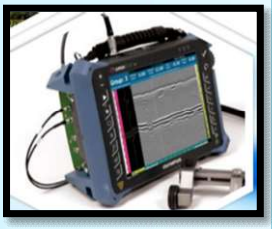
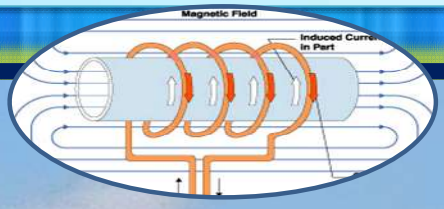
Document No: AA/CQ/GL/011 Rev:01

पावर सेक्टर के लिए वेल्डिंग, हीट ट्रीटमेंट और नॉन डिस्ट्रक्टिव एक्ज़ामिनेशन मैनुअल



MANUALS FOR WELDING, HEAT TREATMENT AND NON- DESTRUCTIVE EXAMINATION FOR POWER SECTOR



कार्पोरेट गुणता एवं व्यावसायिक उत्कृष्टता
CORPORATE QUALITY & BUSINESS EXCELLENCE

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BHARAT HEAVY ELECTRICALS LIMITED, NEW DELHI

Manuals for Welding, Heat Treatment and Non Destructive Examination for Power Sector

DOCUMENT NUMBER : AA/CQ/GL/011, R01 Dated 10.02.2020	
Welding Manual	AA/CQ/GL/011 Part I-WM Rev 01 dtd. 10.02.2020
Heat Treatment Manual	AA/CQ/GL/011 Part II-HTM Rev 01 dtd. 10.02.2020
Non Destructive Examination Manual	AA/CQ/GL/011 Part III-NDEM Rev 01 dtd. 10.02.2020

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RECORD OF REVISIONS:

MANUAL	REV NO.	DATE	CLAUSE NO.	DETAILS OF REVISION/ REMARKS
Welding Manual: AA/CQ/GL/011 Part I-WM	01	10/02/2020	Details of Revisions mentioned at the end of the Manual	
Heat Treatment Manual: AA/CQ/GL/011 Part II-HTM	01	10/02/2020	Details of Revisions mentioned at the end of the Manual	
Non Destructive Examination Manual: AA/CQ/GL/011 Part III-NDEM	01	10/02/2020	Details of Revisions mentioned at the end of the Manual	

MANUALS FOR WELDING, HEAT TREATMENT AND NON-DESTRUCTIVE EXAMINATION FOR POWER SECTOR

DOCUMENT NUMBER

AA/ CQ/ GL/011, R00 Dated 24.10.16	
Welding Manual	AA/CQ/GL/011 Part I-WM Rev 00 dtd 24.10.16
Heat Treatment Manual	AA/CQ/GL/011 Part II-HTM Rev 00 dtd 24.10.16
Non Destructive Examination Manual	AA/CQ/GL/011 Part III-NDEM Rev 00 dtd 24.10.16

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RECORD OF REVISIONS

MANUAL	REV. NO.	DATE	CLAUSE NO.	DETAILS OF REVISION / REMARKS
Welding Manual: AA/CQ/GL/011/ Part I-WM	00	24/10/2016	--	This manual supersedes the earlier manual issued vide reference number PSQ-WM-COM-2010 and is being reissued with major updations under new document number
Heat Treatment Manual: AA/CQ/GL/011/ Part II-HTM	00	24/10/2016	--	This manual supersedes the earlier manual issued vide reference number PSQ-HTM-COM-2010 and is being reissued with major updations under new document number
NDE Manual: AA/CQ/GL/011/Part III-NDEM	00	24/10/2016	--	This manual supersedes the earlier manual issued vide reference number PSQ-NDEM-COM-2010 and is being reissued with major updations under new document number

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Bharat Heavy Electricals Limited

Maharatna Company

MESSAGE

We are in the journey towards creating a BHEL of tomorrow. In this journey, we need to focus on aligning our products, processes and working practices not only with the prevalent technologies in the market, but also with the futuristic ones. We need to continuously review our systems and reference documents and keep them updated such that knowledge remains documented while we adopt newer technologies.

In this light, I am glad that Corporate Quality and Business Excellence, along with HPBP Trichy, Piping Centre, Power Sector Regions have taken up the critical task of reviewing the Welding, Heat Treatment and NDE Manuals and releasing the updated versions now.

I am sure, these updated manuals shall ensure better process controls and prevention of defects both at Construction as well as Servicing Sites. This shall go a long way in improving quality of our products and enhancement of customers' satisfaction.

(S. Biswas)
Director (E, R&D)

Date: 24th October, 2016

"बी. एच. ई. एल. हाउस", सीरी फोर्ट, नई दिल्ली – 110049, दूरभाष: (का.) 011-26001004, 66337002, फैक्स: 011-26493362
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Bharat Heavy Electricals Limited

बीएचईएल BHEL Maharatna Company

MESSAGE

BHEL, a globally competent enterprise is considered to be pride of India. It has been adept at transforming itself in line with the market requirements throughout its illustrious journey. In view of its stature and reputation, it is of paramount importance that we at BHEL relentlessly pursue globally accepted standards of quality in our products and services

Three key processes for a robust product/ service quality at project sites are Welding, Heat Treatment and Non Destructive Examination. To provide a comprehensive guide in all the aforementioned areas, Welding, Heat Treatment and Non Destructive Examination manuals have been revised and prepared to provide a one stop solution by including the new materials that have been introduced since previous version of 2010.

Project sites of BHEL which are responsible for offering the final product/ services to customers have an additional responsibility of delivering the best to its customers amidst constrained resources. Nevertheless, our employees have over the years done a commendable job in ensuring that products/ services supplied and erected meet the quality requirements.

This comprehensive manual involving the three key processes is more concise, relevant and in line with the current material requirements. I hope this effort of CQ & BE supported by MUs and Regions will be highly appreciated by our project site colleagues.

Best wishes for making Quality – A Hallmark of BHEL!

(Akhil Joshi)
Director (Power)

Date: 24th October, 2016

"बी. एच. ई. एल. हाउस", सीरी फोर्ट, नई दिल्ली – 110049, दूरभाष: (का.) 011-26001002, 26001098, फैक्स: 011-26492043
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Bharat Heavy Electricals Limited

Maharatna Company

PREFACE

The products supplied by various BHEL units are integrated to deliver project at the site by various erection processes such as fabrication, assembly, machining, handling, etc. Construction activities at field involve a planned and structured sequence of the activities to ensure that Quality is built into the product during erection.

Welding, Heat treatment (HT) and Non- Destructive Examination (NDE) are main special processes during erection. There are constant changes, up-gradations taking place due to advancement of technology and practices. These changes require regular review and updation of related process documents.

This Manual has been prepared to serve as guide to all construction personnel in ensuring process management of welding, heat treatment and NDE activities. The various aspects of process control covering the stages of planning & preparation for these processes have been covered in the form of specifications, norms and procedures/ instructions in this document. The manual has been updated over the previous version of 2010 taking into account the technology developments and current practices.

This Manual is based on relevant codes/ specifications like IBR, ASME and AWS and also consolidates the rich experience of BHEL based on more than three decades of manufacturing and erection. The document also provides DO's and DONT's for the benefit of users, which would help in preventing errors in the process.

I am sure that this Manual would enable the construction activities to manage their processes effectively to produce defect free quality.

(S. S. WADHAWAN)
GENERAL MANAGER (I/C)
CQ & BE

Date: 24th October, 2016

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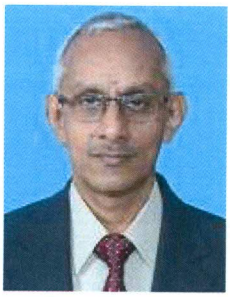

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Bharat Heavy Electricals Limited

Maharatna Company

PREFACE

BHEL has always stood for Quality in its products and services. Welding, Heat Treatment and Non Destructive Examination (NDE) are considered as "Special Processes" where the conformity of the resulting output cannot be readily or economically validated. Process control becomes absolutely essential in such cases in order to ensure defect free operations.

With a large order book and the need to execute projects in many sites under different Power Sector Regions, covering various ranges of projects starting from small capacity Units to Once through Super Critical Units, there was a need to revise the existing Welding, Heat Treatment and NDE Manuals, last prepared in 2010, being used by the BHEL Construction Management groups during installation of the power plants. Present revision of these Manuals has been carried out by a task force comprising of experts in the area of Welding, NDE and Quality Assurance from BHEL (Trichy), Piping Centre (Chennai), Power Sector (Southern & Eastern Regions) and Corporate Quality. This revision takes into account suggestions received from various Power Sector Regions based on their job experience during execution and also aligns with the various Codes & Standards. This also elaborates the requirements of Supercritical Units which include new material specifications like Grade 23, Grade 91, Grade 92 and Super 304H materials. All the requirements are now brought out in a Single Manual.

This Manual provides basic guidelines to all construction personnel in ensuring effective "Process Management" of Welding, Heat Treatment, NDE and allied activities like Procedure Qualification, Personnel Qualification, Storage and Issue Control of electrodes, Inspection, repair of welding, etc. Product specific process controls like Preheat & Inter-pass temperatures required to be maintained during Welding and Post-heat & Post Weld Heat Treatment required to be carried out after welding for different products like Boiler, Critical Piping, Turbine, Generator and its Auxiliaries and Aluminium Bus ducts are governed by the relevant Field Welding Schedules (FWS) and Welding Procedure Specifications (WPS) released by the respective manufacturing units.

I am sure that this revised edition of the Manual will provide all the relevant technical inputs required for producing good quality welds during execution of projects at sites.

Rajay2

(R. RAJAMANOHAR)
GENERAL MANAGER (I/C)
BHEL / TRICHY COMPLEX

Date: 24th October, 2016

बी. एच. ई. एल , हाई प्रेशर बॉयलर प्लांट एंड सीमलेस स्टील ट्यूब प्लांट, तिरुचिरापल्ली; दूरभाष: 0431-2577020.
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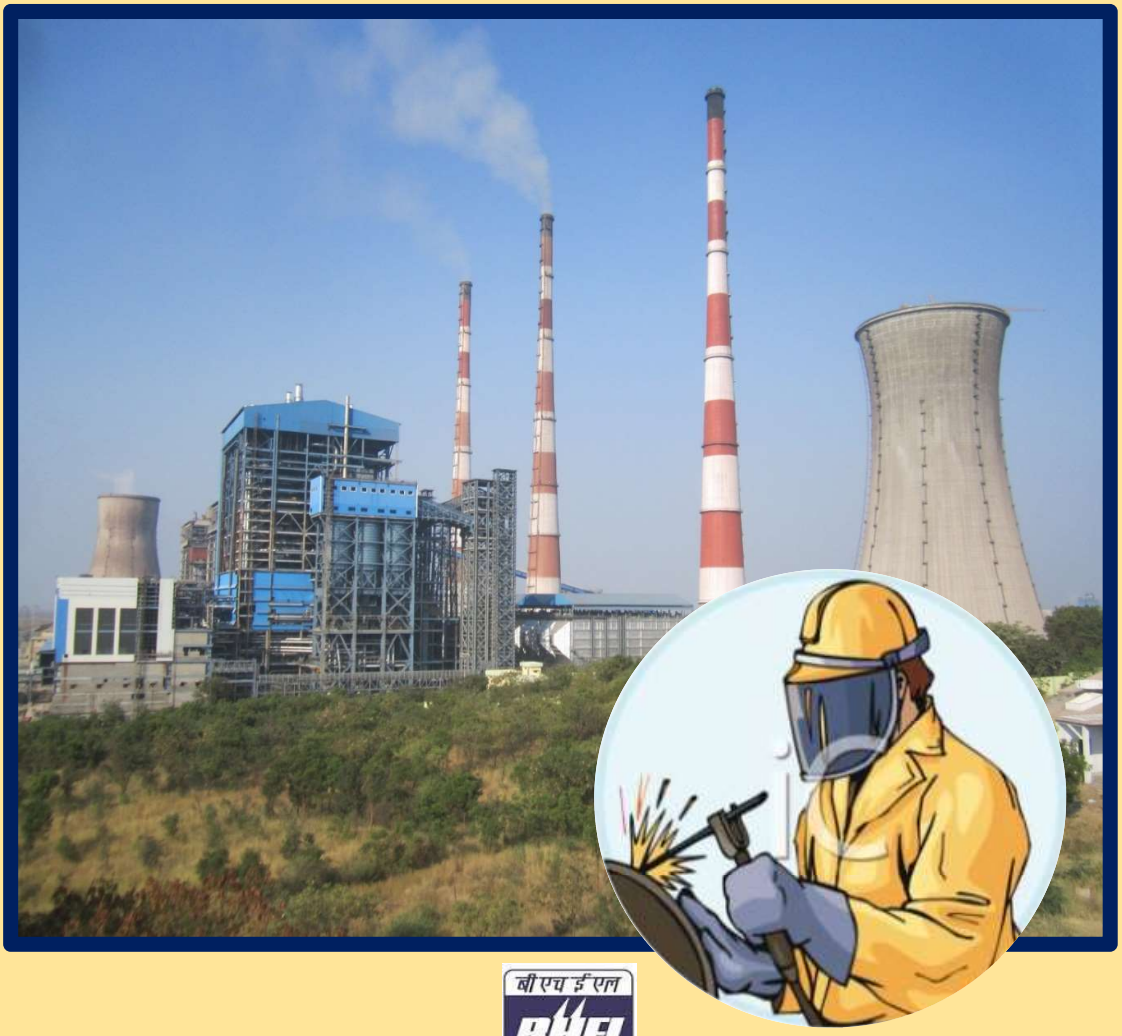
LIST OF MANUALS

Sl. No.	Document Ref No.	No. Of Pages
1	Welding Manual: AA/CQ/GL/011 Part I-WM, Rev 01	165
2	Heat Treatment Manual: AA/CQ/GL/011 Part II-HTM, Rev 01	22
3	Non Destructive Examination Manual: AA/CQ/GL/011 Part III-NDEM, Rev 01	239

Document No : AA/CQ/GL/011 Part I-WM Rev: 01

पावर सेक्टर के लिए वेल्डिंग मैनुअल

WELDING MANUAL FOR POWER SECTOR



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BHARAT HEAVY ELECTRICALS LIMITED, NEW DELHI

IMPORTANT NOTE

THIS WELDING MANUAL PROVIDES BROAD BASED GUIDELINES 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.

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PART A

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 to concerned 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: ***(latest)*** 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	***30.0***
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 ***from original gas manufacturer*** 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	ϕ 2.5 mm	:
	ϕ 3.15 mm	:
	ϕ 4.0 mm	:
Date of LPI for RG Plug		:
Remarks		:
Date of Return		:

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

JOB CARD (WELDING, HEAT TREATMENT & ND EXAMINATION) 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 (WELDING, HEAT TREATMENT & ND EXAMINATION) 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

Table A2.1 - Pipes (ASME)
Table A2.2 - Tubes (ASME)
Table A2.3 - Forgings (ASME)
Table A2.4 - Castings (ASME)
Table A2.5 - Plates / Sheets (ASTM, ASME& IS)
Table A2.6 - Pipes (Other specifications)
Table A2.7 - Tubes (Other specifications)

3.0 The data are for general information purposes. The corresponding P numbers are also indicated. ***Relevant material specification shall be referred to for detailed elemental composition.***

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.	Material Specification	Chemical Composition (%)											Mechanical Properties (Min.)		
			C	Mn	P	S	Si	Ni	Cr	Mo	V	W	Cu	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 *Type 1 **	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	***P 15E /1***	***SA 335 P91 Type 2 ****	***0.07-0.13***	***0.30-0.50***	***0.02 Max.***	***0.005 Max.***	***0.20-0.40***	***0.20 Max.***	***8.00-9.50***	***0.80-1.05***	***0.16-0.27***	***0.05 Max.***	***0.10 Max.***	***585***	***415***	***20***
8	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
9	***P10H/1***	***SA 790 UNS S32750***	***0.030***	***1.2 max***	***0.035 Max.***	***0.020 Max.***	***0.80 max***	***6.0-8.0***	***24.0-26.0***	***3.0-5.0***	***-***	***-***	***-***	***800***	***550***	***15***

****It shall be construed as Type 1 when no Type is specified.***

TABLE-A2.2: TUBES(ASME)

Sl. No.	P. No. /Group No.	Material Specification	Chemical Composition (%)											Mechanical Properties (Min.)		
			C	Mn	P	S	Si	Ni	Cr	Mo	V	W	*Cu*	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	Cu	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 15 E / 1	SA 213 T91 *Type 1 *	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 15E /1***	***SA 213 T91 Type 2 ****	***0.07-0.13***	***0.30-0.50***	***0.02 Max.***	***0.005 Max.***	***0.20-0.40***	***0.20 Max.***	***8.00-9.50***	***0.80-1.05***	***0.16-0.27***	***0.05 max***	***0.10 max***	***585***	***415***	***20***
13	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
15	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
16	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
17	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
18	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	-	-	-	***2.5-3.5***	590	235	35

****It shall be construed as Type 1 when no Type is specified.***

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	Cu	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 5A / 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 15E /1	SA 182 F91 ***Type 1****	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
7	***P 15E /1***	***SA 182 F91 Type 2 ****	***0.07-0.13***	***0.30-0.50***	***0.02 Max.***	***0.005 Max.***	***0.20 - 0.40***	***0.20 Max.***	***8.00-9.50***	***0.80-1.05***	***0.16-0.27***	***W:0.05 max***	***0.10 max***	***620***	***415***	***20***
8	P 15E/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

****It shall be construed as Type 1 when no Type is specified.***

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	Cu	T.S MPa	Y.S MPa	% E Min.
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.	***0.30 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.	***0.30 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	***0.50 Max***	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	***0.50 Max***	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	W Cu	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	SA 516 Gr 70	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	SA 299 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	SA 515 Gr 70	<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	P3/1	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 ind	0.23					-	-		-	-			
			>100	0.25					-	-		-	-			
7	P3/2	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 ind	0.25					-	-		-	-			
			>100	0.27					-	-		-	-			
8	P4/1	SA 387 Gr 12 Class 2	<125 ind	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	P5A/1	SA 387 Gr 22 Class 2	<125 ind	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												

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	W Cu	T.S (MPa)	Y.S (MPa)	% E Min.
10	P15E/1	SA387 Gr91 *Type 1* *	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
11	*P15E/1*	*SA387 Gr91 Type 2* *	*All thickness*	*0.06-0.15*	*0.30-0.50*	*0.020*	*0.005*	*0.20-0.40*	*0.20*	*8.0-9.50*	*0.80-1.05*	*0.16-0.27*	*W: 0.05 Cu: 0.10*	*585*	*415*	*18*
12	P8/1	SA 240 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
13	P 1 / 1	ASTM A 572 Gr50	<40 incl >40	0.23	1.35	0.04	0.05	0.40 0.15-0.40	- -	- -	- -	0.01-0.15†	-	450	345	17
14	P 1 / 1	IS 2062 E250 Gr.A	all thickness	0.23	1.5	0.045	0.045	0.4	-	-	-	-	-	410	230	23
15	P 1 / 1	IS 2062 E250 Gr.BR,BO	all thickness	0.22	1.5	0.045	0.045	0.4	-	-	-	-	-	410	230	23
16	P 1 / 1	IS 2062 E250 GrC	all thickness	0.2	1.5	0.04	0.04	0.4	-	-	-	-	-	410	230	23
17	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
18	P 1 / 1	IS 2062 E350 GrC	all thickness	0.2	1.55	0.04	0.04	0.45	-	-	-	-	-	490	320	22
19	P 1 / 1	IS 2062 E450BR	all thickness	0.22	1.65	0.045	0.045	0.45	-	-	-	-	-	570	450	20
20	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

**It shall be construed as Type 1 when no Type is specified.*

Note: All individual compositional values without range are maximum.

TABLE A2.6: PIPES (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	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 / mm² (MPa)	Y.S Kg / mm² (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 Al others 8.0 1.0 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 Al others Rem[f] 1.0 Total 1.0
E2594-16	***5.4***	***0.04***	***0.5-2.0***	***1.00***	***0.04***	***0.03***	***8.0-10.5***	***24.0-27.0***	***3.5-4.5***	***NS***	***0.75***	***N:0.20-0.30***
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
ER 309-LMo	***5.9***	***0.03***	***1.00-2.50***	***0.30-0.65***	***0.03***	***0.03***	***12.00-14.00***	***23.00-25.00***	***2.0-3.0***	***NS***	***0.75***	
ER2594-16	***5.9***	***0.04***	***2.5***	***1.00***	***0.03***	***0.02***	***8.0-10.5***	***24.0-27.0***	***2.5-4.5***	***NS***	***1.5***	***N:0.20-0.30 W: 1.0***
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 unspecified elements 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 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) %
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			
ER2594-16	***5.9***			
ER309LMo	***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) 1 Ksi 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 Welding Electrodes/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 Maintain a 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, ***E2209, E2594***	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 concerned manufacturing 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 concerned manufacturing 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	***ER347***	
	SMAW			ENiC rFe3	ENiCrFe3	ENiCrFe3	ENiCrFe3	ENiCrFe7	E347	***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: ***All electrodes shall be procured as per ASME section II C requirements with manufacturers TC.***

Note -2 In case of E7018-1 electrodes, required mechanical tests of the test piece shall be done after the test piece has undergone the required PWHT.

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 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 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 Preheat PWHT	E7018 Nil Nil	-	E 7018 150°C 650 – 670°C	-	-	-	-
P3	Electrode Preheat PWHT	E7018 150°C (Note 1) For Thickness>16mm: 620-650°C	E7018-A1 150°C For Thickness>16mm: 620-650°C	-	-	-	-	-
P4	Electrode Preheat PWHT	E7018 150°C (Note 1) For Thickness>13mm: 650-670°C	E7018-A1 150°C For Thickness>13mm: 650-670°	E8018-B2 150°C (Note 1) For Thickness>13mm: 650-670°C	-	-	-	-
P5 A	Electrode Preheat PWHT	-	-	E8018-B2 150°C (Note 1) For Thickness>13: 680-710°C	E9018-B3 150°C (Note 1) For Thickness>13:680-710°C	-	-	-
P8	Electrode Preheat PWHT	E309 Nil Nil	-	E309 Nil Nil	E309 Nil Nil	E347 Nil Nil	E309 Nil Nil	-
P 15E/ 1	Electrode Preheat PWHT	-	-	-	E9018-B3 220°C 730-760 °C	ENi Cr Fe3 220°C (only on P15E side) 730-760 °C	ENi Cr Fe3 220°C (only on P15E side) 730-760 °C	E9015-B91 220°C 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 FILLER WIRE AND 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) > 6 mm: E 7018 For fillets ≤8 mm : E 6013 >8 mm: E 7018	EL 8 EM 12 K EL 8 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-7***
41	SFA-5.14	ERNi-1
41	SFA-5.14	ERNiCr-3 & ***ERNiCrFe-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, **ERNiCrCoMo-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

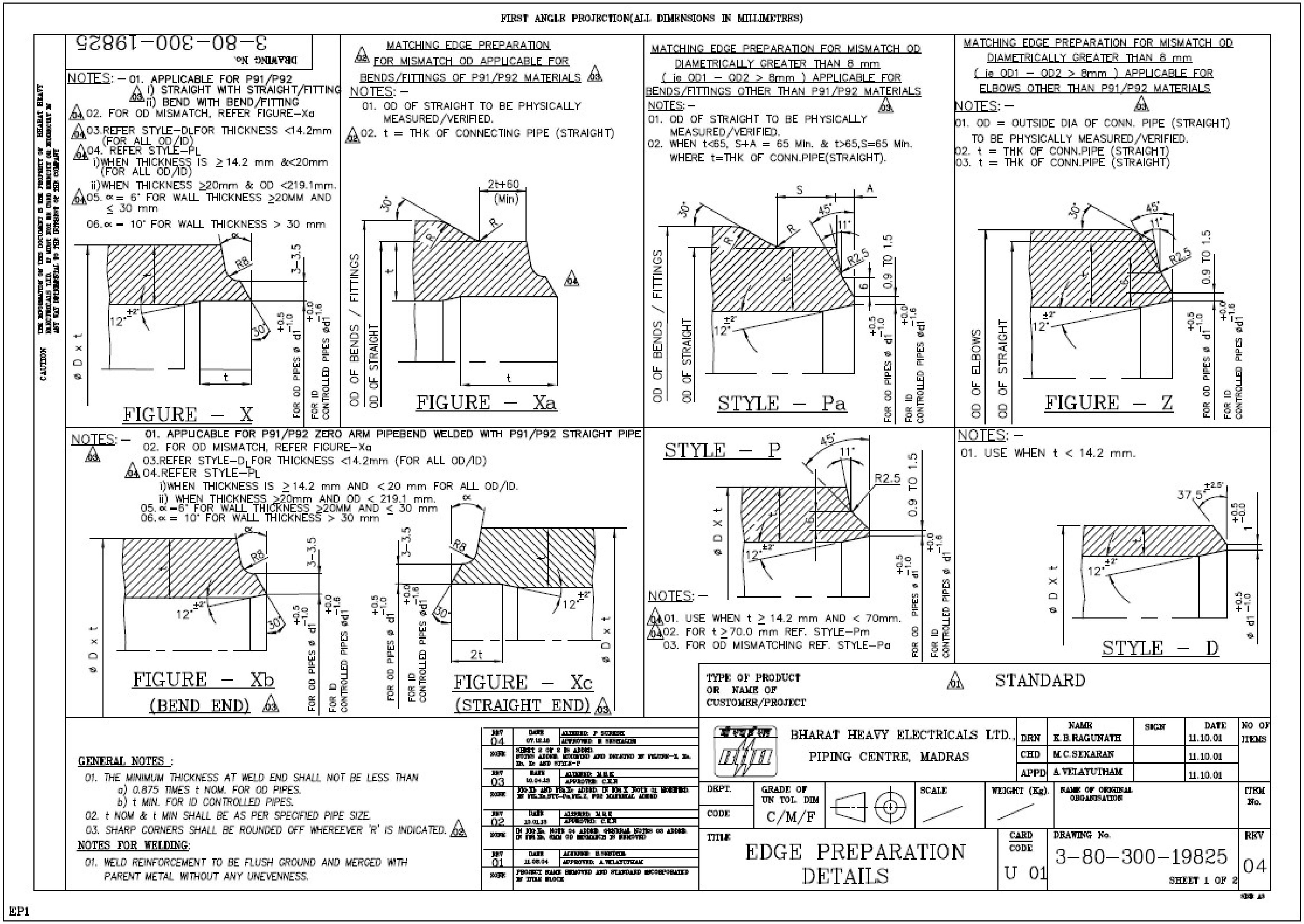
SFA CLASSIFICATION

SFA NO.	DESCRIPTION
5.01	Welding Consumables-Procurement of Filler Materials and Fluxes
5.02	Filler Metal Standard Sizes, Packaging, and Physical Attributes
5.1	Carbon Steel Electrodes for Shielded Metal Arc Welding
5.2	Carbon and Low Alloy Steel Rods for Oxy fuel Gas Welding
5.3	Aluminium and Aluminium Alloy Electrodes for Shielded Metal Arc welding
5.4	Stainless Steel Electrodes for Shielded Metal Arc Welding
5.5	Low-Alloy Steel Electrodes for Shielded Metal Arc Welding
5.6	Copper and Copper Alloy Electrodes for Shielded Metal Arc Welding
5.7	Copper and Copper Alloy Bare Welding Rods and Electrodes
5.8	Filler Metal for Brazing and Braze Welding
5.9	Bare Stainless Steel Welding Electrodes and Rods
5.10	Bare Aluminium and Aluminium Alloy Welding Electrodes and Rods
5.11	Nickel and Nickel Alloy Welding Electrodes for Shielded Metal Arc welding
5.12	Tungsten and Oxide Dispersed Tungsten Electrodes for Arc Welding and Cutting
5.13	Surfacing electrodes for shielded metal arc welding
5.14	Nickel and Nickel Alloy Bare Welding Electrodes and Rods
5.15	Welding Electrodes and Rods for Cast Iron
5.16	Titanium and Titanium Alloy Welding Rods and Electrodes
5.17	Carbon Steel Electrodes and Fluxes for Submerged Arc Welding
5.18	Carbon Steel electrodes and rods for Gas Shielded Arc Welding
5.20	Carbon Steel Electrodes for Flux Cored Arc Welding

SFA CLASSIFICATION (Contd…)

SFA NO.	DESCRIPTION
5.21	Bare electrodes and rods for surfacing
5.22	Stainless Steel Electrodes for Flux Cored Arc Welding and Stainless Steel Flux Cored Rods for Gas Tungsten Arc Welding
5.23	Low Alloy Steel Electrodes and Fluxes for Submerged Arc Welding
5.24	Zirconium and Zirconium Alloy Welding Electrodes and Rods
5.25	Carbon and Low Alloy Steel Electrodes and Fluxes for Electro-slag Welding
5.26	Carbon and Low Alloy Steel Electrodes for Electro-gas Welding
5.28	Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding
5.29	Low Alloy Steel Electrodes for Flux Cored Arc Welding
5.30	Consumable Inserts
5.31	Fluxes for Brazing and Braze Welding
5.32	Welding Shielding gas
5.34	Nickel –Alloy electrodes for Flux Cored Arc Welding
5.36	Carbon and Low-Alloy Steel flux Cored Electrodes for Flux Cored Arc Welding and Metal Cored Electrodes for Gas Metal Arc Welding

CHAPTER – A4
EDGE PREPARATION DETAILS FOR PIPES &TUBES



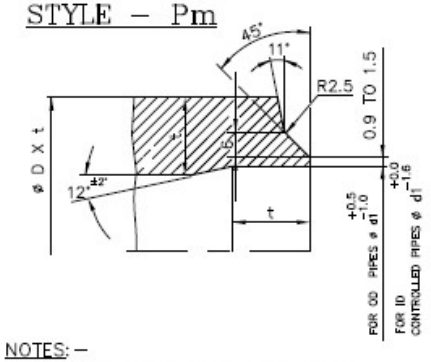
FIRST ANGLE PROJECTION(ALL DIMENSIONS IN MILLIMETRES)
DRAWING No. 3-80-300-19825
NOTES: – 01. APPLICABLE FOR P91/P92
i) STRAIGHT WITH STRAIGHT/FITTING
ii) BEND WITH BEND/FITTING
02. FOR OD MISMATCH, REFER FIGURE–Xa
03.REFER STYLE–D, FOR THICKNESS <14.2mm (FOR ALL OD/ID)
04. REFER STYLE–PL
i)WHEN THICKNESS IS ≥ 14.2 mm &<20mm (FOR ALL OD/ID)
ii)WHEN THICKNESS ≥20mm & OD <219.1mm.
05. ∝ = 6° FOR WALL THICKNESS ≥20MM AND ≤ 30 mm
06. ∝ = 10° FOR WALL THICKNESS > 30 mm
FIGURE – X
MATCHING EDGE PREPARATION FOR MISMATCH OD APPLICABLE FOR BENDS/FITTINGS OF P91/P92 MATERIALS
NOTES: –
01. OD OF STRAIGHT TO BE PHYSICALLY MEASURED/VERIFIED.
02. t = THK OF CONNECTING PIPE (STRAIGHT)
FIGURE – Xa
MATCHING EDGE PREPARATION FOR MISMATCH OD DIAMETRICALLY GREATER THAN 8 mm (ie OD1 – OD2 > 8mm) APPLICABLE FOR BENDS/FITTINGS OTHER THAN P91/P92 MATERIALS
NOTES: –
01. OD OF STRAIGHT TO BE PHYSICALLY MEASURED/VERIFIED.
02. WHEN t<65, S+A = 65 Min. & t>65,S=65 Min. WHERE t=THK OF CONN.PIPE(STRAIGHT).
STYLE – Pa
MATCHING EDGE PREPARATION FOR MISMATCH OD DIAMETRICALLY GREATER THAN 8 mm (ie OD1 – OD2 > 8mm) APPLICABLE FOR ELBOWS OTHER THAN P91/P92 MATERIALS
NOTES: –
01. OD = OUTSIDE DIA OF CONN. PIPE (STRAIGHT) TO BE PHYSICALLY MEASURED/VERIFIED.
02. t = THK OF CONN.PIPE (STRAIGHT)
03. t = THK OF CONN.PIPE (STRAIGHT)
FIGURE – Z
NOTES: – 01. APPLICABLE FOR P91/P92 ZERO ARM PIPEBEND WELDED WITH P91/P92 STRAIGHT PIPE
02. FOR OD MISMATCH, REFER FIGURE–Xa
03.REFER STYLE–D, FOR THICKNESS <14.2mm (FOR ALL OD/ID)
04.REFER STYLE–PL
i)WHEN THICKNESS IS ≥ 14.2 mm AND < 20 mm FOR ALL OD/ID.
ii) WHEN THICKNESS ≥20mm AND OD < 219.1 mm.
05. ∝ =6° FOR WALL THICKNESS ≥20MM AND ≤ 30 mm
06. ∝ = 10° FOR WALL THICKNESS > 30 mm
FIGURE – Xb (BEND END)
FIGURE – Xc (STRAIGHT END)
STYLE – P
NOTES: –
01. USE WHEN t ≥ 14.2 mm AND < 70mm.
02. FOR t ≥ 70.0 mm REF. STYLE–Pm
03. FOR OD MISMATCHING REF. STYLE–Pa
NOTES: –
01. USE WHEN t < 14.2 mm.
STYLE – D
TYPE OF PRODUCT OR NAME OF CUSTOMER/PROJECT
STANDARD
GENERAL NOTES :
01. THE MINIMUM THICKNESS AT WELD END SHALL NOT BE LESS THAN
a) 0.875 TIMES t NOM. FOR OD PIPES.
b) t MIN. FOR ID CONTROLLED PIPES.
02. t NOM & t MIN SHALL BE AS PER SPECIFIED PIPE SIZE.
03. SHARP CORNERS SHALL BE ROUNDED OFF WHEREEVER 'R' IS INDICATED.
NOTES FOR WELDING:
01. WELD REINFORCEMENT TO BE FLUSH GROUND AND MERGED WITH PARENT METAL WITHOUT ANY UNEVENNESS.
BHARAT HEAVY ELECTRICALS LTD.,
PIPING CENTRE, MADRAS
DRN K.B.RAGUNATH 11.10.01
CHD M.C.SEKARAN 11.10.01
APPD A.VELAYUTHAM 11.10.01
GRADE OF UN TOL DIM C/M/F
TITLE EDGE PREPARATION DETAILS
CARD CODE U 01
DRAWING No. 3-80-300-19825
REV 04
SHEET 1 OF 2
EP1

FIRST ANGLE PROJECTION(ALL DIMENSIONS IN MILLIMETRES)

CAUTION: THE INFORMATION ON THIS DOCUMENT IS THE PROPERTY OF BHARAT HEAVY ELECTRICALS LTD. IT MUST NOT BE USED DIRECTLY OR INDIRECTLY IN ANY WAY DETRIMENTAL TO THE INTEREST OF THE COMPANY

DRAWING No. 3-80-300-19825

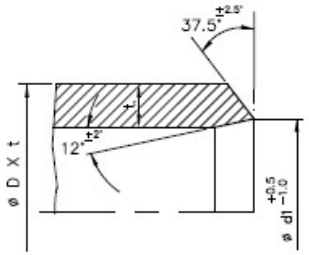
STYLE – Pm



NOTES: –

01. USE FOR SA106GRC PIPES WHEN t ≥ 70.0 mm.
02. FOR OD MISMATCHING REF. FIGURE–Pa
03. FOR FITTINGS USE STYLE–P.

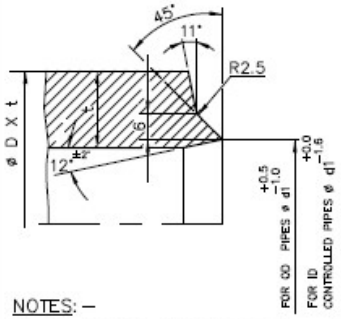
STYLE – D_L



NOTES: –

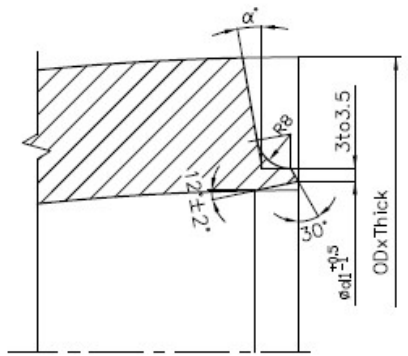
01. USE FOR P91 / P92 PIPES AND FITTINGS WHEN t < 14.2 mm (ALL OD/ID).

STYLE – P_L



NOTES: –

01. USE FOR P91 / P92 PIPES AND FITTINGS
i)WHEN THICKNESS IS ≥14.2 mm AND <20 mm FOR ALL OD/ID.
ii) WHEN THICKNESS ≥20mm AND OD < 219.1 mm.
02. FOR OD MISMATCHING REF. FIGURE–Pa



01. USE FOR P91 / P92 FITTINGS
02. REFER STYLE–D_L FOR THICKNESS <14.2mm FOR ALL OD/ID.
03. REFER STYLE–P_L
i)WHEN THICKNESS IS ≥14.2 mm AND <20 mm FOR ALL OD/ID.
ii) WHEN THICKNESS ≥20mm AND OD < 219.1 mm.
04. ∝ = 6° FOR WALL THICKNESS ≥ 20MM AND ≤ 30 mm
05. ∝ = 10° FOR WALL THICKNESS > 30mm.
06. FIGURE–Xf IS APPLICALBE FOR ALL BUTT WELDED FITTINGS NOT COVERED IN NOTES 02 & 03

FIGURE–Xf

NOTE :
01. FOR GENERAL NOTES AND NOTES FOR WELDING REFER SHEET 1 OF 2.

TYPE OF PRODUCT OR NAME OF CUSTOMER/PROJECT	STANDARD							
BHARAT HEAVY ELECTRICALS LTD., PIPING CENTRE, MADRAS		DRN	P SURESH		07.12.16	NO OF ITEMS		
		CHD	R SESHAGIRI		07.12.16			
		APPD	C KARUNAKARAN		07.12.16			
DRPT. CODE	GRADE OF UN TOL DIM C/M/F	SCALE	WEIGHT (Kg).	NAME OF ORIGINAL ORGANISATION		ITEM No.		
TITLE: EDGE PREPARATION DETAILS		CARD CODE U 01	DRAWING No. 3–80–300–19825 SHEET 2 OF 2			REV 04		

EP1

EDGE PREPARTION AND WELD END DIAMETER (d_1 VALUES)

TP 062 05 99

PAGE–7

STL	TYPE OF WELDING	
	ROOT PASS	FILLER PASS
A	GAS OR MANUAL ARC	GAS OR MANUAL ARC
B	TIG	MANUAL ARC
C	MANUAL ARC	MANUAL ARC
	TIG	TIG
D	GAS OR TIG OR MANUAL ARC	GAS OR TIG OR MANUAL ARC
E	MANUAL ARC	MANUAL ARC
F	INDUCTION PRESSURE WELDING	
G H	STRAIGHT TUBE WELDING (PULSED ARC MIG)	
I	FLASH BUTT WELDING	
P Q R	TIG	MANUAL ARC AND SUBMERGED ARC OR MANUAL ARC
J	ORBITAL TIG WELDING	

OUTSIDE DIA 'D'	STYLE 'J'
31.8 TO 76.1	3.6 TO 12.5

VIEW OF EDGE PREPARATION

OUTSIDE DIA 'D'	STYLE 'J'	VIEW OF EDGE PREPARATION
14.0 TO 21.3	A 2.0 TO 4.5	ROOT GAP 1.5
31.8 TO 76.1	B 3.6 TO 12.5 PANEL /COIL END	ROOT GAP 1.0–2.5
—	C BELOW 22.2 FREE END OF NIPPLES	ROOT GAP 1.0–2.5
31.8 TO 159.0 (ALSO >159.0 WHEN REQD)	D BELOW 14.2	ROOT GAP 1.0–2.5
219.1 AND ABOVE	E BELOW 14.2	ROOT GAP 0–2.0
31.8 TO 76.1	F 3.2 TO 11.0	UPSETTING ALLOWANCE 3MM/JOINT
31.8 TO 76.1	G 2.9 TO 5.6	
31.8 TO 76.1	H 6.0 TO 11.0	
31.8 TO 44.5	I 2.9 TO 6.3	UPSETTING ALLOWANCE 10 MM/JOINT
88.9 AND ABOVE	P 14.2 AND ABOVE	ROOT GAP 2
—	Q 22.2 AND ABOVE FREE END OF NIPPLES	AS SPECIFIED BY DESIGNER; ROOT GAP 2
—	R 32.0 TO 150 TEES, BENDS ETC	ROOT GAP 2

ALL DIMENSIONS ARE IN MM

CHAPTER A5 - SELECTION CHART FOR DUMMY END COVERS & NIPPLES FREE END DETAILS

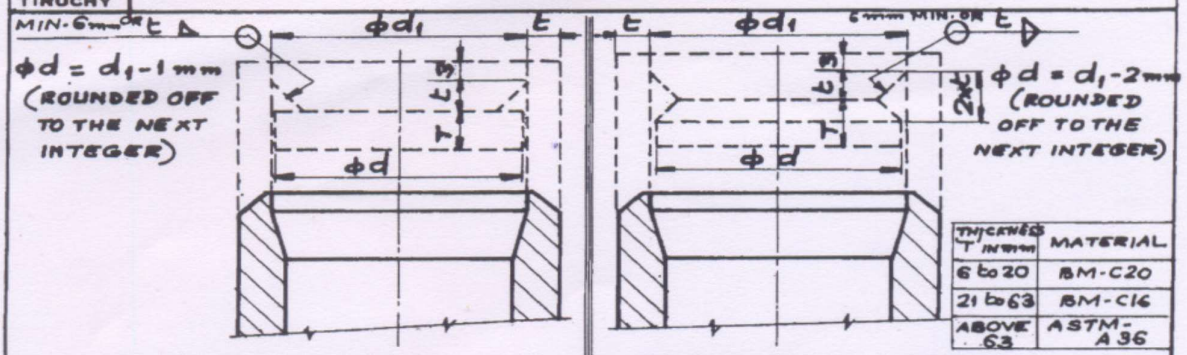
INDEX NO. 2-8

TIRUCHY

SELECTION CHART FOR DUMMY END COVERS FOR HYDRAULIC TEST

THICKNESS 'T' = $0.5 d_1 \sqrt{P/f}$ (IBR-REC. R 831/1968) $f = 1900\ kg/cm^2$

ROUNDED OFF TO THE NEXT NEAREST RATIONALISED PLATE SIZE.



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

CASE WHEN T ≤ 20

CASE WHEN T > 20

THICKNESS OF DUMMY END COVERS FOR HYDRAULIC TEST (T)

'P' TEST PRESSURE kg/cm² / φ OF TUBE/PIPE (d1) IN mm.	30	45	60	75	90	105	120	135	150	165	180	210	240	270	300	350
(MAX) 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	36
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	56	56	56	56	56	56	63	63	65
350	25	32	32	36	40	56	56	56	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	65	70	70	80	85	90	95	100
500	36	40	56	56	56	63	65	70	75	75	80	85	90	95	100	110

MICROFILMED ON ROLL 00037 FRAME 528

PREPARED BY

CHECKED BY

40-B-006-2897

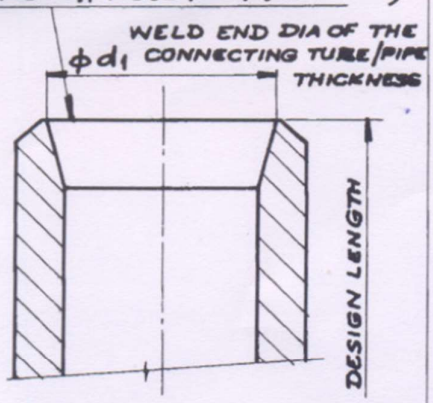
INDEX NO. 2-8

TIRUCHY

NIPPLES - FREE END DETAILS.

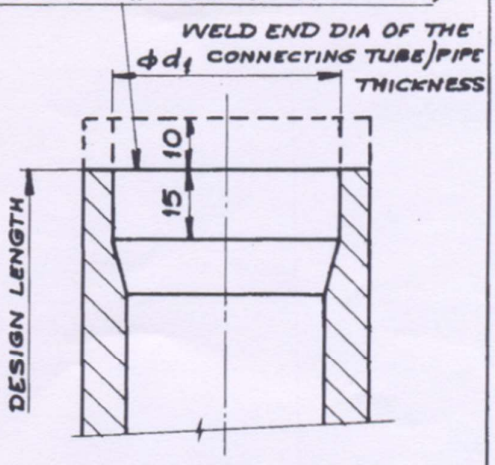
(FOR HEADERS ONLY.)

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.)

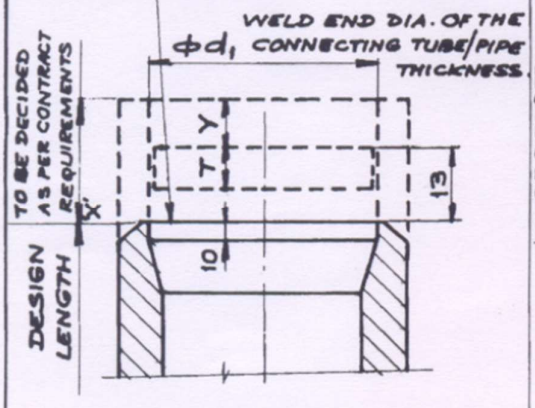
INDICATE STYLE NO 'C' - d_1 TO BPS NO. 710004-74 (LAT. REV.)



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

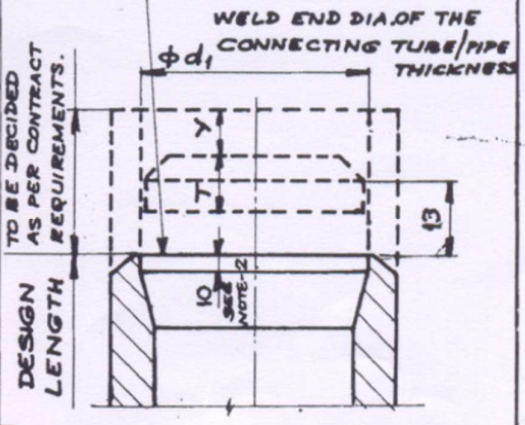
CASE WHEN T ≤ 20

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 28 mm THE INSIDE HEIGHT OF MACHINING (WHICH IS NOW 10 mm) WILL BE INCREASED ACCORDINGLY.

PREPARED BY	CHECKED BY.

MICROFILMED ON

ROLL 00037 FRAME 53

40-B-006-2899

CHAPTER A6 - PROCEDURE FOR WELDER QUALIFICATION

SECTION A6.1-PROCEDURE FOR WELDER QUALIFICATION

1.0 SCOPE:

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

2.0 CONTENTS:

1. Qualification of Welder.
2. Table- A6.1 - Welder Qualification Requirements for non-IBR applications.
3. Figure-A6.1 - Structural Tack Weld Specimen.

Figure- A6.2 - Break test.

Figure- A6.3 - Weld Positions.

Figure- A6.4 - 6G position

Figure- A6.5 - Flat position

Figure- A6.6 - Vertical position

Figure- A6.7 - Horizontal position

Figure- A6.8 - Overhead position

Figure- A6.9- Plate Butt Weld Specimen.

Figure- A6.10- Pipe Butt Weld Specimen.

Figure A6.11: BHEL issued Welder Qualification Certificate

Figure A6.12: Plate to plate fillet weld specimen

Figure A6.13: Square groove weld specimen in butt joints

Figure A6.14: Bend test for square groove welds in butt joints

4. Record of Welder Performance Qualification Tests.
5. Welder performance monitoring.

SECTION A6.2-QUALIFICATION OF WELDER *FOR NON IBR APPLICATIONS*

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 Visual inspection as per Cl. 4.1.8

3.1.2 Break Test as per Figure-A6.2.

3.2 For Plate and Pipe Butt welders:

3.2.1 Visual inspection as per Cl. 4.1.8

3.2.2 ***A minimum of 150mm of weld has to be subjected to Volumetric NDE. In case of small diameter tubes, total circumferential length can be maintained by using multiple test pieces.*** 100% Radiographic examination of test welds shall be carried out. Procedure and acceptance criteria shall be as per NDE Manual (BHEL:PS:NDEM – Latest)

3.3 Welder Qualification Plate to plate fillet welds (applicable only for structural welds):

Nominal test plate thickness shall be minimum 12 mm and weld length 200 mm minimum. Refer figure-A6.12 for fillet weld break and macro etch test plate.

3.3.1 Visual Inspection as per Cl.4.1.8 (c)(i).

3.3.2 Macro etch Test: The test specimens shall be prepared with a finish suitable for macroetch examination. A suitable solution shall be used for etching to give a clear definition of the weld. The face of the macro etch shall be smooth for etching and acceptance criteria as per Cl. 4.1.8 (c)(ii).

3.3.3 Fillet weld Break Test: The entire length of the fillet weld shall be examined visually, and then a 150 mm long specimen shall be loaded in such a way that the root of the weld is in tension. At least one welding start and stop shall be located within test specimen. The load shall be increased or repeated until the specimen fractures or bends upon itself. The acceptance criteria as per Cl. 4.1.8 (c)(iii).

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:

a) **Structural Tack Welding:**

Visual Examination:

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

b) **Plate/Pipe Welding:**

Visual *Examination*:

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).

c) **Plate and Plate Fillet welders**

i. Visual Examination:

- ***No cracks***
- ***All craters shall be filled to the full cross section of the weld***
- ***The fillet size shall not be less than the required leg sizes***
- ***Weld reinforcement shall not be more than 1 mm***
- ***Undercut shall not be allowed more than 1 mm***

ii. Macro Test:

The test specimen shall conform to the following requirements:

- ***Fillet welds shall have fusion to the root of the joint not necessarily beyond***
- ***Minimum leg size shall meet the specified fillet weld size***

iii. Break Test:

The test specimen shall pass if:

- ***The specimen bends flat upon itself or***
- ***The fillet weld, if fractured, has a fracture surface showing complete fusion to the root of the joint with no inclusion or porosity larger than 2.5 mm in greatest dimension and***
- ***The sum of the greatest dimensions of all inclusions and porosity shall not exceed 10 mm in the 150 mm long specimen.***

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.

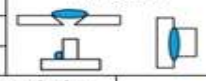
The above register shall be updated for deletions also. Copies of welder identity card (including details as in 7 b and relevant variables qualified) and pertinent radiography reports.

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
13. ***Figure-A6.11: BHEL issued Welder Qualification Certificate***
14. ***Figure-A6.12: Plate to plate fillet weld specimen***
15. ***Figure-A6.13: Square groove weld specimen in butt joints***
16. ***Figure-A6.14: Bend test for square groove welds in butt joints***

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 Metal Note 1	Test Coupon Dimension OD, t	Electrode 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 (E7018) F4	3F&4F 3F&4F	Fig. A6.1 A6.2 & A6.3	T-Unlimited T-Unlimited	All All	F2, F1 F4 & Below
2	Plate Welder (Structural)	- do -	t≥25mm t<25mm	F4 F4	3G & 4G 3G & 4G	Fig.A6.7 & A6.8	T≥3.0 mm ***T:3.0 mm to 2t***	All All	F4 & Below F4 & Below
3	Plate Welder (Other than structural)	- do -	t≥13mm t<13mm	F4 F4	2G, 3G & 4G 2G, 3G & 4G	Fig.A6.6 , A6.7 & A6.8	T-Unlimited OD≥600mm T≤2t OD≥600mm	All All	F4 & Below F4 & Below
4	Pipe/Tube Welder	- do -	OD<25mm OD≥25mm &≤73mm OD>73mm t<13mm t≥13mm	F4 F4 F4 F4 F4	6G 6G 6G 6G 6G	Fig.A6.4	Test piece Dia.& above 25mm & above 73mm & above T≤2t T-Unlimited	All All All All All	F4 & Below F4 & Below F4 & Below F4 & Below F4 & Below
5	***Structural steel - Sheet***	***P1 Gr 1***	***≤3 mm***	***(E6013) F2*** ***(E7018) F4***	***3G&4G*** ***3G&4G***	***Fig.-A6.13 & A6.14***	***Thickness tested***	***All*** ***All***	***F2, F1*** ***F4 & Below***
6	***Structural Plate Welder (for Fillet Qualification)***	***- do -***	***t≥12mm***	***(E6013) F2*** ***(E7018) F4***	***3F & 4F***	***Fig.A6.12 & A6.3***	***3.0 mm - Unlimited***	***All***	***F2, F1*** ***F4 & Below***

Note: Sl. No's 2, 3 and 4 above, 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.

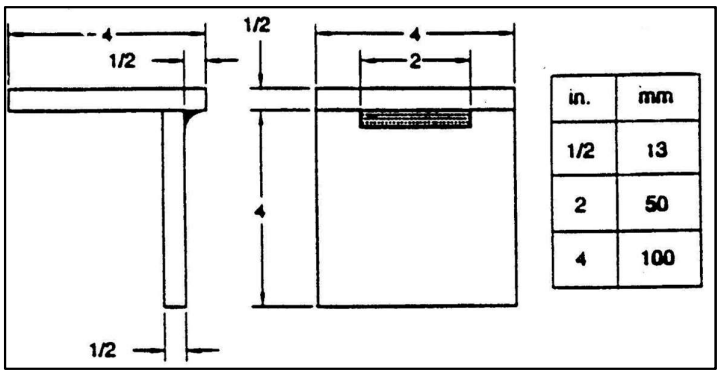


Figure A6.1 – Structural Tack Weld Specimen

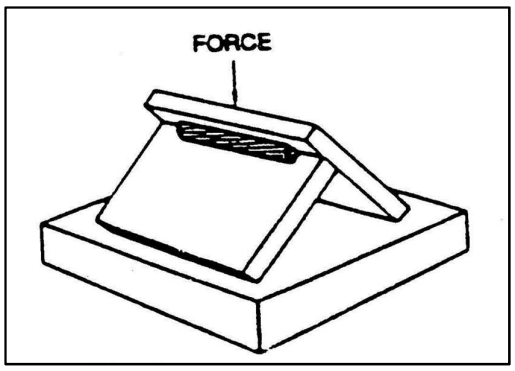


Figure A6.2 – Break Test

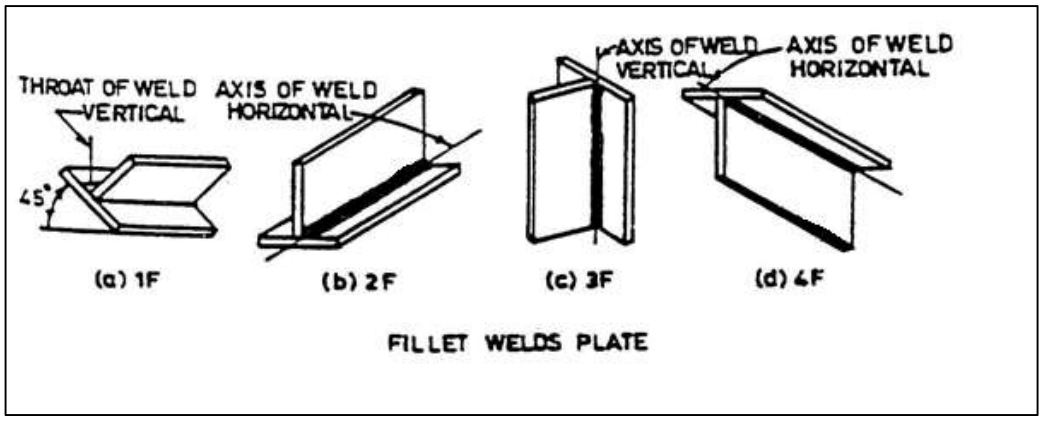


Figure A6.3 – Weld Positions

SECTION A6.3-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 site fabrication, 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 by IBR, 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 have basic 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’ or double ‘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.

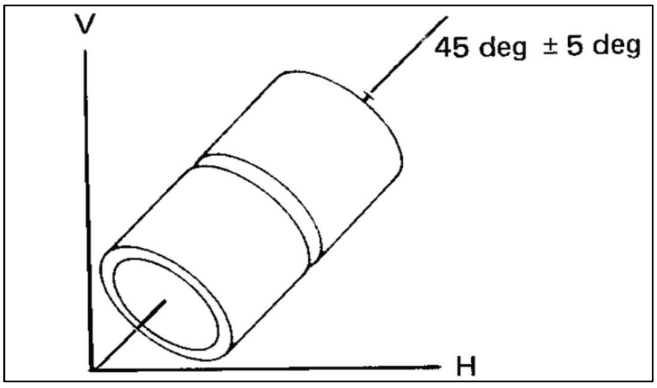


Figure A6.4 6G-Position

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.

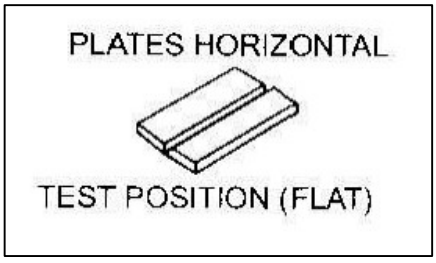


Figure A6.5 Flat position

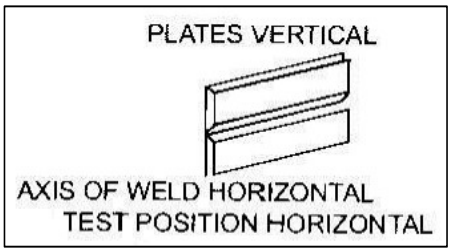


Figure A6.6 Horizontal Position

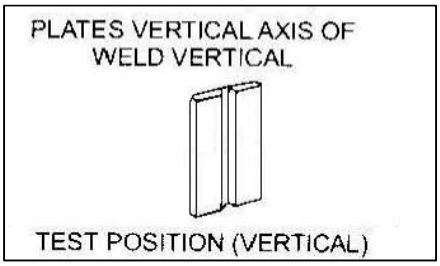


Figure A6.7 Vertical Position

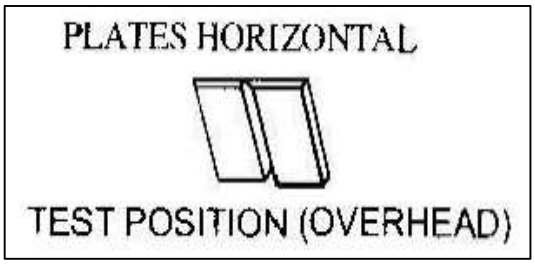


Figure A6.8 Overhead Position

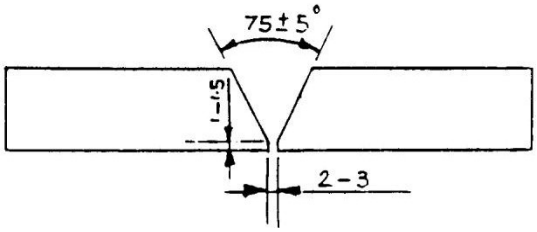
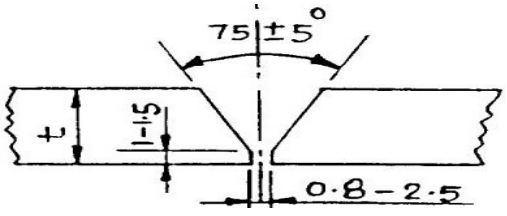
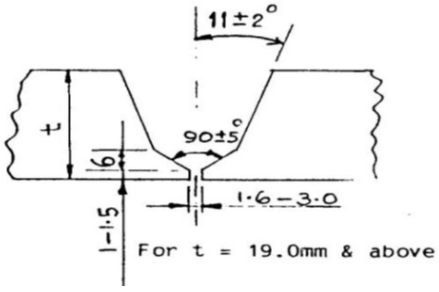


Figure A6.9- Plate butt weld specimen



(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

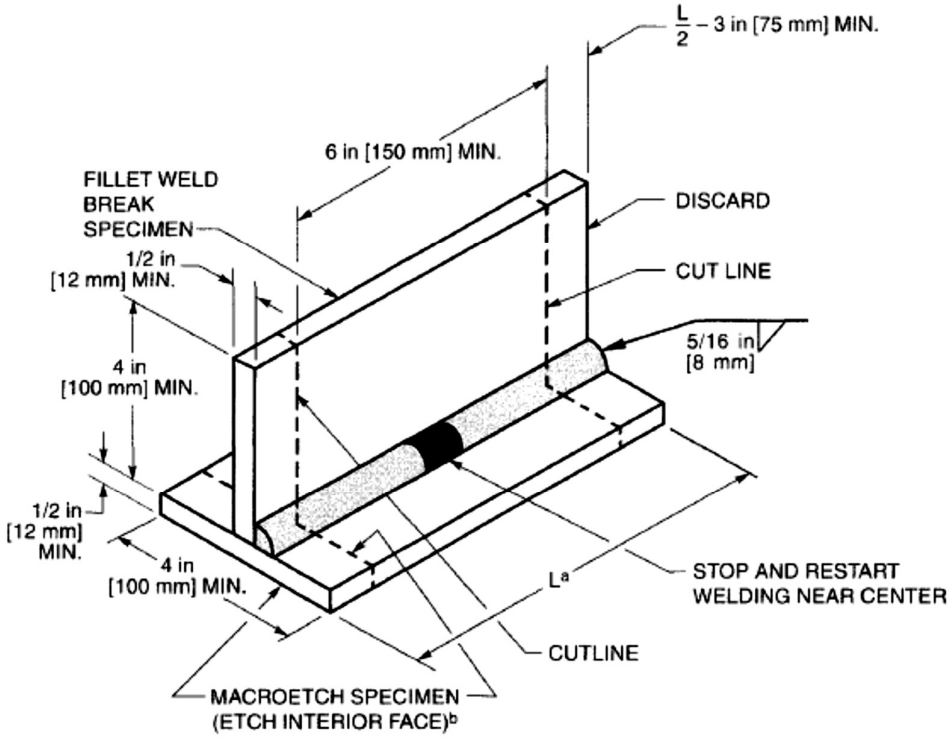


Figure – A6.12 – Plate to plate fillet Weld Specimen

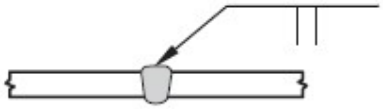


Figure – A6.13 – Square groove weld specimen in butt joints

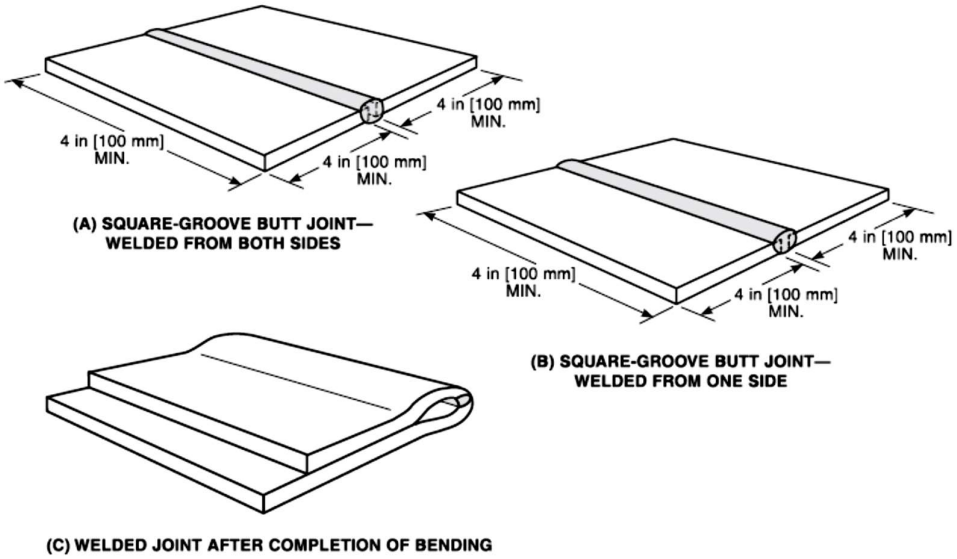


Figure – A6.14 – Bend test for square groove welds in butt joints

SECTION A6.4-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 2.7.1 reviewing 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

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 – A7
INSPECTION OF WELDING

1.0 SCOPE:

1.1 This procedure provides details for performing visual inspection of weld fit-ups, welding in progress & completed welds ***and hardness details of completed welds of Low alloy steels (P4 & P5A 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.

7.0 Hardness of P4 and P5A welds:

Whenever hardness checks are envisaged for P4 and P5A butt joints, the maximum hardness shall be limited to 260 Hv (250 BHN), unless specified otherwise.

CHAPTER – A8
REPAIR WELDING

1.0 SCOPE:

1.1 This procedure details steps to be taken for weld repairs.

2.0 PROCEDURE:

2.1 Unacceptable welds, based on visual inspection or NDE, shall be repaired.

2.2 **Removal of Defects:**

2.2.1 The identified defect area shall be marked on the part.

2.2.2 The defects may be removed by grinding/thermal gouging. Thermal gouging is not permitted for Gr.23, Gr.91, Gr.92and stainless steel materials.

2.2.3 Where thermal gouging is done, adopt the requirements of preheating as detailed in Heat Treatment Manual.

2.2.4 Only grinding is permitted for the last 6 mm from the root.

2.3 Removal of defects shall be verified by visual inspection, PT/MT/ RT, as appropriate.

2.4 The profile of ground portion shall be smooth and wide enough to permit proper fusion during repair welding.

2.5 Repair welding shall be carried out as per the procedure for the initial weld.

2.6 Repair weld shall undergo the same type of NDE as the initial weld.

2.7 Repeat steps 2.1 to 2.6 till acceptable weld is made.

2.8 Where the defect volume is high, Cut and weld of joints is recommended. For repair of tubes , with respect to the cutting , following guidelines shall be followed:

i. For repair of tubular pressure parts (Furnace water wall, super heater, re-heater and economiser tubes), cutting of tubes shall be done only by band saw/ hack saw/ grinding.

ii. Use of gas cutting is prohibited since the spatter, slag and molten metal generated during the process of gas cutting may lead to choking of tubes and subsequent failures during operation.

iii. During cutting/ grinding, enough care shall be taken to avoid damage of adjacent tubes

iv. The cut ends of tubes (open ends) shall be properly covered and protected until the final joint is made to avoid any inadvertent falling/ entry of foreign materials/ object.

V. Prior to fit-up of tubes for welding, it shall be ensured that tube inner surface is free of any obstruction. Videoscopic inspection/Hose check / visual check shall be done as feasible.

3.0 Where a specific repair procedure is provided by the manufacturing unit, the same shall be followed.

4.0 RECORDS :

Record the details of repairs carried out with correlation to welder(s), NDE and heat treatment reports.

CHAPTER – A9
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.

PART - B

CHAPTER - B1
PRE-ASSEMBLY AND WELDING OF CEILING GIRDERS

1.0 PREPARATION FOR PRE-ASSEMBLY:

1.1 Prepare the pre-assembly bed preferably inside the boiler as per Figure B1.1 ***or*** B1.2.

a. Boiler Main Columns on LHS & RHS may be used for supporting bottom beams of pre-assembly bed ***as per*** Figure B1.1.

b. ***In case of pre-assembly on ground as per Figure B1.2***, Concrete blocks shall be placed over plate of ***minimum 36 mm thickness laid on the levelled and compacted ground for the preassembly.***

1.2 Ensure bottom support members are uniformly spaced and closer (approximately 1 metre) on either side of the joint to facilitate locking all around and avoid sagging during welding & PWHT.

1.3 Identify Girder pieces – Check Work order / PGMA / DU No, girder designation etc.
Place girder pieces on bed for pre-assembly in sequence as per drawing.
Check and repair damages of edge preparation of individual pieces, if any, after placement on bed before fit up.

1.4 Check gap between flanges and web at fillet joint location (LHS & RHS) (Reduce web height before fit up, if required by grinding, so as to ensure minimum 3 mm gap at top & bottom for free expansion of web inside flanges on pre-heating).

2.0 PRE-ASSEMBLY FIT UP & ALIGNMENT:

2.1 Do pre-assembly fit up and alignment of all girder pieces using shop match marks. Use 'L' clamps and wedges (Tack welds shall not be permitted on the weld joints) for web alignment to lock the joint during welding of flange joints and to facilitate weld shrinkage. Water level of Ceiling girder in bed is shall be measured just before starting the welding. Water level of bed shall be ensured for every change of Ceiling Girder placed on the bed.

2.2 Check, measure and record the below parameters for the pre-assembly before welding (Figure B1.3/ Figure B1.4). The values shall also be measured & recorded after welding & PWHT being carried out.

- Sweep by piano wire on bottom flange (max 3mm at joints & 10 mm for assembly, (5mm for bolted assembly)
- Camber by water level on bottom flange (max 3mm at joint & 10 mm for assembly, (5mm for bolted assembly)
- Length between girder pin bolt hole centres (overall max 5mm)
- Diagonal difference (max 15 mm , 5mm for bolted assembly)
- Root gap (Flange=4 to 6mm; Web=6 to 8mm)

- Web verticality by plumb (Web verticality shall be maintained within 10mm.)
- Distance between reference punch marks at weld joints (To monitor weld shrinkage)

NOTE:

1. Flange root gap will be absorbed during welding as weld shrinkage.
2. Tolerances given above are indicative.
3. To accommodate weld shrinkage ,ensure
    1. Web root gap 3-4 mm more than flange root gap
    2. Length before welding = Drawing length + root gap of flange joints
4. Ensure temporary locking & welding of the pre-assembly before start of girder welding (Figure B1.5) with provision for longitudinal movement during welding to avoid accumulation of thermal stresses & facilitates controlled weld shrinkage.

3.0 PRE-ASSEMBLY WELDING WITH PRE-HEAT & POST-HEAT

3.1 Weld thermocouples on top & bottom flange and web joints (Figure B1.6). Arrange pre-heating of flange and web joints with electric resistance coil heaters.

Record entire cycle of preheat, inter pass & post-heat temp of joints during welding including intermissions/stoppages with a calibrated temperature recorder.

Engage qualified welders for welding. Issue weld job card (Refer Annexure -VII). Ensure usage of approved welding electrodes with necessary baking before use. Carry electrodes always in portable ovens.

Start welding after ensuring required pre-heat and follow recommended weld sequence (Figure B1.7 with 2 welders per joint) for effective control of weld shrinkage.

Ensure pre-heating temperature after back grinding before start of welding. On completion of welding, prepare the weld surface to facilitate NDE.

4.0 NON-DESTRUCTIVE EXAMINATION (NDE):

4.1 FLANGE BUTT JOINT:

Root Back grinding: 100% LPI/MPI

Interstage radiography after welding 50mm depth in case of thickness > 80mm (desired)

On completion of weld: 100 % RT for thickness >32mm &≤ 70mm

100 % UT for thickness > 70mm

100 % MPI for thickness > 25mm (after PWHT where applicable)

4.2 <u>WEB BUTT JOINT</u>:

Root Back grinding: 100% LPI/MPI

On completion of weld

Spot RT for thickness <32mm – Spot RT shall be done with minimum one Spot/ joint. In case of T joints Spot RT shall cover all "T" spots.

In case of defect in any spot, two more spots in the same joint shall be radiographed. In case of furtherdefects,100%RT shall be done. All defects shall be repaired.

100% RT for thickness >32mm

4.3 <u>FILLET WELDS</u>:

Between flange and web 100% MPI (after PWHT where applicable)

5.0 PRE-HEATING, POST HEATING & PWHT REQUIREMENTS :

Refer applicable WPS & Heat Treatment Manual (AA/CQ/GL/011/ PART II-HTM– Latest)

5.1 PWHT CYCLE:

5.1.1 Weld thermocouples on top & bottom flange and web joints (as per Figure B1.6). Arrange PWHT of flange and web (if t>50mm) joints with electric resistance coil heaters. Issue PWHT job card. (Refer Annexure VIII) Select midpoint of temperature range and control cycle within a tolerance of ±15°C. Record PWHT cycle with a calibrated temperature recorder. Identify PWHT chart with chart No & date and PWHT cycle with weld joint number. Review the cycle and record observations / acceptance on chart.

6.0 FINAL INSPECTION (AFTER PWHT):

6.1 Grind / buff the Flange Butt & Fillet joints (site welds) and conduct MPI. Clean all Site welds and paint with two coats of red oxide primer. Repeat all checks under section B and record measurements (Figure B1.3/ B1.4).Punch center line of girder on flange thicknesses and top surface of top flange.

7.0 OTHER PREPARATORY WORKS FOR ERECTION:

7.1 Use lifting lugs provided in the web of the girder during all handling operations. Blue match girder pin bottom piece with column to ensure minimum 80% contact area and complete support lugs welding in position, Subsequently blue match girder pin top piece

with girder to ensure minimum 80% contact area, tack weld support lugs in position, remove and complete lugs welding. Conduct LPI & maintain record.

7.2 Open the girder pin assembly, buff clean the pin and seating surfaces, apply grease, re-assemble and lock the pin with pin assembly by tack welding of lock plates.

Mount the girder pin assembly on ceiling girder for the easiness of erection of girder pins.

Clean Cement wash in the HSFG bolt area and cleat angles at WB's location.

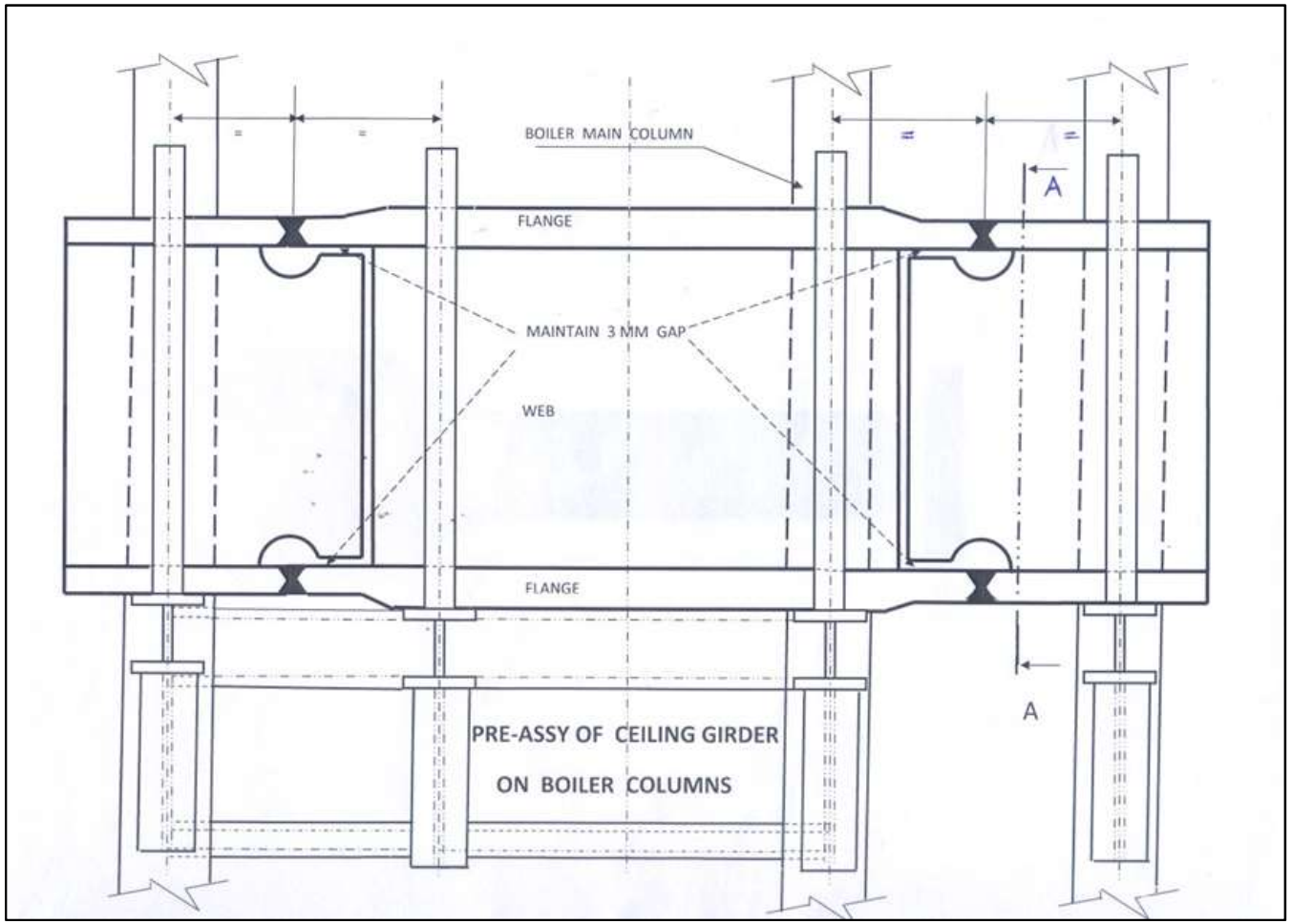


Figure B1.1 – PRE-ASSEMBLY OF CEILING GIRDER ON BOILER COLUMNS

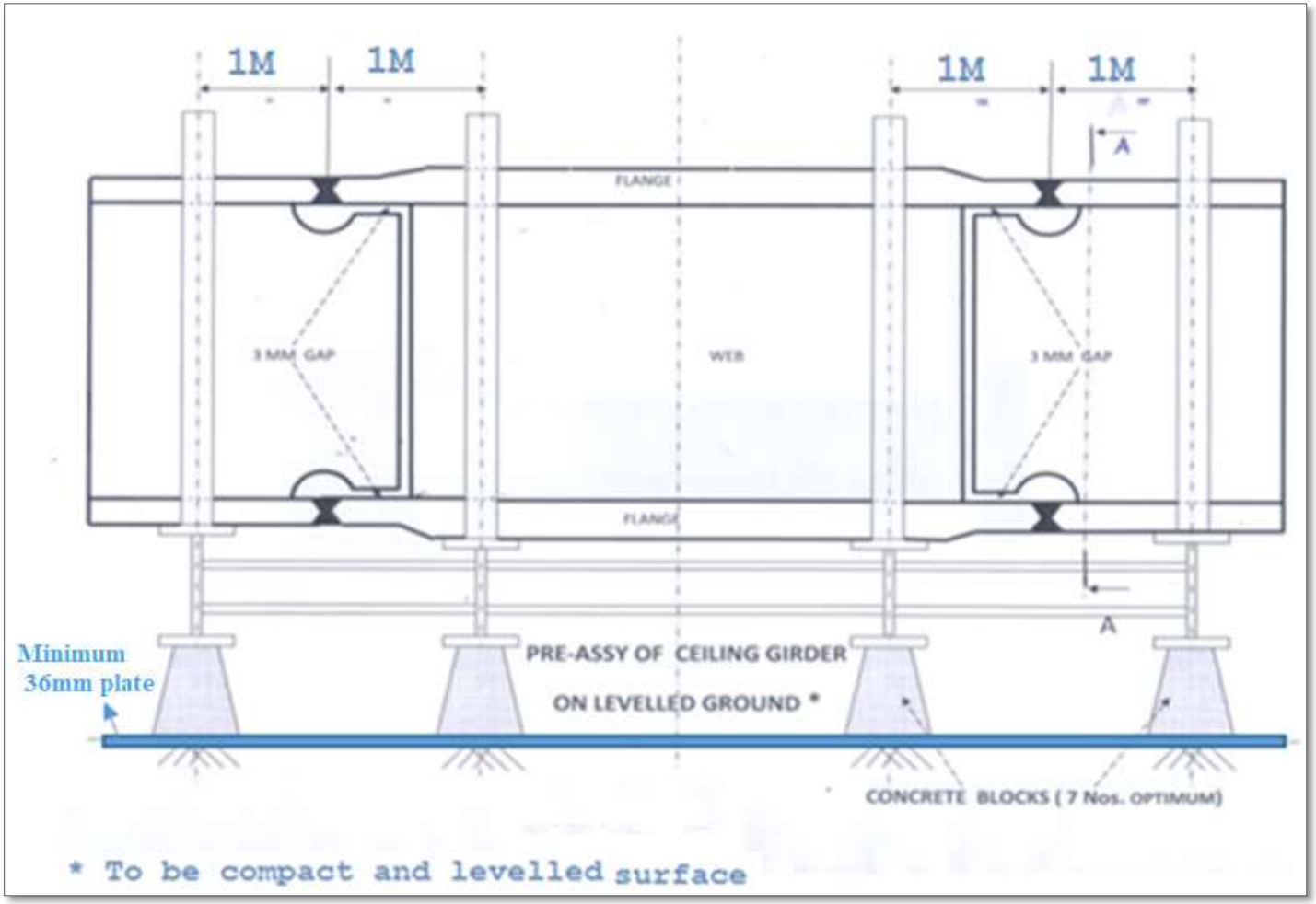


Figure B1.2 – PRE-ASSEMBLY OF CEILING GIRDER ON CONCRETE BLOCKS

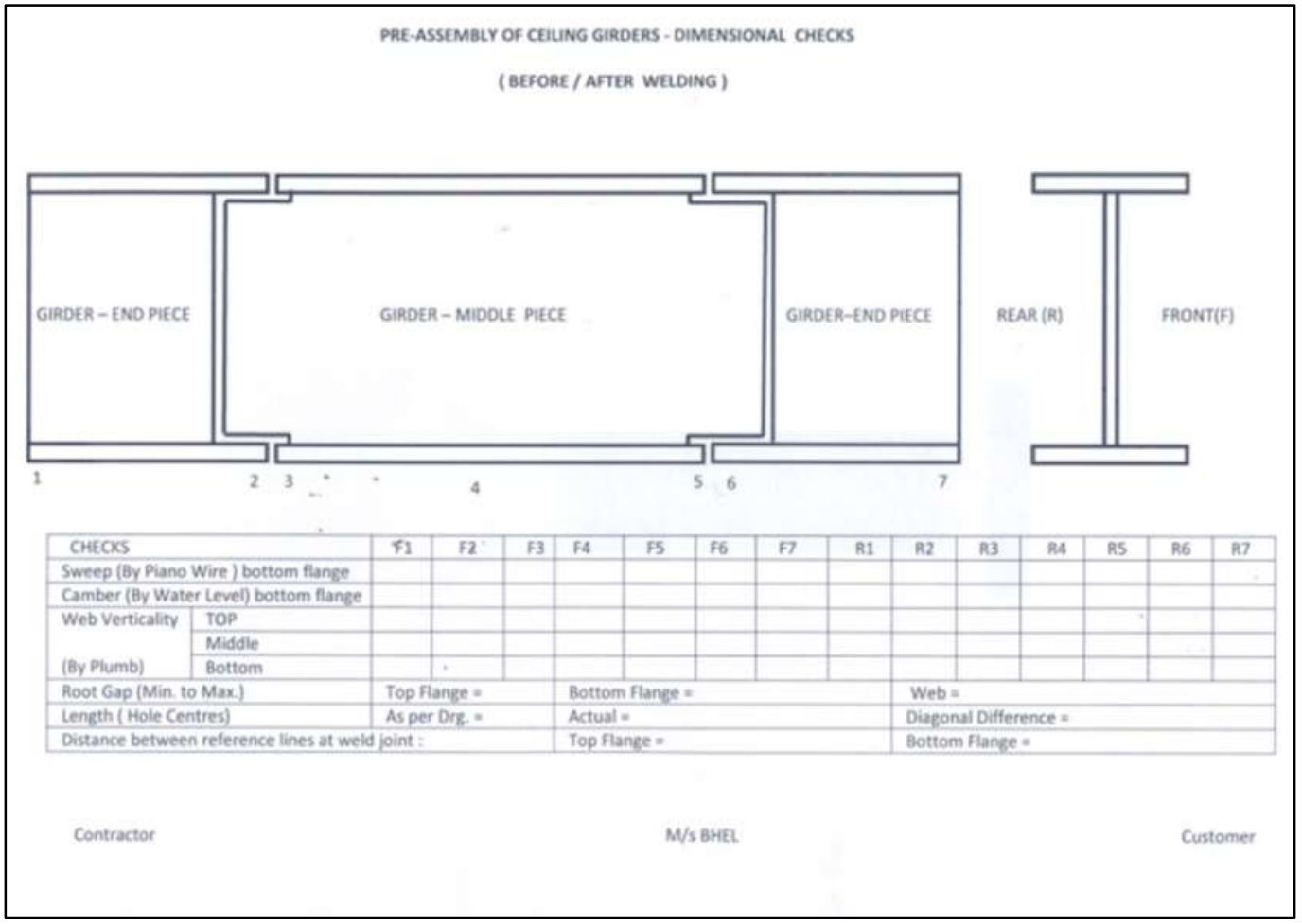
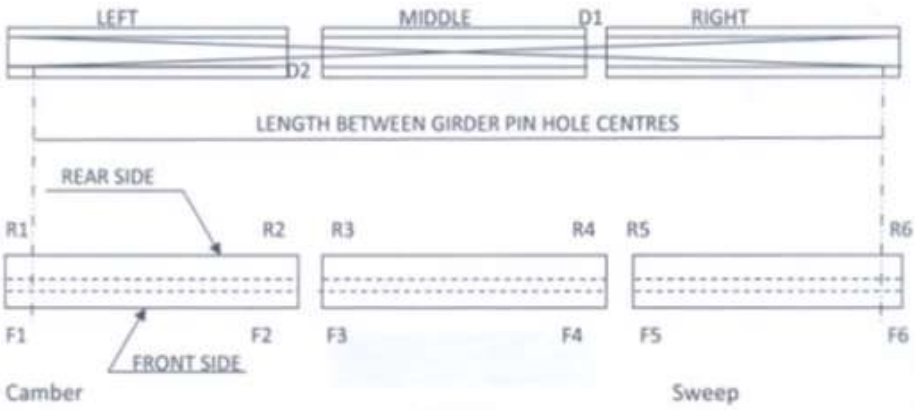


Figure B1.3 - PRE-ASSEMBLY OF CEILING GIRDERS – DIMENSIONAL CHECKS (BEFORE/AFTER WELDING)

CEILING GIRDER PRE – ASSEMBLY (BEFORE / AFTER WELDING)



CHECKS	F1/R1	Centre	F2/R2	F3/R3	Centre	F4/R4	F5/R5	Centre	F6/R6
Sweep (BOTTOM FLANGE)									
Centre (BOTTOM FLANGE)									
Level (Punch mark)									

	LHS JOINT(F2-F3/R2-R3)			RHS JOINT (F4-F5/R4-R5)		
	FRONT SIDE	REAR SIDE		FRONT SIDE	REAR SIDE	
WEB VEARTICALITY-TOP						
WEB VEARTICALITY-MIDDLE						
WEB VEARTICALITY-BOTTOM						
WEB PUNCH DIST-TOP						
WEB PUNCH DIST-MID						
WEB PUNCH DIST-BOTTOM						
T/F PUNCH DIST-FRONT						
T/F PUNCH DIST-MID						
T/F PUNCH DIST-REAR						
B/F PUNCH DIST-FRONT						
B/FPUNCH DIST-MID-FRONT						
B/FPUNCH DIST-MID-REAR						
B/FPUNCH DIST--REAR						
ROOT GAP(before welding)	T/F=	B/F=	WEB=	T/F=	B/F=	WEB=
Length(pin hole centres)	Drg' =			Actual		
Diagonal (web)	DI=	D2=		D1	D2=	

NOTE :

01 Check web verticality on both the pieces at weld joints -100mm centre line of weld
02 Punch distances (at web T/F& B/F) are recorded to monitor weld shrinkage
03 Length before welding =drg. length+2flange root gaps (will be absorbed during welding as weld shrinkage
04 Root gap-At flange =Min 4to6 mm At web=2mm more then flange root gap i.e. = 6to 8mm

Figure B1.4

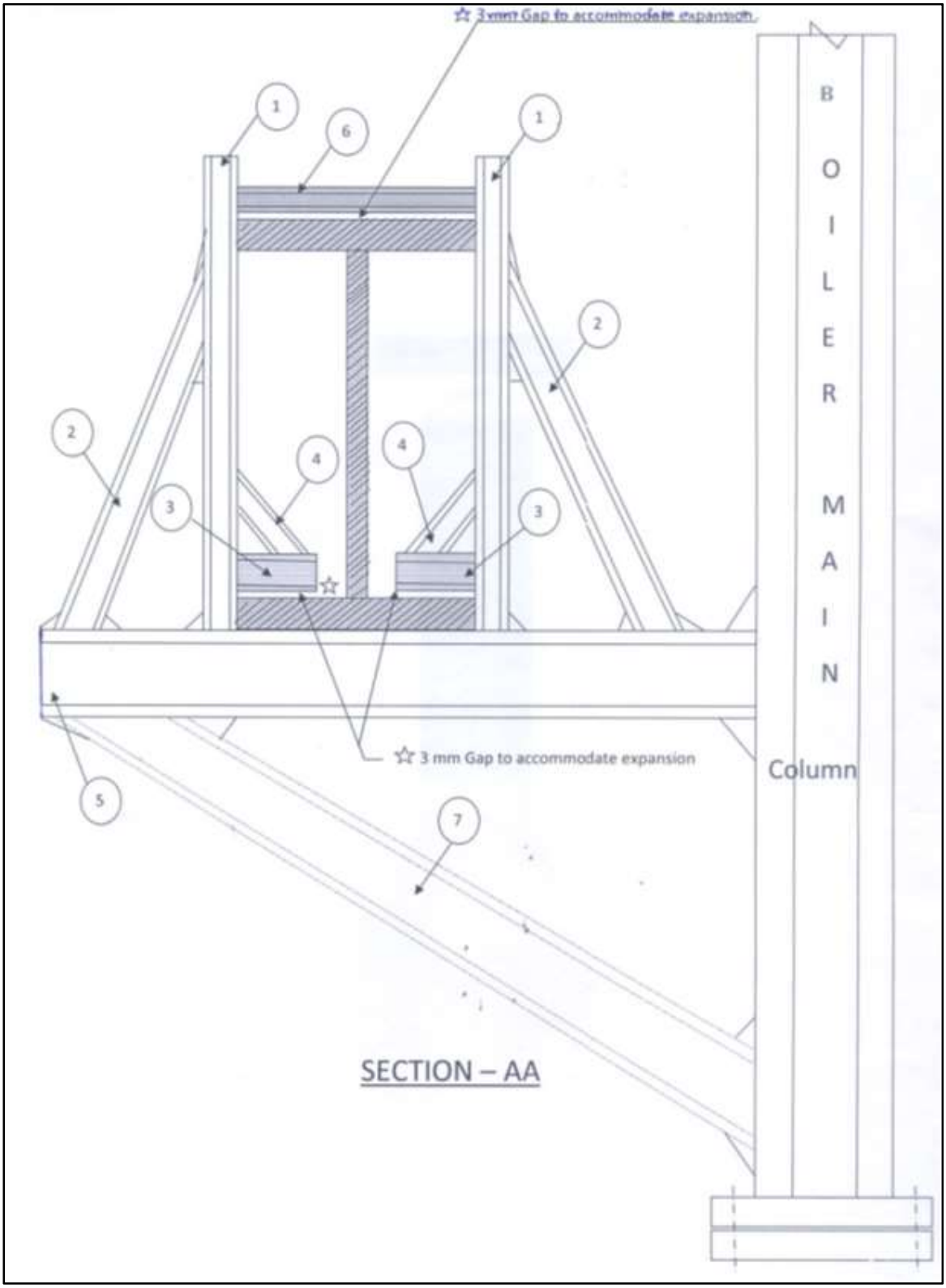


Figure B1.5 – TEMPORARY SUPPORTS AND LOCKING ARRANGEMENT

BILL OF MATERIALS (FOR ONE PRE ASSEMBLY BED)

Item.No.	Material Size	Quantity
01	ISMB 300 - L	12 Nos.
02	ISMB 200 - L	12 Nos.
03	ISMB 200 - L	12 Nos.
04	ISMB 200 - L	12 Nos.
05	ISMB 600 - L	6 Nos.
06	ISMB 300 - L	10 Nos.
07	ISMB 300 - L	10 Nos.

L - Length as required according to Site conditions and Positions of Bed.

(For Guidance Only)

Figure B1.5(Contd…)

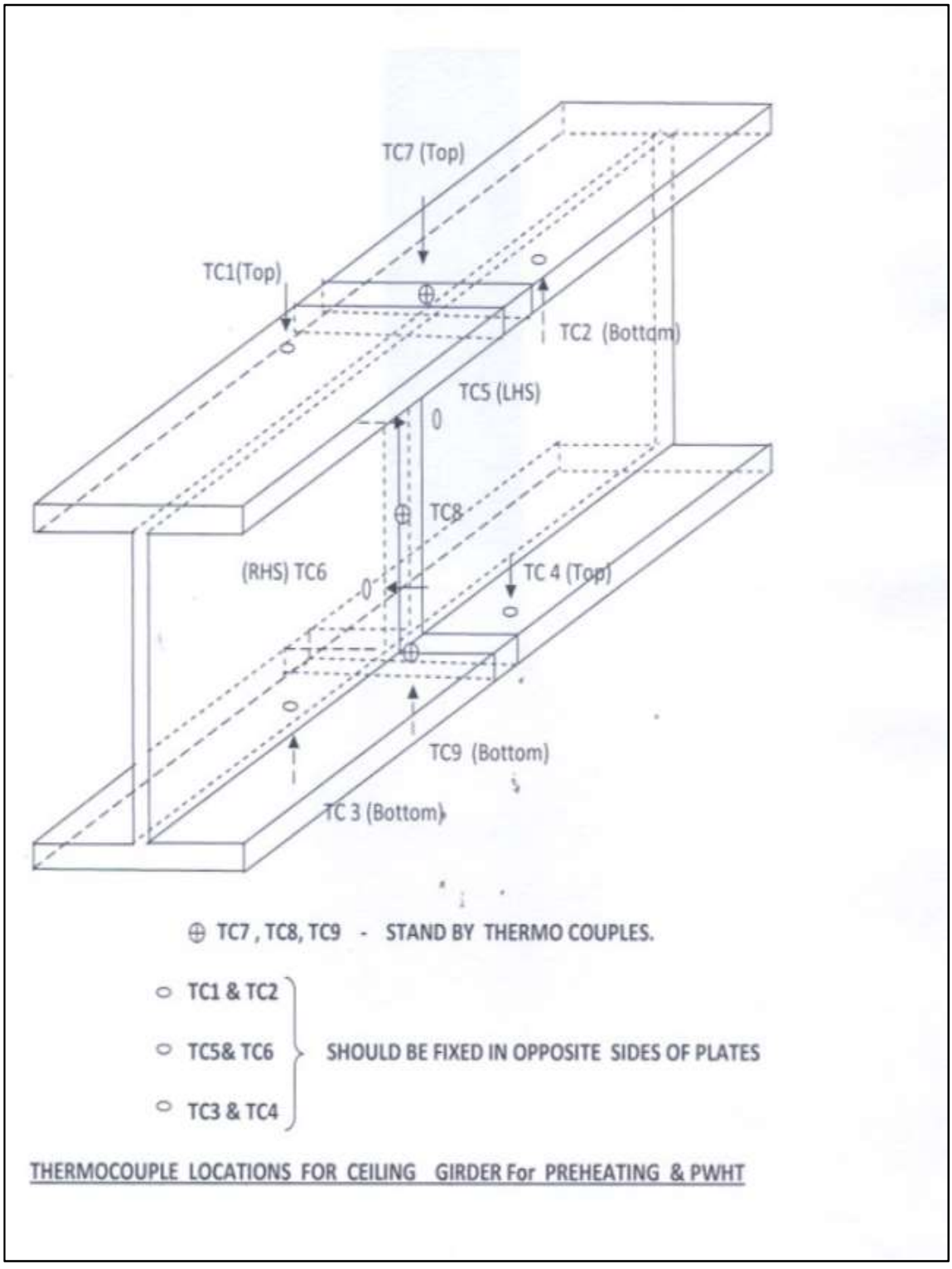

TC7 (Top)
TC1(Top)
TC2 (Bottom)
TC5 (LHS)
TC8
(RHS) TC6
TC 4 (Top)
TC9 (Bottom)
TC 3 (Bottom)
⊕ TC7 , TC8, TC9 - STAND BY THERMO COUPLES.
TC1 & TC2
TC5& TC6
TC3 & TC4
SHOULD BE FIXED IN OPPOSITE SIDES OF PLATES
THERMOCOUPLE LOCATIONS FOR CEILING GIRDER For PREHEATING & PWHT

Figure B1.6

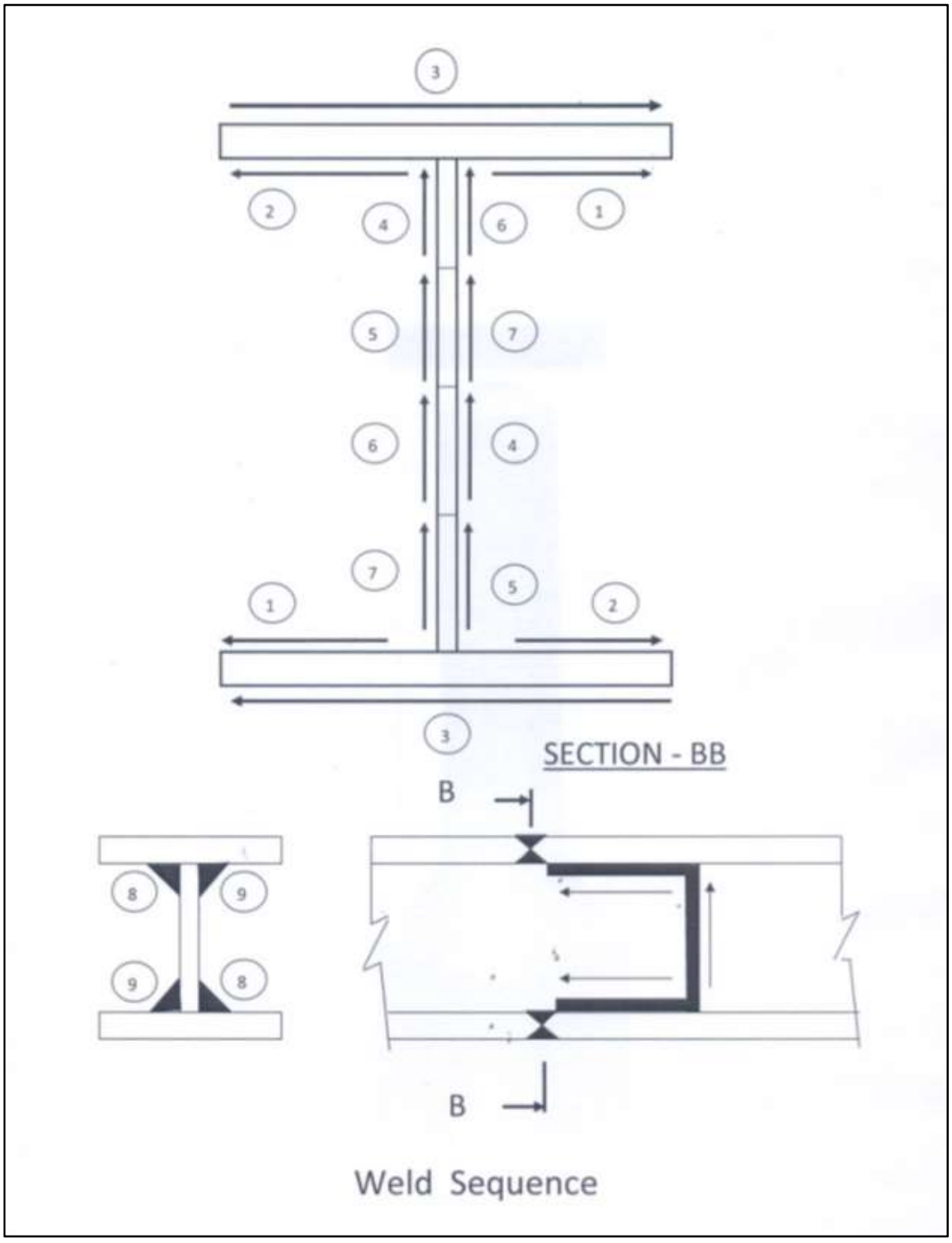


Figure B1.7 WELD SEQUENCE

WELDING SEQUENCE FOR CEILING GIRDER

Sl. No.	SEQ. No.	WELDING SEQUENCE
1	1	Pre heat and weld root run at flange
2	2	Weld root run at flange
3		Repeat step 1 and 2 and weld three runs
		Post heat and cool to room temperature
4		Back grind and do LPI (at flange)
5	3	Pre heat and weld Root + Three runs (at other side of the flange)
6		Follow steps 1, 2 and 3 alternatively and welding upto 50mm depth of the groove of the flange
7		Grind the flange welding and take interstage RT if required Correct the mismatch and check the root gap of the web and grind if required
8	4	Weld root run (at web)
9	5	Weld root run (at web)
10	4	Weld two run (at web)
11	5	Weld two run (at web), post heat and cool to room temperature
12		Back grinding and do LPI (at web)
13	6	Root run (at other side of the web)
14	7	Root run (at other side of the web)
15		Back grinding and do LPI (at web)
16	6	Weld two run at web
17	7	Weld two run at web
18	1,2	Weld three run at flange
19	3	Weld three run at flange
20		Follow steps 1,2 and 3 alternatively and complete the flange welding
21	4	Weld three run at web
22	5	Weld three run at web
23	6	Weld three run at web
24	7	Weld three run at web
25		Follow steps 4, 5,6,7 alternatively and complete the web welding
26	8	Weld root +two run (at flange +web) - Fillet weld
27	9	Weld root +two run (at flange +web) - Fillet weld
28		Follow step 8 and 9 alternatively(each three run and complete flange +web fillet welding)

Annexure - VII

BHEL: _____ SITE
Unit No.: _____

WELDING JOB CARDFOR CEILING GRIDERS

Unit no.	**Area :**	Boiler/TG/PCP
Card no.	**Date:**	
PGMA, DU		
WPS NUMBER		
Joint No.		
Drawing Reference		
Thickness		
Material		
Welder no.(s)		
Date of welding		
Filler wire		
Electrode		
Preheat temp °C		
Post heat temp °C		
Inter pass temp°C		

Contractor	**BHEL**	**Customer**

Annexure - VIII

BHEL: _____ SITE
Unit: _____

PWHT/SR (Stress Relief) JOB CARDFOR CEILING GRIDERS

Unit no.	**Area**	Boiler/TG/PCP
Card no.	**Date**	
PGMA, DU		
Joint No.		
Part name		
Thickness		
Material		
NDE Cleared on		
Rate of heating Max °C / hour		
Soak temperature °C		
Soak time Minutes		
Rate of cooling Max °C/hour		

Contractor	**BHEL**	**Customer**

CHAPTER - B2
ERECTION WELDING PRACTICES FOR SA335 P91/P92, SA182 F91/F92 & SA217 C12A MATERIALS

1.0 SCOPE:

1.1. This document details out the practices to be adopted during erection of SA335 P91/P92, SA182 F91/F92 and SA 217 C12A materials.

2.0 MATERIAL:

2.1 Pipe materials shall be identified as follows:-

1) Colour codes given by the MUs.
2) Hard Stamping: Specification, Heat No, Size.
3) Paint / Stencil: WO DU, as per the relevant drawing & document.

2.2 When any defect like crack, lamination, and deposit noticed during visual examination the same shall be confirmed by Liquid Penetrant Inspection. If confirmed, it shall be referred to unit.

3.0 ERECTION:

3.1 Edge Preparation and fit up:

3.1.1 Cutting of P91/P92/F91/F92 material shall be done by band saw / hacksaw / machining / grinding only. Edge preparation (EP) shall be done by grinding/machining. During machining /grinding, care shall be taken to avoid excessive pressure to prevent heating up of the pipe edges.

3.1.2 All Edge Preparations done at site shall be subjected to Liquid Penetrant Inspection (LPI). Weld build-up on Edge Preparation is prohibited.

3.1.3 The weld fit-up shall be carried out properly to ensure proper alignment and root gap. Neither tack welds nor bridge piece shall be used to secure alignment. Partial root weld of minimum 25mm length by GTAW at minimum 4 locations and fit-up by a clamping arrangement is recommended. Use of site manufactured clamps for fit up is acceptable. The necessary purging and preheat shall be done as per clause 3.3 and 5.0 respectively. Welding shall be done employing IBR qualified welders only.

3.1.4 The fit-up shall be as per the drawing. Root gap shall be 2 to 2.5mm and root mismatch shall be within 1.6mm. Suitable reference punch marks shall be made on both the pipes (at least on three axis).

a) At 200 mm from the EP for UT.
b) At 1000 mm from the EP for identifying weld during PWHT.

3.2. Fixing of thermocouple (TC) and heating elements during preheating and PWHT:

3.2.1 Heat Treatment Manual (AA/CQ/GL/011/ PART II-HTM-Latest),Chapter 1, Clause no. 3.1.1, 3.1.5, 3.2.1, 3.2.2&3.2.6shall be referred for guidelines for fixing of thermocouples and heating elements on the jobs

3.3 Arrangement for purging:

3.3.1 Argon gas conforming to Gr 2 of IS 5760 (latest) shall be used for purging the root side of weld. The purging dam (blank) shall be fixed on either side of the weld bevel prior to pre-heating. The dam shall be fixed inside the pipe and it shall be located away from the heating zone. Purging shall be done for root welding(GTAW) followed by two filler passes of SMAW in case of butt welds. Purging is not required in the case of nozzle and attachment welds, when they are not full penetration joints.

3.3.2 The flow rate which shall be maintained during purging is 10 to 26 litres/minute. Purging shall be started from inside of pipe when root temperature reaches 220°C. Continuous and adequate Argon Gas shall be provided to ensure complete purging in the root area. The minimum pre-flushing time for purging before start of welding shall be 5 minutes, irrespective of the pipe size.

3.3.3 Wherever possible, solid purging gas chambers shall be used which shall be removed after welding. If not possible, only water-soluble paper is to be used. Plastic foils that are not water-soluble are NOT acceptable.

3.3.4 **Using Aluminium dam arrangement**:

In order to retain the Argon gas at the inside of the pipe near root area of the weld joint, the purging dams made of Aluminium (or other suitable material like mild steel) and permanent gaskets may be provided during the weld fit-up work similar to one as indicated in the Figure B2.1.The Aluminium discs shall be firmly secured with a thin wire rope. After completion of the root welding followed by two filler passes, the disc shall be pulled outwards softly.

CAUTION: ENSURE REMOVAL OF PURGE DAM ARRANGEMENT AFTER WELDING

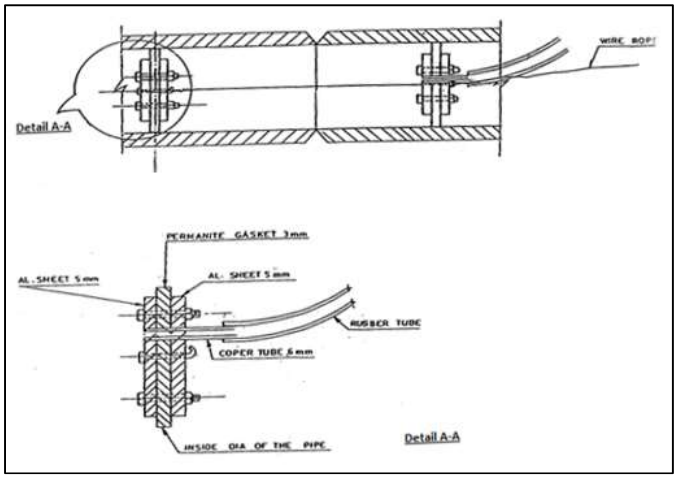


Figure B2.1 ALUMINIUM DAM ARRANGEMENT

3.3.5 **Using water soluble paper:**

The dams can be made of water-soluble paper/water soluble tissue paper for creating the purging chamber. The advantage in such dam arrangement is that dissolving in water can flush the dams. The following are different methods used.

The Purge damming process illustrated as below:

3.3.5.1. For small diameter pipes, simply stuff water soluble paper/water soluble tissue paper into each section to be joined(Refer Figure B2.2).

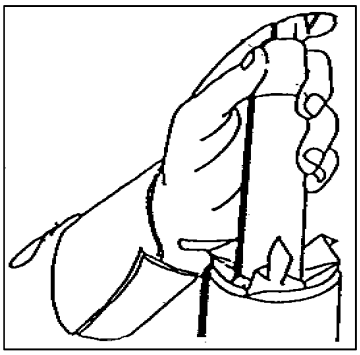


Figure B2.2 – INSERTION OF WATER SOLUBLE PAPER/ WATER SOLUBLE TISSUE PAPER

3.3.5.2. For larger pipes, cut out a circular aluminium foil disc slight larger than the diameter and shape it to the inside pipe circumference. (A small hole may be punched in the paper to ensure complete evacuation of air when purging)(ReferFigureB2.3).

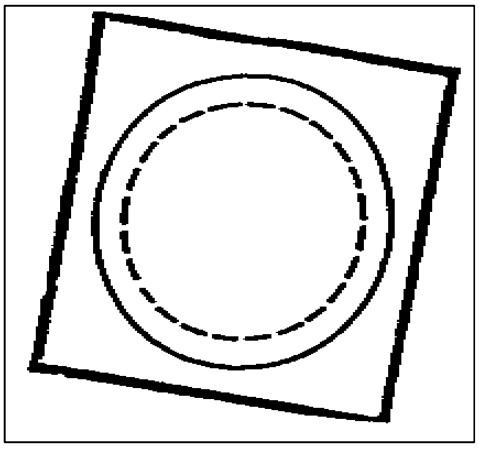


Figure B2.3 – ALUMINIUM FOIL DISC

3.3.5.3. Position the disc within the pipe and tape in place with water soluble paper. Repeat procedure for other section. Insert the backing gas into the joint with a needle valve and make root pass in the usual manner (Refer Figure B2.4).

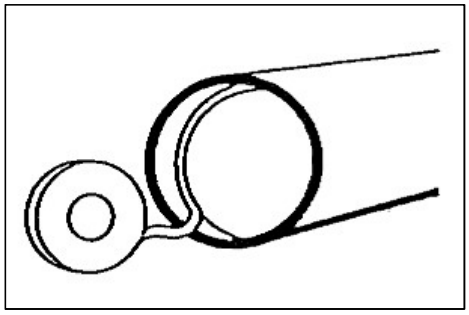


Figure B2.4 – POSITIONING OF DISC

3.3.5.4. For pipes larger than 508 mm diameter, simply splice two sheets of water soluble paper together with water soluble tape as per Figure B2.5 and repeat procedure as shown in Figure B2.3 and B2.4 above.

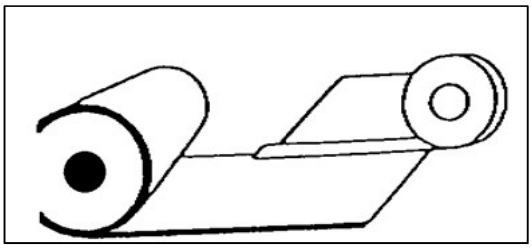


Figure B2.5 – JOINING OF TWO WATER SOLUBLE PAPERS

4.0 WELDING / WELDERS QUALIFICATION:

Welders Qualified as per IBR and qualified at site with Gr.91/Gr.92 material only shall be engaged. Welders log book shall be maintained and welders performance shall be monitored by site engineer. The applicable WPS as per FWS shall be followed for welder qualification and welding.

5.0 PREHEATING:

Heat Treatment Manual (AA/CQ/GL/011/ PART II-HTM-Latest),Chapter 1, Clause 3.1 shall be referred for guidelines for preheating.

6.0 WELDING:

6.1 Root Welding shall be done using GTAW process (as per WPS) five minutes after the start of argon purging. Filler wire shall be cleaned and free from rust or oil. Argon Purging shall be continued till minimum two filler passes of SMAW.

6.2 The inter-pass temperature shall not exceed 350°C. After completion of welding bring down the temp to 80–100°C and hold it at this temperature for one hour minimum. The PWHT shall commence after completing one hour of holding.

7.0 STORAGE OF WELDING CONSUMABLES:

Refer Chapter A3, Section A-3.4of this Manual for guidelines which shall be followed for receipt, storage, drying & holding and issue of welding consumables.

CAUTION: No LPI / Wet MPI/UT shall be carried out on weld before PWHT

8.0 POST WELD HEAT TREATMENT:

8.1 Heat Treatment Manual (AA/CQ/GL/011/ PART II-HTM– Latest), Chapter 1, Clause no. 3.2 shall be referred for guidelines on PWHT. In addition, the below requirements and precautions shall also be followed:

8.2 Welding and PWHT shall be monitored every one hour by site authorized personnel.

8.3 Preventive measures during power failure and non-functioning of equipment: No interruption is allowed during welding and PWHT. Hence all the equipment for the purpose of power supply, welding, heating etc., shall have alternative arrangements.(Diesel generator for providing power to the welding and heating equipment, standby welding and heating equipment, reserve thermocouple connections, gas burner arrangement for maintaining temperature etc.). Following preventive measures shall be adopted until normal power supply or backup power supply through diesel generator is restored.

8.3.1 **Interruption during start of preheating**:

In case of any power failure/interruption during preheating, the weld fit-up shall be insulated and brought to room temperature. After the electric supply resumes the joint shall be preheated as per Clause No: 5.0.

8.3.2 **Interruption during GTAW / SMAW**:

Maintain a preheat temperature of 220°C minimum using LPG gas burners till the welding is restarted. In case, preheat temperature is not maintained, an inter-stage stress relieving shall be carried out followed by visual inspection to ensure that no surface cracks are present in the weld, prior to restart of the welding.

8.3.3 **Interruption during cooling cycle**: After SMAW welding completion and cooling to holding temperature at 80 to 100°C, care shall be taken to avoid faster cooling rate by providing adequate insulation. The required temperature of 80 – 100°C shall be maintained by gas burner arrangements till power resumes / start of PWHT (within 8 hours).

8.3.4 **Interruption during post weld heat treatment**; Heat treatment Manual (AA/CQ/GL/011/ PART II-HTM– Latest), Chapter 1, clause no. 3.2.5 shall be referred for guidelines to be followed for interruption during PWHT.

8.3.5 In all the above cases (8.3.1 to 8.3.4), the temperature measurement on the weld joint shall be recorded using calibrated gauges/instruments at regular Intervals of 15 minutes in the log book by Site Engineer.

8.4 Caution:

The PWHT temperature recorded in the chart shall not deviate from the specified values since any deviations to the specified soaking temperature Range, will adversely affect the mechanical properties of the weldment and may lead to rejection of the weldment. The weld Joints should be kept dry and no water/liquid is allowed to come in contact with the weld or preheated portion of pipe under any circumstances, till PWHT is completed.

9.0 CALIBRATION:

All equipment like recorder, thermocouple, compensating cable, oven thermostat etc. shall have valid calibration carried at BHEL approved laboratories. The calibration reports shall be reviewed and accepted by welding In-charge at site prior to use.

10.0 NONDESTRUCTIVE EXAMINATION (Refer NDE Manual AA/CQ/GL/011/ Part III- NDEM latest):

10.1 All NDE shall be done after PWHT only. Prior to testing all welds shall be smoothly ground. All welds (fillet & butt) shall be subjected to MPI (MPI shall be done by YOKE type only). In addition to MPI, butt-welds and all full penetration welds shall be examined by UT.

UT procedure shall be as per BHE: NDT: PB: UT21 with additional requirements as in (a) through (e):

a) The calibration blocks used shall be of the same product form and material specification or equivalent P-Number grouping as one of the materials being examined. P-Nos. 1, 3, 4, 5A through 5C, and 15A through 15F materials are considered equivalent for this purpose.

b) The UT equipment shall be calibrated prior to use and should be of ‘digital type’ capable of storing calibration data as well as ultrasonic test results as per procedure numberBHE:NDT:PB:UT-21.

c) All recordable indications shall be stored in memory of – either the digital flaw detector or a PC for review at a later period.

d) The equipment calibration data for specific weld as well as the hard copy of ‘Static echo-trace pattern’ – showing the flaw-echo amplitude with respect to DAC, flaw depth, projection surface distance (probe position) and beam-path shall be attached to UT test report. This hard-copy of echo-trace with equipment calibration data shall form part of test documentation.

e) The examination as well as evaluation shall be performed by a qualified Level II personnel, and a test report shall be issued. Any defect noticed during NDT shall be marked with marker.

11.0 REPAIR OF WELD JOINTS:

11.1 Weld repair at root:

If any surface defect is revealed at the time of visual inspection during root welding, the following steps shall be followed:

1. Maintain the temperature at 80-100°C for 1 hour.
2. Perform inter-stage PWHT ***[for temperature and soaking time, refer to Heat Treatment Manual (AA/CQ/GL/011/ PART II-HTM– Latest), Chapter 1, Clause no. 3.2.11]***
3. Remove the defect by grinding.
4. After complete removal of defect, preheat the weld area to 220°C minimum and re weld with GTAW before starting SMAW, if required.

11.2 Weld repair on completion:

11.2.1 Any defect observed on the weld shall be brought to the notice of Site engineer. Any repair on weld shall be carried out with their approval only.

11.2.2 If any defects are noticed on the fully completed weld while performing UT after completion of PWHT, the depth of the defect shall be located from the weld outside surface. The defect area shall be marked and repaired as below:

a) The weld shall be removed by grinding (gouging not permitted) such that the area for repair welding shall be free from sharp corners and provided with sufficient slope towards the weld face sides.

b) Surface examination (MPI/LPI) on the ground area shall be performed to ensure complete defect removal before re-welding. Repair welding shall be carried as per the applicable WPS as for original welding.

12.0 HARDNESS SURVEY:

Hardness shall be measured using portable hardness tester ***(Equotip, Ultrasonic Contact Impedance, Pin Brinell or any other suitable equipment)***. The equipment used for the hardness measurement shall be calibrated as recommended by the equipment manufacturer.

The surface shall be cleaned and prepared as per hardness test instrument manufacturer's recommendation prior to hardness survey. Hardness survey shall be done on each joint at three locations along the circumference. At each location three

readings shall be taken on weld and parent metal. The readings on the parent metal shall be taken within 15mm from the edge of the weld. All the hardness values shall be recorded.

The hardness of the weld metal and the base metal in the soak band (heating band), excluding welding heat-affected zone shall be between ***180HB*** & 300HB for Gr.91 and Gr.92 joints. The hardness measurements shall be recorded in the format as given in Annexure IX. Joints having hardness above 300HB shall be re-heat treated and hardness shall be checked again. If hardness is still more, the case shall be referred to concerned MUs/ECs. In case Hardness falls below ***180HB*** also, the case shall be referred to the concerned MUs/ECs.

Cautionary note: To achieve meaningful and consistent hardness results, below recommendations should be followed:

- The accuracy of the instrument shall be verified prior to use.
- The surface to be tested shall be reasonably flat and free of scale and oxides, grease, paint, etc.
- Prior to hardness test, the de-carburized surface layer with a thickness up to 0.8mm shall be removed by grinding/buffing, without encroaching the specified minimum wall thickness of the pipe/tube.

ANNEXURE IX – HARDNESS MEASUREMENT

BHARAT HEAVY ELECTRICALS LTD

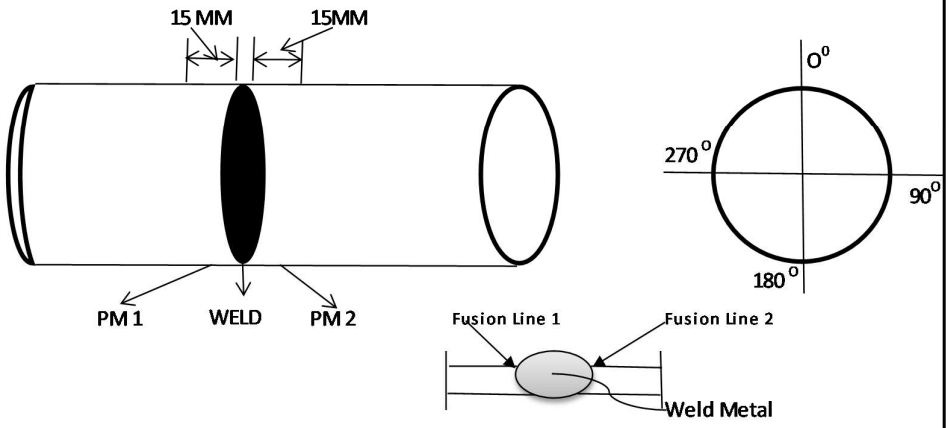
T91/T92/P91/P92/F91/F92/C12A HARDNESS TESTING PROTOCOL

PROJECT NAME :	**UNIT No. :**	**Customer Name :**
Report No.:	**Date :**	**Contractor :**
Description :	**Specn :**	**Stage of test : After PWHT**
Calibration Block No.:	**Equipment details:**	
PGMA :	**Model No :**	
JOINT NO. :		

Location	PM 1	WELD	PM 2
Readings	AVERAGE OF 3 READINGS	AVERAGE OF 3 READINGS	AVERAGE OF 3 READINGS
12 O'Clock/ 0^0			
3 O' Clock/ 90^0			
6 O'Clock/ 180^0			
9 O'Clock/ 270^0			

PM: PARENT MATERIAL (15 MM FROM THE WELD FUSION LINE). ALL AVERAGE READINGS SHOULD BE LESS THAN THE PERMISSIBLE HARDNESS VALUE.

HARDNESS TEST LOCATIONS SKETCH



Gap between successive reading shall be 1mm in the same spot

RECOMMENDATION / RESULT : ACCEPTED / NOT ACCEPTED / RE-PWHT

	AGENCY	NAME	SIGNATURE & DATE
INSPECTED BY	**CONTRACTOR**		
CHECKED BY	**BHEL**		
WITNESSED BY	**CUSTOMER**		

13.0 COMBINATION WELDING:

For other combination of materials with Gr.91/Gr.92, the applicable WPS for the same shall be obtained from concerned MUs/ECs.

14.0 DEMAGNETIZATION:

Refer NDE Manual BHEL:PS:NDM:latest Chapter 1.10

15.0 TRAINING:

15.1 The personnel engaged in P91 piping fabrication shall be trained in the following areas.

a. Method and care to be taken during fit-up.
b. Argon gas root purging arrangement.
c. Fixing of thermocouple and wires.
d. Arrangements for Pre/Post heating requirements and methods.
e. Adjustment of heating pads/cables at the time of controlling the temperature within specified tolerance limits during welding or PWHT in case of induction heating.
f. Good knowledge of the WPS requirements.
g. Handling of P91 welding consumables and re-drying conditions.
h. Special precautions to be taken during the power/equipment failure.
i. Weld joints of dissimilar thickness / material specification.
j. Weld defect control and weld repair systems.

15.2 **Specific training for welders:**

a. The qualified welders who will be engaged in P91 welding shall be given training on pipe joints simulated with P91 welding and heating cycle conditions.
b. The acquaintance on welding positions, as applicable shall be given using P91 pipes and P91 welding consumables.
c. Welding techniques and instructions on Dos and DON'Ts of P91 welding.
d. Welders only who are qualified on P91 welding alone shall be engaged.
e. Whenever new welders have to be engaged they shall undergo all the training as above and shall be qualified with P91 material only.

16.0 CONTROL ON WELDERS:

The welder during welding at site follow the following procedures. The welder shall interact with the HT operator (Induction equipment operator) to ensure that preheat and inter-pass temperature during welding are maintained as per requirements. The

welder shall not mix the welding electrodes with that of the other welder. At the end of the shift, the unused electrodes shall be returned to the stores.

17.0 PERSONNEL / CONTRACTORS ENGAGED FOR HEATING CYCLES (HT OPERATOR):

17.1 The Personnel / Contractor shall have adequate heat treat experience on P91 or similar material.

17.2 HT operator shall be aware of the following:

a. The equipment used and its working principle and operation.
b. The procedures to be followed in using heating equipment.
c. Procedure to be followed in case of power failure or equipment non-functioning so that heating cycle is not disrupted.
d. Calibration of equipment.
e. Method of fixing thermocouples and compensating cables leading to HT recorder.
f. Fixing of heating pads or elements on the pipe joints and also in maintaining the temperature within the specified limits.

18.0 NDE PERSONNEL QUALIFICATIONS:

All NDE personnel performing NDT like UT & MPI/LPI shall be qualified in accordance with BHEL Procedure meeting the requirements of recommended practice SNT–TC-IA.MPI & LPI shall be carried out by level I qualified personnel and shall be evaluated by level II qualified personnel. However UT examination and evaluation shall be done by level II qualified personnel.

19.0 LEVEL OF SUPERVISION

Site In charge shall be responsible for the completion of all activities from weld fit-up to final clearance of weld joints after satisfactory NDE and acceptance by BHEL/Customer/IBR.

20.0 DO'S AND DON'T'S DURING P91/P92/F91/F92/C12A WELDING, HEAT TREATMENT AND NDE AT CONSTRUCTION SITE:

20.1 **DO'S:**

a. Cutting by Band saw/Hack saw/Machining.
b. Pipes Edge Preparation by machining. Machining shall be done without excessive pressure to prevent heating up of pipe
c. Grinding may be done on exceptional cases after approval and taking adequate care to prevent overheating.

d. Thermocouple wire (hot/Cold junctions) shall be welded with capacitor discharge portable spot-welding equipment.

e. Reserve Thermocouples shall be made available, in case of failure of connected thermocouple elements.

f. Ensure adequate Argon Gas for complete purging of air inside the pipe before starting GTAW root welding.

g. Ensure Preheating at 220 °C minimum before GTAW root welding.

h. Start preheating only after clearance from Welding engineer / Quality assurance engineer for weld fit-up and alignment of the joint as well as fixing of Thermocouple connections (for Induction heating)

i. Do visual inspection on root weld maintaining weld preheating temp.

j. Continue Argon purging until the GTAW root welding followed by minimum two filler passes of SMAW, is completed.

k. Perform partial root welding to facilitate fit-up if necessary.

l. Ensure proper use of TIG wires as identified by color coding or suitable hard punching.

m. Keep the GTAW wires in absolutely clean condition and free from oil, rust, etc.

n. Dry the SMAW electrodes before use.

o. Ensure the inter-pass temperature is less than 350°C.

p. Hold at 80-100°C fora period of Minimum 1 hour before the start of PWHT.

q. Record entire heating cycle on Chart through recorders.

r. Exercise control during grinding of weld and adjoining base metal while removing surface/sub-surface defects or during preparation for NDE.

s. Ensure no contact with moisture during preheat, welding, post heat and PWHT of Weld Joints.

t. Ensure removal of argon purging arrangements after welding.

u. Use short Arc only. The maximum weaving shall be limited to 1.5 times the Dia. of the electrode.

20.2 <u>DON'T's</u>:

a. Avoid Oxy-Acetylene flame cutting.

b. Avoid Weld-build up to correct the weld end-d1 or to set right the lip of the weld bevel.

c. Avoid Arc strike on materials at the time of weld fit up or during welding.

d. Do not Tack weld the Thermocouple wires with Manual Arc/TIG welding.

e. NO GTAW root welding without thorough purging of root area.

f. Do not use Oxy-acetylene flame heating for any heating requirements.

g. Do not use Thermal chalks on the weld groove.

h. Do not stop argon purging till completion of GTAW root welding and two layers of SMAW.

i. No Tack welding or Bridge piece welding is permitted.

j. Do not use unidentified TIG wires or electrodes.

k. Do not exceed the maximum interpass temperature indicated in WPS

l. Do not allow moisture, rain, water, cold wind, cold draft etc. to come in contact with the weld zone or heating zone during the entire cycle from preheat to PWHT.

m. Do not exceed the limits of PWHT soaking temperature.

n. Do not Interrupt the Welding/heating cycle except for unavoidable power failures

o. Do not use un-calibrated equipment for temperature measurement during heating, welding, post weld, heat treating etc.

21.0 DOCUMENTATION:

The documentation shall be as per the approved Quality Plan.

CHAPTER – B3
ERECTION WELDING PRACTICES FOR SA 213 T91/T92 MATERIALS

1.0 SCOPE:

1.1 This document details out the practices to be adopted during welding of SA213 T91/T92 material.

2.0 MATERIAL:

2.1 Tube materials shall be identified as follows:-

a) Colour codes given by the Manufacturing Units (MU).

b) Paint / Stencil: WO DU, as per the relevant drawing & document.

2.2 When any defect like crack, lamination, and deposit noticed during visual examination, the same shall be confirmed by Liquid Penetrant Inspection. If confirmed, it shall be referred to unit.

3.0 ERECTION:

3.1 **Edge preparation and Fit up:**

3.1.1 Cutting of T91/T92 material shall be done by band saw/hacksaw/machining/ grinding only. Edge preparation (EP) shall be done by grinding/machining. During machining/ grinding, care should be taken to avoid excessive pressure to prevent heating of the tube edges.

3.1.2 The weld fit-up shall be carried out to ensure proper alignment and root gap. Neither tack welds nor bridge pieces shall be used to secure alignment. Use site fabricated clamps for fit up. Ensure that coil load does not come on stubs/header. Coil load shall be transferred to the crown plate/ end bar assembly. The necessary purging and preheat shall be done as per clause 3.3 and 5.0 respectively.

3.2 **Fixing of thermocouple (TC) and heating elements during preheating and PWHT**

3.2.1 Heat Treatment Manual (AA/CQ/GL/011/ PART II-HTM-Latest), Chapter 1, Clause no. 3.1.1, 3.1.5, 3.2.1, 3.2.2, 3.2.6 & 3.2.7 shall be referred for guidelines for fixing of thermocouples and heating elements on the jobs.

3.3 **Arrangement for purging**:

3.3.1 Argon gas with requisite quality shall be used for purging the root side of weld. The purging dam (water soluble paper) shall be fixed on header nipple side of the weld bevel prior to fit-up and pre-heating. Purging is to be done from cross over tube downstream end. (Refer Figure B3.2 and B3.3). Ensure that atmospheric air is completely purged out through the root gap before starting welding and welding can be continued with Argon backing. The flow rate which shall be maintained for purging is 6 to 8 litres per minute.

3.3.2 When root temperature reaches 220°C, start purging through cross over tube downstream end for 5 minutes. Then the root gap is to be covered by insulating material. Continuous and adequate argon gas shall be provided to ensure complete

purging in the root area. Only water-soluble paper is to be used. Plastic foils that are not water-soluble are NOT acceptable.

3.3.3 Usage of water soluble paper:

3.3.3.1 The dams can be made of water-soluble paper /water soluble tissue paper for creating the purging chamber. The advantage in such dam arrangement is that the dissolving paper dam gets flushed during hydraulic test. The following is the method to be used:

3.3.3.2 Stuff the water-soluble paper/ water soluble tissue paper into the Header Nipples at a distance of 60mm(approximately) from the weld end as per attached Figure B3.1

4.0 WELDING/WELDERS QUALIFICATION:

4.1 Welders Qualified as per IBR and qualified at site with Gr.91/Gr.92 material only shall be engaged. Welders log book shall be maintained and welders performance shall be monitored by site engineer. The applicable WPS as per FWS shall be followed for welder qualification and welding.

5.0 PREHEATING (Bunching of tubes can be followed):

5.1 Heat Treatment Manual (AA/CQ/GL/011/ PART II-HTM-Latest), Chapter 1, Clause 3.1 shall be referred for guidelines for preheating.

6.0 WELDING:

6.1 Welding shall be done as per the WPS. Filler wire shall be clean and free from rust or oil. Argon Purging shall be continued till completion of welding in case of full GTAW and for minimum two filler passes of SMAW in case of GTAW + SMAW.

7.0 POST WELD HEAT TREATMENT (PWHT) – RESISTANCE HEATING METHOD(Bunching of tubes can be followed):

7.1 Heat Treatment Manual (AA/CQ/GL/011/ PART II-HTM– Latest), Chapter 1, Clause no. 3.2.12 shall be referred for guidelines on PWHT.

8.0 HARDNESS SURVEY:

100% hardness survey shall be conducted on welds and parent material in first five coils. Based on satisfactory results, the hardness survey can be reduced to 10% covering each heat treatment cycles as per FWS requirement. ***Hardness shall be measured using portable hardness tester (Equotip, Ultrasonic Contact Impedance, Pin Brinell or any other suitable equipment). The equipment used for the hardness measurement shall be calibrated as recommended by the equipment manufacturer.***

8.1 The surface shall be cleaned and prepared as per hardness test instrument manufacture's recommendation prior to hardness survey. Hardness survey of weld and parent metal (both tubes) shall be carried out. The hardness shall be between

180HB & 300HB. The hardness measurements shall be recorded in the format as given in Annexure IX. Joints having hardness above 300HB shall be re-heat treated and hardness shall be checked again. If hardness is still more, the case shall be referred to concerned MUs. In case Hardness falls below ***180HB*** also, the case shall be referred to the concerned MUs.

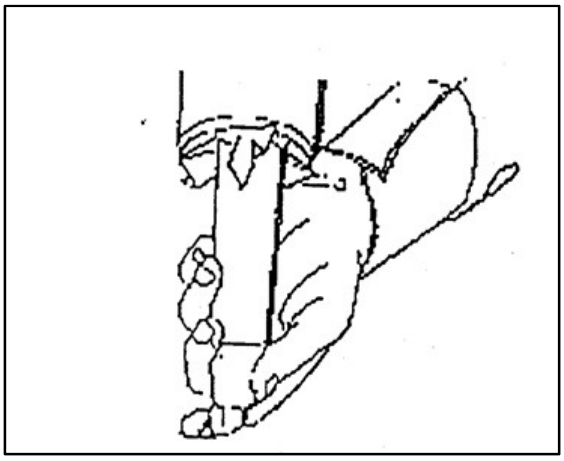


Figure B3.1: Insertion of Water Soluble Tissue paper

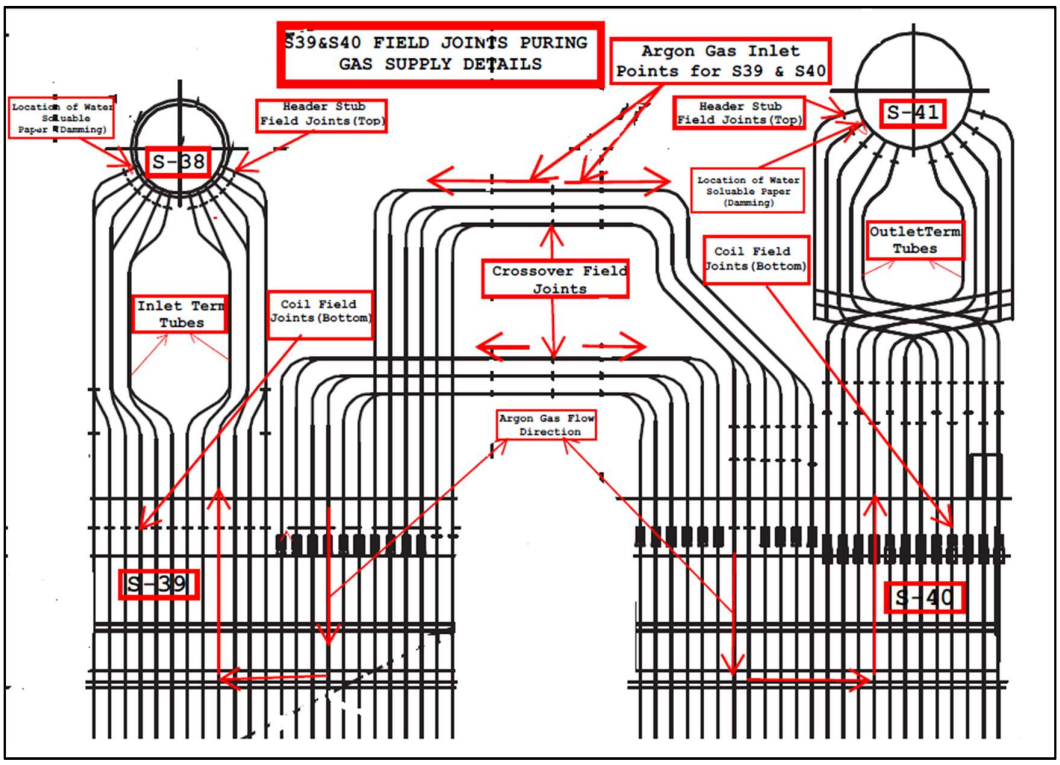


Figure B3.2: Purging Arrangement for SH Header Field Joints

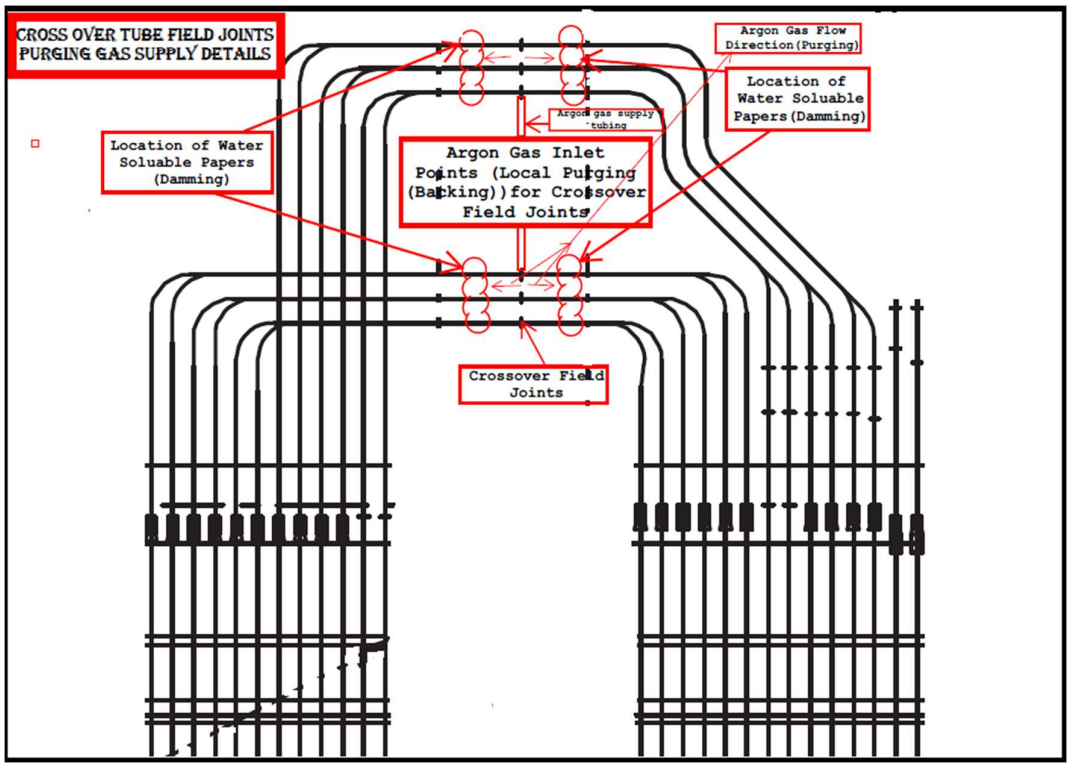


Figure B3.3: Purging Arrangement for Cross Over Tube Field Joints

CHAPTER –B4
ERECTION WELDING PRACTICES FOR SA213 T23 MATERIAL

1.0 SCOPE:

1.1 This procedure is applicable for the welding of T23 tubes at sites.

2.0 Ensure the availability of the following items/characteristics before preparing the joint for welding:

a) LPG gas (for heating in case of interruption in preheating)
b) Grinding machine
c) Mini cutter
d) Conical grinder
e) Proper illumination
f) Thermal chalk or pyrometer
g) Torch light
h) Portable Oven
i) Hacksaw and chisel

3.0 PROCEDURE:

The following procedure shall be followed for T23 Welding at Site:

3.1 Clean the edges of the tube, both OD & ID by buffing upto 30 mm from the edge of the tube.

3.2 Create a purging dam on both tubes at about 200 to 250 mm away from the joint before fit-up.

3.3 Fit-up the tubes for butt joint with a root gap of 2 to 2.5 mm and ensure a land of 1 to 1.5 mm.

3.4 Set up Argon purging for the tube to tube butt joint.

3.5 Carryout preheating by wrapping heating pads/coils uniformly for a width of 200 mm on both sides of the joint. Each tube should be provided with a thermocouple (K type) at a distance of 75 mm from the joint.(Refer FigureB4.1, B4.2 &B4.3)

3.6 Preheat the joint to a minimum of 200°C and ensure the same with a thermal chalk or a pyrometer before the start of welding.

3.7 Ensure drying of SMAW electrodes at 250 to 300°C for 2 hours and keep them at a temperature of 150°C in a Holding oven after drying.

3.8 The electrodes shall be maintained dry at 65 to 100 °C in a portable oven after issue from the holding oven till use.

3.9 Perform welding as per applicable WPS using IBR qualified welders.

3.10 Ensure the welding of root and second pass by TIG welding process and further layers by SMAW process. Alternatively, the entire joint may be welded by TIG process using the applicable WPS.

3.11 Maintain the Interpass temperature at 350°C max. Ensure the same using thermal chalk or pyrometer after each pass of welding.

3.12 Conduct post heating on the completed weld at 250 to 280°C for a minimum of 1 hour immediately after completion of welding and then allow the joint to cool in air to ambient temperature.(Refer Figure B4. 4)

3.13 Perform RT to ensure that the joints are defect free.

3.14 If RT reveals any unacceptable defect, cut the joint and put a spool piece in place for a minimum length of 200 mm. Repeat the procedure from step 3.1 to 3.13.

3.15 Perform PWHT on the weldment within 7 days after post heating.

3.16 Use only calibrated PWHT accessories (thermocouples, temperature recorder, etc.).

3.17 Use only ceramic resistance pads with low voltage heating arrangement for PWHT.

3.18 Ensure the PWHT arrangement to meet the following conditions;

3.19 When heat treating butt welds, the 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 welded. The width of the insulation band shall be at least twice the total width of the heating band.

3.20 Ensure wrapping of heating pads, location of thermocouples before covering with insulation.(referFigure B4.5& B4.6)

3.21 PWHT shall be carried out with 1 thermocouple per joint.

3.22 PWHT time and temperature shall be as per applicable WPS.

3.23 Measure hardness on the joint and ensure it to be within 160 to 260 HB. If hardness exceeds 260 HB, PWHT shall be repeated and hardness checked. The total no. of PWHT cycles shall not exceed 3 times for a joint.

3.24 In case the hardness measures above 260HB even after 3 PWHT cycles, cut the joint and put a spool piece in place for a minimum length of 200 mm. Repeat the procedure from step 3.1 to 3.23. In case the hardness measures below 160HB, it shall be referred to the MUs.

4.0 DOCUMENTATION:

Record the details of welding carried out in correlation to welders, heat treatment and NDE reports.

Figure B4.1: Preheating by Resistance coil winding

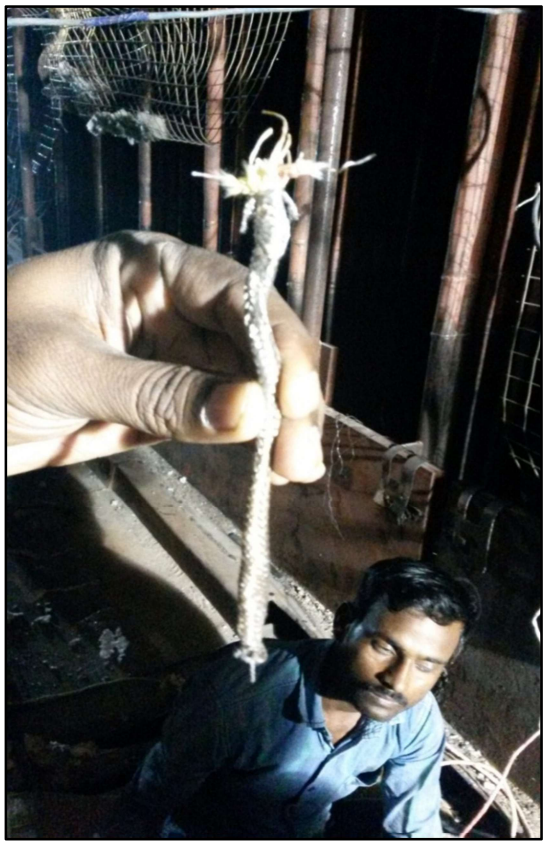


Figure B4.2: K - Type Thermocouple

Figure B4.3: Preheating arrangement with thermocouples in place

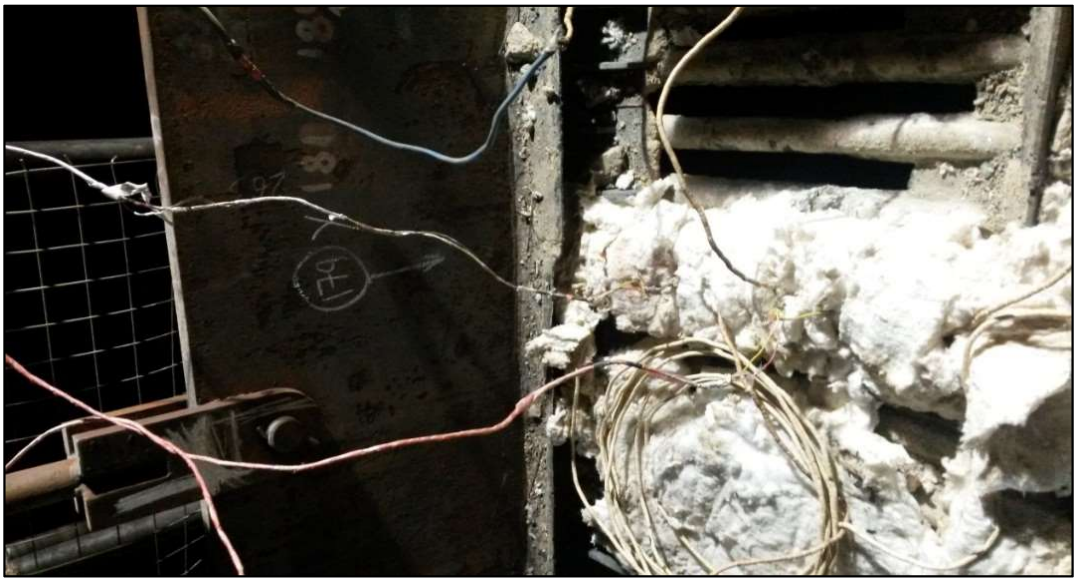


Figure B4.4: Post heating arrangement

Figure B4.5: Heating pads in place for PWHT

Figure B4.6: PWHT in progress

CHAPTER –B5
GENERAL TOLERANCES FOR STRUCTURES

1.0 GENERAL TOLERANCES FOR STRUCTURES

Table B5.1-GENERAL TOLERANCES FOR STRUCTURES

Sl. No.	Structural Parts / Parameters	Tolerance in mm for Bolted structures			Tolerance in mm for Welded structures
1	**Section Depth / width**up to and including 1.0 meter	+3 / -2 (± 1 at the joints)			Upto 1 M : ± 3.0 mm 1M to 2M : ± 5.0 mm Above 2 M : + 8.0 mm / - 5.0 mm
2	**Section Depth/Width** over 1.0 meter	+3 / -2 (± 2 at the joints)			
3	**Web Shift**	± 2 mm			± 2mm
4	Tolerance depending on length dimensions of structural items	Length Dimensions in mm			
		≤ 6000	> 6000 - ≤ 12000	> 12000	
a	Columns	± 1	± 2	± 2.0	1 mm/M and Max. 10 mm
b	Built up beams	+0 / -2	+0 / -3	+0 / -4	
c	Diagonal Bracings	+0 / -2	+0 / -2	+0 / -2	
5	Bow in column Base Plate	1mm per meter of diagonal or 3mm whichever is greater			3mm
6	**Camber**				
	Column /Girder/ Built-up Beam	± L /2000 = 0.50 mm/ m where 'L' is overall length of column/ Beam / Diagonal Bracing subject to maximum of 5mm			10mm
7	**Sweep**				
	Column /Girder/ Built-up Beam	± L /2000 = 0.50 mm/ m where 'L' is overall length of column/ Beam / Diagonal Bracing subject to maximum of 5mm			10mm
8	**Twist**	± a/3000 = ± 0.33mm/m, where 'a' is depth of member, 5mm maximum			0.005h per 5m length or 10 mm whichever is less where "h" is the height of beam / girder in mm.
9	**Combined warpage**	W /100 or 3 mm whichever is greater where 'W' is the width of flange other than joint area			6mm
10	**Column to column spacing**	± 3 mm			± 3 mm
11	**Diagonal difference**	± 5 mm			± 5 mm
12	**Column overall Verticality**	± 10 mm			± 10 mm
13	**Drilled Holes for Bolts**				
13 (a)	Hole Dimension	+0.6 / -0 for others, +0.16/-0 for Fit bolts of TMG (Reaming required)			+1mm/-0mm
13 (b)	Pitch distance of holes and distance between rows of holes	± 1 mm			± 1mm

The tolerances defined in this manual are based on IS 7215 and EN1090 Standards.

CHAPTER –B6
WELDING OF PIPES AND PIPE SHAPED CONNECTIONS IN STEAM TURBINE, TURBO GENERATORS AND AUXILIARIES

1.0 SCOPE

These guide lines cover edge preparation, method of welding for pipes and pipe shaped connections to be used in steam turbine, turbo-generator and heat exchanger of Siemens design.

2.0 WELD EDGE PREPARATION:

2.1 Various forms of edge preparations to be used for shop weld, site weld and edge preparations for pipes manufactured from rolled plates are covered in this standard.

2.2 However edge preparation may be altered if pipe connections are made between customer's pipe line and BHEL supply. In all such cases edge preparation must be given on the drawing.

3.0 ASSEMBLY AND WELDING PROCEDURES:

3.1 Before tacking the weld edges must be aligned. The linear misalignment between weld edges must be maintained according to specifications no. HW0620099.

3.2 Machined weld end preparations of the components being dispatched to site must be protected with a metal cover.

3.3 Shaped parts for piping e.g. flanges, reducer, elbows, T-sections etc. are ordered with edge preparations carried out at suppliers work.

3.4 Welding processes are selected in accordance with Figure B6.1 and B6.2.

3.5 Welders qualified as per ASME section IX are to be employed.

3.6 The distinction is to be made between shop and site welds in the drawing as per plant Standard no.0623.003.

3.7 Tack welds, if not to be removed, must be made with the same filler metal and must be performed by qualified welder.

3.8 Open ends of pipes are to be plugged/ covered and to be purged by inert gas from inside.

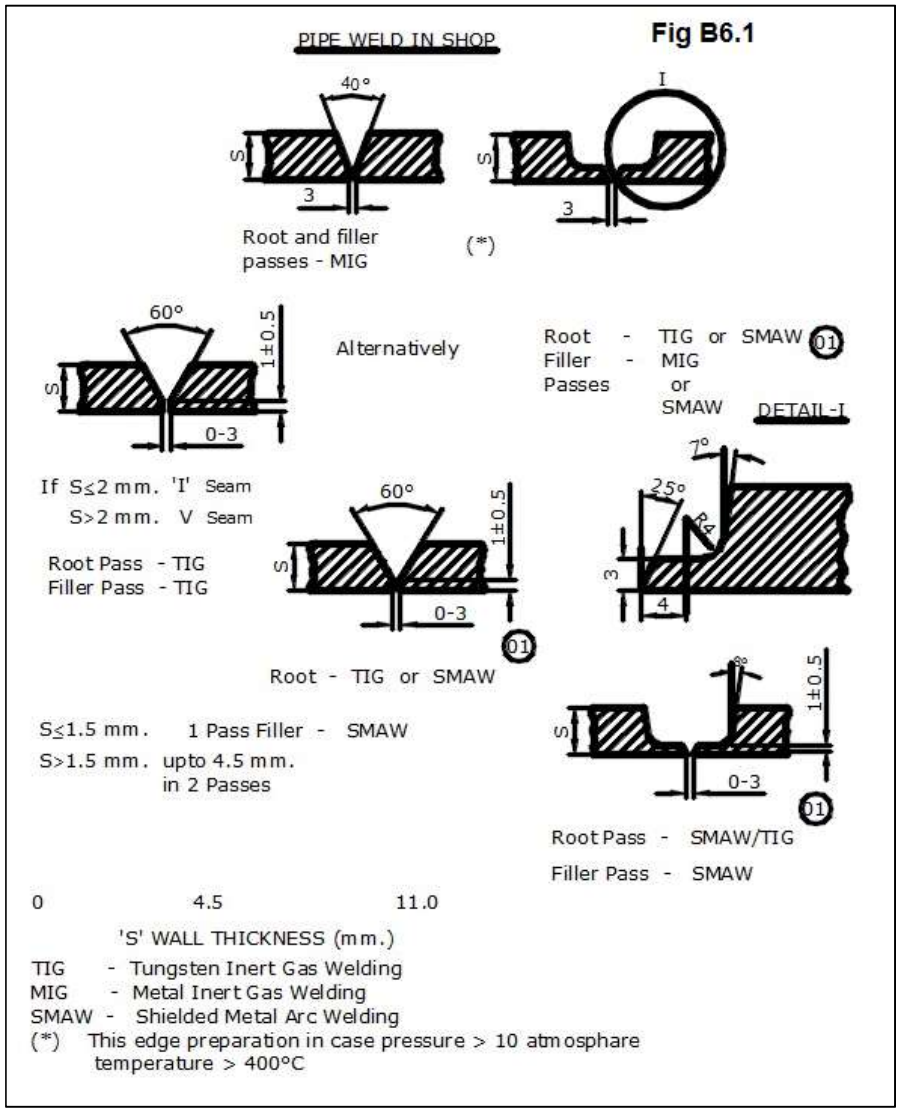
4.0 PIPES ROLLED FROM PLATES

4.1 Weld seams of rolled pipes are welded mainly by shielded metal Arc welding / Submerged Arc Welding/Gas Metal Arc Welding/Tungsten Inert gas welding with or without backing strip.

If required the root is gouged / ground and welded from back side.

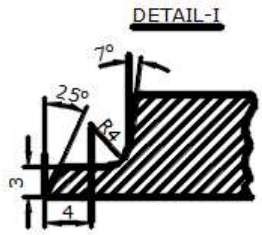
5.0INSPECTION

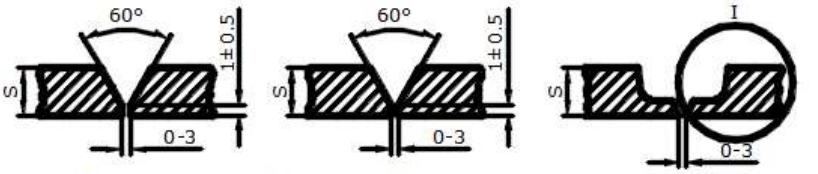
5.1 The weld seams are subjected to internal examination in accordance with HW0850199. The external characteristicsare examined in accordance with HW0620099.


PIPE WELD IN SHOP
Fig B6.1
40°
S
3
I
Root and filler passes - MIG
(*)
60°
1±0.5
0-3
Alternatively
Root - TIG or SMAW 01
Filler - MIG
Passes or SMAW
DETAIL-I
If S≤2 mm. 'I' Seam
S>2 mm. V Seam
Root Pass - TIG
Filler Pass - TIG
7°
2.5°
8
3
4
Root - TIG or SMAW
S≤1.5 mm. 1 Pass Filler - SMAW
S>1.5 mm. upto 4.5 mm. in 2 Passes
Root Pass - SMAW/TIG
Filler Pass - SMAW
0
4.5
11.0
'S' WALL THICKNESS (mm.)
TIG - Tungsten Inert Gas Welding
MIG - Metal Inert Gas Welding
SMAW - Shielded Metal Arc Welding
(*) This edge preparation in case pressure > 10 atmosphare temperature > 400°C

PIPE WELD AT SITE

Fig B6.2





S>2 mm. V Seam
S≤2 mm. 'I' Seam

Root : TIG
Filler Passes : SMAW

Root : TIG/SMAW
Filler Passes : SMAW

Root and filler passes - TIG

0 4.5 11.0

'S' WALL THICKNESS (mm.)

TIG - Tungsten Inert Gas Welding
SMAW - Shielded Metal Arc Welding

CHAPTER – B7
INSTRUCTIONS FOR CARRYING OUT CONDENSER PLATE AND NECK WELDING

Note:

Typical Field welding schedule (FWS) for one project is attached. FWS for Condenser is project specific, supplied by HEEP Haridwar along with Condenser erection drawings.

INSTRUCTIONS FOR CARRYING OUT CONDENSER PLATE AND NECK WELDING

FIELD WELDING SCHEDULE

BHEL, HEEP, HARDWAR	PROJECT :	HXE/10565/FWS
	DRG.NO. : 01601070039E132	SH. 01 OF 08

GENERAL REQUIREMENTS: –

1. CORRECTNESS OF ALIGNMENT BETWEEN VARIOUS PARTS SHOULD BE ENSURED BEFORE TACK WELDING. FINAL WELDING SHALL BE DONE BY STEP BACK METHOD AND IF REQUIRED SUPPORTS/FIXTURES MAY BE USED SO AS TO ENSURE MINIMUM DEFORMATION OF PARTS.
2. ONLY QUALIFIED WELDERS ARE TO BE EMPLOYED.
3. VISUAL INSPECTION OF ALL WELD SEAMS IS TO BE CARRIED OUT ACCORDING TO BHEL STANDARD HW0620099. CLASSIFICATION GROUP.
   (I) CS/BK FOR PRESSURE PARTS/SEALING JOINTS.
   (ii) CS/CK FOR STIFFENERS, GUSSETS, BAFFLES ETC.
4. ALL WELD SEAMS SHALL BE PROPERLY GROUND AND SUBJECTED TO NON-DESTRUCTIVE EXAMINATION ACCORDING TO BHEL STANDARD HW0850199, PART-10. EXAMINATION GRADE (CSR) AS INDICATED IN SH.02 TO SH. 08. THE WELDS NOT SPECIFICALLY INDICATED IN DRAWINGS SHALL BE SUBJECTED TO MINIMUM 10% DPT.
5. NO PREHEATING AND POST WELD HEAT TREATMENT IS REQUIRED. (EXCEPT PRE HEATING REQUIRED FOR SL. NO. 45)
6. TOTAL WEIGHT OF DEPOSITED METAL = 3055kg. (approx)

	DESIGN DEPTT. HEAT EXCHANGER ENGG.			AGREED DEPTT. WELDING TECHNOLOGY			REVISIONS			
	NAME	SIGN.	DATE	NAME	SIGN.	DATE				
WORKED- BY	S K YADAV	-Sd-	20.12.08	I.RAM	-Sd-	30.12.08	REV. NO.	01		
CHECKED BY	S K YADAV	-Sd-	25.12.08				SIGN.	-Sd-		
APPROVED BY	S.BARAI	-Sd-	30.12.08				DATE	05.01.10		

FIELD WELDING SCHEDULE

PROJECT :
CONTRACTOR :
PACKAGE : CONDENSER

FWS NO. : HXE/10565/FWS
REV. NO. : 01
PAGE NO. : 02

SL. NO.	DRG.NO.FOR WELD LOCATION & IDENTIFICATION MARK	MATL. SPEC.	DIMENSIONS			PROCESS OF WELDING	TYPE OF WELD	ELECTRODE FILLER SPEC.	WPS. NO.	MIN. PREHEAT TEMP. °C	HEAT TREATMENT		NDT METHOD QUANTAM		REFERENCE		
			SIZE OF WELD (mm)	LENGTH OF WELD (M)	QTY.OF FILLER METAL IN Kg.						TEMP.	HOLDING TIME	RT/UT	DPT	SPEC. NO.	ACC NORM REF.	ZONE
01	01601170026E132 Bottom Plate	IS: 2062	6	30	12.75	SMAW (SHIELD METAL ARC WELDING)	FILLET	E–7018	CS11294	NIL	NA	NA	–	10%	HW0850199	4	
02	– DO –	– DO –	8	15.8	10.65	– DO –	– DO –	– DO –	– DO –	– DO –	NA	NA	–	10%	– DO –	4	
03	– DO –	– DO –	8	3.65	3.3	– DO –	BUTT	– DO–	– DO–	– DO–	NA	NA	–	10%	– DO –	4	
04	– DO –	– DO –	16	44	61.2	– DO –	–DO–	– DO –	– DO –	– DO –	NA	NA	10%	10%	– DO –	3	
05	– DO –	– DO –	20	9.0	19.75	– DO –	– DO –	–DO–	– DO –	– DO –	NA	NA	10%	10%	– DO –	3	
06	– DO –	– DO –	10	4	2.9	– DO –	– DO –	–DO–	– DO –	– DO –	NA	NA	–	10%	– DO –	4	
07	01601270040E132 Lower Dome Wall (Tur.End)	IS: 2062	16	53	74	– DO –	BUTT	– DO –	– DO –	– DO –	NA	NA	10%	10%	– DO –	3	
08	01601370042E132 Lower Dome Wall (Gen.End)	IS: 2062	16	53	74	– DO –	BUTT	– DO –	– DO –	– DO –	NA	NA	10%	10%	– DO –	4	
09	11601470021E132 Side Wall (Tur. End)	– DO –	12	13.1	19.5	SMAW	FILLET	E–7018	CS11294	NIL	NA	NA	–	10%	HW 0850199	4	
10	– DO –	– DO –	10	6	6.5	– DO –	– DO –	– DO –	– DO –	– DO –	NA	NA	–	10%	– DO –	4	
11	– DO –	– DO –	20	36	78.2	– DO –	BUTT	– DO –	– DO –	– DO –	NA	NA	10%	10%	– DO –	3	

FIELD WELDING SCHEDULE

PROJECT :
CONTRACTOR :
PACKAGE : CONDENSER

FWS NO. : HXE/10565/FWS
REV. NO. : 01
PAGE NO. : 03

SL. NO.	DRG.NO.FOR WELD LOCATION & IDENTIFICATION MARK	MATL. SPEC.	DIMENSIONS			PROCESS OF WELDING	TYPE OF WELD	ELECTRODE FILLER SPEC.	WPS. NO.	MIN. PREHEAT TEMP. °C	HEAT TREATMENT		NDT METHOD QUANTAM		REF.		
			SIZE OF WELD (mm)	LENGTH OF WELD (M)	QTY.OF FILLER METAL IN Kg.						TEMP.	HOLDING TIME	RT/UT	DPT	SPEC. NO.	ACC NORM REF.	ZONE
12	01601570051E132 Lower Dome Wall (FWB Side)	IS: 2062	5▽	2.1	0.3	SMAW (SHIELD METAL ARC WELDING)	FILLET	E-7018	CS11294	NIL	NA	NA	–	10%	HW0850199	4	D5
13	– DO –	– DO –	8▽	9.0	3.0	– DO –	– DO –	– DO –	– DO –	– DO –	NA	NA	–	10%	– DO –	4	C11
14	– DO –	– DO –	16▷	14.0	20.0	– DO –	– DO –	–DO–	– DO –	– DO –	NA	NA	10%	10%	– DO –	3	D8
15	– DO –	– DO –	16▽	13.3	17.3	– DO –	FILLET	–DO–	– DO –	– DO –	NA	NA	–	10%	– DO –		K2
16	– DO –	– DO –	16▷	7.4	10.3	– DO –	BUTT	–DO–	– DO –	– DO –	NA	NA	10%	10%	– DO –		C14
17	– DO –	– DO –	FILL (20X16)	1.26	4.20	– DO –	– DO –	– DO –	– DO –	– DO –	NA	NA	–	10%	– DO –	4	H2
18	01601670055E132 Lower Dome Wall (RWB Side)	–DO–	8▽	1.2	0.4	– DO –	FILLET	– DO –	– DO –	– DO –	NA	NA	–	10%	HW0850199	4	D8
19	– DO –	–DO–	10▽	2.00	1.08	– DO –	– DO –	– DO –	– DO –	– DO –	NA	NA	–	10%	– DO –	4	D14
20	– DO –	–DO–	8▷	4.25	2.10	– DO –	BUTT	– DO –	– DO –	– DO –	NA	NA	–	10%	– DO –	4	C9
21	– DO –	–DO–	16▷	4.00	6.36	– DO –	– DO –	– DO –	– DO –	– DO –	NA	NA	10%	10%	– DO –	3	D12
22	– DO –	–DO–	5▽	2.1	0.30	– DO –	FILLET	– DO –	– DO –	– DO –	**NA**	**NA**	–	10%	– DO –	4	D12
23	– DO –	–DO–	12▽	2.0	8.94	– DO –	– DO –	– DO –	– DO –	– DO –	NA	NA	–	10%	– DO –		E14
24	– DO –	–DO–	16▷	7.4	10.3	– DO –	BUTT	– DO –	– DO –	– DO –	NA	NA	10%	10%	– DO –		D6

FIELD WELDING SCHEDULE

PROJECT :
CONTRACTOR :
PACKAGE : CONDENSER

FWS NO. HXE/10565/FWS
REV. NO. : 01
PAGE NO. : 04

SL. NO.	DRG.NO.FOR WELD LOCATION & IDENTIFICATION MARK	MATL. SPEC.	DIMENSIONS			PROCESS OF WELDING	TYPE OF WELD	ELECTRODE FILLER SPEC.	WPS. NO.	MIN. PREHEAT TEMP. °C	HEAT TREATMENT		NDT METHOD QUANTAM		REF.		
			SIZE OF WELD (mm)	LENGTH OF WELD (M)	QTY.OF FILLER METAL IN Kg.						TEMP.	HOLDING TIME	RT/UT	DPT	SPEC. NO.	ACC NORM REF.	ZONE
32	11601470021E132 Side Wall (Tur & Gen. End)	IS: 2062	10	6	6.5	SMAW (SHIELD METAL ARC WELDING)	FILLET	E–7018	CS11294	NIL	NA	NA	–	10%	HW0850199	4	
33	– DO –	–DO–	12	13.1	19.5	– DO –	– DO–	– DO–	– DO–	– DO –	NA	NA	–	10%	– DO –	4	
34	– DO –	–DO–	20	36	78.2	– DO –	BUTT	–DO–	– DO –	– DO –	NA	NA	10%	10%	– DO –	3	
35	01602770028E132 Dome Internal Stiffening	– DO –	20	9.60	18.6	– DO –	FILLET	– DO –	– DO –	– DO –	NA	NA	–	10%	– DO –	4	
36	– DO –	SA106 GR–B WITH IS: 2062	16	104.57	160	– DO –	BUTT	– DO –	– DO –	– DO –	NA	NA	–	10%	– DO –	4	
37	01602870030E132 Shell Internal Details	IS: 6911, WITH PIPE ERW IS: 1978	6	275	56.8	– DO –	FILLET	E–309cb	AS11127	– DO –	NA	NA	–	10%	– DO –	4	
38	– DO –	IS: 2062	12	322	480	– DO –	FILLET	E–7018	CS11294	– DO –	NA	NA	–	10%	– DO –	4	
39	– DO –	IS: 2062	16	440.0	920	– DO –	– DO –	– DO –	– DO –	– DO –	NA	NA	–	10%	– DO –	4	
40	– DO –	IS: 2062	4	268	25.2	TIG	– DO –	ER70S	CS110114	– DO –	NA	NA	–	10%	– DO –	4	
41	– DO –	IS: 2062	5	174.0	23.20	SMAW	FILLET	E–7018	CS11294	– DO –	NA	NA	–	10%	– DO –	4	
42	– DO –	IS: 2062	8	4.5	1.6	–DO–	– DO –	E–7018	CS11294	– DO –	NA	NA	–	10%	– DO –	4	

FIELD WELDING SCHEDULE

PROJECT :
CONTRACTOR :
PACKAGE : CONDENSER

FWS NO. : HXE/10565/FWS
REV. NO. : 01
PAGE NO. : 05

SL. NO.	DRG.NO.FOR WELD LOCATION & IDENTIFICATION MARK	MATL. SPEC.	DIMENSIONS			PROCESS OF WELDING	TYPE OF WELD	ELECTRODE FILLER SPEC.	WPS. NO.	MIN. PREHEAT TEMP. °C	HEAT TREATMENT		NDT METHOD QUANTAM		REF.		
			SIZE OF WELD (mm)	LENGTH OF WELD (M)	QTY.OF FILLER METAL IN Kg.						TEMP.	HOLD ING TIME	RT/UT	DPT	SPEC. NO.	ACC NORM REF.	ZONE
43	01602870030E132 Shell Internal Detail	IS: 2062	14	11.5	13.57	(SHIELD METAL ARC WELDING)	BUTT	E-7018	CS11294	NIL	NA	NA	–	10%	HW0850199	4	
44	– DO –	ST C20	16	14.78	17.50	– DO –	– DO –	– DO –	– DO –	– DO –	NA	NA	–	10%	– DO –	4	
45	– DO –	ST C20 IS: 1570–91	55	8.58	170.00	– DO –	BUTT	– DO –	CS112186	125°C	NA	NA	10%	10%	– DO –	3	
46	– DO –	IS: 2062	20	26.50	58.60	– DO –	– DO –	– DO –	CS11294	NIL	NA	NA	–	10%	– DO –	3	
47	11603670003E132 Air Extraction Piping	ST. PIPE ERW WITH IS: 2062	6	16.5	1.98	– DO –	– DO –	–DO	– DO –	– DO –	NA	NA	–	10%	– DO –	4	
48	– DO –	ST PIPE ERW IS:1978 WITH ST TUBE ERW IS:1239	6	11.4	3.76	TIG	BUTT	ER 70S	CS110114	–DO–	NA	NA	–	10%	– DO –	4	
49	01603870001E132 LP Heater Support Argmt.	IS: 2062	6	2.04	0.40	(SHIELD METAL ARC WELDING)	FILLET	E-7018	CS11294	– DO –	NA	NA	–	10%	– DO –	4	
50	– DO –	–DO–	8	72.30	24.40	– DO –	– DO –	– DO –	CS11294	– DO –	NA	NA	–	10%	– DO –	4	
51	– DO –	–DO–	10	28.0	15.3	– DO –	– DO –	–DO–	– DO –	– DO –	NA	NA	–	10%	– DO –	4	
52	– DO –	–DO–	12	2.88	4.30	– DO –	– DO –	–DO–	– DO –	– DO –	NA	NA	–	10%	– DO –	4	
53	– DO –	–DO–	16	1.52	4.65	– DO –	BUTT	–DO–	CS11294	– DO –	NA	NA	10%	10%	– DO –	3	

FIELD WELDING SCHEDULE

PROJECT :
CONTRACTOR :
PACKAGE : CONDENSER

FWS NO. : HXE/10565/FWS
REV. NO. : 01
PAGE NO. : 06

NO.	DRG.NO.FOR WELD LOCATION & IDENTIFICATION MARK	MATL. SPEC.	DIMENSIONS			PROCESS OF WELDING	TYPE OF WELD	ELECTRODE FILLER SPEC.	WPS. NO.	MIN. PREHEAT TEMP.°C	HEAT TREATMENT		NDT METHOD QUANTAM		REF.		ZONE
			SIZE OF WELD (mm)	LENGTH OF WELD (M)	QTY.OF FILLER METAL IN Kg.						TEMP.	HOLDING TIME	RT/UT	DPT	SPEC. NO.	ACC NORM REF.	
54	01603870001E132 LP Heater Support Argmt.	IS: 2062	32	13.11	63.00	SMAW (SHIELD METAL ARC WELDING)	BUTT	E-7018	CS11294	NIL	NA	NA	10%	10%	HW0850199	3	
55	– DO –	IS: 2062	32	0.654	2.90	– DO –	– DO –	– DO –	– DO –	– DO –	NA	NA	–	10%	– DO –	4	
56	– DO –	ST C20 IS: 1570–91	16	0.56	1.45	– DO –	FILLET	– DO –	– DO –	– DO –	NA	NA	–	10%	– DO –	4	
57	**– DO –**	IS: 2062	6	1.704	0.35	– DO –	BUTT	– DO –	– DO–	– DO–	NA	NA	–	10%	– DO –	4	
58	– DO –	– DO –	10	0.70	0.50	– DO –	– DO –	– DO –	– DO –	– DO –	NA	NA	–	10%	– DO –	4	
59	– DO –	– DO –	12	1.44	1.20	– DO –	– DO –	– DO –	– DO –	– DO –	NA	NA	–	10%	– DO –	4	
60	– DO –	– DO –	5	0.80	0.40	– DO –	– DO –	– DO –	– DO –	– DO –	NA	NA	–	10%	– DO –	4	
61	01604570038E132 Hotwell	– DO –	8	13.7	4.6	SMAW	FILLET	– DO –	– DO –	– DO –	NA	NA	–	10%	– DO –	4	
62	– DO –	– DO –	16	1.0	1.30	– DO –	FILLET	– DO –	– DO –	– DO –	NA	NA	–	10%	– DO –	4	
63	01601070039E132 Condenser, General Assy.	ST TUBE ERW IS: 1239	3	0.52	0.03	– DO –	FILLET	– DO –	– DO –	– DO –	NA	NA	–	10%	– DO –	4	
64	– DO –	ST TUBE ERW IS: 1239	4	6.00	0.56	– DO –	FILLET	ER 70S	– DO –	– DO –	NA	NA	–	10%	– DO –	4	
65	– DO –	ST TUBE ERW IS: 1239	5	2.20	0.528	SMAW	BUTT	E-7018	– DO –	– DO –	NA	NA	–	10%	– DO –	4	

FIELD WELDING SCHEDULE

PROJECT :
CONTRACTOR :
PACKAGE : CONDENSER

FWS NO. : HXE/10565/FWS
REV. NO. : 01
PAGE NO. : 07

SL. NO.	DRG.NO.FOR WELD LOCATION &IDENTIFICATION MARK	MATL. SPEC.	DIMENSIONS			PROCESS OF WELDING	TYPE OF WELD	ELECTRODE FILLER SPEC.	WPS. NO.	MIN. PREHEAT TEMP°C	HEAT TREATMENT		NDT METHOD QUANTAM		REF.		
			SIZE OF WELD (mm)	LENGTH OF WELD (M)	QTY.OF FILLER METAL IN Kg.						TEMP.	HO.D ING TIME	RT/UT	DPT	SPEC. NO.	ACC NORM REF.	ZONE
66	016010700039E132 Condenser General Assy.	IS: 2062	8 ▽	24.5	0.72	(SHIELD METAL ARE WELDING)	FILLET	E-7018	CS11294	NIL	NA	NA	–	10%	HW0850199	4	
67	– DO –	– DO –	8 ⊻	20.58	20.16	– DO –	BUTT	E-7018	– DO –	– DO –	NA	NA	–	10%	– DO –	4	
68	– DO –	IS: 2062	16 ▷	155.00	237.15	– DO –	BUTT	– DO –	– DO –	– DO –	NA	NA	10%	10%	– DO –	3	H8 B10 (SH.3)
69	– DO –	– DO –	20 ▷	1.76	3.9	– DO –	– DO –	– DO –	– DO –	– DO –	NA	NA	10%	10%	– DO –	3	
70	– DO –	IS: 2062	10 ▽	25.7	14.3	– DO –	– DO –	– DO –	– DO –	– DO –	NA	NA	10%	10%	– DO –	3	
71	– DO –	– DO –	45 ▽	2.0	13	– DO –	– DO –	– DO –	– DO –	–DO–	NA	NA	10%	10%	– DO –	3	
72	– DO –	– DO –	8 ▷	114	8.436	SMAW	FILLET	– DO –	– DO–	–DO–	NA	NA	–	10%	– DO –	4	
73	– DO –	– DO –	12 ▽	29.3	21.8	– DO –	FILLET	E-7018	– DO –	– DO –	NA	NA	–	10%	– DO –	4	
74	– DO –	– DO –	16 ▽	30.6	46.8	– DO –	BUTT	– DO –	– DO –	– DO –	NA	NA	100%	100%	– DO –	1	
75	– DO –	– DO –	10 ⊳	30.0	30.35	– DO –	FILLET	E-7018	– DO –	– DO –	NA	NA	–	10%	– DO –	4	
76	– DO –	– DO –	20 ⊻	0.5	2.75	– DO –	BUTT	E-7018	CS11294	– DO –	NA	NA	–	10%	– DO –	1	
77	11607170026E132 Condenser Support	– DO –	16 ▽	17	23.63	– DO –	FILLET	E-7018	– DO –	– DO –	NA	NA	–	10%	– DO –	4	

FIELD WELDING SCHEDULE

PROJECT :
CONTRACTOR :
PACKAGE : CONDENSER

FWS NO. : HXE/10565/FWS
REV. NO. : 01
PAGE NO. : 08

SL. NO.	DRG.NO.FOR WELD LOCATION & IDENTIFICATION MARK	MATL. SPEC.	DIMENSIONS SIZE OF WELD (mm)	DIMENSIONS LENGTH OF WELD (M)	QTY.OF FILLER METAL IN Kg.	PROCESS OF WELDING	TYPE OF WELD	ELECTRODE FILLER SPEC.	WPS. NO.	MIN. PREHEAT TEMP.°C	HEAT TREATMENT TEMP.	HEAT TREATMENT HOLDING TIME	NDT METHOD QUANTAM RT/UT	NDT METHOD QUANTAM DPT	REF. SPEC. NO.	REF. ACC. NORM REF.	ZONE
78	ASME BASKET VACUUM GRID 01605170008E132	IS: 2062	3 ▽	3.7	0.20	(SHIELD METAL ARC WELDING)	FILLET	E-309Cb	AS11127	NIL	NA	NA	–	10%	HW0850199	4	
79	– DO –	– DO –	4 ▽	0.57	0.05	– DO –	FILLET	E-7018	CS11294	–DO–	NA	NA	–	10%	– DO –	4	
80	– DO –	ST C20 IS:2062	6 ▽	5.2	1.1	– DO –	FILLET	– DO –	– DO –	–DO–	NA	NA	–	10%	– DO –	4	

NOTE:

There are two types of design for Rear water box & Rear water chamber

1. Bolted Type Design: Flanges of front & Rear water boxes & chambers are joined by bolts. Current projects follow this design only.

2. Welded type design: These were supplied for Rear Water Box & Rear water Chamber to 210 MW Amarkantak, 600 MW Raigarh sites etc.

For Sites with Welded Designs, following procedure can be referred

Erection Procedure for Rear Water Box & Rear water Chamber (Welded Design)

Condensers supplied by Haridwar for 210/250/500 MW ratings are having flanged connection between water box and water chamber at both the ends. (Front & rear). This is to facilitate retubing in case it is required. With the use of stainless steel, reliability of condenser tube material has increased and chances of failures and re-tubing has reduced tremendously.

In Amarkantak 210 MW, flanges have been removed from rear water box & water chamber and both have been directly welded together. Space for re-tubing has been kept on front water box side.

A- Pre assembly

1. Place both Rear water chambers on horizontal surface with water side surface of tube plate on top position. Level the water chambers w.r.t tube plate. Mark top & bottom position of water chambers.
2. Weld backing strip on all four walls of water chambers as shown in Fig.I. In Rear water chamber (GS) backing strip will be welded inside on all the four walls and on Rear water chamber (TS) it will be welded inside on three walls and outside on vertical wall near condenser centre line.
3. Measure tube sheet flatness as per recommended procedure and record the dimensions in log sheet L-02.
4. Water box inside length & width and corresponding dimensions of water chamber to be checked w.r.t. horizontal & vertical centre lines and recorded in log sheet to ascertain trueness of dimensions.
5. If logged dimensions indicate any mismatch, same may be corrected
6. Match Rear Water Box (TS/GS) by lowering it over respective water chamber / backing strip such that the weld edges of water chamber and water box match for proper welding. In case of mismatch, the same to be rectified.

B - Assembly

Assembly can be done in two ways as per site's convenience.

Option 1

1. Remove the water box after completing the activity as per A (6) above.
2. Weld 4 number channels (2 horizontal & 2 vertical) of size 100x50 along the length and width to stiffen the water chamber. Refer Fig. I. Holes in the tube plate to be suitably protected.

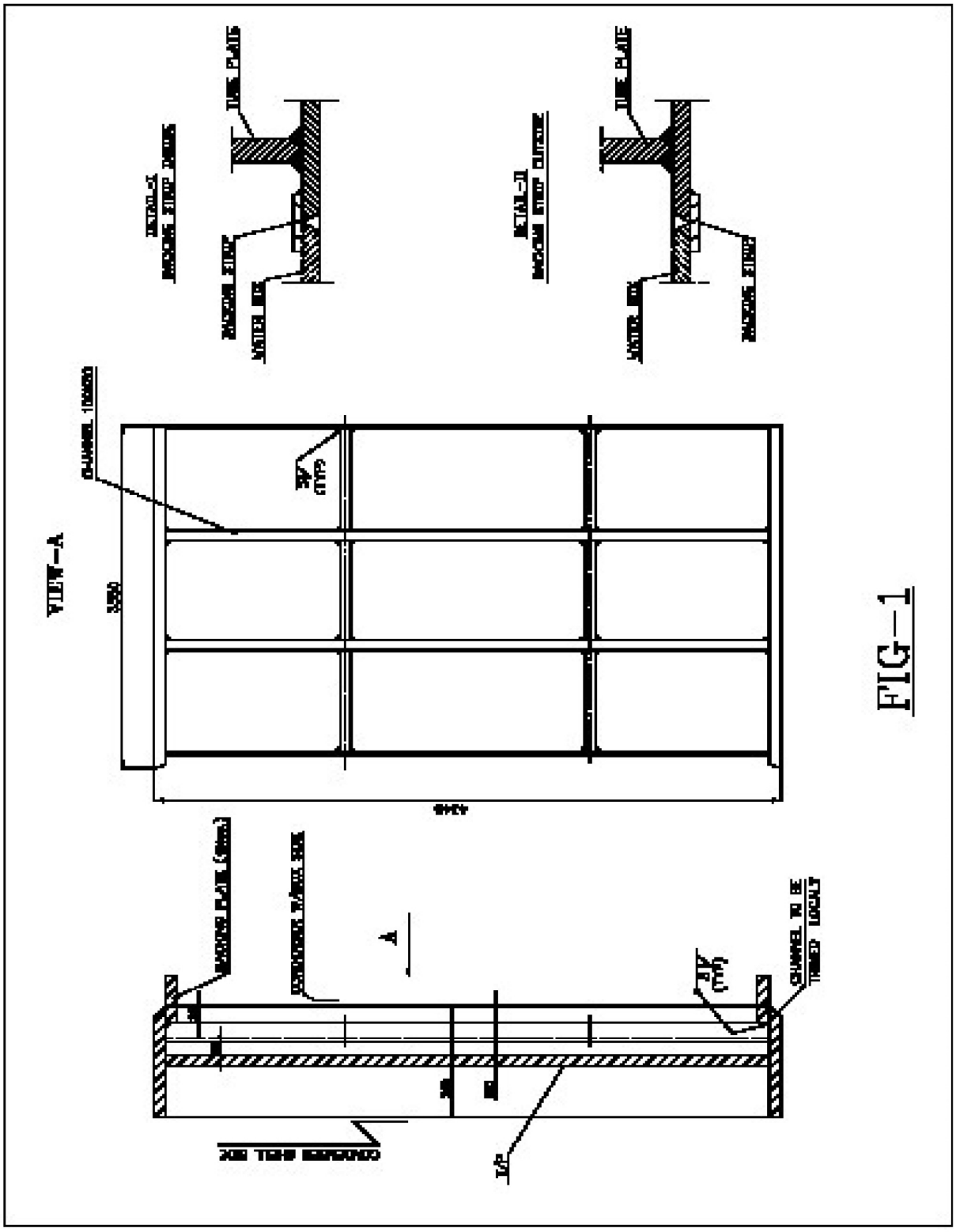
3. Lower the water chamber (without water box) on bottom plate for erection as per standard procedure.
4. Tack weld / final weld water chamber with side walls and bottom plate.
5. Carry out tubing.
6. Weld the water boxes using proper welding sequence as given (C) below.

Option II (Refer Fig.-2)

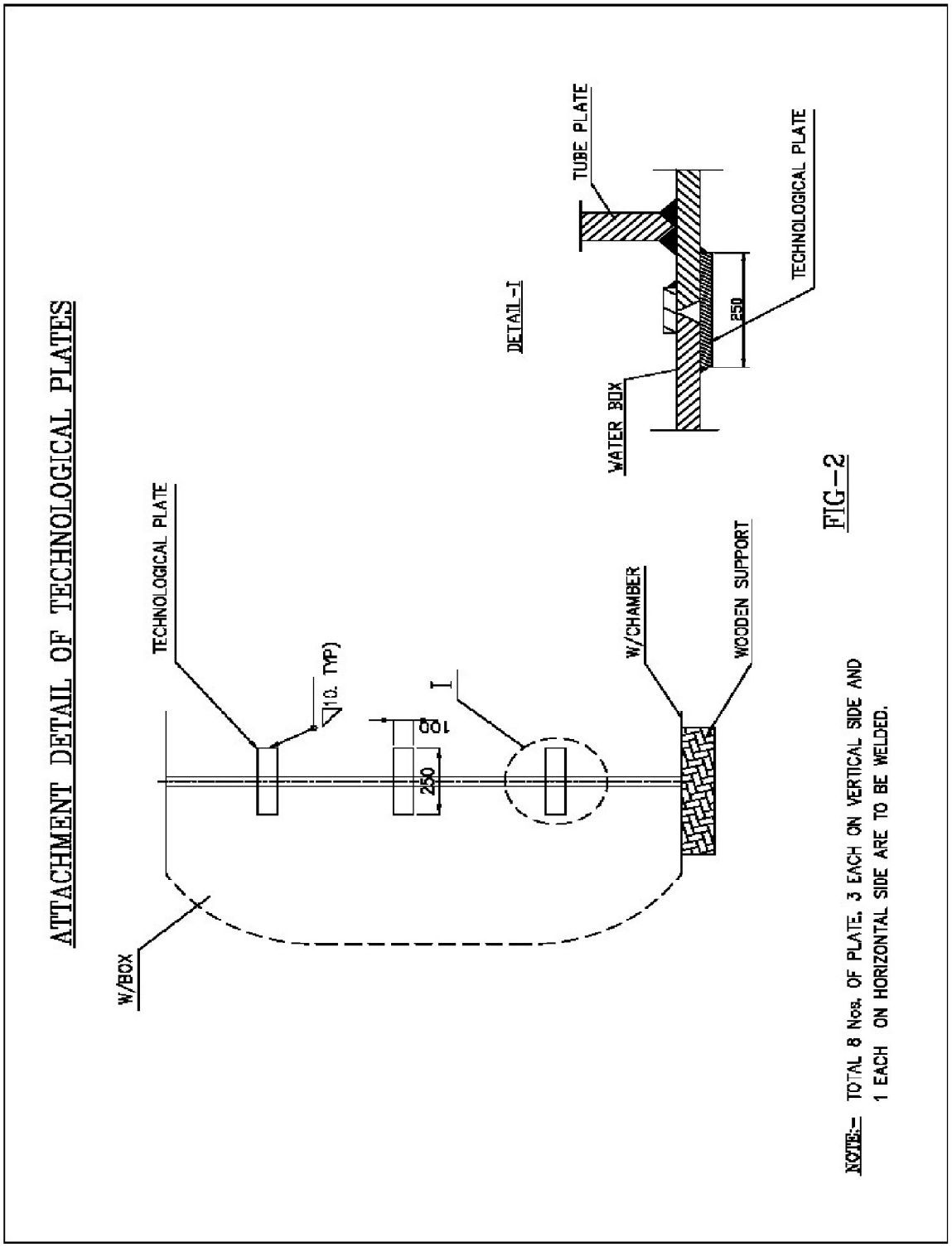
1. Weld water box and chamber with the help of technological plates (12 x 100 x 250) as shown in the drawing.
2. Lower water box and chamber together for erection.
3. Tack weld / Final weld water chamber with side walls and bottom plate.
4. Remove water box to facilitate tubing & expansion by cutting stiffening plates.
5. Carry out tubing.
6. Weld the water boxes using proper welding sequence as given (C) below.

C- Welding sequence for water box & water chamber (Refer Fig-3)

1. Tack weld Water box (GS) and Chamber(GS) -100 (200).
2. Root run on all sides.
3. Final welding to be done as per Detail-I.
4. Welding of Generator side water Box-Water chamber to be completed first as it has all welds from outside.
5. Bring Turbine side water box in position. Repeat steps 1-4 indicated above.
6. All welding is from outside except vertical welding of Rear water box & water chamber (TS) near condenser centreline which is from inside.
7. Direction of welding shall be as indicated in the drawing.
8. Overhead welding is required for carrying out bottom welding of water boxes and water chambers.



FIG–1


ATTACHMENT DETAIL OF TECHNOLOGICAL PLATES
TECHNOLOGICAL PLATE
10. TYP)
100
250
I
W/CHAMBER
WOODEN SUPPORT
W/BOX
DETAIL-I
TUBE PLATE
TECHNOLOGICAL PLATE
250
WATER BOX
FIG-2
NOTE:- TOTAL 8 Nos. OF PLATE, 3 EACH ON VERTICAL SIDE AND
1 EACH ON HORIZONTAL SIDE ARE TO BE WELDED.

CHAPTER – B8
REPAIR PROCEDURE FOR ARRESTING THE LEAKAGE OF STRENGTH WELDS ON TUBE TO TUBE SHEET JOINTS OF 'U' TUBE H.P. HEATER

REPAIR PROCEDURE FOR ARRESTING THE LEAKAGE OF STRENGTH WELDS ONTUBE TO TUBE

TUBESHEET/TUBE END EXAMINATION:

The face of the tubesheet, the tube ends and the inlet pass tube inside surfaces are to be visually examined using a bright light, from a distance of approximately 300mm. This examination should disclose any pitting, "bug holes", or other indications of damage.

If any tubes have been previously plugged, they must be checked to ensure no leak paths have developed around the plug.

TUBE PLUGGING

These instructions cover the plugging of feedwater heater tubes. Plugging is divided into the following categories, depending on the nature of the tube failure.

1. Tube-end Plugging, where failure has occurred in the tube itself, and the tube-to-tubesheet joint is sound.

2. Safety Plugging, where tubes are plugged because of possible erosion damage due to a failure in an adjacent tube.

3. Tube sheet Plugging, where the tube-to-tubesheet joint has failed beyond repair, specific instructions will be issued by BHEL HYDERABAD Field Service Department.

Tube failures tend to have a chain reaction effect; impingement on adjacent tubes can cause additional failures. As a result, it is recommended that all tubes immediately adjacent to a leaking tube be safety plugged as a precaution.

GENERAL PREPARATION FOR TUBE PLUGGING.

Plugs conforming to the material and dimensions given in these instructions should be obtained.

GENERAL PRECAUTIONS WHEN USING WELDED PLUGS:

Weld wire substitutions are not to be made without prior approval by BHEL's Field Service Department.

Do not weld until the welding area and the tubes, including plugs, are clean and dry. Clean the tube holes and plugs with a high grade, non-residue solvent. Tools, hoses, etc., in the work area must be clean.

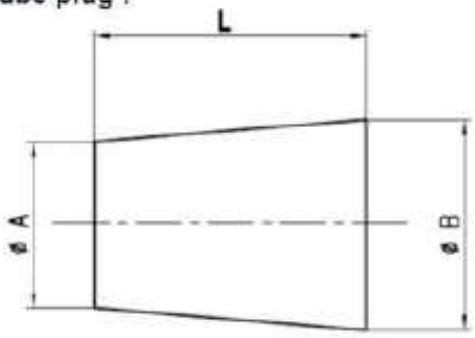
Heat the area in the tube sheet to be welded, as required, to remove moisture. The bar used for plugs that are to be welded must not be of a "free machining" type material.

Please refer to the following "Tube End and Safety Plugging" instructions which provide the correct material and dimensions of the tapered tube plug to be used.

TUBE END AND SAFETY PLUGGING FOR WELDED AND EXPANDED TUBE TO-TUBESHEET JOINT

Both the inlet and outlet end of the problem tube(s) is to be reamed to the larger diameter of the tube plug in line with the tube plug dimension indicated below.

Tube plug :



Plug Material : SS Rounds.

Dimensions :

A : Dia 12 mm

B : Dia 15 mm

Length : 25 mm

Check the reamed hole using a tube plug that conforms to the dimensions and the plug material.

TUBE PLUG DIMENSIONS

Clean and dry the tube plug(s) and reamed holes using a non-residue solvent. Workmen's hand and tools must be clean to ensure minimum contamination of the weld area.

1. Insert the tube plug(s) into the reamed tube end and drive it into a depth of 3 mm below the face of the tubesheet.

2. Weld the tube plug as follows:

a. Preheat the tubesheet to remove any moisture.

b. Welding shall be manual TIG. It is recommended that welding rod or wire not exceeding 2.4 mm diameter be used. Weld as per the table below

TUBE MATERIAL	TS WELD OVERLAY MATERIAL	PLUG MATERIAL **	SHIELDED METAL ARC WELD	GAS TUNGSTEN ARC WELD
STAINLESS STEEL	STAINLESS STEEL	SA-182 F304L F316L F347	SFA-5.4 E308L-16 E316L-16 E347-16	SFA-5.9 ER308L ER316L ER347
MONEL OR COPPER NICKEL	MONEL	SB-164 UNS N04400	SFA-5.11 EniCu-7	SFA 5.14 ERNiCu-7
CARBON STEEL	CARBON STEEL	SA-105 OR C-1018	SFA-5.1 E7018	SFA-5.18 ER70S-2
SA-213 T22	INCONEL	SB-166 UNS N06600	SFA-5.11 EniCrFe-3	SFA-5.14 ERNiCr-3

**** Select plug material to match grade of tubesheet weld overlay material, or to match the tubesheet base material if there is no corrosion resistant weld overlay on the tubesheet.**

TESTS: FOR PLUGGED TUBES

Air and soap leak test the plug(s) by applying air or nitrogen at 1 kg/sq cm on the shellside.

A color contrast liquid penetrant examination is to be performed on welded plugs. Hydrostatic test the shellside at a pressure approximately 10% below the shellside design pressure stated on the nameplate. Any test pressure exceeding the design pressure will require gagging or blanking off the shell safety valve. Hold the test pressure for at least four hours, preferably overnight, and check for any droplets.

CHAPTER – B9
SPECIAL INSTRUCTIONS FOR THE REPAIR OF STEAM TURBINE CASINGS

1.0 GENERAL INSTRUCTIONS:

1.1 This instruction is valid for the repair of steam turbine castings by welding. The materials for which this instruction is applicable are as above.

1.2 The repair by welding may be carried out only by qualified welder, for particular material combination and position, having enough experience in this line.

1.3 The castings of casings supposed to be repaired by welding must be in the heat treated state specified in the respective drawing. It is forbidden to carry out any repair by welding on castings which were not annealed or subjected to the prescribed heat treatment.

1.4 MATERIAL GRADES BEING USED IN STEAM TURBINE COMPONENTS

I. Carbon Steel Castings:
0500.401(C-steel casting)
AA19511
AA19512
AA19521(1.5% Mn Steel)
HW19562
HW19572(GP240GH)
HW19573(GP240GH)
HW19586(Si-Mn Casting)
HW19591(GS-45)
HW19592(GP240GH)
AA19510(GP240GH)
AA19513(GS-45)

II. SS Castings:
HW19699(Gx4 CrNi 13-4)[13/4 Casting)

III. Special Castings(Nodular Cast Iron):
HW19789 (EN-GJS-400-18U-RT)
HW19791(EN-GJS-400-18U-RT)(GGG-40.3)
HW19793(EN-GJS-400-18U-RT)(GGG-40.3)
HW19798(EN-GJS-400-15U)
HW19799(EN-GJS-400-18U-RT)(GGG-40.3)

IV. Alloy Steel castings:
0500.501(Cr-Mo-V casting)
AA19522(G17 CrMo V5-10)
HW19563(GS 18 CrMo 9-10)
HW19565(Gx23 CrMo V 12-1)
HW19568 (Gx22 CrMo 12-1)
HW19574(G17 CrMo 5-5)
HW19576(G17 CrMo 9-10)
HW19578(G20 Mo5)
HW19581(G17CrMo V5-10)
HW19587(GS 17CrMo 5-5)
HW19589 (G 17 CrMo V 5-10)
HW19595(G20 Mo5)
HW19598(G17 CrMo V5-10)
HW19687(Gx12 CrMo V Nb N9-1)
HW19688(Gx12 CrMo W V Nb N 10-1-1)
HW19689(C12A ASTM A217 M)(9Cr+1Mo +0.25V→MS & HRH Steam Strainer Housing)
HW19691(G 17 CrMo 5-5)
AA19516(G 20 Mo5)
AA19515(G 17 CrMo 9-10)
AA19514(G 17 CrMo 5-5)

2.0 DECISION ON REPAIR:

2.1 No repair must be carried out without the approval of the manufacturing unit.

2.2 The manufacturing department takes the decision about the repair based on a strict visual and Non-Destructive examination taking into consideration the type and size of the defect and its location with regard to the possibility of repair. No repair must be undertaken, would it endanger the proper operation and safety of the equipment.

3.0 EXECUTING THE REPAIR:

3.1 The defects in castings ascertained by the manufacturing unit, must be chipped off, gouged or ground out or drilled out in such a way as to obtain a clean metallic surface. Even then the gouged portion must be ground in order to obtain a metallic surface. In case of doubts whether the defect has been completely removed or not, the MPI / DPT/LPI must be applied.

3.2 The defective portions must be removed in such a way as to enable the welder to carry out the welding successfully. There must be no sharp edges and the transition from the defective portion to the faultless material must be done in a smooth way. The welding engineer has to certify whether the preparation has been carried out properly.

3.3 In case cracks develop during welding, the welder is obliged to stop the welding operation and call the welding engineer immediately who will instruct the welder how to proceed further on.

3.4 If preheating for welding is prescribed, it is recommended to heat the whole casting upto the required temperature. The preheating temperature has to be maintained throughout the welding operation. Heating can be done by fuel gases, annealing mats or induction heating as is suitable. It is essential to protect the casting during welding against any sudden cooling which could cause the increase of inner stresses. The surface exposed to the atmosphere should be covered by suitable insulating materials (silica blankets, glass wool etc.). The temperature of preheating is being checked during welding by means of suitable temperature indicating aids like thermo-chalks etc. If the preheating temperature/ inter pass temperature falls during welding below the minimum required value, welding must be interrupted and the temperature regained.

3.5 Welding must proceed without any interruption. In case welding is interrupted for any unexpected reason the casting must not cool down fast, but must be heated by gas burners in order to cool down slowly to the room temperature. The same procedure has to be followed when concluding the welding operation.

3.6 In case of large welds intermediate annealing has to be carried out according to the enclosure of this instruction.

4.0 INSPECTION OF THE REPAIR:

4.1 All major repairs done on casing by welding must be recorded. The manufacturing unit / inspection department is obliged to keep these records (including a sketch about the location of the defect). Only small repairs like local porosity need not be recorded.

4.2 The welds shall be inspected visually. Larger repairs shall always be inspected by applying Non-destructive examination methods. The weld must be homogenous without any cracks.

4.3 Defects found in the weld must be again repaired following the same procedure as stated above.

5.0 HEAT TREATMENT:

5.1 The repaired and inspected castings must be again heat treatedwith proper temperature recording devices and thermocouples. The type of heat treatment will be given by the welding engineering department from case to case.

6.0 RESPONSIBILITY:

6.1 The manufacturing unit is responsible for:

a) The exact determination of the repair to be carried out on the casing.

b) Ascertaining that the found defects were properly removed.

c) Inspection of the executed repair.

d) Record keeping on repairs.

6.2 The welding engineering department / manufacturing unit is responsible for:

a) Certifying that the places on which welding is supposed to be done are properly prepared for undertaking the repair.

b) Follow up of welding procedure specification.

c) Supervision of the welding operation.

d) Ascertaining that the preheating temperature has been reached and inter pass temperature maintained as prescribed.

e) Co-operating with the manufacturing unit when evaluating the result of the welding operation.

f) Prescribing necessary heat treatment after welding, if required.

CHAPTER – B10
WELDING & HEAT TREATMENT DETAILS OF THERMOCOUPLE PADS & CLAMPS

WELDING THERMOCOUPLE PADS & CLAMPS TO WATERWALLS, SEPARATORS, S.H. & R.H. COILS FOR METAL TEMPERATURE MEASUREMENT

1. Pad/Clamp Material : **SS304, 310, 316, 321**
2. Pre-heat & post weld heat treatment : **Refer below Table**

Table B11.1- Pre-Heat & Post Weld Heat Treatment

Sl.No.	Tube Material (SH & RH)	Base Material Thickness	Thermocouple Pad Material	Preheat (Min.)	Post Weld Heat Treatment (PWHT)	Consumable Electrode
FOR TUBES & PIPES OUTSIDE DIAMETER≤102 MM & FILLET THROAT THICKNESS MAX.13 MM						
01	SA210 Gr.A1/ SA210 Gr. C	≤19 mm	SS304, 310, 316, 321	Nil	Nil	E7018-A1
02	SA213 T11/ SA213 T12	≤ 13 mm	-do-	150 ^{0}C	Nil	E7018-A1
03	SA213 T22	≤ 12 mm	-do-	150 ^{0}C	Nil	E7018-A1
04	SA213 T23	All	-do-	220°C	745±15°C	ENiCrFe-3
05	SA213 T91/ SA213 T92	All thickness	-do-	220 ^{0}C on T91/T92 side	730-770 ^{0}C (Min. 30 Minutes)	ENiCrFe-3
06	SA213 TP347H/ Super 304H	All Thickness	-do-	Nil	Nil	E308H-15/16
FOR PIPES OUTSIDE DIAMTER>102 MM & FILLET THROAT THICKNESS MAX.13 MM						
07	SA 106Gr.B/C	≤19 mm 19-75 mm >75 mm	-do-	Nil 150 ^{0}C 150 ^{0}C	Nil Nil 610 ±15 ^{0}C	E309-15/16
08	SA335 P12	All Thickness	-do-	150 ^{0}C	665±15 ^{0}C (Min. 30 minutes)	E309-15/16
09	SA335 P22	All Thickness	-do-	150 ^{0}C	695±15 ^{0}C (Min. 30 Minutes)	E309-15/16
10	SA335 P91/ SA335 P92	All Thickness	-do-	220 ^{0}C on P91/P92 side	730-770 ^{0}C (Min. 30 Minutes)	ENiCrFe-3

3. Electrode size : 2.5 mm
4. Welder shall strike ARC on Thermocouple Pad or “Run-on Run-off” Block and bring arc up to side of thermocouple pad using as low a current as possible to avoid burn trough.

CHAPTER -B11
WELDING AND PWHT SEQUENCE FOR LOWER RING HEADER (500/600MW Subcritical boilers)

B11: WELDING AND PWHT SEQUENCE FOR LOWER RING HEADER (500/600MW Subcritical boilers)

1.0 PURPOSE

1.1 To describe the welding, NDE and Post Weld Heat Treatment (PWHT) sequences for the four field welds in the lower ring header assembly.

2.0 WELDING & INTERSTAGE RADIOGRAPHY TESTING (RT)

2.1 One of the sequences of 2.1.1 or 2.1.2 given below shall be followed while welding the four joints in the lower ring header assembly.

2.1.1 All four corner joints are to be welded simultaneously upto 60 mm thickness and inter stage RT shall be taken. After inter stage RT clearance, balance welding of all four corner joints are to be done simultaneously.

2.1.2 Two diagonally opposite joints are to be welded simultaneously upto 60 mm thickness and inter stage RT shall be taken. Then balance two joints are to be welded simultaneously upto 60 mm thickness and inter stage RT shall be taken. After inter stage RT clearance, balance welding of these two joints shall be done simultaneously and then balance welding of the remaining two joints are to be done simultaneously.

3.1 ULTRASONIC TESTING

3.1 All weld joints shall be dressed smoothly for UT and ultrasonic testing shall be carried out.

4.0 PWHT

4.1 PWHT of each weld joint shall be done individually in any order

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Records of revision:

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: 10.02.2020 Reviewed and revised for updation as per the below table. All changes made in Rev 1 marked in red.

Chapter no.	Clause no.	Details of Revision	Remarks
A1	5.2	Year 1998 deleted and "latest" added	To ensure usage of latest document
	5.2	In table under 5.2, nitrogen content for Grade 3 Ar corrected	Errata corrected.
	5.3	Revised	Revised for clarity
A2	3.0	Text specifying reference to material specification added	Revised for clarity
	Table A2.1	SA790 UNS S32750 and SA 335 P91 type 1 & 2 updated in the table.	Updated as per latest ASME Edition
	Table A2.2	SA 213 T91 type 1 & 2 updated in the table. Cu for Code case 2328 -S30432 material updated	Updated as per latest ASME Edition
	Table A2.3	SA 182 F91 type 1 & 2 updated in the table.	Updated as per latest ASME Edition
	Table A2.4	Cu content specified where applicable	Updated
	Table A2.5	SA 3387 Gr.91 type 1 & 2 updated in the table and note added.	Updated as per latest ASME Edition & revised for clarity
A3	Table A3.1	E2594-16, ER 309-LMo & ER2594-16 updated in the table.	Updated
	Table A3.2	ER2594-16 & ER309-LMo added to the table	New specification added
	Drying and Holding Parameters	Table updated	New specifications added
	Table A3.3	Table updated and Note 1 added and Note 1 renumbered as Note 2 and revised	Revised for clarity
	Table A3.9	Typographical error corrected and table updated	Revised
A4	--	Edge preparation drawing for piping centre 3-80-300-19825 rev 04 updated	Updated
A6	Section A6.1	Title Revised	Errata corrected
	Section A6.1/ 2.0	Figures references added	Reference to new figures added
	Section A6.2	Title Revised	Errata corrected
	Section A6.2/ 3.1	New clause added and subsequent clause renumbered.	Revised for clarity

	Section A6.2/ 3.2	New clause added and clauses renumbered. Existing clause revised for clarity.	Revised for clarity
Chapter no.	**Clause no.**	**Details of Revision**	**Remarks**
	Section A6.2/ 3.3	New clause on "Welder Qualification for plate to plate fillet welds" added	New clause added
	Section A6.2/ 4.1.8	Elaborated acceptance criteria for each weld type	Revised for clarity
	Section A6.2/ 8.0	List of enclosures updated.	Updated.
A6	Table A6.1	Sl. No. 2 modified and note added	Updated for clarity
	Table A6.1	Sl. No. 5 & 6 added to include requirements of Structural steel – Sheet & Structural Plate Welder (for Fillet Qualification)	New requirements added
	Figure A6.12, 6.13 & 6.14	New figures added	New figures added
A7	1.1	Scope updated to include hardness values for P4 and P5A welds.	Updated
	7.0	Added to include hardness values for P4 and P5A welds.	Updated
B1	1.1	Existing clause split and plate thickness revised	Revised
	Figure B1.2	Plate thickness revised	Revised
B2	11.1	Reference for ‘Soaking time and temperature for inter-stage PWHT’ added.	Revised for clarity
	12.0	Option for different types of Portable hardness tester given & Lower hardness value for P91 welds revised.	Revised
B3	8.0	Revised the requirement specifying usage of hardness tester in-line with chapter B2 (clause 12.0)	Revised for clarity
	8.1	Lower hardness value for T91 welds revised.	Revised
B7	--	Updated in totality	Updated in totality
-	--	List of Figures updated	Updated

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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.

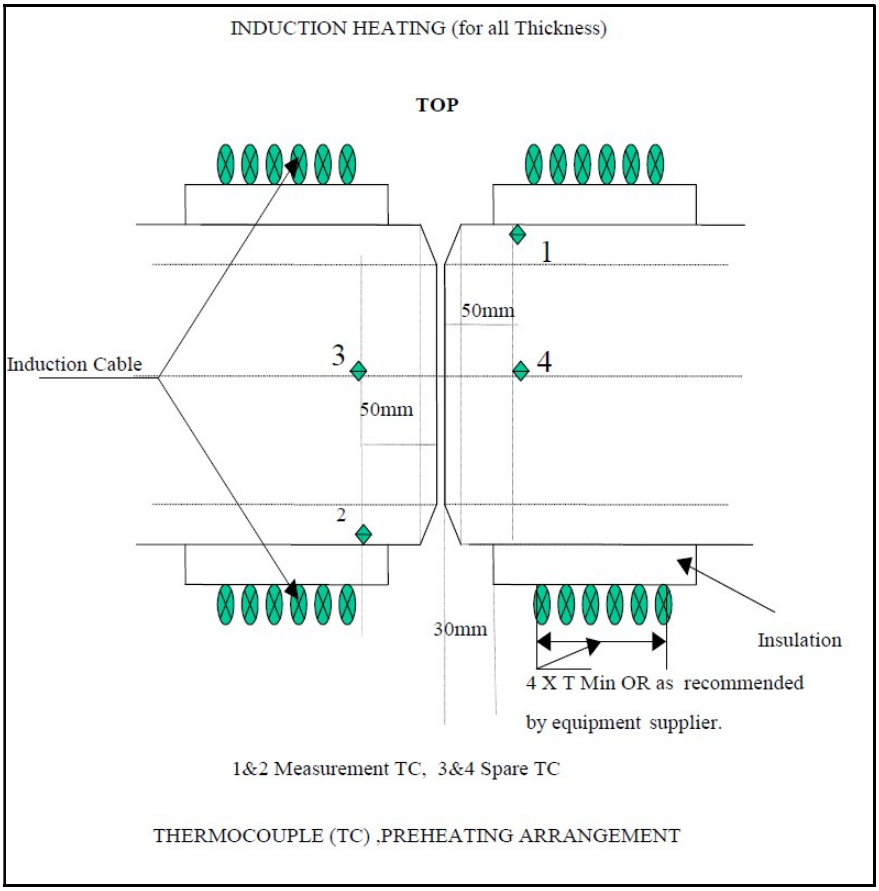

Figure 1.1: Placement of Thermocouples on P91/P92/F91/F92/C12A materials for Preheating

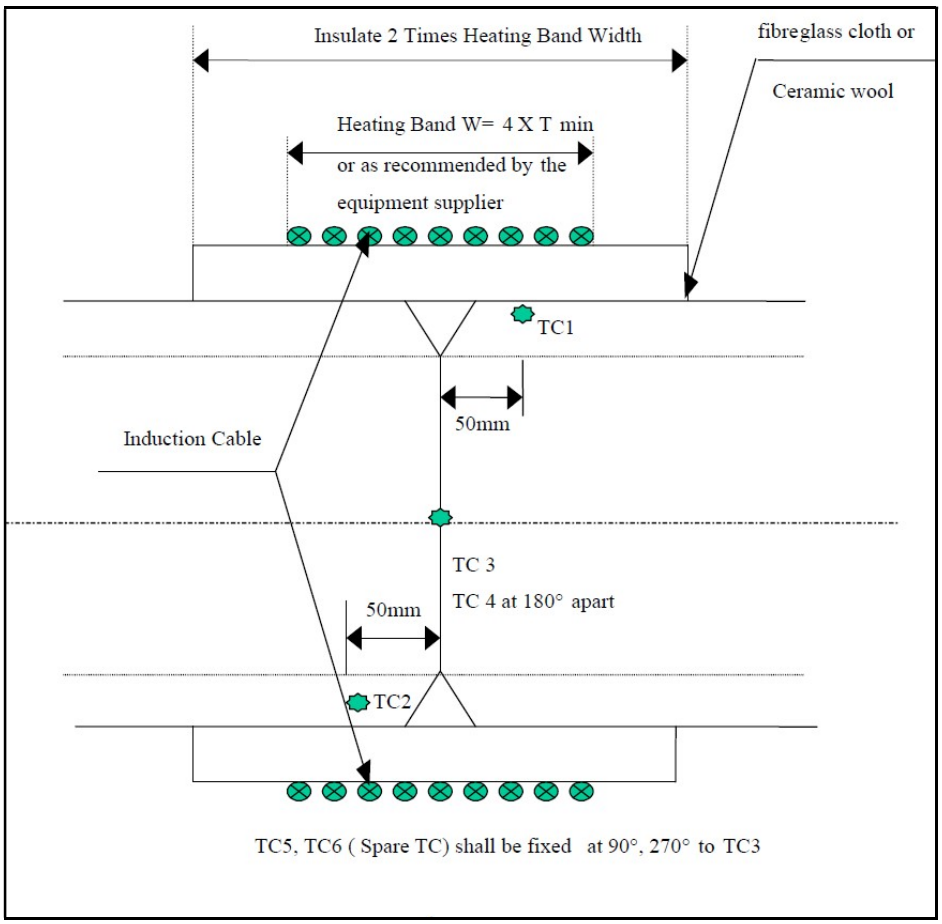

Figure 1.2: Placement of Thermocouples on P91/P92/F91/F92/C12A materials for PWHT

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.

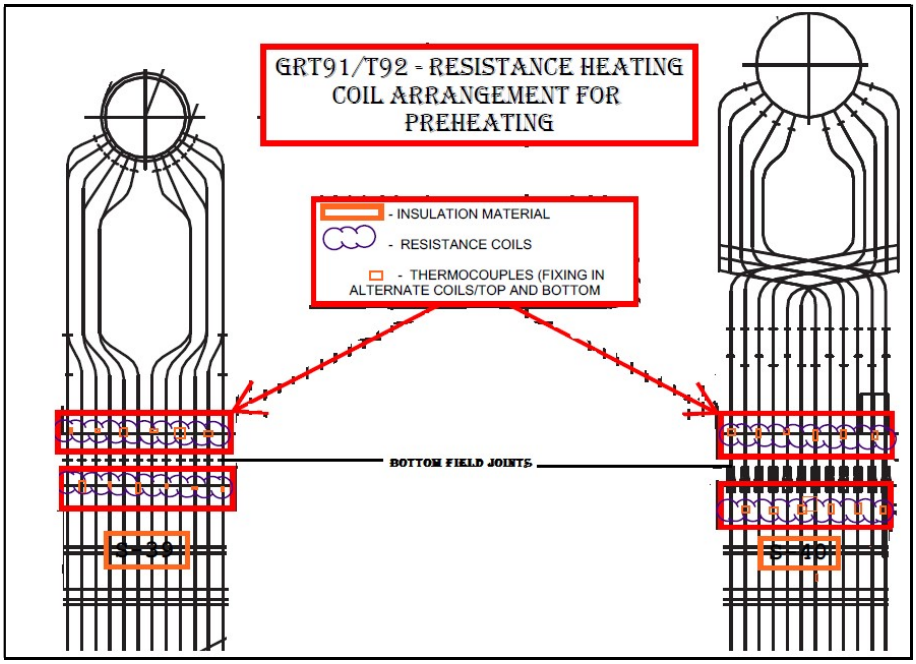

Figure 1.3: Resistance heating Coil arrangement for Preheating of T91/T92 tube assembly

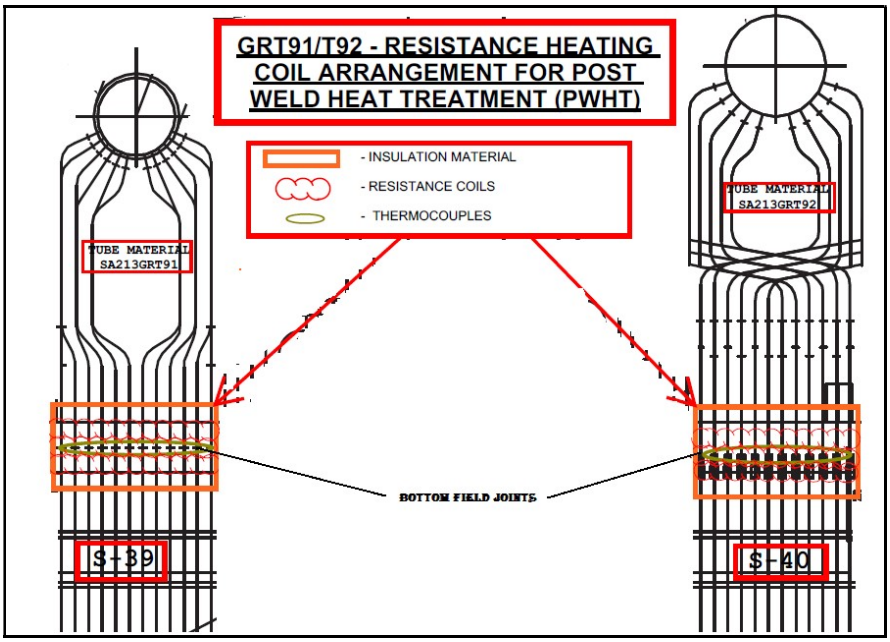

Figure 1.4: Resistance heating Coil arrangement for PWHT of T91/T92 tube assembly

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

S.NO.	ANNEXURE	DESCRIPTION	PAGE NO.
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LIST OF TABLES:

S.NO.	TABLE	DESCRIPTION	PAGE NO.
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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

Document No: AA/CQ/GL/011 Part III-NDEM Rev: 01

पावर सेक्टर के लिए नॉन डिस्ट्रक्टिव एक्ज़ामिनेशन मैनुअल

NON DESTRUCTIVE EXAMINATION MANUAL FOR POWER SECTOR

कार्पोरेट गुणता एवं व्यावसायिक उत्कृष्टता
CORPORATE QUALITY & BUSINESS EXCELLENCE

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

IMPORTANT NOTE

THIS NDE MANUAL PROVIDES BROAD BASED GUIDELINES FOR WELDING WORK AT SITES. HOWEVER, SITES MUST ENSURE ADHERENCE TO THE PRIMARY DOCUMENTS LIKE CONTRACT DRAWINGS, ERECTION WELDING SCHEDULE, PLANT / CORPORATE STANDARDS, WHEREVER SUPPLIED, STATUTORY DOCUMENTS, WELDING PROCEDURE SPECIFICATIONS, CONTRACTUAL OBLIGATIONS, IF ANY AND SPECIAL INSTRUCTIONS ISSUED BY RESPECTIVE MANUFACTURING UNITS SPECIFIC TO THE PROJECT.

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CHAPTER 1.0

NDE PROCEDURES FOR BOILER AND AUXILIARIES

CHAPTER 1.1

PROCEDURE FOR LIQUID PENETRANT EXAMINATION

PROPRIETARY DATA NOT TO BE DISCLOSED OR REPRODUCED WITHOUT THE PERMISSION OF BHEL.

PROCEDURE FOR LIQUID PENETRANT EXAMINATION

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01/01/2020	01/01/2020	01-01-2020	01/01/2020

Effective from 01.01.2020

PROPRIETARRY DATA NOT TO BE DISCLOSED OR REPRODUCED WITHOUT THE PERMISSION OF BHEL

RECORD OF REVISION

Rev. No	Revision Date	Revision of Details
07	01-07-1991	1.2 Re designated as 2.0 and modified 4.4 Re designated as 5.4 and revised 5.1.3 Re designated as 6.1.3 and revised 5.3.2 Re designated as 6.3.2 and revised
08	28-03-1994	Clause 3 numbered as 1.2 and rest of the clauses renumbered. ASME Section VIII added as reference. 6.4 Added 7.0 Modified. 'Qualification of procedure for Non-Standard Temperatures'- deleted and rest of the clauses renumbered.
09	01-08-1996	Revised in entirety
10	01-06-1997	1.0 Scope of application enhanced 8.2 Maximum Dwell time included 10.3 Evaluation to meet AWS code added 10.4 Title changed to meet ASME Code 12.2 &12.3 Acceptance Standards added for structural applications
11	04-01-1999	Clauses 2.0, 7.1.1, 8.2.1, 8.4.3.1, 9.1, 9.3, 10.3,10.4 and 11.1.1modified 11.2.4 Added and rest of the clauses renumbered. Editorial Corrections made. Annexure A added
12	28-12-2002	5.4 Modified 6.1 Revised Annexure A incorporated in main text, revised and renumbered.
13	22-01-2004	4.0, 6.1, 8.4.1,8.4.3.1 Modified 7.2 combined with 5.4 5.4, 9.3 Revised
14	27-12-2007	Clause 2.0, 7.0, 8.2,11.2.2 , 11.2.3 and 19.1-Revised
15	02-05-2009	Clause 2.0, 5.4, 9.2 and 18.1 revised
16	30-12-2010	Clause 1.1, 2.0, 5.4, 8.2.1 and 8.4.2.1 Revised. Table 3 added
17	30-01-2015	Clause 15.2 modified
18	01-01-2016	Clause 2, 9.1 revised. Sr.11, Column-3, of Table-3 revised. Clause 5.5 Added. Clauses 6.1, 8.1, 8.2.1, 8.2.2, 8.3.2.1, 8.4.2.1 Clause 9.1, 9.2, 10.1 modified. Table-1, Table-2 modified.
19	*03-10-2017*	*Clause 8.2.1, 10.1 and 16.1 modified.*
20	*30-05-2018*	*Clause 1.3 added. Clause 2.1,2.2,4.4,4.5,8.1,8.2.1,8.4.2.1,8.4.2.2,10.1,18.1, Table 1& 3 revised.*
21	*07.01.2019*	*Clause 2.3, 8.4 & Clause 15.1.*
22	*01.01.2020*	*Clauses 1.1, 2.1, 2.2, 9.1 revised..5.4 & 5.5 modified. Table 1 revised.*

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1.0 SCOPE

1.1. This procedure defines the method, techniques and acceptance standards for Liquid Penetrant Examination by Solvent removable color contrast technique, for all shapes of weldment and materials used for Boilers, Pressure Vessels, Heat Exchangers, Piping and Non pressure parts.

1.2. In pressure vessels the examination shall include all welds around openings, attachment welds with a throat thickness over 6 mm and on finished surfaces of welds as required by referencing code. The examination includes base material 13 mm on each side of the weld.

1.3. This procedure shall also be applicable for Ferrous and Non-Ferrous materials and Welded components used for AUSC Projects

2.0 REFERENCE

2.1. ASME Section V, I and VIII (Division 1&2) / *2019*
2.2. ASME B 31.1 / *2018*
2.3. AWS D 1.1 / D1.1M:2015

3.0 EQUIPMENT

3.1. The term 'penetrant materials' as used in this procedure is intended to include all Liquid penetrants, Solvents (penetrant removers) or cleaning agents, developers etc. used for 'Liquid Penetrant Examination'.

4.0 CHEMICALS FOR EXAMINATION

4.1 The cleaner used for the surface cleaning will be an organic chemical such as Acetone or Trichloro-ethylene.

4.2 Penetrant- Solvent removable type with good color contrast like Red or Pink.

4.3 Developer- Non-aqueous suspendable type.

4.4 Sulphur content in Penetrant materials for Nickel base alloys testing shall be less than 0.1 % of the residue by weight.

4.5 Chlorine plus Fluorine content shall not exceed 0.1% of the residue by weight in Penetrant materials when used for testing of Stainless steel or Titanium.

4.6 The certification of contaminant shall be obtained from the supplier with Batch number details.

5.0 SURFACE PREPARATION

5.1 In general as welded, as rolled, as forged or as cast condition is accepted. When the surface irregularities might mask the indications of unacceptable discontinuities, the surface shall be prepared by grinding or Machining or any other suitable method.

5.2 The surface to be examined and all adjacent areas within at least 25 mm shall be dry and free of any dirt, grease, lint, scale, welding flux, weld spatter, rust, paint, oil or any other extraneous matter that could prevent the penetration.

5.3 Shot / sand blasting of the surface is not acceptable for conducting penetrant examination. If the component is shot blasted, the surface is to be etched before conducting penetrant examination.

5.4 Cleaning of the surface shall be done with lint free white cotton cloth moistened in solvent cleaner.

5.5 The following Brands of Penetrant chemicals will be used.or other brands may also be used with the approval

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of Level III / NDT. Intermixing of penetrant materials from different families or different manufacturers is not permitted.

Table – 1
LIST OF PENETRANT MATERIALS

Manufacturer	MATERIAL (DESIGNATION)		
	CLEANER	PENETRANT	DEVELOPER
Pradeep NDT	Flaw guide	Flaw guide	Flaw guide
MR Chemie	Crack marker	Crack marker	Crack marker
Ferrochem	Crack Check	Crack Check	Crack Check

6.0 DRYING AFTER PREPARATION

6.1. After cleaning, drying of the surfaces shall be by normal evaporation. The minimum time required for the cleaner to dry from the surface shall be 60 Seconds *and maximum time shall be 10 minutes.*

7.0 TEMPERATURE

7.1. The temperature of the penetrant and the surface of the part shall not be below 5° C and not above 52° C throughout the examination period.

8.0 EXAMINATION

8.1. Penetrant Application

The penetrant shall be applied by brushing or spraying. For spraying, an aerosol spray can is recommended

8.2. Penetration Time:

8.2.1 *The penetration time (dwell time) shall be minimum 10 minutes and maximum 20 minutes for the standard testing temperature which is within 16 to 50 Deg. Celsius.*

For Nickel and Titanium based material and Welds**,** the penetration time (dwell time) shall be 20 minutes

Any change from this duration shall be qualified by demonstration. The penetrant shall be allowed to remain wet on the part for a minimum and *maximum period* (dwell time) as qualified by demonstration for specific application.

8.2.2 Regardless of the length of the dwell time, the penetrant shall not be allowed to dry. If for any reason the penetrant does dry, the examination procedure shall be repeated, beginning with a cleaning of the examination surface.

8.3. Removal of Excess Penetrant:

8.3.1 After the required dwell time has elapsed, the excess penetrant remaining on the surface shall be removed by wiping with a lint free cloth, repeating the operation until most traces of penetrant have been removed. Final left out penetrant shall be removed by wiping with a clean cloth moistened with the solvent. Excessive application of the cleaner shall be avoided to prevent the possibility of removing the penetrant from discontinuities causing a decrease in the sensitivity of the test. Flushing the material surface with the solvent following the application of penetrant and prior to developing is prohibited.

8.3.2 Drying after excess penetrant removal:

8.3.2.1 After the removal of excess penetrant the surface shall be dried by normal evaporation. The minimum time

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required for the surface to get dried by normal evaporation shall be 60 seconds and maximum shall be 10 minutes

8.4. Developer Application

8.4.1 Prior to application, the developer must be thoroughly agitated to ensure adequate dispersion of suspended particles. The developer shall be applied as soon as possible by spraying using aerosol spray can for complete coverage of the part with a thin, uniform film of developer. The maximum time interval between excess penetrant removal and application of developer shall be 10 minutes. Drying of developer shall be by normal evaporation.

8.4.2 Development Time

8.4.2.1 Developing time for final interpretation begins immediately after the drying of wet developer coating.

8.4.2.2 Final inspection shall be made after a minimum period of developing time as detailed below.

Developing Time for conventional steels and Welds: Min.10 minutes to Max 60 Minutes
Developing time for Nickel and Titanium based material and Welds: 60 minutes

9.0 LIGHTING

9.1. A minimum light intensity of 100 foot candle (1076 lux) is required to ensure adequate sensitivity during the examination and evaluation of indications. "A Hand lamp with *240* Volts, *09* Watt LED *Electric* bulb *white light* is held at 300 mm distance normal to the test surface within a circle of 280 mm diameter" is considered adequate to provide above level of illumination. The *supplemental white* light source, technique used, and light level verification shall be demonstrated one time, documented, and maintained on file.

9.2. Light meters shall be calibrated at least once a year or whenever a meter has been repaired. *If meter has not been used for one year it shall be calibrated before use.*

10.0 EVALUATION

10.1. Flaws at the surface will be indicated by bleed out of the penetrant. However localized surface irregularities such as machining marks or other surface conditions may produce false indications. In case of excessive diffusion of penetrant in to the developer, close observation of the formation of indications during application of the developer may assist in characterizing and determining the extent of the indications.

10.2. The surface shall be examined in increments if the surface to be examined is large enough to complete the inspection within the prescribed time.

10.3. An indication of an imperfection may be larger than the imperfection that causes it; however, the size of the indication is the basis for acceptance evaluation.

10.4. Relevant indications are those which result from mechanical discontinuities (imperfection).

10.5. Only indications with major dimension greater than 1.5 mm shall be considered relevant.

10.6. Any indication which is believed to be non-relevant shall be regarded as a defect until the indication is either eliminated by surface conditioning or it is evaluated by other non-destructive testing methods and proved to be non-relevant.

10.7. Linear indication - length is more than three times the width.

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10.8. Rounded indication -circular or elliptical with the length equal to or less than three times the width.

10.9. Any questionable or doubtful indications shall be reexamined to determine whether or not they are relevant.

11.0 ACCEPTANCE STANDARD

11.1. Welds and Materials (as per ASME Sec I and VIII / Div. 1 and 2)

11.1.1 All surfaces to be examined shall be free of

11.1.2 a) Relevant linear indications.

b) Relevant rounded indications greater than 5.0 mm.

c) All relevant indications shall be investigated to assure that no leak-path exists in welds joining nipples to drums, dished-ends and headers.

11.1.3 Four or more relevant rounded indications in a line separated by 1.5 mm or less edge to edge.

11.1.4 In attachment welds of non-load carrying class, indications from cracks or due to material separation are unacceptable.

11.2. For Power Piping (as per ASME B31.1 Power Piping)

11.2.1 11.2.1 Indications whose major dimensions are greater than 2.0 mm shall be considered relevant.

11.2.2 11.2.2 The following relevant indications are unacceptable:

a) Any cracks or linear indications

b) Rounded indications with dimensions greater than 5.0 mm

c) Four or more rounded indications in a line separated by 2.0 mm or less edge to edge

d) Ten or more rounded indications in any 3870 mm² of surface with the major dimension of this area not to exceed 150 mm with the area taken in the most unfavorable location relative to the indications being evaluated

12.0 WELDS MADE TO STRUCTURAL WELDING CODE -AWS D 1.1

12.1. For Statically and cyclically loaded non-tubular connections made to AWS code the acceptance of any discontinuity shall be based upon a visual examination of the discontinuity after the removal of developer medium and evaluated for its nature and size. Where the discontinuity cannot be seen after removal of the developer medium either directly or using magnifying glass evaluation shall be based on the size and nature of liquid penetrant indication.

13.0 ACCEPTANCE STANDARD TUBULAR CONNECTIONS

13.1. Statically loaded non-tubular connections

13.1.1 Indications from Cracks, Lack of penetration and lack of fusion are not acceptable.

13.2. Porosity

13.2.1 Complete joint penetration groove welds in butt joints transverse to the computed tensile stress shall have no visible piping porosity.

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13.2.2 For all other groove welds and for fillet welds, the sum of the visible piping porosity 1.0 mm or greater in diameter shall not exceed 10 mm in any linear 25 mm of weld and shall not exceed 20 mm in any 300 mm length of weld.

13.3. Undercut

13.3.1 For material less than 25 mm thick, undercut shall not exceed 1.0 mm except that a maximum 2.0 mm is permitted for an accumulated length of 50 mm in any 300 mm.

13.3.2 For material equal to or greater than 25 mm thick, undercut shall not exceed 2.0 mm for any length of weld.

14.0 Cyclically loaded non-tubular connections

14.1. Indications from Cracks, Lack of penetration and lack of fusion are not acceptable in any welds.

14.2. Porosity

14.2.1 Complete joint penetration groove welds in butt joints transverse to the direction of computed tensile stress shall have no piping porosity. For all other groove welds, the frequency of piping porosity shall not exceed one in 100 mm of length and the maximum diameter shall not exceed 2.5 mm.

14.2.2 The frequency of piping porosity in fillet welds shall not exceed one in each 100 mm of weld length and the maximum diameter shall not exceed 2.5 mm. EXCEPTION: for fillet welds connecting stiffeners to web, the sum of the diameters of piping porosity shall not exceed 10mm in any linear 25mm of weld and shall not exceed 20mm in any 300 mm length of weld.

14.3. Undercut

14.3.1 In primary members, undercut shall not be more than 0.25 mm deep when the weld is transverse to tensile stress under any design loading condition. Undercut shall not be more than 1 mm deep for all other cases.

15.0 REPAIR AND RE-EXAMINATION

15.1. Whenever an imperfection is repaired by chipping or grinding the excavated area shall be blended into the surrounding surface so as to avoid sharp notches, crevices or corners. The extent of the crack shall be ascertained by use of acid etching, MT, PT, or other equally positive means; the crack and sound metal 50mm beyond each end of the crack shall be removed.

15.2. After a defect is thought to have been removed and where welding is required after repair, the area shall be examined for removal of defects, area cleaned and repair carried out. The repaired area shall be blended into the surrounding surface as in 13.1 and re-examined by the liquid penetrant or any other NDT methods originally required for the affected area.

16.0 PERSONNEL QUALIFICATION

16.1. All personnel carrying out the examination and evaluation shall be qualified to as per BHE: NDT: G: CRT. The testing shall be done by minimum Level-I *working under the NDT Level II* and Evaluation by Level II / III Personnel.

17.0 POST CLEANING

17.1. After the examination and evaluation is completed all penetrant testing materials shall be removed from the surface by using white cloth soaked with cleaner, so that it will not interfere with the subsequent processing or service requirements.

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18.0 REPORTING AND RETENTION PERIOD

18.1. Report shall be given in the format, signed by Level II / III after the completion of the examination. All the reports for ASME Coded works shall be retained for a period of 5 years.

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Table-3

Sl No	Requirement (As per TABLE T-*621.1*, Article 6 of ASME Section –V)	Type of variable	Applicable clause in the procedure
01	Identification of and any change in type or family group of penetrant materials including developers, emulsifiers, etc.	Essential	Clause 5.4: As per Table-1
02	Surface preparation (finishing and cleaning, including type of cleaning solvent)	Essential	Clause 5.1 & 5.5: As welded / as ground / as machined condition and cleaning with lint free cotton cloth moistened in solvent cleaner (table-1).
03	Method of applying penetrant	Essential	Clause 8.1: By brushing
04	Method of removing excess penetrant	Essential	Clause 8.3.1: Manual Wiping with lint free cloth till the traces of excess penetrant on the surface disappear. Then, remove by gentle wiping with lint free cloth moistened with solvent.
05	Hydrophilic/ lipophilic emulsifier concentration and dwell time in dip tanks and agitation time for hydrophilic emulsifiers	Essential	Not Used & Not applicable
06	Hydrophilic emulsifier concentration in spray application	Essential	Not Used & Not applicable
07	Method of applying developer	Essential	Clause 8.4.1: By spraying with aerosol spray can
08	Minimum and maximum time between steps and drying aids	Essential	Drying time after preparation- Clause 6.1: Natural Evaporation, Minimum 60 seconds & max 10 minutes. Drying after excess penetrant removal time- Clause 8.3.2.1: Minimum 60 seconds & max 10 minutes.
09	Decrease in penetrant dwell time	Essential	Dwell time-Clause 8.2.1: minimum 10 minutes & maximum 20 minutes for steels. 20 minutes for nickel and titanium based alloys
10	Increase in developer dwell time(Interpretation time)	Essential	Development time- Clause 8.4.2.2: Minimum 10 minutes and maximum 60 minutes for steels. 60 minutes for for nickel and titanium based alloys
11	Minimum light intensity	Essential	Clause 9.1:Minimum 100fc, Source: A hand lamp with *240* V/ *09* W *LED electric* bulb *white light* at a maximum distance of *300 mm*.
12	Surface temp. outside 5 to 52 deg. C or as previously qualified	Essential	Clause7.1: The temperature of the penetrant and the surface of the part shall not be below 16° C and not above 50° C throughout the examination period.
13	Performance demonstration , if required	Essential	A change in values of variables 1 to 12 in this table beyond their range specified range will call for demonstration and re-qualification of this procedure.

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14	Personnel qualification requirement	Non-Essential	Clause 13.0: BHEL's Written Practice
15	Material shape / size to be examined and extent of examination	Non-Essential	Clause 1.1: For all shapes of weldment and materials used for Boilers, Pressure Vessels, Heat Exchangers, Piping and Structural components.
16	Post- examination cleaning technique	Non-Essential	Clause 17.1:Dry white cotton cloth & finally cleaning with dry white cotton cloth soaked with solvent cleaner

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BHARAT HEAVY ELECTRICALS LIMITED
Trichirappalli-620014
Dept. 235-Non-destructive testing /
Quality PENETRANT TESTING REPORT

Report No: Date: Notification Ref:

Work Order: Material: Stage of test:

Form: Part: Drawing No:

Thickness: Surface Condition:

Temperature of part: Pre-cleaning: Solvent cleaning Drying Time: Secs

Penetrant: Visible –Solvent Removable Dye Application: By
Brush Brand & Identification:
Penetrant:
Cleaner
Developer

Dwell Time : Mts Excess Penetrant cleaning: Using

Cloth Drying time after removal of excess penetrant: Seconds

Time interval for Developer Application: Minutes

Developer Application: Aerosol can-Spraying Development Time: Mts

Post Cleaning: Using Cloth Lighting Equipment: Hand Lamp 230V 100W

Light Intensity: lux Date of Examination:
(A hand lamp is held at 200 mm distance normal to the test surface within a circle of 280 mm diameter.) Procedure & Acceptance: BHE:NDT:PB:PT- Rev)

Sl.No	Joint No	Details of Part	Reference fro	Indication Location			Findings	Disposition
				From	To	Length		

SAMPLE

Operator's Name	Evaluated By	Reviewed by
(Level I / II)	(Level II / III)	AI

CHAPTER 1.2

PROCEDURE FOR MAGNETIC PARTICLE EXAMINATION OF WELDS IN BOILER COMPONENTS, PRESSURE VESSELS, HEAT EXCHANGERS AND NON PRESSURE PARTS

PROPRIETARRY DATA NOT TO BE DISCLOSED OR REPRODUCED WITHOUT THE PERMISSION OF BHEL.

PROCEDURE FOR MAGNETIC PARTICLE EXAMINATION OF WELDS IN BOILER COMPONENTS, PRESSURE VESSELS,HEAT EXCHANGERS AND NON PRESSURE PARTS

EFFECTIVE FROM 01.01.2020

Prepared by	Reviewed by	Approved by	Issued by
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01/01/2020	01/01/2020	01-01-2020	01/01/2020

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RECORD OF REVISION

Rev. No	Revision Date	Revision of Details
05	01-01-1993	Revised to include the requirements of ASME Section VIII, Div 1 Testing by Longitudinal Magnetization method included. Clause 2.0, 3.2, 3.3, 4.5, 5.6 and 10.5 included.
06	28-03-1994	Revised to include ASME Section VIII, Div 2.
07	01-08-1996	Revised in entirety.
08	27-07-1998	Fluorescent Examination method and requirements of Structural as per AWS D 1.1 included. Clauses 2.0, 4.5, 6.1.2.1 and 14.0 modified. 17.3 and 17.4 renumbered as 18.2 and 18.3 respectively. Annexure I added
09	20-03-2000	Clause 14.0 added and rest of the clauses renumbered. 15.1 modified. A4 added.
10	28-12-2002	15.1.1 Revised. 19.4.4 Added. Annexure A incorporated in main text, revised and renumbered
11	21-01-2004	14.0 Deleted
12	27-12-2007	Clause 2.0, 9.2.2, 18.3, 18.4.2, 18.4.3 Revised Clause 26.1 Modified
13	02-05-2009	Clause 2.0, 4.1, 7.1, 13.1.2, 14.1.1 and 14.2.1 revised
14	30-12-2010	Clause 2.0, 16.0, 19.0 revised Table 1 and 2 added.
15	15-12-2011	Clause 2.0 revised Fig 5.0 added
16	08-03-2014	Clauses 7.2 and 7.3 added
17	30-01-2015	Clauses 12.0, 23.4, 23.5 and 23.6 modified. Figure 6 added.
18	01-01-2016	Clause- 2.0, 14.1.1 revised. Sl.7, column 4 of Table- 2 revised.
19	30-09-2017	Clauses 1.1, 4.2, 25.1 modified, Clause 15.2, 15.3 added.
20	21-11-2017	Clauses 3.2, 4.3, 4.4, 4.5, 6.3, 9.2, 14.2 and 15.2 added.
21	28-06-2018	Clauses 2.0, 7.3, 9.2.1 revised.
22	03-01-2019	Clause 17.1.2 added, Clause 24.1 modified.
23	21-11-2019	Clause 4.2 modified.
24	01-01-2020	Title and Clause 1.1 of Scope changed for clarity. Clause 2.0 revised, clause 9.2 modified, 9.2.1 added, 9.3 and 9.3.1 deleted, clause 14.1.1 modified, Table 1 revised, Table 2 modified.

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1.0 SCOPE

1.1. This procedure describes the method, techniques and acceptance standards for Magnetic Particle Examination of Butt welds, fillet welds, partial penetration welds, Full penetration butt and corner welds, Nozzles, branch and piping connections attached to full penetration butt weld joints for Boiler components, pressure vessels, heat exchangers, power piping and Non pressure parts. This procedure shall be used for Prod (HWDC)-Visible dry particle or wet particle examination on ferritic steel products.

1.2. Extent of examination: All the external, accessible internal weld surfaces and adjacent base material at least 15 mm on each side of the weld shall be subjected to 100% surface examinations.

2.0 REFERENCE

a) ASME SECTION V / I / VIII (Division 1 & 2) / *2019*

b) ASME B 31.1 / 2018

c) AWS D 1.1 / D1.1M:2015

3.0 EQUIPMENT

3.1. Equipment generating half wave rectified direct current employing prods at the end of magnetizing cables shall be used for examination.

3.2. Direct/Alternating current electromagnetic yokes shall be used to detect discontinuities that are open to the surface of the part by longitudinal magnetization method and to examine the surfaces where arcing is not permitted or prod method is not practicable.

4.0 EXAMINATION MEDIUM

4.1. The finely divided ferromagnetic dry visible (non-fluorescent pigments) particles shall be used as examination medium. The particle size used for dry shall be average 100 microns (specified by the supplier of the particles).

4.2. Dry magnetic particles Brick red in color (Table 1) or wet magnetic particles brick red in color shall be used as the examination medium for examination of welds and other product forms to provide adequate contrast with the surface being examined. The surface temperature of the part examined with dry particles shall be within the range of 17^0C to 315^0C (within maximum temperature specified by the supplier of the particles) and wet particles shall be within maximum temperature specified by the supplier of the particles.

4.3. Non fluorescent wet particles will be black or reddish brown in color that provide adequate contrast with the surface being examined. Wet particles shall be suspended in kerosene or water for application to the test surface by flowing or spraying. Suitable conditioning agents shall be added to the water to provide proper wetting and corrosion protection for the parts being examined.

4.4. The temperature of the wet particle suspension and the surface of the part being examined shall not exceed 57°C.

4.5. The bath concentration shall be determined by measuring the settling volume through the use of pear-shaped centrifuge tube. The suspension shall be mixed thoroughly or shall be run through the re-circulating system for at least 30 minutes to ensure thorough mixing of all particles. The settling time shall be 30 minutes'

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minimum with water based suspension or 60 minutes' minimum with petroleum distillate suspension before taking the reading. The settling volume shall be within 1.2 to 2.4 mL for non-fluorescent particles and 0.1 to 0.4 mL for fluorescent particles, per 100 mL of vehicle or as recommended by the manufacturer.

5.0 SURFACE CONDITIONING

5.1. Preparation

5.1.1 As welded, as ground, as rolled, as cast or as forged surface is generally acceptable provided the surface irregularities will not mask the indications due to discontinuities. Otherwise surface preparation by grinding or machining may be necessary. Undercuts, overlaps or abrupt ridges and valleys in the welds and openings shall be smoothly merged with the parent metal.

5.1.2 Prior to magnetic particle examination, the surface to be examined and adjacent area within at least 25 mm of the area of interest shall be dry and free of any dirt, grease, lint, scale, welding flux, spatter, oil or other extraneous matter that would interfere with the examination.

5.1.3 Cleaning may be accomplished by detergents, organic solvents cleaner methods.

5.1.4 Non-Magnetic coating shall not be present/permitted on the surface to be examined.

5.1.5 The color of the magnetic particle selected shall be sufficiently different than the color of the examination surface to give a good contrast for evaluation. Non-magnetic surface contrasts may be applied by the examiner to uncoated surfaces, only in amounts sufficient to enhance particle contrast. When nonmagnetic surface contrast enhancement is used, it shall be demonstrated that indications can be detected through the enhancement. Thickness measurement of this nonmagnetic surface contrast enhancement is not required.

6.0 METHOD OF EXAMINATION

6.1. Examination shall be made by continuous method.

6.2. Dry continuous magnetization method

6.2.1 The magnetizing current remains on while the examination medium (Brick red Dry particle) is being applied and while the excess of the examination medium is being removed.

6.3. Wet continuous magnetization method

6.3.1 Wet magnetic particles application involves bathing the surface of the part with examination medium and terminating the bath application immediately prior to cutting off the magnetizing current with two or more shots given to the part. The duration of the magnetizing current is typically on the order of 1/2 seconds with two or more shots given to the part.

7.0 TECHNIQUES

7.1. Prod Technique shall be used as magnetization technique.

7.2. Magnetizing Procedure: Magnetization is accomplished by portable prod type electrical contacts pressed against the surface in the area to be examined. To avoid arcing, a remote control switch, which is built into the prod handles, shall be used to permit the current to be applied after the prods have been properly positioned.

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7.3. For inspection of components of Gr 91 material including Gr C12A, prod technique shall not be used. *This shall be inspected by Yoke technique using Dry method based on suitable approved procedure.*

8.0 TYPE OF CURRENT FOR MAGNETISATION

8.1. Single phase half-wave rectified Direct Current shall be employed for testing with prod techniques.

8.2. The amperage required with single-phase Half-wave rectified direct current shall be verified by measuring the average current during the conducting half cycle only.

9.0 CALIBRATION

9.1. Ammeter of magnetizing equipment shall be calibrated at least once in a year, or whenever the equipment has been subjected to major electrical repair, periodic overhaul or damage. If equipment has not been in use for a year or more, calibration shall be done prior to first use. The ammeter shall be calibrated through Instrumentation section of Maintenance and Services Department.

9.2. For *electromagnetic* yoke the magnetizing power shall be verified prior to use each day the yoke is used or whenever the yoke has been damaged or repaired. The yoke shall have a lifting power of *at least* 4.5 kg in AC mode and *at least* 18 kg in DC mode at the maximum pole spacing that will be used, *with contact similar to what will be used during the examination.*

9.2.1 Each weight used for lifting power assessment shall be weighed with a scale from a reputable manufacturer and stenciled with the applicable nominal weight prior to first use. A weight need only be verified again if damaged in a manner that could have caused potential loss of material.

10.0 EXAMINATION

10.1. Direction of Magnetization

10.1.1 At least two separate examinations shall be performed on each area. During the second examination the prods are spaced so that the lines of magnetic flux are approximately perpendicular to those used during the first examination. Examination shall be made by continuous method.

10.2. Examination Coverage

10.2.1 Examination shall be made with sufficient field overlap to assure 100% coverage of testing.

11.0 PROD TECHNIQUE: (Fig.1, 2 &3)

11.1. Magnetizing Procedure

11.1.1 The prod electrodes are pressed firmly against the surface in the area to be examined. In order to avoid arcing a remote control switch shall be built into the prod handles, to permit the current to be turned on after the prods have been properly positioned and to be turned off before they are removed.

11.2. Magnetizing Current

11.2.1 The current shall be 4 (minimum) amperes /mm to 5 (maximum) amperes/mm of prod spacing for sections 19 mm thick or greater.

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11.2.2 For sections less than 19 mm thick, the current shall be 3.6 (minimum) amperes /mm to 4.4 (maximum) amperes/mm of prod spacing.

11.3. Prod Spacing

11.3.1 Prod spacing shall not be less than 85 mm nor exceed a maximum of 190 mm.

11.3.2 The prod tips shall be kept clean and dressed and the contact areas of the test surface shall be free from dirt, scale, oil etc. to minimize electrical arcing. If the open circuit voltage of the magnetizing current is greater than 25 Volts, Lead, Steel or Aluminum rather than copper tipped prods shall be preferred to avoid copper deposits on the part being examined.

12.0 YOKE TECHNIQUE

12.1. This technique is primarily intended to cover the region between the poles. The pole spacing shall be between 100 mm to 150 mm. In order to ensure that the region of interest gets 100 % coverage, every region (or segment of the test area, divided according to the pole spacing), shall be tested twice such that the pole space displacements are mutually perpendicular in the former and later cases. For example, in the case of the weld, the pole space orientation can be 45 Deg. and 135 Deg. Respectively with respect to the weld center line orientation, in the first and second attempts.

12.2. A Pie shaped magnetic particle field indicator shown in Figure 5 shall be used to check the adequacy as well as direction of the field. It shall be positioned on the surface to be examined, such that the copper-plated side is away from the inspected surface. A suitable field strength is indicated when a clearly defined line (or lines) of magnetic particles form(s) across the copper face of the indicator when the magnetic particles are applied simultaneously with the magnetizing force. When a clearly defined line of particles is not formed, the magnetizing technique shall be changed as needed.

13.0 APPLICATION OF MPI PARTICLES

13.1. DRY PARTICLES

The dry particles shall be applied in such a manner that a light uniform dust-like coating settles on the surface of the area being examined. The application technique shall be such that the particles are suspended in air and reaches the examination surface in a uniform cloud with a minimum force, using hand powder applicators (squeeze bulb) or specially designed mechanical blower or by a spray nozzle.

13.1.1 Dry particles shall not be applied to a wet surface nor when there is excessive wind. The particles shall not be applied by pouring, throwing, or spreading with fingers.

13.1.2 Any excess powder shall be removed while the magnetization current is on and shall be with a gentle air stream by a blower or squeeze bulb without removing or disturbing particles attracted by a leakage field that may prove to be a relevant indication.

13.2. WET PARTICLES

13.2.1 The application of wet particles involves the bathing of the area to be examined, by spraying or flowing during the application of magnetizing current.

13.2.2 Two or more shots shall be applied, but the last shot shall be applied while the bath still remains on the area to be examined and after the particle flow has been stopped. Care shall be taken to cut off the bath