -80 °C. For cryogenic steels with nickel contents up to 3.5% filler metals of similar chemical composition must be used for welding.

With nickel contents between 5% and 9% austenitic or nickel based filler metals should be used. For joining of these steels with austenitic stainless steels, austenitic filler metals with similar chemical composition to the stainless steel should be used.

6.0 POST WELD HEAT TREATMENT

Post weld heat treatments of carbon and low alloy steels shall meet with the following requirements:

- **For vessels and equipment: ELOT EN 13445**, TABLE 3 herein "Guide for Welding Ferritic Steels" and the equipment column of Table 5 herein "PWHT requirements for Ferritic Steels". If the Standards specify higher post weld heat treating temperatures, they shall take precedence.
- **For piping components** : **ELOT EN 10208-2** and or **ELOT EN 13480,** TABLE 3 herein "Guide for Welding Ferritic Steels" and the piping column of Table 5 herein "PWHT requirements for Ferritic Steels" of this specification.
  If the Standards specify higher post weld heat treating temperatures, they shall take precedence.

All sizes and wall thickness of Group 5 and 6 (**ISO/TR 15609**) alloy steels shall be post weld heat treated.

When joining parts of different thicknesses, holding time shall be that for the thicker material.

Post weld heat treatment of solid austenitic stainless steel and/or high nickel alloy components shall not be performed, unless specifically required and approved by Owner.

Stress relieve procedure for joints between austenitic stainless steel and other materials shall be submitted to Owner for review.

Post weld heat treatment of solid aluminium and/or aluminium alloy components shall not be performed, unless specifically required and approved by Owner.

Post weld heat treatment may be performed by electric induction, by electric resistance method, or in fuel- fired or electrical furnaces.

Equipment shall be provided to record the metal temperatures of the part of components being heat treated and to control heating and cooling rates and holding times.

When partial, multiple, or field post weld treatment and/or local PWHT of lined, clad, or overlaid equipment is involved, Contractor shall present details of proposed post weld heat treatment method to Owner for his review and approval.

All machined surfaces shall be protected against oxidation during heat treatment.

Unless otherwise allowed in writing by Owner, no welding nor striking of arcs are permitted after final post weld heat treatment.

7.0 WELD QUALITY

7.1 REPAIR, INSPECTION, REJECTION

Weld repairs shall comply with the requirements of the applicable Standard as mentioned herein above, including preheat requirements or recommendations, postweld heat treatment requirements, and non-destructive examination.

Defects shall be removed by chipping, gouging, or grinding and the repaired weld shall be post weld heat treated, if P.W.H.T. was originally required, re-examined by the original method(s) for freedom from defects.

Welds indicating irremediable or injurious defects, improper fabrication and/or excessive repairs, shall be subject to rejection at any time, at Owner discretion.

For pressure-containing items, all required repairs of base metal shall be reported to Owner for review and approval, prior to making the repair.

Inspection shall be performed on all full thickness butt welds as stated below:

7.1.1 PIPING

a. Radiographic technique and acceptance requirements shall conform to **ELOT EN 1435** and **ELOT EN 12517-1** acceptance level 1 respectively.

b. Three-fifths of the welds examined shall consist of welds joints a welding neck
flange to another component, if the fabrication involves such joints.

c. The work of all welders and welding operators or combinations thereof of each
low alloy, high alloy, non- ferrous materials, as per applicable **ENs** shall be included in radiography. Sufficient coverage on random or spot radiography shall also include the welding process(es) used by each
welder or welding operator.

d. Non Destructive Evaluation by Time of Flight Diffraction Method (TOFD)

Ultrasonic examination of welds may be applied as alternative to the radiographic
technique under the terms that will be agreed in the contract. The ultrasonic
examination will be the TOFD technique based on diffraction of ultrasonic waves
on tips of discontinuities.

TOFD technique shall be applied only if wall thickness is greater

than 6 mm.

For the application of the TOFD technique Contractor must have a fully computerized system able to scan, store and evaluate indications in terms of height, length and position with a high grade of accuracy.
TOFD shall be applied according to the following standards:
EN 15617, **EN 583-6**, **CEN/TS 14751**

Deffects shall be evaluated according to **BS 7910**

7.1.2 VESSELS AND EXCHANGERS

a. Radiographic technique and acceptance requirements shall conform to **ELOT EN 1435** and **ELOT EN 12517-1** acceptance level 1 respectively.

b. The work of all welders employed on the job shall be included in this radiography.

c. When submerged arc welding has been used for main seams, all intersections of seams, and all stopping and starting points of weld beads shall be radiographed.

7.2 HARDNESS LIMITATIONS

Permitted maximum hardness values for weld metal, and/or heat affected zones of piping and equipment shall be accordance with the requirements of **ELOT EN 15614-1** Table2.

If other hardness limits are mentioned in equipment job specification, those values shall govern.

To verify compliance with the hardness limitations, the following shall apply as minimum:

- For items or equipment-at least one hardness measurement shall be taken on 10% of the longitudinal seams, on 10% of the girth seams and on 10% of the nozzles-shell weldments.
- For piping and piping components-at least one hardness measurement shall be taken on 10% of the welds on pipe which does not require P.W.H.T. and on each furnace batch of piping which is heat treated after welding, hot forming, and hot bending. At least one hardness measurement shall be taken on 100%

of those joints which are locally heat treated.

Areas to be checked shall be located by the Owner Inspector. If hardness measurements exceed the limitations, Owner shall be contacted for further resolution.

Owner approval shall be obtained for all multiple stress relieve treatments beyond that required by standards, item drawing, or this specification when used for the purpose of decreasing hardness.

Where two or more different base materials are joined, the maximum hardness of the weld metal shall not exceed the lesser of the hardnesses required for the base materials involved.
The hardness of each heat affected zone shall not exceed the hardness requirement for the adjacent base material.

7.2.1 ADDITIONAL REQUIREMENTS FOR WELDING PROCEDURE QUALIFICATIONS

Procedure qualification tests for welding steels and steel alloys shall include hardness tests of the weld metal and heat affected zone in as welded conditions or after post-weld heat treatment, if any.

The terminal ends of the welding test coupon shall be cut and on the cross section of the cut samples, after adequate surfaces preparation and etching, a hardness test shall be carried out.

The hardness shall be checked in fused zone, in heat affected zone (to the distance of 0.5 mm from the nearest point of the fuse zone) and in base material.

At least are required six check points for each line:

- The first line shall be positioned 1 mm below the external surface of the deposited material.
- The second line shall be positioned as near as practical midway between the surface and the center of thickness.
- The third line shall be positioned perpendicularly to the above line and shall be symmetrical to the welded area (center of weld).
- Where more than one welding process is involved (e.g. first pass TIG/ MMA (SMAW) all the remaining passes, or SMAW/SAW combination) one additional check points line shall be foreseen, so that the passes of all processes are crossed by lines parallel to the first/second line.

The hardness test of PQR shall be carried out with Vickers Pyramid (VPN) 10 kp load or with Brinell std. ball 10 mm 3.000 kp.

If the manufacturer already holds record of hardness tests (on cross section), performed other than indicated above, he may be exempted, only after Owner written approval, to produce a new

coupon to perform hardness test, provided that:

- Weld hardness is detected on the weld surface of production welds with the material removed as minimum as possible to permit the test.
- The ball for hardness detection is as small as necessary to avoid a blended reading in HAZ (blending between F.Z., H.A.Z. and B.M. hardness).

7.3 FERRITE MEASUREMENTS OF SOLID AUSTENITIC STAINLESS STEELS

The need for conducting ferrite measurements on austenitic stainless steel production weldments shall be specified on the Owner drawings and/or requisitions and shall conform to the following restrictions:

- Ferrite measurements shall be taken in the as- welded condition prior to P.W.H.T., if P.W.H.T. is required.
- Ferrite measurements shall be performed in the center of the weld utilizing a Ferritscope or by using the DeLong or Schaeffler diagrams in conjunction with the results of a chemical analysis.

The chemical analysis samples shall be removed from the center of the weld deposit at a thickness of 2 mm form the weld surface.

The magnetic gage shall be calibrated before measurements by the manufacturer on at least two standards (calibration test blocks) having a ferrite content in the range 3 ÷ 10, and with a minimum spread of five (5) numbers, the standards shall be either primary or secondary weld metal standards as referenced in **EN ISO 17655.**

An annual calibration certification shall be available for the inspector.

One ferrite measurement shall be taken for every 3 m of weld with a minimum of four (4) measurements for each circumferential and two (2) measurements for each longitudinal weld.

A minimum of two (2) measurements shall be taken on each piping circumferential and longitudinal (if fabricated) joint.

A minimum of one ferrite measurement shall be taken on all nozzles penetration welds.

Measurement sites shall be designated by the Owner Inspector.

Unless otherwise specified on the Owner drawings, all ferrite measurement shall fall within the ferrite number range of 4 to 10.

If any ferrite measurement falls outside the permitted range, two

additional measurements shall be taken adjacent to the original test. If these additional measurements fall outside the specified number range, the readings shall be referred to Owner for resolution and further action.

Ferrite measurements of solid austenitic stainless steel shall be reported on PQR, when required in production.

Test methods, acceptable values, etc, shall be as for production welds.

7.4 WELDING REQUIREMENTS FOR IMPACT TESTING

7.4.1 PROCEDURE QUALIFICATION:

Welding procedures for impact properties using the Charpy V-notch method at the temperature specified on the individual specification.

7.4.2 TEST PIECES FOR PROCEDURE QUALIFICATION:

Test pieces for the qualification of welding procedures for material over 19 mm thickness shall be of a thickness not less than that of the materials for which qualification is required.

7.4.3 PREVENTION OF STRESS RISERS

Special care shall be taken to eliminate or prevent stress risers which might cause low impact strength due to notch effect or abrupt change in section.

Reference lines shall not be stamped upon the vessel.

Welder's and welding operator's symbols may be stamped upon the vessel in accordance with the provisions of **ELOT EN 13445**, provided that a round nose stamp is employed and that the symbol is located at least 25 mm from the edge of the weld.

7.5 WORKMANSHIP

Unless otherwise specified, reinforcement of butt weld on plate joints shall not exceed the following:

Plate Thickness	Max. Thickness of Reinforcement, mm
Up to 13 incl.	2
Over 13 to 25, incl.	2.5
Over 25 to 50, incl.	3
Over 50	4

Weld reinforcement of pipe joints shall not exceed 2 mm for wall thicknesses up to and including 13 mm or 3 mm for wall thicknesses over 13 mm and shall be dressed to blend smoothly into the adjacent surface.

Internal penetration on single welded butt joints shall not exceed 3 mm.

TABLE 1. - Acceptable Welding Processes

Welding Process	Items to be specified in Welding Procedures (See table 2)	Restrictions (See next page)
MMA (SMAW) - Manual Metal Arc.	a, b	16
TIG – Tungsten Inert Gas	a, b, c, d, e, f, h, k	1,13
PAW - Plasma Arc	a, b, c, d, e, f, h	1
MAG – Metal Active Gas	a, b, e, f, h, k	1,2,3,12,13
MAG – Metal Active Gas - $C0_2$ Spray	a, b, e, h, k	12,13
MIG – Metal Inert Gas	a, b, e, f, h, i, k	1,12,13
MIG – Metal Inert Gas - Pulsed Arc	a, b, e, f, h, i, k	1,2,3,12,13
FCAW - Flux - Cored Arc - CO_2 Shielded	a, b, e, h, i	5,9,11
FCAW - Flux - Cored Arc - Self Shielded	a, b, e, h, i	5,9,11,14
SAW - Submerged Arc	a, b, g, h, i, j	4,5,8,10,11
EGW - Electrogas	a, b, e, h, i, j	6, 9
ESW - Electroslag	a, b, d, g, h, i, j	6, 9
FGW - Oxy Fuel Gas	b, e	7

Restrictions:

Unless otherwise authorized in writing by Owner, the use of these welding processes is subject to indicated restrictions:

1. Internal purging with inert gas is required for consumable insert welding of all materials
and for root/second passes of single welded butt joints in materials with over 3% total
alloy content.

2. Manual short arc or pulsed arc welding is:

a. Allowed for root pass welding of butt joints in any material regardless of thickness.

b. Allowed for full thickness butt welds and fillet welds in pressure parts, structural
supports, and equipment internals if the thickness of either material at the joint does
not exceed 9 mm.

c. Not allowed where large material mass heat sinks can affect the integrity of welds,
such as nozzle welds, reinforcing pads, flange welds, etc., where the thickness of
either material at the joint exceeds 9 mm.

d. Not allowed for piping of nominal diameter less than 75 mm, then only where the
direction of travel is indicated in the procedure.

e. To be inspected as stated in previous paragraphs, with 5% of welds radiographed in
addition to applicable European Standard requirements.
The work of all welders employed utilizing this process shall be included in the radiography.

f. Shall not be used to deposit filler passes or cover passes in the downhill direction.

3. Automatic short arc or pulsed arc welding is allowed for full thickness butt welds in all
sizes of piping within the following limitations:

a. 1G (Roller) position only.

b. For thickness over 9 mm, use of an automatic arc oscillator is recommended and a
minimum current of 170 amperes is required for all passes after the root pass.

c. 5% of welds in thicknesses up to 9 mm and 10% of welds in thicknesses over 9 mm
must be radiographed in addition to any applicable Standard requirements. Technique
and acceptance standards shall be as stated in this specification.
The work of all welders employed utilizing this process shall be included in this radiography.

d. Not allowed where large material mass heat sinks can affect the integrity of welds, as
with couplings, weldolets, branch welds, fillet welds on slip-on flanges, socket-welded
flanges and fittings, etc, where the thickness of either material at the joint exceeds 9
mm.

e. Not allowed for piping of nominal diameter less than 75 mm, then only where the
direction of travel is indicated in the procedure.

f. Shall not be used to deposit filler passes or cover passes in the downhill direction.

4. The use of neutral flux (non-voltage sensitive) is required for submerged arc welding of carbon steel base metals thicker than 25 mm and for all materials over than carbon steel.
If voltage sensitive flux is used, each production weld shall be tested for hardness. Maximum allowed hardness is 200 HB.

5. The use of alloy wire and neutral flux, rather than alloying through the flux, is required where an alloy weld deposit is desired.

6. Welding shall be followed by appropriate normalizing treatment to restore notch toughness to base material and weldments.

7. Not allowed, unless authorized in writing by Owner.

8. Use of manual submerged arc welding is not permitted.
The manufacturer and brand name or grade of flux shall be specified in the welding procedure.

9. This welding process is not acceptable for field welding.

10. Start and run off pads of same materials as base material shall be used on all longitudinal seams.

11. The flux and wire combination actually used shall be the same used in the procedure qualification.

12. Gas Metal Arc welding shall not be used for welding attachment of nozzles to vessels.

13. When this welding process is used for field welding, suitable precautions shall be taken to shield the welding area from wind or drafts which could interfere with the shielding gas protection.

14. Self-shielded flux-cored arc welding, without external shielding gas, of carbon or alloy steels is not acceptable for pressure joints or for welds subject to vibration.
15. Individual beads deposited by standard automatic processes shall not exceed 6.35 mm deep.
16. Only low-hydrogen electrodes shall be used for shielded metal arc welding all carbon and low alloy steels, except for root pass welding of single welded joints as specified in relevant paragraph of this specification.

TABLE 2. - Specific items to be included in welding procedures

Code used in table 1	Description
a	Welding current type, polarity, amperage(s) and voltage(s) including appropriate ranges.
b	Filler metal type, classification, where classified and manufacturer's designation.
c	Non consumable electrode type.
d	Arc starting aids or devices.
e	Shielding gas composition and flow rate.
f	Composition and flow rate of internal gas purging.
g	Classification, if any, and manufacturer's trade name or designation for welding flux.
h	Travel speed for mechanized welding.
i	Special requirements such as constant potential power sources, pulse setting, wire feed or oscillation rates, electrode stickout, e.t.c. (as applicable).
j	Single or multiple arcs.
k	Specific precautions that will be taken for field welding, if applicable, to prevent wind or drafts from interfering with the shielding gas protection.

TABLE "3" - FILLER METAL SELECTION GUIDE FOR WELDING FERRITIC STEELS

MATERIALS TO BE WELDED	C.S	C0.5Mo	Mn-Mo	1.25Cr-0.5Mo	2.25Cr-Mo	5Cr-0.5Mo	9Cr-1Mo	410 S (NOTE 1)
Carbon Steel	A/B V	B/C W	*B/D* W	B/E X	B/F Y	B/G Z	B/H Z	I W
C-0.5Mo		C W	C/D W	C/E X	C/F Y	C/G Z	C/H Z	I X
Mn-Mo			D W	D/E X	D/F Y	D/G Z	D/H Z	I X
1-1/4Cr 1/2 Mo				E X	E/F Z	E/G Z	E/H Z	I Z
2-1/4Cr 1Mo					F Z	F/G Z	F/H Z	I Z
5Cr 1/2Mo						G Z	G/H Z	G/I Z
9 Cr 1Mo							H Z	H/I Z
410S (Note 1)								I Z

NOTE 1 : Only applicable to non-pressure 410 S parts not exceeding 10 mm in thickness.
X/X : Filler Metal Code (see TABLE "4")
X : P.W.H.T. (see TABLE "5")

TABLE 4. - Acceptable Filler Metals for Joining Ferritic Steels

Filler Code	Manual Metal Arc (7) (8)	Submerged Arc		Flux Cored Arc	Gas Tungsten Arc	Gas Metal Arc
		Wire	Flux (9)			
A	ISO 2560: E 35 3 C 2 5	Carbon Steel	Neutral	EN 758: T 46 0 R C 3 H5 EN 758: T 42 4 B C/M 2 H5	EN 1668: W 42 5 W2Si	EN 440: G 42 2 M G2Si
B	ISO 2560: E 46 3 B 3 2 H5 ISO 2560: E 42 3 B 1 2 H5	Carbon Steel (10)	Neutral	EN 758: T 46 0 R C 3 H5 EN 758: T 42 4 B C/M 2 H5	EN 1668: W 42 5 W2Si	EN 440: G 42 2 M G2Si
C	EN 1599: E Mo B 3 2 H5	EN 756: S2Mo EN 756: S4Mo Mn-Mo	Neutral	EN 12071: T MoL P M 2 H5	EN 12070: W MoSi EN 1668: W 46 3 W2Mo (Mn-Mo)	EN 440: G 46 3 M G2Mo (Mn-Mo)
D(2)	EN757: E55 3MnMoB T42 H10 EN1599: EZB22 H5	EN 756: S4Mo	Neutral		G4Mo	G4Mo
E(4)	EN 1599: E CrMo1 B 3 2 H5	EN 12070: S CrMo1	Neutral	1.25Cr 0.5 Mo EN 12071: T CrMo1 P M 2 H5	ISO 21952-A: W CrMo1Si	ISO 21952-A: G CrMo1Si
F(4)	EN 1599: E CrMo2 B 3 2 H5	EN 12070: S CrMo2	Neutral	2.25 Cr 1.0 Mo EN 12071: T CrMo2 P M 2 H5	ISO 21952-A: W CrMo2Si	ISO 21952-A: G CrMo2Si
G	EN 1599: E CrMo5 B 3 2 H5	EN 12070: S CrMo5	Neutral	5Cr-0.5 Mo	ISO 21952-A: W CrMo5Si	ISO 21952-A: G CrMo5Si
H	EN 1599: E CrMo9 B 3 2 H5	EN 12070: S CrMo9			ISO 21952-A: W CrMo9Si	ISO 21952-A: G CrMo9Si
I	EN 1600: E 23 12 L B 2 2	EN 12072: S 23 12 L		ISO 17633: T 23 12 L R C/M 3 ISO 17633: T 23 12 L P C/M 3	EN 12072: W 23 12 L Si	EN 12072: G 23 12 L Si

TABLE 4. - Acceptable Filler Metals for Joining Ferritic Steels (Cont'd)

Notes:

1. Use only as root pass.
2. For hydrogen service, special order filler metals resulting in welds with 0.40 to 0.60% Mo content must be used.
3. This refers to special EZB22H5 (EN 1599) electrode developed by Champion to weld Mn-Mo steel.
4. For equipment operating in creep range, do not use low carbon grade of filler metal.
5. If austenitic stainless steel filler metal is used, thermal stresses resulting from difference in coefficient of thermal expansion shall be considered.
6. E553MnMoBT42H10 (EN 757) electrodes shall have at least a 0.4% Mo content (min.).
7. E 38 0 RC11 and E 38 0 RR54 (EN 499) electrodes are not suitable for welding non-pressure attachments to pressure components.
8. Low hydrogen electrodes shall be stored and used only in accordance with electrode manufacturer's instructions.
9. Welding electrodes shall have the alloying agents in the wire and not in the flux.
10. Manganese - Molybdenum steel electrode wires may be used provided that the weld metal hardness does not exceed 200 HBN.

TABLE 5. - P.W.H.T. Requirements for Ferritic Steels

	Temperature Range Degrees C (7)		
Code from Table 3	Items of Equipment and Vessels	Piping and Piping Components	See note(s)
V	600-650	600-650	(1)
W	635-660	620-675 (4) 635-660 (5)	(1), (2)
X	660-690	700-745	(2), (3), (6)
Y	675-700	700-760	(2), (3), (6)
Z	720-745	700-760	(2), (3), (6)

TABLE 5. - P.W.H.T. Requirements for Ferritic Steels (Cont'd)

Notes:

1. Weldment is only to be P.W.H.T. if required by Standards and/or by service requirements. If P.W.H.T. is required, use the indicated temperature range for holding temperature. Heating and cooling rates and holding time shall be as per requirements of applicable European Standards, and in case something is not covered by them, ASME, Piping Code, or applicable International Codes, unless otherwise specified.

2. P.W.H.T. over 660°C may damage properties of carbon steel, carbon 1/2 Mo and Mn-Mo. Contractor shall be responsible to procure materials that will satisfy specified materials properties after P.W.H.T. at the specified temperatures. Mill test reports shall be based on test samples post weld heat treated at the specified temperatures. Consult with Owner, if necessary.

3. Where restraint conditions necessitate the practice of post weld heat treating the chrome-moly alloy steels immediately upon completion of welding, it is recommended that the welds be cooled to 120°-150°C after welding and prior to initiating the post weld heat treatment.

4. Use for alloy steels having a minimum specified tensile strength of less than or equal to 500 N/mm^2 for thicknesses greater than 19 mm.

5. Use for alloy steels having a minimum specified tensile strength greater than 500 N/mm^2 for all thicknesses.

6. Welds for all thicknesses shall require P.W.H.T.
   Use the indicated temperature range for the holding temperature.Heating and cooling rates and holding time shall be as per requirements of applicable European Standards, and in case something is not covered by them, ASME, Piping Code, or applicable International Codes, unless otherwise specified.

7. When chrome-moly castings are to be welded either in shop or in field, they shall always be postweld heat treated.
   Chrome moly piping and fittings shall always be postweld heat treated except as allowed by standard and piping material specifications.

TABLE 6 - ACCEPTABLE FILLER METALS FOR JOINING AUSTENITIC STAINLESS STEELS

AND HIGH NICKEL (1),(2),(3),(4),(5),(6),(7),(8)

MAT'LS TO BE USED	301 302 304(6)	304L	309 309S	310 310S	316 (3) (6)	316L (3)	317 (3)	321 (6)	347 (6)	348	Incoloy 800 Inconel 600	Monel
301 302 304 (6)	308	308	308	308 309	308 309	308	308	308	308	308	ENi6082 (EN ISO 14172) SNi6082 (EN ISO 18274)	—
304L		308L	308	308 309	308	308L	308	308L	308L	308L	ENi6082 (EN ISO 14172) SNi6082 (EN ISO 18274)	—
309 309S			309	309	309 316	316 309	317 309	347 309	347 309	348 309	ENi6082 (EN ISO 14172) SNi6082 (EN ISO 18274)	—
310 310S				310	309 316	309 316	309	309	309	309	ENi6082 (EN ISO 14172)	—
316 (3)(6)					316	316	316	316	316	316	ENi6082 (EN ISO 14172) SNi6082 (EN ISO 18274)	—
316L (3)						316L	316	316L 321	316L 347	316L 348	ENi6082 (EN ISO 14172) SNi6082 (EN ISO 18274)	—
317 (3)							317	317 321	317 347	317 348	ENi6082 (EN ISO 14172) SNi6082 (EN ISO 18274)	—
321 (6)								321 347	321 347	347 348	ENi6082 (EN ISO 14172) SNi6082 (EN ISO 18274)	—
347 (6)									347	347 348	ENi6082 (EN ISO 14172) SNi6082 (EN ISO 18274)	—
348										348	ENi6082 (EN ISO 14172) SNi6082 (EN ISO 18274)	—
Incoloy 800 Inconel 600											ENi6082 (EN ISO 14172) SNi6082 (EN ISO 18274)	
Monel											ENi4060 (EN ISO 14172) SNi4060 (EN ISO 18274)	—

TABLE 6. -Acceptable Filler Metals for Joining Austenitic Stainless Steels and High-Nickel Alloys (1), (2), (3), (4), (5), (6), (7), (8) (Cont'd)

Notes:

1. Deposited stainless steel weld metal shall have delta ferrite content as specified in this specification.
2. Low carbon filler wires will result in lower tensile strengths. They shall only be used if either specifically requested by Owner or specifically approved in writing by Owner.
3. Filler metals used in welding 316, 316L, or 317 parts in fatty acid service shall contain a minimum Mo content of 2.5% and a maximum carbon content of 0.03%.
4. Where type 347 filler metal is specified, this applies to coated electrodes. For bare welding filler metal, use type 321.
5. For materials and/or combinations of materials not listed in table 6, consult Owner for specific recommendations.
6. Where High carbon grade materials (i.e 304H, 316H, 321H, 347H) are welded together the filler metal shall have a carbon content of 0,04% to 0.08%, this is applied in equipment and piping operating in "Creep" range.
7. Do not use type 347 filler materials when design temperature is above 400°C consult Owner when higher design temperature is encountered.
8. Filler metal used in welding Monel parts in hydrofluoric acid service shall contain no colombium.

TABLE 7. - Acceptable Filler Metals for Weld Deposit and Clad Restoring

Cladding material	Filler materials for weld deposit and clad restoring (3),(4)	
70 Ni 30 Cu (5)	ENi4060 (EN ISO 14172) (1)	
12%Cr Type 410	Do not overlay	
12%Cr Type 410 S (2)	Cyclic service :	ENi6082 & ENi6092 (ELOT EN ISO 14172) SNi6082 (ELOT EN ISO
	Low sulphur S ≤ 0.5% max.	Temp ≤ 425 °C : T 2312L (ISO 17633) S 2312L (EN 12072)
		Temp > 425 °C : ENi6082 (ELOT EN ISO 14172)
	High sulphur S > 0.5%	T 2312L (ISO 17633) S 2312L (EN 12072)
Austenitic stainless steel	First pass	Subsequent passes
Type 304	309L	308
Type 304	309L	308L
Type 316	309L	316
Type 316	309L	316L
Type 321/347	309L	347
Nickel 200	E Ni 1	

Notes:

1. Monel welding electrode 190 or equal.
2. Consult Owner Material/Welding engineer for the selection of filler material.
3. The chemical composition of weld overlays shall meet the requirements of **ELOT EN 1011-5 and ELOT EN ISO 9692-4,** pertinent specifications.
4. All overlaying requires at least two passes, unless Vendor verifies that other processes can meet chemical requirements.
   Overlays usually require a minimum of two layers however, single-layer overlays are acceptable provided dimensional requirement are met, chemical composition, at the specified depth, and soundness are satisfactory.
   Owner approval is required prior to use in fabrication.
   The number of layers in production shall not be less than the number of layers in the procedure qualification test.
5. Annealed Monel material.

TABLE 8 -ACCEPTABLE FILLER METALS FOR JOINING ALUMINUM AND ALUMINUM ALLOYS (1)

Material to be welded	1060	1100	3003	3004	5050	5052 5652	5083	5086	5154 5254	5456	6061 6063
1060	ER 1260 ER 4043	ER 1100 ER 4043	ER 1100 ER 4043	ER 4043	ER 1100 ER 4043	ER 4043	ER 4043 ER 5356	ER 4043 ER 5356	ER 4043 ER 5183	ER 4043 ER 5356	ER 4043
1100		ER 1100 ER 4043	ER 1100 ER 4043	ER 4043 ER 5356	ER 4043 ER 5356	ER 4043 ER 5356	ER 4043 ER 5356	ER 4043 ER 5356	ER 4043 ER 5183	ER 4043 ER 5356	ER 4043
3003			ER 1100 ER 4043	ER 4043 ER 5356	ER 4043 ER 5356	ER 4043 ER 5356	ER 4043 ER 5356	ER 4043 ER 5356	ER 4043 ER 5183	ER 4043 ER 5356	ER 4043
3004				ER 4043 ER 5356	ER 4043 ER 5356	ER 4043 ER 5356	ER 5356 ER 5556	ER 5356 ER 5556	ER 5356 ER 5654	ER 5356 ER 5556	ER 4043 ER 5356
5050					ER 4043 ER 5356	ER 4043 ER 5356	ER 5356 ER 5556	ER 5356 ER 5556	ER 5356 ER 5654	ER 5356 ER 5556	ER 4043 ER 5356
5052 5652						ER 4043 ER 5356	ER 5356 ER 5556	ER 5356 ER 5556	ER 5356 ER 5654	ER 5356 ER 5556	ER 5356 ER 5556
5083							ER 5183 ER 5356	ER 5356 ER 5556	ER 5356 ER 5556	ER 5183 ER 5556	ER 5356 ER 5556
5086								ER 5356 ER 5556	ER 5356 ER 5556	ER 5356 ER 5556	ER 5356 ER 5556
5154 5254									ER 5356 ER 5654	ER 5356 ER 5556	ER 5356 ER 5556
5456										ER5356 ER5556	ER5356 ER5556
6061 6063											ER4043 ER5356

Notes:

1. The filler metal listed on the top line of each combination is the preferred wire. The filler metal listed on the bottom line of each combination is an acceptable alternate.

2. The choice of filler metal may be limited by service conditions such as immersion in fresh or salt water, exposure to specific chemicals, or to a sustained temperature between 65 °C and 230 °C.
   Contact Owner if such condition exists for specific recommendation.