Document No: AA/CQ/GL/011 Part II-HTM Rev: 01

पावर सेक्टर के लिए हीट ट्रीटमेंट मैनुअल

HEAT TREATMENT MANUAL FOR POWER SECTOR

बी एच ई एल
BHEL
Maharatna Company

कार्पोरेट गुणता एवं व्यावसायिक उत्कृष्टता
CORPORATE QUALITY & BUSINESS EXCELLENCE

भारत हेवी इलेक्ट्रिकल्स लिमिटेड, नई दिल्ली
BHARAT HEAVY ELECTRICALS LIMITED, NEW DELHI

IMPORTANT NOTE

THIS HEAT TREATMENT MANUAL 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. ***When OD ≤ 170 mm, PWHT by resistance heating may also be used for thickness***

beyond 32 mm and up to 40 mm, provided the heat treatment is performed in two stages as follows:

i. In the first stage, half of the total weld thickness shall be deposited and PWHT shall be carried out for the deposited weld thickness (soaking time not less than 60 minutes).

ii. In the second stage, the balance thickness shall be deposited and PWHT shall be carried out for the total weld thickness.

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.

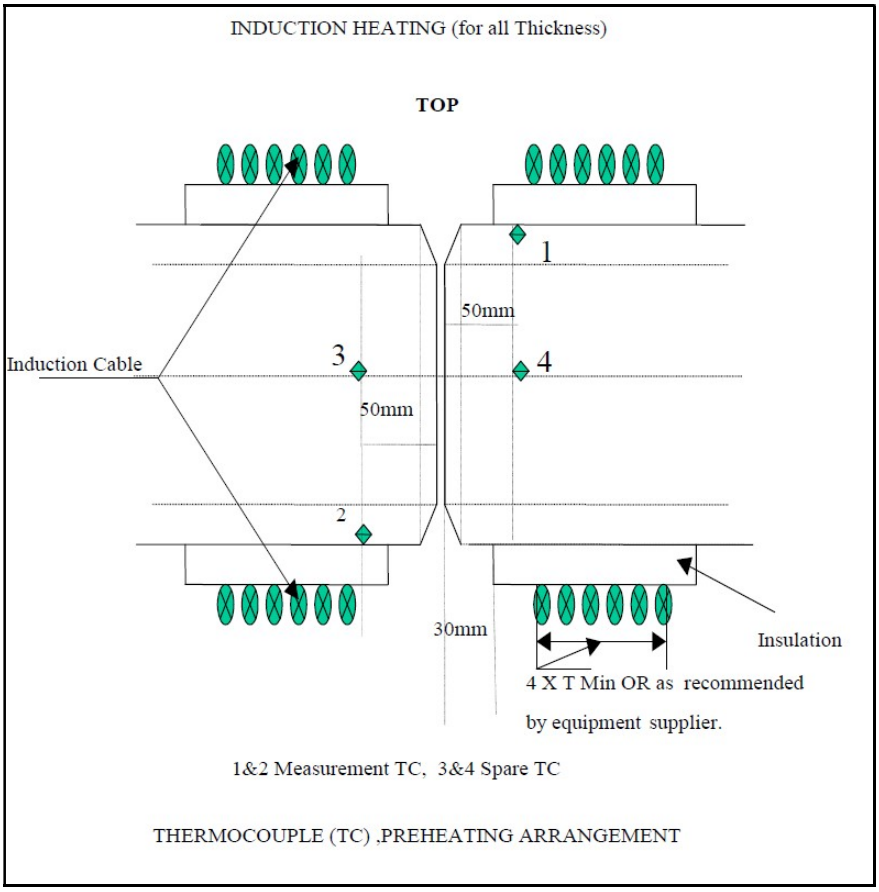

Figure 1.1: Placement of Thermocouples on P91/P92/F91/F92/C12A materials for Preheating

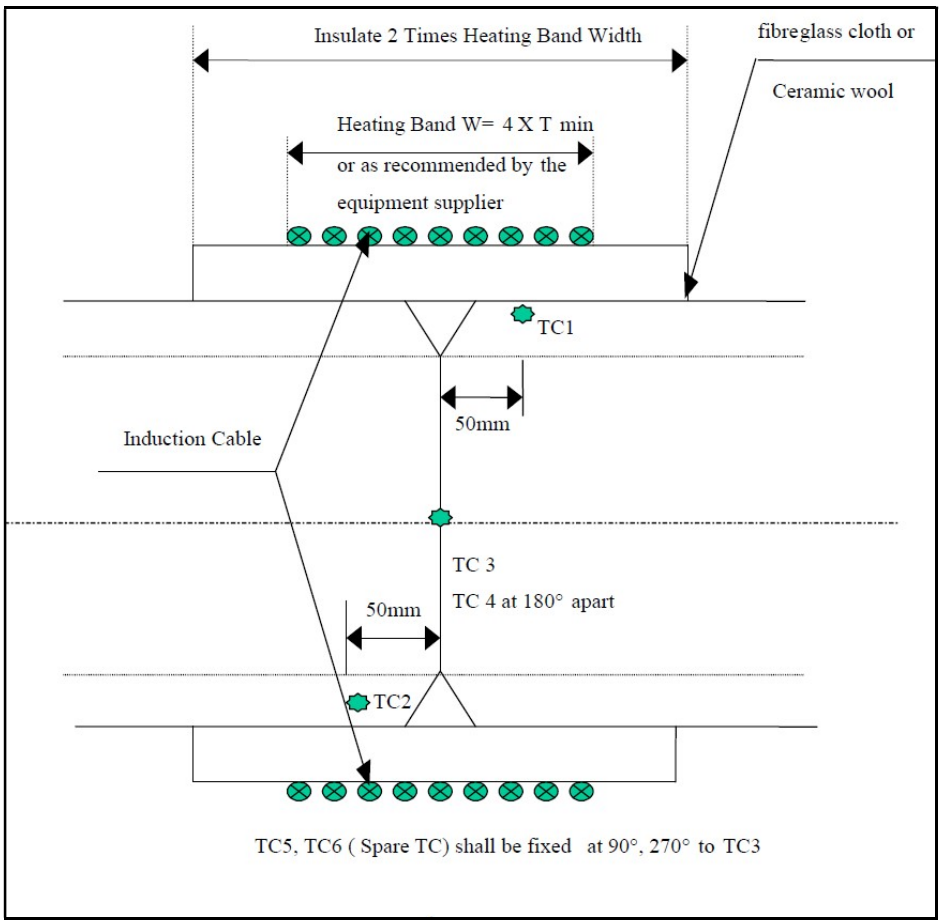

Figure 1.2: Placement of Thermocouples on P91/P92/F91/F92/C12A materials for PWHT

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. ***Flexible ceramic pads may also be used for carrying out PWHT of T91/T92 welds.***

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.

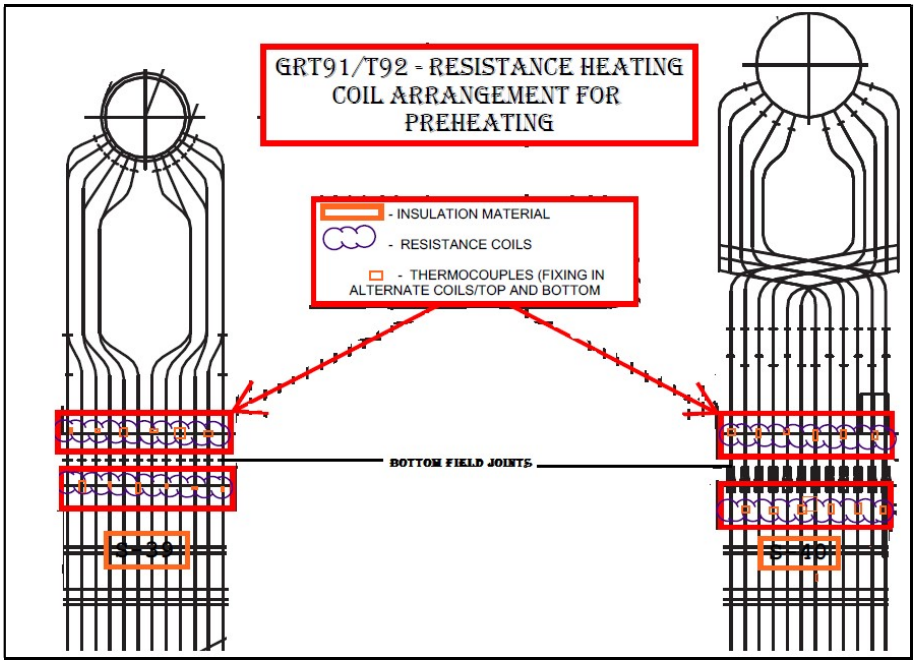

Figure 1.3: Resistance heating Coil arrangement for Preheating of T91/T92 tube assembly

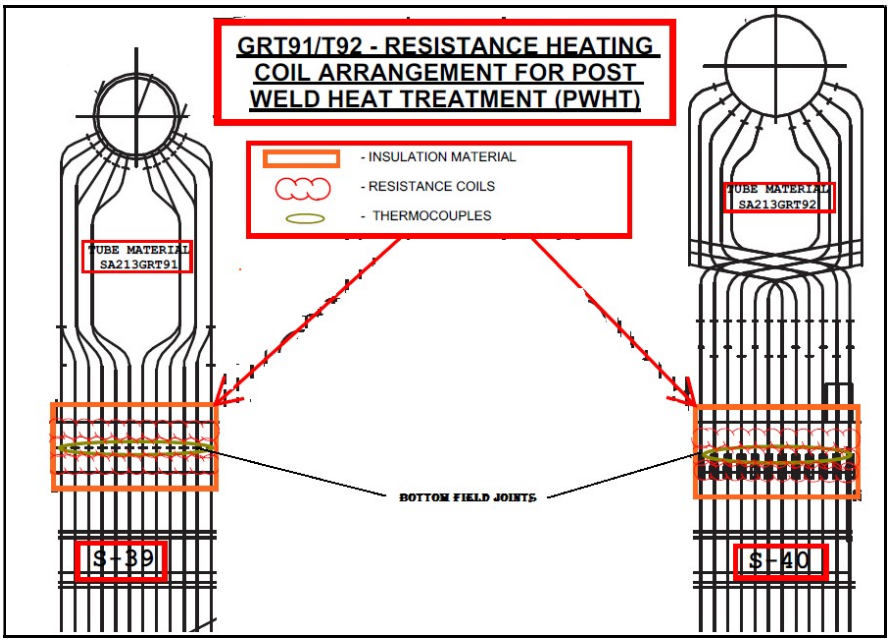

Figure 1.4: Resistance heating Coil arrangement for PWHT of T91/T92 tube assembly

3.5 **List of Tables:**

- Table-1.1: Weld preheat and PWHT for tubes and pipes outside diameter ≤ 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. : _____

Thermocouple Locations :

Minimum 2

Distance of TC from the weld centre =

Heating Band =

Insulation Band =

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 ≤ 19	Nil	Nil	Nil
	19 < t ≤ 25	Nil	Nil	595 - 625
	25 < t ≤ 75	100	Nil	595 - 625
	t > 75	150	Nil	595 - 625
P1Gr 2	t ≤ 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

**** Minimum 650°C for ASME jobs***

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	***Minimum 650°C for ASME jobs***
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 E250 BR, E350 BR,E350C	≤ 50 > 50	Nil 100	≤ 38 > 38 ≤ 63 > 63	Nil 100 150	595-625 1.0 All butt welds > 50 mm thick 2.0 For Ceiling girders if thickness > 50 mm 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 a) All butt welds in tension member 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 a) All butt welds in tension member 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 All welds (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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CHAPTER -2
HEAT TREATMENT PROCEDURE - STEAM TURBINE, TURBO-GENERATOR AND AUXILIARIES

Table 2.1
Pre heat & PWHT of Critical Piping with Turbine & Auxiliaries

Sl. No	Material Spec 1	Material Spec 2	OD	Thickness	Type of Weld	Pre heat Deg. C	PWHT Temp. Deg. C	Holding time minimum (minutes)
1	GS 17 CrMoV 511	SA335 P91	≥110	>30	G	200 to 300	690±10 (Notes)	240
2	G17 CrMo 9 10	SA335 P22	≥110	>30	G	200 to 300	690±10 (Notes)	240
3	21 Cr Mo Ni V47	SA335 P22	≥110	>30	G	200 to 300	690±10 (Notes)	240

Notes: Maximum rate of heating: 50 °C per hour above 300 °C
Maximum rate of cooling: 30°C per hour up to 3

LIST OF ANNEXURE

LIST OF TABLES:

LIST OF FIGURES

RECORD OF REVISIONS

Rev:00 Date**:** 24.10.2016 Completely revised the previous manual of 2010 version with new document number to include new materials and updated in-line with the current practices.

Rev:01 Date**:** 31.01.2020 Reviewed and revised for updation as per the below table.
All changes made in Rev 1 marked in red.

Chapter	Clause no.	Changes	Remarks
1	3.2.11.2	Revised to include PWHT by resistance method for Gr 91 materials up to 40 mm thickness.	Revised
	3.2.12.2	Revised to include usage of Flexible ceramic pads for PWHT of T91/T92 welds.	Revised
	Table 1.3	Updated minimum PWHT temperature of P4 material in-line with ASME	Revised
	Record of Revisions	Record of Revisions updated	Updated