PQR For Fr5 Transition piece body

Sl. No.	Terms & Conditions	Supplier confirmation (YES/NO)	Deviations (if any mention clearly)
1.	**Scope of Supply:** Fr5 Transition piece body to be supplied as per BHEL Material code: SG9710480014, Material Specification HY12763, Rev 01, Drg. No. 03510951003-02, Rev 01.		
2.	**Pre-Qualifying Requirements for Vendors:** The bidder is required to furnish self-attested documentary proof for having acquired following pre-qualification requirement (PQR) The following conditions have to be satisfied by the vendor, with documentary proof to be enclosed with tender (Technical), failing which the offer will not be considered for evaluation: i. Vendor should furnish the sheet metal forming/Fabrication experience with Stainless steel/Super alloys (like Hastealloy, Nimonic etc...). Latest PO copies not less than 5 years, Material test reports, quality plans etc. shall be submitted to BHEL. ii. Vendor should submit the evidence of formed component Stainless steel/Super alloys have minimum size of Length = 400mm, Breadth = 200mm, Thickness = 1.6mm & above. iii. Vendor should provide details on making Dye, jigs & Fixture required to manufacture the transition piece. iv. Vendor should provide in house facility of TIG welding facility / Automatic welding facility (Robotic welding) v. Vendor should have in house facility of Press (min. 1000 ton) for sheet formation (upper Half & Lower Half), Laser cutting/CNC cutting for trimming of extra length, Heat treatment, FPI (fluorescent penetrant inspection), Die penetrant (DP) and Radio Graphic Test. vi. If the vendor doesn't have the facility of Hydraulic press, laser cutting machine, Heat treatment and Radiography facility, in this case vendor shall submit the alternate source details during technical scrutiny. vii. Vendor shall submit the complete manufacturing process plan for Fr5 Transition piece body. Local hammering, Local Heating/Strengthening is strictly prohibited. viii. Vendor should confirm complete compliance to following BHEL specifications GT10169- General requirements combustion transition piece GT54031-Gas turbine fusion arc welding GT10157-Flourescent penetrant test HY12763 - Raw material specification, Hastealloy-X (3.15MM thick)		

	GT10206-Radiography-Combustion components HY0230261-List of applicable standards on limits fits and tolerances. ix. Development of tooling for fabrication and templates for inspection of TRANSITION PIECE BODY, FR5 is in vendor scope. Template shall be submitted to BHEL for approval. x. It shall be the responsibility of supplier to thoroughly understand the work scope and all documentation needed to complete the work. Prior to initiation of any manufacturing activity, the applicable drawing shall be jointly reviewed by SG Engineering, BHEL Hyderabad and supplier to document any discrepancies in the drawing. xi. Vendor to ensure uniformity in weld bead throughout welding length of Transition piece body. If non uniformity of weld beads are found, Transition Piece body is liable for rejection. xii. First piece qualification of TRANSITION PIECE BODY, FR5 to be carried out by BHEL, after first piece approval vendor to manufactured the balance quantity. xiii. New vendors, who are interested to participate and to do business with BHEL, shall get registered with BHEL after technical scrutiny. xiv. BHEL representative shall have free entry and access to all areas where the manufacture/machining of Transition piece body is carried out. All reasonable facilities shall be extended to him including labour wherever necessary. xv. BHEL representative shall be given sufficient advance intimation to verification/witness the various process, tests, etc xvi. "The offers of the bidders who are on the banned list and also the offer of the bidders, who engage the services of the banned firm shall be rejected. The list of banned firms is available on BHEL website "www.bhel.com".		
3.	**Documents to be submitted by vendor.** A. Manufacturing Process Plan, Inspection and Quality Plan B. Tooling drawings C. Inspection template drawings D. Test certificates E. FPQ documentation and Major BHEL witness points F. Deviation if any, to be furnished clearly.		

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BHARAT HEAVY ELECTRICALS LIMITED

HEAVY POWER EQUIPMENT PLANT

SWITCHGEAR PURCHASE DIVISION

RAMACHANDRAPURAM, HYDERABAD

PRE-QUALIFICATION REQUIREMENTS - FINANCE

PRODUCT:	TRANSITION PIECE BODY, FR5 (SG9710480014) PR: 1200030170, 1200030032

CRITERIA FOR EVALUATION - FINANCIAL

Average annual financial turnover during the last Three Financial Years should not be less than	**INR 22,50,000/-**
(In Words, Indian Rupees Twenty two Lakhs Fifty Thousand(s) Only)	

Notes:-

a. The Average annual Financial turnover during last 03 (three) years, ending of the previous financial year, should be at least **INR 22,50,000/-** and positive net worth as per latest balance sheet. The bidder has to submit financial accounts comprising of Audit report, Balance Sheet, Profit & Loss A/c Statement and Notes/Schedules pertaining to Turnover/Sales/Revenue, certified by Charted Accountant for the last three years as on tender due date to review the above criteria.

b. Other Income shall not be considered for arriving at Annual Turnover/Sales. For evaluation purpose, only revenue from operations shall be considered.

FLUORESCENT PENETRANT TESTING

1. SCOPE

1.1 This specification establishes the minimum requirements for the fluorescent penetrant inspection method which is used for the detection of surface discontinuities.

1.2 Fluorescent penetrant inspection shall be performed in accordance with one of the testing methods listed below:

1.2.1 Water-washable fluorescent penetrant

1.2.2 Post-emulsifiable fluorescent penetrant

1.2.3 Solvent-removable fluorescent penetrant

1.3 This specification is intended to define testing parameters which meet the requirements of ASTM E-165. In the event of conflict between this specification and ASTM E-165, this specification shall be the governing document.

2. COMMUNICATION

2.1 External Supplier (See Definition)

BHEL GT PURCHASE is the authorized interface for all communication between BHEL and the External Supplier. All questions or requests for additional information shall be submitted to BHEL for clarification.

2.2 Internal Supplier (See Definition)

All communication, including questions or requests for additional information shall be submitted to Materials and Processes Engineering (MPE).

2.3 Requests For Deviations - Requests for deviations to the requirements of this specification shall be submitted as follows:

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

2.3.2 Internal Supplier - To the appropriate Engineering personnel by Quality Control Report (QCR).

3. APPLICABLE DOCUMENTS

3.1 The following documents shall form an integral - part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue shall apply.

3.1.1 American Society for Nondestructive Testing

SNT-TC-1A	Personnel Qualification and Certification in Nondestructive Testing

3.1.2 American Society for Testing and Materials

ASTM E165	Standard Test Method for Liquid Penetrant Examination
ASTM E1316	Standard Terminology for Nondestructive Examinations
ASTM E1417	Standard Practice for Liquid Penetrant Examination

3.1.3 BHEL

~~GT11013~~	~~Nickel - Iron Alloy Forgings (Alloy 706 Type)~~
~~GT11017~~	~~Nickel - Iron Alloy Forgings (Alloy 718 Type)~~

4. DEFINITIONS

4.1 Personnel

4.1.1 Purchaser - BHEL

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

4.1.3 Internal Supplier ——

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

4.2 Specification Deviation Documents

4.2.1 Applicable to External Supplier

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

4.2.2 Applicable to Internal Supplier

4.2.2.1 Quality Control Report (QCR) - BHEL Manufacturing Department non-conformance report initiated during processing through the factory. Used by Manufacturing to document non-conformance to governing documents and request corrective action.

4.3 Technical Terms

4.3.1 Characteristic - The dimensional, visual, functional, mechanical, and material features or properties which describe and constitute the design of an item and can be measured, observed, or identified to determine conformance to the design requirements.

4.3.2 Critical To Quality Characteristic (CTQ) - Those characteristics of a nondestructive test of a component which, if non-conforming, may prevent or seriously affect the unit performance, reliability, production, or customer satisfaction with a component.

* 4.3.3 Linear Indication - An indication whose length is more than 3 times its width.

* 4.3.4 Relevant Indication - An indication which is due to a discontinuity in the material.

* 4.3.5 TAM Panel - Standard used in penetrant testing. Contains star shaped defects of various sizes. Used to verify sensitivity of a penetrant system.

4.3.6 For standard terminology used in nondestructive testing, refer to ASTM E1316.

5. ENGINEERING REQUIREMENTS

5.1 Critical To Quality Characteristics (CTQs) - The following Critical Quality Characteristics have been identified for the fluorescent penetrant testing and shall be monitored by the supplier.

5.1.1 System performance verification (see Para. 7.1.1)

5.1.2 Black light intensity at the inspection surface

5.1.3 Ambient white light in the inspection area

5.1.4 Part temperature

5.1.5 Wash water temperature (if applicable)

5.1.6 Wash water pressure (if applicable)

5.1.7 Emulsifier dwell time (if applicable)

5.1.8 Drying oven temperature (if applicable)

5.1.9 Development time

5.2 Acceptance Requirements

5.2.1 The acceptance requirements applicable to the part or group of parts shall be incorporated as part of the supplier's written procedure either specifically or by reference to other applicable documents containing the necessary information.

5.2.2 Applicable drawings and/or specifications used by the supplier to perform the test must specify the acceptance size and concentration of discontinuities for the component.

5.2.3 Specific acceptance requirements for nickel based superalloy forgings are provided in Para. 9.2.

5.3 Personnel Qualification

5.3.1 All tests shall be performed by personnel qualified and certified through an established program that reflects the intent of the recommended guidelines provided in ASNT document SNT-TC-1A.

5.3.2 If the requirements of SNT-TC-1A have been modified to meet the needs of the supplier, the modifications shall be specifically described in the company's written practice for qualification and certification of personnel.

5.4 Written Procedure/Method

5.4.1 Each fluorescent penetrant inspection shall be performed in accordance with a written procedure/method. This procedure may be either a master procedure which covers details common to a variety of components or a specific individual procedure or a combination of both.

5.4.2 The procedure/method shall be capable of detecting the smallest acceptable discontinuity specified in the acceptance requirements. The capability of the method shall be demonstrated as outlined in Para. 7.1.1.

5.4.3 All written procedures shall be approved by a BHEL.

5.5 Elements of the Written Procedure/Method

5.5.1 The written procedure/method shall include at least the following elements, either directly or by reference to an applicable document:

5.5.1.1 Procedure identification and date written

5.5.1.2 Details of the pre-cleaning and etching (where applicable) process, including materials used, drying parameters and processing times.

5.5.1.3 Conformance of penetrant examination materials in accordance with MIL-I-25135.

5.5.1.4 Complete processing parameters for the penetrant materials including concentrations, application methods, dwell times, drying times, temperatures, and controls to prevent excessive drying of penetrant or overheating of component

5.5.1.5 Complete examination requirements including black light intensity, ambient white light intensity and method and location of marking.

5.5.1.6 Identification of components or areas within a component requiring inspection in accordance with the procedure.

5.5.1.7 Acceptance requirements to be used for evaluating indications and disposition of parts after evaluation.

5.5.1.8 Post-inspection cleaning requirements.

5.6 Examination Sequence

5.6.1 Fluorescent penetrant inspection shall be performed after the completion of all operations that could cause surface connected discontinuities or operations that could expose discontinuities not previously open to the surface. These operations include, but are not limited to, heat treating, welding, grinding, straightening, and machining.

5.6.2 Final fluorescent penetrant inspection shall be performed prior to treatments that can smear the surface but not by themselves cause surface discontinuities. Such treatments include, but are not limited to, vapor blasting, deburring, sanding, buffing, sandblasting, lapping, and peening.

5.6.3 All coatings and other surface conditions, such as paint, plating, corrosion, etc., shall be removed from the area to be inspected prior to fluorescent penetrant inspection, except when performing fluorescent penetrant inspections of coatings themselves.

5.7 Process Limitations

5.7.1 Fluorescent penetrant inspections shall not be performed subsequent to visible dye penetrant inspections of the same surface (i.e. when no machining or other surface removal has taken place between inspections).

5.7.2 Intermixing of penetrant materials from different manufacturers is strictly prohibited in accordance with this specification.

5.8 Penetrant Materials

5.8.1 All penetrant materials used in accordance with this process specification shall meet the requirements for Type I (fluorescent dye) penetrants contained in MIL-I-25135.

5.8.2 All penetrant materials used in BHEL Plants shall be approved by Plant Environmental Health and Safety.

5.9 General Requirements

5.9.1 Fluorescent penetrant examinations shall be performed in a darkened area with a maximum ambient visible light level of 2 foot candles (20 lux) measured at the part surface.

* 5.9.2 Minimum acceptable black light intensity is 1200 microwatts/cm2 at a distance of 15 inches unless otherwise specified in a component's product acceptance specification. Black lights shall be checked at the interval specified herein and after bulb replacement, for output intensity. Black light reflectors and filters shall be checked daily for cleanliness and integrity. Damaged or dirty reflectors or filters shall be replaced or otherwise corrected.

5.9.3 Black Light Intensity Procedure

5.9.3.1 An intensity check is required for each black light used for evaluation.

5.9.3.2 Intensity check shall be accomplished with the black light in a fixed position pointing toward a flat surface.

5.9.3.3 The face of the black light filter shall be 12 inches (+1/4 inch, -0 inch) from the sensing element of the light intensity meter when verifying light intensity.

5.9.3.4 The sensor shall be moved around on the flat surface until the maximum reading on the meter is obtained. The black light shall not be moved during an intensity check of the blacklight.

5.9.3.5 A Black Light Intensity Log/Record shall be kept and shall include as a minimum the date, identification of person taking reading, black light intensity, identification of black light meter/sensor, and the date the meter and sensor were last calibrated/certified.

5.9.4 The temperature of the penetrant materials and the surface of the part to be inspected shall be in the temperature range of 50 and 100°F. When it is not possible to comply with these temperature limits, the procedure must be qualified using the temperature to be used.

5.9.5 When drying ovens are used during the inspection process, the oven temperature shall not exceed 160°F.

6. PRACTICE

6.1 Surface Preparation

6.1.1 All surfaces to be inspected shall be clean, dry, and free of soil, oil, grease, paint - and other coatings, corrosion products, scale, smeared metal, welding flux, chemical residues or any other materials that could prevent the penetrant from entering discontinuities, suppress dye performance, or produce unacceptable background.

6.1.2 Solvent cleaning, including ultrasonic cleaning, or aqueous based cleaning solutions shall be used for removal of oils, grease and wax. Cleaning solvents shall not have more than 100 ppm of chlorine or 5000 ppm of sulfur. No alkaline solutions shall be used.

6.1.3 Chemical cleaning (such as use of paint strippers, pickling baths, etc.) shall be used for the removal of paint, varnish, scale, carbon or other contaminants which are not removed by solvents. Purchaser approval is required prior to use of any of these processes.

6.1.4 Etching is required where evidence exists that a previous condition or operation has produced a surface condition that degrades the effectiveness of the penetrant examination.

6.1.5 Parts shall be thoroughly dry after cleaning. Drying may be accomplished by warming the parts using drying ovens, infrared lamps, forced hot air, blotting/wiping, or exposure to ambient temperature in still air. **The minimum drying time is 5 minutes**. The part temperature shall not exceed 125°F.

6.2 Penetrant Application

6.2.1 After the part has been cleaned, dried, and cooled to an acceptable temperature (50 - 100°F.), apply the penetrant to the surface to be inspected so that the entire part or area to be inspected is completely covered with penetrant.

6.2.2 Various modes of application of penetrant are effective and acceptable, including immersion, brushing, flooding, conventional, aerosol spraying, dipping, the use of electrostatic spray guns, and high volume low pressure (HVLP) atomizing.

6.2.3 After application, allow the excess penetrant to drain from the part (taking care to prevent pooling of penetrant on the part) while allowing for the proper dwell time. **The minimum penetrant dwell time shall be 10 minutes.** The maximum penetrant dwell time shall be 2 hours. During the penetrant dwell time the penetrant shall not be allowed to dry on the part surface.

6.2.4 Areas of the part which are not to be penetrant tested may be masked or otherwise protected during penetrant inspection.

6.3 Penetrant Removal

6.3.1 After the required penetrant dwell time, remove the excess penetrant as described in:

- Para. 6.3.3 for water-washable penetrants,
- Para. 6.3.4 for post-emulsifiable penetrants using hydrophilic emulsifiers,
- Para. 6.3.5 for post-emulsifiable penetrants using lipophilic emulsifiers, and
- Para. 6.3.6 for solvent-removable penetrants.

6.3.2 Adequate penetrant removal has been accomplished when all interfering background is removed, without causing penetrant to be washed out of discontinuities. The adequacy of penetrant removal shall be verified using a blacklight.

6.3.3 Water-washable Penetrant Removal

6.3.3.1 Water-washable penetrant shall be removed with a manual or automated water spray, by careful manual wiping, by dip with agitation, or by a combination of these techniques.

6.3.3.2 For rinses using a manual or automated spray, a coarse water spray which does not exceed a pressure of 40 psi shall be used. The water pressure shall remain constant. The spray nozzle shall be held a minimum distance of 12 inches from the part.

6.3.3.3 The water temperature shall be maintained relatively constant and shall be in the temperature range of 50 to 100°F. If hydro-air spraying is used, air pressure shall not exceed 25 psi maximum.

6.3.3.4 Washing off of penetrant from the part surface shall be conducted under proper black light illumination to ensure that over washing does not occur.

6.3.3.5 The duration time for the water rinse will depend on the removal characteristics of the penetrant, the surface condition of the part, and the water spray temperature and pressure. The optimum rinse time may need to be determined experimentally, but shall not exceed 120 seconds. An adequate rinse will be evident when no interfering background remains on the part surface.

6.3.3.6 For special cases approved by the purchaser (i.e. where water rinse facilities are not available or where uncontrollable rinse water is potentially harmful to surrounding components) penetrant removal may be performed by gently wiping the excess penetrant from the surface with a clean, dry, lint-free cloth or absorbent toweling. Then the remainder of the surface penetrant shall be removed by careful wiping with a water-dampened cloth or towel. Adequate penetrant removal shall be determined by examination under black light. The surface shall not be flushed with water and the cloth or towel shall not be saturated with water.

6.3.3.7 After rinsing, excess water shall be drained from the part. Utilize repositioning, suction, blotting with clean, absorbent materials, or filtered shop air at less than 25 psi to prevent pooling in cavities, recesses, and pockets. Use air blow-off sparingly in order to avoid re-depositing of unwashed penetrant as fluorescent specks on clean surfaces.

6.3.4 Removal of Post-Emulsifiable Penetrants by Hydrophilic Emulsifiers

6.3.4.1 The water pressure of the hydrophilic pre-rinse system shall be 40 psi maximum. The water temperature shall be maintained between 50 and 100 degrees F.

6.3.4.2 The drain time after water pre-rinsing of hydrophilic post-emulsifiable penetrants shall be 30 minutes maximum.

6.3.4.3 Emulsifier concentration shall be in accordance with manufacturer's recommendations relative to the mode of application (immersion vs. spraying).

6.3.4.4 Immersion emulsification processing systems must provide scrubbing (kinetic) action between the emulsifier and the part. This can be accomplished by mild mechanical motion, air agitation, or submerged re-circulation through multiple nozzles when the part is in contact with the emulsifier. Immersion emulsifier bath shall be maintained between 50 and 100 degrees F.

6.3.4.5 The part shall not be immersed in the emulsifier for longer than 120 seconds.

6.3.4.6 The emulsifier drain time begins immediately after the parts have been withdrawn from the emulsifier tank and continues until the parts are washed in the final rinse station (post-wash). The draining process shall be kept to a minimum to avoid over-emulsification and shall not exceed 90 seconds.

6.3.4.7 For spray application of the emulsifier after the pre-rinse, all part surfaces shall be evenly and uniformly sprayed to effectively emulsify the residual penetrant.

6.3.4.8 The temperature of the sprayed emulsifier solution shall be maintained between 50 and 100 degrees F. The spray pressure shall be 25 psi maximum for air and 40 psi maximum for water.

6.3.4.9 The contact time between sprayed on emulsifier and the part surface shall not exceed 120 seconds.

6.3.4.10 Verification of the emulsifier concentration in water shall be accomplished using a refractometer.

6.3.4.11 Penetrant contamination in the emulsifier shall be monitored by the presence of excessive background on the parts. The emulsifier shall be changed if evidence of penetrant contamination is noted.

6.3.4.12 Post-rinsing of emulsified penetrant from the part surface can be accomplished by using either manual, semi-automated, or automated water immersion or spray equipment or combinations thereof.

6.3.4.13 If parts are to be completely immersed in a post-rinse water bath with air or mechanical agitation, the temperature of the water shall be relatively constant and shall be maintained within the range of 50 to 100 degrees F. The maximum dip rinse time shall not exceed 120 seconds. A touch-up rinse may be necessary after immersion.

6.3.4.14 Parts may be post-rinsed by water spray rinsing using rinse water between 50 and 100 degrees F at a maximum pressure of 40 psi. The maximum spray rinse time shall not exceed 120 seconds.

6.3.5 Removal of Post-Emulsifiable Penetrants by Lipophilic Emulsifiers

6.3.5.1 The mode of application of the emulsifier shall be by dip and dwell only. The part must be drained in such a manner that prevents emulsifier from pooling in the part.

6.3.5.2 The maximum dwell time of lipophilic emulsifier on the part surface shall be 3 minutes for fluorescent penetrants or as recommended by the manufacturer.

6.3.5.3 Effective post-rinsing of the emulsified penetrant from the surface can be accomplished using either manual, semi-automated, or automated water immersion or spray equipment or combinations thereof.

6.3.5.4 For immersion post-rinsing, parts shall be immersed in the water bath with air or mechanical agitation. The time and temperature shall be kept constant. The maximum dip-rinse time shall not exceed 120 seconds. The temperature of the water shall be relatively constant and shall be maintained between 50 and 100 degrees F. A touch-up rinse may be necessary after immersion.

6.3.5.5 If manual or automated water spray is used, the rinse water temperature shall be between 50 and 100 degrees F. Spray rinse pressure shall be in accordance with the emulsifier manufacturer's recommendations. The maximum spray time shall not exceed 120 seconds.

6.3.5.6 If the emulsification and final rinse steps are not effective, as evidenced by excessive residual surface penetrant after emulsification and rinsing, dry and re-clean the part and reapply the penetrant for the prescribed dwell time.

6.3.6 Solvent-removable Penetrant Removal

6.3.6.1 Solvent-removable penetrant shall be removed by first wiping the excess penetrant with a clean, lint-free, dry cloth or absorbent towel, repeating the wiping operation until most traces of penetrant have been removed.

6.3.6.2 A clean, lint-free material shall then be lightly moistened with solvent and used to wipe the remaining penetrant from the surface of the part. The part surface shall not be flushed with solvent and the cloth or towel shall not be saturated with solvent.

6.4 Drying After Penetrant Removal

6.4.1 Drying of the part is necessary either following application of the aqueous wet developer or to dry the rinse water preceding the application of dry or non-aqueous developers.

6.4.2 During water-washable and post-emulsifiable penetrant tests, parts can be dried using a hot air re-circulating oven, by exposure to ambient temperature, using hot or cold air blasts, or by wiping/blotting with clean, absorbent cloth or paper. When a hot air re-circulating oven is used, the oven temperature shall not exceed 160°F. In addition, the part temperature shall not exceed 125°F. Monitoring of the part temperature shall performed on a random sampling basis provided that the results of the sampling are documented.

6.4.3 The maximum time allowed between the final rinse and drying of the part shall be 30 minutes.

6.4.4 In order to speed up drying, pooled water in blind areas shall be siphoned out, drained, or blown off with clean, dry shop air as per 6.3.3.7.

6.4.5 Parts shall not be allowed to remain in the drying oven any longer than is necessary for the surface to dry. Excessive time in the dryer may cause evaporation of the penetrant, thereby causing fluorescent indications to fade and a reduction in the sensitivity of the inspection.

6.4.6 During solvent-removable penetrant tests where the excess penetrant is removed with the solvent wipe-off technique, drying of the surface shall be accomplished by normal evaporation.

6.5 Developer Application

6.5.1 Dry Developer

6.5.1.1 Application of dry developer requires that the area to be developed must be dry prior to application.

6.5.1.2 Developer shall be applied immediately after the part has dried, while it is still hot.

6.5.1.3 Dry powder developer may be applied by immersion of the part into a container of developer, dusting with a hand bulb, powder gun, or in a dynamic or swirl cloud chamber. It may also be applied by conventional or electrostatic powder spray, or sprinkling.

6.5.1.4 Excess powder may be removed by shaking, lightly tapping, or blowing with low-pressure (not exceeding 5 psi) clean, dry air.

6.5.1.5 The developing time for dry powder developers shall be 10 minutes minimum and 4 hours maximum.

6.5.2 Non-Aqueous Developer

6.5.2.1 Application of non-aqueous developer requires that the area to be developed must be dry prior to application.

6.5.2.2 Parts shall be allowed to cool to room temperature prior to applying non-aqueous wet developer.

6.5.2.3 Non-aqueous developer shall be thoroughly agitated prior to being applied to the part surface.

6.5.2.4 Non-aqueous developer shall be applied to the part by conventional and aerosol spraying only. The developer shall be applied to provide a thin, even coating over the entire area being inspected. The coating shall be applied as uniformly as possible. The coating shall not be so thick as to mask any potential light indications.

6.5.2.5 A dryer may not be used for this type of developer. Dipping or flooding of parts with non-aqueous developer is prohibited

6.5.2.6 The minimum development time is 10 minutes and the maximum development time is 60 minutes.

6.5.3 Aqueous Developer

6.5.3.1 The concentration of aqueous developers shall be verified by hydrometer reading. The concentration shall be in accordance with the manufacturer's recommendations.

6.5.3.2 Aqueous developers shall be applied to the part immediately after the excess penetrant has been removed from the part and prior to drying.

6.5.3.3 Apply aqueous developers by flowing the developer onto the part or by immersing the part in the mixture. Spray application may be used for developing solvent-removable penetrants only. Atomized spray is not authorized.

6.5.3.4 Only approved water-suspendible developers shall be used with water-washable fluorescent penetrants.

6.5.3.5 The area of the part to be inspected must be completely covered with developer. The part shall be immersed only long enough to coat all of the part surface with developer.

6.5.3.6 All excess developer shall be drained from recesses and trapped sections to eliminate any potential pooling of developer.

6.5.3.7 The part shall be air or oven dried. When oven drying is used, the part shall not remain in the oven any longer than is required for it to adequately dry. The minimum and maximum development times, after the part is dry, are 10 minutes and 2 hours, respectively.

6.6 Test Evaluation

6.6.1 After the minimum development time (and before the maximum development time) has elapsed, the part shall be examined for indications. It is recommended that the surface of the part be observed during the entire development time, when possible, to observe the formation of indications.

6.6.2 Continuous fluorescent penetrant inspection by one individual shall be limited to a maximum of 2 hours at a time. Inspection may be resumed after a 15 minute break, followed by a 1 minute minimum adjustment period for the inspector's eyes in the darkened area prior to examining components.

6.6.3 The location of all rejectable indications shall be marked on the part.

6.6.4 Indications which are not acceptable in accordance with the applicable acceptance standards require submittal of the appropriate request for deviation document (SDR or QCR) in accordance with Para. 2.3.

6.7 Post-Inspection Cleaning

6.7.1 Post-inspection cleaning is necessary in those cases where residual penetrant or developer could interfere with subsequent processing or service requirements. It is particularly important where residual penetrant inspection materials might combine with other factors in service to produce corrosion. A solvent soak or ultrasonic cleaning shall be employed. In the case of developers, it is recommended that if post-inspection cleaning is necessary, that it be carried out as soon as possible after inspection so that the developer does not fix on the part.

7. PROCESS/QUALITY CONTROLS

7.1 System Performance

7.1.1 System Performance Verification

7.1.1.1 The test system shall be qualified using a TAM panel or a known defect standard which represents the smallest defects required by the specific procedure to be used.

7.1.1.2 For systems where chemicals do not come in spray cans, the system shall be qualified each time chemicals are added. Immediately after this qualification, either a sample of the mix shall be removed and stored for use as a baseline penetrant solution, or a high quality photograph shall be taken that clearly shows the smallest indication required.

7.1.1.2.1 A daily check of the system shall be made by testing a TAM panel or known defect standard and comparing the result to either the same test using the baseline solution of the photograph of the baseline results.

7.1.2 Other Required Verification Intervals - For a more detailed description of the verification checks contained below, refer to ASTM E1417. Suppliers who wish to deviate from any of the verification intervals listed below must submit a written request for the deviation. In addition, the Supplier must provide documentation which supports this request for deviation and obtain written approval from MPE.

7.1.2.1 Black light intensity shall be checked at least once per day.

7.1.2.2 Ambient white light intensity shall be checked at least once per day.

7.1.2.3 Penetrant contamination check shall be performed at least once per day (for penetrant systems using bulk immersion systems only.)

7.1.2.4 Aqueous developer contamination check shall be performed at least once per day.

7.1.2.5 Dry developer condition shall be checked at least once per day.

7.1.2.6 Water wash temperature shall be checked at least every 8 hours or every shift change.

7.1.2.7 Water wash pressure shall be checked at least every 8 hours or every shift change.

7.1.2.8 Hydrophilic emulsifier concentration shall be checked weekly.

7.1.2.9 Penetrant sensitivity shall be checked weekly (for penetrant systems using bulk immersion systems only.)

7.1.2.10 Lipophilic emulsifier water content shall be checked monthly.

7.1.2.11 Drying oven calibration shall be checked quarterly.

7.1.3 System Performance Records

7.1.3.1 A record of all verifications described in Para. 7.1.2 is required. Records shall be maintained for the time period specified in the contract.

7.2 Equipment Calibration

7.2.1 Black light and white light intensity meters shall be calibrated annually.

7.3 Eye Glasses

7.3.1 When using fluorescent materials, inspectors shall not wear eyeglasses that are photochromic or that have permanently darkened lenses.

7.3.2 Eyeglasses with lenses treated to absorb ultraviolet light are permitted.

7.4 Safety

7.4.1 The safe handling of liquid penetrant materials is governed by the suppliers' Material Safety Data Sheets.

7.4.2 Cracked or broken ultraviolet filters shall be replaced immediately. Broken bulbs can continue to radiate ultraviolet energy and must be replaced immediately.

7.5 Dark Adaptation

7.5.1 Personnel shall wait at least 1 minute after entering a darkened area for their eyes to adjust to the low-level lighting before performing fluorescent penetrant examination.

8. EVALUATION OF INDICATIONS

8.1 All indications in weld craters shall be considered relevant and shall be evaluated in accordance with applicable acceptance standards.

8.2 If indications are believed to be non-relevant, at least 10 percent of each type of indication shall be explored by removing the surface roughness or other condition believed to have caused the type of indication to determine if actual defects are present.

8.3 The absence of indications upon re-testing by liquid penetrant inspection after removal of the surface roughness, or other condition, shall be considered to prove that the indications were of non-relevant origin.

8.4 If a re-test again reveals indications, these and all of the original indications shall be considered to be relevant and shall be evaluated in accordance with applicable acceptance standards.

8.5 The following method of evaluating indications is permitted in order to verify that an indication was caused by a surface discontinuity or to interpret the type of surface discontinuity causing the indication and to measure the defect size:

8.5.1 Wipe the surface once with a light application of fast drying solvent using a camel's hair brush or equivalent. After the solvent has dried, redevelop the surface with dry powder developer. Indications which reappear within 2 minutes developing time shall be considered to be caused by surface discontinuities. They shall be evaluated under black light and dispositioned in accordance with the applicable acceptance standard. If the indication does not reappear, it shall be accepted at fluorescent penetrant inspection.

8.6 BHEL approval must be obtained prior to removal of any indications.

9. ACCEPTANCE CRITERIA

9.1 All relevant indications must be recorded and reported to the purchaser for resolution by Engineering via SDR.

* 9.2 For all superalloy rotor forgings the following acceptance criteria shall apply:

* 9.2.1 All relevant indications 0.062 inches (1.6 mm) or longer are rejectable and must be reported.

* 9.2.2 Two adjacent indications are considered to be interactive and part of a given group when they are closer than three times the maximum dimension of the smaller indication. Once established, a given group shall be considered the same as a single indication regardless of the number of individual indications in the group. Single indications and groups greater than 1/16" in length are unacceptable.

10. RECORD OF TEST

10.1 The following information shall be supplied by the Supplier:

10.1.1 Supplier name

10.1.2 Part identification

10.1.3 Shop order or purchase order number

10.1.4 Part drawing number

10.1.5 Final disposition of part

10.1.6 Date of test and name of person performing the test

10.2 Copies of the fluorescent penetrant test report shall be submitted to the appropriate Quality group through appropriate channels.

RECORD OF REVISIONS

Rev. No.	Date	Revision Details	Revised	Approved
00	20.12.11	FIRST MADE	RSR	(NVS MURTHY)

Ref. Doc

BHEL

PRODUCT STANDARD

GAS TURBINES

GT 10169

GEN REQT, COMB TRANSN PIECE

1. SCOPE

1.1 This Process Specification supplements the applicable drawings for combustion transition pieces, and parts thereof, made from Hastelloy X material. It specifies requirements for forming, cleaning, welding, marking, heat treatment, process qualification and approval, inspection and final product quality.

1.2 The requirements set forth herein shall apply to all applicable drawings.

1.3 Suppliers are responsible for meeting, in all respects, the requirements of this specification. This responsibility also applies to the prime suppliers for any or all sub-suppliers.

1.4 In the event of conflict, the order of precedence is: part drawing, this specification, other referenced specifications.

2. APPLICABLE DOCUMENTS

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

2.1.1 BHEL - Gas Turbine Division

GT 10157	Flourescent Penetrant Testing
GT 10206	Radiography of Combustion Parts
GT 10221	Machining of Superalloys
GT54031	Welding, General Specifications
GT10222	Heat Treat Process Contr...

2.1.2 American Welding Society

A3.0	Terms and Definitions for Welding and Cutting

Concurred:	STANDARDS	Revision	Issued		
		00	GAS TURBINES HYDERABAD-500032 (INDIA)		
		Date 7.XI.90	Prepared	Approved	Date 7.XI.90

REV. 00

3. DEFINITIONS

3.1 For purposes of this specification, the following definitions shall apply.

3.1.1 Customer - The procuring activity of the Gas Turbine Division of the BHEL or other Agency that issued the procurement document invoking this specification.

3.1.2 Customer Review Team - This shall include, as a minimum, representative of Combustion Design Engineering, Quality Assurance, Advanced Manufacturing Engineering and Materials and Process Engineering.

3.1.3 Supplier - The source duly contracted by the customer to perform the manufacture of the component. The term "Supplier" may also refer to an organizational unit of the BHEL.

3.1.4 Process Plan - A detailed step by step list of operating by which the applicable part (s) is planned to be manufactured and inspected.

3.1.5 Frozen Process - A process plan which has been proven, by applicable testing, to produce a part which meet the intended quality requirements and has been approved by the customers review team for production.

3.1.6 Weld Definitions - Reference to American Welding Society Publication A3.0 - "Terms and Definitions for Welding and Cutting".

3.1.7 Vendor Request for Material Deviation (VRMD) or CP A method for the documentation, control and approval of a temporary planned waiver for materials, processes or dimensions which deviate from Gas turbine Division drawings and specifications.

VRMD's may be prepared and submitted by any supplier other than the Gas Turbine Division of the BHEL.

3.1.8 Manufacturing Request for Material Deviation (MRMD) "CP" - Similar to "VRMD" but specifically designated for usage only by facilities of the Gas Turbine Division.

4. ENGINEERING REQUIREMENTS

4.1 Forming

4.1.1 Part shapes may be formed by any conventional hot or cold forming operation with the following limitations:

4.1.1.1 In-process thermal treatments shall be limited to a maximum of one (1) cycle at 1175°C for a maximum of fifteen (15) minutes at temperature for each specific part.

4.1.1.2 In-process thermal treatments at 1065°C are permitted without limitation.

4.1.1.3 All thermal treatments shall be controlled to±14°C.

4.1.1.4 Forming with tooling faced with low melting point materials, such as "Kirksite", is allowed provided that parts are cleaned adequately to remove any residue of such material prior to any welding or heat treating operations.

4.1.1.5 Localized heat straightening is strictly prohibited.

4.1.2 Tooling or locating holes should be postioned in surplus stock areas on applicable parts/assemblies. When it is impossible to remove such tooling holes as surplus metal, these holes must be repaired in accordance with this specification and shall be considered as full penetration requirement, per GT54031 inspection code (1).

4.2 Welding

4.2.1 All fusion welds are to be made in accordance with GT54031 Class I using Gas Tungsten Arc Welding (GTAW) process with proper gas backing where applicable. Weld filler material and weld class shall be as set forth on each drawing.

4.2.1.1 Use of filler material ether than that set forth on the specific drawings is strictly probibited.

4.2.2 Weld inspection codes shall be as set forth for each specific weld on the applicable drawing (s).

4.2.3 Weld configurations shall be in accordance with GT 54031 with the following exceptions:

4.2.3.1 Mismatch of butt welds shall not exceed 0.7 mm.

4.2.3.2 Maximum weld gap shall not exceed 2.3 mm.

4.3 Heat Treatment

4.3.1 Final heat treatment shall be performed on each welded assembly, less floating seals and uni-ball joints, or other parts set forth on any specific drawing, as follows.

4.3.1.1 Assemblies with 3.15 mm nominal body wall thickness shall be held at 735°C for fifteen (15) minutes minimum at temperature, followed by a rapid air cool to below 260°C.

4.3.1.2 Assemblies with 5.0 mm nominal body wall thickness shall be held at 1120°C for thirty (30) minutes minimum at temperature, followed by a rapid air cool to below 260°C.

4.3.1.3 All heat treatments shall be controlled to±14°C.

4.3.1.4 Cooling rate, above 540°C, shall not be less than 540°C per hour.

4.3.1.5 All heat treatments refer to maximum metal thickness temperature.

4.3.1.5.1 Correlations of furnace temperature to part temperature may be used, if approved by the Customer Review Team, Provided the furnace loading and part configuration are not changed.

4.4 Radiographic Requirements

4.4.1 Welds shall be radiographically inspected, as required by the specific drawing, in the finished component or assembly condition following the final dimensional and heat treatment adjustment, in accordance with GT54031 AND GT10026

4.4.1.1 No slag inclusions allowed.

4.4.1.2 Tungsten inclusions are limited to a maximum size of one-sixth (1/6) the minimum metal thickness of the joint with an accumulated length of one-half (1/2) the minimum metal thickness in any length of weld equal to twelve (12) times the minimum metal thickness.

4.4.1.2.1 Tungsten inclusions are not allowed within 12 mm of the weld end or point of intersection with another weld.

4.4.1.3 Lack of fusion not allowed.

4.4.1.4 **Porosity**

4.4.1.4.1 Maximum size of one-third (1/3) of the minimum metal thickness of the joint.

4.4.1.4.2 Maximum number of twelve (12) indications in any 150 mm length of weld.

4.4.1.4.3 Maximum of three (3) aligned indications separated by 1.5 mm or less.

4.4.1.4.4 Maximum of five (5) inclustered indications separated by 1.5 mm or less.

4.4.1.5 No cracks or lack of penetration allowed.

4.4.2 **Special Radiographic Allowance**

4.4.2.1 Welds which are specifically identified on the applicable drawing as "Reduced Radiographic Requirement - shall meet all of the radiographic requirements of this specification with the exception of the

following lack of penetration requirements.

4.4.2.1.1 Lack of Penetration shall be allowed for local areas to a maximum of one (1) times the minimum metal thickness of the joint. Separation for multiple spots shall be no less than two (2) times the minimum metal thickness of the joint. The total accumulated length shall not exceed ten (10) percent of any given weld length.

4.4.2.1.2 Such lack of penetration shall not be allowed within 12 mm of the weld end or point of intersection with another weld.

Note: The "Reduced Radiographic Requirement" will be set forth in the inspection area of the weld symbol for each applicable weld.

4.5 Visual Requirements

4.5.1 Welds shall be visually inspected in accordance with GT54031 with the following requirements:

4.5.1.1 No porosity allowed.

4.5.1.2 Weld reinforcement of butt welds shall not exceed 1.5 mm.

4.5.1.3 No undercuts are allowed for component thicknesses up to 3 mm inclusive. A maximum of 0.8 mm is allowed for component thickness from 3.0 to 12 mm.

4.5.1.4 No cracks are allowed.

4.5.1.5 Linear indications up to one-quarter 6 mm inclusive, in length are allowed.

4.5.1.6 Arc strikes in the base metal are not allowed.

4.5.1.7 All fillet welds shall have a tolerance of ± 1.5

4.5.1.8 Blending in the base metal shall not exceed the undercut allowance.

4.6 Flourescent Penetrant Requirements

4.6.1 Each weld shall be flourescent penetrant inspected, as required by the specific drawing, in the finished condition following the final dimensional adjustment and final heat treatment, in accordance with GTl0157 Group A1 to the following limits.

4.6.1.1 No cracks allowed.

4.6.1.2 Indications up to 1 mm confined to the weld or to the heat affected zone of the parent metal within 2.3 mm of the weld line, are acceptable.

4.6.1.3 Linear indications with length less than 3 times the width are acceptable up to 1 mm.

4.6.1.4 Indications must be separated by at least 3 times the maximum dimension of the larger adjacent indication.

4.6.1.5 Aligned linear indications must be separated by at least 25.0 mm minimum spacing.

4.6.1.6 No indications are allowed in weld craters.

4.6.1.7 Indications are defined as the size of the penetrant indication and not the actual defect size.

4.6.1.8 Wiping technique, as set forth in GT10157 for investment casting, may be used as an aid in verification of indications.

4.7 Temporary Marking

4.7.1 Materials used for temporary marking on combustion parts must be controlled to avoid accidental contamination of the part with low melting point or corrosive materials. The following limitations apply.

4.7.1.1 Graphite or lead type marking systems are prohibited.

4.7.1.2 The following temporary markers are approved.

Carter Co., Marks-A-Lot - Black
Carter Co., Marks-A-Lot - Blue
Dixon Co., Black
Dixon Co., Blue
Everhard Faber # 7500 Water Color Black
Dykem Co. Dark Blue Dykem DSL
Light Blue Dykem DMP
High Spot Blue Dykem 107
Joseph Dixon - Lead Free Yellow Lumber Crayons
Wallace Pencil Co., # 800 Black Marker
Machine Mfg. Co., Marco S-1141 Black
Marco S-1141 White

4.7.1.3 Any temporary marking compound other than those allowed by this specification must have specific approval by the customers review team prior to use on

Combustion parts.

4.8 Process Qualification and Approval

4.8.1 The following conditions require qualification and approval by the Customer Review team of the manufacturing processes prior to production.

4.8.1.1 New design

4.8.1.2 New supplier

4.8.1.3 Old supplier but no production of the specific part for a period in excess of six months elapsed time period.

4.8.1.4 New material or major configuration change.

4.8.2 First-Piece Qualification shall include the following requirements.

4.8.2.1 Documented manufacturing process plan with all operations sequentially identified.

4.8.2.2 Welding procedures, welding procedure qualifications and welder qualifications, as applicable to the specific part. (Ref. GT54031).

4.8.2.3 Heat treat facility qualification (Ref. GT10222).

4.8.2.4 Radiographic procedures and techniques (Ref. GT 10206)

4.8.2.5 Flouresoent penetrant procedures (Ref. GT10157)

4.8.2.6 Non conventional machining parameters and qualification (Ref. GT 10221)

4.8.2.7 Cleaning procedures.

4.8.2.8 100% Dimensional layout.

4.8.2.9 Pilot production run of a minimum of ten (10) parts/assemblies.

4.8.3 All welds which require radiographic examination, at any inspection code level, require a 100% radiographic coverage until first piece approval.

4.8.3.1 Upon receipt of first piece approval, all welds requiring inspection code (3) per GT54031, may be placed on audit plan at the direction of the Customer Quality Assurance Representative.

4.8.3.2 Audit requirement may not be lower than five (5) percent coverage, on verification by the Customer's Quality Assurance Representative that the quality level has been adequately proven.

4.8.4 Upon receipt of first-piece approval, the supplier is released for production of the specific part (s) by the process used for the approved part (s). Any adjustment or changes to the approved "Frozen Process" must be documented and approved by the customers review team prior to implementation. Such reapproval may require partial or complete re-qualification, dependent on the changes involved as defined by the customers review team.

4.8.5 Customer representatives shall have the option of reviewing the specific operations for conformance to the approved qualification, i.e. "Frozen Process" Failure of any audit or review to show a proper level of compliance to said frozen process or indications of lack of adequate control will require re-qualification.

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4.9 Permanent Marking

4.9.1 Each finished assembly shall be permanently marked in the location set forth on the applicable assembly drawing. The marking shall include the following.

4.9.1.1 Drawing Number, (Group Number) Variant and Revision Level

4.9.1.2 Date of Shipment, including Month and Year

4.9.1.3 Vendor Code Identification

4.9.1.4 Serial Number

4.9.1.5 Any applicable "CP"

4.9.2 The permanent marking shall be made by Vibro-Peen to a depth range of 0.1 to 0.2 mm.

4.9.3 The supplier should request the identification location, from the customer, for parts which do not have said location designated in the applicable drawing.

4.10 Repair Welding

4.10.1 Welds which require repair may be repair welded prior to final heat treatment, using welding procedures approved by the customer.

4.10.2 Welds requiring repair after the final scheduled heat treatment are subject to the following limitations.

4.10.2.1 Approved welding procedures are required

4.10.2.2 Repair welds on the floating seal retaining system, aft FIFTY (50) mm.s of the transition piece, will be considered on an individual basis. Certain repairs, as determined by the customer, may require a re-heat treatment.

4.10.2.3 Fillet welds may be repair welded up to 12 mm lenth, minimum spacing between repair of 100 mm without requirement for subsequent heat treatment.

4.10.2.4 Body butt welds, other than in the aft 50 mm of the assembly, may be repaired up to 6.0 mm length, with a minimum spacing between repairs of 150 mm without requirement for subsequent heat treatment.

4.10.2.5 Parent metal cracks, other than in the aft 50 mm of the assembly, may be repaired up to 6 mm length, with a minimum spacing between repairs of 76.0 mm without requirement for subsequent heat treatment.

4.10.2.6 All repairs shall be inspected, following welding, and heat treatment if required, to the original inspection level requirements for the particular weld or in the case of parent metal repairs, to the requirements of an inspection code (1) weld (Ref. GT54031)

4.10.2.7 Parts which require re-heat treatment, must be completely reinspected to the original requirements following the re-heat treatment.

4.11 Final Finish

4.11.1 Finished assemblies which meet all the quality and dimensional requirements, as set forth herein and on the specific part drawing, shall be lightly grit blasted, using silica or Alumnia grit size 120-180, to a light matt finish.

4.11.1.1 Caution: Do not plug cooling holes.

4.11.1.2 Protect finish machined surfaces, movable seals and uni-balls, where applicable, to prevent grit erosion of said surfaces.

4.12 **Packing**

4.12.1 Each part shall be boxed or crated in such a manner to be protected from damage during shipment Particular attention must be directed at protection of the floating seals, the aft bracket and the forward brackets.

4.12.2 Each shipping container shall be legibly marked with the purchase order number, the manufacture's name, customers complete address, BHEL drawing and group number, part serial number and all other information specified by the customers purchase order.

5. QUALITY ASSURANCE REQUIREMENTS

5.1 The supplier shall maintain appropriate records of all details of the manufacturing process. Said records will be made available on request for review by any customer representative (s).

5.2 The supplier shall provide the customer with appropriate test material, as required, for items which involve non conventional machining operations.

5.3 The supplier shall prepare, for review and approval by customers Quality Assurance Representative, the routines for obtaining and recording all critical dimensional data. The dimensional records, "Dim-Data" sheets, shall become an integral part of the production recording requirements.

5.4 The documentation for First-Piece Qualification shall be submitted to the customers Quality Assurance Representative for approval by the customers review team.

5.4 The supplier will be responsible for proper material segregation and avoidance of material mix-up situations.

5.6 A supplier may request deviations to the drawing requirements by means of a CP (CHANGE PROPOSAL) as applicable to the particular supplier.

5.6.1 CP's to be submitted through the Combustion Purchasing Representative for action.

5.6.2 CP's to be submitted through Combustion Design Engineering for action.

5.6.3 CP's which have been properly approved must become a permanent part of the records for all parts involved. Allowed CP's shall be permanently marked by CP number, or approved traceable code, on the applicable part (s) (Ref. Para 4.9)

6.0 NOTES

6.1 The application of this specification on any part or assembly shall make null and void any prior agreement, understanding or documentation which violates the requirements set forth in this specification.

RADIOGRAPHY - COMBUSTION COMPONENTS

1. SCOPE

1.1 This specification covers radiographic process requirements for examination of combustion parts.

2. APPLICABLE DOCUMENTS

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

2.1.1. American Society for Testing and Materials:

ASTM - E 94	Recommended Practice for Radiographic Testing
ASTM - E 142	Standard Method for Controlling Quality of Radiographic Testing.
ASTM - E 192	Standard Reference Radiographs of Investment Steel Castings for Aerospace Applications

2.1.2 BHEL - GT-DESIGN

GT-4024	Radiographic Technique Chart

3. DEFINITIONS - Not applicable.

4. SPECIFIC ENGINEERING REQUIREMENTS

4.1 General radiographic practice shall be in accordance with the latest revisions of ASTM - E 94, ASTM - E142, and ASTM - E 192.

4.2 Prior to production, the vendor shall obtain written approval of radiographic technique for each part design from the purchaser To obtain this the vendor must submit to Turbine Materials & processes Engineering and Quality Assurance one set of sample radiographs; and, the radiographic technique used, including number of exposures types of film, voltages, use of screens and filters, source-to-film distance, type of equipment, sketches or photographs of the positioning of the parts, view number, explanation of area covered, and all other pertinent parameters on form GT-4024 (form attached).

4.2.1 The usage of real time imaging radiographic systems does not require submittal of sample radiographs. Such systems require on site approval by GTD Turbine Materials & Processes Engineering and Quality Assurance. The vendor must submit a completed GT-4024 to GTD, Turbine Materials & Processes Engineering and Quality Assurance for approval.

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4.3 After approval per 4.2, the radiographic technique shall not be altered without the prior written permission from Turbine Materials & Processes Engineering and Quality Assurance.

4.4 Film Types - Kodak Type "M" film or equivalent must be used except as noted and approved in the applicable Radiographic Technique Chart, or as allowed for real time imaging systems (Ref. Para. 4.2.1).

4.5 Film Identification

4.5.1 Packing List - Each shipment of radiographic film, when required (Ref. Para. 4.2), must be accompanied by a packing list which shall include the following;

(1) Drawing number
(2) Part number
(3) Material specification
(4) Purchase order number
(5) A list of x-ray serial numbers in the shipment
(6) Number of vendor rejects and their serial number(s)
(7) Number of pieces in the shipment

4.5.2 Film Envelope - Unless otherwise permitted, all film must be shipped in film envelopes. All first order packaging, i.e., packaging such as envelopes in direct contact with the film, must be labeled as to drawing number, part number, x-ray serial numbers covered and the date of film exposure.

4.5.3 Individual Film - The drawing number, part number, and serial number, must appear on each sheet of film. The parts must be serialized consecutively on the film in such a manner that they can be positively identified. Film from re-x-rayed parts must be labeled as such.

4.5.4 Recording Tape - A record shall be made of real time imaging radiographs on recording tape of sufficient quality to comply with the sensitivity and minimum storage time requirements herein set forth.

4.5.4.1 Each cassette/reel of video tape shall contain or be labeled with the following information: video tape serial number, part serial number, drawing number, date of inspection.

4.6 Part Identification

4.6.1 All radiographed parts shall be serialized and the radiographs and/or radiographic record shall be suitably identified with the applicable serial numbers.

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4.6.2 All x-ray serial number sequences must be approved by Turbine Materials & Processes Engineering and Quality Assurance before implementation on a specific part by the vendor.

5. ENGINEERING TEST AND QUALITY ACCEPTANCE REQUIREMENTS

5.1 Sensitivity - Radiographic sensitivity level shall be 2-2T unless otherwise specified. Penetrameters of a metal of similar radiographic density to that being examined shall be used. On a given radiograph, satisfactory coverage shall be considered to exist only in those areas where the film density for part corresponds to the film density for penetrameters in which the 2T hole is clearly visible. A penetrameter validates only the film upon which it appears and other films exposed simultaneously with it. Special techniques without penetrameters must have prior written approval.

5.2 Radiograph Quality

5.2.1 Radiographic film supplied (as required) must be free of scratches, dirt, water marks, fingerprints, or any other artifact which could interfere with proper interpretation of the film.

5.2.1.1 Interpretation - It is the vendor's responsibility to review parts for conformance to the applicable quality standard as detailed in the applicable specification and to reject those parts which do not conform. All indications which show on the x-ray film must be labeled as to their cause be they small water marks, scratches, dirt particles, film defects, visual defects, defects which will machine out, defects of allowable size, etc. If in any shipment of radiographic film more than 2% of the parts show unlabeled and/or out-of-specification indications, then the entire shipment, both parts and film are subject to return to the vendor for re-examination and sorting after which the in-specification parts may be re-submitted.

5.2.2 Real time radiographic records shall be uniform in quality, reproducible to the original sensitivity.

5.2.2.1 Real time radiographic records shall be stored in a protective enclosure suitably protected from accidental damage by other radiation and magnetic fields for a period of seven (7) years.

5.2.2.2 Supplier shall maintain appropriate records of all details of the processing, such records together with the actual radiographic records shall be made available on request, for review by the customer representative

6 NOTES - Not applicable.

Form No. TO-106-2 REV. 2

P38-AG11

PRODUCT STANDARD

GAS TURBINES

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GT 10206

VENDOR: VENDOR CODE:

Part Number: Part Name:

ITEM						
1. Kilovoltage						
2. Milliamperage						
3. Time (Sec.)						
4. Focal Distance						
5. Film/Tape Type						
6. Film/Tape Size						
7. No. of film						
8. Lead Screens						
9. Processing Time						
10. Penetrameter Type						
11. Penetrameter Size						
12. Material						
13. Material Thickness						
14. AQL application for subsequent lot/part acceptance, i.e. 100%, 1.0%, .65%, etc.						

PROCEDURE:

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 pi[illegible] 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 $\pm$ 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.

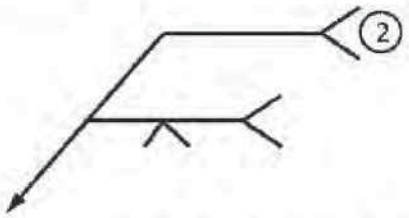
9.2.2 Requirements for root pass inspection (Codes 10 through 13) are as follows:

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

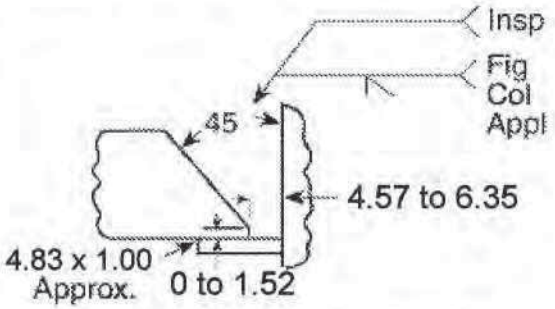
If a preferred weld preparation does not suit the required application, the weld preparation shall be described by the weld symbol.

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.

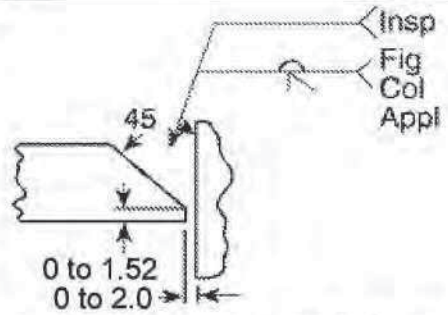
For all open root welds on stainless steel base materials, inert shielding backing gas required.

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



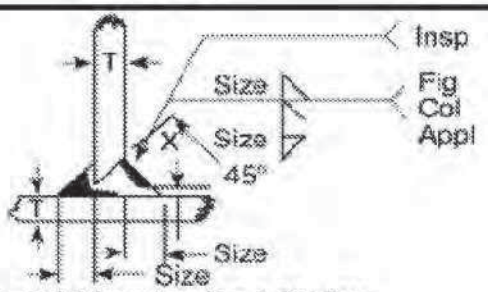
Complete Penetration – One Side Accessible – Weld One Side

Fig. B1



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

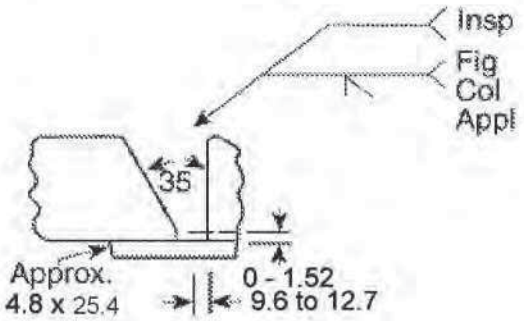
Fig. B2



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

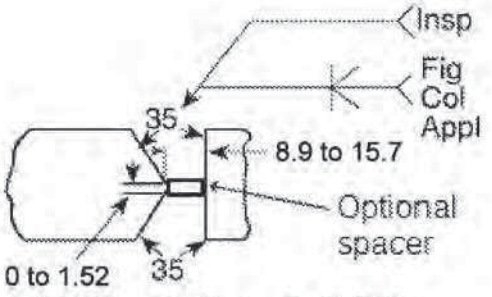
Complete Penetration – Both Sides Accessible – Weld Both Sides – Excavate To Sound Metal Before Welding Second Side.

Fig. F3



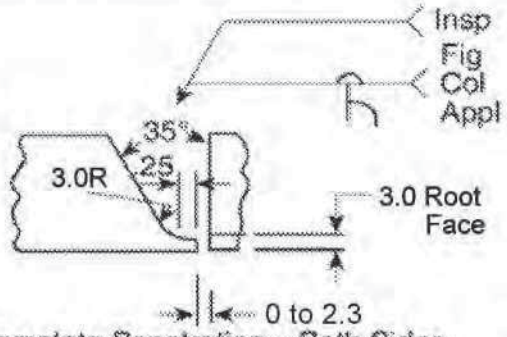
Complete Penetration – One Side Accessible – Weld One Side

Fig. J1



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

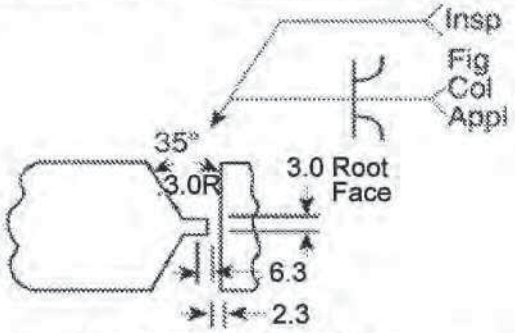
Fig. J2



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

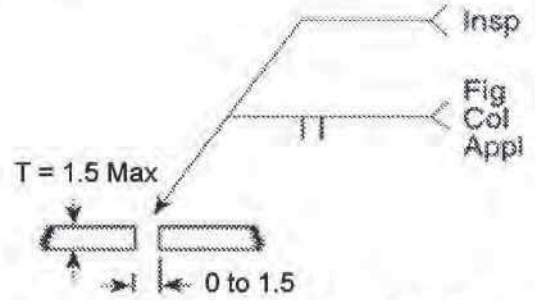
Fig. J3

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



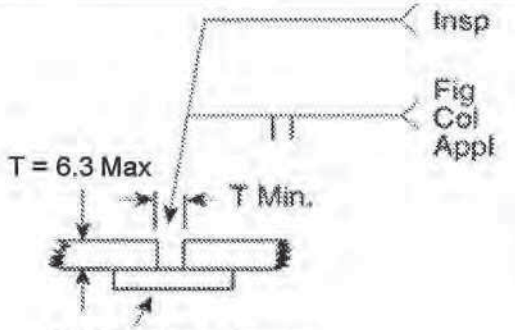
Complete Penetration – Both Sides Accessible – Weld Both Sides Excavate To Sound Metal Before Welding Second Side.

Fig. J4



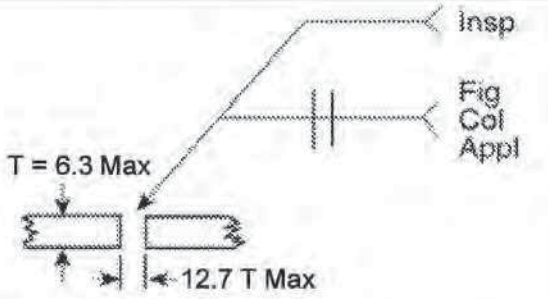
Complete Penetration – Weld One Side. Inert Gas Backing May Be Used.

Fig. S1



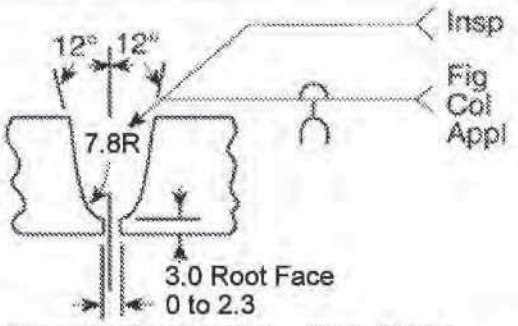
Complete Penetration – One Side Accessible – Weld One Side.

Fig. S2



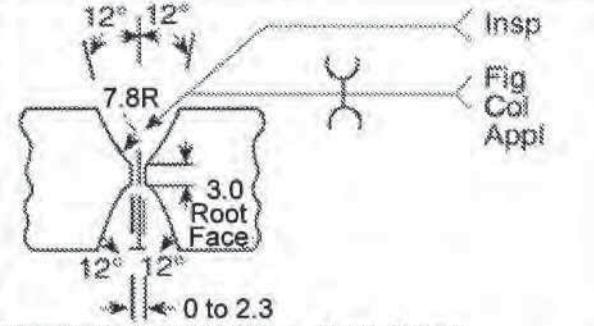
Complete Penetration – Both Sides Accessible – Weld Both Sides Excavate To Sound Metal Before Welding Second Side.

Fig. S3



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

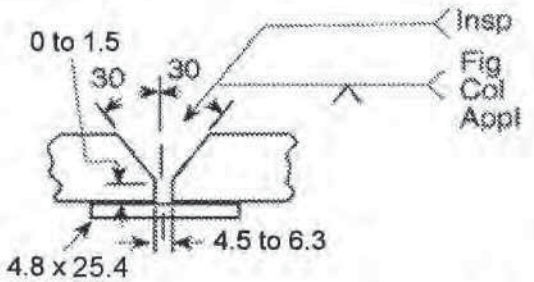
Fig. U3



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

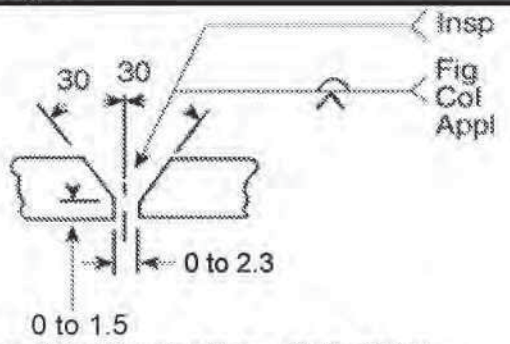
Fig. U4

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



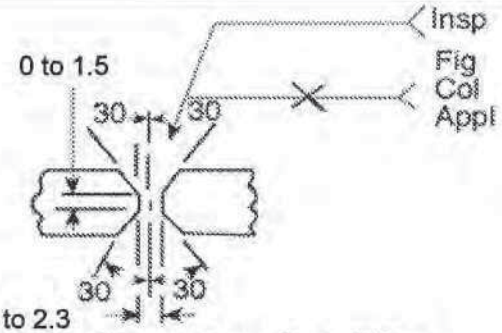
Complete Penetration – One Side Accessible – Weld One Side

Fig. V1



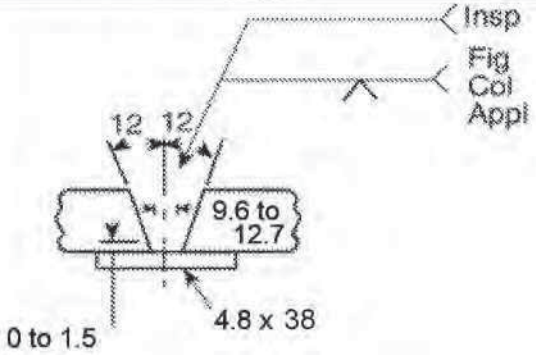
Complete Penetration – Both Sides Accessible – Weld Both Sides – Excavate To Sound Metal Before Welding Second Side.

Fig. V2



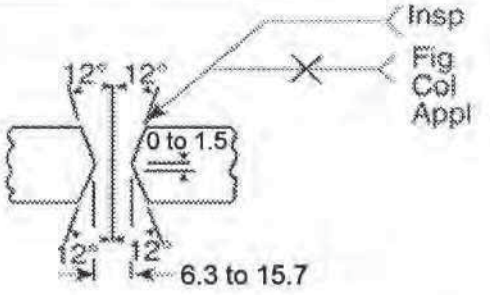
Complete Penetration – Both Sides Accessible – Weld Both Sides Excavate To Sound Metal Before Welding Second Side.

Fig. V3



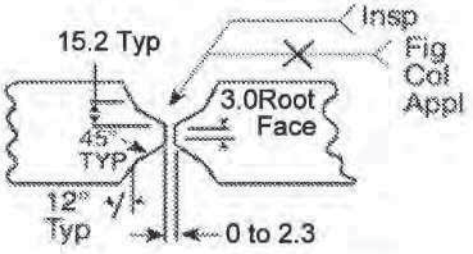
Complete Penetration – One Side Accessible – Weld One Side

Fig. V6



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

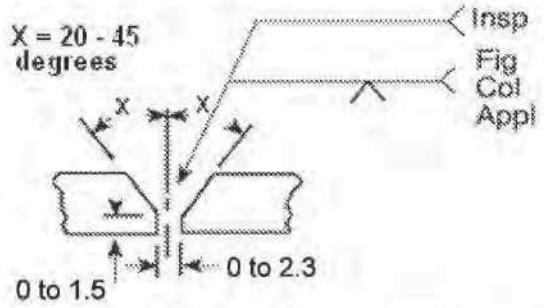
Fig. V7



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.

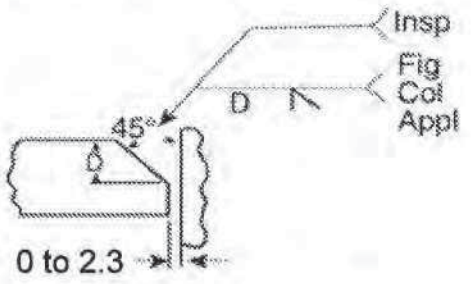
IV-2 Use of Preferred Weld Joint Designs for Partial Penetration Welds

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°.

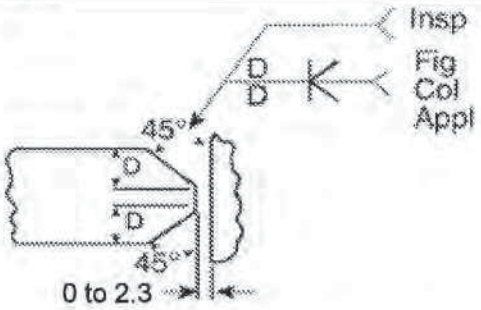
For all open root welds on stainless steel base materials, inert shielding backing gas required.

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

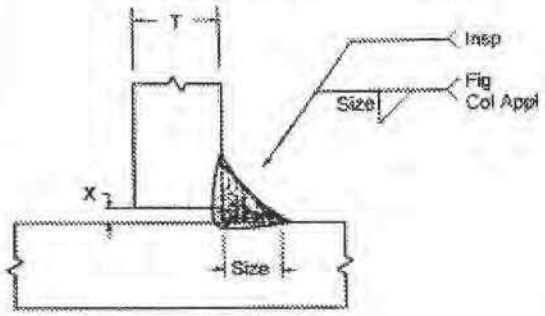
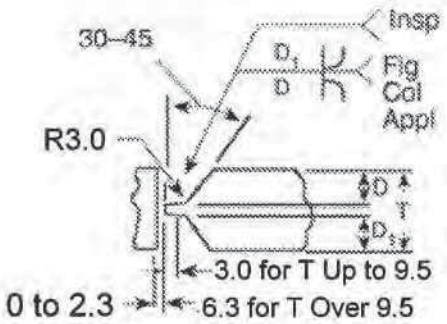
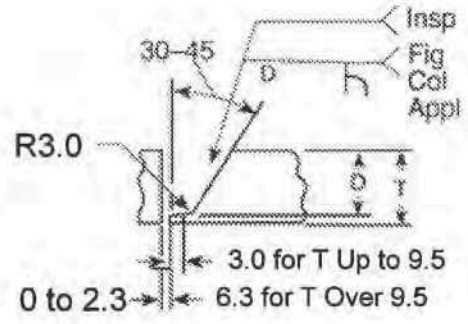


Fig. F1



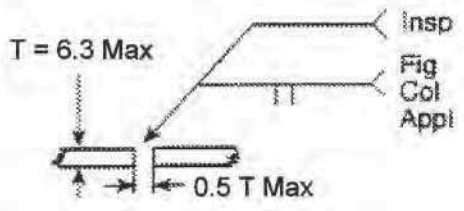
Partial Penetration – Both Sides Accessible – Weld Both Sides.

Fig. J5



Partial Penetration – Weld One Side

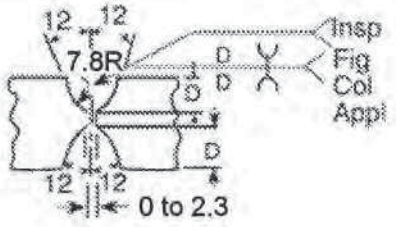
Fig. J6



Partial Penetration – Weld One Side

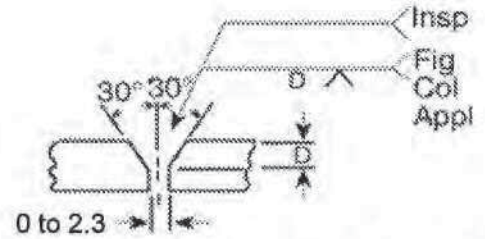
Fig. S4

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



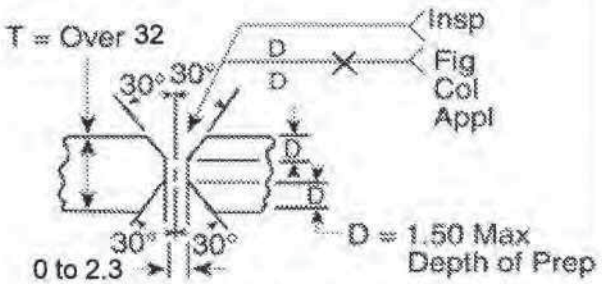
Partial Penetration – Both Sides Accessible – Weld Both Sides.

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°.

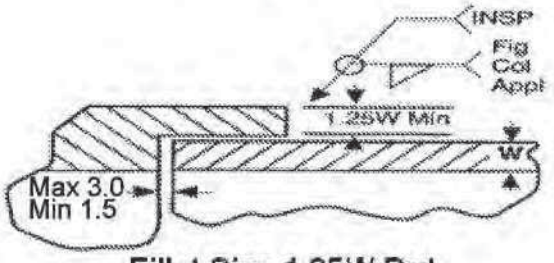
For open root weld accessible from one side only, must use GTAW for root and a hot pass before any other welding process.

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.

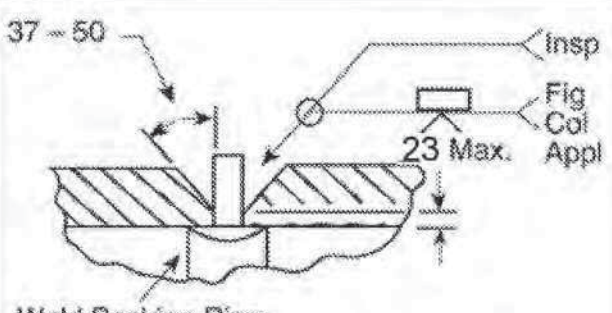
Fig.-P9 was removed.

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

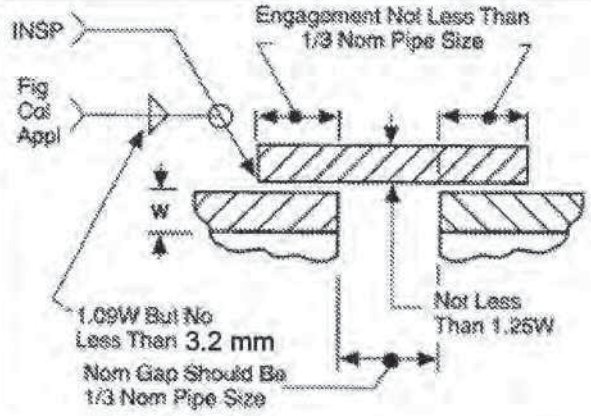


Fig. P3

D = DEPTH OF WELD PREP

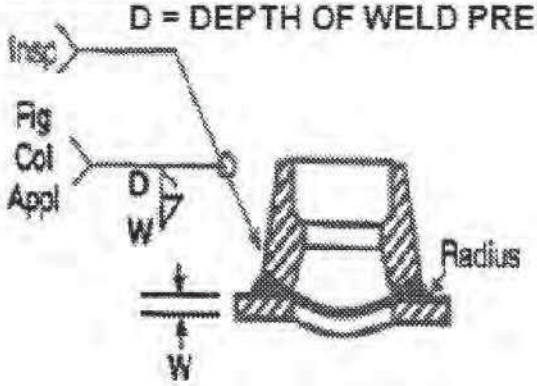


Fig. P4 Logitudinal Section

Blend Weld Into Pipe (No Undercut Permitted)

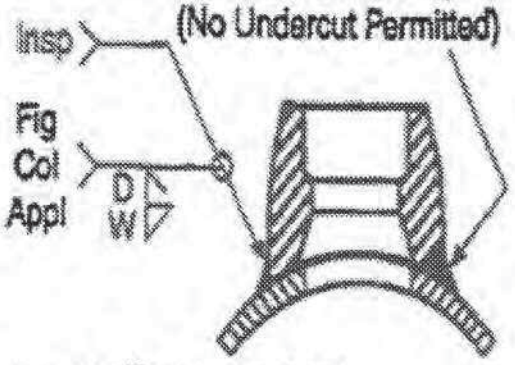
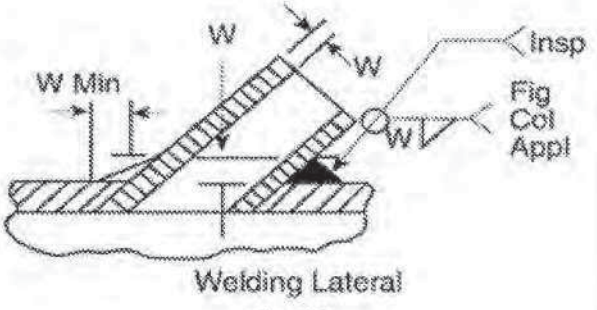


Fig. P4 Transverse Section



Welding Lateral

Fig.P5

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

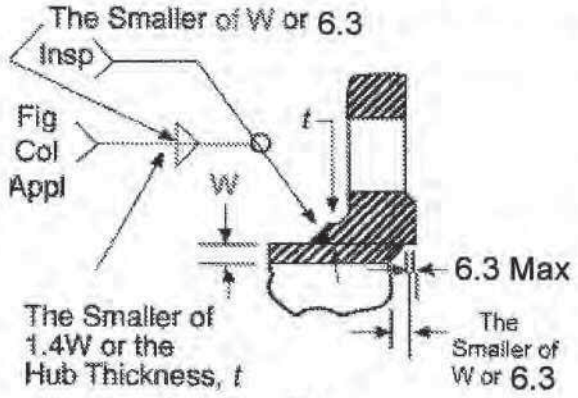


Fig. P6

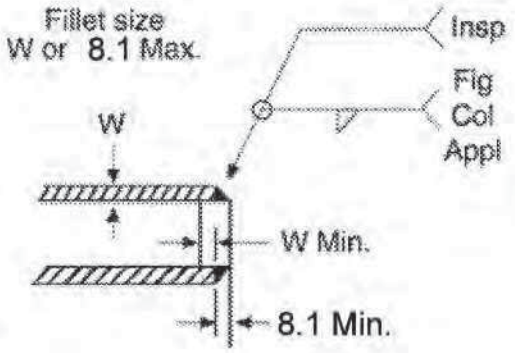


Fig. P7

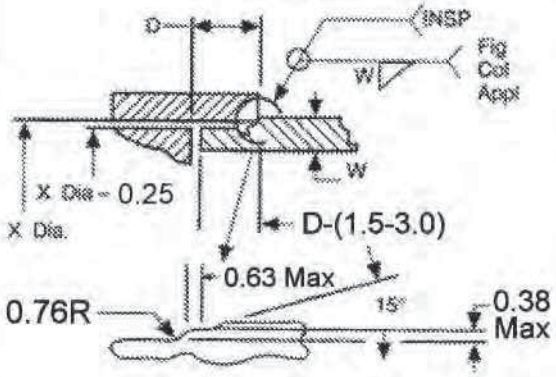


Fig. P8

Fig. P9 Deleted

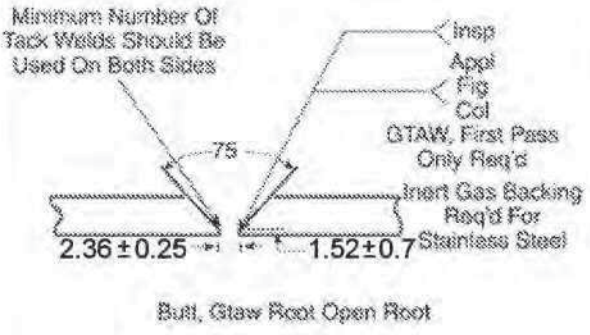


Fig. P10

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.

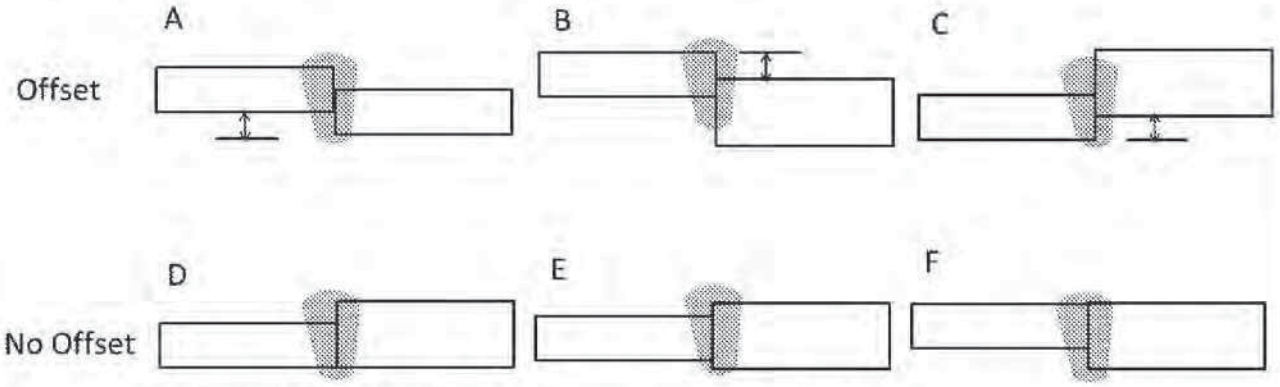


Figure VI.1: A-C: Joint Offset as noted. D-F No Offset.

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.

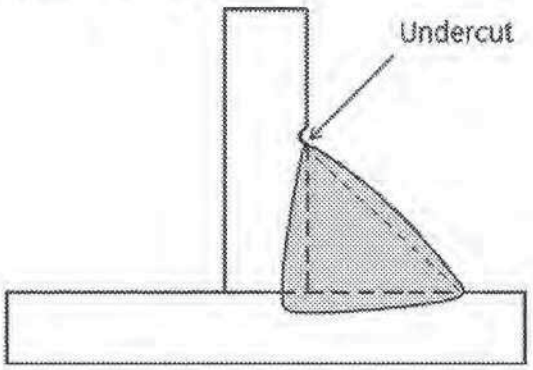


Figure VI.2: Weld undercut

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

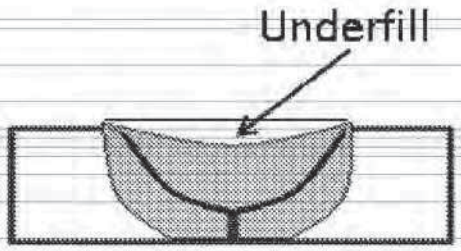


Figure VI.3: Weld underfill

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.

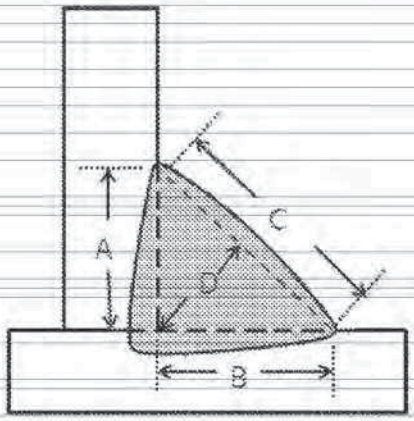


Figure VI.4: Weld fillet and throat size measurements. A: Leg size. B: Leg size. C: Largest 90° triangle you can fit in the weld. D: Throat size.

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.

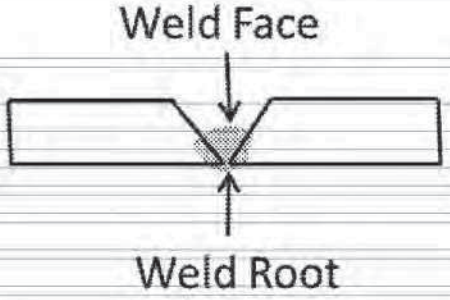


Figure VI.5: Weld face and weld root

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).

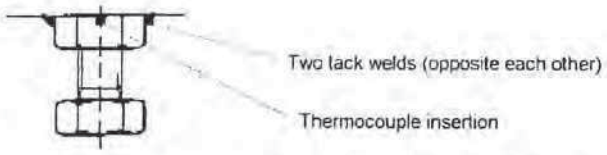


Figure 3 Thermocouple attachment

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:

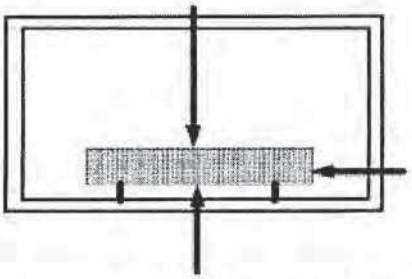


Figure 4. Thermocouple placement for full body heat treatment

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.

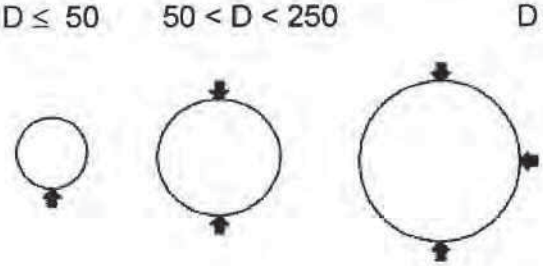


Figure 5. Thermocouple positioning for local heat treatment of pipe

Environment.

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

BHEL

PRODUCT STANDARD

HYDERABAD

GT54031

Rev No. 04

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.

NICKEL BASE ALLOY SHEET, PLATE AND STRIP
(HASTELLOY X)

1.0 GENERAL:

This specification governs the quality requirements of, Nickel base alloy sheets and plates for high temperature application.

2.0 APPLICATION :

For combustion liner and transition piece in Gas Turbines.

3.0 CONDITION OF DELIVERY:

3.1 **Sheet & Strip :** Hot or cold rolled, solution heat treated and descaled unless solution heat treatment is done in an atmosphere yielding a bright finish..

3.2 **Plate:** Hot rolled, solution heat treated and descaled.

4.0 COMPLIANCE WITH NATIONAL STANDARDS:

This specification in general complies with ASTM B435: UNS-N6002.

5.0 DIMENSIONS AND TOLERANCES:

5.1 Dimensions shall be as specified in the purchase order.

5.2 Tolerances on the plates & sheets shall be as per ASTM B 435.

6.0 MANUFACTURE:

The material is produced by Vacuum Induction Melting (VIM) followed by Vacuum Arc Refining (VAR) or Electro Slag Refining (ESR). Any other process shall be mutually agreed upon.

7.0 HEAT TREATMENT:

This material shall be solution heat treated by heating to 1175°C (2150°F), holding at the temp. for not more than 30 minutes and rapidly cooling.

8.0 FREEDOM FROM DEFECTS:

The sheets shall be free from cracks, seams, fissures, laps and other harmful defects.

9.0 FINISH:

The material should possess a bright finish and have surface appearance as close as possible to a commercial corrosion resistant steel No.2D finish.

10.0 TEST SAMPLES:

10.1 Chemical Analysis: One test sample shall be taken per melt.

10.2 Mechanical Tests: One test sample for lot comprising of plate/sheet/strip of the same size, melt and heat treatment batch shall be taken for Mechanical Testing.

11.0 CHEMICAL COMPOSITION:

The chemical analysis of the material shall be as follows:

Element	C	Mn	Si	P	S	Cr	Co	Mo	W	Fe	B	Ti	Ni
Min.%	0.05	-	-	-	-	20.50	0.50	8.00	0.20	17.00	-	-	Bal.
Max.%	0.15	1.00	1.00	0.040	0.030	23.00	2.50	10.00	1.00	20.00	0.010	0.15	-
Permi-ssible variation	±0.01	+0.03	+0.05	+0.005	+0.005	±0.25	-0.02 +0.05	±0.15	±0.04	±0.30	LAP Note(2)	LAP Note(2)	-

Note: 1) Elements not listed in this table shall not be intentionally added without prior approval of BHEL.

2) LAP – As low as possible.

12.0 MECHANICAL PROPERTIES:

The material shall conform to the following mechanical properties when tested in accordance with ASTM E8.

12.1 Tensile properties:

Thickness mm	Tensile strength Mpa min.	Yield strength 0.2% offset Mpa min.	Elongation % in L=50 mm min.
Upto 0.254 excl.	725	310	-
0.254 to 0.508 excl.	725	310	29
0.508 to 4.572 incl.	725	310	35
4.572 to 50.8 incl.	690	275	35
over 50.8	660	275	35

12.2 **Hardness:** Hardness shall be 90 HRB max.

13.0 RETESTS:

13.1 If, any of the test specimen fails to meet the requirement specified, the sample sheet from which the test specimen are taken shall be rejected and two further sample sheet from the same lot shall be taken for retest.

13.2 If, any of the retests also fails, manufacturer is at liberty to heat treat the sheet in question. However, not more than two heat treatments are allowed.

.

13.3 If, after heat treatment, the mechanical properties are not complied with, the entire lot shall be rejected.

14.0 STRESS RUPTURE TESTS:

The material shall be capable of meeting the following minimum stress rupture requirements when tested at 815° C (1500°F). This test is conducted as per ASTM E139.

Thickness mm	Stress MPa	Life hours	Elongation % in l = 50 mm
0.254 to 0.508 excl.	110	15	3
0.508 and over	110	24	8

NOTE: Stress rupture testing may be conducted at stress levels higher than that specified provided all other test conditions are maintained. The specified life and elongation requirements shall apply and stress shall remain constant while the test is in progress. Stress values used shall be reported in the vendor's test certificate.

15.0 BENDING:

Material shall withstand without cracking, bending at room temperature through an angle indicated below around a diameter equal to the bend factor times the nominal thickness of the material, with axis of bend parallel to the direction of rolling. Inspect bend test specimens at 20x magnification. This test shall be done in accordance with ASTM A370.

Thickness mm	Angle, degrees min.	Bend factor
0.254 to 1.27 excl.	180	1.5
1.27 to 4.57 incl.	180	2

16.0 METALLOGRAPHIC INSPECTION:

16.1 Grain Size: The material shall conform to the following grain size requirements when examined as per ASTM E112 Plate I.

Thickness, mm	Average grain diameter (Max.) (mm)	ASTM Micrograin Size No.
3.175 & under	0.127	3.0 or finer
Over 3.175	0.214	1.5 or finer

16.2 Microstructure: The microstructure in the solution annealed condition shall be clean and exibit uniform austenitic structure. The microstructure shall not show massive carbide precipitation in the matrix or at the grain boundaries. Photomicrographs shall be enclosed to the test report.

17.0 INSPECTION AT SUPPLIER'S WORKS:

The representative of BHEL shall have free access to the supplier's works at all times during the execution of the order, to satisfy himself that the material is produced as per the quality requirement of this specification. All reasonable facilities shall be extended to him, free of charge. He may witness sampling, testing and marking called for in this specification/order.

18.0 TEST CERTIFICATES:

Five copies of the test certificates shall be supplied furnishing the following details:

(a) HY 12763 Rev.01

(b) Material grade : Hastelloy X

(c) BHEL Order No.

(d) Dimensions

(e) Melt Number

(f) Process of Manufacture

(g) Heat treatment and details batch number

(h) Results of Chemical analysis, Mechanical Tests, Stress Rupture, Bend Tests and Metallographic tests with representative photomicrographs.

19.0 PACKING AND MARKING:

19.1 Marking: Sheets shall be bundled together as per size and each bundle shall have a metal tag with following information.

(a) HY 12763 Rev.01

(b) BHEL Order No.

(c) Melt No./Heat treatment batch

(d) Size/weight

(e) Manufacturer's Trade transit.

19.2 Packing: The sheet shall be suitably packed to prevent corrosion and damage during transit.

20.0 REJECTION AND REPLACEMENT:

In the event of any material proving defective in the course of processing or testing, such material shall be rejected and the supplier shall make immediate arrangements to replace the same free of cost.

LIST OF APPLICABLE STANDARDS ON LIMITS, FITS AND TOLERANCES

1.0 SCOPE:

The standard covers the list of applicable standards on Limits, Fits and Tolerances. These standards are applicable unless or otherwise specified.

2.0 LIST OF APPLICABLE STANDARDS:

SL. NO.	STANDARD NO.		TITLE
1.	AA0230201	-	Limits and Fits (Tolerance grade, Position and Class).
2.	AA0230202	-	Limits and sizes for commercial bolts and nuts.
3.	AA0230204	-	Guide for selection of Fits.
4.	AA0230206	-	Standard limits for Shafts (upto 500 mm).
5.	AA0230207	-	Standard limits for Shafts (above 500 mm and upto 3150 mm).
6.	AA0230208	-	Allowable deviations for dimensions without specified tolerances (linear and angular).
7.	AA0230402	-	Permissible deviations for untoleranced dimensions of castings.
8.	AA0230403	-	Tolerancing system ISO Metric Screw Threads
9.	AA0621101	-	Tolerances and Machining allowances for Flame cutting.
10.	AA0621104	-	General tolerances for welding constructions for length and angles.
11.	AA0621105	-	General tolerances for welded structures – form and position.

NOTE:

1) AA 023 02 08

Medium class of deviation is applicable, if the same is not mentioned on the drgs./specs.

2) AA 023 04 02

Tolerance class 5 is applicable, if the same is not mentioned on the drgs./specs.

3) AA 062 11 04

Accuracy class A is applicable if the same is not mentioned on the drgs.

4) AA 062 11 05

Accuracy class E is applicable, if the same is not applicable on drgs.

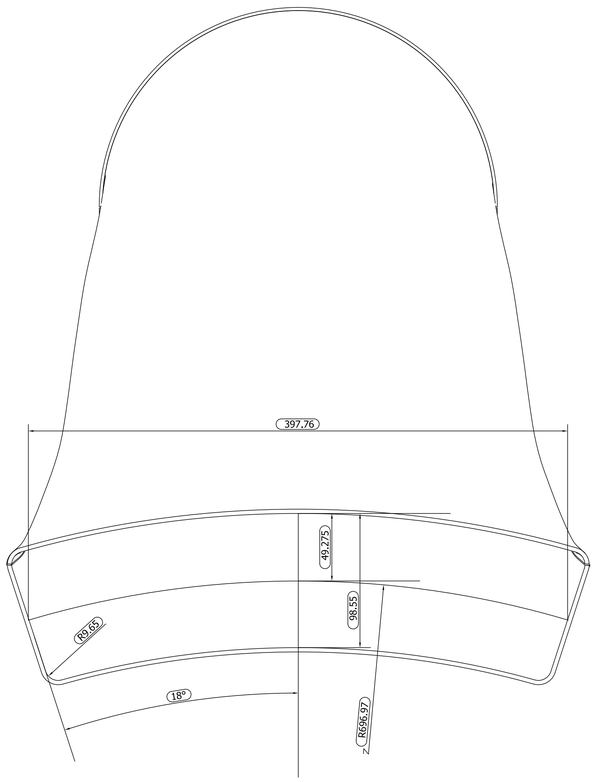
FIRST ANGLE PROJECTION

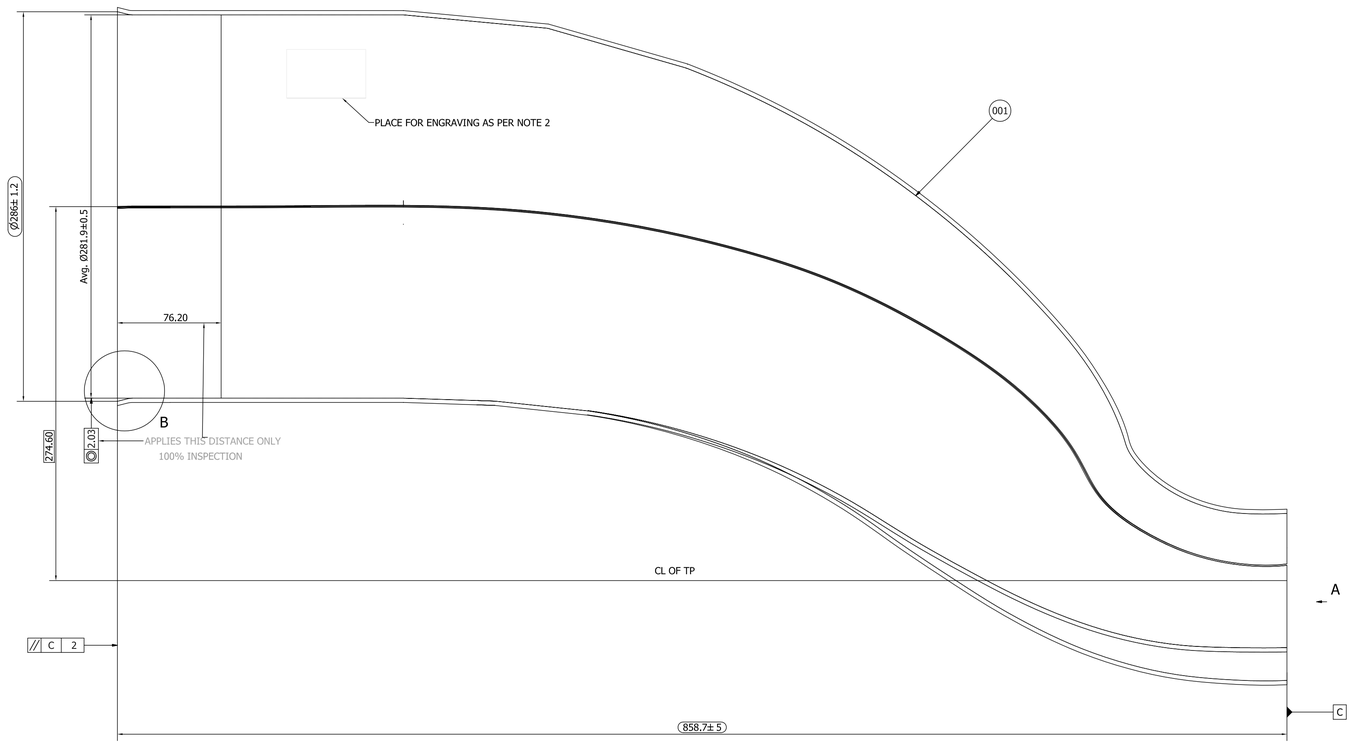
(ALL DIMENSIONS ARE IN mm)

SH. OF

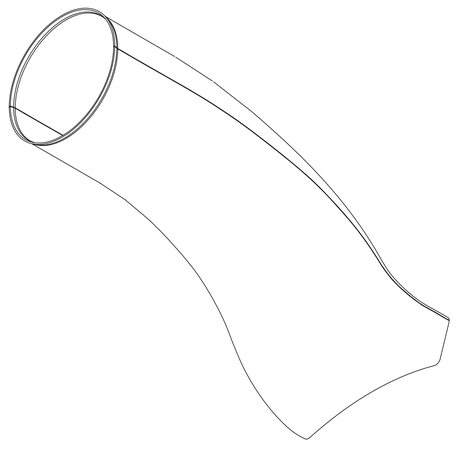
DRG. NO. 03510951003

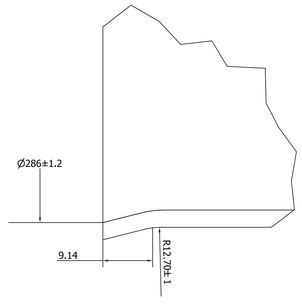
A (1 : 1.5)





B (1.33 : .5)





NOTES:

1. UNLESS OTHERWISE SPECIFIED BHEL STANDARD MANUFACTURING QUALITY PLAN DOCUMENT NUMBER SHALL BE FOLLOWED: HYQA/SQP/GT/1415/34

2. SUPPLIER IDENTIFICATION TO BE ENGRAVED AS BELOW: VVVVVV/WWWWWWWWW/MM-YY/ZZ

   VVVVVV = BHEL VENDOR CODE
   WWWWWWWWW = BHEL P.O. NUMBER
   MM = MONTH OF MFG
   YY = YEAR OF MFG
   ZZ = SL. NO. (If 10 no's order In P.O. 01 to 10)

   Example: AP00306/G614A0014/01-15/01

3. REFER GT 10169 FOR GENERAL REQUIREMENTS OF COMBUSTION TRASITION PIECE WHERE EVER APPLICABLE.

4. AS SHOWN IN VIEW B FLARING SHALL BE CARRIED OUT BY FIXTURE. FIXTURE SHALL BE ORGNISED BY THE VENDOR.

5. AFTER FLARING CHECK FOR VISUAL CRACKS AND CARRYOUT DP TEST AS PER GT10160 ACCEPTING NORMS AS PER CLAUSE 9.5.3 OFGT 54031.

6. ⬭ 100% INSPECTION DIMENSION MEASURMENT BY CONVENTIONAL METHODS IS NOT POSSIBLE THE SAME CAN BE MEASURED WITH TEMPLATE. TEMPLATE SHALL BE APPROVED BY BHEL.

7. FINAL FINISHED TP ASSEMBLY TO BE CHECKED IN ASSEMBLY FIXTURE FOR PROFILE AND DIMENSION.

ITEM NO.	DESCRIPTION	PART NUMBER	VAR	VAR 02	WELDING DRG NO	MATERIAL CODE	REMARK
001	TRANSITION PIECE BODY (WELDED)	03510951003	---	001	03510951006-01	SG97710480014	HASTELLOY -X
~~001~~	~~TRANSITION PIECE BODY(WELDED)~~	~~03510951006~~	~~001~~	~~---~~	~~03510951006-01~~	~~--~~	~~S. S~~

TYPE OF PRODUCT OR NAME OF CUSTOMER/PROJECT: Fr. 5 GAS TURBINE TRANSITION PIECE

BHARAT HEAVY ELECTRICALS LTD. HYDERABAD

	NAME	SIGN.	DATE	NO.OF VAR.
DRN.	JR		10.01.15	
CHD.	MSK		11.01.15	
APPD.	KVS		11.01.15	

REV.	DATE	ALTERED	CHD/APPD
01	23.01.15	CHD/APPD : MSK/KVS	

Var 01 Deleted & Drg Re - drawn

DEPT. SQE CODE 435 | UNTOL. DIMS. GR. C/M/F | SCALE 1:1.5 | WEIGHT (KG) 21.9 Kg | REF. TO ASSY. DRG. 33510951009 | ITEM NO. 01 | NO.OF ITEMS 01

TITLE: TRANSITION PIECE BODY

CARD CODE N.A. | DRAWING NO. 03510951003 | REV. 01 | SHT. No 01 | NO. OF SHT. 01

GENERAL DIMENSIONAL LIMITS,FITS & TOLERANCES AS PER HY0230261

COMPUTER FILE NAME | REF. DRG. NO. | SIGN. AND DATE | INVENTORY NO

Mar Tue 10 08:42 2015