PRODUCT STANDARD

HYDERABAD

GAS TURBINE FUSION ARC WELDING - SPECIFICATION

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GAS TURBINE FUSION ARC WELDING - SPECIFICATION

1. SCOPE

1.1 Statement of Applicability

This specification states the fusion arc welding and related process requirements for all parts, other than piping, made to engineering drawings for the Gas Turbine Manufacturing Operation or other products as deemed applicable. Specification GT54031 applies to fabrications made by BHEL and by other companies contracted by BHEL.

1.2 Exclusions

Welding and related requirements for piping are covered by Specification GT54160, which shall be the applicable document for welding of all fluid-containing (includes both liquids and fuel gas) piping assemblies and systems, including any that were previously covered by GT54031. However, GT54031 remains the applicable specification for welding tubular components used for mechanical purposes or functions other than those typically associated with fluid-containing piping systems (e.g. welding of combustion liners, flow sleeves, wrappers, and transition pieces is governed by GT54031).

2. COMMUNICATION

2.1 External Supplier

BHEL - is the authorized interface for all communication between BHEL and the External Supplier. All questions or requests for additional information shall be submitted to Sourcing for clarification. Conflicts between applicable Specifications and/or drawings shall be submitted to Sourcing for resolution by Engineering.

2.2 Internal Supplier

All communication, including questions or request for additional information shall be submitted to Materials and Processes Engineering - (MPE) or the appropriate Design Engineering component.

2.3 Requests for Deviation

Deviations from this specification must be approved by MPE. Requests for deviations to the requirements of this specification shall be submitted as follows:

2.3.1 External Supplier - To Sourcing by Supplier Deviation Request (SDR).

2.3.2 Internal Supplier - To the appropriate engineering personnel by Quality Control Report (QCR) or Non Conformance Notice (NCN).

3. APPLICABLE DOCUMENTS

3.1 Documents

The following documents shall form a part of this specification to the extent specified herein. Unless otherwise specified, the latest issue shall apply.

3.1.1 BHEL

GT10146	Magnetic Particle Testing
GT10160	Visible Dye Penetrant Testing
GT10157	Fluorescent Penetrant Testing
GT54160	Welded Fabrication of Gas Turbine Piping
GT10222	Heat Treat Process Control
GT11060	Visual Inspection Requirements for Weldments
GT10620	Suppliers Quality Requirements

3.1.2 American Welding Society (AWS)

AWS A2.4	Symbols for Welding & Non-Destructive Testing
AWS A3.0	Standard Welding Terms and Definitions
AWS B2.1	Specification for Welding Procedure and Performance Qualification

AWS B1.11	Guide for the Visual Examination of Welds
AWS D.17.1	Specification for Fusion Welding for Aerospace Applications

3.1.3 American Society for Testing & Materials (ASTM)

E 1742	Standard Practice for Radiographic Examination
ASTM E164-03	Standard Practice for Ultrasonic Contact Examination of Weldment
ASTM A370	Standard Test Methods and Definitions for Mechanical Testing of Steel Products

3.1.4 American Society of Mechanical Engineers (ASME Boiler & Pressure Vessel Code)

SFA-5.5 - Specification for Low-Alloy Steel Electrodes for Shielded Metal Arc Welding

Section I - Rules for Construction Of Power Boilers

Section V-Non-Destructive Examination

Section VIII-Div. I-Rules for Construction of Pressure Vessels

Section IX-Welding & Brazing Qualification

3.1.5 European Standards

EN 287-1	Qualification Test of Welders – Fusion Welding
EN 875	Destructive Tests on Welds in Metallic Materials – Impact Tests
EN 1011-1	Welding – Recommendations for Welding of Metallic Materials
EN 1418	Approval testing of welding operators for fusion welding and resistance weld setters for fully mechanized and automatic welding of metallic materials

ISO 6947	Welds – Working positions – Definitions of angles of slope and rotation
ISO 9606	Approval testing of welders – Fusion welding
ISO 15609	Specification and Qualification of Welding Procedures for Metallic Materials – Welding procedure specification
ISO 15612	Specification and Qualification of Welding Procedures for Metallic Materials – Qualification by adoption of a standard welding procedure
ISO 15613	Specification and qualification of Welding Procedures for Metallic Materials – Qualification based on pre-production welding test
ISO 15614-1	Specification and Qualification of Welding Procedures for Metallic Materials – Welding Procedure Test

3.2 Hierarchy of Documents

In the event of a conflict between documents, the order of precedence from highest to lowest is:

- Purchase Order
- Part Drawing
- Part Specification
- Process Specification (casting, forging, welding, coating, etc.)
- Material Specification

4. DEFINITIONS

4.1 Documentation

4.1.1 First Piece Qualification (FPQ) - First Piece Qualification documentation containing the results of the tests and inspections performed on the First Piece as required for qualification.

4.1.2 Manufacturing Process Plan (MPP) - A BHEL-approved, detailed, step-by-step list of operations by which the parts are planned to be processed, tested and inspected.

4.1.3 Procedure Qualification Record (PQR) - A PQR is a record of the welding variables used to weld a test coupon, and the test results of having tested the welded coupon.

4.1.4 Welding Procedure Specification (WPS) - A WPS is a written qualified welding procedure prepared to provide direction for making production welds to specified requirements. A WPS is verified to make sound welds by its supporting PQR.

4.1.5 Welder Performance Qualification Record (WPQR) – A WPQR is a written record certifying the qualification ranges of an individual welder or welding operator.

4.2 Material Classification

4.2.1 Aerospace Materials Specification (AMS) – Specifications used in the aerospace industry.

4.2.2 "P" Number – Base materials are classified by welding "P" numbers in accordance with the ASME Boiler and Pressure Vessel Code Section IX, or by BHEL Specification number for materials with no ASME-assigned "P" number, or by trade names for unassigned materials.

4.2.3 Weld filler materials are classified by industry specifications, BHEL internal specifications, or by trade names for unassigned materials.

4.3 Personnel

4.3.1 External Supplier - The corporation, company, partnership, sole proprietorship or individual engaged to perform the process covered by this specification.

4.3.2 Internal Supplier - Any BHEL Energy Manufacturing Department.

4.3.3 MPE – GT Engg.

4.3.4 Purchaser - The BHEL Energy or its Business Associate.

4.3.5 Supplier - As used herein, unless specifically designated, refers to either an External or an Internal Supplier.

4.4 Specification Deviation Documents

4.4.1 Applicable to External Supplier

Supplier Deviation Request (SDR) - A method for the documentation, approval, and control of a waiver, substitution, or request for non-conformance corrective action for materials, processes, quality, or dimensions which deviate from Purchase Order documents (drawings, specifications, engineering instructions, etc.).

4.4.2 Applicable to Internal Supplier

Quality Control Report (QCR) or Non Conformance Notice (NCN) -BHEL Energy Manufacturing Department non-conformance report initiated during processing through the factory and used by Manufacturing to document non-conformance to governing documents and to request corrective action.

4.4.3 Frozen Process Change Request (FPCR)

After qualification the process is considered "frozen". In order to change the process, a frozen process change request must be made and approved by BHEL .

4.5 Standards – codes, specifications, recommended practices, methods, classifications, drawings, and guides.

4.6 Weld Symbols – The American Welding Society in AWS A2.4 defines weld symbols.

5. RESPONSIBILITIES

5.1 MPE shall maintain and update this specification as needed.

5.2 Suppliers shall qualify all welders and welding procedures used. Approval of all qualifications shall be in accordance with Section 7.

5.3 Suppliers shall maintain all records identified in this specification.

5.4 Sourcing Quality shall ensure that all External Supplier welders and welding procedures are properly qualified to this document before they begin production work.

5.5 BHEL Gas Turbines Plant Welding Engineer shall ensure that welding procedures are qualified according to ASME Section IX, AWS B2.1, or ISO 15609 and that all Internal Supplier welders and welding procedures are qualified to the requirements of this specification before they begin production work.

5.6 Certificate of Conformance

External suppliers shall promptly submit a Certificate of Conformance (CoC), to the buyer, for each component/fabrication stating that the component/fabrication was processed in accordance with the requirements of this Specification and other applicable documents. The Certificate shall be signed and dated by an authorized Supplier Representative and shall, as a minimum, include the following information:

- Supplier Name, Address and BHEL-designated External Supplier Code
- BHEL Purchase Order Number and date
- BHEL Drawing and Serial Number
- MPP Identification Number (if applicable), Revision Level, and Revision Date
- SDR Numbers

The buyer can request that all CoC's be maintained by the supplier in lieu of submittals, but must be available upon request or audit.

5.7 Audit of Supplier's Facilities and Practices

5.7.1 The Purchaser reserves the right to periodically audit the Supplier's facilities and practices. Such audits shall not relieve the Supplier from the responsibility of producing the fabrications in a suitable condition.

5.7.2 The Purchaser reserves the right to perform additional checks, such as UT or RT, in order to verify if the weld quality meets the requirements, even if there is no such check required by the drawing/specification. The acceptance criteria will be those of GT54031 for the relevant inspection method used. If BHEL is satisfied that the Purchaser's inspection methods, techniques, and results are valid and that the parts are truly defective, the Supplier shall repair or replace such parts at the Supplier's own expense.

6. WELD CLASSIFICATION

6.1 Assignment of Classifications

6.1.1 BHEL Engineering shall assign the relevant Weld Classification for each weld joint, and it shall be stated on the applicable drawing. Weld classifications are based on a parametric evaluation by the design engineering team, on a case-by-case basis, to establish weld control requirements.

6.1.2 Classifications I, II, III, IV, in order of declining criticality, are assigned to each weld as follows:

Class I Welds that have the potential to cause system un-scheduled outages, affect critical system reliability or safety.

Class II Welds that have the potential to cause events that degrade system performance but do not impact overall system availability, or welds that are part of a complex component.

Class III Welds that are not critical to component structural or functional integrity but still must be qualified.

Class IV Weld that requires no procedure qualification, such as capacitance discharge welding for attaching thermocouples.

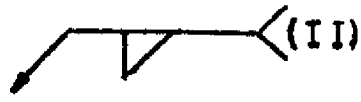
6.1.3 Qualification requirements for each classification are shown in Table 7.1.

6.2 Weld Classifications on Drawings

6.2.1 The classification shall be written as a general drawing note or shown in the tail of the weld symbol.

A If all or most welds on a particular drawing are of one Class, a general note may be used. For example,"Unless otherwise specified, all welds are classification II."

B For individual weld joint asssigment, place the Class of the weld in the tail of the weld symbol. Any Class specified in the tail of a weld symbol supercedes general drawing notes. For example, see below:



6.2.2 If no welding class is specified on the drawing, the weld is Class II.

7. QUALIFICATION REQUIREMENTS

7.1 Approval

7.1.1 Welding is not released for production until the WPSs, PQRs, and welder qualifications have been approved.

7.1.2 For fabrications made by suppliers outside the Gas Turbine Operation, WPSs, PQRs, and WPQRs shall be submitted through Sourcing to the SQE and MPE for approval in accordance with Table 7.1.

7.1.3 For fabrications made inside BHEL Gas Turbines Manufacturing Plant Welding Engineer shall be responsible for issuing welding special process and manufacturing engineering instruction and qualification packages. Approval for Class I and II welds shall be by the qualification team in accordance with Table 7.1.

7.2 MPP and FPQ

An MPP and FPQ are required for each new supplier and a new design unless otherwise authorized by BHEL. Detailed requirements for the MPP and FPQ shall be presented according to the applicable part specific process specifications or GT10620.

7.3 Procedure Qualification Record

7.3.1 Each manufacturer is responsible for the welding done by their organization and shall conduct the tests required to qualify the welding procedures they use in a PQR as required by Table 7.1.

7.3.2 PQRs are to be in accordance with ASME Section IX, AWS B2.1, ISO 15613, or ISO 15614-1 standard and shall comply with any standard required by local regulation or contract.

7.3.3 PQRs developed by acquired companies may be used to qualify WPSs for the new owners. The source of the PQRs shall be preserved.

7.4 Welding Procedure Specifications

7.4.1 Detailed WPSs shall be prepared for all welds. WPSs for Class I, II, and III welds shall be qualified and documented in accordance with one of the following standards, whichever is most suitable for the application: ASME Section IX, AWS B2.1, or ISO 15614-1.

7.4.2 WPSs for Class I, II, and III welds shall be qualified by a PQR in accordance with Paragraph 7.3 and ASME Section IX, AWS B2.1, or ISO 15609.

7.4.3 Short circuiting gas metal arc welding is prohibited on metal thicknesses greater than ¼"[6.3mm], except for the root pass of a groove weld that is either removed by back gouging or totally consumed by another approved welding process.

7.4.4 Heat input shall be calculated per Paragraph 8.9.2.

7.4.5 For materials with less than 3% elongation, a macro-etch specimen in accordance with ASME Section IX, QW-183(a) shall be used in lieu of each required bend test.

7.4.6 Standard WPS's (SWPS) for P1 and P8 materials, per ASME Section IX Article 5 or AWS B2.1, are considered prequalified, and may be used as specified by the issuing standard.

SWPS's that use GMAW-S are not allowed.

7.5 Welder Performance Qualification Record

7.5.1 All welders and welding operators are qualified in accordance with either ASME Section IX, AWS B2.1, EN 287-1 or EN 1418 standard. Qualifications shall be documented in accordance with the same standard by which they are qualified.

7.5.2 Suppliers shall maintain self-certified records of the procedures used and welders and welding operators employed, showing the date and results of procedure and performance qualifications, and the identification designation assigned to each welder and welding operator.

7.5.3 Internal Supplier welders shall also meet the visual acuity requirement of AWS D17.1 Paragraph 4.2.1.

TABLE 7.1: REQUIREMENTS FOR EACH WELD CLASSIFICATION

Para	Title	Class			
		I	II	III	IV
7.1	Approval by Qualification Team (Including MPE)	X			
7.1	Approval by Sourcing or Manufacturing Qualification Team	X	X	X	
7.3	Procedure Qualification Record	X	X	X	
7.4	Welding Procedure Specifications	X	X	X	X
7.5	Welder Performance Qualification Record	X	X	X	
8.4	Calibration (Electrical Characteristics)	X	X	X	
8.21	Welder Identification Record	X	X		
All	All other general requirements	X	X	X	X

8. PRODUCTION PROCESS REQUIREMENTS

8.1 Adding Weld Joints

BHEL approval through SDR, NCN, or FPCR is required if additional weld joints not shown on the drawing are required to fabricate a component. The new weld joint, including weld joint design and inspection requirements as defined by BHEL, shall be documented in an approved qualification (with an approved WPS) prior to use.

8.2 Backing Gas

The purpose of backing gas, or purging gas, is to prevent oxidation on the backside of open butt welds and welds on thin sections. General requirements for backing gas are as shown in Table 8.1.

TABLE 8.1: BACKING GAS REQUIREMENTS

Material	Purging Requirement on Open Butt Welds
Carbon and low alloy steels up to 3% alloying addition or Chrome-Moly grade 22	None
Steels with alloy content above 3%, including 5-9% Cr, and all stainless steels	Always
Nickel, Cobalt, and Copper Alloys	Always

8.3 Backing Plates

8.3.1 When allowed, backing plates used for full penetration welds shall be documented on the MPP. Backing plates shall be of the same P number composition as the base material except backing plates made from P1 material may be used for welding P1, P3, P4, P5A, or P11B materials. Any other backing materials shall be approved through SDR, NCN, or FPCR.

8.3.2 Backing plate removal is recommended.

8.4 Calibration

To assure that welders, welding operators and inspectors can determine the electrical characteristics of automatic and semi-automatic welding operations, a means shall be provided for determining amperage and voltage output of the welding equipment. The welding equipment measuring electrical characteristics are to be calibrated annually as a minimum as follows:

At zero amperes, 50 amperes, and maximum meter ampere reading, and in 5-volt increments from the minimum to the maximum qualified voltages. After calibration, instrument readings must be within five percent of the meter reading.

For mechanized welding, travel speed of manipulator equipment shall be calibrated annually to within five percent of indicator reading.

Calibration shall be traceable to NIST standards or other suitable national standards if outside the United States.

8.5 Cleaning and Joint Preparation

8.5.1 Surfaces to be welded shall be suitably prepared. Undercuts, gouges and obstructions shall be blended free of re-entrant angles such that they would be suitable for MPI or LPI inspection. Cracks must be removed to sound metal and excavations shall be inspected by MPI or LPI. Repaired regions shall be inspected by MPI or LPI per Section 9 after repair. Approval through SDR is required before repairing laminations.

8.5.2 Prior to welding, all surfaces of base metals approximately two inches adjacent to the weld joint must be cleaned of loose materials and protective coatings that could leave a harmful residue in the weld. The weld joint surfaces and base metal for approximately ½-inch distance adjacent to the weld preparation shall be free of oil, grease, moisture, scale, rust, weld spatter, zinc coating, slag, dirt, paint, or other foreign matter.

8.5.3 Cleaning may be accomplished by wire brushing, abrasive blasting, grinding, or by using a solvent cleaner such as acetone or isopropyl alcohol. Abrasive blasting or power wire brushing is not recommended if subsequent liquid penetrant examination is to be performed on these surfaces.

8.5.4 Cleaning compounds, cutting lubricants, or crayons that contain harmful amounts of sulfur, lead, or halides (chlorides and fluorides) shall not be used in the weld joint areas prior to or during welding. If the weld area surfaces have been exposed to contaminate, a solvent cleaner such as acetone or isopropyl alcohol shall be used to clean the area prior to welding.

8.5.5 Grinding should be with resin-bonded aluminum oxide or silicon carbide grinding wheels or tungsten carbide deburring tools. Wire brushes used on stainless steel and nonferrous alloys shall be stainless steel. Brushes must be appropriately marked to prevent mixing with brushes used on carbon and low-alloy steels.

8.5.6 Electric grinders are recommended, because air used to operate air grinders may contain a mist of oil. For stainless and nonferrous welding, solvent cleaning should be performed after use of air grinders.

8.5.7 Interpass Cleaning: Each weld bead shall be cleaned of slag, oxides, or other contaminants prior to depositing the next weld bead. Weld beads shall be free of cracks, excessive convexity, sharp ridges and valleys, and blowholes.

8.5.8 When ferrous alloys are cut by thermal processes, preheat shall be applied for those materials which require preheat for welding as specified in Paragraph 8.13.1. The reaction layer shall be removed by mechanical means to bright metal and the cut surface shall be magnetic particle inspected for defects per Paragraphs 9.1.3 and 9.4.1.

8.5.9 Alloys containing more than 10% cobalt are prone to liquid metal embrittlement when contaminated with copper. When copper fixtures are used during fabrication, check for presence of copper on part surfaces before subjecting part to heat treatment or coating. Light abrasive cleaning followed by alcohol rinse can be used to remove the presence of copper. Appropriately inspect the potentially contaminated area after welding or other elevated temperature exposure. BHEL approval on MPP or SDR required for cleaning and inspection methods on these materials.

8.6 Filler Metal

8.6.1 The weld filler metal may be specified in the tail of the welding symbol or as a drawing note. It shall be identified by column letter designation per Appendix II, or by BHEL or AWS/AMS specification in the drawing notes. Any deviation from the specified filler metal shall be approved through SDR, NCN, or FPCR.

8.6.2 If not designated on the drawing, filler metal shall be per Appendix II unless otherwise approved and documented in WPS.

8.6.3 Appendix II is provided as a list of common filler metals for various base metal combinations.

8.7 Full Penetration Welds

8.7.1 Where single-welded full penetration joints are used, particular care shall be taken in aligning and separating the components to be joined so there will be complete penetration and fusion for the full length of the joint root.

8.7.2 Where double welded full penetration joints are used, the reverse side shall be prepared by air arc or plasma arc cutting inaccordance with 8.5.8, grinding, or chipping to sound metal before weld metal is deposited from the second side. After grinding, 100% visually inspect the backgouged surface prior to second side welding, unless otherwise noted on drawing.

8.8 Furnace Requirements

8.8.1 Furnaces shall be calibrated per GT10222.

8.8.2 Each furnace charge shall have a minimum of 2 thermocouples placed in direct contact with the metal so as to adequately monitor the temperature of the anticipated hottest and coldest sections.

8.8.3 All temperatures refer to metal temperature, not gas or furnace temperature.

8.8.4 The tolerance on temperatures shall be ± 25F [15C].

8.8.5 Parts shall be placed in furnace at a temperature not exceeding 800F [427C], or 500F [260C] more than the temperature of the weldment at time of insertion into the furnace, whichever is less.

8.9 Heat Input Restrictions

8.9.1 When welding the high yield and special treatment steels, such as HY-80, HY-100 and T-1, the heat input of each production weld shall be no greater than that qualified.

8.9.2 Heat input for non-waveform controlled power supplies shall be determined according to ASME Section IX QW-409.1 or EN 1011-1 clause 19. Heat input for waveform controlled power supplies shall be determined according to the 2010 edition or later of ASME Section IX QW-409.1.

8.10 Impact Test Requirements.

8.10.1 Welds that must meet notch toughness shall be identified on the drawing.

8.10.2 When notch toughness is specified on the drawing the specified impact test shall be included as part of the procedure qualification. Impact testing shall be conducted at a temperature that meets design requirements and in accordance with a nationally recognized standard, such as ASTM A370 or EN 875.

8.10.3 When notch toughness is specified on the drawing the heat input of each production weld shall be no greater than that qualified. Heat input shall be calculated per Paragraph 8.9.2.

8.10.4 When notch toughness requirements are specified, the weld filler metals shall be tested and certified to the specified properties.

8.11 Material Control

8.11.1 Materials shall be clearly identified and stored in a manner to prevent mixing.

8.11.2 Flux-covered electrodes shall be clean and dry when used and stored in a clean, dry area in a manner to maintain their original condition.

8.11.3 Low hydrogen SMAW electrodes (EXX15, -16, -18, -28) and (EXXX15, -16, -18):

A Shall be kept in their original hermetically sealed shipping containers or stored in heated ovens to assure their low hydrogen characteristics are maintained.

B Electrodes of the EXXX15, 16, or 18 class shall be used within 1 hour after removal from their sealed container or the oven. Electrodes of the EXX15, 16, 18, or 28 class and stainless steel, nickel base, and cobalt base SMAW electrodes shall be used within 4 hours after removal from their sealed container or the oven.

C Electrodes that have been removed from their original containers or holding ovens that were not used within the specified time shall be discarded or be reconditioned according to ASME SFA-5.5 Table A1.

D Holding temperatures shall be according to the manufacturer's requirements. If no requirements are provided, then oven temperature shall be held at 300F ± 50F [150C +/- 28C].

8.11.4 Bare wire shall be stored in a manner that will keep it clean. Spools of wire used for automatic welding shall be covered or removed from the wire feeder if they could become contaminated from exposure to the work place environment.

8.11.5 Flux shall be stored in hermetically sealed shipping containers in such a manner that the material is protected against exposure to moisture pick-up. This includes both warehouse storage and transportation. If moisture pick-up is suspected, the flux shall be dried and stored in accordance with the manufacturer's recommended practice before the material is put in service. The distribution of flux with pneumatic equipment shall be applied with a cleaned, dried and filtered air supply system. Flux that was fused during the welding operation shall not be recovered and re-used.

8.11.6 Any material not conforming to these handling requirements shall be discarded or re-conditioned per the manufacturer's recommendations.

8.12 Peening

Peening of any weld surfaces shall not be performed without MPE approval, and when used shall be included as a nonessential variable in the weld procedure qualification. Cleaning of welds with chipping hammers or needle descalers used to remove flux and slag is not considered peening, as long as the weld metal is not deformed by such action on the final weld cap pass.

8.13 Preheat

8.13.1 Table 8.2 stipulates the minimum preheat requirements for welding Gas Turbine components. Preheating as specified in Table 8.2 shall also be employed for thermal cutting and tack welding. When the customer or local prevailing regulations require higher preheating temperature, the specific requirements shall be identified on the drawing or ordering sheet and shall take precedence.

8.13.2 When welding two different P-Number materials, the minimum preheat will be the higher temperature for the materials being welded.

8.13.3 When it is not feasible to uniformly preheat the entire part, local heating may be performed in such a manner that the heated area completely surrounds the welded area for a minimum of 3" [76mm] or 1.5 times the base metal thickness, whichever is greater. Base metal thickness is the greater of the nominal thicknesses at the weld of the parts to be joined.

8.13.4 After welding commences, the minimum preheat temperature shall be maintained until any required PWHT is performed on P-Nos. 3, 4, 5A, 5B, and 6.

TABLE 8.2: WELD PREHEAT REQUIREMENTS

MATERIAL	MIN PREHEAT	NOTES	MAX INTERPASS
P1 (Low Carbon Steel)	• 170F [77C] (C >0.3% & t >1" [25.4mm]) • 50F [10C] for all others when t <1.5" [38mm] • 150F [66C] for all others when t >1.5" [38mm]	1	750F [399C]
P3 (C - 1/2 Mo)	• 175F [77C] (UTS >70 KSI (500 Mpa) or t >1/2" [12.7mm]) • 50F [10C] for all others	2	750F [399C]
P4 (1-1/4 Cr - 1/2 Mo)	• 300F [149C]	2	750F [399C]
P5A (2-1/4 Cr - 1 Mo)	• 350F [177C]	3	750F [399C]
P6 (410SS)	• 400F [204C]	3	750F [399C]
P7 (405SS, 409SS)	• 50F [10C]		600F [316C]
P8 (304SS, 310SS)	• 50F [10C]		350F [177C]
P15E (9Cr-1Mo-V)	• 400F [204C]	4	750F [399C]
HY-80	• 50F [50C] (t <1-1/8" [28.6mm]) • 150F [66C] (t >1-1/8" [28.6mm])		300F [149C]
P-11B (T-1)	• 50F [10C] (t <1" [25.4mm]) • 150F [66C] (1" [25.4mm]. <t <2" [51mm]) • 200F [93C] (2" [51mm]<t <4" [102mm]) • 350F [177C] (t >4" [102mm])		400F [204C] 400F [204C] 450F [232C] 450F [232C]
1-1.5Cr, 1-1.5Mo, 0.25-0.5V	• 450F [232C]	1	750F [399C]
Fe, Co & Ni Base Super Alloys	• 50F [10C]		350F [177C]

NOTE 1 Preheat over 50°F [10C] during thermal cutting, section 8.6.8, is not required for P1 materials with a carbon content < 0.30% regardless of thickness. However, the supplier may preheat to maintain cut quality as needed.

NOTE 2 Preheat shall be maintained until the start of the stress-relief treatment.

NOTE 3 Preheat shall be maintained until the start of the stress-relief cycle; or preheat temperature shall be elevated above 400F [204C], and less than 800F [427C], held 1 hour per 1" [25.4mm] of thickness with a minimum of 2 hours, and the part covered with a refractory insulating blanket or equivalent and allowed to slow cool.

NOTE 4 Upon completion of welding (prior to cooling down), the part needs to maintain a hydrogen bake out at 500F [260C] minimum for 4 hours. After hydrogen bake out a mandatory cool down to 200F [93C] max or below throughout the wall thickness with a cooling rate is 200F [93C] / hr is required prior to post weld heat-treatment.

8.14 Post weld heat treatment

8.14.1 Post weld heat treat temperatures shall be per Table 8.3.

8.14.2 Minimum holding time is 1 hour/inch of weld deposit thickness. Maximum holding time of production welds cannot exceed 20% of the holding time used in the procedure qualification. That is, the maximum holding time for production welds is:

$$\frac{1.2 * (\text{Production Weld thickness}) * (\text{PQR Hold Time})}{(\text{PQR Weld thickness})}$$

8.14.3 All parts shall be free of foreign material such as dirt, oil, grease, etc. before PWHT.

8.14.4 If multiple heat treatments are to be performed on a part, the PQR heat treatment shall include all PWHT time and temperatures that will be experience by the part.

8.14.5 The weldment may be removed from the furnace when the temperature of the metal has fallen below 600F [315.5C].

8.14.6 When welding two different P-Number materials, the minimum postweld heat treatment will be the higher temperature specified for the materials being welded.

8.14.7 Post weld heat treatment of P1 materials is required when at least one of the members being welded exceeds 1-1/2" [38mm] in thickness unless the weld is less than 3/4" [19mm] in depth (throat measurement for fillet weld).

8.14.8 Post weld heat treatment of P3 materials is required as follows:

A All thickness of ASTM A-302 material.

B All materials in excess of 5/8" [16mm] thick unless only welded with a fillet weld with throat dimension less than 3/8" [9.5mm].

C All materials less than 5/8" [16mm] thick if they are greater in thickness than the procedure qualification samples.

8.14.9 For joining P8 materials (300 series stainless steels) to materials that require PWHT, the materials requiring PWHT shall be buttered with the appropriate

filler metal selected from Appendix II, given the applicable PWHT and then joined to the P8 material, without a subsequent PWHT.

8.14.10 Post weld heat treat exclusion allowed per ASME B&PVC Section I as long as applicable requirements (thickness, chemistry, preheat) are met.

8.14.11 When it is impractical to PWHT at temperatures listed in Table 8.3, it is permissible to PWHT P1 Group 1 and 2 materials per Table 8.4.

8.14.12 The required PWHT may be performed by local heating operations when the procedure is approved by MPE.

TABLE 8.3: POST WELD HEAT TREATMENT TEMPERATURES

Material	**Min**	**Max**
P1 Group 1,2,3	1100F [580C]	1250F [677C]
P3 Group 1,2	1100F [580C]	1275F [691C]
P4 Group 1	1200F [649C]	1300F [704C]
P4 Group 2	1200F [649C]	1350F [732C]
P5A	1250F [677C]	1400F [760C]
P5B Group 1	1250F [677C]	1425F [774C]
P6 Group 1,2,3	1400F [760C]	1475F [802C]
P7 Group 1,2	1350F [732C]	1400F [760C]
P15E	1375F [746C]	1400F [760C]

TABLE 8.4: ALTERNATE PWHT TEMPERATURES [1]

Decrease in Temperature Below Specified Minimum Temperatures	Minimum Holding Time Per Inch of thickness
50F (10C)	2 hours
100F (38C)	4 hours

Note 1 Lower postweld heat treatment temperatures are permitted only for P1, Group 1 and 2 materials.

8.15 Heating and Cooling Rates

Temperature during preheat and PWHT shall be raised and lowered uniformly according to Table 8.5.

TABLE 8.5: HEATING AND COOLING RATES

Metal Thickness	Maximum Rate (°/Hr)
0"-1" [0-25.4mm]	400F [222C]
2" [51mm]	200F [111C]
3" [76 mm]	135F [75C]
4" [102mm] & Up	100F [56C]

8.16 Pressure Retaining Welds

Pressure retaining welds shall be made with a minimum of two layers wherever possible. Where it is impractical to use two layers, any interruptions in the weld layer (starts and stops) should be carefully made to avoid leaks. In the case of the shielded metal arc process, for example, the weld shall be back stepped in increments not exceeding the length of weld deposited with one electrode. The end of each bead shall overlap the preceding bead by approximately ½" [12.7mm] and the crater shall be reduced to a minimum.

8.17 Tack Welds

All welds shall be made by qualified welders in accordance with a qualified procedure. Cracked or defective tack welds shall be removed prior to final welding. Tack welds shall be kept small or shall be tapered by chipping, grinding or burring to assure complete fusion with the subsequent weld.

8.18 Weld Joint Designs

8.18.1 The weld joint design shall be as specified on the drawing by figure number per Appendix III, IV, or V, or by welding symbol.

8.18.2 The Supplier may submit a request through MPP or FPCR process to change the weld joint design from that specified on the drawing. The proposed weld joint design and any new inspection requirements determined necessary by BHEL shall be documented in an approved qualification (with an approved WPS) prior to use.

8.19 Weld Position

8.19.1 Welding shall be done in the flat position when possible.

8.19.2 Welding positions are defined in ASME IX QW-460 or ISO 6947. The basic codes for positions are shown in Table 8.6.

TABLE 8.6: WELD POSITION CODES

PLATE	**ASME IX**		**ISO 6947**	
Position	Groove	Fillet	Groove	Fillet
Flat (F)	1G	1F	PA	PA
Horizontal (H)	2G	2F	PC	PB
Vertical (V)	3G	3F	PF (up) PG (down)	PF (up) PG (down)
Overhead (O)	4G	4F	PE	PD
PIPE	**ASME IX**			
Flat (F)	1G	1F (Rotated)		
Horizontal (H)	2G	2F or 2FR		
Vertical (V)	5G	5F		
Overhead (O)		4F		

8.19.3 Welding progression shall be upward in the vertical position unless the base metal thickness is 1/8" [3.2mm] or less.

8.20 Weld Weave Limitations

8.20.1 Shielded Metal Arc Welding - Weld weaves shall not exceed (3) three times the electrode core diameter for P1, P3, P4 and P5A materials. Welds made with "Fast Fill Electrodes" (EXX20, EXX27, EXX28) are restricted to stringer passes. The weave limitations for all other SMAW electrodes shall not exceed (2) times the electrode core diameter, except with the vertical up technique the weave may be up to (3) times the electrode core diameter. Weld weave limits may be further restricted when impact requirements must be met. Any deviations from these requirements may be approved through WPS-PQR or an MPP.

8.20.2 All Other Welding Processes - electrode weave shall not exceed 5/8" [15.9mm] without prior evaluation of workmanship samples suitably examined to determine that weld quality standards will consistently be met. Weld weave limits may be further restricted when impact requirements shall be met. Any deviations from these requirements must be approved through WPS-PQR or an MPP.

8.21 Welder Identification

8.21.1 Each welder making Class I or II welds shall be assigned an individual identification.

8.21.2 The welder shall stamp all Class I or II welds with the identification mark assigned, at three foot or smaller intervals within 1" [25.4mm] of the weld. Stamping shall be with low stress design stamps (round dot style or radius nose stamp).

8.21.3 As an alternate to stamping, the manufacturer may keep a record of the location of welds made by each welder.

8.21.4 Thin wall parts (less than 1/8" [3.2mm]) shall not be stamped unless specified on the drawing.

8.22 WPS Availability and Use

The WPS shall be available to the welder on the shop floor at all times and in a format and language understandable to the welder.

The welder shall be familiar with and comply with the WPS.

9. NONDESTRUCTIVE INSPECTION

9.1 Inspection Requirements and Responsibility

9.1.1 All welds shall be visually inspected to the acceptance criteria of Paragraph 9.5.1. Additional inspection shall be as specified on the drawing.

9.1.2 All exposed defects which exceed the specified allowances are the responsibility of the Supplier.

9.1.3 Nondestructive inspection methods shall be performed in accordance with the following specifications. Quality Assurance and MPE may approve other methods.

Visual Inspection
~~BHEL~~ Specification ~~GT11060.~~
AWS B1.11

Liquid Penetrant Inspection (LPI or FPI)
~~When fluorescent penetrant (FPI) is required, it shall be specified on the~~ drawing.
Gas Turbine Specification GT10160 or
Gas Turbine Specification GT10157 or
ASME Boiler & Pressure Vessel Code, Section V, Article 6.

Magnetic Particle Inspection (MPI)
Gas Turbine Specification GT10146 or
ASME Boiler and Pressure Vessel Code, Section V, Article 7.

Radiographic Testing (RT)
ASTM E 1742 or
ASME Boiler and Pressure Vessel Code, Section V, Article 2.

Ultrasonic Testing (UT)
ASME Boiler and Pressure Vessel Code, Section V, Article 5.
~~ASTM E164-03 Standard Practice for Ultrasonic Contact Examination of~~ Weldment

9.2 Inspection Codes

9.2.1 The weld inspection requirements are determined by the design engineer and materials and processes engineer consistent with the criticality of the joint.

The inspection requirements for each weld shall be specified on the drawing, and may be specified by a code as defined in Table 9.1.

TABLE 9.1: INSPECTION REQUIREMENTS

Code	Visual (9.5.1)		Liquid Penetrant or Magnetic Particle (9.5.3)		Radiographic (9.5.4)	Ultrasonic (9.5.5)
	Face	Root [1]	Face	Root [1]		
1	100%	100%	100%	N/A	100%	N/A
2	100%	100%	N/A	N/A	100%	N/A
3	100%	100%	100%	N/A	Audit [2]	N/A
4	100%	100%	Audit [2]	N/A	Audit [2]	N/A
5	100%	100%	100%	N/A	N/A	N/A
6	100%	100%	Audit [2]	N/A	N/A	N/A
7	100%	100%	N/A	N/A	Audit [2]	100%
8	100%	100%	N/A	N/A	N/A	100%
9	100%	100%	N/A	N/A	N/A	Audit [2]
10	100% + 100% per 9.2.2	100%	N/A	N/A	N/A	N/A
11	100% + Audit per 9.2.2 [2]	100%	N/A	N/A	N/A	N/A
12	100%	100%	100% per 9.2.2	See 9.2.2	N/A	N/A
13	100%	100%	Audit per 9.2.2 [2]	See 9.2.2	N/A	N/A

NOTE 1 When accessible.

NOTE 2 For Codes requiring audits, see Paragraph 9.4.

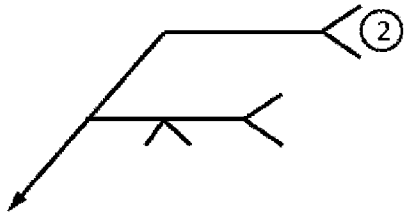
9.2.2 Requirements for root pass inspection (Codes 10 through 13) are as follows:

A The root pass inspection of fillet welds, partial penetration groove welds, and full penetration single-welded groove joints shall be made on the face of the deposited root pass and on the root of the weld if accessible.

B The root pass inspection of full penetration double-welded groove joints shall be made on (1) the face of the initial root pass, (2) the backside of the weld remaining after backgouging prior to second side welding, and (3) the face of the second-side root pass weld.

9.2.3 The inspection code may be used in the weld symbol tail, or in a general weld note.

For example, for weld joint requiring Code 2 (100% Visual, 100% RT inspection) it may appear on the drawing like this:



If all or most of the joints on a particular drawing would require one category of inspection, a general weld note may be used. For example, "Unless otherwise specified, all welds are to be inspected per GT54031 ②"

9.3 General Inspection Recommendations

If no inspection requirements are specified on the drawing, the minimum inspection requirements for each weld classification are shown in Table 9.2. Inspection requirements specified on the drawing over-ride the minimum requirements shown below.

TABLE 9.2: General Inspection Recommendations

Classification	Minimum Recommended Inspection
I	Code 4
II	Code 6
III	100% Visual Only
IV	100% Visual Only

9.4 Audit Inspection

9.4.1 Unless otherwise specified on the purchase order or the drawing, when audit inspection per GT54031 acceptance standards is specified, the length of weld inspected shall be a minimum of 5 percent the weld deposited by each welder.

When audit inspection per ASME acceptance standards is specified, it shall be to the extent defined by Paragraph UW-52 of Section VIII, Division I.

9.4.2 When a segment of weld length subjected to audit inspection is acceptable per GT54031 acceptance standards, the entire weld length represented by this inspection is acceptable.

9.4.3 When a segment of weld length subjected to audit inspection is unacceptable per GT54031 acceptance standards, the full extent of the defect shall be determined, removed, repaired, and be re-inspected. Additional audit inspections shall thereafter be conducted in accordance with audit plan requirements established by Sourcing Quality. In the absence of an established Quality Assurance or Sourcing Quality audit plan, two additional segments shall be inspected at different locations in welds made by the same welder(s) whose initially audited welds were unacceptable. The same audit percentage applied to the original segment shall be applied to the two additional segments.

A If the two additional segments meet GT54031 acceptance standards and the defects in the unacceptable segment are removed, repaired, re-inspected and meet GT54031 acceptance standards, then the entire weld represented by the three segments is acceptable.

B If one or both of the additional inspected segments are unacceptable per GT54031 acceptance standards, the entire weld made by that welder is rejected. The entire weld made by that welder must either (a) be completely removed, repaired and re-inspected, or must be (b) 100 percent inspected and all defects removed, repaired, and re-inspected to GT54031 acceptance standards.

9.5 Acceptance Criteria

9.5.1 Visual Acceptance Criteria

Appearance – Welds shall have a workmanship appearance with minimum variations in width and size of weld, and absence of sharp notches at face or root reinforcement. Spatter and projections from welding and any remaining tack welds shall be removed. All slag shall be completely removed.

Arc Strikes – In the base metal are unacceptable.

Blending – In the base metal shall not exceed the undercut allowance.

Contour -- The contour of the weld, with the exception of allowable undercut, shall blend smoothly and gradually into the base material. NOTE: The requirement for blending smoothly into the base material does not imply that grinding is encouraged. Rather, a carefully controlled welding procedure without the need for grinding is preferred.

Cracks – None allowed

Fillet Weld Size Tolerance – Shall be according to Table 9.3.

Table 9.3: FILLET WELD SIZE TOLERANCE

Fillet Size	Tolerance	Added Allowance
Up to 3/8" [9.5mm]	+ 1/8" [3.2mm] - 0	--
3/8" [9.5mm]. to 3/4" [19mm]	+ 1/8" [3.2mm] - 0	May be as much as 1/16" [1.6mm] undersize in any 2" [50.8mm] per 12" [304.8mm] of fillet weld length
Over 3/4" [19mm]	+ 3/16" [4.8mm] - 0	May be as much as 3/32" [2.4mm] undersize in any 2" [50.8mm] per 12" [304.8mm] of fillet weld length

Linear Indications – None allowed

Overlap (cold lap) – None allowed

Offset Tolerances – Weld joint offset shall be as shown in Table 9.4. See Appendix VI for more the definition of offset.

Joints exceeding the tolerance limits of Table 9.4 shall be reinforced and shall blend in with the base stock with a minimum 4:1 taper (for example, an offset requiring 1/8" [3.2mm] build-up at the edge shall join the base stock at least 1/2" [12.7mm] from the edge).

TABLE 9.4: MAXIMUM ALLOWABLE OFFSET IN WELDED JOINTS

Section Thickness	Maximum Offset
Less than ½" [12.7mm]	1/4t
½" [12.7mm] to 2" [50.8mm]	1/8" [3.2mm]
2" [50.8mm] over	1/16t (3/8" [9.5mm]. max.)

Porosity – None allowed

Reinforcement:

- 1/16" (1.6mm) max. for component thickness up to 3/16" (4.8mm);
- 1/8" (3.2mm) max. for component thickness of 3/16" to 1/2" (4.8mm to 12.7mm);
- 3/16" (4.8mm) max. for component thickness over 1/2" (12.7mm).

Starts/Stops – Starts and stops shall tie in to existing weld and blend smoothly, and for multipass welds starts/stops shall be staggered.

Undercuts (Including Burnback) – None allowed for component thickness up to 1/8" [3.2mm]. 1/32" [0.8mm] maximum for component thickness over 1/8" [3.2mm].

Underfill – None allowed except for acceptable undercut.

Weld Root: When accessible, the root of the weld shall be inspected in addition to the face of the weld.

9.5.2 Weld Flaws Exposed by Machining

Visual Inspection of Finish machined surfaces in weld metal subsequent to visual inspection of the prior weld surface shall be visually inspected without magnification. The inspection shall be limited to the machined surface within weld metal and adjacent base material within 1" [25.4mm] of the weld metal. Imperfections discovered within the specified regions during this visual inspection shall not exceed the following limits:

A Cracks, lack of penetration, or lack of fusion shall not be permitted.

B Porosity and Slag Inclusions less than 1/16" [1.5mm] length or diameter shall be non-relevant if separated by at least 1" [25.4mm] from any other indication and if they are not aligned for more than a 6" [152.4mm] length of weld.

C A maximum of three relevant pores or slag inclusions up to size shown in Table 9.5 shall be permitted in any 6" [152.4mm] of weld.

D Clusters of no more than three pores or slag inclusions, with the maximum individual size not greater than permitted by Table 9.5, shall be permitted within any 1" [25.4mm] circle, but with no more than one such cluster in any 12" [305mm] of weld.

TABLE 9.5: VISIBLE PORE OR SLAG INCLUSION SIZE EXPOSED BY MACHINING

Weld Thickness	Maximum Allowed Pore or Slag Size
3/4" [19mm] or less	3/32" [2.4mm]
>3/4" [19mm]	1/8" [3.2mm]

9.5.3 Magnetic Particle and Liquid Penetrant Acceptance Criteria. All of the following apply:

A. Indications up to ½ T where T is the weld thickness, or 1/16" [1.6mm], whichever is less, shall be considered non-relevant.

B. Relevant linear indications are not permitted.

C. Relevant rounded indications greater than ½ T, or 3/16" [4.8mm] maximum, are not permitted.

D. Four or more relevant rounded indications in a line separated by 1/16" [1.6mm] or less (edge to edge) are not permitted.

9.5.4 Radiographic Acceptance Criteria. All of the following apply:

A. No cracks, incomplete fusion, or incomplete penetration are permitted.

B. Elongated slag or tungsten inclusions with lengths greater than the following are not permitted:

- 1/4" [6.4mm]. for T up to 3/4" [19mm]
- 1/3 T for T from 3/4" [19mm]. to 2-1/4" [57mm]
- 3/4" [19mm] for T over 2-1/4" [57mm]
- Where T is the thickness of the weld, or thinner member when parts of unequal thickness are butt welded.

C. Groups of aligned indications that have an aggregate length greater than T in a length of 12T are not permitted, except when the distance between successive indications exceeds 6L (L = length of longest indication in group).

D. The through thickness of slag inclusions shall not exceed 1/4 of the thickness of the thinner member being joined.

E. Porosity in excess of that specified in Table 9.6 shall not be permitted.

TABLE 9.6: MAXIMUM PERMISSIBLE POROSITY IN 6" [152.4mm] LENGTH OF WELD

Weld Thickness	Maximum Size Pore	Total Permissible Area
Less than 1/8" [3.2mm]	t/4	$8(t/4)^2$
1/8" [3.2mm]	1/32" [0.8mm]	.008" [0.2mm]
1/4" [6.4mm]	1/16" [1.6mm]	.030" [0.8mm]
1/2" [12.7mm]	1/8" [3.2mm]	.060" [1.5mm]
3/4" [19mm]	3/16" [4.8mm]	.09" [2.3mm]
1" [25.4mm]	1/4" [6.4mm]	.120" [3.0mm]
2" [50.8mm]	1/4" [6.4mm]	.240" [6.1mm]
3" [76.2mm]	1/4" [6.4mm]	.360" [9.1mm]
4" [101.6mm]	1/4" [6.4mm]	.480" [12.2mm]

9.5.5 Ultrasonic Acceptance Standards. All of the following apply:

A. Indications are unacceptable if the amplitude exceeds the reference level established by the basic calibration block for ultrasonic examination of welds as stipulated in ASME Boiler and Pressure Vessel Code, Section V, Article 5 or by ASTM E164-03 Standard. The lengths exceed the following:

- 1/4" [6.4mm]. for T up to 3/4" [19mm]
- 1/3T for T from 3/4" [19mm] to 2-1/4" [57.2mm]
- 3/4" [19mm] for T over 2-1/4" [57.2mm]
- Where T is the thickness of the weld, or thinner member when parts of unequal thickness are butt welded.

B. Where indications are interpreted as cracks, lack of fusion, or lack of penetration, they are unacceptable regardless of length.

9.6 ASME Boiler and Pressure Vessel Code Acceptance Criteria

9.6.1 If the weld is to meet the requirements of the ASME Boiler and Pressure Vessel Code, a note shall appear in the note section of the drawing which reads "Welds shall be inspected using inspection methods and acceptance criteria specified in the ASME Boiler and Pressure Vessel Code as referenced in GT54031".

9.6.2 When ASME Boiler and Pressure Vessel Acceptance Standards are required by the drawing, the acceptance criteria shall be as follows:

- Liquid Penetrant: Appendix 8, Section VIII, Division I
- Magnetic Particle: Appendix 6 Section VIII Division I
- Radiographic: UW-51, Section VIII, Division I
- Ultrasonic: Appendix 12, Section VIII, Division I

9.7 Inspection of Heat Treated Welds

All acceptance inspections shall be performed after final heat treatment except as follows:

- Welds not accessible for inspection after final heat treat shall be inspected immediately prior to the assembly operation resulting in the inaccessibility, and after an intermediate post weld heat treatment.
- Welds in P1 or P3 materials subjected to multiple stress relieving heat treatments during fabrication may be inspected after an intermediate stress relief if the intermediate stress relief is performed at a temperature equal to or higher than any subsequent thermal treatment.

9.8 Repairs

9.8.1 Welds that do not meet the minimum specified acceptance standards shall have the defects removed and be weld repaired if necessary.

9.8.2 Defects shall be removed to the extent that the weldment is acceptable upon re-inspection by the same method and acceptance standards that originally disclosed the defect prior to weld repair.

9.8.3 All repairs shall be performed by a process approved for making the original weld or in accordance with an approved MPP. Any repairs required after post weld heat treatment shall require approval by SDR.

10. NOTES

None

APPENDIX I: METALLOGRAPHIC EVALUATION

I-1 Scope

This section on metallographic evaluation is provided as a consideration when other directions or specifications are not provided.

I-2 Preparation

Cross-sections should be prepared for metallographic evaluation using standard metallographic practices.

I-3 Evaluation Criteria

Evaluation criteria of weld flaws should consider the inspection requirements of the production parts.

If RT/UT is not required of production parts, cross-sections should be 80% sound (flaw free). If RT/UT is required of production parts, then flaws identified within cross-sections should meet the specified RT requirements.

Volumetric Examination (RT/UT) required of Production Part	Approximate Minimum Acceptable Weld Joint Soundness (%)
No	80 [1]
Yes	Use RT acceptance criteria specified on the drawing

Note 1: Based on ASME B31.1 Table 102.4.3 Longitudinal Weld Joint Efficiency Factors.

I-4 Acceptance Criteria

Acceptance Criteria must consider the joint design. For example, partial penetration welds often appear to have lack of fusion at the weld root.

Ni-based filler metals typically contain micro cracks up to 0.003" [0.0762mm]. That may be acceptable if the analyst considers that the density of cracking is as expected.

In the absence of clearly defined, metallographic acceptance criteria, acceptability ultimately relies on the customer's request and the analyst's judgment. The analyst's judgement includes what he considers to be typical for the joint design, the welding

processes used, the materials involved, and the amount of sound weld exhibited relative to the weld size required.

APPENDIX II: FILLER METAL SELECTION

II-1 Scope

This section on filler metal selection is provided as a consideration when other directions or specifications are not provided.

II-2 Use of Filler Metal Tables

To use the Filler Metal Selection Tables II.1-II.4, locate the row of the first base metal to be joined and the column of the second base metal to be joined. The intersect of the column and row gives the recommended Filler Metal Column to be used for that base metal combination. If the box is on the top-right half of the table, switch the column and row as only half of the table is filled in to prevent duplication. If no filler metal is listed for a particular combination, contact MPE to determine correct filler metal.

II-3 Use of Filler Metal Columns

Once a Filler Metal Column is determined from Tables II.1 through II.4, use Table II.5 to determine the acceptable filler metals for that Column.

Unless the process is specified on the engineering drawing, Weld Filler Metals in the same Column may be used interchangeably provided that (1) there is a qualified procedure for that class of filler and process, (2) the electrode and process are suitable for use in the intended welding position and within any limitations imposed on joint accessibility by component configuration, and (3) consideration has been given to the advisability of use of low carbon version of electrodes to avoid intergranular carbide precipitation and reduced weld corrosion resistance, or to avoid lower weld creep and rupture strength that may result from use of the low carbon versions. MPE shall be consulted regarding the details of items (2) and (3).

Table II.1 – Iron Based Materials Filler Metal Selection Table

ASME P#		P1	P3	P3	P4	P5A		P5B	P6	P7	P8	P8	P11
	Base Metal Welded To	Low C Steels	Corten	1/2 Mo Alloy Steel	1-1.25Cr-1/2Mo	2.25Cr-1Mo	1.25Cr-1Mo-0.3V	5Cr .5Mo or 9Cr 1Mo	403, 410	405, 409, 410S	300 Series SS	300L Series SS	T-1
P1	Low C Steels	AB/AD											
P3	Corten	AB	AB										
P3	1/2 Mo Alloy Steel	AB	AB	AG									
P4	1-1.25Cr-1/2Mo	AB	AB	AG	AI								
P5A	2.25Cr-1Mo	AB	AB	AG	AL	AL							
	1.25Cr-1Mo-0.3V	AB	AB	AG	AI	AL	AL						
P5B	5Cr .5Mo or 9Cr 1Mo												
P6	403, 410	AU	AU	BT/AU	BT/AU	BT/AU	BT/AU	BT/AU	AS				
P7	405, 409, 410S	AU	AU	BT/AU	BT/AU	BT/AU	BT/AU	BT/AU	AU	BQ/AU			
P8	300 Series SS	AU	AU	BT/AU	BT/AU	BT/AU	BT/AU	BT/AU	AU	AU	AE/AF/BE		
P8	300L Series SS	AU-L	AU-L	BT/AU	BT/AU	BT/AU	BT/AU	BT/AU	AU	AU-L	AE-L	AE-L	
P11	T-1	AB	AB	AB	AB	AB	AB	AB	AU	AU	AU	AU-L	AN

Table II.2 – Iron Based Materials to High Alloy Filler Metal Selection Table

ASME P#		P1	P3	P4	P5A		P5B	P6	P7	P8	P8	P11
	Base Metal Welded To	Low C Steels	Corten	1-1.25Cr-1/2Mo	2.25Cr-1Mo	1.25Cr-1Mo-0.3V	5Cr .5Mo or 9Cr 1Mo	403, 410	405, 409, 410S	300 Series SS	300L Series SS	T-1
	Alloy 120											
	Alloy 188											
	Alloy 230										BC	
	Alloy 263										BF/BC	
P15E	9Cr-1Mo-V(grade91)	AB	BK	AL	BK	AL	BK					
P42	Alloy 400	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD
P43	Alloy 600	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC
	Alloy 617											
P43	Alloy 625	BC	BC	BC	BI	BI	BI	BI	BI	BI/BF	BI	BI
	Alloy 718										BC	
	Alloy 750									BI	BI	
P45	Alloy 800	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC/AE-L	BC
	X40,X45,FSX-414							BA	BA	AE-L/BH	AE-L/BH	
	GTD-111											
	GTD-222							BA	BF	BF	BF	
	GTD-241									BF	BF	
	GTD-262										BF	
P43	Hast X, RA333	AU								BC	BC/AE-L /AZ/BE	
	N155											
	L-605 (Haynes 25)	BL		BL	BL	BL						
	19-9 DL											
	Haynes 282											
	Rene 108											

Table II.3 – High Alloy Filler Metal Selection Table

ASME P#						P15E	P42	P43		P43			P45
	Base Metal Welded To	Alloy 120	Alloy 188	Alloy 230	Alloy 263	9Cr-1Mo-V (grade 91)	Alloy 400	Alloy 600	Alloy 617	Alloy 625	Alloy 718	Alloy 750	Alloy 800
	Alloy 120	BI/BL/BO											
	Alloy 188		BG										
	Alloy 230			BL									
	Alloy 263		BF	BF	BF								
P15E	9Cr-1Mo-V(grade91)					BK							
P42	Alloy 400						BD						
P43	Alloy 600							BC					
	Alloy 617			BL					BM				
P43	Alloy 625									BI			
	Alloy 718										BB/BF		
	Alloy 750			BC	AZ/BC					BI		BC	
P45	Alloy 800							BC					BC/BN
	X40,X45,FSX-414		BH		BH/BF			BC			BC		BC/BH
	GTD-111									BI/BF			
	GTD-222		BF		BF			BC		BI			BC/BF
	GTD-241									BI			
	GTD-262									BI			
P43	Hast X, RA333	BI/BL/BO	AZ		BF			BH		BI		BC	BC/BH
	N155												
	L-605 (Haynes 25)				BA/BH								
	19-9 DL												
	Haynes 282												
	Rene 108									BF			

Table II.4 – High Alloy Filler Metal Selection Table

ASME P#							P43					
	Base Metal Welded To	X40, X45, FSX-414	GTD-111	GTD-222	GTD-241	GTD-262	Hast X, RA333	N155	L-605 (Haynes 25)	19-9 DL	Haynes 282	Rene 108
	X40,X45,FSX-414	AO/BH/BS										
	GTD-111											
	GTD-222			BF/BI/BP								
	GTD-241				BF							
	GTD-262					BF/BM						
	Hast X, RA333	AZ/BH		BF			AZ/BC/BF/BR					
	N155							AQ				
	L-605 (Haynes 25)	BA					BA		BA			
	19-9 DL									AP		
	Haynes 282										BR	
	Rene 108											

Table II.5 – Filler Metal Columns

Code	NOTES	**BHEL** Spec	Industry Spec	ASTM/ASME Classification	ASME F-No.	UNS No.	Trade Name
AA		B21B10A	A5.1	E6010	3		
		B21B10B	A5.1	E6020	1		
		B21B10D	A5.1	E6013	2		
		B21B40A2	A5.1	E7016	4		
		B21B89A	A5.1	E6027	1		
		B21B81A	A5.1	E7018	4		
		None	A5.1	E7018-1	4		
		None	A5.17	F6A2-EL8K	6		
		None	A5.17	F6A2-EL12	6		
		None	A5.17	F7A2-EM12K	6		
		None	A5.17	F7A2-EM13K	6		
		B50A631B,C	A5.20	E70T-1	6		
		B50A631D,E	A5.20	E71T-1	6		
		B21B126C1	A5.20	E70T-4	6		
		B21B126C2	A5.20	E70T-G	6		
		None	A5.20	E70T-6	6		
		B21B90B	A5.18	ER70S-2	6		
		B21B60	A5.18	ER70S-3	6		
		None	A5.18	ER70S-4	6		
		B21B90D	A5.18	ER70S-6	6		

Table II.5 – Filler Metal Columns (continued)

Code	NOTES	BHEL Spec	Industry Spec	ASTM/ASME Classification	ASME F-No.	UNS No.	Trade Name
AB		B21B40A2	A5.1	E7016	4		
		B21B81A	A5.1	E7018	4		
		None	A5.1	E7018-1	4		
		None	A5.17	F7P2-EM12K	6		
		None	A5.17	F7P2-EM13K	6		
		B21B103	A5.20	E70T-1	6		
		B21B153	A5.20	E71T-1	6		
		B21B152	A5.20	E70T-5	6		
		B21B90B	A5.18	ER70S-2	6		
		None	A5.18	ER70S-4	6		
		B21B90D	A5.18	ER70S-6	6		
AD		None	A5.5	E8016C1	4		
		None	A5.5	E8018C1	4		
		None	A5.23	F7A8-ENi2-Ni2	6		
		None	A5.28	ER80S-Ni2	6		
		None	A5.29	E80T1-Ni2	6		
		None	A5.29	E81T1-Ni2	6		
AE	2	B21B29	A5.4	E308-15/16	5		
		B21B101	A5.9	ER308	6		
		B21B144A1	A5.22	E308TX-Y	6		
AE-L	2	B21B120	A5.4	E308L-15/16	5		
		B21B137	A5.9	ER308L	6		
		B21B144B1,B2	A5.22	E308LTX-Y	6		

Table II.5 – Filler Metal Columns (continued)

Code	NOTES	BHEL Spec	Industry Spec	ASTM/ASME Classification	ASME F-No.	UNS No.	Trade Name
AF	2	B21B34A	A5.4	E310-15/16	5		
		B21B99	A5.9	ER310	6		
		None	A5.22	E310TX-Y	6		
AG		None	A5.5	E7016-A1	4		
		None	A5.5	E7018-A1	4		
		None	A5.29	E70T5-A1	6		
AH	2	B21B69	A5.9	ER316	6		
		B21B31	A5.4	E316-15/16	5		
		None	A5.22	E316TX-Y	6		
AH-L	2	B21B131	A5.4	E316L-15/16	5		
		B31B138	A5.9	ER316L	6		
		None	A5.22	E316LTX-Y	6		
AI		B21B54A2	A5.5	E8015/16-B2	4		
		B21B134A1	A5.5	E8018-B2	4		
		None	A5.5	E8016-B2L	4		
		None	A5.5	E8018-B2L	4		
		None	A5.29	E80T5-B2	6		
		None	A5.29	E80T5-B2L	6		
		B21B1507	A5.29	E80T1-B2	6		
		None	A5.29	E81T1-B2	6		
		None	A5.28	ER80S-B2	6		
		None	A5.28	ER80S-B2L	6		
AK	obsolete						

Table II.5 – Filler Metal Columns (continued)

Code	NOTES	**BHEL** Spec	Industry Spec	ASTM/ASME Classification	ASME F-No.	UNS No.	Trade Name
AL		B21B44A2	A5.5	E9015/16-B3	4		
		B21B92A2	A5.5	E9018-B3	4		
		B21B156	A5.28	ER90S-B3	6		
		None	A5.23	F9PZ-EB3-B9	6		
		None	A5.29	E91T5-B3	6		
		None	A5.29	E9XT1-B3	6		
AN		B21B123A2	A5.1	E11018M	4		
		None	A5.28	ER110S-1	6		
		None	A5.29	E110T5-K4	6		
		None	A5.29	E111T1-K4	6		
AP		B21B26	AMS 5782, A5.4	E349-15/16	5		19-9 W Mo
		None	AMS 5782, A5.9	ER349	6		19-9 W Mo
AQ		B50A485	AMS 5795BM				Multimet N-155
		None	AMS 5794A				Multimet N-155
AR	obsolete						
AS	1, 2	B21B35	A5.4	E410-15/16	4		
		B21B77	A5.9	ER410	6		
		None	A5.22	E410TX-Y	6		
AU	2, 3	B21B33	A5.4	E309-15/16	5		
		B21B135	A5.9	ER309	6		
		None	A5.22	E309TX-Y	6		
AU-L	2	B21B157	A5.4	E309L-15/16	5		
		None	A5.9	ER309L	6		
		None	A5.22	E309LTX-Y	6		

Table II.5 – Filler Metal Columns (continued)

Code	NOTES	BHEL Spec	Industry Spec	ASTM/ASME Classification	ASME F-No.	UNS No.	Trade Name
AY	obsolete						
AZ		B21B111	AMS 5798	ERNiCrMo-2	43	N06002	Hastelloy X
BA		B21B63B2	AMS 5797				
		B21B70	AMS 5796			R30605	L-605, Haynes 25
BB		None	A5.14, AMS	ERNiFeCr-2, 5832		N07718	Inconel 718
BC		B21B88	A5.11	ENiCrFe-3	43	W86182	Inco 182
		B21B110	A5.14	ERNiCr-3	43	N06082	Inco 82
BD		None	A5.11	ENiCu-7	42		
		None	A5.14	ERNiCu-7	42		
BE	2	B21B30	A5.4	E347-15/16	5		
		B21B17	A5.9	ER347	6		
		None	A5.22	E347TX-Y	6		
BF		B50A783A	AMS 5966, 5872			N07263	Nimonic 263, C263
BG		None	AMS 5801			R30188	Haynes 188
BH		B50A824	None	Mar-M918			
BI			AMS 5837, A5.14	ERNiCrMo-3	43	N06625	Inconel 625
BJ		same as BB					
BK	5	None	A5.28	ER90S-B9	6		
		None	A5.29	E100T1-B9M	6		
		None	A5.23	F9PX-EB9-B9	6		
		None	A5.5	E9015-B9	4		
		None	A5.5	E9016-B9	4		
		None	A5.5	E9018-B9	4		

Table II.5 – Filler Metal Columns (continued)

Code	NOTES	BHEL Spec	Industry Spec	ASTM/ASME Classification	ASME F-No.	UNS No.	Trade Name
BL		None	A5.14	ERNiCrWMo-1	43	N06230	Haynes 230W
BM		None	A5.14	ERNiCrCoMo-1	43		Inconel 617
BN		None	A5.14	ERNiCrMo-9	45	N06985	Hastelloy G3
BO	4	None					Haynes 556
BP		None	None	GTD-222			
BQ			A5.9	ER409Cb	6	S40940	
BR			None	Haynes 282			Haynes 282
BS		B50AG7	None				Nozzaloy
BT	6		AMS 5786/5787	ERNiMo-3/ENiMo-3	44	N10004	Hastelloy W
							EPRI P87

NOTE 1 Weldments between 410 and Cr-Mo steels should be limited to applications where the operating temperature is below 950F (510 C).
NOTE 2 For FCAW electrodes, "X" may be 0 or 1, and "Y" may be 1 or 4 as appropriate for the qualified welding procedure.
NOTE 3 For welds joining low alloy steels to austenitic alloys, the 309 filler metal will create a low carbon zone (LCZ) in the low alloy steel heat affected zone. This LCZ will compromise creep strength in applications that experience service temperatures over 800F (427C). Nickel based filler metals with nominally no more than 5 % chromium minimize the severity of the LCZ. For joining low alloy steels to austenitic alloys in applications where the weld joint may experience service temperatures over 800F (427C), it is recommended to use Col BT.
NOTE 4 Haynes 556 is prone to microfissuring. The filler metal listed in Col BI or Col BL are much less prone to objectionable microfissuring.
NOTE 5 E9015-B9 is recommended over the E9016-B9 and E9018-B9, as it doesn't contain iron powder and so eliminates one source of contaminates.
NOTE 6 EPRI P87 is available from Euroweld.

APPENDIX III: PREFERRED WELD JOINT DESIGNS FOR FULL PENETRATION WELDS

III-1 Scope

This section on full penetration joint design selection is provided to encourage use of preferred weld joint designs for full penetration welds.

III-2 Use of Preferred Weld Joint Designs for Full Penetration Welds

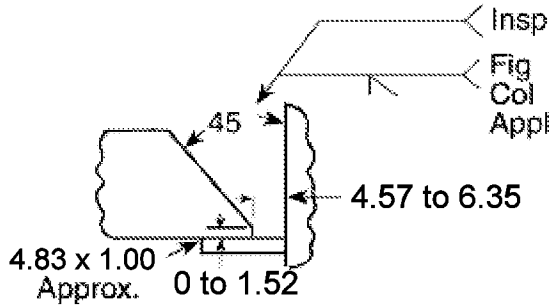
If a preferred weld preparation does not suit the required application, the weld preparation shall be described by the weld symbol.

Allowable tolerances on angles for weld preparation is +5°, -0°(+10, -5 as set-up or as fit-up).

For open root weld accessible from one side only, must use GTAW for root and a hot pass before any other welding process.

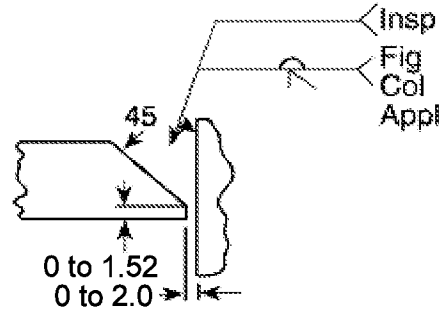
For all open root welds on stainless steel base materials, inert shielding backing gas required.

Table III.1 – B1, B2, F3, J1, J2, and J3 Joint Designs



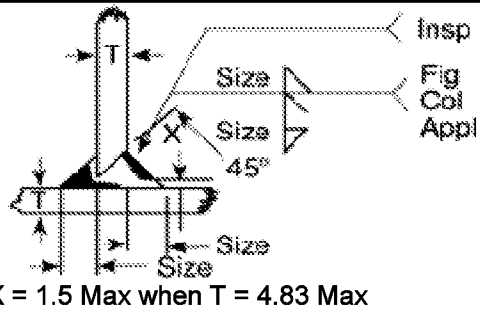
Complete Penetration – One Side Accessible – Weld One Side

Fig. B1



Complete Penetration – Both Sides Accessible – Weld Both Sides Excavate To Sound Metal Before Welding Second Side

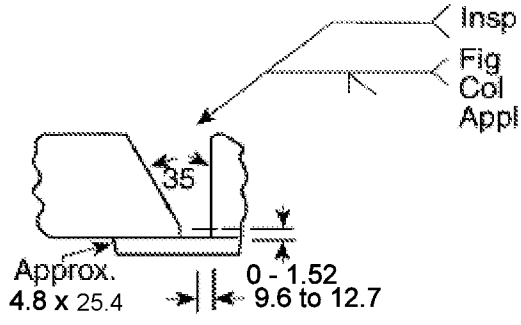
Fig. B2



X = 1.5 Max when T = 4.83 Max
X = 2.3 Max when T = 5.0 Up

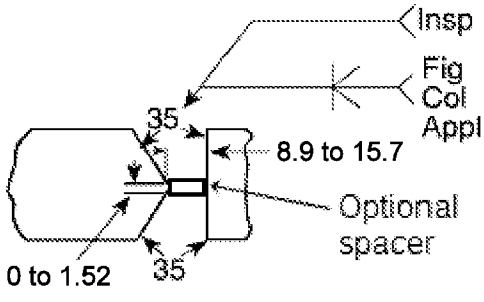
Complete Penetration – Both Sides Accessible – Weld Both Sides – Excavate To Sound Metal Before Welding Second Side.

Fig. F3



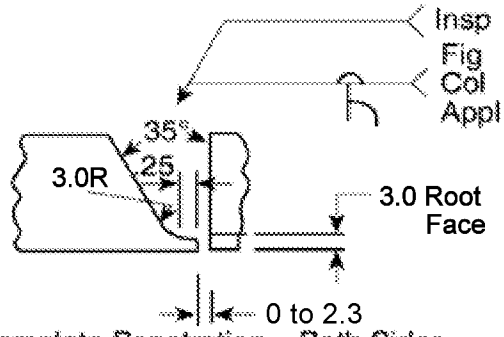
Complete Penetration – One Side Accessible – Weld One Side

Fig. J1



Complete Penetration – Both Sides Accessible – Weld Both Sides Excavate To Sound Metal Before Welding Second Side

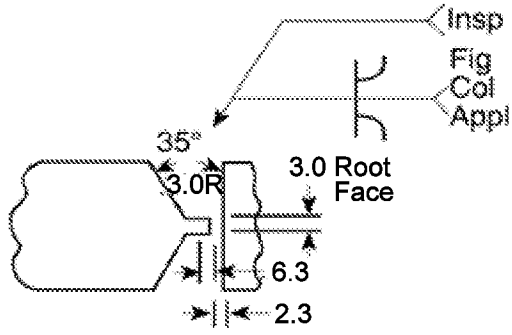
Fig. J2



Complete Penetration – Both Sides Accessible – Weld Both Sides Excavate To Sound Metal Before Welding Second Side.

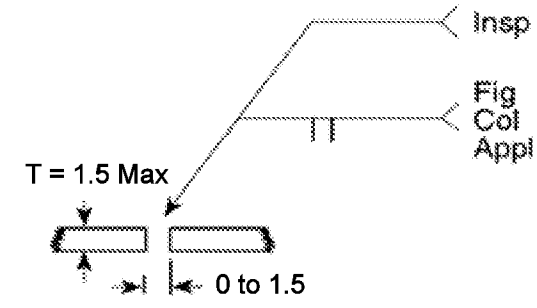
Fig. J3

Table III.2 – J4, S1, S2, S3, U3, and U4 Joint Designs



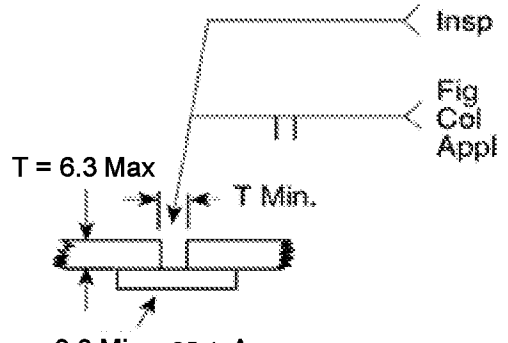
Complete Penetration – Both Sides Accessible – Weld Both Sides Excavate To Sound Metal Before Welding Second Side.

Fig. J4



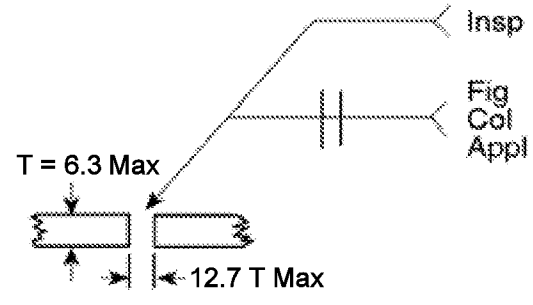
Complete Penetration – Weld One Side. Inert Gas Backing May Be Used.

Fig. S1



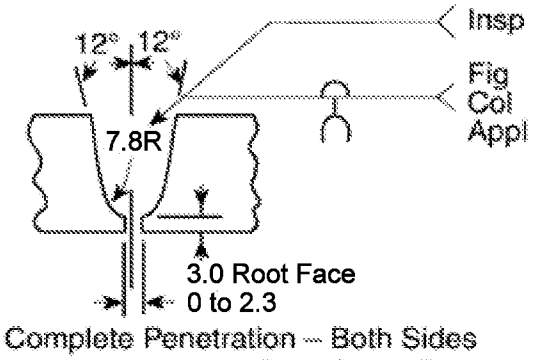
Complete Penetration – One Side Accessible – Weld One Side.

Fig. S2



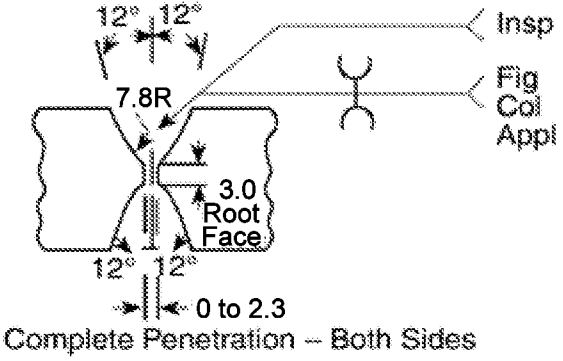
Complete Penetration – Both Sides Accessible – Weld Both Sides Excavate To Sound Metal Before Welding Second Side.

Fig. S3



Complete Penetration – Both Sides Accessible – Weld Both Sides Excavate To Sound Metal Before Welding Second Side.

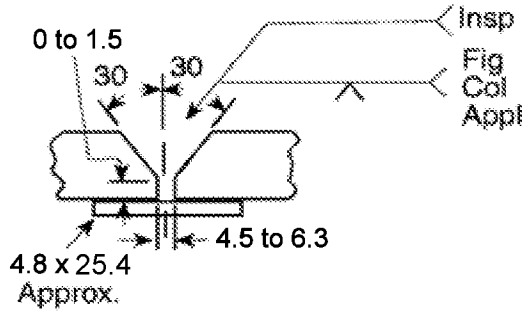
Fig. U3



Complete Penetration – Both Sides Accessible – Weld Both Sides – Excavate To Sound Metal Before Welding Second Side.

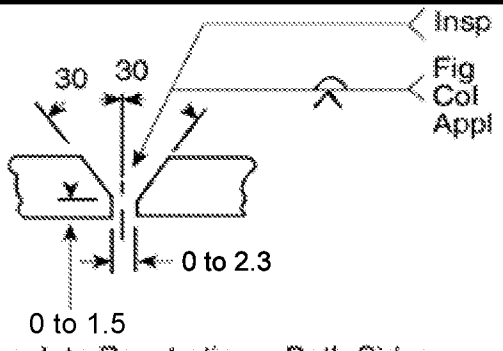
Fig. U4

Table III.3 – V1, V2, V3, V6, V7, and V8 Joint Designs



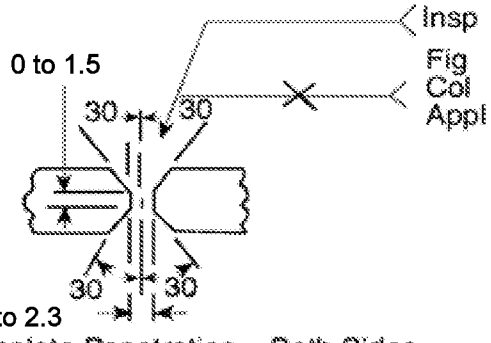
Complete Penetration – One Side Accessible – Weld One Side

Fig. V1



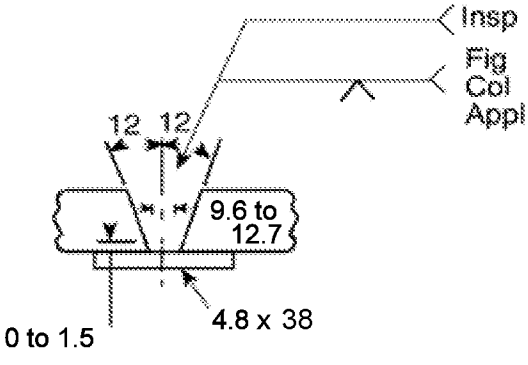
Complete Penetration – Both Sides Accessible – Weld Both Sides – Excavate To Sound Metal Before Welding Second Side.

Fig. V2



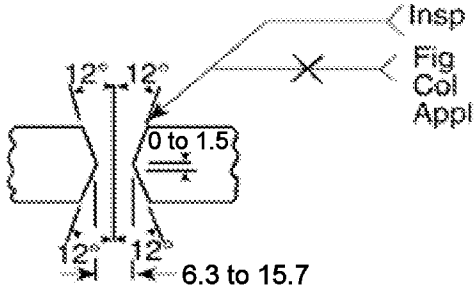
Complete Penetration – Both Sides Accessible – Weld Both Sides Excavate To Sound Metal Before Welding Second Side.

Fig. V3



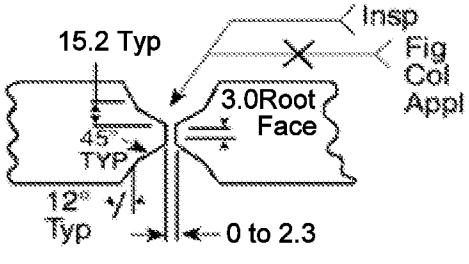
Complete Penetration – One Side Accessible – Weld One Side

Fig. V6



Complete Penetration – Both Sides Accessible – Weld Both Sides – Excavate To Sound Metal Before Welding Second Side.

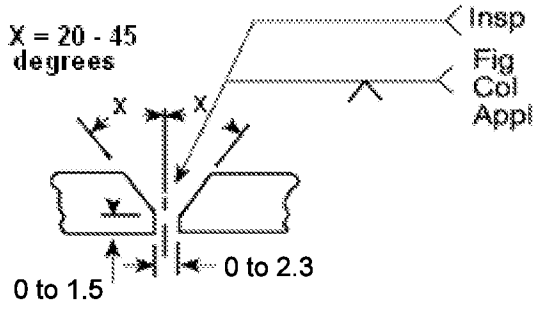
Fig. V7



Complete Penetration – Both Sides Accessible – Weld Both Sides – Excavate To Sound Metal Before Welding Second Side.

Fig. V8

Table III.4 – V9 Joint Design

 Complete Penetration – One Side Accessible – Weld One Side Fig. V9	

APPENDIX IV: PREFERRED WELD JOINT DESIGNS FOR PARTIAL PENETRATION WELDS

IV-1 Scope

This section on partial penetration weld joint design selection is provided to encourage use of preferred weld joint designs for partial penetration welds.

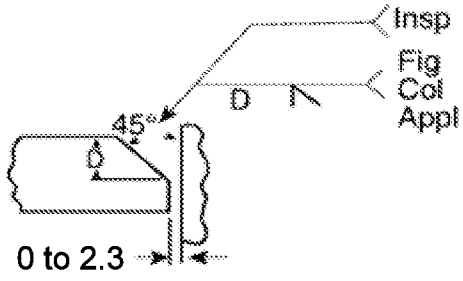
IV-2 Use of Preferred Weld Joint Designs for Partial Penetration Welds

If a preferred weld preparation does not suit the required application, the weld preparation shall be described by the weld symbol.

Allowable tolerances on angles for weld preparation is +5°, -0°.

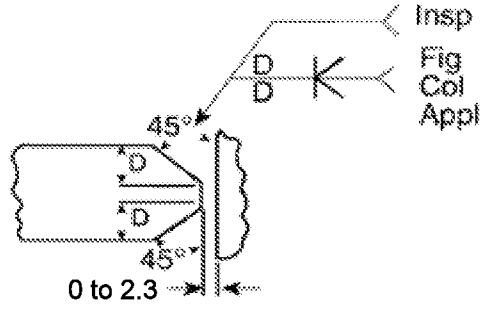
For all open root welds on stainless steel base materials, inert shielding backing gas required.

Table IV.1 – B3, B4, F1, J5, J6, and S4 Joint Designs



Partial Penetration

Fig. B3



Partial Penetration – Both Sides Accessible – Weld Both Sides.

Fig. B4

X = 1.5 Max, When T = 4.8 Max
X = 2.3 Max, When T = 5.0 More

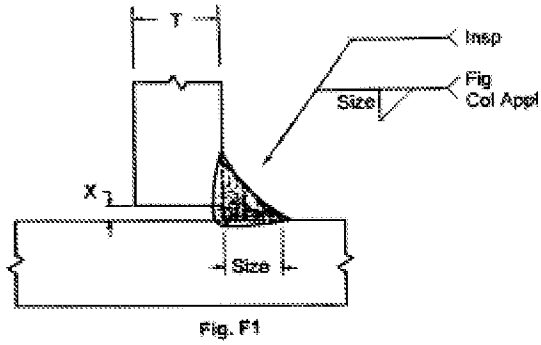
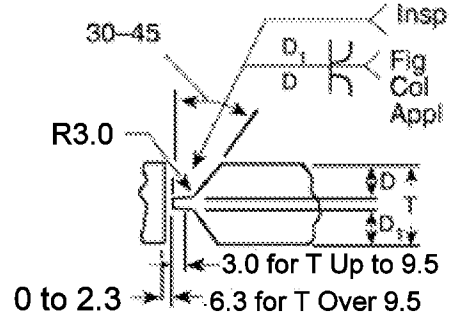
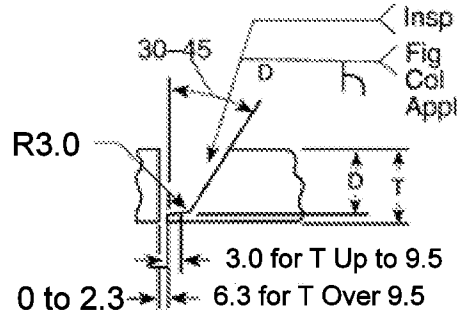


Fig. F1



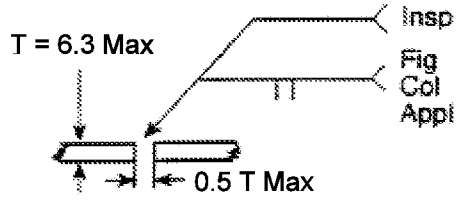
Partial Penetration – Both Sides Accessible – Weld Both Sides.

Fig. J5



Partial Penetration – Weld One Side

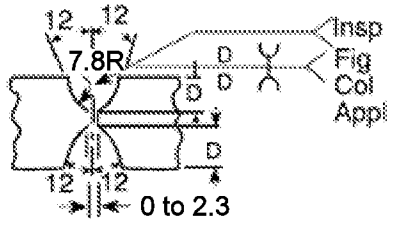
Fig. J6



Partial Penetration – Weld One Side

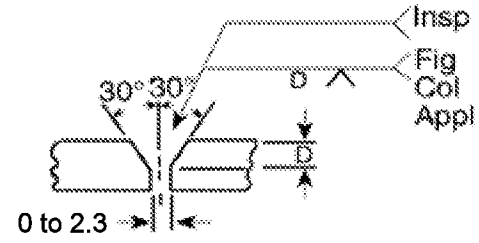
Fig. S4

Table IV.2 – U5, V4, and V5 Joint Designs



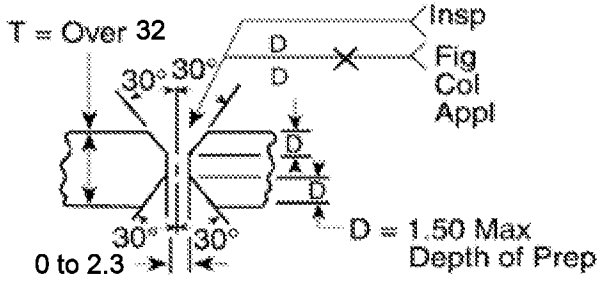
Partial Penetration – Both Sides Accessible – Weld Both Sides.

Fig. U5



Partial Penetration – Weld One Side

Fig. V4



Partial Penetration – Both Sides Accessible – Weld Both Sides.

Fig. V5

APPENDIX V: PREFERRED WELD JOINT DESIGNS FOR TUBULAR CONNECTIONS

V-1 Scope

This section on tubular joint design selection is provided to encourage use of preferred weld joint designs for tubular connections.

V-2 Use of Preferred Weld Joint Designs for Tubular Connections

These joint designs are intended for welding tubular-type members for applications not covered by GT54160, Welded Fabrication of Gas Turbine Piping.

If a preferred weld preparation does not suit the required application, the weld preparation shall be described by the weld symbol.

Allowable tolerances on angles for weld preparation is +5°, -0°.

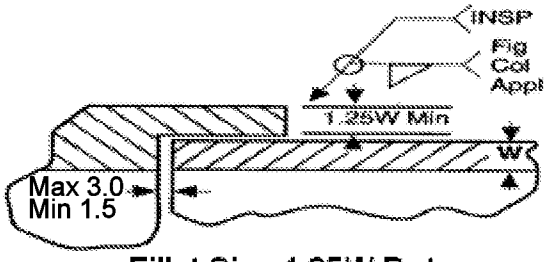
For open root weld accessible from one side only, must use GTAW for root and a hot pass before any other welding process.

For all open root welds on stainless steel base materials, inert shielding backing gas required.

Fig.-P8 is a special socket weld for fuel nozzle application. Use on other components requires cognizant engineer's approval.

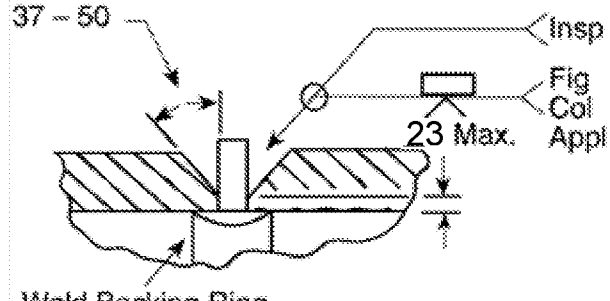
Fig.-P9 was removed.

Table V.1 – P1, P2, P3, P4, and P5 Joint Designs



Fillet Size 1.25W But No Less Than 3.2 mm

Fig. P1



Complete Penetration – One Side Accessible – Weld One Side

Fig.P2

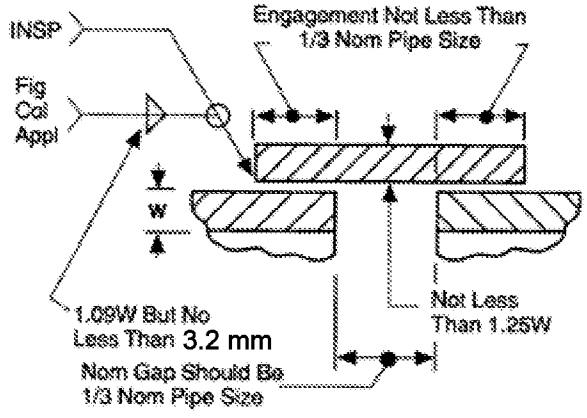


Fig. P3

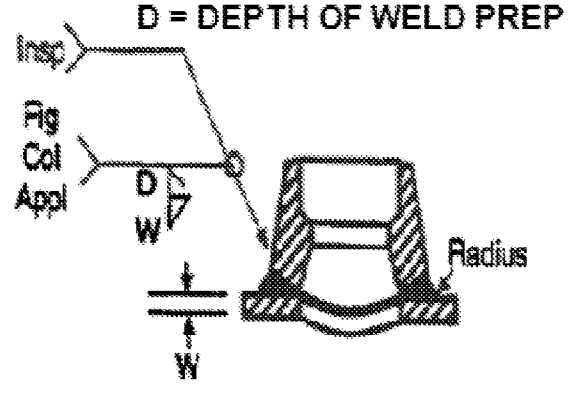


Fig. P4 Logitudinal Section

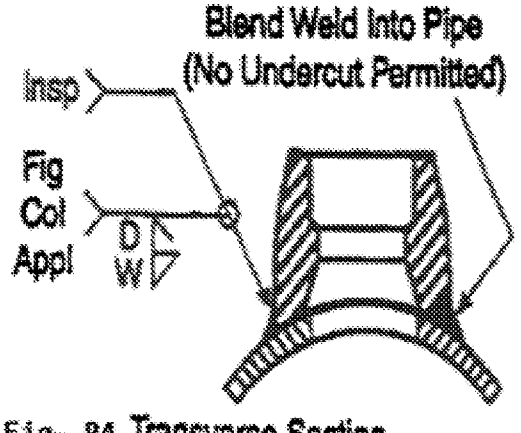


Fig. P4 Transverse Section

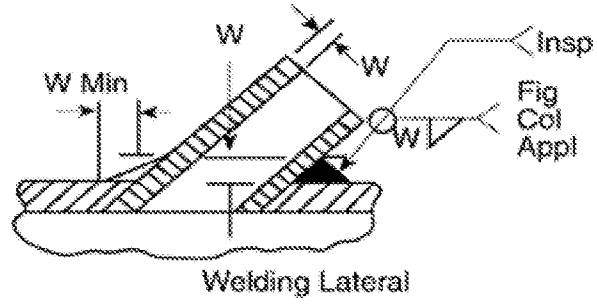


Fig.P5

Table V.2 – P6, P7, P8, and P10 Joint Designs

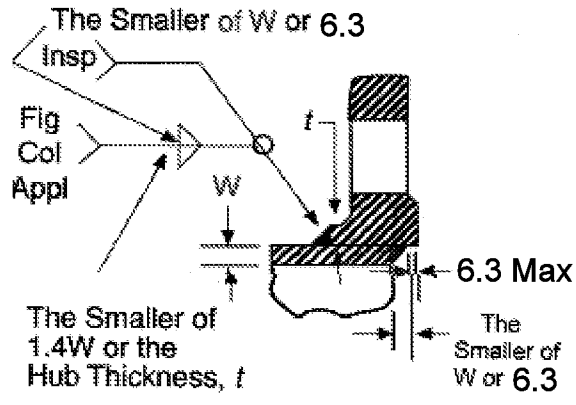


Fig. P6

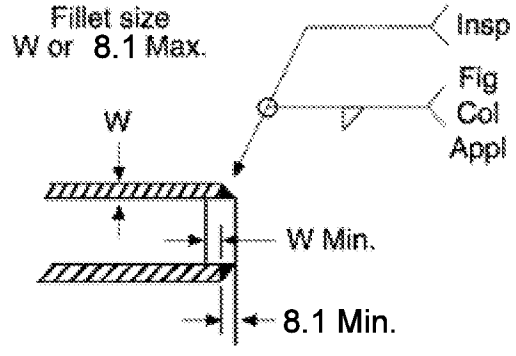


Fig. P7

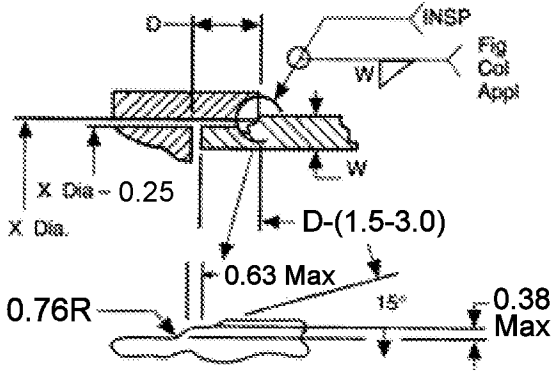


Fig. P8

Fig. P9 Deleted

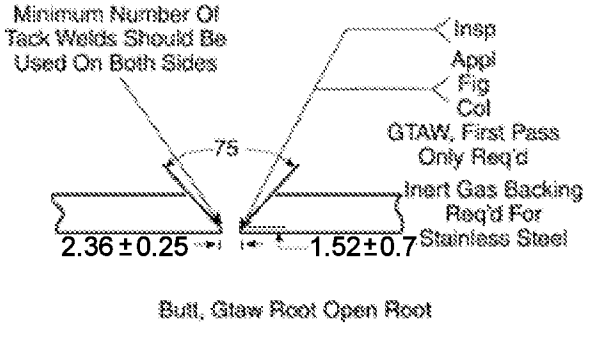


Fig. P10

APPENDIX VI: WELDING DEFINITIONS DIAGRAMS

VI-1 Scope

This section on welding definitions diagrams is provided for information purposes only. See AWS A3.0 – Standard Welding Terms and Definitions for a complete guide to all welding definitions.

VI-2 Use of Welding Definitions Diagrams

These welding defition diagrams should be used for information purposes only. They are not designed to represent actual joint designs or instructions.

VI-3 Welding Definitions Diagrams

Joint Offset: Difference in alignment between the two members being welded, see Figure VI.1.

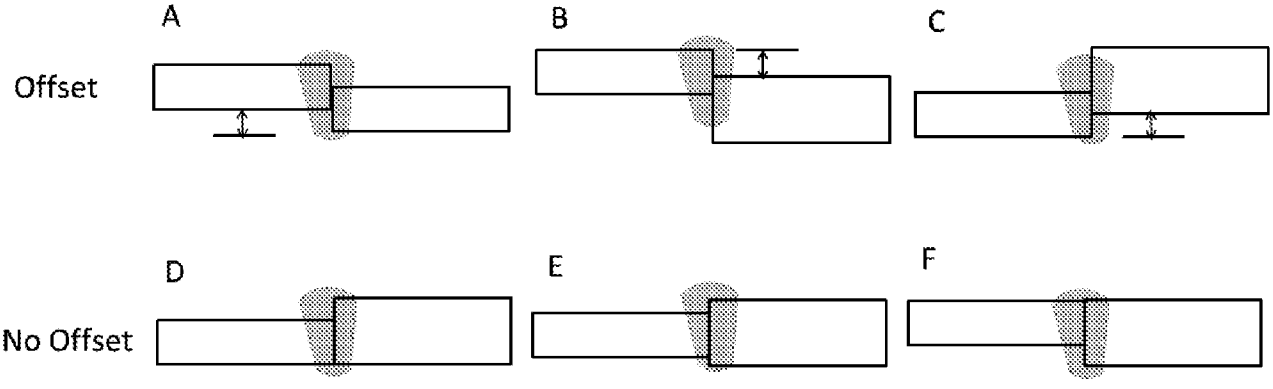


Figure VI.1: A-C: Joint Offset as noted. D-F No Offset.

Undercut: A groove melted into the base metal near the weld toe or root that is not filled in with filler metal, see Figure VI.2.

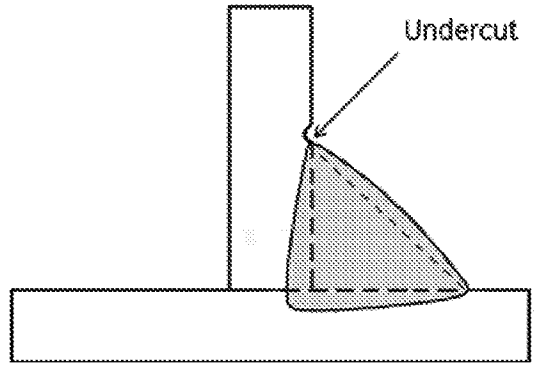


Figure VI.2: Weld undercut

Underfill: Missing weld metal from the weld profile resulting in the weld metal face being below the adjacent base metal, see Figure VI.3.

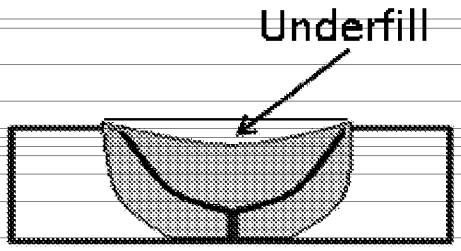


Figure VI.3: Weld underfill

Weld Fillet Sizing: The size of a fillet weld is the smaller of leg sizes (A or B) as shown in Figure VI.4. The largest possible right triangle (dashed lines in Figure VI.4) that can be placed completely inside of the weld profile determines the true leg size, measure from the base of the joint to each edge of the triangle.

Weld Throat: The theoretical throat of a weld (D in Figure VI.4) is determined by measuring from the original base of the joint to the hypotenuse of the largest right angle triangle that can be placed completely inside of the weld profile.

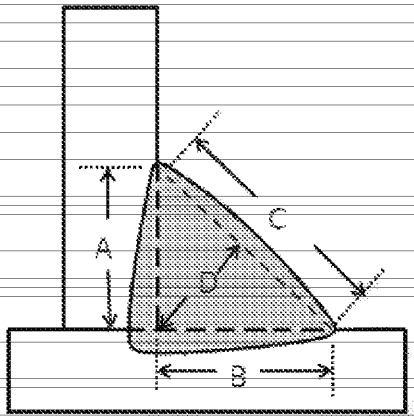


Figure VI.4: Weld fillet and throat size measurements. A: Leg size. B: Leg size. C: Largest 90° triangle you can fit in the weld. D: Throat size.

Weld Face: The face of the weld is the top of the weld, nearest the welder. See Figure VI.5

Weld Root: The root of the weld is the bottom of the weld, farthest from the welder. See Figure VI.5.

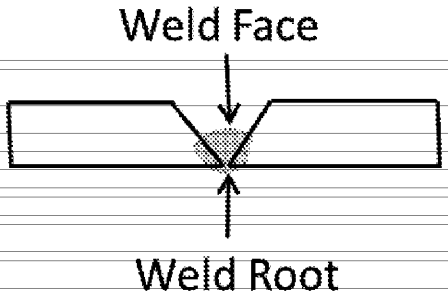


Figure VI.5: Weld face and weld root

Weld preparation

Flame cutting may be used for un-alloyed and low-alloy steels.

Plasma cutting should be used for high-alloy steels and clad steels.

For plates less than 25 mm thick, cold shearing may be used.

Thermally-cut surface edges of low alloy and high alloy steels and cold-sheared plates shall be dressed back approximately 2 mm by machining or grinding to remove notches and scale. Cold-sheared plates of 10 mm and less need not be dressed back. Two-sided welding shall be applied whenever possible.

Permanent backing strips shall not be used unless specified.

Temporary backing devices (ceramics, fluxes, copper backing strips etc.) may be used provided that the chemical composition of the weld metal is not influenced by the backing strip. The strip shall be removed without damage to the surrounding material. The areas involved shall be ground flush and cleaned after removal. Welds of low-alloy ferritic steels shall be inspected by MPI after the removal of the metallic backing strips or other temporary weldments, with acceptance criteria in accordance with the design code.

Weld application

Arc strikes shall be situated in the fusion path. If welding is interrupted, a proper restart procedure shall be applied, ensuring full fusion with the previously deposited weld metal.

Irrespective of the base material, root runs shall be made without interruption other than for changing electrodes or to allow the welder to reposition himself. Welds shall not be allowed to cool down until at least half the wall thickness has been welded.

Thorough inter-run cleaning and slag removal shall be carried out.

Back-chipping, or gouging and grinding, shall be carried out thoroughly to sound metal before deposition of subsequent layers. For very stringent or critical applications, intermediate NDE may be required

Preheat requirements (Source of Preheat)

For preheating temperatures below 200 °C, fuel gas/air burner systems, high-velocity gas/oil burners or infra-red radiators may be employed (either locally or in a furnace), or electric resistance, induction heating or infra-red radiators may be employed.

For preheating temperatures > 200 °C, electric resistance, ~~or~~ induction heating or infra-red radiators may be used.

Shielding and Purging Gases

When shielding gases are used, the WPS shall indicate the shielding gas(or gas mixture), percent composition of gas(es) and flow rate.

Shielding gases shall meet the purity requirements of AWS 5.32. Gas purity should be recorded on the PQR and WPS when a single gas is used.

Back purging is required for the GTAW and GMAW processes for welding materials having a nominal chromium content greater than 21/4% unless the joint is ground or back gouged to sound metal

When back purge is used, the WPS shall state the gas used and the flow rate.

Whenever a back purging gas is selected to prevent oxidation or scale formation on the undesirable of the weld, the purge shall be maintained until at least 6.3mm depth of weld metal has been deposited.

Thermocouples

Thermocouple attachments should be:

- capacitor discharge connection, or
- nut and bolt construction (as shown in Figure 3).

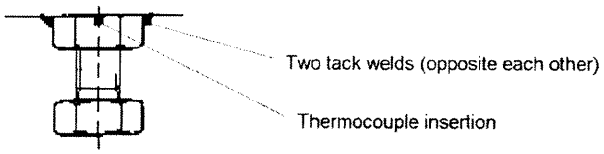


Figure 3 Thermocouple attachment

If the latter method is used, the materials should be of a compatible composition. The weld metal shall be removed by careful dressing followed by MT or PT examination after PWHT to confirm absence of linear indications.

Other types of thermocouple attachments may be used provided it is demonstrated that the same temperature reading is obtained as with a capacitor discharge or a bolt/nut connection.

All thermocouple attachments shall be adequately insulated to avoid temperature misreading caused by the effect of radiation.

The number and positions of the thermocouples shall be in accordance with the design code, but at least as described below:

- For full body heat treatment, at least 3 thermocouples shall be directly welded on the work piece, as indicated in Figure 4:

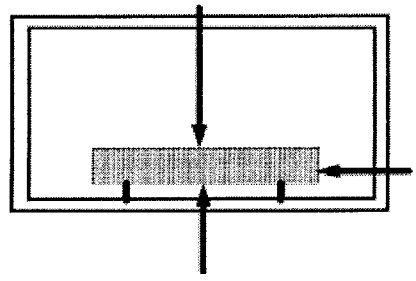


Figure 4. Thermocouple placement for full body heat treatment

NOTE: For a hollow configuration, there shall be one additional thermocouple on the inside.

For local heat treatment of pipe the number of thermocouples shall be:

1 for pipe diameter < DN 50

2 for pipe diameter from DN 50 to DN 250

3 for pipe diameter > DN 250

The thermocouples shall be positioned on the OD on the weld cap or on the HAZ as shown in Figure 5.

$D \leq 50$ $50 < D < 250$ $D \geq 250$

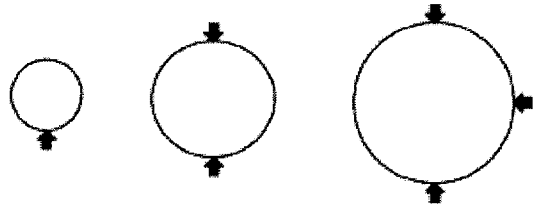


Figure 5. Thermocouple positioning for local heat treatment of pipe

Environment.

Any local rules regarding fumes, environment, waste, etc. in direct relation to welding shall be followed.

RECORD OF REVISIONS

Rev.No.	Date	Revisions Details	Revised	Approved
00	14.07.88	FIRST MADE	YVR	BIB
01	16.02.93	REVISED AS PER P8A-AG1 REV'N'	YVR	BIB
02	08.09.03	REVISED AS PER P8A-AG1 REV'AA'	YVR	BIB
03	06.09.10	REVISED TO ADD BHEL WPS	YVR	BSN
04	17.07.13	GENERALLY REVISED AS PER P8A-AG1 REV'AC' & SH.64 TO 66 ARE ADDED (IN LINE WITH PDO DEP 30.10.60.18)	RSR	(NVS MURTHY)

Rev. Doc.