# GUIDE LINES FOR HEAT TREATMENT

# IMPORTANT NOTE

**THIS GUIDELINES FOR HEAT TREATMENT PROVIDES BROAD BASED GUIDELINES FOR CARRYING OUT HEAT TREATMENT WORKS AT SITES. HOWEVER, SITES SHALL ENSURE ADHERENCE TO THE PRIMARY DOCUMENTS LIKE CONTRACT DRAWINGS, FIELD WELDING SCHEDULES, WELDING PROCEDURE SPECIFICATIONS, PLANT / CORPORATE STANDARDS, STATUTORY DOCUMENTS, CONTRACTUAL OBLIGATIONS, AS APPILCABLE AND SPECIAL INSTRUCTIONS, IF ANY, ISSUED BY RESPECTIVE MANUFACTURING UNITS SPECIFIC TO THE PROJECTS.**

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# CHAPTER-1
# HEAT TREATMENT PROCEDURE - BOILER AND AUXILIARIES

## 1.0 SCOPE:

1.1 This procedure provides information, method and control for Pre-Heat, Post Heat and Post Weld Heat Treatment (PWHT) of welds of boiler and piping components at sites.

## 2.0 DOCUMENTS:

2.1 The following documents are referred in preparation of this procedure:

- ASME Sec I & Sec IX
- ASME B31.1
- Indian Boiler Regulations
- AWS D1.1
- BHEL Welding Manual (AA/CQ/GL/011/ Part I-WM – Latest)

2.2 The following are to be referred as Primary Documents:

- Contract drawings
- Field Welding Schedule or equivalent
- Plant / Corporate standards, wherever supplied
- Welding procedure specification
- Contractual obligations, if any

2.2.1 Where parameter for Pre-Heat, Post Heat and PWHT are not available in the primary documents, reference may be made to this procedure.

2.2.2 Where such parameters are not contained either in the primary documents or in this procedure, reference may be made to Manufacturing Units.

## 3.0 PROCEDURE:

3.1 **Preheating & Post heating**:

3.1.1 Prior to start of preheating, ensure that surfaces are clean and free from grease, oil and dirt. Preheating temperature shall be maintained as per applicable WPS. Preheating shall be checked and recorded, using thermal chalks/ crayons or pyrometers in case of tubes other than T91/T92/T23. For all other components including T91/T92/T23 tube joints, the preheat temperature shall be ensured by using a calibrated chart recorder and two calibrated thermocouples fixed at 0° and 180° positions on both sides of the joint. Preheating shall be checked at a distance of 1.5 times the part thickness or 75mm (whichever is greater) from weld end. The thermocouple shall be fixed using the capacitor discharge welding machine. The preheating arrangements shall be inspected and approved by site engineer.

3.1.1.1 Bunching of tubes for Preheating:

Where a bunch of closely placed tube welds (e.g. Super Heater / Reheater Coils) requires to be preheated, the same may be grouped together as if they form a single component. The maximum number of tubes bunched together in such cases shall be limited to 12. Each joint

within the bunch shall have at least one thermocouple fixed near the joint for preheat monitoring.

3.1.2 When parts of two different thicknesses are welded together, the preheating requirements of the thicker part shall govern.

3.1.3 When parts of two different P numbers are joined together, the material requiring higher preheat shall govern (please refer Tables A2.1 to A2.7 of Welding Manual, AA/CQ/GL/011/ PART I-WM – Latest, for P numbers).

3.1.4 In case of any power interruption during welding, the joint shall be wrapped with dry thermal insulating blankets to ensure slow and uniform cooling. **Requirement of uninterrupted power supply shall be ensured for materials like Gr.91, 92 & 23 and BS EN 10025**

3.1.5 Preheating & Post Heating Methods:

3.1.5.1 Preheating & Post heating shall be applied by any of the methods given below:

a) Electrical resistance heating
b) Induction heating
c) LPG burners

3.1.5.2 Preheating/post heating using cutting/ heating torches with oxy-acetylene flame is not permitted.

3.1.6 In addition, the following requirements shall also be followed:

3.1.6.1 Alternate burner arrangements shall be made for preheating/post heating during power failure to maintain the required temperature.

3.1.6.2 Two additional spare thermocouples shall be fixed for emergency use.

3.1.6.3 Preheating/Post heating shall be done locally BY heating a circumferential band covering the parent material away from the weld groove by induction or electrical resistance heating. The heating element (Coil/Finger/Ceramic Pad) placed on the heating band shall be closely packed without any gaps between the element. The area shall be free of grease, oil etc. prior to preheating/post heating.

## 3.2 Post Weld Heat Treatment (PWHT):

3.2.1 PWHT shall be done by locally heating a circumferential band covering the entire weld and adjacent area of base metal, by induction or electrical resistance heating. The heating element (coil/ finger element/ pad) placed on the heating band shall be closely packed without any gaps between the elements. The area shall be free of grease, oil etc. prior to PWHT.

3.2.1.1 Unless otherwise specified in the FWS/WPS, the PWHT parameters shall be as per the Tables 1.1, 1.2, 1.3, 1.4.

3.2.2 **Heating and Insulation band for PWHT:**

3.2.2.1 When heat treating butt joints, width of the circumferential heating band on either side of the weld must be at least 3 times the width of the widest part of the weld groove; but not less than twice the thickness of the thicker part being welded. When heat treating nozzles and attachment welds, the width of the heating band beyond the welding to be heat treated on either side of weld shall be at least 3 times the base material thickness. The heating band shall extend axially around the entire vessel. Width of the insulation band on either side shall be at least twice the width of the heating band.

3.2.2.2 In case of fin welded panels where circumferential winding of the coil is not possible heating elements shall be placed on both sides of the panels

3.2.3 Post weld heat treatment temperature cycle shall be measured and monitored by use of thermocouples with calibrated recorders.

3.2.4 Where the soaking temperature is found to be lesser than specified, the PWHT cycle shall be repeated.

3.2.5 In case of interruption during PWHT, the following actions shall be taken depending on the stage during which interruption has occurred.

**1) During heating cycle**

Repeat the whole operation from beginning.

**2) During soaking**

Heat treat subsequently for balance soaking. If the balance soaking time required is less than 15 minutes, soaking time shall be maintained for 15 minutes minimum.

**3) During cooling (above 300 °C).**

If the Rate of Cooling (ROC) during interruption meets the specified rate, cool subsequently at the required rate. Otherwise, reheat to the soaking temperature, hold for 15 minutes and then cool at the specified rate.

3.2.6 **Fixing of thermocouple (TC) during preheating, post heating and PWHT:**

3.2.6.1 Thermocouples shall be fixed on the job using capacitor discharge welding method. Thermocouple leads shall be attached within 6 mm of each other. A Welding Procedure Specification shall be prepared, describing the low-energy capacitor discharge equipment, the combination of materials to be joined, and the technique of application. No preheating is required. Also Qualification of the welding procedure is not required. The energy output of the welding process shall be limited to 125 W-sec. After temporary attachments are removed, the areas shall be examined by LPI.

Following are the equipment / facilities for heating cycles.

(1) Thermo couples: Ni-Cr / Ni-Al of 0.5 mm gauge size (K-Type).

(2) Temperature Recorders: 6 Points / 12 Points/ 24 Points.

3.2.6.2 Following are guidelines regarding number and placement of thermocouples:

- Minimum of two thermocouples shall be placed for each joint, 180° apart.
- Thermocouples shall be located at a distance of approximately 1.5 times the parent metal thickness from the weld centre.
- Additionally, one point of the temperature recorder shall be used for recording ambient temperature.
- For placement of thermocouples on P91/P92/F91/F92/C12A Figure 1.1 shall be referred for preheating and Figure 1.2 shall be referred for PWHT.

3.2.6.3 Thermocouple leads shall be suitably insulated to protect the ends from direct radiation from heating elements.

3.2.6.4 The temperature variation between any two thermocouples shall be within 50°C for temperature above 300°C during heating and cooling.

3.2.7 **Bunching of tubes for PWHT:**

3.2.7.1 Where a bunch of closely placed tube welds (e.g. Super Heater / Reheater Coils) require to be Post weld heat treated, the same may be grouped together as if they form a single component. The maximum number of tubes bunched together in such cases shall be limited to 12. Each joint within the bunch shall have at least one thermocouple fixed near the joint for PWHT temperature monitoring.

3.2.8 **Soaking Time:**

3.2.8.1 Unless otherwise specified in the FWS/WPS, the soaking time shall be calculated as 2.5 minutes per mm of thickness with 30 minutes minimum for tube welds and 60 minutes minimum for other welds. For P1 material, the soaking time shall be calculated as 2.5 minutes per mm of thickness upto 50mm with an additional 15 minutes for every 25mm thickness above 50mm.

3.2.8.2 The following guidelines shall be used to determine the thickness and subsequent selection of the soaking time of PWHT:

*(a)* For full penetration butt welds, the nominal thickness is the thinner of the parts being joined.

*(b)* For full penetration corner welds, the nominal thickness is the depth of the weld.

*(c)* For partial penetration groove and material repair welds, the nominal thickness is the depth of the weld. The total depth of partial or full penetration groove welds made from both sides shall be taken as the sum of the depth of both sides at a given location.

*(d)* For fillet welds, the nominal thickness is the weld throat. When a fillet weld is used in conjunction with a groove weld, the nominal thickness is the total of groove depth and fillet throat thickness.

3.2.8.3 Soaking time is to be reckoned from the time temperature of the joint crosses the recommended lower temperature of the cycle, to the time it comes down below the same recommended lower temperature of the cycle.

3.2.9 **Heating and Cooling Rates:**

3.2.9.1 Wherever not specified, the heating rate above 300°C and cooling rate after soaking upto 300°C shall be as follows: This is applicable for all materials except Gr.91/Gr.92 materials for which Cl. 3.2.11.3 shall be referred.

| **Thickness of Material** | **Maximum Heating Rate Above 300°C** | **Maximum Cooling Rate Upto 300°C** |
|---|---|---|
| ≤ 25 mm | 220°C/hour | 220°C/hour |
| > 25 ≤ 50 mm | 110°C/hour | 110°C/hour |
| > 50 ≤ 75 mm | 75°C/hour | 75°C/hour |
| > 75mm | 55°C/hour | 55°C/hour |

3.2.10 **PWHT Job Card:**

3.2.10.1 Prior to start of PWHT operations, a job card shall be prepared including details of weld reference, soaking time, soaking temperature, maximum rates of heating and cooling, temperature recorder details and date of PWHT as per Annexure I of this manual except Gr.91/Gr.92/Gr.23 materials. For P91/P92/F91/F92/C12A/T91/T92/T23 materials Annexures II, III, IV in Chapter A1 of Welding Manual - AA/CQ/GL/011/ PART I-WM – Latest, as applicable, shall be referred.

3.2.10.2 Obtain the clearance for post weld heat treatment cycle from the site engineer.

3.2.10.3 On completion of PWHT, the actual parameters shall be recorded on the job card.

3.2.10.4 A chart number shall be given to each chart and attached to the job card.

3.2.11 **Heat Treatment of P91/P92/F91/F92/C12A welds:**

3.2.11.1 A minimum of four thermocouples shall be placed such that at least two are on the weld and the other two on the base material on either side of the weld within the heating band, 180° apart, at a distance of 50mm (approximately) from the center of the weld joint as per Figure 1.2. Two standby thermocouples shall also be provided on the weld (to be used in case of any failure of the thermocouple).

3.2.11.2 The PWHT temperature shall be 740-770°C and the soaking time shall be 2.5 minutes per mm of weld thickness, subject to a minimum of one hour. All records shall be reviewed by site Engineer prior to PWHT clearance. Heating shall be done by Induction heating only. However for thickness upto 32 mm, Resistance heating may also be used.

3.2.11.3 The rate of heating / cooling (above 300 ° C):-

Thickness up to 50 mm - 110°C / hour (max)

Thickness 50 to 75mm - 75°C / hour (max)

Thickness above 75mm - 55°C / hour (max)

3.2.11.4 Welding and PWHT shall be monitored every one hour by site engineer. Job card for PWHT shall be maintained as per Annexure II, Chapter A1 of Welding Manual - AA/CQ/GL/011/ PART I-WM – Latest.

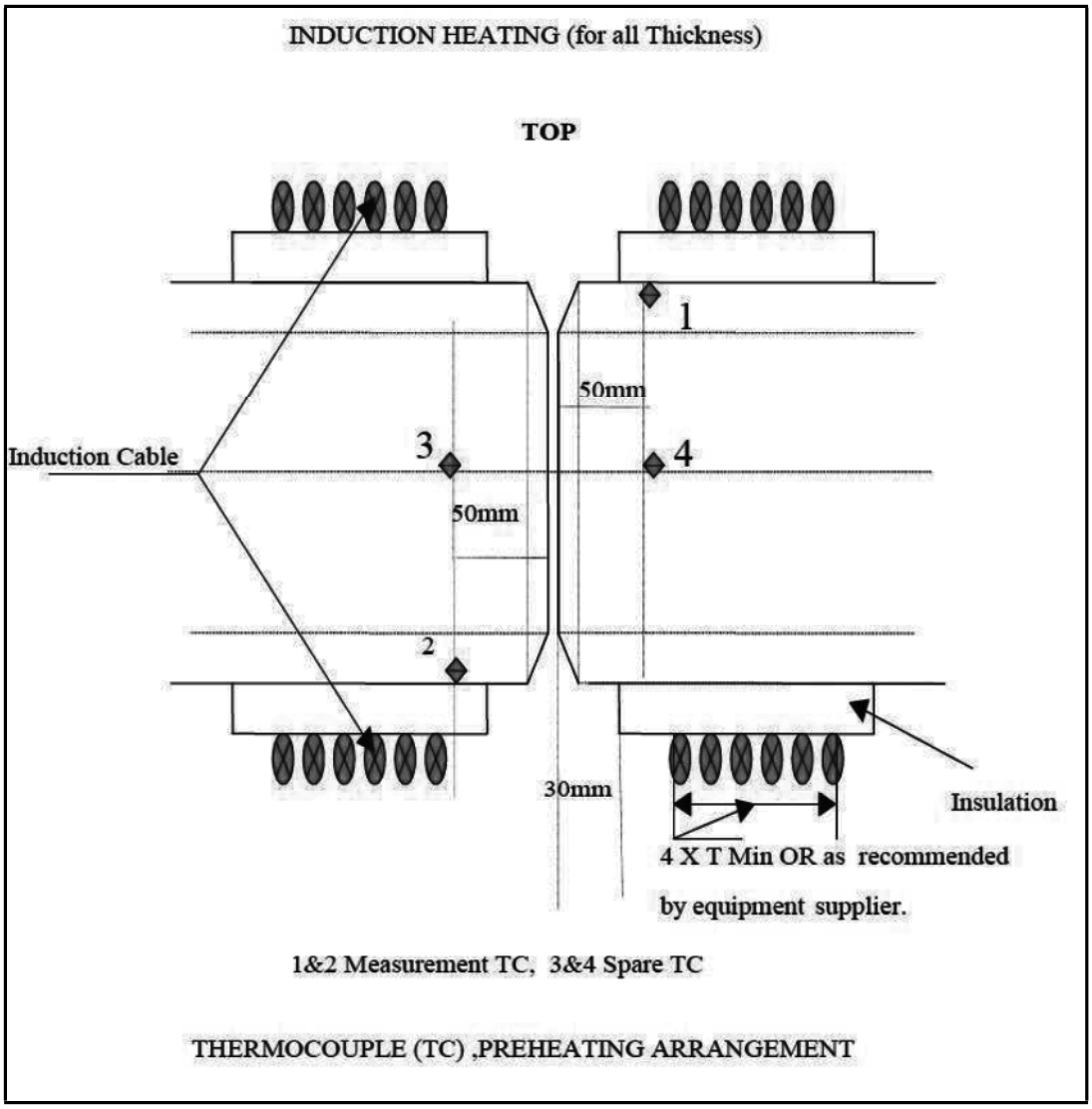


**Figure 1.1: Placement of Thermocouples on P91/P92/F91/F92/C12A materials for Preheating**

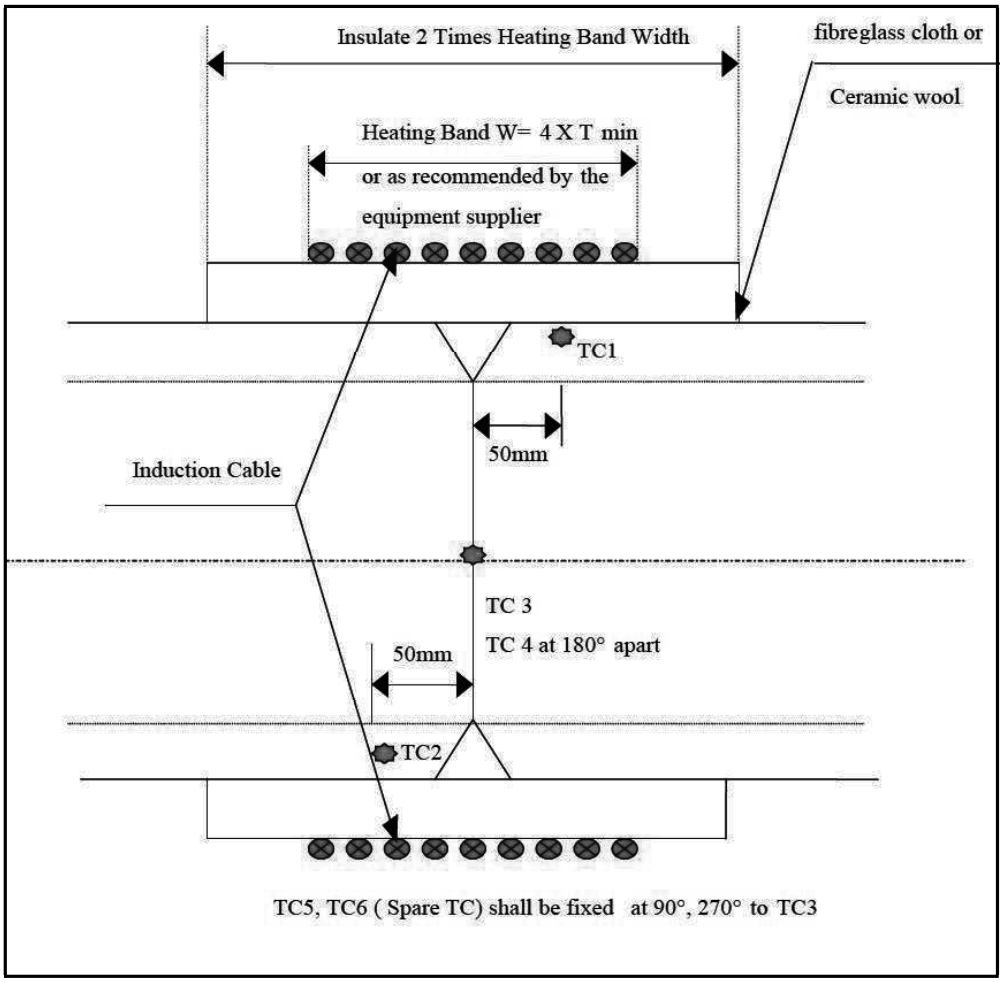


**Figure 1.2: Placement of Thermocouples on P91/P92/F91/F92/C12A materials for PWHT**

3.2.12 **Heat Treatment of T91/T92/T23 welds:**

3.2.12.1 Heat treatment controls of T91/T92 welds shall be as detailed in Cl. 3.2.1 to Cl.3.2.10 of this Manual.

3.2.12.2 Figure 1.2 & 1.3 of this manual shall be referred for Resistance heating coil arrangement for Preheating and PWHT of T91/T92 tube assembly.

3.2.12.3 The PWHT temperature shall be 730-760°C and the soaking time shall be 2.5 minutes per mm of weld thickness, subject to a minimum of 30minutes. All records shall be reviewed by site Engineer prior to PWHT clearance.

3.2.12.4 The rate of heating / cooling (above 300 ° C) for T91/T92 welds shall not exceed 140°C/hour.

3.2.12.5 Heat treatment controls of T23 welds shall be as detailed in Chapter B4 of Welding Manual - AA/CQ/GL/011/ PART I-WM – Latest.

3.3 **Heat Treatment of Components /Systems other than Boiler and Piping:**

3.3.1 Preheating, post heating and PWHT methodologies and parameters shall be as recommended by the concerned equipment suppliers.

3.4 **Heat Treatment Operator Requirements:**

The operator for the Heat Treatment shall be a qualified technician and shall be conversant in the operation & maintenance of heat treatment machines & process. He shall be trained by the concerned Site Engineer in order to operate and maintain the equipment and carry out the process properly.

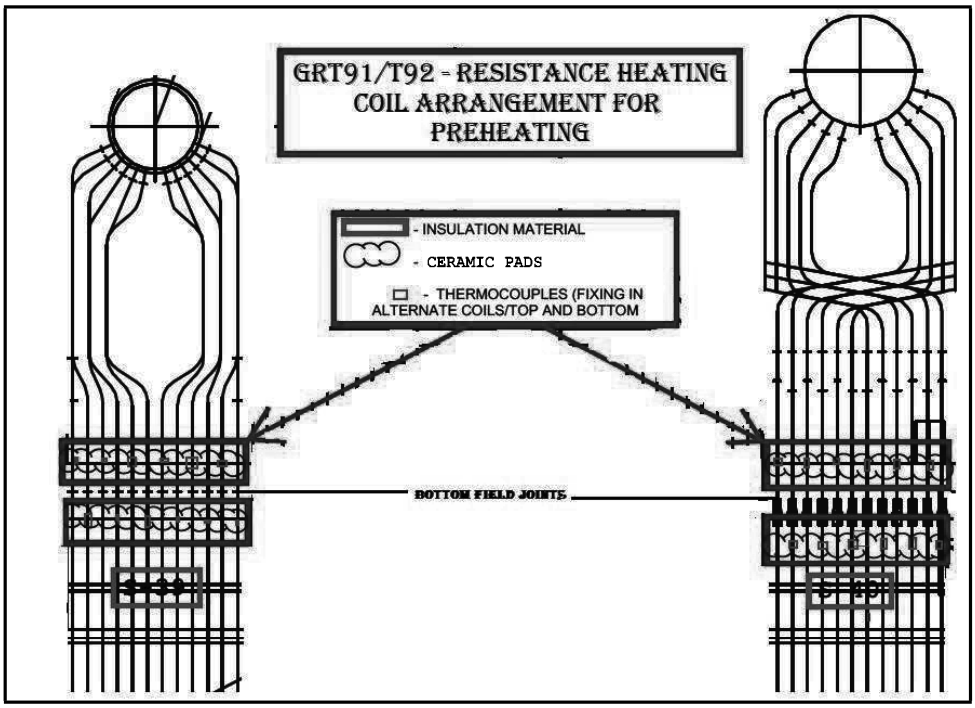


**Figure 1.3: Resistance heating Coil arrangement for Preheating of T91/T92 tube assembly**

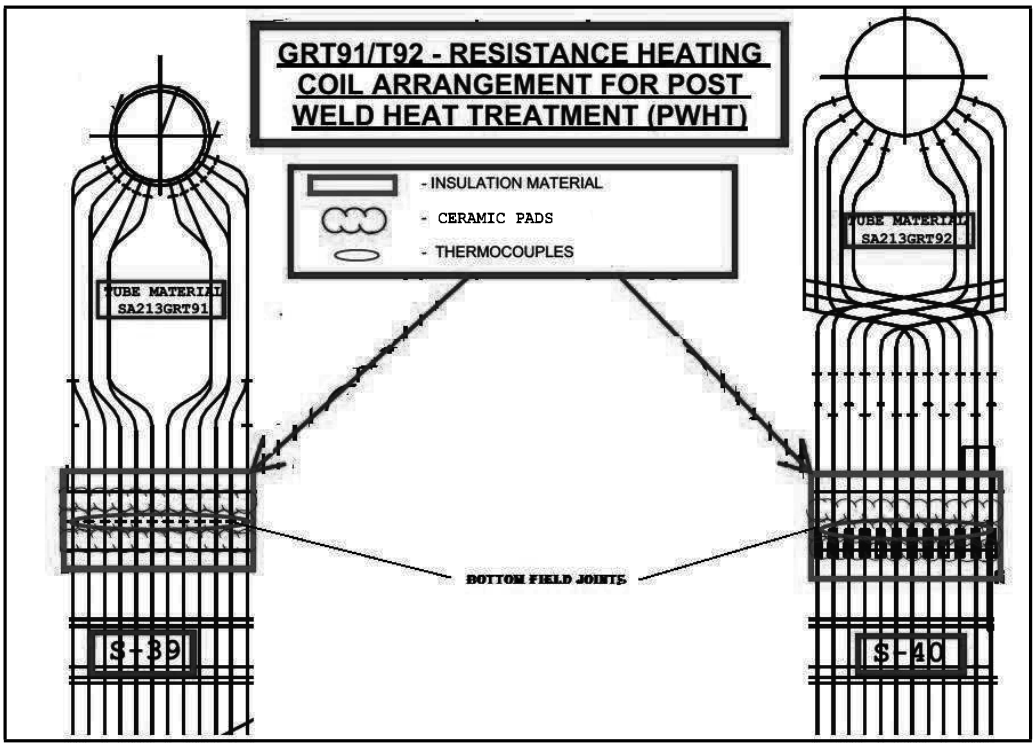


**Figure 1.4: Resistance heating Coil arrangement for PWHT of T91/T92 tube assembly**

3.5 **List of Tables:**

- Table-1.1: Weld preheat and PWHT for tubes and pipes outside diameter $\leq$ 102 mm.
- Table-1.2: Weld preheat and PWHT for Boiler Header welds.
- Table-1.3: Weld preheat and PWHT for pipes outside diameter > 102 mm.
- Table-1.4: Pre-heat and PWHT for Non-Pressure Parts including Structural.

## 4.0 RECORDS:

Relevant records like Job card and HT Charts shall be maintained by the Site Engineer till the closure of the project. The records may be handed over to the customer at the time of project closure if required by the contract

## ANNEXURE I: PWHT JOB CARD

### POST WELD HEAT TREATMENT (PWHT) JOB CARD

**Project:** _____

Card No. : _____ Date : Unit

No. : _____ Package :

Description: Temp. Recorder Details :

Weld Reference : _____ 1. Make : _____

Material Spec. : _____ 2. Type : _____

Size: Dia. mm _____ 3. Sl. No. _____

Thick (t) mm _____ 4. Chart speed: _____ mm / hour

NDE Cleared on : _____ 5. Calibration Due on : _____

Report No. : _____

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**Thermocouple Locations :**

Minimum 2

Distance of TC from the weld centre =

Heating Band =

Insulation Band =

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Date of PWHT Chart No. : _____

Start Time : _____ End Time :

| | Required | Actual | | |
|---|---|---|---|---|
| Rate of Heating (Max) °C/h | | | | |
| Soaking Temperature °C | | | | |
| Soaking Time (Minutes) | | | | |
| Rate of cooling (Max)° C | | | | |

Ambient temperature recorded on the PWHT Chart: _____

**TABLE – 1.1**
**WELD PRE HEAT AND PWHT FOR TUBES & PIPES**
**OUTSIDE DIAMETER ≤ 102 mm**
**(Applicable for Butt Welds and Socket Welds)**

| P. No. of Material | Thickness (mm) | Preheat (°C) | PWHT (°C) |
|---|---|---|---|
| P1 Gr 1 | ≤ 19 | Nil | Nil |
| P1 Gr 2 (C ≤0.25%) | ≤ 19 | Nil | Nil |
| P1 Gr 2 (C > 0.25%) | ≤ 9 | Nil | Nil |
| | > 9 | Nil | 595-625 |
| P3 Gr 1 | ≤ 13 | Nil | Nil |
| P3 Gr 2 | > 13 | 100 (Note 1) | 620 - 650 |
| P4 Gr 1 | ≤ 13 | 150 | Nil |
| | > 13 | 150 | 650 - 670 |
| P5 A Gr 1 | ≤ 8 | 150 | Nil |
| | > 8 | 150 | 680 -710 |
| P15 E Gr 1 (Gr. 91 & Gr.92) | All | 220 | 730 - 760 |
| SA 213 T23 | All | 220 | 730 - 760 |
| P8 | All | Nil | Nil |

**Note 1: Pre-heating is necessary for t >16mm.**

**TABLE – 1.2**
**WELD PREHEAT AND PWHT FOR BOILER HEADER WELDS**
**(Applicable For Welding of Header to Header Joints)**

| P. No. of Header Material | Thickness (mm) | Preheat °C | Post Heating °C | PWHT °C |
|---|---|---|---|---|
| P1Gr 1 | $t \leq 19$ | Nil | Nil | Nil |
| | $19 < t \leq 25$ | Nil | Nil | 595 - 625 |
| | $25 < t \leq 75$ | 100 | Nil | 595 - 625 |
| | $t > 75$ | 150 | Nil | 595 - 625 |
| P1Gr 2 | $t \leq 19$ | Nil | Nil | 620 – 635 |
| | $t > 19$ | 150 | 150 for 2 hours | 620 – 635 |
| P4 Gr 1 | All | 150 | Nil | 650 - 670 |
| P5 A | All | 150 | 250 for 2 hours | 680 - 710 |
| P15E Gr1 (Gr 91 & Gr 92) | All | 220 | Nil | 740 - 770 |
| P15 E Gr1 + P5 A | All | 220 | Nil | 730-760 |
| T23 | All | 220 | 250 for 1 hour | 730 - 760 |

**TABLE – 1.3**
**WELD PREHEAT AND PWHT FOR PIPES**
**OUTSIDE DIAMETER >102 MM**

| P No. of Material | Thickness (mm) | Butt Welds | | Stub and Attachment welds | | | | Post heat °C |
|---|---|---|---|---|---|---|---|---|
| | | Preheat °C | PWHT °C | Throat ≤ 19 mm | | Throat > 19 mm | | |
| | | | | Preheat °C | PWHT °C | Preheat °C | PWHT °C | |
| P1 Gr 1 | ≤ 19 | Nil | Nil | Nil | Nil | Nil | 595 - 625 | Nil |
| | >19≤25 | Nil | 595 - 625 | Nil | 595 - 625 | Nil | 595 - 625 | Nil |
| | >25≤75 | 150 | 595 - 625 | 150 | 595 - 625 | 150 | 595 - 625 | Nil |
| | >75 | 150 | 595 - 625 | 150 | 595- 625 | 150 | 595 - 625 | Nil |
| P1 Gr 2 | ≤9 | Nil | Nil | Nil | Nil | Nil | 595 - 625 | Nil |
| | >9≤19 | Nil | 595 - 625 | Nil | 595 - 625 | Nil | 595 - 625 | Nil |
| | >19 | 150 | 595 - 625 | 150 | 595 - 625 | 150 | 595 - 625 | 150 for 2 hrs |
| P4 Gr 1 | All | 150 | 640-670 | 150 | 640- 670 | 150 | 640- 670 | Nil |
| P5 A | All | 150 | 680 - 710 | 150 | 680- 710 | 150 | 680- 710 | 250 for 2 hrs |
| P15 E Gr1 | All | 220 | 740-770 | 220 | 740- 770 | 220 | 740- 770 | NA |
| P15 E Gr1 + P5 A | All | 220 | 730-760 | 220 | 730- 760 | 220 | 730- 760 | NA |

For butt welds of different P group combinations, PWHT temperature may be as follows:

| | |
|---|---|
| P1 + P3 - | 620 to 650°C |
| P1 + P4 - | 640 to 670°C |
| P4 + P5A- | 680 to 710°C |

(For other P Group combinations, refer to Manufacturing unit)

**TABLE – 1.4**
**PREHEAT AND PWHT FOR NON PRESSURE PARTS INCLUDING STRUCTURALS**

| P. No. of Material / Material Specification | Gas Cutting | | Welding | | |
|---|---|---|---|---|---|
| | Thickness (mm) | Preheat °C | Thickness (mm) | Preheat (°C) | PWHT (°C) |
| P1 / IS 2062<br>E250 BR,<br>E350 BR,E350C | > 50 | Nil<br>100 | > 63 | Nil<br>100<br>150 | 595-625<br>1.0 All butt welds > 50 mm thick<br>2.0 For Ceiling girders if thickness > 50 mm<br>3.0 No HT required for web to flange fillet welds. |
| BS EN 10025 Gr 420 N ( Ceiling Girder ) | All | 220 | All | 220 | 620 – 650 |
| P3 Gr 1 and Gr 2 | T>25 | 150 | All | 150 | 620-650<br>a) All butt welds in tension member<br>b) All butt welds of fabricated components > 16mm thick and fillet welds with throat thickness > 13 mm |
| P4 Gr 1 | All | 150 | All | 150 | 650-680<br>a) All butt welds in tension member<br>b) All butt welds of fabricated components > 16mm thick and fillet welds with throat thickness > 13 mm |
| P5A Gr 1 | All | 150 | All | 150 | 680-710<br>All welds<br>(Note 2) |
| P15E Gr.1 | Not permitted | Not permitted | All | 220 | 740-770 |

**NOTE:**

1. All gas cut edges shall be ground for a width of 3mm to remove the HAZ.
2. All welds of P5A material shall be post heated at 250°C for 2 hours immediately after welding.

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# GUIDELINES
# FOR
# WELDING

# IMPORTANT NOTE

**THIŞ GUIDELINEŞ FOR WELDING PROVIDEŞ BROAD BAŞED GUIDELINEŞ FOR CARRYING OUT WELDING WORK AT SITES. HOWEVER, SITES SHALL ENSURE ADHERENCE TO THE PRIMARY DOCUMENTS LIKE CONTRACT DRAWINGS, FIELD WELDING SCHEDULES, WELDING PROCEDURE SPECIFICATIONS, PLANT / CORPORATE STANDARDS, STATUTORY DOCUMENTS, CONTRACTUAL OBLIGATIONS,AS APPILCABLE ANDSPECIAL INSTRUCTIONS, IF ANY, ISSUED BY RESPECTIVE MANUFACTURING UNITS SPECIFIC TO THE PROJECTS.**

# INDEX

# CHAPTER–A1
# WELDING - GENERAL

# A1: WELDING-GENERAL

## 1.0 SCOPE:

1.1 This manual deals with activities and information related to welding at site. Where specific documents are supplied by the Manufacturing Units (MUs)/Engineering Centers (ECs), the same shall be adopted.

## 2.0 DOCUMENTS REFERRED:

2.1 The following documents are referred in preparation of this manual.

1. AWS D1.1
2. AWS D1.6
3. ASME sections I, II (A&C), V & IX
4. ASME B31.1
5. IBR
6. BHEL Manufacturing Units/Engineering Centers Standards & practices

## 3.0 PROCEDURE:

3.1 The following documents shall be referred as primary documents

1. Contract drawings
2. Field Welding Schedule or equivalent
3. Plant / Corporate standards, wherever applicable
4. Statutory documents
5. Welding Procedure Specifications
6. Contractual obligations, if any.

## 4.0 WELDER QUALIFICATION:

4.1 Ensure, personnel qualified as per statutory requirements are engaged, where required.

4.2 For welding not under the purview of statutory requirements, qualification of welders shall be as in this manual.

4.3 Monitor performance of qualified butt welders as in this manual.

4.4 Ensure selection, procurement, storage, drying & issue of welding consumables, as detailed in this manual.

4.5 List of approved vendors of general purpose welding electrodes as provided by BHEL-Tiruchy Unit shall be used for selection of brands at sites. Alternatively specific contractual requirements, if any may be followed.

4.6 Where Tiruchy list does not cover site requirements, such specific cases may be referred toconcerned unit and Head (Quality) of the region.

4.7 Welding in-charge shall assign a unique identification for all the butt welds coming under the purview of statutory regulations. Such identification may be traceable through documents like drawings, sketches etc.

4.8 A welding "job card" incorporating the welding parameters and heat treatment requirements is recommended to be issued for all critical welds like pressure part welds, piping welds and

ceiling girder welds. The formats of the job card are enclosed for illustration in Annexure I, II, III and IV.

## 5.0 SELECTION OF ARGON GAS FOR GTAW:

### 5.1 USE OF ARGON GAS AT SITES:

In the welding process, Argon is used for **SHIELDING** and **PURGING** (**BACKING**) purpose. The welding process when exposed to air, most metals exhibit a strong tendency to combine with Oxygen, and to lesser extent with Nitrogen, especially when in the molten condition. The rate of oxide formation will vary with different metals, but even a thin film of oxide on the surface of metals to be welded can lead to difficulties. For the most part, the oxides are relatively weak, brittle materials that in no way resemble the metal from which they are formed. A layer of oxide can easily prevent the joining of two pieces by welding.

Argon is a shielding gas used in Gas Tungsten Arc Welding (GTAW). It is also used for purging (backing) during the root welding of Gr.91/Gr.92/Stainless steel materials. Argon protects welds against oxidation as well as reduces fume emissions during welding. The compressed argon is supplied in cylinders. The cylinder used for argon will have the body colour of BLUE without band, size of 25 cm dia. &1.5 m length, capacity of 6.2 $m^3$ and pressure of 137 $Kg/Cm^2$ when fully charged at 15°C (approximately).

### 5.2 PURITY LEVEL OF ARGON

As per IS 5760: 1998 there are 3 grades of argon, namely:

- **Grade 1:** Ultra high purity argon for use in electronics and allied industries and indirect reading vacuum spectrograph.
- **Grade 2:** High purity argon for use in lamp and allied industries.
- **Grade 3:** Commercial grade argon for use in welding industry and for other metallurgical operations.

Accordingly the argon shall comply with the requirements given below:

| Sl. No. | CHARACTERISTIC | REQUIREMENT | | |
|---|---|---|---|---|
| | | Grade 1 | Grade 2 | Grade 3 |
| i. | Oxygen, ppm, Max. | 0.5 | 5.0 | 10.0 |
| ii. | Nitrogen, ppm, Max. | 2.0 | 10.0 | 300 |
| iii. | Hydrogen, ppm, Max. | 1.0 | 2.0 | 5.0 |
| iv. | Water vapors, ppm. Max. | 0.5 | 4.0 | 7.0 |
| v. | Carbon dioxide, ppm, Max. | 0.5 | 0.5 | 3.0 |
| vi. | Carbon monoxide, ppm, Max. | 0.5 | 0.5 | 2.0 |
| vii. | Hydrocarbons, ppm, Max. | 0.2 | 0.5 | - |

### 5.3 PURCHASE SPECIFICATION FOR ARGON:

Argon gas as per Grade 2 of IS-5760: 1998 with Argon purity level of min. 99.99%. The supply should accompany Test Certificate for the batch indicating compliance to the above requirements.

**5.4 HEAT TREATMENT:**

5.4.1 Preheat, inter pass, post heat and Post Weld Heat Treatment (PWHT) requirements shall be as per applicable documents; where these are not supplied, reference may be made to Welding / Heat Treatment Manual.

5.4.2 Prior to PWHT operation, a "job card" containing material specification, weld reference, size, rate of heating, soaking temperature, soaking time and rate of cooling shall be prepared referring to applicable documents, and issued.

5.4.3 The PWHT chart shall contain the chart number,Weld Joint No., Temperature recorder details (like Sl. No. make, range, chart speed), date of PWHT, start and end time of operation.

5.4.4 The chart shall be evaluated and results recorded on the PWHT job card. Refer Heat Treatment Manual (Document No. AA/CQ/GL/011/ Part II-HTM- Latest) for details.

**6.0 EQUIPMENT & INSTRUMENTS:**

6.1 Equipment/accessories used shall be assessed for fitness prior to use.

6.2 Use calibrated thermocouples, temperature measuring instruments and recorders.

6.3 Preheating shall be checked and ensured using temperature indicating crayons.

**7.0 INSPECTION:**

7.1 Inspection of welding shall be done as per Chapter A5 of this manual and records maintained as appropriate.

7.2 Weld log containing the following information shall be prepared for all completed systems.

Project / Unit reference
Drawing No.
Weld Joint No.
FWS/ Equivalent
Material specification
Consumable used
Welder code
Date of welding
NDE report No. and results (including repair details)
PWHT Chart No. and results
Remarks, if any.

## 8.0 SAFETY:

8.1 Safe access to weld area shall be provided.

8.2 Adequate protection shall be provided against wind and rain water entry during welding.

## 9.0 RECORDS:

9.1 All records, as required, shall be maintained by welding in-chargeand handed over to the appropriate authority at the end of the project closure.

## Annexure – I: Welding Job Card



**Welding Job Card**

| | | | |
|---|---|---|---|
| Project | : | | |
| Unit No. | : | Area: Boiler/TG/PCP: | |
| Job Card No. | : | Date | : |
| FWS Number | : | | |
| Joint No. | : | | |
| Drawing No. | : | | |
| System Description | : | | |
| Size (Dia. x thick) | : | | |
| Material Specification | : | | |
| Consumable used | : | | |
| Welder No.(s) | : | | |
| Date of welding | : | | |
| Filler wire Specification | : | | |
| Electrode Specification | : | | |
| Preheat temperature | : | | |
| Inter pass temperature | : | | |
| Post Heat temperature | : | | |
| PWHT temperature | : | | |

Welding engineer



**Filler wire/Electrode consumption**

| | | |
|---|---|---|
| SMAW | $\phi$ 2.5 mm | : |
| | $\phi$ 3.15 mm | : |
| | $\phi$ 4.0 mm | : |
| Date of LPI for RG Plug | | : |
| Remarks | | : |
| Date of Return | | : |

## Annexure – II: Welding Job Card for P91/P92 Welds

| JOB CARD<br>(WELDING, HEAT TREATMENT & ND EXAMINATION)<br>FOR P91/P92 WELDS | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Card No.:** | | | | | | | | **Date:** | | | | |
| **Project:** | | | | **Unit No.** | | | | **Contractor:** | | | | |
| System: | | | | | | | | Drawing No. | | | | |
| PGMA: | | | | | | | | DU No.: | | | Joint No.: | |
| Material Specification: | | | + | | | | | OD (mm): | | | Thick(mm) | |
| Filler metal: | GTAW | | | | | | | SMAW | | | | |
| Joint fit-up: | Min. WT: | | Root gap: | | | Root mismatch: | | | Log sheet filled: | | Y / N | |
| No. of T/Cs: | | Location: | | | | Distance from EP edge: | | | | mm | | |
| Welders' ID: | | | | | | M/c No.: | | | | | | |
| Preheat Temp.: | | °C Minimum | | | | Rate of heating: | | | | °C per hour | | |
| Purging flow rate: | | | Litres / min. | | | Purging time: | | | | | Minutes | |
| Shielding flow rate: | | | Litres / min. for GTAW | | | Distance bet. dams: | | | | | Metres | |
| Interpass Temp.: | | ° C Maximum | | | | Rate of cooling: | | | | °C per hour | | |
| Holding Temp. before PWHT: | | ° C for min. 1 hour | | | | | | | | | | |
| PWHT: | | ° C | | | | Rate of heating / cooling: | | | | °C per hour | | |
| Soaking time | | | Minutes (2.5 minutes per mm) | | | Cooling to: | | | 300° C | | | |
| Preheating started at | | Hrs. on | | | | Preheating completed at | | | | Hrs. | | |
| Root welding started at | | Hrs. | | | | Root welding completed at | | | | Hrs. | | |
| Welding started at | | Hrs. | | | | Welding completed at | | | | Hrs. | | |
| Interpass temp. maintained between | | °C and | | °C | | | | | | | | |
| Holding temp. reached at | | Hrs. | | | | Holding completed at | | | | Hrs. | | |
| No. of T/Cs: | | Location | | | | | | | | | | |
| PWHT started at | | Hrs. on | | . | | Soaking started at | | | | Hrs. | | |
| Soaking completed at | | Hrs. | | | | 300°C reached at | | | | Hrs. | | |
| UT Equipment used: | | | | | | Calibration validity: | | | | | | |
| UT carried out on | | | | | | Result : OK / Not OK | | | | | | |
| MPI Equipment used: | | | | | | Calibration validity: | | | | | | |
| MPI carried out on | | | | | | Result: OK / Not OK | | | | | | |
| Hardness test Equipment used: | | | | | | Calibration validity: | | | | | | |
| Hardness test carried out on | | | | | | Value: | | | | | | |
| History of interruption if any, with time: | | | | | | | | | | | | |
| **Contractor** | | | | **BHEL** | | | | | | **Customer** | | |

## Annexure – III: Welding Job Card for T91/T92 Welds

**JOB CARD**
**(WELDING, HEAT TREATMENT & ND EXAMINATION)**
**FOR T91/T92 WELDS**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Card No.:** | | | | | **Date:** | | |
| **Project** | | | **Unit No.** | | **Contractor:** | | |
| System: | | | | Drawing No. | | | |
| PGMA: | | | | DU No.: | | Joint No.: | |
| Material Specification: | | + | | OD (mm): | | Thick(mm) | |
| Filler metal: | GTAW | | | SMAW | | | |
| Joint fit-up: | Min. t: | | Root gap: | | Root mismatch: | Log sheet filled: | Y / N |
| No. of T/Cs: | | Location : | | Distance from EP edge: | | mm | |
| Welders' ID: | | | | M/c No.: | | | |
| Preheat Temp.: | °C Minimum | | | Rate of heating: | °C per hour | | |
| Purging flow rate: | | Litres / min. | | Purging time: | | | Minutes |
| Shielding flow rate: | | Litres / min. for GTAW | | Distance bet. dams: | | | Metres |
| Interpass Temp.: | ° C Maximum | | | Rate of cooling: | °C per hour | | |
| PWHT: | ° C | | | Rate of heating / cooling: | °C per hour | | |
| Soaking time | | Minutes (2.5 minutes per mm) | | Cooling to: | 300° C | | |
| Preheating started at Hrs. | Hrs. on | | | Preheating completed at | | | |
| Root welding started at Hrs. | Hrs. | | | Root welding completed at | | | |
| Welding started at Hrs. | Hrs. | | | Welding completed at | | | |
| Interpass temp. maintained between | °C and | °C | | | | | |
| Holding temp. reached at | Hrs. | | | Holding completed at | Hrs. | | |
| No. of T/Cs: | | Location | | | | | |
| PWHT started at | Hrs. on | . | | Soaking started at | Hrs. | | |
| Soaking completed at | Hrs. | | | 300°C reached at | Hrs. | | |
| RT carried out on | | | | Result : OK / Not OK | | | |
| Hardness test Equipment used | | | | Calibration validity: | | | |
| Hardness test carried out on | | | | Value: | | | |
| History of interruption if any, with time: | | | | | | | |

| **Contractor** | **BHEL** | **Customer** |
|---|---|---|

## Annexure – IV: Welding Job Card for T23 Welds

| JOB CARD<br>(WELDING, HEAT TREATMENT & ND EXAMINATION)<br>FOR T23 WELDS | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Card No.:** | | | | | | | | **Date:** | | | | |
| **Project:** | | | | **Unit No.** | | | | **Contractor:** | | | | |
| System: | | | | | | Drawing No. | | | | | | |
| PGMA: | | | | | | DU No.: | | | Joint No.: | | | |
| Material Specification: | | | + | | | OD (mm): | | | Thick(mm) | | | |
| Filler metal: | GTAW | | | | | SMAW | | | | | | |
| Joint fit-up: | Min. t: | | Root gap: | | | Root mismatch: | | | Log sheet filled: | Y / N | | |
| No. of T/Cs: | | Location: | | | | Distance from EP edge: | | | | mm | | |
| Welders' ID: | | | | | | M/c No.: | | | | | | |
| Preheat Temp.: | °C Minimum | | | | | Rate of heating: | | | °C per hour | | | |
| Purging flow rate: | | Litres / min. | | | | Purging time: | | | | Minutes | | |
| Shielding flow rate: | | Litres / min. for GTAW | | | | Distance bet. dams: | | | | Metres | | |
| Interpass Temp.: | ° C Maximum | | | | | Rate of cooling: | | | °C per hour | | | |
| Holding Temp.: | ° C for min. 1 hour. for post heating | | | | | | | | | | | |
| PWHT: | ° C | | | | | Rate of heating / cooling: | | | °C per hour | | | |
| Soaking time | | Minutes (2.5 minutes per mm) | | | | Cooling to: | | | 300° C | | | |
| Preheating started at | | Hrs. on | | | | Preheating completed at | | | | Hrs. | | |
| Root welding started at | | Hrs. | | | | Root welding completed at | | | | Hrs. | | |
| Welding started at | | Hrs. | | | | Welding completed at | | | | Hrs. | | |
| Interpass temp. maintained between | | °C and | | °C | | | | | | | | |
| Holding temp. reached at | | Hrs. | | | | Holding completed at | | | Hrs. | | | |
| No. of T/Cs | | Location | | | | | | | | | | |
| PWHT started at | | Hrs. on | | . | | Soaking started at | | | Hrs. | | | |
| Soaking completed at | | Hrs. | | | | 300°C reached at | | | Hrs. | | | |
| RT carried out on | | | | | | Result : OK / Not OK | | | | | | |
| Hardness test Equipment used | | | | | | Calibration validity: | | | | | | |
| Hardness test carried out on | | | | | | Value: | | | | | | |
| | | | | | | Result: | OK / Not OK | | | | | |
| History of interruption if any, with time: | | | | | | | | | | | | |
| **Contractor** | | | **BHEL** | | | | | | **Customer** | | | |

# CHAPTER–A2
# BASE MATERIALS

## 1.0 SCOPE:

1.1. This chapter contains tabulations of chemical compositions and mechanical properties of various materials generally used at BHEL sites.

## 2.0 CONTENTS:

**CHEMICAL COMPOSITION AND MECHANICAL PROPERTIES**



**3.0** The data are for general information purposes. The corresponding P numbers are also indicated.

**4.0** For materials not covered in this chapter,refer the relevant Material Specification Standard. In case it is not available at site, same shall be referred to Head quality of the region.

## TABLE-A2.1: PIPES (ASME)

| Sl. No. | P. No. /Group No. | MaterialSpecification | Chemical Composition (%) | | | | | | | | | | Mechanical Properties (Min.) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | C | Mn | P | S | Si | Ni | Cr | Mo | V | W | T.S MPa | Y.S MPa | % E Min. |
| 1 | P 1 / 1 | SA 106 Gr. B (Remarks: Carbon restricted to 0.25% Max.) | 0.30 Max. | 0.29-1.06 | 0.035 Max. | 0.035 Max. | 0.10 Min. | 0.40 Max. | 0.40 Max. | 0.15 Max. | 0.08 Max | - | 415 | 240 | 30 |
| 2 | P 1 / 2 | SA 106 Gr. C (Remarks: Carbon restricted to 0.25% Max.) | 0.35 Max. | 0.29-1.06 | 0.035 Max. | 0.035 Max. | 0.10 Min. | 0.40 Max. | 0.40 | 0.15 Max. | - | - | 485 | 275 | 30 |
| 3 | P4/1 | SA 335 P 11 | 0.15 Max | 0.30–0.60 | 0.025 | 0.025 | 0.50–1.00 | - | 1.00–1.50 | 0.44–0.65 | - | - | 380 | 205 | 30 |
| 4 | P 4 / 1 | SA 335 P 12 | 0.15 Max. | 0.30-0.61 | 0.025 Max. | 0.025 Max. | 0.50 Max. | - | 0.80-1.25 | 0.44-0.65 | - | - | 415 | 220 | 30 |
| 5 | P 5A / 1 | SA 335 P 22 | 0.15 Max. | 0.30-0.60 | 0.025 Max. | 0.025 Max. | 0.50 Max. | - | 1.90-2.60 | 0.87-1.13 | - | - | 415 | 205 | 30 |
| 6 | P 15E /1 | SA 335 P91 | 0.08-0.12 | 0.30-0.60 | 0.02 Max. | 0.01 Max. | 0.20-0.50 | 0.40 Max. | 8.00-9.50 | 0.85-1.05 | 0.18-0.25 | - | 585 | 415 | 20 |
| 7 | P15E/1 | SA 335 P 92 | 0.13 Max | 0.30-0.60 | 0.020 | 0.010 | 0.50 max | 0.40 max | 8.50-9.50 | 0.0- | 0.15-0.25 | 1.5-2.0 | 620 | 400 | 20 |

## TABLE-A2.2: TUBES(ASME)

| Sl. No. | P. No. /Group No. | MaterialSpecification | Chemical Composition (%) | | | | | | | | | | Mechanical Properties (Min.) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | C | Mn | P | S | Si | Ni | Cr | Mo | V | W | T.S MPa | Y.S MPa | % E Min. |
| 1 | P 1 / 1 | SA 192 | 0.06-0.18 | 0.27-0.63 | 0.035 Max. | 0.035 Max. | 0.25 Max. | - | - | - | - | - | 325 | 180 | 35 |
| 2 | P 1 / 1 | SA 210 Gr A1 (Remarks: Carbon restricted to 0.25% Max.) | 0.27 Max. | 0.93 Max. | 0.035 Max. | 0.035 Max. | 0.10 Max. | - | - | - | - | - | 415 | 255 | 30 |
| 3 | P 1 / 1 | SA 179 | 0.06-0.18 | 0.27-0.63 | 0.035 Max. | 0.035 Max. | - | - | - | - | - | - | 325 | 180 | 35 |
| 4 | P 1 / 2 | SA 210 Gr C (Remarks: Carbon restricted to 0.30% Max.) | 0.35 Max. | 0.29-1.06 | 0.035 Max. | 0.035 Max. | 0.10 Max. | - | - | - | - | - | 485 | 275 | 30 |
| 5 | P 3 / 1 | SA 209 T1 | 0.10-0.20 | 0.30-0.80 | 0.025 Max. | 0.025 Max. | 0.10-0.50 | - | - | 0.44-0.65 | - | - | 380 | 205 | 30 |
| 6 | P 4 / 1 | SA 213 T11 | 0.05-0.15 | 0.30-0.60 | 0.025 Max. | 0.025 Max. | 0.50-1.00 | - | 1.00-1.50 | 0.44-0.65 | - | - | 415 | 205 | 30 |
| 7 | P 4 / 1 | SA 213 T12 | 0.05-0.15 | 0.30-0.61 | 0.025 Max. | 0.025 Max. | 0.50 Max. | - | 0.80-1.25 | 0.44-0.65 | - | - | 415 | 220 | 30 |
| 8 | P 5 A / 1 | SA 213 T22 | 0.05-0.15 | 0.30-0.60 | 0.025 Max. | 0.025 Max. | 0.50 Max. | - | 1.90-2.60 | 0.87-1.13 | - | - | 415 | 205 | 30 |

## TABLE-A2.2: TUBES(ASME) (Contd…)

| Sl. No. | P. No. / Group No. | Material Specification | Chemical Composition (%) | | | | | | | | | | Mechanical Properties (Min.) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | C | Mn | P | S | Si | Ni | Cr | Mo | V | W | T.S MPa | Y.S MPa | % E Min. |
| 9 | P 5 B / 1 | SA 213 T5 | 0.15 Max. | 0.30-0.60 | 0.025 Max. | 0.025 Max. | 0.50 Max. | - | 4.00-6.00 | 0.45-0.65 | - | - | 415 | 205 | 30 |
| 10 | P 5 B / 1 | SA 213 T9 | 0.15 Max. | 0.30-0.60 | 0.025 Max. | 0.025 Max. | 0.25-1.00 | - | 8.00-10.00 | 0.90-1.10 | - | - | 415 | 205 | 30 |
| 11 | P 1 5 E / 1 | SA 213 T91 | 0.07-0.14 | 0.30-0.60 | 0.02 Max. | 0.01 Max. | 0.20-0.50 | 0.40 Max. | 8.00-9.50 | 0.85-1.05 | 0.18-0.25 | - | 585 | 415 | 20 |
| 12 | P 8 / 1 | SA 213 TP 304 H | 0.04-0.10 | 2.00 Max. | 0.045 Max. | 0.03 Max. | 1.00 Max. | 8.00-11.00 | 18.00-20.00 | - | - | - | 515 | 205 | 35 |
| 13 | P8/1 | SA 213 TP 321H | 0.04-0.10 | 2.00 Max. | 0.045 Max. | 0.03 Max. | 1.00 Max. | 9.00-12.00 | 17.00-19.00 | - | - | - | 515 | 205 | 35 |
| 15 | P 8 / 2 | SA 213 TP 347 H | 0.04-0.10 | 2.00 Max. | 0.045 Max. | 0.03 Max. | 1.00 Max. | 9.00-13.00 | 17.00-19.00 | - | - | - | 515 | 205 | 35 |
| 15 | Code case 2199 | SA213 T23 | 0.04-0.10 | 0.10-0.60 | 0.030 | 0.010 | 0.050 | -- | 1.90-2.60 | 0.05-0.30 | 0.20-0.30 | 1.45-1.75 | 510 | 400 | 20 |
| 16 | 15E/1 (Code case 2169) | SA213 T92 | 0.07-0.13 | 0.30-0.60 | 0.020 | 0.010 | 0.50 | 0.40 | 8.5-9.5 | 0.30-0.60 | 0.15-0.25 | 1.5-2.0 | 620 | 440 | 20 |
| 17 | P8/1 (Code case 2328 - S30432) | SA 213 UNS S30432 (Super 304H) | 0.07-0.13 | 1.00 | 0.040 | 0.010 | 0.30 | 7.5-10.5 | 17.0-19.0 | - | - | - | 590 | 235 | 35 |

## TABLE A2.3: FORGINGS (ASME)

| Sl. No. | P. No. / Group No. | Material Specification | Chemical Composition (%) | | | | | | | | | | Mechanical Properties (Min.) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | C | Mn | P | S | Si | Ni | Cr | Mo | V | W, Cb | T.S MPa | Y.S MPa | % E Min. |
| 1 | P 1 / 2 | SA 105 (Remarks: Carbon restricted to 0.25% Max.) | 0.35 Max. | 0.60-1.05 | 0.035 Max. | 0.04 Max. | 0.1 - 0.35 | 0.40 Max. | 0.30 Max. | 0.12 Max. | 0.08 Max | - | 485 | 250 | 30 |
| 2 | P 4 / 1 | SA 182 F11 Class 3 | 0.10-0.20 | 0.30-0.80 | 0.04 Max. | 0.04 Max. | 0.50 - 1.00 | - | 1.00-1.50 | 0.44-0.65 | - | - | 515 | 310 | 20 |
| 3 | P 4 / 1 | SA 182 F 12 Class 2 | 0.10-0.20 | 0.30-0.80 | 0.04 Max. | 0.04 Max. | 0.10 - 0.60 | - | 0.80-1.25 | 0.44-0.65 | - | - | 485 | 275 | 20 |
| 4 | P 5 A / 1 | SA 182 F 22 Class 3 | 0.15 Max. | 0.30-0.60 | 0.04 Max. | 0.04 Max. | 0.50 Max. | - | 2.00-2.50 | 0.87-1.13 | - | - | 515 | 310 | 20 |
| 5 | P 1 5 E / 1 | SA 182 F91 | 0.08-0.12 | 0.30-0.60 | 0.02 Max. | 0.01 Max. | 0.20 - 0.50 | 0.40 Max. | 8.00-9.50 | 0.85-1.05 | 0.18-0.25 | - | 620 | 415 | 20 |
| 6 | P 1 5 E / 1 | SA 182 F92 | 0.7-0.13 | 0.30-0.60 | 0.02 Max. | 0.01 Max. | 0.50 Max. | 0.40 Max. | 8.50-9.50 | 0.30-0.60 | 0.15-0.25 | W:1.50-2.00; Cb: 0.04-0.09 | 620 | 440 | 20 |

## TABLE A2.4: CASTINGS (ASME)

| Sl. No. | P. No. /Group No. | Material Specification | Chemical Composition (%) | | | | | | | | Mechanical Properties (Min.) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | C | Mn | P | S | Si | Ni | Cr | Mo | MPa | MPa | % EMin. |
| 1 | P 1 / 2 | SA 216 WCB (Remarks: Carbon restricted to 0.25% Max.) | 0.30 Max. | 1.00 Max. | 0.04 Max. | 0.045 Max. | 0.60 Max. | 0.50 Max. | 0.50 Max. | 0.20 Max. | 485 | 250 | 22 |
| 2 | P 1 / 2 | SA 216 WCC | 0.25 Max. | 1.20 Max. | 0.04 Max. | 0.045 Max. | 0.60 Max. | 0.50 Max. | 0.50 Max. | 0.20 Max. | 485 | 275 | 22 |
| 3 | P 4 / 1 | SA 217 WC6 | 0.20 Max. | 0.50-0.80 | 0.04 Max. | 0.045 Max. | 0.60 Max. | - | 1.00-1.50 | 0.45-0.65 | 485 | 275 | 20 |
| 4 | P 5 A / 1 | SA 217 WC 9 | 0.18 Max. | 0.40-0.70 | 0.04 Max. | 0.045 Max. | 0.60 Max. | - | 2.00-2.75 | 0.90-1.20 | 485 | 275 | 20 |
| 5 | P 8 / 1 | SA 351 CF 8 | 0.08 Max. | 1.50 Max. | 0.04 Max. | 0.04 Max. | 2.00 Max. | 8.00-11.00 | 18.00-21.00 | 0.50 Max. | 485 | 205 | 35 |
| 6 | P 8 / 1 | SA 351 CF 8M | 0.08 Max. | 1.50 Max. | 0.04 Max. | 0.04 Max. | 1.50 Max. | 9.00-12.00 | 18.00-21.00 | 2.00-3.00 | 485 | 205 | 30 |
| 7 | P 8 / 1 | SA 351 CF 8C | 0.08 Max. | 1.50 Max. | 0.04 Max. | 0.04 Max. | 2.00 Max. | 9.00-12.00 | 18.00-21.00 | 0.50 Max. | 485 | 205 | 30 |
| 8 | P 8 / 2 | SA 351 CH 20 | 0.04-0.20 | 1.50 Max. | 0.04 Max. | 0.04 Max. | 2.00 Max. | 12.00-15.00 | 22.00-26.00 | 0.50 Max. | 485 | 205 | 30 |
| 9 | P15E / 1 | SA 217 C12A | 0.08-0.12 | 0.30-0.60 | 0.030 Max. | 0.010 Max. | 0.20-0.50 | 0.40 Max. | 8.00-10.00 | 0.85-1.05 | 585 | 415 | 18 |

## TABLE A2.5: PLATES/SHEETS

| Sl. No. | P. No./ Group No. | Material Specification | Thickness mm | C | Mn | P | S | Si | Ni | Cr | Mo | V | T.S (MPa) | Y.S (MPa) | %E Min. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | P 1 / 1 | ASTM A36 | 20 incl. | 0.25 | - | 0.04 | 0.05 | 0.40 | - | - | - | - | 400 | 250 | 20 |
| | | | 20-40 incl. | 0.25 | 0.80-1.20 | | | 0.40 | - | - | - | - | | | |
| | | | 40-65 incl. | 0.26 | 0.80-1.20 | | | 0.40 | - | - | - | - | | | |
| | | | 65-100 incl. | 0.27 | 0.85-1.20 | | | 0.15-0.40 | - | - | - | - | | | |
| | | | over 100 | 0.29 | 0.85-1.20 | | | 0.15-0.40 | - | - | - | - | | | |
| 2 | P 1 / 1 | SA 516 Gr 60 | 12.5 incl | 0.21 | 0.55-0.98 | 0.035 | 0.035 | 0.13-0.45 | - | - | - | - | 415 | 220 | 25 |
| | | | 12.5-50 incl | 0.23 | 0.79-1.30 | | | | - | - | - | - | | | |
| | | | 50-100 incl | 0.25 | | | | | - | - | - | - | | | |
| | | | 100-200 incl | 0.27 | | | | | - | - | - | - | | | |
| | | | over 200 | 0.27 | | | | | - | - | - | - | | | |
| 3 | P 1 / 2 | SA516 Gr70 | 12.5 incl | 0.27 | 0.79-1.30 | 0.035 | 0.035 | 0.13-0.45 | - | - | - | - | 485 | 260 | 21 |
| | | | 12.5-50 incl | 0.28 | | | | | - | - | - | - | | | |
| | | | 50-100 incl | 0.3 | | | | | - | - | - | - | | | |
| | | | 100-200 incl | 0.31 | | | | | - | - | - | - | | | |
| | | | over 200 | 0.31 | | | | | - | - | - | - | | | |
| 4 | P 1 / 2 | SA299 Gr.A | <25 | 0.26 | 0.84-1.52 | 0.035 | 0.035 | 0.13-0.45 | - | - | - | - | 515 | 275 | 19 |
| | | | >25 | 0.28 | 0.84-1.62 | | | | - | - | - | - | | | |
| 5 | P 1 / 2 | SA515 Gr70 | <25 | 0.31 | 1.30 | 0.035 | 0.035 | 0.13-0.45 | - | - | - | - | 485 | 260 | 21 |
| | | | 25-50 incl | 0.33 | | | | | - | - | - | - | | | |
| | | | 50-100 incl | 0.35 | | | | | - | - | - | - | | | |
| | | | 100-200 incl | 0.35 | | | | | - | - | - | - | | | |
| | | | >200 | 0.35 | | | | | - | - | - | - | | | |
| 6 | P311 | SA204 Gr A | <25 incl | 0.18 | 0.98 | 0.025 | 0.025 | 0.13-0.45 | - | - | 0.41-0.64 | - | 450 | 255 | 23 |
| | | | >50 incl | 0.21 | | | | | - | - | | - | | | |
| | | | >100 incl | 0.23 | | | | | - | - | | - | | | |
| | | | >100 | 0.25 | | | | | - | - | | - | | | |
| 7 | P312 | SA204 Gr B | <25 incl | 0.20 | 0.98 | 0.025 | 0.025 | 0.13-0.45 | - | - | 0.41-0.64 | - | 485 | 275 | 21 |
| | | | >50 incl | 0.23 | | | | | - | - | | - | | | |
| | | | >100 incl | 0.25 | | | | | - | - | | - | | | |
| | | | >100 | 0.27 | | | | | - | - | | - | | | |
| 8 | P411 | SA 387 Gr 12 Class 2 | <125 incl | 0.04-0.17 | 0.35-0.73 | 0.025 | 0.025 | 0.13-0.45 | - | 0.74-1.21 | 0.40-0.65 | - | 450 | 275 | 22 |
| | | | >125 | 0.17 | | | | | | | | | | | |
| 9 | P5N1 | SA387 Gr 22 Class 2 | <125 incl | 0.04-0.15. | 0.25-0.66 | 0.025 | 0.025 | 0.50. | | 1.88-2.62 | 0.85-1.15 | - | 515 | 310 | 18 |
| | | | >125 | 0.17 | | | | | | | | | | | |
| 10 | P15El1 | SA387 Gr 91 | all thickness | 0.06-0.15 | 0.25-0.66 | 0.025 | 0.012 | 0.18-0.56 | 0.43 | 7.90-9.60 | 0.80-1.10 | 0.16-0.27 | 585 | 415 | 18 |

TABLE A2.5: PLATES/SHEETS (Contd...)

| Sl. No. | P.No./ Group No. | Material Specification | Thickness mm | C | Mn | P | S | Si | Ni | Cr | Mo | V | T.S (MPa) | Y.S (MPa) | %E Min. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 | P811 | SA240 TYPE 304 | all thickness | 0.07 | 2 | 0.045 | 0.03 | 0.75 | 8.00-10.50 | 17.5.-19.5.0 | - | | 515 | 205 | 40 |
| 12 | P 1 / 1 | ASTM A572 Gr50 | <40 incl | 0.23 | 1.35 | 0.04 | 0.05 | 0.4 0 | - | - | - | 0.01-0.1 | 450 | 345 | 17 |
| | | | >40 | | | | | 0.15-0.40 | - | - | | | | | |
| 13 | P 1 / 1 | IS 2062 E250 Gr.A | all thickness | 0.23 | 1.5 | 0.045 | 0.045 | 0.4 | - | - | - | - | 410 | 230 | 23 |
| 14 | P 1 / 1 | IS 2062 E250 Gr.BR BO | all thickness | 0.22 | 1.5 | 0.045 | 0.045 | 0.4 | - | - | - | - | 410 | 230 | 23 |
| 15 | P 1 / 1 | IS 2062 E250 GrC | all thickness | 0.2 | 1.5 | 0.04 | 0.04 | 0.4 | - | - | - | - | 410 | 230 | 23 |
| 16 | P 1 / 1 | IS 2062 E350 Gr A.BR,BO | all thickness | 0.2 | 1.55 | 0.045 | 0.045 | 0.45 | - | - | - | - | 490 | 320 | 22 |
| 17 | P 1 / 1 | IS 2062 E350 GrC | all thickness | 0.2 | 1.55 | 0.04 | 0.04 | 0.45 | - | - | - | - | 490 | 320 | 22 |
| 18 | P 1 / 1 | IS 2062 E450BR | all thickness | 0.22 | 1.65 | 0.045 | 0.045 | 0.45 | - | - | - | - | 570 | 450 | 20 |
| 19 | P 1 / 1 | BSEN10025 Gr 420N | all thickness | 0.2 | 1.0-1.7 | 0.03 | 0.025 | 0.6 | 0.8 | 0.3 | 0.1 | 0.2 | 500 | 320 | 18 |

## TABLE A2.6: PIPES (OTHER SPECIFICATION)

| Sl. No. | Equivalent P. No. /Group No. | Material Specification | Chemical Composition (%) | | | | | | | | | Mechanical Properties (Min.) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | C | Mn | P | S | Si | Ni | Cr | Mo | V | T.S Kg / $mm^2$ | Y.S Kg / $mm^2$ | % EMin. |
| 1 | P1/1 | DIN St. 35.8 | 0.17 Max. | 0.40-0.80 | 0.04 Max. | 0.04 Max. | 0.10-0.35 | - | - | - | - | 36.70-48.96 | 24 | 25 |
| 2 | P1/1 | DIN St. 45.8 | 0.21 Max. | 0.45-1.20 | 0.04 Max. | 0.04 Max. | 0.10-0.35 | - | - | - | - | 41.80-54.10 | 26 | 21 |
| 3 | P1/1 | BS 3602 / 410 | 0.21 Max. | 0.40-1.20 | 0.045 Max. | 0.045 Max. | 0.35 Max. | - | - | - | - | 41.82-56.10 | 25 | 22 |
| 4 | P1/1 | BS 3602 / 460 | 0.22 Max. | 0.80-1.40 | 0.045 Max. | 0.045 Max. | 0.35 Max. | - | - | - | - | 46.90-61.20 | 28.60 | 21 |
| 5 | P4/1 | BS 3604 620-460 HFS or CDS 620-440 | 0.10-0.15 | 0.40 Max. | 0.04 Max. | 0.04 Max. | 0.10-0.35 | - | 0.70-1.10 | 0.45-0.65 | - | 46.90-62.22 | 18.36 | 22 |
| | | | 0.10-0.18 | 0.40-0.70 | 0.04 Max. | 0.04 Max. | 0.10-0.35 | - | 0.70-1.10 | 0.45-0.65 | - | 44.90-60.20 | 29.58 | 22 |
| 6 | P5/1 | BS 3604 622 HFS or CDS | 0.08-0.15 | 0.40-0.70 | 0.04 Max. | 0.04 Max. | 0.50 Max. | - | 2.00 2.50 | 0.90-1.20 | - | 48.80 | 26.80 | 17 |
| 7 | - | BS 3604 HFS 660 Or CDS 660 | 0.15 Max. | 0.40-0.70 | 0.04 Max. | 0.04 Max. | 0.10-0.35 | - | 0.25-0.50 | 0.50-0.70 | 0.22-0.30 | 47.30 | 30 | 17 |
| 8 | P5B/2 | X20CrMoV121D IN17175 | 0.17-0.23 | ≤ 1.00 | 0.030 Max. | 0.030 Max. | ≥ 0.50 | 0.30-0.80 | 10.00-12.50 | 0.80-1.20 | 0.25-0.35 | 70-86 | 50 | 17 |

## TABLE A2.7: TUBES (OTHER SPECIFICATIONS)

| Sl. No. | Equivalent P. No. /Group No. | Material Specification | Chemical Composition (%) | | | | | | | | | Mechanical Properties (Min.) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | C | Mn | P | S | Si | Ni | Cr | Mo | V | T.S Kg / $mm^2$ (MPa) | Y.S Kg / $mm^2$ (MPa) | % E Min. |
| 1 | P1/1 | DIN St. 35.8 | 0.17 Max. | 0.40-0.80 | 0.04 Max. | 0.04 Max. | 0.10-0.35 | - | - | - | - | 36.70-48.96 | 24 | 25 |
| 2 | P1/1 | DIN St. 45.8 | 0.21 Max. | 0.40-1.20 | 0.04 Max. | 0.04 Max. | 0.10-0.35 | - | - | - | - | 41.80-54.06 | 26 | 21 |
| 3 | P1/1 | BS 3059 / 360 | 0.17 Max. | 0.40-0.80 | 0.045 Max. | 0.045 Max. | 0.35 Max. | - | - | - | - | 36.70-51.00 | 22 | 24 |
| 4 | P1/1 | BS 3059 / 440 | 0.12-0.18 | 0.90-1.20 | 0.040 Max. | 0.035 Max. | 0.10-0.35 | - | - | - | - | 44.88-59.20 | 25 | 21 |
| 5 | P3/1 | 15 Mo3 DIN17175 | 0.12-0.20 | 0.40-0.80 | 0.035 Max. | 0.035 Max. | 0.10-0.35 | - | - | 0.25-0.35 | - | 45.90-61.20 | 27.50 | 22 |
| 6 | P4/1 | 13 Cr Mo 4-5DIN17175 | 0.10-0.18 | 0.40-0.70 | 0.035 Max. | 0.035 Max. | 0.10-0.35 | - | 0.70-1.10 | 0.45-0.65 | - | 44.88-60.18 | 29.60 | 22 |
| 7 | P4 /1 | BS 3059 / 620 | 0.10-0.15 | 0.40-0.70 | 0.040 Max. | 0.040 Max. | 0.10-0.35 | - | 0.70-1.10 | 0.45-0.65 | - | 46.90-62.20 | 18.40 | 22 |
| 8 | P5/1 | 10 Cr Mo 9-10DIN17175 | 0.08-0.15 | 0.40-0.70 | 0.035 Max. | 0.035 Max. | 0.50 Max. | - | 2.00-2.50 | 0.90-1.20 | - | 45.90-61.20 | 28.60 | 20 |
| 9 | P5/1 | BS 3059 (622) - 440 | 0.08-0.15 | 0.40-0.70 | 0.04 Max. | 0.04 Max. | 0.50 Max. | - | 2.00-2.50 | 0.90-1.20 | - | 44.90-60.18 | 17.85 | 20 |
| 10 | P5/1 | BS 3059 (622) - 490 | 0.08-0.15 | 0.40-0.70 | 0.040 Max. | 0.040 Max. | 0.50 Max. | - | 2.00-2.50 | 0.90-1.20 | - | 49.98-65.00 | 28.05 | 20 |
| 11 | - | 14 Mo V 63 DIN17175 | 0.10-0.18 | 0.40-0.70 | 0.035 Max. | 0.035 Max. | 0.10-0.35 | | 0.30-0.60 | 0.50-0.70 | 0.22-0.32 | 46.90-62.22 | 32.60 | 20 |
| 12 | P5B/2 | X20CrMoV121 DIN17175 | 0.17-0.23 | ≤ 1.00 | 0.030 Max. | 0.030 Max. | ≥ 0.50 | 0.30-0.80 | 10.00-12.50 | 0.80-1.20 | 0.25-0.35 | 70-86 | 50 | 17 |

# CHAPTER A3: WELDING MATERIAL SPECIFICATION AND CONTROL

## SECTION A3.1-WELDING MATERIAL SPECIFICATION AND CONTROL

### 1.0 SCOPE:

1.1. This chapter details out the welding material specification and controls at sites.

### 2.0 CONTENTS:

1. Table- A3.1 - Weld Metal Chemical Composition.
2. Table - A3.2 - Mechanical property requirement for all-weld metal.
3. Receipt inspection of welding electrodes/filler wires.
4. Storage and identification of welding electrodes/filler wires.
5. Drying and holding of welding electrodes.
6. Selection and issue of welding electrodes/filler wires.
7. Table-A3.3 - Selection of GTAW filler wire, SMAW electrodes for butt welds in tubes, pipes, headers.
8. Table-A3.4 - Selection of electrodes for welding attachments to tubes.
9. Table-A3.5 - Selection of electrodes, preheat, PWHT for attachment to attachment welds.
10. Table-A3.6 -Selection of electrodes for welding nozzle attachments, hand hole plate, RG plug etc. to headers, pipes.
11. Table-A3.7 –Selection of filler wire and electrodes for non-pressure parts( including structures )
12. Table-A3.8 -A numbers
13. Table-A3.9 -F numbers
14. SFA Classification

**3.0** For welding consumables not covered in this chapter, relevant details may be obtained from the concerned Manufacturing Units.

**Table-A3.1**
**WELD METAL CHEMICAL COMPOSITION**

| Electrode/ Consumable | SFA No. | Weight, % | | | | | | | | | | Other Elements %[a] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | C | Mn | Si | P | S | Ni | Cr | Mo | V | Cu | |
| E 6010 | 5.1 | 0.20 | 1.20 | 1.00 | NS | NS | 0.30 | 0.20 | 0.30 | 0.08 | NS | Combined Limit for Mn+Ni+Cu+Mo+V=1.75 |
| E 6013 | 5.1 | 0.20 | 1.20 | 1.00 | NS | NS | 0.30 | 0.20 | 0.30 | 0.08 | NS | |
| E 7018 | 5.1 | 0.15 | 1.60 | 0.75 | 0.035 | 0.035 | 0.30 | 0.20 | 0.30 | 0.08 | NS | |
| E 7018-1 | 5.1 | 0.15 | 1.60 | 0.75 | 0.035 | 0.035 | 0.30 | 0.20 | 0.30 | 0.08 | NS | |
| E 7018-A1 | 5.5 | 0.12 | 0.90 | 0.80 | 0.03 | 0.03 | NS | NS | 0.40-0.65 | NS | NS | |
| E 8018-B2 | 5.5 | 0.05-0.12 | 0.90 | 0.80 | 0.03 | 0.03 | NS | 1.00-1.50 | 0.40-0.65 | NS | NS | |
| E 9018-B3 | 5.5 | 0.05-0.12 | 0.90 | 0.80 | 0.03 | 0.03 | NS | 2.00-2.50 | 0.90-1.20 | NS | NS | |
| E 9015-B91 | 5.5 | 0.08-0.13 | 1.20 | 0.30 | 0.01 | 0.01 | 0.80 | 8.00-10.50 | 0.85-1.20 | 0.15-0.30 | 0.04-0.25 | |
| E9015-B92 | 5.5 | 0.08-0.15 | 1.20 | 0.60 | 0.020 | 0.015 | 1.0 | 8.0-10.0 | 0.30-0.70 | 0.15-0.30 | 0.25 | W: 1.50-2.00; Nb: 0.02-0.08 B:0.006; Al: 0.04; N: 0.03-0.08 |
| E9018-B23/ E9015-B23 | 5.5 | 0.04-0.12 | 1.00 | 0.60 | 0.015 | 0.015 | 0.5 | 1.9-2.9 | 0.30 | 0.15-0.30 | 0.25 | W: 1.50-2.00; Nb: 0.02-0.10 B:0.006; Al: 0.04; N: 0.05 |
| E 308 | 5.4 | 0.08 | 0.50-2.50 | 1.00 | 0.04 | 0.03 | 9.00-11.00 | 18.00-21.00 | 0.75 | NS | 0.75 | |
| E 308-L | 5.4 | 0.04 | 0.50-2.50 | 1.00 | 0.04 | 0.03 | 9.00-11.00 | 18.00-21.00 | 0.75 | NS | 0.75 | |

## Table-A3.1 (Contd...)
## WELD METAL CHEMICAL COMPOSITION

| Electrode/ Consumable | SFA No. | Weight, % | | | | | | | | | | Other Elements %[a] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | C | Mn | Si | P | S | Ni | Cr | Mo | V | Cu | |
| E 309 | 5.4 | 0.15 | 0.50-2.50 | 1.00 | 0.04 | 0.03 | 12.00-14.00 | 22.00-25.00 | 0.75 | NS | 0.75 | |
| E 309-L | 5.4 | 0.04 | 0.50-2.50 | 1.00 | 0.04 | 0.03 | 12.00-14.00 | 22.00-25.00 | 0.75 | NS | 0.75 | |
| E 347 | 5.4 | 0.08 | 0.50-2.50 | 1.00 | 0.04 | 0.03 | 9.00-11.00 | 18.00-21.00 | 0.75 | NS | 0.75 | Cb+Ta 8XC Min. to 1.00 Max. |
| E316 | 5.4 | 0.08 | 0.5-2.5 | 1.00 | 0.04 | 0.03 | 11.0-14.0 | 17.0-20.0 | 2.0-3.0 | NS | 0.75 | |
| E2209-16 | 5.4 | 0.04 | 0.5-2.0 | 1.00 | 0.04 | 0.03 | 7.5-9.5 | 21.5-23.5 | 2.5-3.5 | NS | 0.75 | N:0.08-0.20 |
| ENiCrFe-3 | 5.11 | 0.10 | 5.0-9.5 | 1.00 | 0.03 | 0.015 | 59.0 min | 13.0-17.0 | NS | NS | 0.50 | Fe: 12.0; Ta+ Cb: 1.0-2.5; Ti: 1.0; others: 0.5 |
| ENiCrFe-7 | 5.11 | 0.05 | 5.0 | 0.75 | 0.03 | 0.015 | Rem | 28.0-31.5 | 0.5 | NS | 0.50 | Fe: 7.0-12.0; Ta+ Cb: 1.0-2.5; others: 0.5 |
| ENi-CI | 5.15 | 2.00 | 2.50 | 4.00 | NS | 0.03 | 85[d] min | NS | NS | NS | 2.5[e] | Fe 8.0 Al 1.0 others Total 1.0 |
| ENiFe-CI | 5.15 | 2.00 | 2.50 | 4.00 | NS | 0.03 | 45[d]-60 | NS | NS | NS | 2.5[e] | Fe Rem[f] Al 1.0 others Total 1.0 |
| ER70S-2 | 5.18 | 0.07 | 0.90-1.40 | 0.40-0.70 | 0.025 | 0.035 | 0.15 | 0.15 | 0.15 | 0.03 | 0.50[b] | Ti 0.05-0.15 Zr 0.02-0.12 Al 0.05-0.15 |
| ER70S-A1 | 5.28 | 0.12 | 1.30 | 0.30-0.70 | 0.025 | 0.025 | 0.20 | NS | 0.40-0.65 | NS | 0.35 | Others : 0.50 |
| E8018-G | 5.5 | 0.08 | 1.0-1.8 | 0.5 | 0.025 | 0.025 | 0.5-1.20 | NS | 0.5 | NS | NS | |

**Table-A3.1 (Contd…)**
**WELD METAL CHEMICAL COMPOSITION**

| Electrode/ Consumable | SFA No. | Weight, % | | | | | | | | | | Other Elements %[a] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | C | Mn | Si | P | S | Ni | Cr | Mo | V | Cu | |
| ER80S-B2 | 5.28 | 0.07-0.12 | 0.40-0.70 | 0.40-0.70 | 0.025 | 0.025 | 0.20 | 1.20-1.50 | 0.40-0.65 | NS | 0.35[c] | Total other Elements 0.50 |
| ER90S-B3 | 5.28 | 0.07-0.12 | 0.40-0.70 | 0.40-0.70 | 0.025 | 0.025 | 0.20 | 2.30-2.70 | 0.90-1.20 | NS | 0.35[c] | Total other Elements 0.50 |
| ER80S-D2 | 5.28 | 0.07-0.12 | 1.60-2.10 | 0.50-0.80 | 0.025 | 0.025 | 0.15 | NS | 0.40-0.60 | NS | 0.50[c] | Total other Elements 0.50 |
| ER90S-B9 | 5.28 | 0.07-0.13 | 1.20 | 0.15-0.30 | 0.01 | 0.01 | 0.80 | 8.00-10.50 | 0.80-1.20 | 0.15-0.23 | 0.20 | Total other Elements 0.50 |
| ER 308 | 5.9 | 0.08 | 1.00-2.50 | 0.30-0.65 | 0.03 | 0.03 | 9.00-11.00 | 19.50-22.00 | 0.75 | NS | 0.75 | |
| ER 309 | 5.9 | 0.12 | 1.00-2.50 | 0.30-0.65 | 0.03 | 0.03 | 12.00-14.00 | 23.00-25.00 | 0.75 | NS | 0.75 | |
| ER 309-L | 5.9 | 0.03 | 1.00-2.50 | 0.30-0.65 | 0.03 | 0.03 | 12.00-14.00 | 23.00-25.00 | 0.75 | NS | 0.75 | |
| ER316L | 5.9 | 0.03 | 1.0-2.5 | 0.30-0.65 | 0.03 | 0.03 | 11.0-14.0 | 18.0-20.0 | 2.0-3.0 | NS | 0.75 | --- |
| ER 347 | 5.9 | 0.08 | 1.00-2.50 | 0.30-0.65 | 0.03 | 0.03 | 9.00-11.00 | 19.00-21.50 | 0.75 | NS | 0.75 | Cb+Ta 10XC Min. to 1.0 Max. |
| ER2209 | 5.9 | 0.03 | 0.5-2.0 | 0.90 | 0.03 | 0.03 | 7.5-9.5 | 21.5-23.5 | 2.5-3.5 | NS | 0.75 | N:0.08-0.20 |

**Table-A3.1 (Contd…)**
**WELD METAL CHEMICAL COMPOSITION**

| Electrode/ Consumable | SFA No. | Weight, % | | | | | | | | | | Other Elements %[a] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | C | Mn | Si | P | S | Ni | Cr | Mo | V | Cu | |
| ERNiCr-3 | 5.14 | 0.10 | 2.5-3.5 | 0.50 | 0.03 | 0.015 | 67.0 min | 18.0-22.0 | NS | NS | 0.50 | Fe: 3.0; Cb+Ta: 2.0-3.0; Ti: 0.75; Other: 0.5 |
| ERNiCrFe-7A | 5.14 | 0.04 | 1.0 | 0.50 | 0.02 | 0.015 | Rem. | 28.0-31.5 | 0.50 | | 0.30 | Fe: 7.0-11-0; Cb+Ta: 0.5-1.0; Ti: 1.0; Other: 0.5; Co: 0.12; Al: 1.10 |
| YT 304H | -- | Proprietary GTAW rod for Super 304H | | | | | | | | | | |
| THERMANIT 304H Cu | -- | | | | | | | | | | | |
| TGS2CW | -- | Proprietary GTAW rod for T23 | | | | | | | | | | |
| YT-HCM2S | | | | | | | | | | | | |
| 2CrWV-TIG | -- | | | | | | | | | | | |
| 9CRWV TIG | -- | Proprietary GTAW rod for Gr.92 | | | | | | | | | | |
| THERMANIT MTS 616 | -- | | | | | | | | | | | |

## TABLE – A3.1 (Contd...)
## WELD METAL CHEMICAL COMPOSITION

**Notes:**

a) Other elements listed without specified values shall be reported, if intentionally added. The total of these latter unspecifiedelements and all other elements not intentionally added shall not exceed 0.50%.

b) The maximum weight percent of copper in the rod or electrode due to any coating plus the residual copper content in the steel shall be 0.50.

c) The maximum weight percent of copper in the rod or electrode due to any coating plus the residual copper content in the steel shall comply with the stated value.

d) Nickel plus incident Cobalt.

e) Copper plus incident Silver.

f) "Rem" stands for remainder.

g) Manufacturer's certification to have met the requirements of ASME Sec. II Part C is acceptable in cases where the chemical analysis are not reflected.

h) Single values are maximum.

i) NS – Not Specified

**TABLE-A3.2**
**MECHANICAL PROPERTY REQUIREMENTFOR ALL-WELD METAL**

| Electrode | SFA No. | Tensile Strength Ksi / MPa | Yield Strength at 0.2% of Proof Stress, Ksi/ MPa | Elongation In 2 inch (50.8 mm) % |
|---|---|---|---|---|
| E6010 | 5.1 | 60 / 430 | 48 / 330 | 22 |
| E6013 | 5.1 | 60 /430 | 48 / 330 | 17 |
| E7018 | 5.1 | 70 / 490 | 58 / 400 | 22 |
| E7018-1[a] | 5.1 | 540 | 58 / 400 | 22 |
| E7018-A1 | 5.5 | 70 / 490 | 57 / 390 | 22 |
| E8018-G[b] | 5.5 | 570 | 450 | 19 |
| E8018-B2 | 5.5 | 80 /550 | 67 / 460 | 19 |
| E9018-B3 | 5.5 | 90 /620 | 77 / 530 | 17 |
| E9015-B91 | 5.5 | 90 /620 | 77 / 530 | 17 |
| E9015-B92 | 5.5 | 90/620 | 77/530 | 17 |
| E9018-B23 | 5.5 | 90/620 | 77/530 | 17 |
| E308 | 5.4 | 80 / 550 | - | 35 |
| E308L | 5.4 | 75 / 520 | - | 35 |
| E309 | 5.4 | 80 / 550 | - | 30 |
| E309L | 5.4 | 75 / 520 | - | 30 |
| E347 | 5.4 | 75 / 520 | - | 30 |
| E316 | 5.4 | 75/520 | -- | 30 |
| E2209 | 5.4 | 100/690 | -- | 22 |
| ENiCrFe-3 | 5.11 | 80/550 | -- | 30 |
| ENiCrFe-7 | 5.11 | 80/550 | -- | 30 |
| ENi-CI | 5.15 | 40-65 / 276-448 | 38-60 / 268-414 | 3-6 |
| ENiFe-CI | 5.15 | 58-84 / 400 -579 | 43-63 / 294 -434 | 6-18 |

a. These electrodes shall meet the lower temperature impact requirement of average minimum. (27 Joules at – 45° C) and other properties at 620±20°C for 300 minutes.

b. These electrodes shall meet the impact requirement of average minimum (20 Joules at + 25° C) and other properties at 550±10°C for 60 minutes.

**Table- A3.2 (Contd...)**

**MECHANICAL PROPERTY REQUIREMENT FOR ALL-WELD METAL**

| Electrode | SFA No. | Tensile Strength Ksi / MPa | Yield Strength at 0.2% of Proof Stress, Ksi / MPa | Elongation In 2 inch (50.8 mm) % |
|---|---|---|---|---|
| ER70S-6 | 5.18 | 70/480 | 58/400 | 22 |
| ER70S-A1 | 5.28 | 75/515 | 58/400 | 19 |
| ER80S-B2 | 5.28 | 80 / 550 | 68 / 470 | 19 |
| ER90S-B3 | 5.28 | 90 / 620 | 78 / 540 | 17 |
| ER80S-D2 | 5.28 | 80 / 550 | 68 / 470 | 17 |
| ER90S-B9 | 5.28 | 90 / 620 | 60 / 410 | 16 |
| ER308 | 5.9 | These values are not required in the test certificate | | |
| ER308L | 5.9 | | | |
| ER309 | 5.9 | | | |
| ER309L | 5.9 | | | |
| ER347 | 5.9 | | | |
| ER316 | 5.9 | | | |
| ER2209-16 | 5.9 | | | |
| ERNiCr-3 | 5.14 | 80/550 | -- | |
| ERNiCrFe-7A | 5.14 | 85/590 | -- | |

NOTE:

a) Single values are minimum.

b) Manufacturer's certification to have met the requirements of ASME-Section II Part C is acceptable in cases where the mechanical properties are not reflected.

c) 1Ksi is approximately equal to 6.89 MPa.

## Section A3.2- Receipt Inspection of Welding Electrodes / Filler Wires

1.0 All electrodes/filler wires received at site stores shall be segregated for type and size of electrode.

2.0 Ensure that electrode packets received are free from physical damage.

3.0 Where electrodes are damaged, the same shall be removed from use.

4.0 Only electrodes identified in the "list of approved vendors of welding electrodes" shall be accepted.

5.0 Where filler metals are supplied by manufacturing unit, inspect for damages, if any.

6.0 Ensure availability of relevant test certificates. Refer tables of chemical compositions and mechanical properties for acceptance.

7.0 Endorse acceptance/rejection on the test certificate.

# Section A3.3- Storage & Identification of WeldingElectrodes/Filler Wires

## 1.0 SCOPE:

**1.1** This procedure is applicable for storage of welding electrodes/filler wires used at sites.

## 2.0 PROCEDURE:

**2.1** Only materials accepted (based on receipt inspection) shall be taken into account for storage.

### 2.2 STORAGE FACILITY:

2.2.1 The storage facility shall be identified.

2.2.2 Access shall be made available to authorized personnel.

2.2.3 The storage area shall be clean and dry.

2.2.4 Steel racks may be used for storage. Avoid usage of wooden racks for storing inside the storage room.

2.2.5 Maintain the temperature of the storage facility above the ambient temperature. This can be achieved by the use of appropriate heating arrangements.

**2.3** The electrodes/filler wire shall be segregated and identified for

a. Type of electrode e.g. E7018.

b. Size of electrode e.g. Dia. 3.15 mm.

**2.4** Identification of filler wires:

2.4.1 On receipt of GTAW filler wires, check AWS No. or brand name embossed and retain the same identification throughout.

# Section A3.4-Drying and Holding of Welding Electrodes

## 1.0 SCOPE:

1.1 This section details activities regarding drying and holding of welding electrodes used at sites.

## 2.0 PROCEDURE:

2.1 While handling, avoid contact of oil, grease with electrodes. Do not use oily or wet gloves.

2.2 It is recommended that not more than two days' requirements electrodes are dried.

## 3.0 GTAW Filler Wires:

3.1 These wires do not require any drying.

## 4.0 Covered Electrodes:

### 4.1 Drying and holding :

4.1.1 Identify drying oven and holding oven.

4.1.2 They shall preferably have a temperature control facility upto 400°C for drying oven and 200°C for holding oven.

4.1.3 A calibrated thermometer shall be provided for monitoring temperature.

4.2 On opening a packet of electrodes, segregate and place them in the drying oven. Mix-up of electrodes shall be avoided.

4.2.1 After loading, raise the drying oven temperature to the desired range as per table in 4.2.5.

4.2.2 Note the time when the temperature reaches the desired range. Maintain this temperature for the duration required as per Table in 4.2.5.

4.2.3 On completion of drying, the electrodes shall be transferred to holding oven immediately and maintained at minimum temperature of 150°C till issue.

4.2.4 The electrode shall not be subjected to more than three cycles of drying.

4.2.5 Maintaina register containing following details:

| Sl. No. | Date | AWS number/Specification | Batch No./Size | Dia. | Qty. | Drying temperature Start time | Drying Temperature end time | Remarks |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| | | | | | | | | |

## Drying and Holding Parameters

| AWS Classification | Drying (*) | | Minimum Holding Temperature °C (@) |
|---|---|---|---|
| | Temperature °C | Time (Hours) | |
| E7018 | 250 - 300 | 2 | 150 |
| E7018-1 | 250 - 300 | 2 | 150 |
| E7018-A1 | 250 - 300 | 2 | 150 |
| E8018-G | 250 - 300 | 2 | 150 |
| E8018-B2 | 250 - 300 | 2 | 150 |
| E9018-B3 | 250 - 300 | 2 | 150 |
| E9018-B23 | 250 - 300 | 2 | 150 |
| E9015-B91 | 250 - 300 | 2 | 150 |
| E9015-B92 | 250 - 300 | 2 | 150 |
| E308, E309, E310 E316& E347 | 250 - 300 | 1 | 150 |
| ENiCrFe-3 | 250 - 300 | 2 | 150 |
| ENiCrFe-7 | 250 - 300 | 2 | 150 |

Note: (*) - Guideline has been given however, supplier's recommendations shall be followed.

(@) - Maintain the temperature in the oven till issue.

4.2.4 After issue, maintain the electrodes in a portable oven at a minimum temperature of 65°C till use. This is not applicable for E6013 (Rutile) electrodes, however the following instruction shall be followed for E6013 electrodes:

(1) Rutile electrodes require some moisture in the coating and they would not require drying. If they become damp, re-drying at around 120 to 150°C for 1 hour will be sufficient.

(2) These electrodes with potassium silicate binder can be used on both DCEP/DCEN polarities and on AC. E6013 electrodes generally have better arc striking and stability characteristics with an easily detachable slag.

4.3 Unused, returned electrodes shall be segregated and reused only after repeating drying and holding cycles.

## Section A3.5- Selection and Issue of Welding Electrodes / Filler Wires

### 1.0 SCOPE:

1.1. This procedure details methods for selection and issue of welding electrodes/filler wires for site operations.

### 2.0 PROCEDURE:

#### 2.1 Selection:

2.1.1 The type of filler wire/electrode for welding shall be based on the details given in the contract documents like Field Welding Schedule, drawings, Welding Procedure Specifications as supplied by the concernedmanufacturing units.

2.1.2 Where not specified by the manufacturing units, selection shall be based on the tables enclosed (Table A3.3 to Table A3.7. as applicable).

2.1.3 Where electrodes/ filler wires are not covered in the documents mentioned in 2.1.1 and 2.1.2, refer to the concernedmanufacturing units.

#### 2.2 Issue:

2.2.1 Issue of welding electrodes / filler wires shall be based on authorised welding electrodes issue voucher.

2.2.2 It is recommended to restrict quantity issued to not more than 4 hours' requirements.

2.2.3 Re-dried low hydrogen electrodes shall be carried to the work spot in a portable oven.

2.2.4 Maintain the temperature in the portable oven at the work spot above 65°C.

2.2.5 Unused electrodes shall be segregated and reused only after repeating drying and holding cycles.

**Table- A3.3**
**SELECTION OF GTAW FILLER WIRE, SMAW ELECTRODE FOR BUTT WELDS IN TUBES, PIPES AND HEADERS**

| Material | Welding Process | P1 Gr 1/ P1 Gr 2 | P3 Gr 1 | P4 Gr 1 | P5A Gr 1 | P15 E Gr 1 | T23 | T92/P92 | P8 | P8 SA 213 UNS S 30432 | DIN14MoV6 3 or equivalent |
|---|---|---|---|---|---|---|---|---|---|---|---|
| P1 Gr 1 | GTAW | ER 70S-A1 | | | | | | | | | |
| P1 Gr 2 | SMAW | E7018-1 Note 1 | | | | | | | | | |
| P3 Gr 1 | GTAW | ER 70S-A1 | ER 70S-A1 | | | | | | | | |
| | SMAW | E7018-1 | E7018-A1 | | | | | | | | |
| P4 Gr 1 | GTAW | ER 70S-A1 | ER 70S-A1 | ER 80S-B2 | | | | | | | |
| | SMAW | E7018-1 | E7018-A1 | E8018-B2 | | | | | | | |
| P5A Gr 1 | GTAW | ER 70S-A1 | ER 70S-A1 | ER 80S-B2 | ER 90S-B3 | ER 90S-B3 | ER90S-B3 | | | | |
| | SMAW | E7018-1 | E7018-A1 | E8018-B2 | E9018-B3 | E9018-B3 | E9018-B3 | | | | |
| P15 E Gr.1 Gr.91 | GTAW | | | | | ER90S-B9 | TGS2CW/ 2CrWVTIG/ YT-SCM2S | ER90S-B9 | | | |
| | SMAW | | | | | E9015-91 | E9018-B23 | E9015-B91 | | | |
| T23 | GTAW | | | | | | TGS2CW/ 2CrWVTIG/YT-SCM2S | TGS2CW/ 2CrWVTIG/ YT-SCM2S | | | |
| | SMAW | | | | | | E9018-B23 | E9018-B23 | | | |

**Table- A3.3 (Contd...)**

| Material | Welding Process | P1 Gr 1 P1 Gr 2 | P3 Gr 1 | P4 Gr 1 | P5A Gr 1 | P15 E Gr 1 | T23 | T92/P92 | P8 | P8 SA 213 UNS S 30432 | DIN14MoV63 or equivalent |
|---|---|---|---|---|---|---|---|---|---|---|---|
| P15 E Gr.1 Gr.92 | GTAW | | | | | | | 9CrWV-TIG/ Themanit-MTS616 | | | |
| | SMAW | | | | | | | E9015-B92 | | | |
| P8 | GTAW | | | ERNi Cr3 | ERNiCr3 | ERNiCr3 | ERNiCr3 | ERNiCrFe7A | ER347 | | |
| | SMAW | | | ENiC rFe3 | ENiCrFe3 | ENiCrFe3 | ENiCrFe3 | ENiCrFe7 | E347 | | |
| P8 SA 213 UNS S30432 | GTAW | | | | | | | | | YT304H/ THERMANIT 304H Cu | |
| DIN14MoV63 or equivalent | GTAW | | | | ER 90S-B3 | | | | | | ER90S-B3 |
| | SMAW | | | | E9018-B3 | | | | | | E9018-B3 |

Note-1: E7018-A1 for P1 Gr2 + P1 Gr2 when PWHT is involved.

**Table- A3.4**
**SELECTION OF ELECTRODES FOR WELDING ATTACHMENTS TO TUBES**

| Tube Material | Attachment Material | | | |
|---|---|---|---|---|
| | **P1 Group 1** | **P4 Group 1** | **P5A Group 1** | **P8** |
| P1 Group 1<br>P1 Group 2 | E 7018 | E 7018 | E 7018 | E 309 |
| P3 | E 7018-A1 | E 7018-A1 | E 7018-A1 | E 309 |
| P4 Group 1 | E 8018-B2 | E 8018-B2 | E 8018-B2 | E 309 |
| P5A Group 1 | E 9018-B3 | E 9018-B3 | E 9018-B3 | E 309 |
| P8 including SA 213<br>UNS S30432 | | E 309 | E 309 | E 347 |
| P15E Gr.1 (Gr. 91/92) | | | E9018-B3 | ENiCrFe-3 |
| SA213T23 | | | E9018-B3 | ENiCrFe-3 |

**Table- A3.5**
**SELECTION OF ELECTRODES, PREHEAT, PWHT**
**FOR ATTACHMENT TO ATTACHMENT WELDS**
**(Seal Bands, High Crown Bars, End Bars, End Bar Lifting Lugs and Collector Plates etc.)**

| Material (Note 2) | Welding Requirements | P1 | P3 | P4 | P5 A | P8 Group 1 | P8 Group 2 | P 15E / 1 |
|---|---|---|---|---|---|---|---|---|
| P1 | Electrode<br>Preheat<br>PWHT | E7018<br>Nil<br>Nil | - | E 7018<br>150°C<br>650 – 670°C | - | - | - | - |
| P3 | Electrode<br>Preheat<br>PWHT | E7018<br>150°C (Note 1)<br>For Thickness>16mm: 620-650°C | E7018-A1<br>150°C<br>For Thickness>16mm: 620-650°C | - | - | - | - | - |
| P4 | Electrode<br>Preheat<br>PWHT | E7018<br>150°C (Note 1)<br>For Thickness>13mm: 650-670°C | E7018-A1<br>150°C<br>For Thickness>13mm: 650-670° | E8018-B2<br>150°C (Note 1)<br>For Thickness>13mm: 650-670°C | - | - | - | - |
| P5 A | Electrode<br>Preheat<br>PWHT | - | - | E8018-B2<br>150°C (Note 1)<br>For Thickness>13: 680-710°C | E9018-B3<br>150°C (Note 1) For Thickness>13:680-710°C | - | - | - |
| P8 | Electrode<br>Preheat<br>PWHT | E309<br>Nil<br>Nil | - | E309<br>Nil<br>Nil | E309<br>Nil<br>Nil | E347<br>Nil<br>Nil | E309<br>Nil<br>Nil | - |
| P 15E/ 1 | Electrode<br>Preheat<br>PWHT | - | - | - | E9018-B3<br>220°C<br>730-760 °C | ENi Cr Fe3<br>220°C (only on P15E side)<br>730-760 °C | ENi Cr Fe3<br>220°C (only on P15E side)<br>730-760 °C | E9015-B91<br>220°C<br>740-770 °C |

Note – 1 : Preheat is not required for P3/P4up to 16 mm& for P5 A up to 13 mm, if PWHT is carried out.
Note - 2: For load carrying members, PWHT is required irrespective of thickness.

**Table- A3.6**
**SELECTION OF ELECTRODES FOR WELDING NOZZLE ATTACHMENTS, HAND HOLE PLATE, RG PLUG ETC. TO HEADERS, PIPES**

| Header, Pipe Material | Attachment Material | | | | | |
|---|---|---|---|---|---|---|
| | **P1** | **P3** | **P4** | **P5 A** | **P15 E/1** | **P8** |
| P1 | E7018-1 | E7018-1 | E7018-1 | - | - | ENiCrFe3 |
| P4 | E7018-1 | E7018-A1 | E8018-B2 | E8018-B2 | - | - |
| P5 A | - | - | E8018-B2 | E9018-B3 | E9018-B3 | ENiCrFe3 |
| P15 E/1 | - | - | - | E9018-B3 | E9015-B91 | ENiCrFe3 |
| DIN 14MoV63 or equivalent | - | - | - | E9018-B3 | - | ENiCrFe3 |

**Table – A3.7**
**SELECTION OF ELECTRODES FOR NON-PRESSURE PARTS (INCLUDING STRUCTURES) (NOTE 1)**

| Material | SMAW Electrodes | SAW Wires | $CO_2$ Wires |
|---|---|---|---|
| P1 + P1 (IS2062 E250) | For butt welds ≤ 6 mm: E 6013 (only for Ducts)<br>> 6 mm: E 7018<br>For fillets ≤8 mm : E 6013<br>>8 mm: E 7018 | EL 8<br>EM 12 K<br>EL 8<br>EM 12 K | E 71 T - 1 |
| Corten Steel + P1 | E 6013 or E 7018 | EM 12 K | |
| Corten Steel + Corten Steel | E 8018 – B2 | EB 2 | E 81 T 1 – B2 |
| IS2062 E350+E350/ E250 | E7018-1 | EM 12 K | NA |
| IS2062 E450+E450 | E8018-G | EG | NA |
| SA 204 Gr.A | E7018-A1 | NA | NA |

Note 1: E 6013 Electrodes can be used for all non-load carrying welds of all thickness of IS 2062 plates up to 20 mm thickness and 8 mm fillets

## TABLE- A3.8
## A NUMBERS
## CLASSIFICATION OF FERROUS WELD METAL ANALYSIS FOR PROCEDURE QUALIFICATION

| A. No. | Types of Weld Deposit | Analysis, % (Note 1) | | | | | |
|---|---|---|---|---|---|---|---|
| | | C | Cr | Mo | Ni | Mn | Si |
| 1 | Mild steel | 0.20 | – | – | – | 1.60 | 1.00 |
| 2 | Carbon-Molybdenum | 0.15 | 0.50 | 0.40-0.65 | – | 1.60 | 1.00 |
| 3 | Chrome (0.4% to 2%)-Molybdenum | 0.15 | 0.40-2.00 | 0.40-0.65 | – | 1.60 | 1.00 |
| 4 | Chrome (2% to 6%)-Molybdenum | 0.15 | 2.00-6.00 | 0.40-1.50 | – | 1.60 | 2.00 |
| 5 | Chrome (6% to 10.5%)-Molybdenum | 0.15 | 6.00-10.50 | 0.40-1.50 | – | 1.20 | 2.00 |
| 6 | Chrome-Martensitic | 0.15 | 11.00-15.00 | 0.70 | – | 2.00 | 1.00 |
| 7 | Chrome-Ferritic | 0.15 | 11.00-30.00 | 1.00 | – | 1.00 | 3.00 |
| 8 | Chromium-Nickel | 0.15 | 14.50-30.00 | 4.00 | 7.50-15.00 | 2.50 | 1.00 |
| 9 | Chromium-Nickel | 0.30 | 19.00-30.00 | 6.00 | 15.00-37.00 | 2.50 | 1.00 |
| 10 | Nickel to 4% | 0.15 | – | 0.55 | 0.80-4.00 | 1.70 | 1.00 |
| 11 | Manganese-Molybdenum | 0.17 | – | 0.25-0.75 | 0.85 | 1.25-2.25 | 1.00 |
| 12 | Nickel-Chrome-Molybdenum | 0.15 | 1.50 | 0.25-0.80 | 1.25-2.80 | 0.75-2.25 | 1.00 |

Note 1: Single values shown above are maximum.

## Table A3.9
## F NUMBERS GROUPING OF ELECTRODES AND WELDING RODS FOR QUALIFICATION

| | ASME Specification No. | AWS Classification No. |
|---|---|---|
| 1 | SFA-5.1 | EXX20 |
| 1 | SFA-5.1 | EXX22 |
| 1 | SFA-5.1 | EXX24 |
| 1 | SFA-5.1 | EXX27 |
| 1 | SFA-5.1 | EXX28 |
| 1 | SFA-5.4 | EXXX(X)-26 |
| 1 | SFA-5.5 | EXX20-X |
| 1 | SFA-5.5 | EXX27-X |
| 2 | SFA-5.1 | EXX12 |
| 2 | SFA-5.1 | EXX13 |
| 2 | SFA-5.1 | EXX14 |
| 2 | SFA-5.1 | EXX19 |
| 2 | SFA-5.5 | E(X)XX13-X |
| 3 | SFA-5.1 | EXX10 |
| 3 | SFA-5.1 | EXX11 |
| 3 | SFA-5.5 | E(X)XX10-X |
| 3 | SFA-5.5 | E(X)XX11-X |
| 4 | SFA-5.1 | EXX15 |
| 4 | SFA-5.1 | EXX16 |
| 4 | SFA-5.1 | EXX18 |
| 4 | SFA-5.1 | EXX18M |
| 4 | SFA-5.1 | EXX48 |
| 4 | SFA-5.4 other than austenitic and duplex | EXXX(X)-15 |
| 4 | SFA-5.4 other than austenitic and duplex | EXXX(X)-16 |
| 4 | SFA-5.4 other than austenitic and duplex | EXXX(X)-17 |
| 4 | SFA-5.5 | E(X)XX15-X |
| 4 | SFA-5.5 | E(X)XX16-X |
| 4 | SFA-5.5 | E(X)XX18-X |
| 4 | SFA-5.5 | E(X)XX18M |
| 4 | SFA-5.5 | E(X)XX18M1 |

## Table- A3.9 (Contd...)
## F NUMBERS GROUPING OF ELECTRODES AND WELDING RODS FOR QUALIFICATION

| F.No. | ASME Specification No. | AWS Classification No. |
|---|---|---|
| 5 | SFA-5.4 austenitic and duplex | EXXX(X)-15 |
| 5 | SFA-5.4 austenitic and duplex | EXXX(X)-16 |
| 5 | SFA-5.4 austenitic and duplex | EXXX(X)-17 |
| | | |
| 6 | SFA-5.2 | All classifications |
| 6 | SFA-5.9 | All classifications |
| 6 | SFA-5.17 | All classifications |
| 6 | SFA-5.18 | All classifications |
| 6 | SFA-5.20 | All classifications |
| 6 | SFA-5.22 | All classifications |
| 6 | SFA-5.23 | All classifications |
| 6 | SFA-5.25 | All classifications |
| 6 | SFA-5.26 | All classifications |
| 6 | SFA-5.28 | All classifications |
| 6 | SFA-5.29 | All classifications |
| 6 | SFA-5.30 | INMs-X |
| 6 | SFA-5.30 | IN5XX |
| 6 | SFA-5.30 | IN3XX(X) |
| | | |
| Aluminium and Aluminium-Base Alloys | | |
| 21 | SFA-5.3 | E1100 |
| 21 | SFA-5.3 | E3003 |
| 21 | SFA-5.10 | ER1100 |
| 21 | SFA-5.10 | R1100 |
| 21 | SFA-5.10 | ER1188 |
| 21 | SFA-5.10 | R1188 |
| | | |
| 22 | SFA-5.10 | ER5183 |
| 22 | SFA-5.10 | R5183 |
| 22 | SFA-5.10 | ER5356 |
| 22 | SFA-5.10 | R5356 |
| 22 | SFA-5.10 | ER5554 |
| 22 | SFA-5.10 | R5554 |
| 22 | SFA-5.10 | ER5556 |

## TABLE- A3.9 (Contd...)
## F NUMBERS GROUPING OF ELECTRODES AND WELDING RODS FOR QUALIFICATION

| F.No. | ASME Specification No. | AWS Classification No. |
|---|---|---|
| 22 | SFA-5.10 | R5556 |
| 22 | SFA-5.10 | ER5654 |
| 22 | SFA-5.10 | R5654 |
| 23 | SFA-5.3 | E4043 |
| 23 | SFA-5.10 | ER4009 |
| 23 | SFA-5.10 | R4009 |
| 23 | SFA-5.10 | ER4010 |
| 23 | SFA-5.10 | R4010 |
| 23 | SFA-5.10 | R4011 |
| 23 | SFA-5.10 | ER4043 |
| 23 | SFA-5.10 | R4043 |
| 23 | SFA-5.10 | ER4047 |
| 23 | SFA-5.10 | R4047 |
| 23 | SFA-5.10 | ER4145 |
| 23 | SFA-5.10 | R4145 |
| 23 | SFA-5.10 | ER4643 |
| 23 | SFA-5.10 | R4643 |
| 24 | SFA-5.10 | R206.0 |
| 24 | SFA-5.10 | R-C355.0 |
| 24 | SFA-5.10 | R-A356.0 |
| 24 | SFA-5.10 | R357.0 |
| 24 | SFA-5.10 | R-A357.0 |
| 25 | SFA-5.10 | ER2319 |
| 25 | SFA-5.10 | R2319 |
| | | |
| **Copper And Copper Alloys** | | |
| 31 | SFA-5.6 | ECu |
| 31 | SFA-5.7 | ERCu |
| 32 | SFA-5.6 | ECuSi |
| 32 | SFA-5.7 | ERCuSi-A |

**TABLE- A3.9 (Contd...)**
**F NUMBERS**
**GROUPING OF ELECTRODES AND WELDING RODS FOR QUALIFICATION**

| F.No. | ASME Specification No. | AWS Classification No. |
|---|---|---|
| 33 | SFA-5.6 | ECuSn-A |
| 33 | SFA-5.6 | ECuSn-C |
| 33 | SFA-5.7 | ERCuSn-A |
| 34 | SFA-5.6 | ECuNi |
| 34 | SFA-5.7 | ERCuNi |
| 34 | SFA-5.30 | IN67 |
| 35 | SFA-5.8 | RBCuZn-A |
| 35 | SFA-5.8 | RBCuZn-B |
| 35 | SFA-5.8 | RBCuZn-C |
| 35 | SFA-5.8 | RBCuZn-D |
| 36 | SFA-5.6 | ECuAl-A2 |
| 36 | SFA-5.6 | ECuAl-B |
| 36 | SFA-5.7 | ERCuAl-A1 |
| 36 | SFA-5.7 | ERCuAl-A2 |
| 36 | SFA-5.7 | ERCuAl-A3 |
| 37 | SFA-5.6 | ECuNiAl |
| 37 | SFA-5.6 | ECuMnNiAl |
| 37 | SFA-5.7 | ERCuNiAl |
| 37 | SFA-5.7 | ERCuMnNiAl |
| **Nickel And Nickel Alloys** | | |
| 41 | SFA-5.11 | ENi-1 |
| 41 | SFA -5.11 | ENiCrFe-3 & ENiCrFe-7A |
| 41 | SFA-5.14 | ERNi-1 |
| 41 | SFA-5.14 | ERNiCr-3 & ENiCrFe-7A |
| 41 | SFA-5.30 | IN61 |
| 42 | SFA-5.11 | ENiCu-7 |
| 42 | SFA-5.14 | ERNiCu-7 |
| 42 | SFA-5.14 | ERNiCu-8 |
| 42 | SFA-5.30-7 | IN60 |

**TABLE- A3.9 (Contd...)**
**F NUMBERSGROUPING OF ELECTRODES AND WELDING RODS FOR QUALIFICATION**

| F.No. | ASME Specification No. | AWS Classification No. |
|---|---|---|
| | | |
| 45 | SFA5.11 | ENiCrMo-11 |
| 45 | SFA5.14 | ERNiCrMo-1 |
| 45 | SFA5.14 | ERNiCrMo-8 |
| 45 | SFA5.14 | ERNiCrMo-9 |
| 45 | SFA5.14 | ERNiCrMo-11 |
| 45 | SFA5.14 | ERNiFeCr-1 |
| | | |
| **Hard-Facing Weld Metal Overlay** | | |
| | | |
| 71 | SFA-5.13 | E Co Cr – A & All classifications |
| 72 | SFA-5.21 | ER Co Cr – A & All classifications |

INDEX NO. 2-8

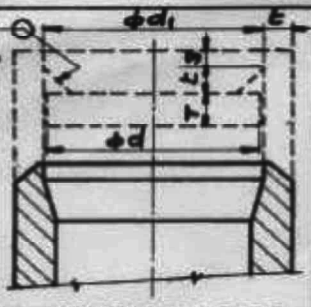
TIRUCHY

# SELECTION CHART FOR DUMMY END COVERS FOR HYDRAULIC TEST

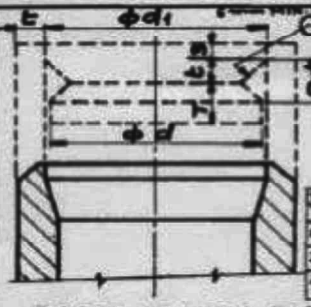
THICKNESS 'T' = 0·5 $d_1\sqrt{\frac{P}{f}}$ (ISO · REC · R 831/1968) $f$ = 1900 kg/cm²
ROUNDED OFF TO THE NEXT NEAREST RATIONALISED PLATE SIZE.

MIN·6mm t

$\phi d = d_1 - 1$ mm (ROUNDED OFF TO THE NEXT INTEGER)




CASE WHEN T ≤ 20




$\phi d = d_1 - 2$ mm (ROUNDED OFF TO THE NEXT INTEGER)

CASE WHEN T > 20

| THICKNESS 'T' mm | MATERIAL |
|---|---|
| 6 to 20 | BM-C20 |
| 21 to 63 | BM-C16 |
| ABOVE 63 | ASTM-A 36 |

THICKNESS OF DUMMY END COVERS FOR HYDRAULIC TEST (T)

| 'd' / 'P' | 30 | 45 | 60 | 75 | 90 | 105 | 120 | 135 | 150 | 165 | 180 | 210 | 240 | 270 | 300 | 350 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 15 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 25 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 6 | 6 | 6 | 8 |
| 30 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 6 | 6 | 6 | 8 | 8 | 8 | 8 |
| 35 | 5 | 5 | 5 | 5 | 5 | 5 | 6 | 6 | 6 | 6 | 8 | 8 | 8 | 8 | 8 | 10 |
| 40 | 5 | 5 | 5 | 5 | 6 | 6 | 6 | 8 | 8 | 8 | 8 | 8 | 8 | 10 | 10 | 10 |
| 45 | 5 | 5 | 5 | 6 | 6 | 6 | 8 | 8 | 8 | 8 | 8 | 10 | 10 | 10 | 10 | 12 |
| 50 | 5 | 5 | 6 | 6 | 8 | 8 | 8 | 8 | 8 | 10 | 10 | 10 | 10 | 12 | 12 | 12 |
| 55 | 5 | 6 | 6 | 8 | 8 | 8 | 8 | 10 | 10 | 10 | 10 | 10 | 12 | 12 | 12 | 14 |
| 60 | 5 | 6 | 8 | 8 | 8 | 8 | 10 | 10 | 10 | 10 | 10 | 12 | 12 | 14 | 14 | 14 |
| 65 | 5 | 6 | 8 | 8 | 8 | 10 | 10 | 10 | 10 | 12 | 12 | 12 | 14 | 14 | 14 | 16 |
| 70 | 6 | 8 | 8 | 8 | 10 | 10 | 10 | 12 | 12 | 12 | 12 | 14 | 14 | 14 | 16 | 16 |
| 75 | 6 | 8 | 8 | 10 | 10 | 10 | 12 | 12 | 12 | 12 | 14 | 14 | 16 | 16 | 16 | 20 |
| 80 | 6 | 8 | 8 | 10 | 10 | 12 | 12 | 12 | 12 | 14 | 14 | 14 | 16 | 16 | 20 | 20 |
| 85 | 8 | 8 | 10 | 10 | 10 | 12 | 12 | 14 | 14 | 14 | 14 | 16 | 16 | 20 | 20 | 20 |
| 90 | 8 | 8 | 10 | 10 | 12 | 12 | 14 | 14 | 14 | 14 | 16 | 16 | 20 | 20 | 20 | 20 |
| 95 | 8 | 10 | 10 | 12 | 12 | 12 | 14 | 14 | 16 | 16 | 16 | 20 | 20 | 20 | 20 | 25 |
| 100 | 8 | 10 | 10 | 12 | 12 | 14 | 14 | 16 | 16 | 16 | 20 | 20 | 20 | 20 | 25 | 25 |
| 125 | 10 | 12 | 12 | 14 | 16 | 16 | 20 | 20 | 20 | 20 | 20 | 25 | 25 | 25 | 32 | 32 |
| 150 | 12 | 14 | 16 | 16 | 20 | 20 | 20 | 25 | 25 | 25 | 25 | 32 | 32 | 32 | 32 | 38 |
| 175 | 12 | 16 | 20 | 20 | 20 | 25 | 25 | 25 | 32 | 32 | 32 | 32 | 32 | 36 | 36 | 40 |
| 200 | 14 | 20 | 20 | 25 | 25 | 25 | 32 | 32 | 32 | 32 | 32 | 36 | 40 | 40 | 56 | 56 |
| 250 | 20 | 20 | 25 | 32 | 32 | 32 | 36 | 36 | 36 | 40 | 40 | 56 | 56 | 56 | 56 | 56 |
| 300 | 20 | 25 | 32 | 32 | 36 | 36 | 40 | 36 | 56 | 56 | 56 | 56 | 56 | 63 | 63 | 63 |
| 350 | 25 | 32 | 32 | 36 | 40 | 36 | 36 | 36 | 56 | 56 | 56 | 63 | 63 | 70 | 75 | 80 |
| 400 | 32 | 32 | 40 | 56 | 56 | 56 | 56 | 56 | 63 | 63 | 63 | 70 | 75 | 80 | 85 | 90 |
| 450 | 32 | 36 | 56 | 56 | 56 | 56 | 63 | 63 | 63 | 70 | 70 | 80 | 85 | 90 | 95 | 100 |
| 500 | 36 | 40 | 56 | 56 | 56 | 63 | 63 | 70 | 75 | 75 | 80 | 85 | 90 | 95 | 100 | 110 |



PREPARED BY

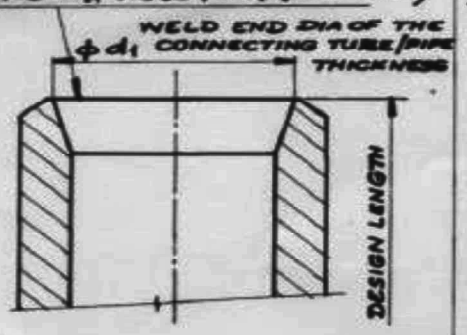
CHECKED BY

TIRUCHY

# NIPPLES - FREE END DETAILS.

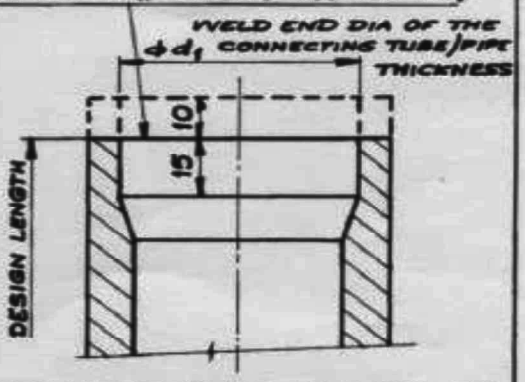
(FOR HEADERS ONLY.)

INDICATE STYLE NO 'D' - $d_1$ TO BPS NO 710004-74 (LAT. REV.)




STRAIGHT NIPPLES WHICH DO NOT REQUIRE ANY ALLO-WANCE. (NO SHOP HYD. TEST.)

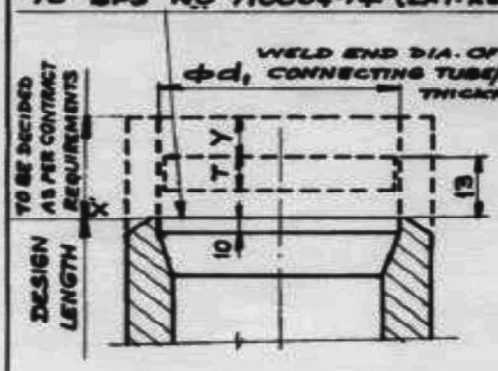
INDICATE STYLE NO 'C' - $d_1$ TO BPS NO 710004-74 (LAT. REV.)




STRAIGHT & BENT NIPPLES WHICH REQUIRE 10 mm ALLO-WANCE. (NO SHOP HYD. TEST.)

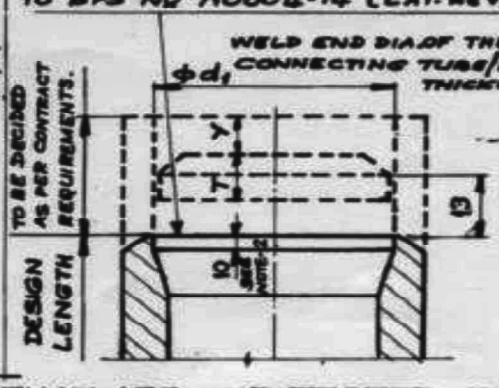
## CASE WHEN T ≤ 20

INDICATE STYLE NO 'C' - $d_1$ TO BPS NO 710004-74 (LAT. REV.)




## CASE WHEN T > 20

INDICATE STYLE NO 'C' - $d_1$ TO BPS NO 710004-74 (LAT. REV.)




STRAIGHT & BENT NIPPLES THAT ARE HYD. TESTED AT SHOPS. (WHETHER THEY REQUIRE ANY ALLOWANCE OR NOT)

NOTE: 1. FOR VALUES OF T & Y FOR DIFFERENT SIZES OF NIPPLES AT VARIOUS TEST PRESSURES REFER DRG. NO 40-B-006-2897.

2. IN CASE THE THICKNESS REQUIRED FOR THE DUMMY END COVER IS MORE THAN 25 mm THE INSIDE HEIGHT OF MACHINING (WHICH IS NOW 10 mm) WILL BE INCREASED ACCORDINGLY.

| PREPARED BY | CHECKED BY. |
|---|---|
| Bhaskar C. | |



40-B-006-2899

# CHAPTER A4 - PROCEDURE FOR WELDER QUALIFICATION

## SECTION A4.1-PROCEDURE FOR WELDER QUALIFICATION FOR NON-IBR APPLICATIONS

**1.0 SCOPE:**

1.1 This chapter details the procedure for qualification of welder and performance monitoring.

**2.0 CONTENTS:**

## SECTION A4.2-QUALIFICATION OF WELDER

### 1.0 BASE METAL:

1.1 For selection refer Tables provided in Chapter II (Base Materials) of this manual.

### 2.0 TEST COUPON:

2.1 Depending on the range to be qualified, choose the appropriate test coupon from Table-A6.1

2.2 For plate butt welds, details of edge preparation shall be as per Figure-A6.9.

2.3 For pipe butt welds, details of edge preparation shall be as per Figure-A6.10.

2.4 For structural tack welds, refer Figure-A6.1.

### 3.0 REQUIREMENT OF TESTS:

### 3.1 For Structural Tack Welders:

3.1.1 Break Test as per Figure-A6.2.

### 3.2 For Plate and Pipe Butt welders:

3.2.1 100 % Radiographic examination of test welds shall be carried out. Procedure and acceptance criteria shall be as per NDE Manual (BHEL:PS:NDEM – Latest)

### 4.0 ESSENTIAL VARIABLES :

4.1 Changes to the following variables require requalification.

4.1.1 **Process:** Example: Change from GTAW to SMAW or vice versa.

4.1.2 **Joint:** A change from one type of bevel to another. Example: 'V' bevel to 'U' bevel.

4.1.3 **Base Metal :**A change in thickness or pipe diameter beyond the limits as prescribed in Table- A6.1

4.1.4 **Filler Metal:**A change from one F number to another F-number, except as specified in Table-A6.1.

4.1.5 **Positions:**This procedure envisages qualification of welders to perform in all positions. Deviation to this is not recommended.

4.1.6 **Gas:**This procedure envisages test to pre-prescribed gas as for production welds. Deviation to this is not recommended.

4.1.7 **Electrical Characteristics:**

a) AC to DC and vice versa.

b) In DC, DCEN (Electrode Negative) to DCEP (Electrode Positive) and vice versa.

4.1.8 **Technique:** This procedure envisages only use of uphill progression technique.

**Acceptance Criteria:**

**Structural Tack Welding:**

- No cracks.
- No lack of fusion.
- Undercut not exceeding 1 mm.
- Not more than 1 porosity (max. diameter of porosity 2 mm).

**Plate/Pipe Welding:**

**Visual Inspection:**

a) No cracks.

b) No lack of fusion or incomplete penetration.

c) Not more than 1 porosity in a length of 100 mm of length of weld (max. porosity diameter 2mm).

## 5.0 VALIDITY:

5.1 When a welder meets the requirements of this procedure, the validity will be for a maximum of 2 years from the date of test, limited to validity specified by statutory authority, as applicable.The validity may be extended by one year each time, based on satisfactory performance, with sufficient back up records.

## 6.0 REQUALIFICATION :

6.1 Requalification is required for the following :

a) Where there is a specific reason to doubt the skill of the welder.

b) Due to non-engagement of the welder for a continuous period of 6 months.

## 7.0 RECORDS:

The welding in charge at site shall maintain the following records:

a) Record of Welder Performance qualification Test (as per Annexure V).

b) Register of qualified welders (employer-wise) containing the following details:

1) Name of welder.
2) Age.
3) Tested for pipe / tube / plate / tack.
4) Performance Test No.
5) Validity.
6) Welder Code.
7) Remarks.

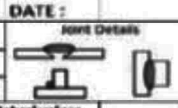
The above register shall be updated for deletions also.Copies of welder identity card (including details as in 7 b and relevant variables qualified) and pertinent radiography reports.

## 8.0 ENCLOSURES :

1. Table –A6.1: Welder Qualification Requirements.
2. Record of Welder Performance Qualification Test.
3. Figure-A6.1: Structural Tack Weld Specimen.
4. Figure-A6.2: Break Test.
5. Figure-A6.3:Weld Positions.
6. Figure- A6.4 - 6G position
7. Figure- A6.5 - Flat position
8. Figure- A6.6 - Vertical position
9. Figure- A6.7 - Horizontal position
10. Figure- A6.8 - Overhead position
11. Figure-A6.9: Plate Butt Weld Specimen.
12. Figure-A6.10: Pipe Butt Weld Specimen

## ANNEXURE - V: RECORD OF WELDER PERFORMANCE QUALIFICATION TEST

**WELDER/TACK WELDER QUALIFICATION TEST RECORD -NON IBR**

| | | | | |
|---|---|---|---|---|
| Site : | | Test Record No. : | | Affix welder photo |
| Contractor Name : | | DATE : | | |
| NAME Sri. | | Joint Details  | | |
| ID NO : | | | | |
| WPS No. : | Rev : | | | |

| Variables | Recorded Actual values used in Qualification | Qualification Range |
|---|---|---|
| Process / Type | | |
| Electrode (Single or Multiple) | | |
| Current / Polarity | | |
| Position | | |
| Weld Progression | | |
| Backing | | |
| Material / Specification | to | |
| Thickness : (Plate) | | |
| Groove | | |
| Fillet | | |
| Thickness : (Pipe / Tube) | | |
| Groove | | |
| Fillet | | |
| Diameter : (Pipe) | | |
| Groove | | |
| Fillet | | |
| **Filler Rod / Electrode** | | |
| SFA No | | |
| AWS Class | | |
| F.No | | |
| Gas / Flux Type : | | |

Pre-heat temp : Inter-pass Temp : Post-heat Temp :

**VISUAL INSPECTION**

ACCEPTABLE : YES or NO DATE :

**Guided Bend Test Results**

| Type | Result | Type | Result |
|---|---|---|---|
| | | | |

**Fillet Test Results**

| | | | |
|---|---|---|---|
| Apperance | | Fillet Size | |
| Fracture Test Root Penetration | | Macroetch | |
| Inspected by | | Test Number | |
| Organization | | Date | |

**RADIOGRAPHIC TEST RESULTS**

| Report No/Date | Result | Report No/Date | Result |
|---|---|---|---|
| | | | |

| | | | |
|---|---|---|---|
| Reviewed by | | Reviewer Level : | |
| NDT Company Name : | | Date | |

We certify that the statement in this record is correct and that the test weld were prepared, welded and tested in accordance with requirements.

**This is valid upto**

| | | | |
|---|---|---|---|
| Contractor : | | Signature : | Date : |
| BHEL : | | Signature : | Date : |
| Customer : | | Signature : | Date : |

## TABLE – A6.1
## WELDER QUALIFICATION REQUIREMENTS (FOR NON-IBR APPLICATIONS)

| Sl. No. | Test For | Base[6] Metal Note 1 | Test Coupon Dimension OD, t | Electrode[6] to be used Note 2, 4 | Weld Positions | Reference Figure | Range Qualified Dia. & T | Position Qualified | Electrode Qualified Note 2, 4 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Structural tack | P1 Gr 1 | t=10mm or 12mm | (E6013) F2 | 3F&4F | Fig. A6.1 A6.2 & A6.3 | T-Unlimited | All | F2, F1 |
| | | | | (E7018) F4 | 3F&4F | | T-Unlimited | All | F4 & Below |
| 2 | Plate Welder (Structural) | - do - | t≥25mm | F4 | 3G & 4G | Fig.A6.7 & A6.8 | T≥3.0 mm* | All | F4 & Below |
| | | | t<25mm | F4 | 3G & 4G | | T>3.0 mm*≤2t | All | F4 & Below |
| 3 | Plate Welder (Other than structural) | - do - | t≥13mm | F4 | 2G, 3G & 4G | Fig.A6.6 , A6.7 & A6.8 | T-Unlimited OD≥600mm | All | F4 & Below |
| | | | t<13mm | F4 | 2G, 3G & 4G | | T≤2t OD≥600mm | All | F4 & Below |
| 4 | Pipe/Tube Welder | - do - | OD<25mm | F4 | 6G | Fig.A6.4 | Test piece Dia.& above | All | F4 & Below |
| | | | OD≥25mm &≤73mm | F4 | 6G | | 25mm & above | All | F4 & Below |
| | | | OD>73mm | F4 | 6G | | 73mm & above | All | F4 & Below |
| | | | t<13mm | F4 | 6G | | T≤2t | All | F4 & Below |
| | | | t≥13mm | F4 | 6G | | T-Unlimited | All | F4 & Below |

* Also qualifies for welding fillet welds on material of unlimited thickness.

**TABLE – A6.1 (contd...)**

**NOTES:**

1. For P grouping refer Chapter II.
2. For F grouping refer Chapter III.
3. Base material limitation:
   a. Where test coupons belong to P1 thro' P15E, welder is qualified for base materials P1 thro' P15E.( ASME Sec IX QW 423, Alternate base material for welder qualification)

      It means, if a welder is qualified with carbon steel material, he is also qualified for alloy steel and vice versa.
   b. Use appropriate F group electrodes.
4. Qualification in one F number, qualifies for that F-number only, except as stated below in A, B, C & D.
   A. Qualification in F4 qualifies for F4 and below.
   B. Qualification in F5 qualifies for F5 only.
   C. Qualification in any of F41 thro' F45 qualifies for F41 thro' F45.
   D. For non-ferrous materials, the base materials shall be typical of production material and appropriate filler materials shall be selected. Qualification is limited to the base material, process and filler F group. Diameter and thickness limitations apply as per Table –A6.1

   OD = outer diameter, t = thickness of test coupon; T = thickness qualified.
5. Where qualification is for GTAW followed by SMAW, the welder is also qualified up-to 6 mm thickness by GTAW process.
6. Base material indicated is carbon steel; for other base materials, corresponding electrodes are to be chosen. Also for GTAW process, the corresponding filler wire should be chosen.

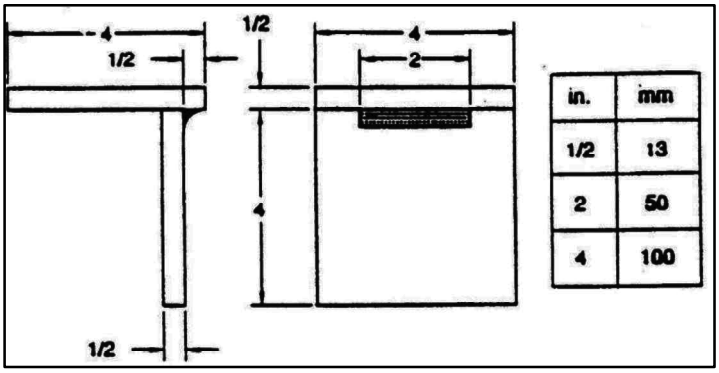



Figure A6.1 – Structural Tack Weld Specimen

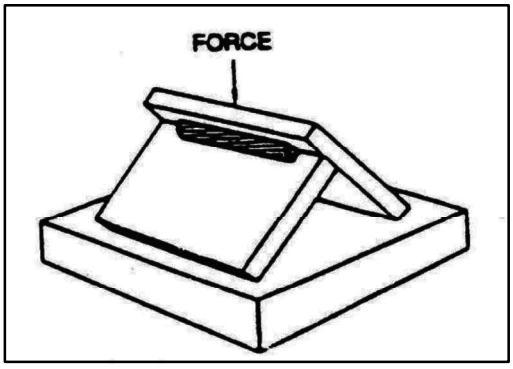



Figure A6.2 – Break Test

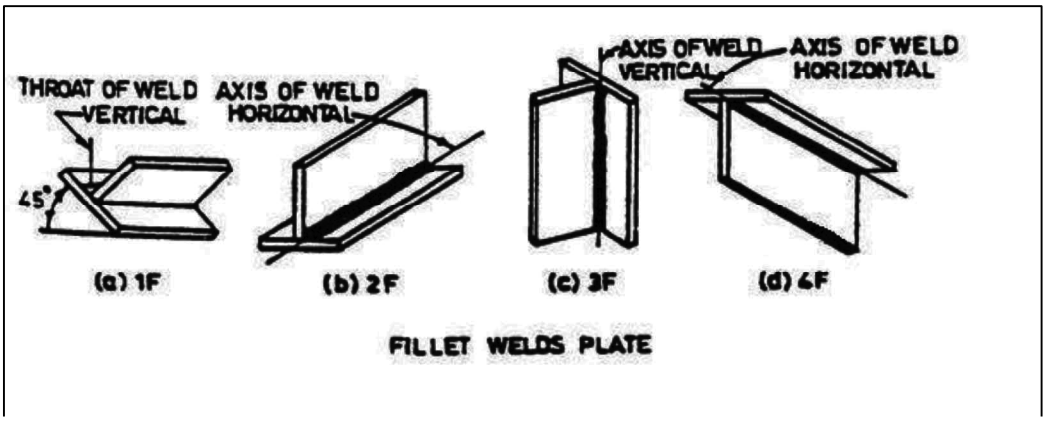



Figure A6.3 - WeldPositions

## SECTION A4.3-PROCEDURE FOR WELDER QUALIFICATION FOR IBR APPLICATIONS

### 1.0 SCOPE

1.1 These requirements shall apply to testing of welders/welding operators engaged in the manufacture and welding connected with sitefabrication, erection and repair of boilers and piping of ferrous material under the purview of IBR.

### 2.0 DEFINITION

**Welder**: one who performs manual or semiautomatic welding.

### 3.0 ENGAGING OF CERTIFIED WELDERS

All welders engaged on welding of boilers or piping under fabrication, erection and repair at site shall possess a valid certificate as required byIBR, as per Form XIII issued by the Competent Authority under IBR.

### 4.0 QUALIFICATION TEST AND ISSUE OF CERTIFICATE

Every welder shall be duly tested and qualified at site to the satisfaction of BHEL/Customer.Every welded test piece for the examination of welders/welding operator shall be stamped by BHEL with an identification mark on either side of the weld. After satisfactory completion of the tests, BHEL shall issue a Certificate/ID Card to each Qualified Welder as per the Format given in Figure no.A6.9.

**4.1** Each welder shall havebasic knowledge on the following:

i. Weld edge preparation
ii. Working of welding equipment.
iii. Properties of material to be welded – cold and hot working, thermal conductivity, fusion point, oxidation (for welders engaged in alloy steel welding).
iv. Electro-technical principles viz. kinds of current, striking arc voltage, welding arc voltage, etc.
v. Weld defects, their causes and prevention.
vi. Electrodes for different types of materials, welds and joints in different positions.

**4.2** **MATERIAL FOR TESTS** – The material of plates, tubes, pipes and electrodes used for these tests shall conform to the requirements given below:

#### 4.2.1 TEST WELDS FOR QUALIFICATION

**(a) PLATE WELDING –**

i. One weld joint of two pieces of boiler quality plates with double 'V' ordouble 'U' grooves over a minimum length of 300 mm shall be made in the following positions (size of plates to be welded being not less than 229 mm x 381 mm x 16 mm each):

(1) Flat position (figure A6.5) - Plate in a horizontal plane with the weld metal deposited from above.

(2) Horizontal Position (figure A6.6) – Plate in a vertical plane with the axis of the weld horizontal.

(3) Vertical Position (figure A6.7)- Plate in a vertical plane with the axis of the weld vertical

(4) Overhead Position (figure A6.8) – Plate in a horizontal plane with the weld metal deposited from underneath.

Qualification in Horizontal position shall automatically qualify Flat position. Qualification in Vertical position shall automatically qualify Flat and Horizontal positions. Also, qualification in Overhead position shall automatically qualify Flat, Horizontal and Vertical positions.

**(b) For Pipe Welding –**6G-Position:

Tube/Pipe with its axis inclined at 45 Deg. to horizontal. Welding shall be done without rotating the Tube/ pipe. Refer FigureA6.4.

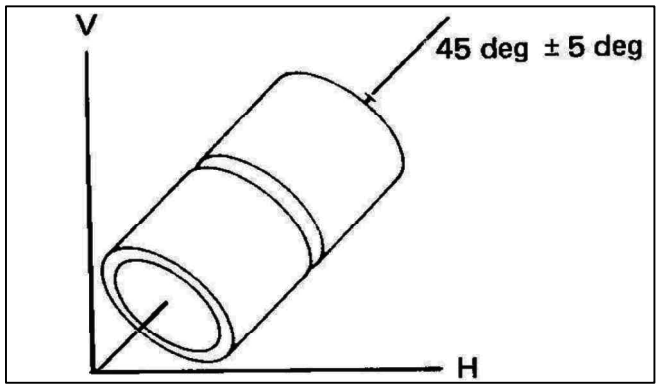



**Figure A6.46G-Position**

## 5.0 VALIDITY OF CERTIFICATE

a) Certificate issued to a welder shall remain valid for a period of twenty-four months from the date of issue, provided that the welder has, subsequent to the test, been continuously (gap not more than six months) employed on the class and type of work for which he is qualified.

b) The certificate may be extended, after the validity period, for another twenty-four months after conducting the re-qualification tests in-line with the initial Qualification tests.

c) In case of unsatisfactory performance of the Certified Welder as observed by the site engineer, the welder shall be re-qualified as per the requirements prior to engaging in subsequent welding works.

d) A welder qualified for a type and process of higher grade of steel can be allowed to weld the lower grade of steel.

e) A welder qualified on groove weld shall automatically qualify for fillet and socket welds.

## 6.0 EXAMINATION OF TEST SPECIMENS FOR QUALIFICATION TESTS

(a) The test specimens shall be visually examined as per Cl 6.0 of Chapter A7 of this Manual.

(b) After visual examination, the test specimen shall be subjected to radiographic examination as per the requirements specified in NDE Manual (BHEL:PS:NDEM-Latest).

## 7.0 MAINTENANCE OF RECORDS

Records of Qualified welders shall be maintained by the site engineer till the closure of the project. At the time of project closure, these records shall be handed over to the customer, if required by the Contract.

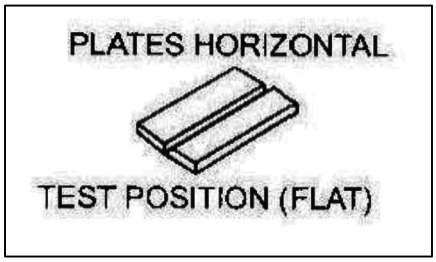



Figure A6.5Flat position

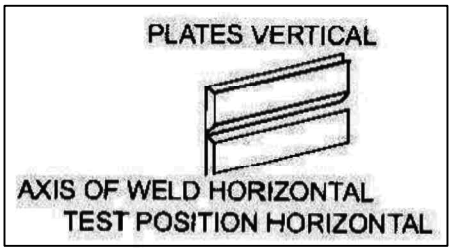



Figure A6.6Horizontal Position

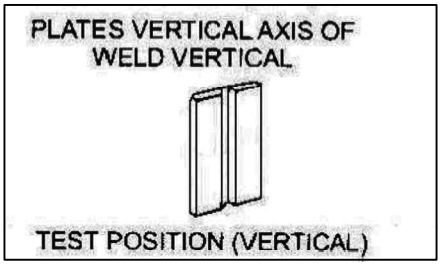



Figure A6.7Vertical Position

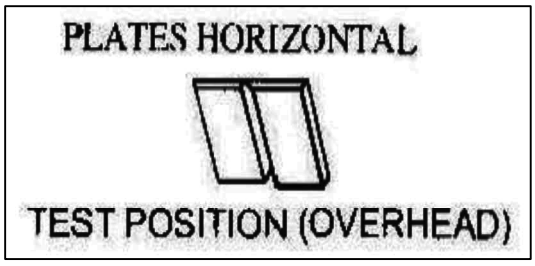



Figure A6.8Overhead Position

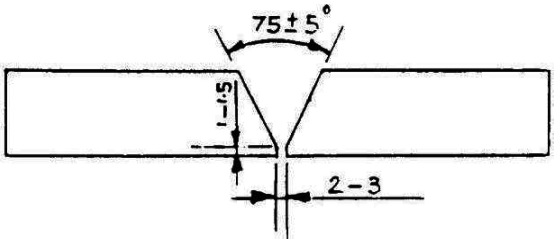
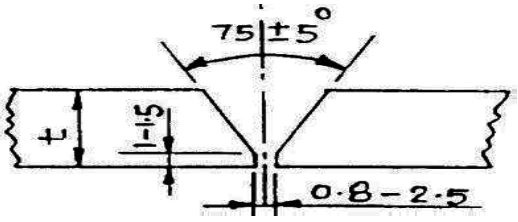
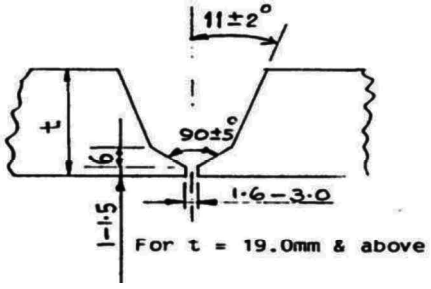



Figure A6.9- Plate butt weld specimen

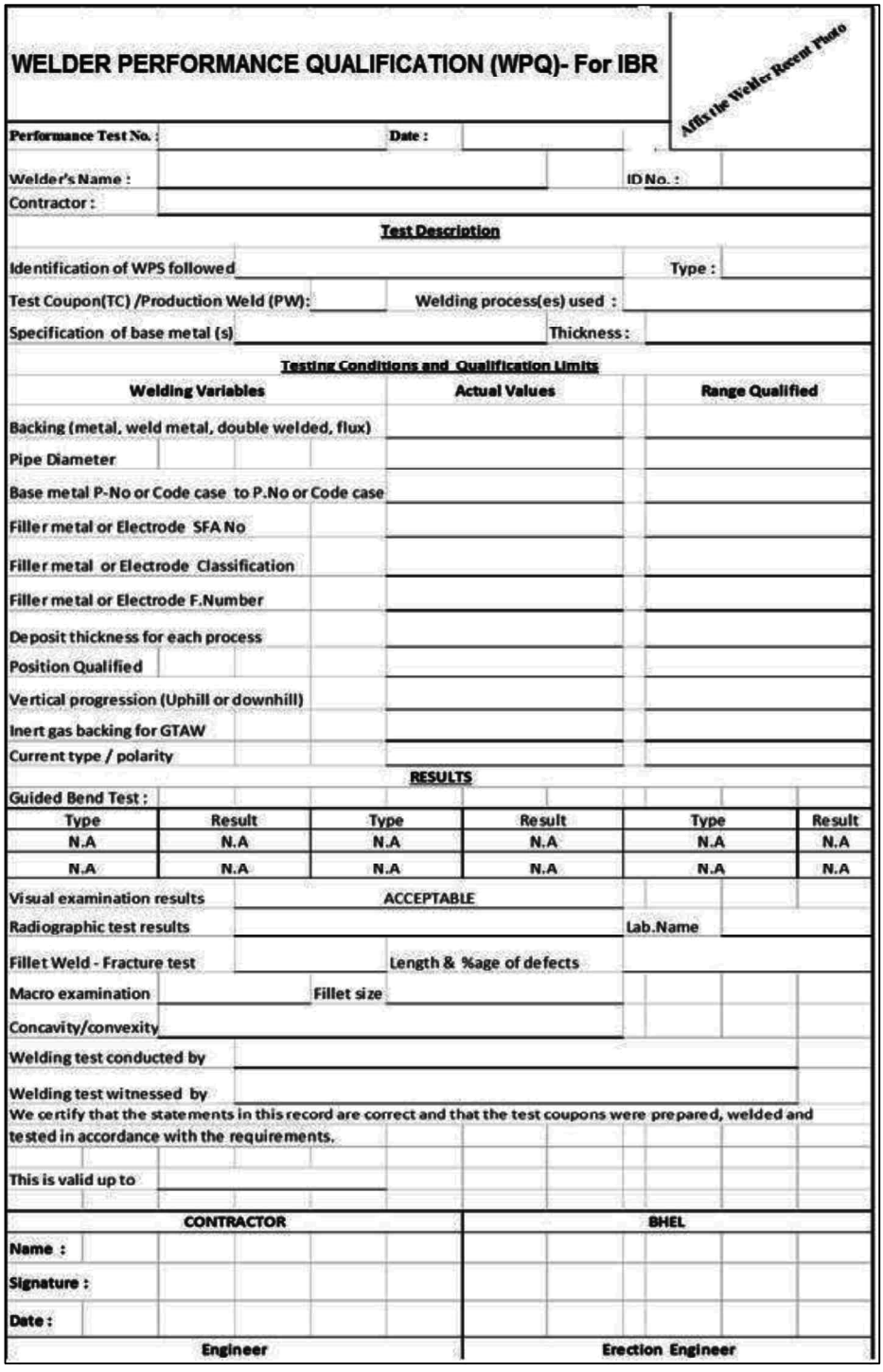



(A) for T upto 19 mm




(B) For T = 19.0mm &Above

Figure – A6.10 – Pipe Butt Weld Specimen



## WELDER PERFORMANCE QUALIFICATION (WPQ)- For IBR

Affix the Welder Recent Photo

Performance Test No. : Date :

Welder's Name : ID No. :

Contractor :

**Test Description**

Identification of WPS followed Type :

Test Coupon(TC) /Production Weld (PW): Welding process(es) used :

Specification of base metal (s) Thickness :

**Testing Conditions and Qualification Limits**

| Welding Variables | Actual Values | Range Qualified |
|---|---|---|
| Backing (metal, weld metal, double welded, flux) | | |
| Pipe Diameter | | |
| Base metal P-No or Code case to P.No or Code case | | |
| Filler metal or Electrode SFA No | | |
| Filler metal or Electrode Classification | | |
| Filler metal or Electrode F.Number | | |
| Deposit thickness for each process | | |
| Position Qualified | | |
| Vertical progression (Uphill or downhill) | | |
| Inert gas backing for GTAW | | |
| Current type / polarity | | |

**RESULTS**

Guided Bend Test :

| Type | Result | Type | Result | Type | Result |
|---|---|---|---|---|---|
| N.A | N.A | N.A | N.A | N.A | N.A |
| N.A | N.A | N.A | N.A | N.A | N.A |

Visual examination results ACCEPTABLE

Radiographic test results Lab.Name

Fillet Weld - Fracture test Length & %age of defects

Macro examination Fillet size

Concavity/convexity

Welding test conducted by

Welding test witnessed by

We certify that the statements in this record are correct and that the test coupons were prepared, welded and tested in accordance with the requirements.

This is valid up to

| CONTRACTOR | BHEL |
|---|---|
| Name : | |
| Signature : | |
| Date : | |
| Engineer | Erection Engineer |

**Figure A6.11: BHEL issued Welder Qualification Certificate**

# SECTION A4.4-WELDER PERFORMANCE MONITORING

## 1.0 PURPOSE:

1.1 This procedure deals with monitoring the performance of welders engaged at sites. This procedure is applicable where radiography is performed.

## 2.0 PROCEDURE:

2.1 The welder performance shall be monitored on a calendar month basis.

2.2 Extent of radiography shall be representative of weekly outputs of the welder.

2.3 Quantum of radiography shall be as per contractual requirements.

2.4 Evaluation of welds radiographed shall be as per NDE manual or other documents as specifically applicable.

2.5 **Welder performance evaluation:**

2.5.1 **For welds having diameter≤ 88.9 mm:**

2.5.1.1 The percentage of defects shall be calculated as a percentage of number of unaccepted welds to those radiographed.

2.5.1.2 Upto and including 5% defects: Performance is satisfactory else unsatisfactory.

2.5.2 **For welds having diameter>88.9 mm and plate welds:**

2.5.2.1 The percentage of defects shall be calculated as a percentage of length of defects to the length radiographed.

2.5.2.2 Upto and including 2.5% defects: performance is satisfactory else unsatisfactory.

2.6 When a welder gives unsatisfactory performance for a continuous period of 3 months, he shall be re-qualified.

2.6..1 Requalification of welder shall be called for when there is a specific reason to question his ability to make acceptable welds. This shall override requirements of clause 2.6.

2.7 Welds produced during any month shall be radiographed and evaluated latest by 10th of the succeeding month.

2.7..1 Under circumstances when clause 2.7 is not satisfied for any particular welder, he may be disengaged from the job till such time his performance is evaluated for the month in study.

2.7..2 Site in-charge may waive the restriction imposed in 2.7.1reviewing the situations for non-compliance with Cl.2.7 and may allow engagement of the welder in question for a period not exceeding one successive month to the month in study.

## 3.0 RECORDS:

3.1 Welding in-charge shall prepare and maintain Welder Performance Records, welder-wise as per the Annexure VI.

## ANNEXURE VI: WELDERS PERFORMANCE MONITORING RECORD

| WELDERS PERFORMANCE MONITORING RECORD - MONTH/YEAR : | | | | | | |
|---|---|---|---|---|---|---|
| | Dia ≤ 88.9 mm (Note -1) | | | Dia > 88.9mm (Note-2) | | |
| Welder Code | No of joints RT taken | No of defective joints | %age of defects | Length Radiographed | Length of defects | %age of defects |
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**Note :** 1. Upto and including 5% defects., performance is satisfactory else unsatisfactory.
2. Upto and including 2.5% defects, peformance is satisfactory else unsatisfactory.

# CHAPTER – A5
# INSPECTION OF WELDING

## 1.0 SCOPE:

1.1 This procedure provides details for performing visual inspection of weld fit-ups, welding in progress and completed welds.

## 2.0 REFERENCE:

2.1 Contract drawings.

2.2 Field Welding Schedule (supplied by Units) or equivalent.

2.3 Welding Procedure Specification, where supplied.

2.4 Indian Boiler Regulations (for boilers erected in India)

## 3.0 GENERAL REQUIREMENTS:

3.1 Ensure that the components to be welded are in accordance with the contract drawings, Welding Schedule and other relevant documents.

3.2 The condition of welded surfaces to be inspected shall be clean and dry.

3.3 There shall be sufficient lighting to allow proper interpretation of visual inspection.

## 4.0 WELD FIT-UP INSPECTION:

4.1 The surface to be welded shall be smooth and free from deep notches, irregularities, scale, rust, oil, grease and other foreign materials.

4.2 Positive Material Identification (PMI) shall be carried out for all alloy steel and stainless steel materials for the parent metal before fit-up and for weld after welding.However, in case of tubes random PMI check shall be done on the parent metal and on 10% of the welds made by each welder per day. The procedure recommended by the PMI equipment manufacturer shall be followed for testing.

4.3 Piping, tubing and headers to be joined shall be aligned within allowable tolerances on diameters, wall thicknesses and out-of-roundness as below:

**Maximum permissible misalignment at bore**

| Bore (mm) | Max. Misalignment (mm) | |
|---|---|---|
| | For GTAW | For SMAW |
| Up to 100 | 1.0 | 1.0 |
| Over 100 to 300 | 1.6 | 1.6 |
| Over 300 | 1.6 | 2.4 |

4.4 While fit up, components to be welded shall not show any appreciable off-set or misalignment when viewed from positions apart.

4.5 The root opening of components to be joined shall be adequate to provide acceptable penetration.

4.6 On fillet welds, the parts to be joined shall be brought as close to contact as practical, although in most instances a small opening between the parts is desirable.

4.7 Weld area shall be protected from drafts and wind, to maintain inert gas shield.

## 5.0 CHECKS DURING WELDING OPERATION:

5.1 Ensure the required minimum preheat temperature is maintained during welding. Preheating shall be done using resistance heating or induction heating or LPG burners. Preheating by cutting/ heating torches is not permitted.

5.2 Ensure correct electrode / filler metal is used for welding.

5.3 Tack welds shall be examined by the welder before they are incorporated in the final weld.

5.4 Ensure proper drying / holding of electrodes prior to use.

5.5 Ensure inter pass temperature mentioned in WPS is not exceeded during welding.

5.6 Ensure proper cleaning of weld between beads.

## 6.0 CHECKS ON THE COMPLETED WELD:

6.1 There shall be no visible cracks, pin-holes or incomplete fusion.

6.2 The weld surface must be sufficiently free of coarse ripples, grooves, overlaps, abrupt ridges and valleys, visible slag inclusions, porosity and adjacent starts and stops.

6.3 Undercuts shall not exceed 0.8 mm (0.4 mm for tubes) or 10% of wall thickness whichever is less.

6.4 Where inside surface is readily accessible, the same shall be inspected for excess penetration and root concavity. The permissible limits are given below:

- Root concavity: max of 2.5 mm or 20% of thickness at weld, whichever is lesser, provided adequate reinforcement is present.
- Excess penetration: up to and including 3.2 mm.

6.5 For plate butt welds, the weld reinforcement shall not exceed 3.2 mm.

6.6 For circumferential joints in piping and tubing the maximum weld reinforcements permitted are given below :

**Maximum Permissible Reinforcements (ASME Sec I – PW 35)**

| Thickness of base metal in mm | Reinforcement in mm |
|---|---|
| Up to 3.0 | 2.5 |
| Over 3 to 5 | 3.0 |
| Over 5 to 13 | 4.0 |
| Over 13 to 25 | 5.0 |
| Over 25 to 50 | 6.0 |
| Over 50 | Max of 6.0 or 1/8 of weld width |

6.7 There shall be no overlaps.The faces of fillet welds are not excessively convex or concave and the weld legs are of proper length.

6.8 In case of weld joints in pressure parts and joints like ceiling girder, the weld joint shall be suitably identified.

# CHAPTER – A6
# SAFE PRACTICES IN WELDING

## (This is included for information purposes only)

1.0 This covers many of the basic elements of safety general to arc welding processes. It includes many, but not all, of the safety aspects related to structural welding. The hazards that may be encountered and the practices that will minimize personal injury and property damage are reviewed here.

2.0 **Electrical Hazards**

2.1 Electric shock can kill. However, it can be avoided. Live electrical parts should not be touched. Read and understand the manufacturer's instructions and recommended safe practices. Faulty installation, improper grounding, and incorrect operation and maintenance of electrical equipment are all sources of danger.

2.2 **All electrical equipment and the work-pieces should be grounded.** A separate connection is required to ground the work-piece. The work lead should not be mistaken for a ground connection.

2.3 To prevent shock, the work area, equipment, and clothing should be kept dry at all times. Dry gloves and rubber soled shoes should be worn. The welder should stand on a dry board or insulated platform.

2.4 Cables and connections should be kept in good condition. Worn, damaged or bare cables should not be used. In case of electric shock, the power should be turned off immediately. If the rescuer must resort to pulling the victim from the live contact, non-conducting materials should be used. A physician should be called and CPR continued until breathing has been restored, or until a physician has arrived.

**3.0 Fumes and Gases**

3.1 Many welding, cutting, and allied processes produce fumes and gases which may be harmful to one's health. Fumes and solid particles originate from welding consumables, the base metal, and any coating present on the base metal. Gases are produced during the welding process or may be produced by the effects of process radiation on the surrounding environment. Everyone associated with the welding operation should the possible effects of over-exposure to fumes and gases range from irritation of eyes, skin, and respiratory system to more severe complications. Effects may occur immediately or at some later time. Fumes can cause symptoms such as nausea, headaches, dizziness, and metal fumes fever. Sufficient ventilation, exhaust at the arc,

or both, should be used to keep fumes and gases from breathing zones and the general work area.

**4.0 Noise**

4.1 Excessive noise is a known health hazard. Exposure to excessive noise can cause a loss of hearing. This loss of hearing can be either full or partial, and temporary or permanent. Excessive noise adversely affects hearing capability. In addition, there is evidence that excessive noise affects other bodily functions and behaviour. Personal protective devices such as ear muffs or ear plugs may be employed. Generally, these devices are only accepted when engineering controls are not fully effective.

**5.0 Burn Protection**

5.1 Molten metal, sparks, slag, and hot work surfaces are produced by welding, cutting and allied process. These can cause burns if precautionary measures are not used.

5.2 Workers should wear protective clothing made of fire resistance material. Pant cuffs or clothing with open pockets or other places on clothing that can catch and retain molten metal or sparks should not be worn. High top shoes or leather leggings and fire resistant gloves should be worn. Pant legs should be worn over the outside of high top boots. Helmets or hand shields that provide protection for the face, neck, and ears, should be worn, as well as head covering to protect. Clothing should be kept free of grease and oil. Combustible materials should not be carried in pockets. If any combustible substance is spilled on clothing it should be replaced with fire resistance clothing before working with open arc or flame.

5.3 Appropriate eye protection should be used at all times. Goggles or equivalent also should be worn to give added eye protection.

Insulated gloves should be worn at all times when in contact with hot items or handling electrical equipment.

**6.0 Fire Prevention**

6.1 Molten metal, sparks, slag, and hot work surfaces are produced by welding, cutting, and allied processes. These can cause fire or explosion if precautionary measures are not used.

6.2 Explosions have occurred where welding or cutting has been performed in spaces containing flammable gases, vapours, liquid, or dust. All combustible material should be removed from the work area. Where possible, move the work to a location well

away from combustible materials. If neither action is possible, combustibles should be protected with a cover or fire resistant material. All combustible materials should be removed or safely protected within a radius of 35 ft. (11m) around the work area.

6.3 Welding or cutting should not be done in atmospheres containing dangerously reactive or flammable gases, vapours, liquid, or dust. Heat should not be applied to a container that has held an unknown substance or a combustible material whose contents when heated can produce flammable or explosive vapours. Adequate ventilation should be provided in work areas to prevent accumulation of flammable gases, vapours or dusts. Containers should be cleaned and purged before applying heat.

**7.0 Radiation**

7.1 Welding, cutting and allied operations may produce radiant energy (radiation) harmful to health. Everyone should acquaint themselves with the effects of this radiant energy.

7.2 Radiant energy may be ionizing (such as X-rays) or non-ionizing (such as ultraviolet, visible light, or infrared). Radiation can produce a variety of effects such as skin burns and eye damage, if excessive exposure occurs.

7.3 Some processes such as resistance welding and cold pressure welding ordinarily produce negligible quantities of radiant energy. However, most arc welding and cutting processes (except submerged arc when used properly), laser welding and torch welding, cutting, brazing, or soldering can produce quantities of non-ionizing radiation such that precautionary measures are necessary.

1. Welding arcs should not be viewed except through welding filter plates.
2. Transparent welding curtains are not intended as welding filter plates, but rather, are intended to protect passersby from incidental exposure.
3. Exposed skin should be protected with adequate gloves and clothing as specified.
4. The casual passersby to welding operations should be protected by the use of screens, curtains, or adequate distance from aisles, walkways, etc.
5. Safety glasses with ultraviolet protective side shields have been shown to provide some beneficial protection from ultraviolet radiation produced by welding arcs.