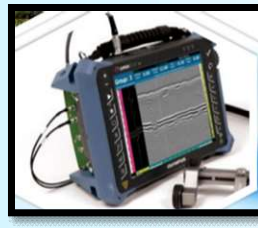
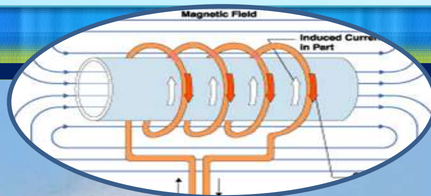
Document No: AA/CQ/GL/011 Rev:01

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

भारत हेवी इलेक्ट्रिकल्स लिमिटेड, नई दिल्ली
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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Reviewed & Approved By	A K Sarkar		GM and Head/ CQ&BE	10.02.2020

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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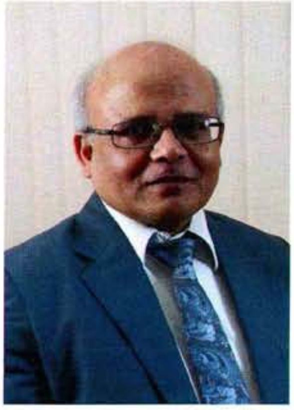
Reviewed by		A.K. Sarkar	GM /CQ& BE	
Approved By		S. S. Wadhawan	GM(I/C) /CQ& BE	

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



भारत हेवी इलेक्ट्रिकल्स लिमिटेड
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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भारत हेवी इलेक्ट्रिकल्स लिमिटेड

Bharat Heavy Electricals Limited

बी एच ई एल

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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भारत हेवी इलेक्ट्रिकल्स लिमिटेड

Bharat Heavy Electricals Limited

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BHEL

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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.

Date: 24th October, 2016

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

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भारत हेवी इलेक्ट्रिकल्स लिमिटेड

Bharat Heavy Electricals Limited

बी एच ई एल

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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.

(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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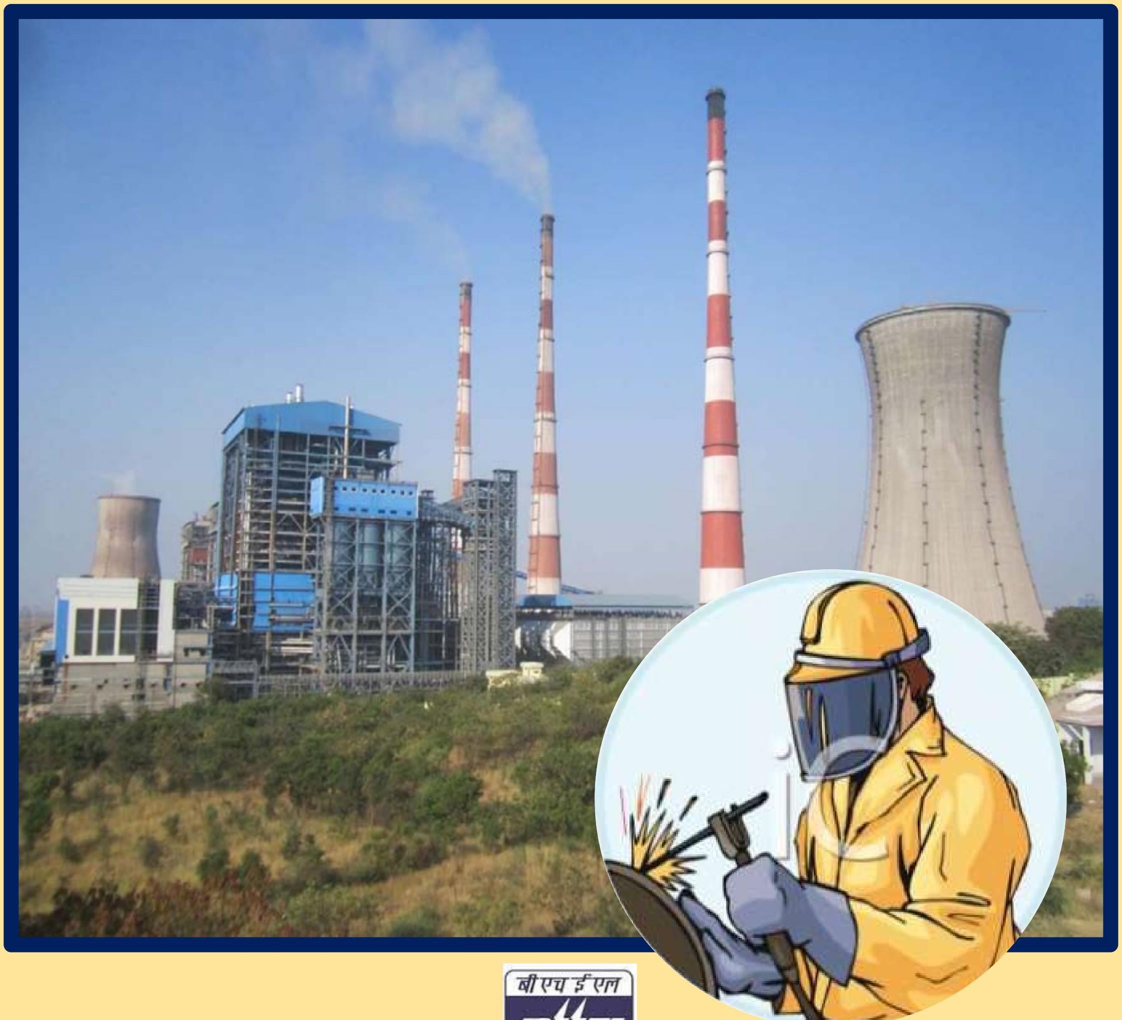
LIST OF MANUALS

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



कार्पोरेट गुणता एवं व्यावसायिक उत्कृष्टता

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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.

Table of Contents

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

Page 1 of 2

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

Page 2 of 2

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

<table>
<tr><td colspan="12">JOB CARD
(WELDING, HEAT TREATMENT & ND EXAMINATION)
FOR P91/P92 WELDS</td></tr>
<tr><td colspan="8">Card No.:</td><td colspan="4">Date:</td></tr>
<tr><td colspan="5">Project:</td><td colspan="3">Unit No.</td><td colspan="4">Contractor:</td></tr>
<tr><td>System:</td><td colspan="5"></td><td colspan="3">Drawing No.</td><td colspan="3"></td></tr>
<tr><td>PGMA:</td><td colspan="5"></td><td colspan="3">DU No.:</td><td colspan="3">Joint No.:</td></tr>
<tr><td colspan="2">Material Specification:</td><td></td><td>+</td><td colspan="2"></td><td colspan="2">OD (mm):</td><td></td><td>Thick(mm)</td><td colspan="2"></td></tr>
<tr><td>Filler metal:</td><td>GTAW</td><td colspan="4"></td><td colspan="2">SMAW</td><td colspan="4"></td></tr>
<tr><td>Joint fit-up:</td><td>Min. WT:</td><td></td><td>Root gap:</td><td></td><td>Root mismatch:</td><td></td><td colspan="2">Log sheet filled:</td><td colspan="3">Y / N</td></tr>
<tr><td>No. of T/Cs:</td><td></td><td>Location:</td><td></td><td colspan="3">Distance from EP edge:</td><td colspan="2"></td><td colspan="3">mm</td></tr>
<tr><td>Welders’ ID:</td><td colspan="5"></td><td colspan="2">M/c No.:</td><td colspan="4"></td></tr>
<tr><td>Preheat Temp.:</td><td colspan="4">°C Minimum</td><td colspan="3">Rate of heating:</td><td colspan="4">°C per hour</td></tr>
<tr><td>Purging flow rate:</td><td colspan="2"></td><td colspan="2">Litres / min.</td><td colspan="3">Purging time:</td><td colspan="2"></td><td colspan="2">Minutes</td></tr>
<tr><td>Shielding flow rate:</td><td colspan="2"></td><td colspan="2">Litres / min. for GTAW</td><td colspan="3">Distance bet. dams:</td><td colspan="2"></td><td colspan="2">Metres</td></tr>
<tr><td>Interpass Temp.:</td><td colspan="4">° C Maximum</td><td colspan="3">Rate of cooling:</td><td colspan="4">°C per hour</td></tr>
<tr><td colspan="3">Holding Temp. before PWHT:</td><td colspan="9">° C for min. 1 hour</td></tr>
<tr><td>PWHT:</td><td colspan="4">° C</td><td colspan="3">Rate of heating / cooling:</td><td colspan="4">°C per hour</td></tr>
<tr><td>Soaking time</td><td colspan="2"></td><td colspan="3">Minutes (2.5 minutes per mm)</td><td colspan="2">Cooling to:</td><td colspan="4">300° C</td></tr>
<tr><td colspan="12">Preheating started at Hrs. on Preheating completed at Hrs.</td></tr>
<tr><td colspan="12">Root welding started at Hrs. Root welding completed at Hrs.</td></tr>
<tr><td colspan="12">Welding started at Hrs. Welding completed at Hrs.</td></tr>
<tr><td colspan="12">Interpass temp. maintained between °C and °C</td></tr>
<tr><td colspan="6">Holding temp. reached at Hrs.</td><td colspan="6">Holding completed at Hrs.</td></tr>
<tr><td>No. of T/Cs:</td><td></td><td>Location</td><td colspan="3"></td><td colspan="6"></td></tr>
<tr><td colspan="6">PWHT started at Hrs. on .</td><td colspan="6">Soaking started at Hrs.</td></tr>
<tr><td colspan="6">Soaking completed at Hrs.</td><td colspan="6">300°C reached at Hrs.</td></tr>
<tr><td colspan="3">UT Equipment used:</td><td colspan="3"></td><td colspan="3">Calibration validity:</td><td colspan="3"></td></tr>
<tr><td colspan="3">UT carried out on</td><td colspan="3"></td><td colspan="6">Result : OK / Not OK</td></tr>
<tr><td colspan="3">MPI Equipment used:</td><td colspan="3"></td><td colspan="3">Calibration validity:</td><td colspan="3"></td></tr>
<tr><td colspan="3">MPI carried out on</td><td colspan="3"></td><td colspan="6">Result: OK / Not OK</td></tr>
<tr><td colspan="3">Hardness test Equipment used:</td><td colspan="3"></td><td colspan="3">Calibration validity:</td><td colspan="3"></td></tr>
<tr><td colspan="3">Hardness test carried out on</td><td colspan="3"></td><td>Value:</td><td colspan="5"></td></tr>
<tr><td colspan="6">History of interruption if any, with time:</td><td colspan="6"></td></tr>
<tr><td colspan="4">Contractor</td><td colspan="4">BHEL</td><td colspan="4">Customer</td></tr>
</table>

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. 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:			
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 / mm^2 (MPa)	Y.S Kg / mm^2 (MPa)	% E Min.
1	P1/1	DIN St. 35.8	0.17 Max.	0.40-0.80	0.04 Max.	0.04 Max.	0.10-0.35	-	-	-	-	36.70-48.96	24	25
2	P1/1	DIN St. 45.8	0.21 Max.	0.40-1.20	0.04 Max.	0.04 Max.	0.10-0.35	-	-	-	-	41.80-54.06	26	21
3	P1/1	BS 3059 / 360	0.17 Max.	0.40-0.80	0.045 Max.	0.045 Max.	0.35 Max.	-	-	-	-	36.70-51.00	22	24
4	P1/1	BS 3059 / 440	0.12-0.18	0.90-1.20	0.040 Max.	0.035 Max.	0.10-0.35	-	-	-	-	44.88-59.20	25	21
5	P3/1	15 Mo3 DIN17175	0.12-0.20	0.40-0.80	0.035 Max.	0.035 Max.	0.10-0.35	-	-	0.25-0.35	-	45.90-61.20	27.50	22
6	P4/1	13 Cr Mo 4-5DIN17175	0.10-0.18	0.40-0.70	0.035 Max.	0.035 Max.	0.10-0.35	-	0.70-1.10	0.45-0.65	-	44.88-60.18	29.60	22
7	P4 /1	BS 3059 / 620	0.10-0.15	0.40-0.70	0.040 Max.	0.040 Max.	0.10-0.35	-	0.70-1.10	0.45-0.65	-	46.90-62.20	18.40	22
8	P5/1	10 Cr Mo 9-10DIN17175	0.08-0.15	0.40-0.70	0.035 Max.	0.035 Max.	0.50 Max.	-	2.00-2.50	0.90-1.20	-	45.90-61.20	28.60	20
9	P5/1	BS 3059 (622) - 440	0.08-0.15	0.40-0.70	0.04 Max.	0.04 Max.	0.50 Max.	-	2.00-2.50	0.90-1.20	-	44.90-60.18	17.85	20
10	P5/1	BS 3059 (622) - 490	0.08-0.15	0.40-0.70	0.040 Max.	0.040 Max.	0.50 Max.	-	2.00-2.50	0.90-1.20	-	49.98-65.00	28.05	20
11	-	14 Mo V 63 DIN17175	0.10-0.18	0.40-0.70	0.035 Max.	0.035 Max.	0.10-0.35		0.30-0.60	0.50-0.70	0.22-0.32	46.90-62.22	32.60	20
12	P5B/2	X20CrMoV121 DIN17175	0.17-0.23	$\leq$ 1.00	0.030 Max.	0.030 Max.	$\geq$ 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 Zr Al 0.05-0.15 0.02-0.12 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			ERNiCr3	ERNiCr3	ERNiCr3	ERNiCr3	ERNiCrFe7A	ER347	***ER347***	
	SMAW			ENiCrFe3	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

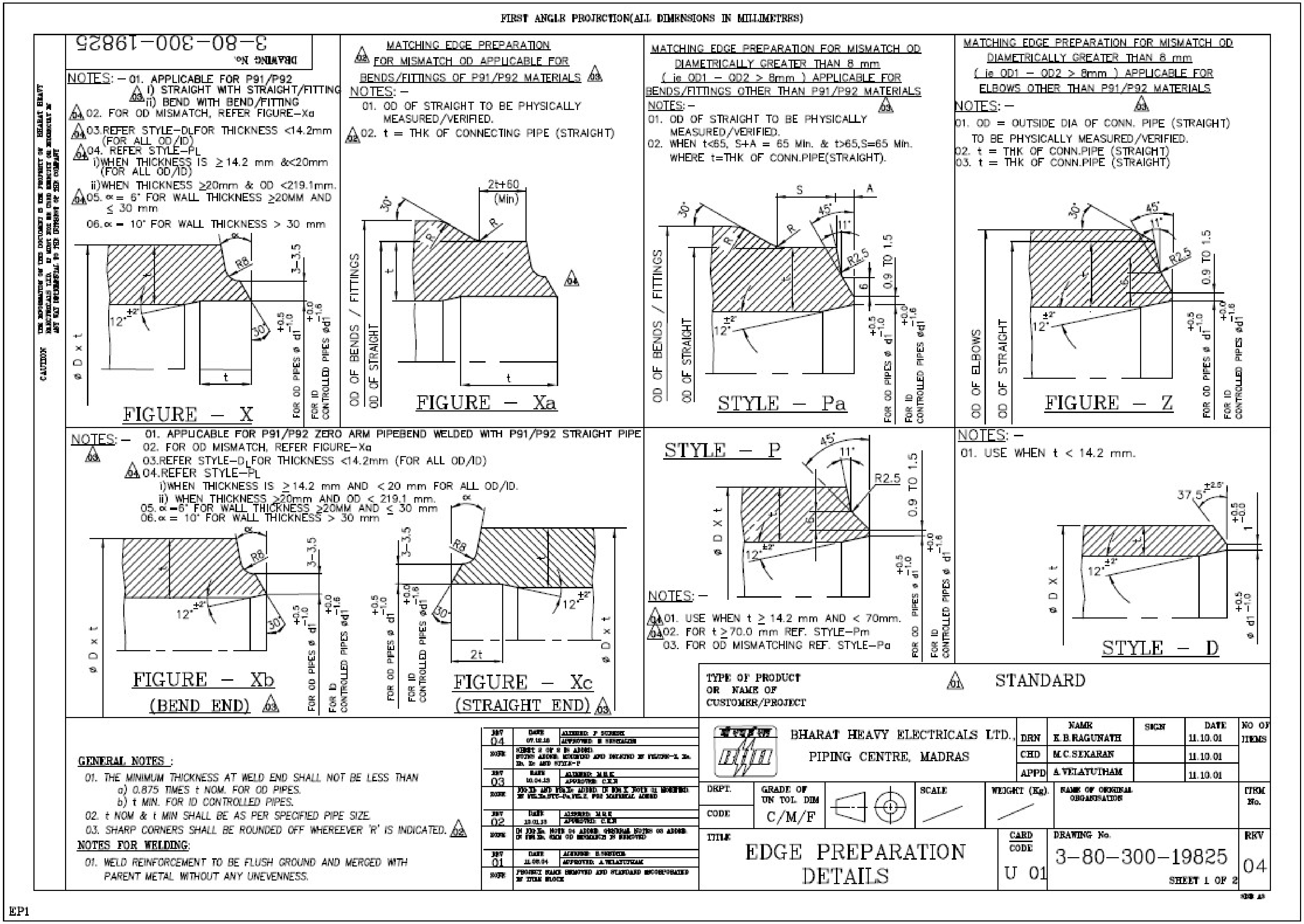
SFA CLASSIFICATION

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



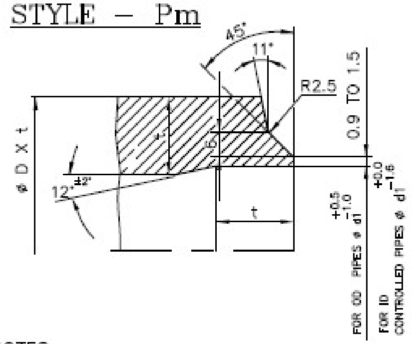
FIRST ANGLE PROJECTION(ALL DIMENSIONS IN MILLIMETRES)
DRAWING No. 3-80-300-19825
NOTES: – 01. APPLICABLE FOR P91/P92
i) STRAIGHT WITH STRAIGHT/FITTING
ii) BEND WITH BEND/FITTING
02. FOR OD MISMATCH, REFER FIGURE–Xa
03. REFER STYLE–D, FOR THICKNESS <14.2mm (FOR ALL OD/ID)
04. REFER STYLE–PL
i) WHEN THICKNESS IS ≥ 14.2 mm &<20mm (FOR ALL OD/ID)
ii) WHEN THICKNESS ≥20mm & OD <219.1mm.
05. α = 6° FOR WALL THICKNESS ≥20MM AND ≤ 30 mm
06. α = 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. α = 6° FOR WALL THICKNESS ≥20MM AND ≤ 30 mm
06. α = 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
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.
TYPE OF PRODUCT OR NAME OF CUSTOMER/PROJECT
STANDARD
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
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)

DRAWING No. 3-80-300-19825

CAUTION

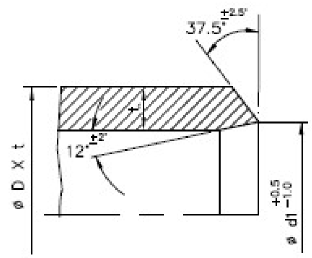
STYLE – Pm



NOTES: –

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

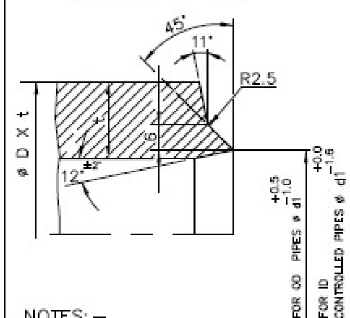
STYLE – D_L



NOTES: –

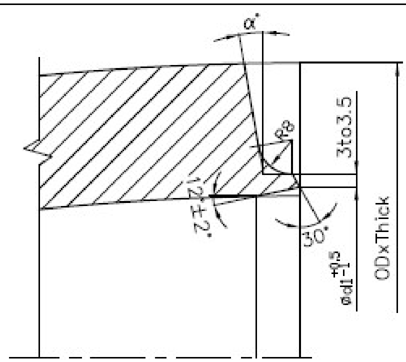
01. USE FOR P91 / P92 PIPES AND FITTINGS WHEN t < 14.2 mm (ALL OD/ID).

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. α = 6° FOR WALL THICKNESS ≥ 20MM AND ≤ 30 mm
05. α = 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		NAME	SIGN	DATE	NO OF ITEMS
	DRN	P SURESH		07.12.16	
	CHD	R SESHAGIRI		07.12.16	
	APPD	C KARUNAKARAN		07.12.16	
DEPT. / 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)

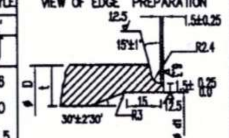
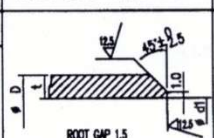
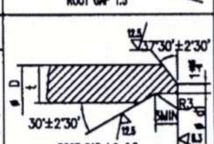
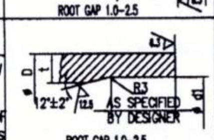
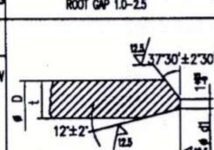
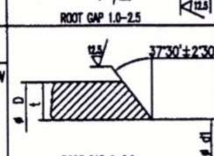
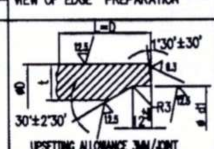
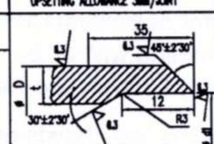
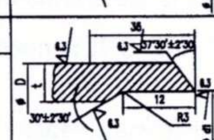
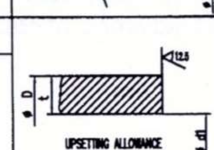
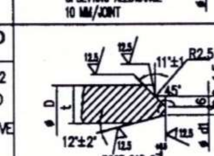
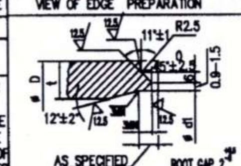
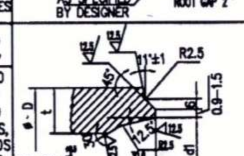
TP 062 05 99

PAGE–7

t / D	14.0	15.9	19.05	21.3	31.8	38.0	44.5	47.63	51.0	54.0	57.0	60.3	63.5	70.0	76.1	88.9	101.6	108.0	127
1.8	10.4	12.3	15.4																
2.0	10.0	11.9	15.0	17.3															
2.3	9.4	11.3	14.4	16.7	26.8														
2.6	8.8	10.7	13.8	16.1	26.2	32.4	38.8	41.9	45.3	48.3									
2.9	8.2	10.1	13.2	15.5	25.6	31.8	38.2	41.3	44.7	47.7	50.7	54.0	57.1	63.8	69.6				
3.2	7.6	9.5	12.6	14.9	25.0	31.2	37.6	40.7	44.1	47.1	50.1	53.4	56.5	63.0	69.0	82.5			
3.4	7.2	9.1	12.2	14.5	24.6	30.8	37.2	40.3	43.7	46.7	49.7	53.0	56.1	62.6	68.6	82.1			
3.5	7.0	8.9	12.0	14.3	24.4	30.6	37.0	40.1	43.5	46.5	49.5	52.8	55.9	62.4	68.4	81.9			
3.8	6.8	8.7	11.8	14.1	24.2	30.4	36.8	38.9	43.3	46.3	49.3	52.6	55.7	62.2	68.2	81.7	94.4	100.8	
4.0		7.9	11.0	13.3	23.4	29.6	36.0	38.1	42.5	45.5	48.5	51.8	54.9	61.4	67.4	80.9	93.6	100.0	119.0
4.5			10.0	12.3	22.4	28.6	35.0	38.1	41.5	44.5	47.5	50.8	53.9	60.4	66.4	79.9	82.9	98.0	118.0
4.8				11.7	21.8	28.0	34.4	37.5	40.9	43.9	46.9	50.2	53.3	58.8	65.8	79.3	92.0	98.4	117.4
5.0				11.3	21.4	27.6	34.0	37.1	40.5	43.5	46.5	49.8	52.9	58.4	65.4	78.9	91.6	98.0	117.0
5.2					21.0	27.2	33.6	36.7	40.1	43.1	46.1	49.4	52.5	58.0	65.0	78.5	91.2	97.6	116.6
5.4					20.6	26.8	33.2	36.3	39.7	42.7	45.7	49.0	52.1	58.6	64.6	78.1	90.8	97.2	116.2
5.6					20.2	26.4	32.8	35.9	39.3	42.3	45.3	48.6	51.7	58.2	64.2	77.7	90.4	96.8	115.8
5.7					20.0	26.2	32.6	35.7	39.1	42.1	45.1	48.4	51.5	58.0	64.0	77.5	90.2	96.6	115.6
5.9					19.6	25.8	32.2	35.3	38.7	41.7	44.7	48.0	51.1	57.6	63.7	77.1	89.8	96.2	115.2
6.0					19.4	25.6	32.0	35.1	38.5	41.5	44.5	47.8	50.9	57.4	63.4	76.9	89.6	96.0	115.0
6.3					18.8	25.0	31.4	34.5	37.9	40.9	43.9	47.2	50.3	56.8	62.8	76.3	89.0	95.4	114.4
6.6					18.2	24.4	30.8	33.9	37.3	40.3	43.3	46.6	49.7	56.2	62.2	75.7	88.4	94.8	113.8
7.1					17.2	23.4	29.8	32.9	36.3	39.3	42.3	45.6	48.7	55.2	61.2	74.7	87.4	93.8	112.8
7.5					16.4	22.6	29.0	32.1	35.5	38.5	41.5	44.8	47.9	54.4	60.4	73.9	86.6	93.0	112.0
7.6					16.2	22.4	28.8	31.9	35.3	38.3	41.3	44.6	47.7	54.2	60.2	73.7	86.4	92.8	111.8
8.0					15.4	21.6	28.0	31.1	34.5	37.5	40.5	43.8	46.9	53.4	59.4	72.9	85.6	92.0	111.0
8.6						20.4	26.8	29.9	33.3	36.3	39.3	42.6	45.7	52.2	58.2	71.7	84.4	90.8	108.8
8.8						20.0	26.4	29.5	32.9	35.9	38.9	42.2	45.3	51.8	57.8	71.3	84.0	90.4	108.4
9.0						19.6	26.0	29.1	32.5	35.5	38.5	41.8	44.9	51.4	57.4	70.9	83.6	90.0	108.0
10.0						17.6	24.0	27.1	30.5	33.5	36.5	39.8	42.9	49.4	55.4	68.9	81.6	88.0	107.0
11.0							22.0	25.1	28.5	31.5	34.5	37.8	40.9	47.4	53.4	68.7	81.3	87.7	106.5
12.0							20.0	23.1	28.5	29.5	32.5	35.8	38.9	45.4	51.4	67.0	79.6	85.9	104.7
12.5							19.0	22.1	25.5	28.5	31.5	34.8	37.9	44.4	50.4	66.1	78.7	85.0	103.9
14.0									22.5	25.5	28.5	31.8	34.9	41.4	47.4	63.5	76.1	82.4	101.2
14.2									22.1	25.1	28.1	31.4	34.5	41.0	47.0	63.1	75.7	82.1	100.9
16.0											24.5	27.8	30.9	37.4	43.4	60.0	72.6	78.9	97.7
17.5														34.4	40.4	57.4	70.0	78.3	95.1
18.0															39.4	56.5	69.1	75.4	94.2
20.0															35.4	53.0	65.6	71.9	90.7
22.2																49.2	61.7	68.1	86.9
25.0																	56.8	63.2	82.0
28.0																			78.7

t / D	141.3	159	168.3	177.8	193.7	219.1	244.5	248.5	273	298.5	323.9	355.6	368	406.4	457.2	508	558.8	609.6	711.2
4.5	132.3	150.0	159.3																
4.8	131.7	149.4	158.7																
5.0	131.3	149.0	158.3	167.8															
5.2	130.9	148.6	157.9	167.4															
5.4	130.5	148.2	157.5	167.0	182.9														
5.6	130.1	147.8	157.1	166.6	182.5														
5.7	129.9	147.6	156.9	166.4	182.3														
5.9	129.5	147.2	156.5	166.0	181.9	207.3													
6.0	129.3	147.0	156.3	165.8	181.7	207.1													
6.3	128.7	146.4	155.7	165.2	181.1	206.5	231.9	235.9	260.4										
6.6	128.1	145.8	155.1	164.6	180.5	205.9	231.3	235.3	259.8										
7.1	127.1	144.8	154.1	163.6	179.5	204.9	230.3	234.3	258.8	284.3	309.7								
7.5	128.3	144.0	153.3	162.8	178.7	204.1	229.5	233.5	258.0	283.5	308.9								
7.6	128.1	143.8	153.1	162.6	178.5	203.9	229.3	233.3	257.8	283.3	308.7								
8.0	125.3	143.0	152.3	161.8	177.7	203.1	228.5	232.5	257.0	282.5	307.9	338.6	352.0						
8.6	124.1	141.8	151.1	160.6	176.5	201.9	227.3	231.3	255.8	281.3	306.7	338.4	350.8						
8.8	123.7	141.4	150.7	160.2	176.1	201.5	226.9	230.9	255.4	280.9	306.3	338.0	350.4	388.8					
9.0	123.3	141.0	150.3	159.8	175.7	201.1	226.5	230.5	255.0	280.5	305.9	337.6	350.0	388.4					
10.0	121.3	139.0	148.3	157.8	173.7	199.1	224.5	228.5	253.0	278.5	303.9	335.6	348.0	386.4	437.2				
11.0	120.6	138.2	147.4	156.8	172.5	197.1	222.5	226.5	251.0	276.5	301.9	333.6	346.0	384.4	435.2	486.0			
12.0	118.9	138.4	145.6	155.0	170.8	195.1	220.5	224.5	248.0	274.5	299.9	331.6	344.0	382.4	433.2	484.0			
12.5	118.0	135.5	144.7	154.2	169.9	194.1	219.5	223.5	248.0	273.5	298.9	330.6	343.0	381.4	432.2	483.0	533.8		
14.0	115.4	132.9	142.1	151.5	167.3	194.2	219.5	223.5	247.8	273.2	298.5	333.0	342.4	380.6	431.1	481.7	532.2		
14.2	115.0	132.6	141.8	151.2	166.9	193.9	219.1	223.1	247.5	272.9	298.1	329.7	342.0	380.2	430.8	481.3	531.9		
16.0	111.9	129.4	138.6	148.0	163.8	190.8	216.1	220.1	244.4	269.8	295.1	326.6	339.0	377.2	427.7	478.3	528.8	579.4	
17.5	109.3	126.8	136.0	145.4	161.1	188.8	213.5	217.5	241.9	267.3	292.5	324.1	336.4	374.6	425.2	475.7	526.3	576.8	
18.0	108.4	125.9	135.1	144.5	160.3	187.4	212.7	216.7	241.0	266.4	291.7	323.2	335.6	373.8	424.3	474.9	525.4	576.0	
20.0	104.9	122.4	131.6	141.0	156.8	184.0	209.3	213.3	237.8	263.0	288.3	319.8	332.2	370.4	420.9	471.5	522.0	572.6	
22.2	101.0	118.6	127.8	137.2	152.9	180.3	205.5	209.5	233.9	259.3	284.5	316.1	328.4	366.6	417.2	467.7	518.3	568.8	
25.0	96.1	113.7	122.9	132.3	148.0	175.5	200.8	204.8	229.1	254.5	279.8	311.3	323.7	381.9	412.4	463.0	513.5	564.1	665.1
28.0	90.9	108.4	118.6	127.0	142.8	169.2	194.6	198.5	223.0	248.4	273.8	305.4	317.8	356.1	406.7	457.4	508.0	558.7	659.9
30.0		104.9	114.8	123.5	139.3	164.9	190.3	194.3	218.7	244.2	269.5	301.2	313.5	351.9	402.5	453.2	503.8	554.5	655.7
32.0		101.4	110.6	120.0	135.8	160.7	186.0	190.0	214.5	240.0	265.3	296.9	309.3	347.6	398.3	449.0	499.6	550.2	651.2
35.0				114.8	130.5	154.3	178.7	183.7	208.1	233.6	258.9	290.6	302.9	341.3	391.9	442.8	493.3	543.9	645.2
38				113.0	128.8	152.2	177.5	181.5	208.0	231.4	256.8	288.4	300.0	339.1	389.8	440.5	491.2	541.8	643.1
40					121.8	143.6	169.0	173.0	197.5	222.9	248.3	279.9	292.3	331.6	381.3	432.0	482.7	533.4	634.7
41.5					119.1	140.4	165.8	169.8	194.3	219.7	245.1	276.8	289.1	327.5	378.2	428.8	479.5	530.2	631.5
43					116.5	137.3	162.8	166.6	191.1	216.6	241.9	273.6	285.9	324.3	375.0	425.7	476.3	527.0	628.3
45					113.0	133.0	158.4	162.4	186.3	212.3	237.7	269.3	281.7	320.0	370.7	421.4	472.1	522.8	624.1
50					104.3	122.3	147.7	151.7	176.2	201.7	227.0	258.4	271.1	309.4	360.1	410.8	461.5	512.2	613.5
55						111.7	137.1	141.1	165.5	191.0	216.4	248.0	260.4	298.8	349.5	400.2	450.9	501.6	602.9
58						109.5	134.9	138.9	163.4	188.9	214.2	245.9	258.3	296.6	347.4	398.1	448.8	499.5	600.8
60						101.0	126.4	130.4	154.9	180.3	205.7	237.4	249.8	288.1	338.8	389.6	440.3	481.0	592.4
63						94.6	120.0	124.0	148.5	174.0	199.3	231.0	243.4	281.7	332.5	383.2	433.9	484.6	586.0
65										175.0	200.4	232.1	244.5	282.9	333.7	384.5	435.3	486.1	587.7
70										165.5	190.9	222.6	235.0	273.4	324.2	375.0	425.8	476.6	578.2
72										161.7	187.1	218.8	231.2	269.6	320.4	371.2	422.0	472.8	574.4
75										156.0	181.4	213.1	225.5	263.9	314.7	365.5	416.3	467.1	568.7
80													216.0	254.4	305.2	356.0	406.8	457.6	559.2
84													208.4	246.8	297.6	348.4	399.2	450.0	551.6
85													206.5	244.9	295.7	346.5	397.3	448.1	549.7
90														235.4	286.2	337.0	387.8	438.6	540.2
95														225.9	276.7	327.5	378.3	429.1	530.7
100														216.4	267.2	318.0	368.8	419.6	521.2
105														206.9	257.7	308.5	359.3	410.1	511.7
110														197.4	248.2	299.0	349.8	400.6	502.2
115														187.9	238.7	289.5	340.3	391.1	492.7
120														178.4	229.2	280.0	330.8	381.6	483.2
125															219.7	270.5	321.3	372.3	473.6
130															210.2	261.0	311.8	362.6	464.2
135															200.7	251.5	302.3	353.1	454.7
140																	292.8	343.6	445.2
145																	283.3	334.1	435.7
150																	273.8	324.6	426.2

STL	TYPE OF WELDING: ROOT PASS	TYPE OF WELDING: FILLER PASS
A	GAS OR MANUAL ARC	GAS OR MANUAL ARC
B	TIG	MANUAL ARC
C	MANUAL ARC	MANUAL ARC
C	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 't'	VIEW OF EDGE PREPARATION
31.8 TO 76.1	J 3.6 TO 12.5	
14.0 TO 21.3	A 2.0 TO 4.5	
31.8 TO 76.1	B 3.6 TO 12.5 PANEL /COIL END	
—	C BELOW 22.2 FREE END OF NIPPLES	
31.8 TO 159.0 (ALSO >159.0 WHEN REQD)	D BELOW 14.2	
219.1 AND ABOVE	E BELOW 14.2	
31.8 TO 76.1	F 3.2 TO 11.0	
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	
88.9 AND ABOVE	P 14.2 AND ABOVE	
—	Q 22.2 AND ABOVE FREE END OF NIPPLES	
—	R 32.0 TO 150 TEES, BENDS ETC	

ALL DIMENSIONS ARE IN MM

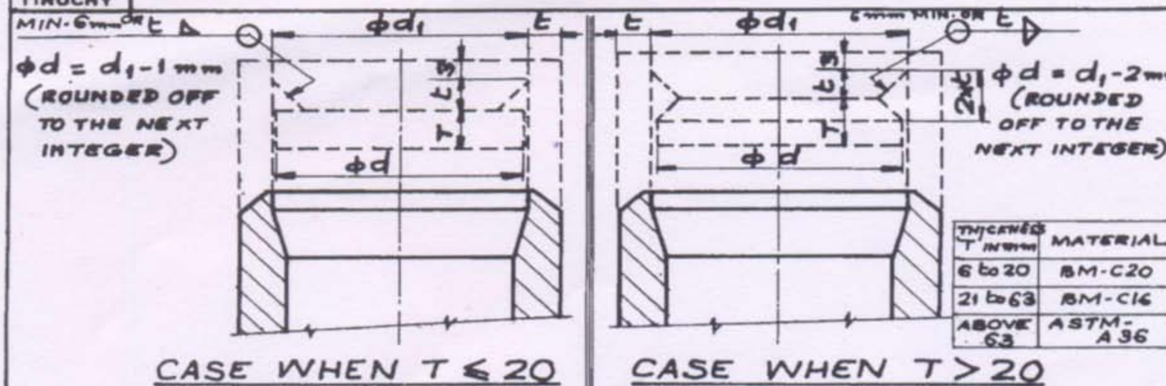
CHAPTER A5 - SELECTION CHART FOR DUMMY END COVERS & NIPPLES FREE END DETAILS

INDEX NO. 2-8

TIRUCHY

SELECTION CHART FOR DUMMY END COVERS FOR HYDRAULIC TEST

THICKNESS 'T' = $0.5 d_1 \sqrt{P/f}$ (ISO-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-A36

THICKNESS OF DUMMY END COVERS FOR HYDRAULIC TEST (T)

BORE φ OF TUBE/PIPE 'd₁' IN mm (MAX) \ TEST PRESSURE 'P' IN kg/cm²	30	45	60	75	90	105	120	135	150	165	180	210	240	270	300	350
15	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
25	5	5	5	5	5	5	5	5	5	5	5	5	6	6	6	8
30	5	5	5	5	5	5	5	5	5	6	6	6	8	8	8	8
35	5	5	5	5	5	5	6	6	6	6	8	8	8	8	8	10
40	5	5	5	5	6	6	6	8	8	8	8	8	8	10	10	10
45	5	5	5	6	6	6	8	8	8	8	8	10	10	10	10	12
50	5	5	6	6	8	8	8	8	8	10	10	10	10	12	12	12
55	5	6	6	8	8	8	8	10	10	10	10	10	12	12	12	14
60	5	6	8	8	8	8	10	10	10	10	10	12	12	14	14	14
65	5	6	8	8	8	10	10	10	10	12	12	12	14	14	14	16
70	6	8	8	8	10	10	10	12	12	12	12	14	14	14	16	16
75	6	8	8	10	10	10	12	12	12	12	14	14	16	16	16	20
80	6	8	8	10	10	12	12	12	12	14	14	14	16	16	20	20
85	8	8	10	10	10	12	12	14	14	14	14	16	16	20	20	20
90	8	8	10	10	12	12	14	14	14	14	16	16	20	20	20	20
95	8	10	10	12	12	12	14	14	16	16	16	20	20	20	20	25
100	8	10	10	12	12	14	14	16	16	16	20	20	20	20	25	25
125	10	12	12	14	16	16	20	20	20	20	20	25	25	25	32	32
150	12	14	16	16	20	20	20	25	25	25	25	32	32	32	32	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

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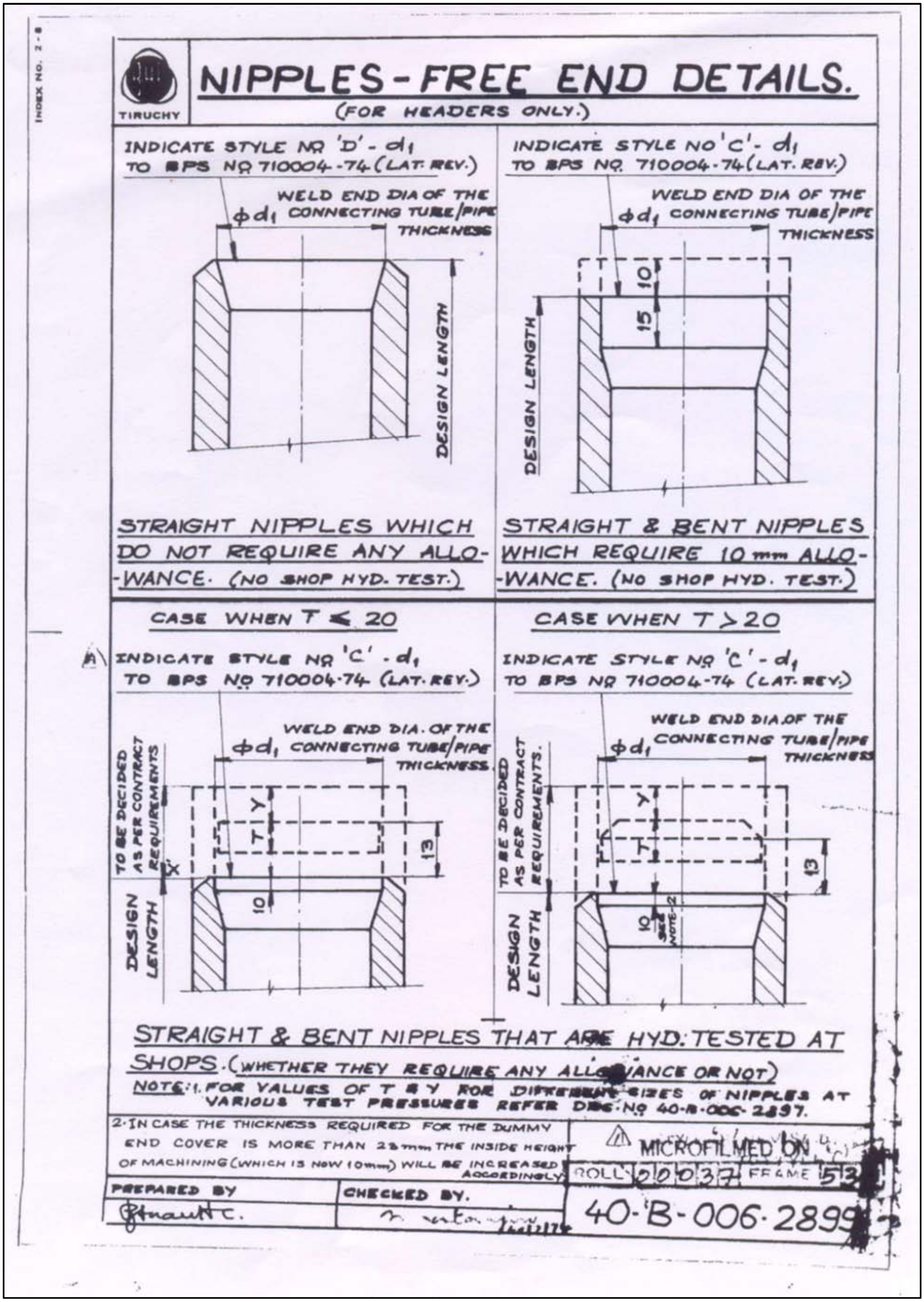
[signature]	[signature] 2/8/74	



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.)
WELD END DIA OF THE CONNECTING TUBE/PIPE THICKNESS
ϕd_1
DESIGN LENGTH
STRAIGHT NIPPLES WHICH DO NOT REQUIRE ANY ALLOWANCE. (NO SHOP HYD. TEST.)
INDICATE STYLE NO 'C' - d_1 TO BPS NO. 710004-74 (LAT. REV.)
WELD END DIA OF THE CONNECTING TUBE/PIPE THICKNESS
ϕd_1
10
15
DESIGN LENGTH
STRAIGHT & BENT NIPPLES WHICH REQUIRE 10 mm ALLOWANCE. (NO SHOP HYD. TEST.)
CASE WHEN T ≤ 20
INDICATE STYLE NO 'C' - d_1 TO BPS NO 710004-74 (LAT. REV.)
WELD END DIA. OF THE CONNECTING TUBE/PIPE THICKNESS.
ϕd_1
TO BE DECIDED AS PER CONTRACT REQUIREMENTS
Y
T
X
13
10
DESIGN LENGTH
CASE WHEN T > 20
INDICATE STYLE NO 'C' - d_1 TO BPS NO 710004-74 (LAT. REV.)
WELD END DIA. OF THE CONNECTING TUBE/PIPE THICKNESS
ϕd_1
TO BE DECIDED AS PER CONTRACT REQUIREMENTS.
Y
T
13
10
SEE NOTE-2
DESIGN LENGTH
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 23 mm THE INSIDE HEIGHT OF MACHINING (WHICH IS NOW 10 mm) WILL BE INCREASED ACCORDINGLY.
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CHECKED BY.
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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.

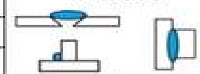
8.0 ENCLOSURES :

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.

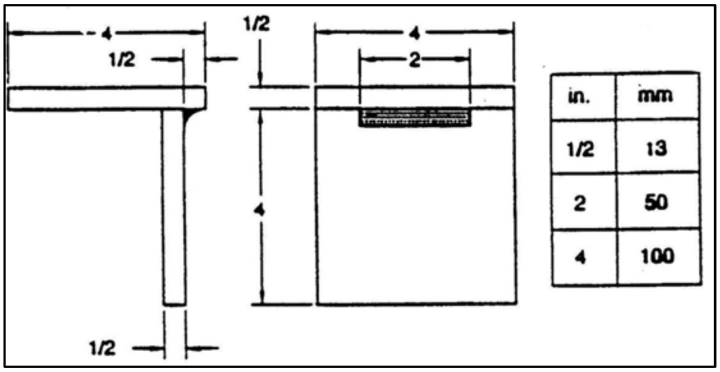


Figure A6.1 – Structural Tack Weld Specimen

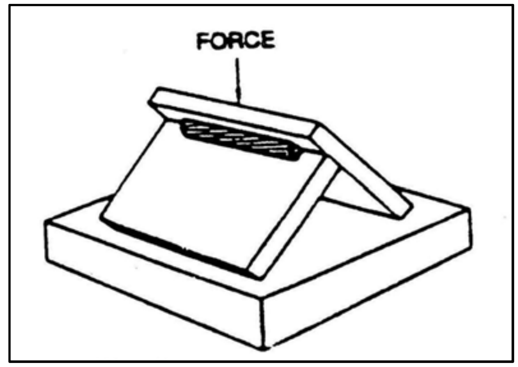


Figure A6.2 – Break Test

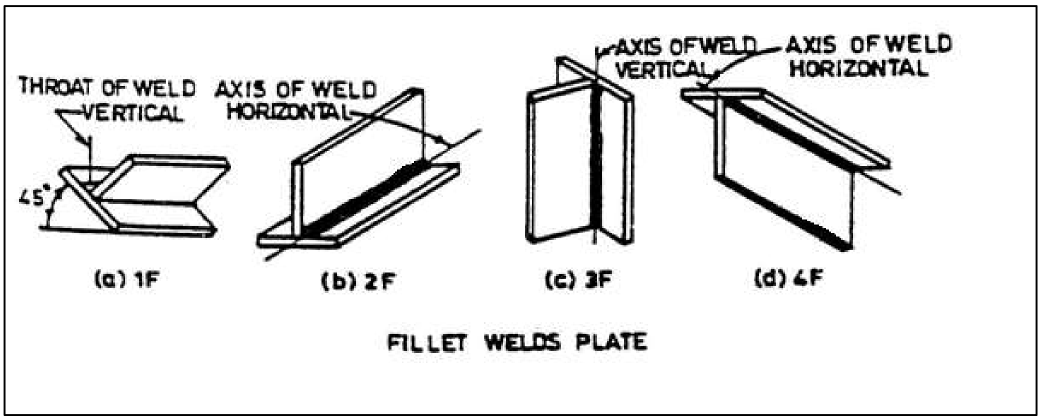


Figure A6.3 – Weld Positions

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.

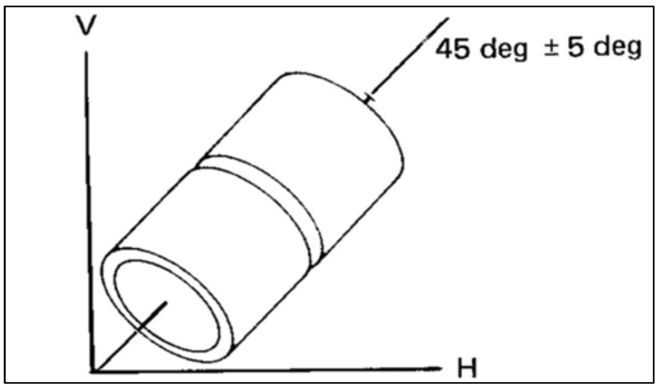


Figure A6.4 6G-Position

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.

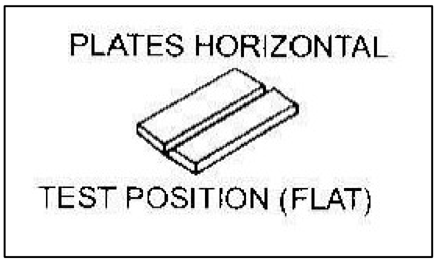


Figure A6.5 Flat position

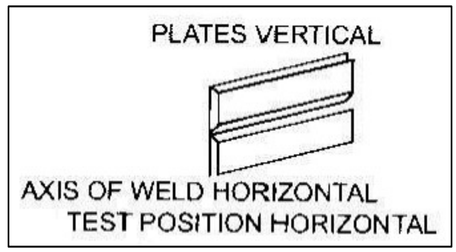


Figure A6.6 Horizontal Position

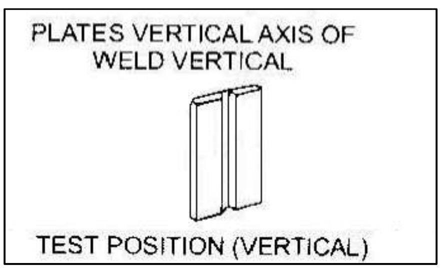


Figure A6.7 Vertical Position

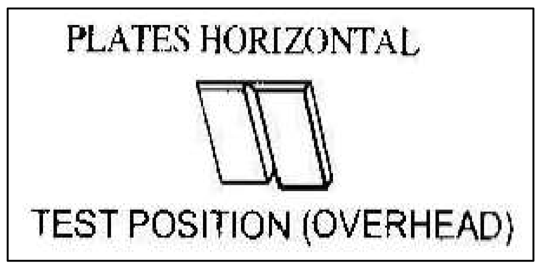


Figure A6.8 Overhead Position

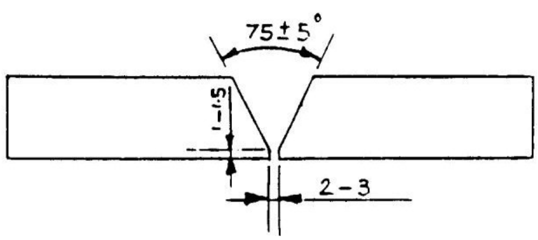
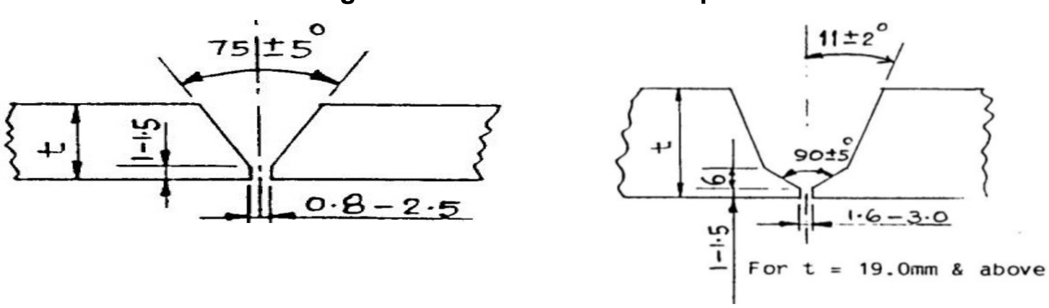


Figure A6.9- Plate butt weld specimen



(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

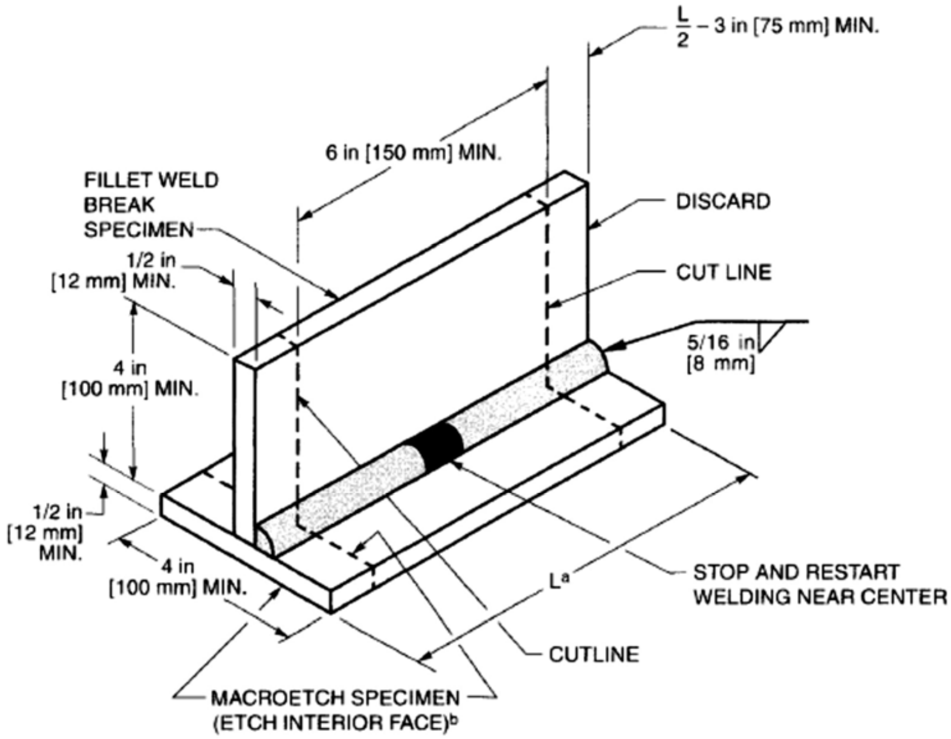


Figure – A6.12 – Plate to plate fillet Weld Specimen

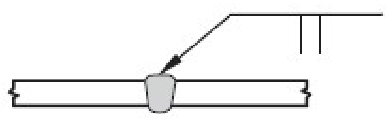


Figure – A6.13 – Square groove weld specimen in butt joints

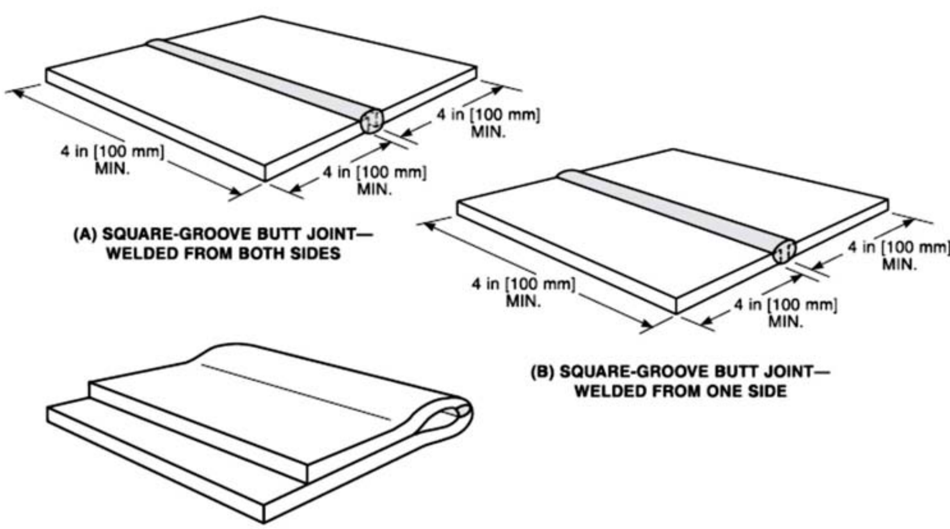


Figure – A6.14 – Bend test for square groove welds in butt joints

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$\leq$ 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 <u>Upto and including 5% defects:</u> 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 <u>Upto and including 2.5% defects</u>: 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.

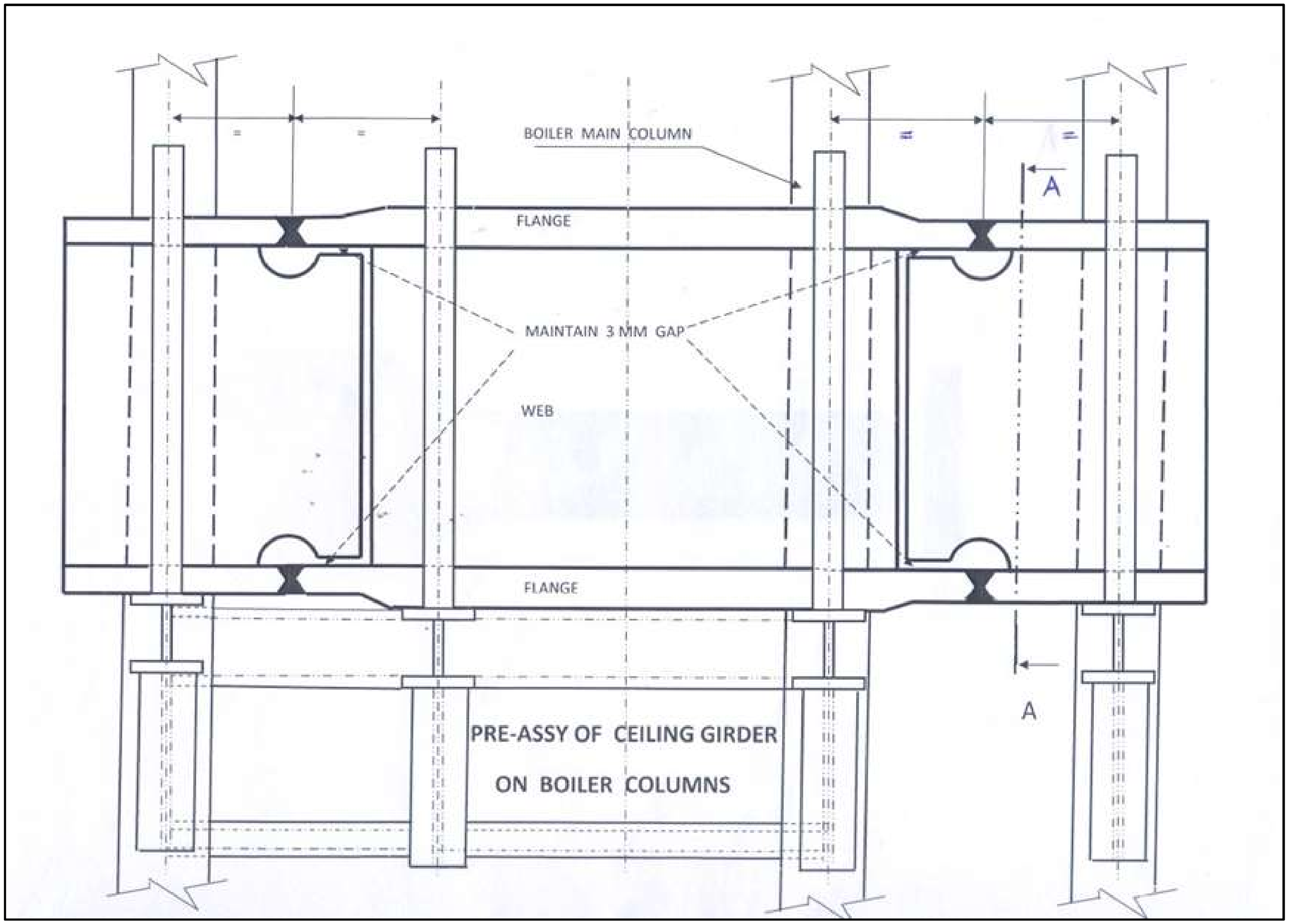


Figure B1.1 – PRE-ASSEMBLY OF CEILING GIRDER ON BOILER COLUMNS

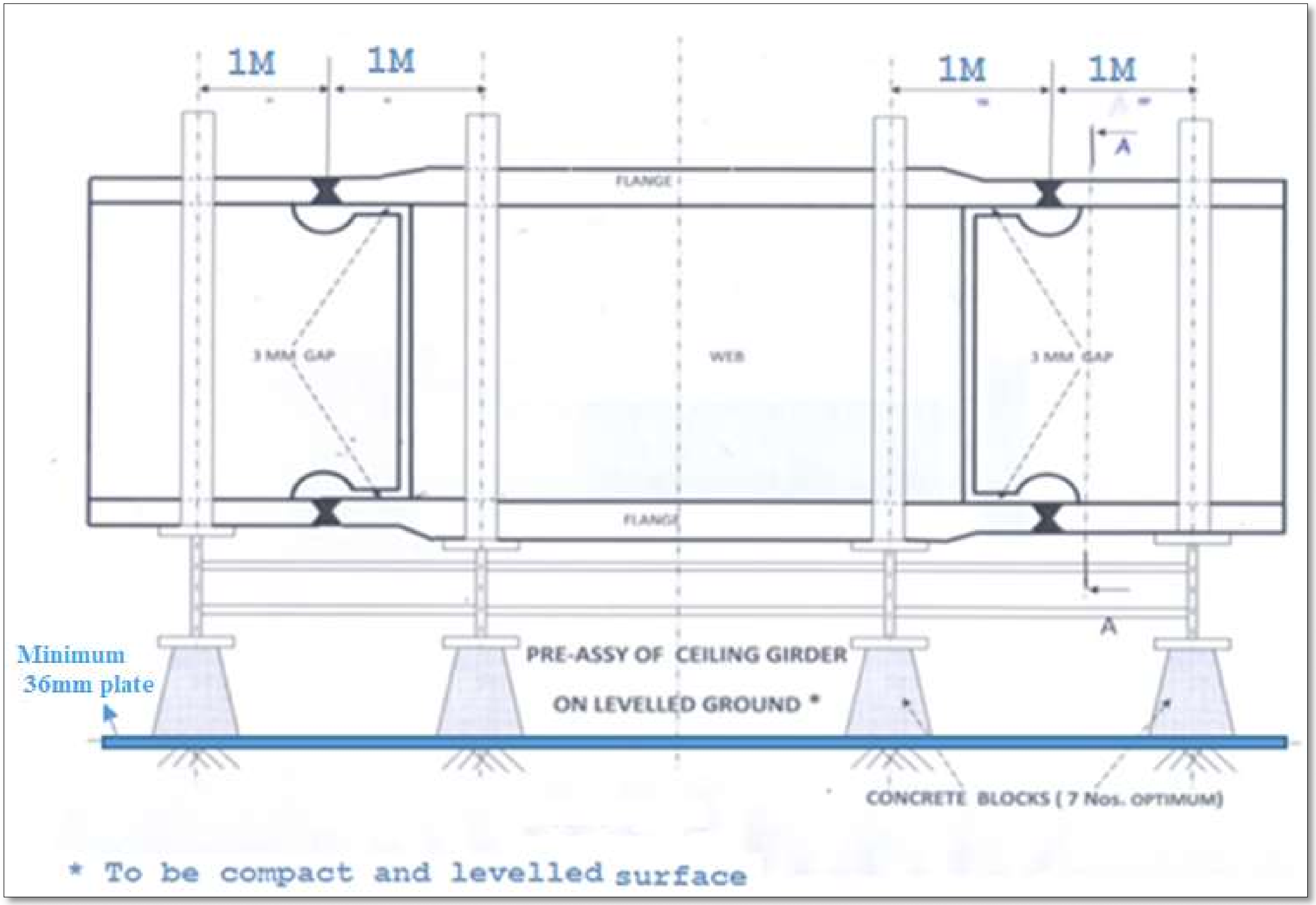
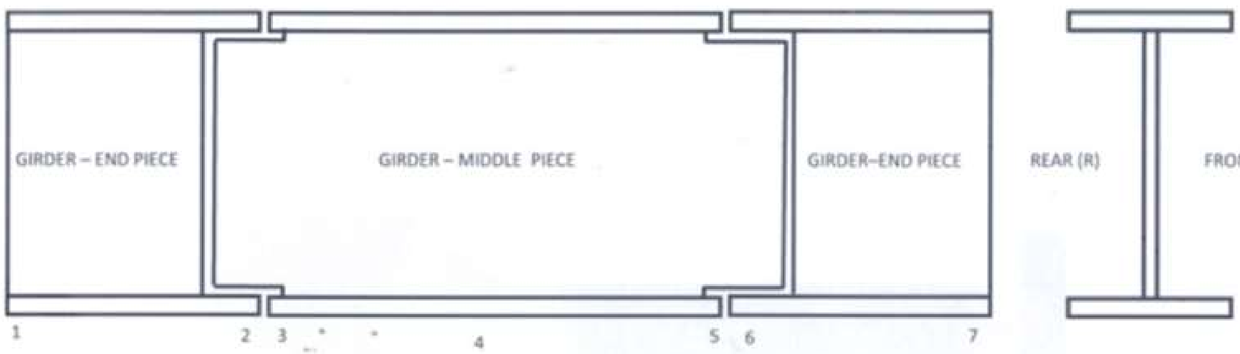


Figure B1.2 – PRE-ASSEMBLY OF CEILING GIRDER ON CONCRETE BLOCKS

PRE-ASSEMBLY OF CEILING GIRDERS - DIMENSIONAL CHECKS

(BEFORE / AFTER WELDING)

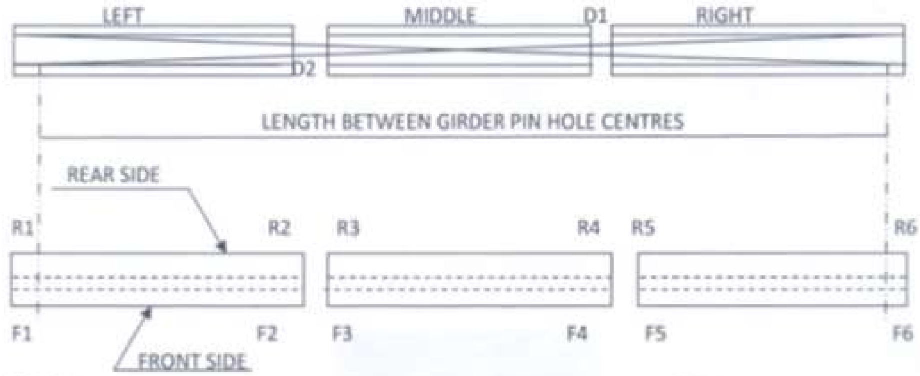


CHECKS		F1	F2	F3	F4	F5	F6	F7	R1	R2	R3	R4	R5	R6	R7
Sweep (By Piano Wire) bottom flange															
Camber (By Water Level) bottom flange															
Web Verticality	TOP														
	Middle														
(By Plumb)	Bottom														
Root Gap (Min. to Max.)		Top Flange =			Bottom Flange =					Web =					
Length (Hole Centres)		As per Drg. =			Actual =					Diagonal Difference =					
Distance between reference lines at weld joint :					Top Flange =					Bottom Flange =					

Contractor M/s BHEL Customer

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

CEILING GIRDER PRE – ASSEMBLY (BEFORE / AFTER WELDING)



CHECKS	FI/RI	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

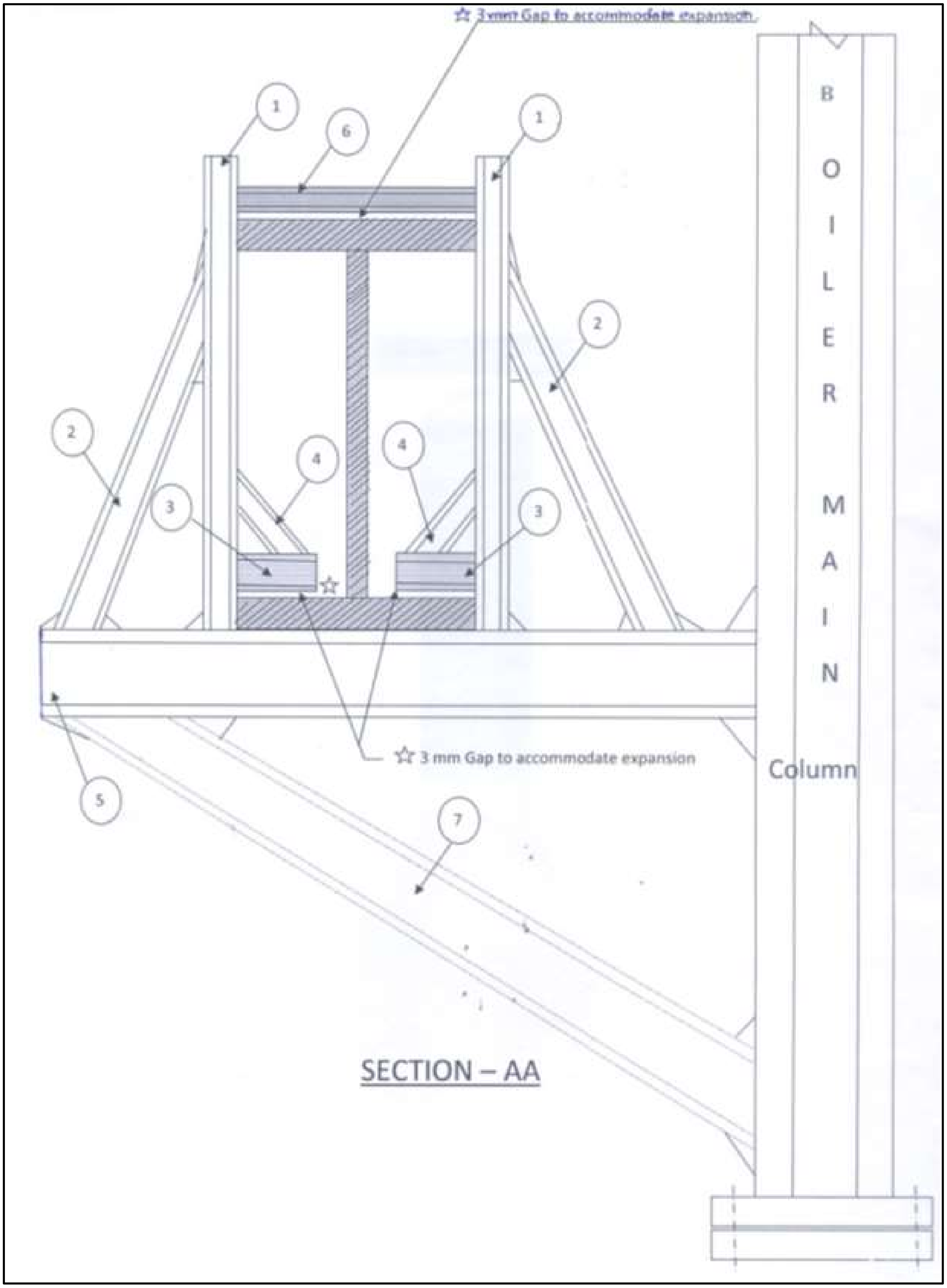


Figure B1.5 – TEMPORARY SUPPORTS AND LOCKING ARRANGEMENT

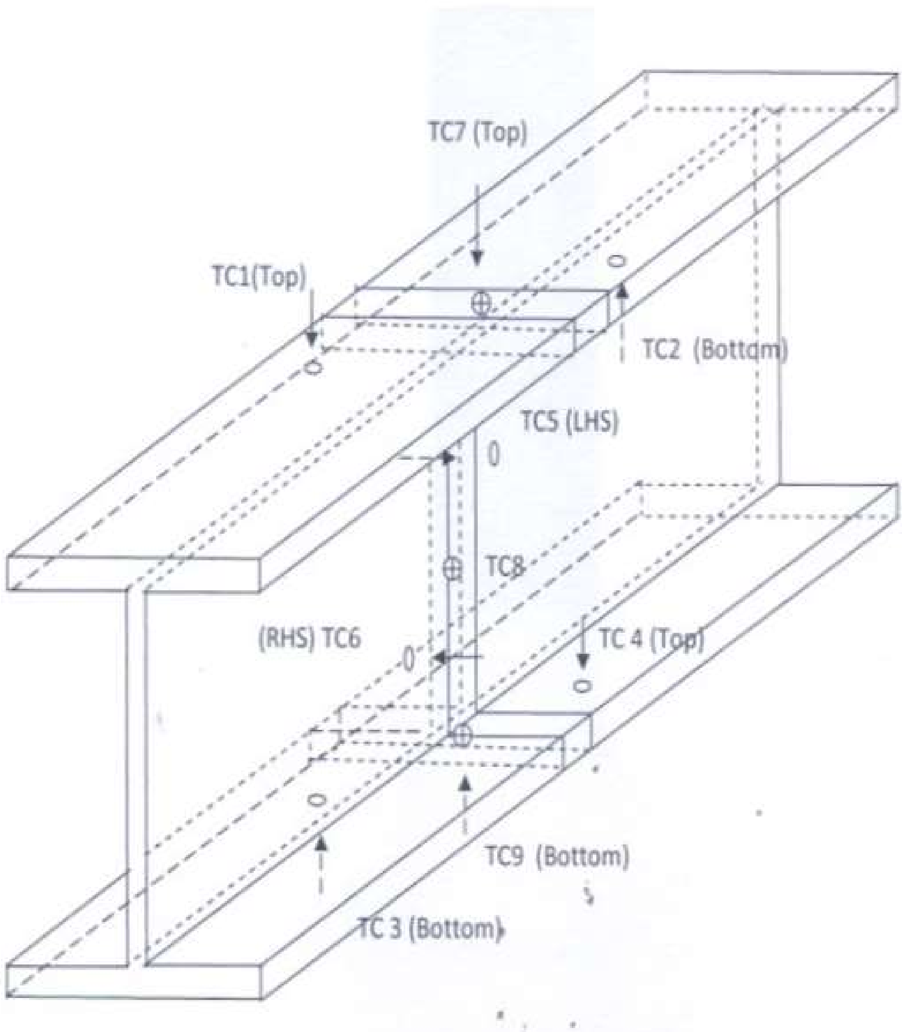
BILL OF MATERIALS (FOR ONE PRE ASSEMBLY BED)

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 , TC8, TC9 - STAND BY THERMO COUPLES.

○ TC1 & TC2
○ TC5& TC6 } SHOULD BE FIXED IN OPPOSITE SIDES OF PLATES
○ TC3 & TC4

THERMOCOUPLE LOCATIONS FOR CEILING GIRDER For PREHEATING & PWHT

Figure B1.6

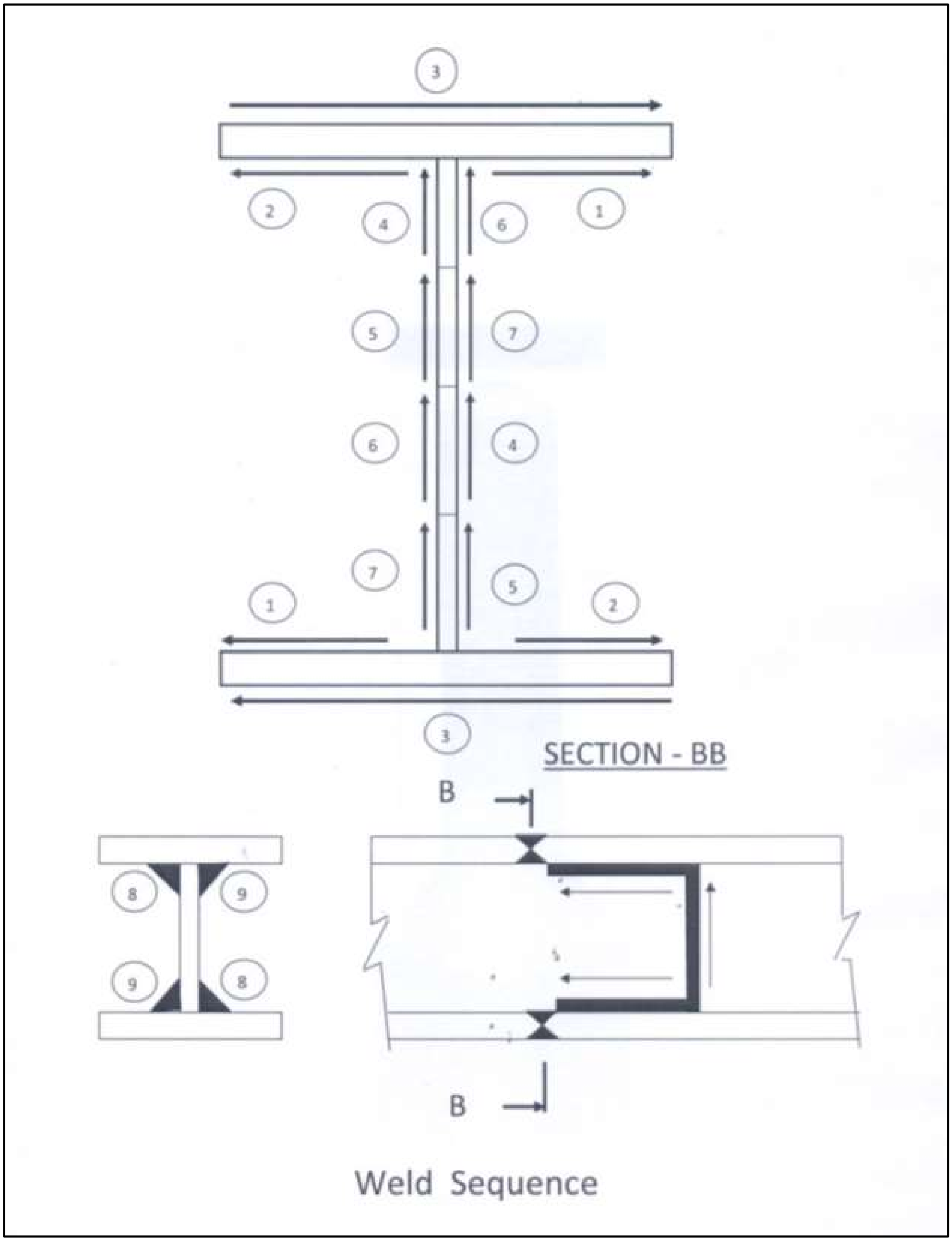


Figure B1.7 WELD SEQUENCE

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.: _______________________

<u>WELDING JOB CARDFOR CEILING GRIDERS</u>

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

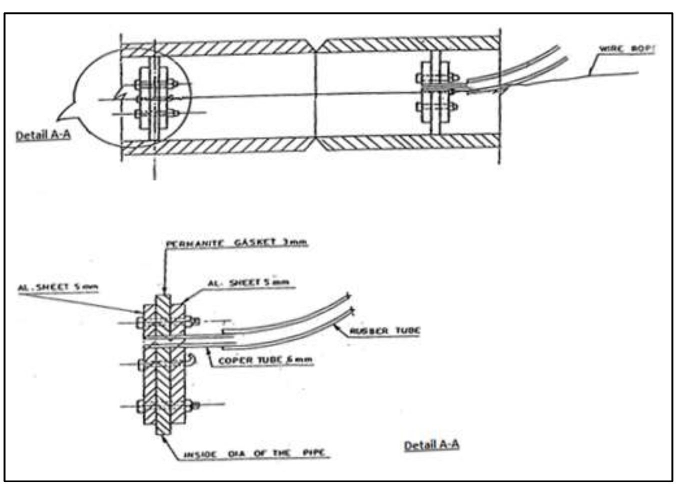


Figure B2.1 ALUMINIUM DAM ARRANGEMENT

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).

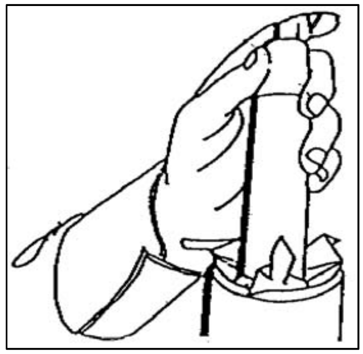


Figure B2.2 – INSERTION OF WATER SOLUBLE PAPER/ WATER SOLUBLE TISSUE PAPER

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).

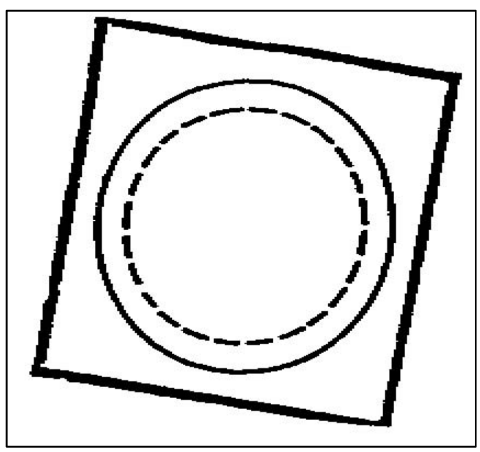


Figure B2.3 – ALUMINIUM FOIL DISC

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).

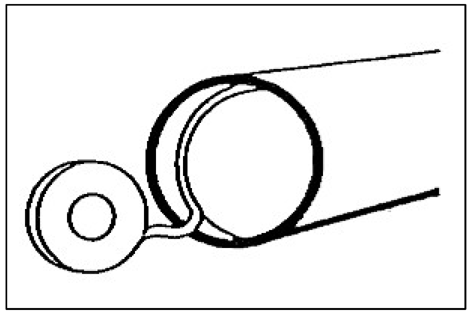


Figure B2.4 – POSITIONING OF DISC

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.

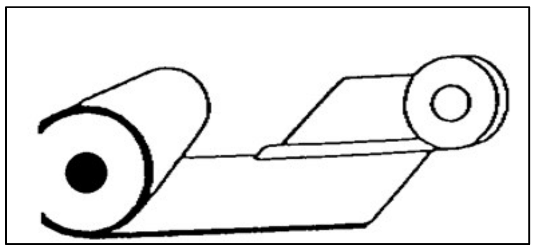


Figure B2.5 – JOINING OF TWO WATER SOLUBLE PAPERS

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

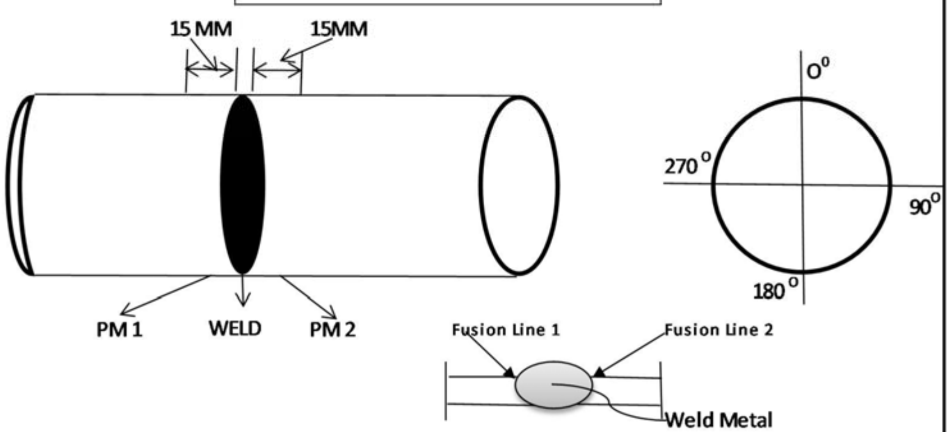
T91/T92/P91/P92/F91/F92/C12A HARDNESS TESTING PROTOCOL

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 <u>DOCUMENTATION:</u>

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.

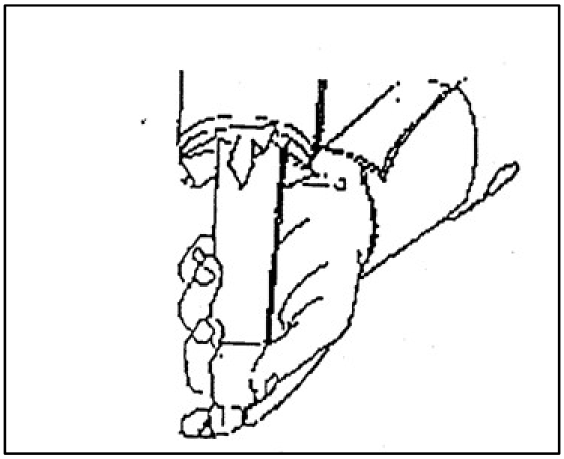


Figure B3.1: Insertion of Water Soluble Tissue paper

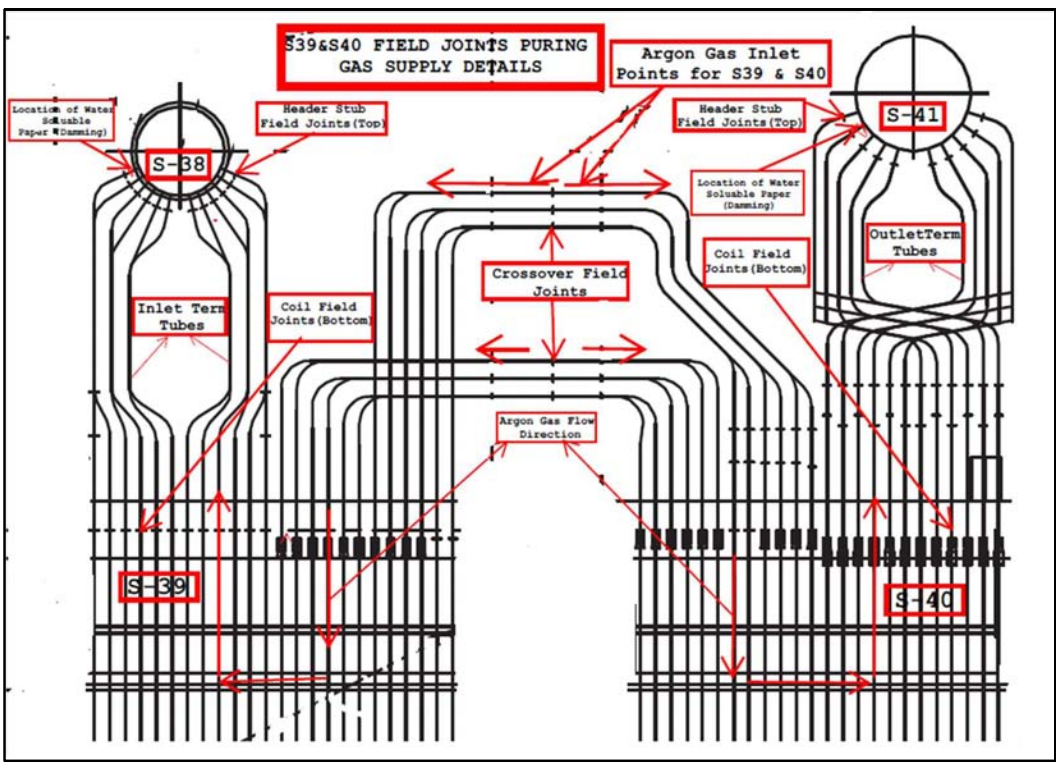


Figure B3.2: Purging Arrangement for SH Header Field Joints

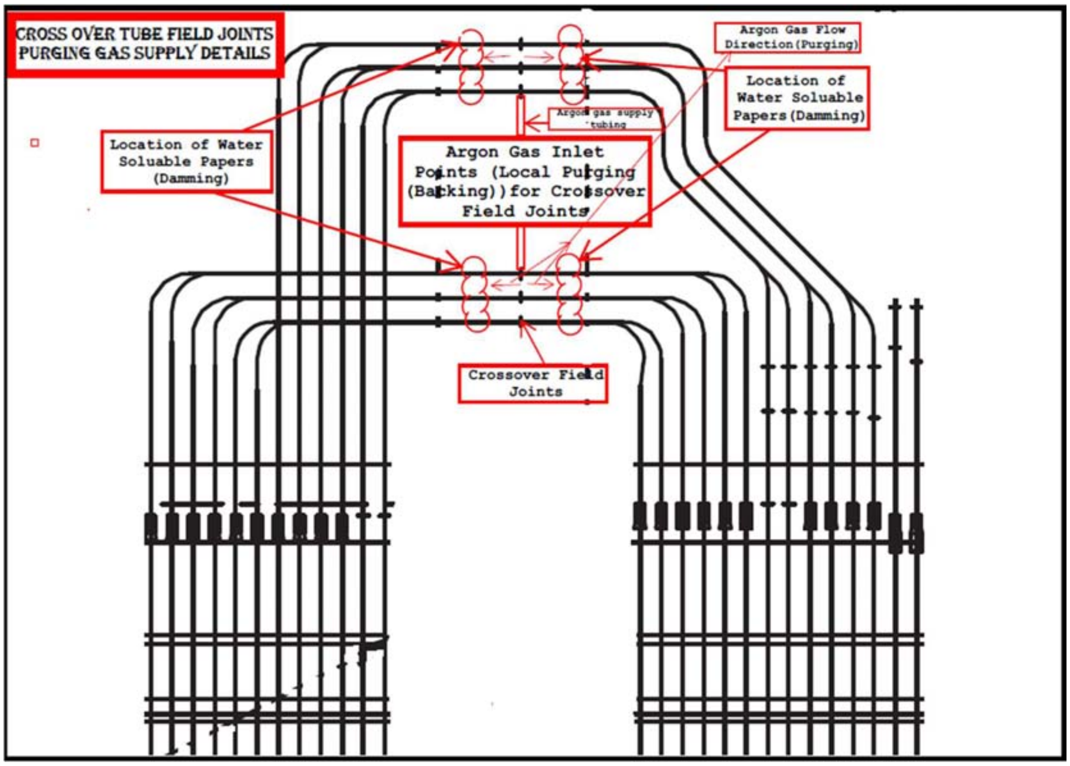


Figure B3.3: Purging Arrangement for Cross Over Tube Field Joints

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

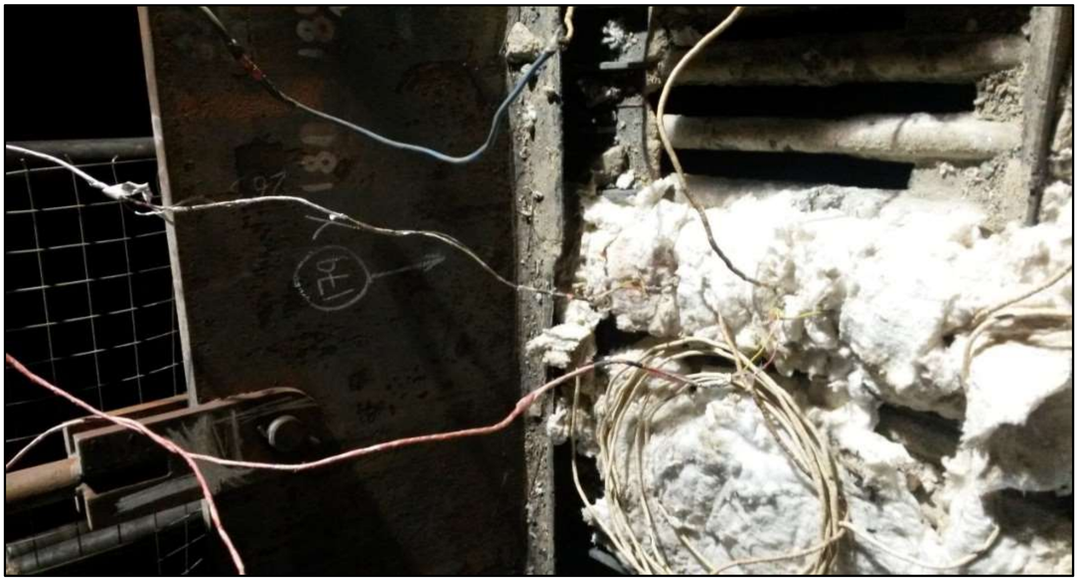


Figure B4.4: Post heating arrangement

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.

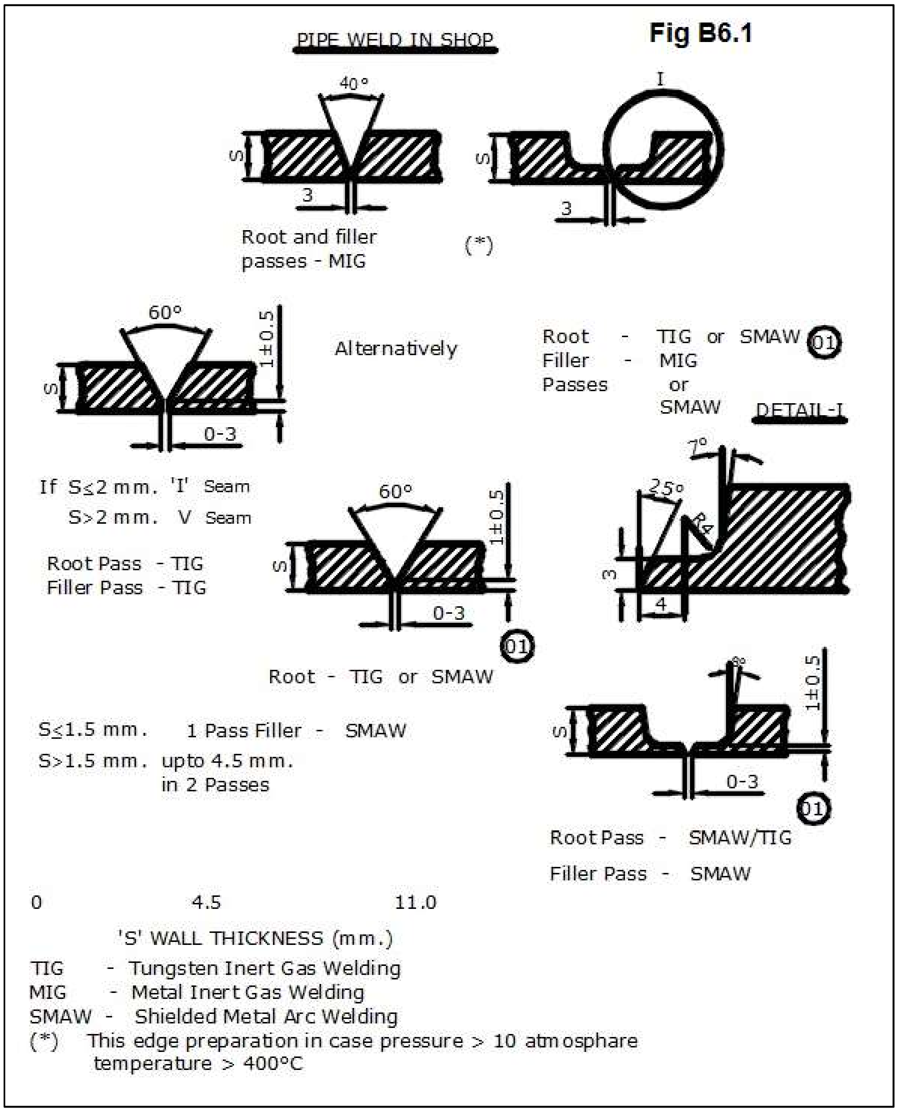
4.0 PIPES ROLLED FROM PLATES

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.

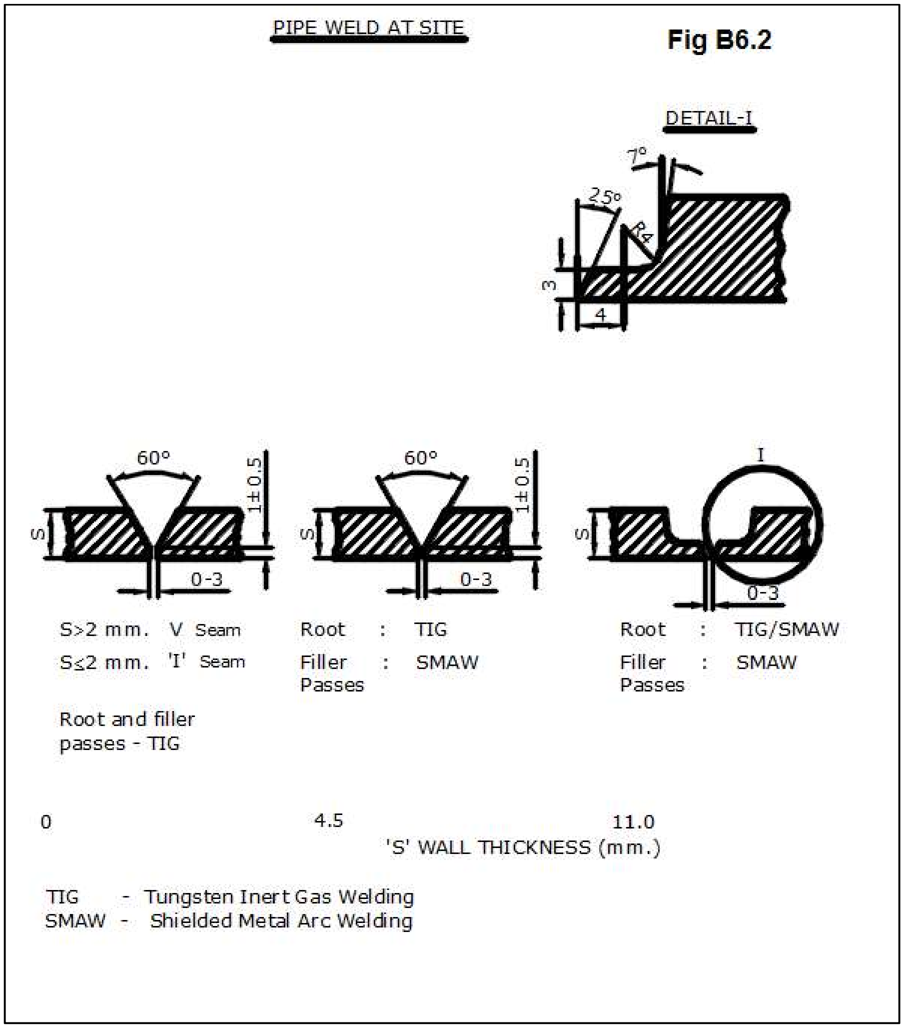
If required the root is gouged / ground and welded from back side.

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
Root and filler passes - MIG
(*)
I
60°
1±0.5
0-3
Alternatively
Root - TIG or SMAW
Filler Passes - MIG or SMAW
01
DETAIL-I
7°
25°
R4
4
If S≤2 mm. 'I' Seam
S>2 mm. V Seam
Root Pass - TIG
Filler Pass - TIG
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
DETAIL-I
7°
25°
R4
3
4
60°
1±0.5
S
0-3
I
S>2 mm. V Seam
S≤2 mm. 'I' Seam
Root and filler passes - TIG
Root : TIG
Filler Passes : SMAW
Root : TIG/SMAW
Filler Passes : SMAW
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 : [illegible] DRG.NO. : 01601070039E132	HXE/10565/FWS 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.	HOLD ING 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.	HOLD ING 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.	HOLDING 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	NTL	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.		
			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
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 SIZE OF WELD (mm)	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.	HOLD ING TIME	NDT METHOD QUANTAM RT/UT	DPT	REF. SPEC. NO.	ACC NORM REF.	ZONE
66	01601070039E132 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)	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.	HOLDING TIME	NDT METHOD QUANTAM RT/UT	DPT	REF. SPEC. NO.	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.

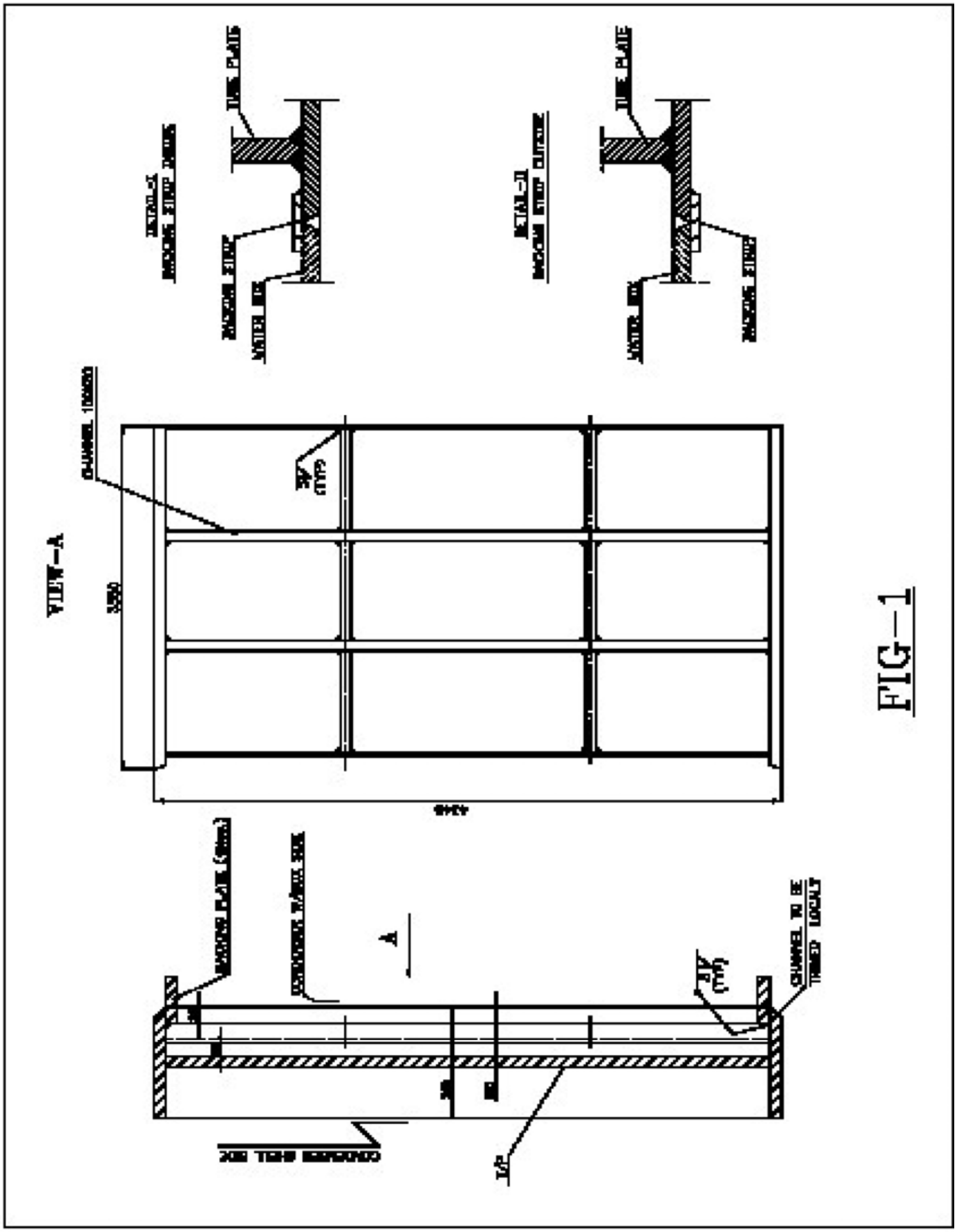
3. Lower the water chamber (without water box) on bottom plate for erection as per standard procedure.
4. Tack weld / final weld water chamber with side walls and bottom plate.
5. Carry out tubing.
6. Weld the water boxes using proper welding sequence as given (C) below.

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

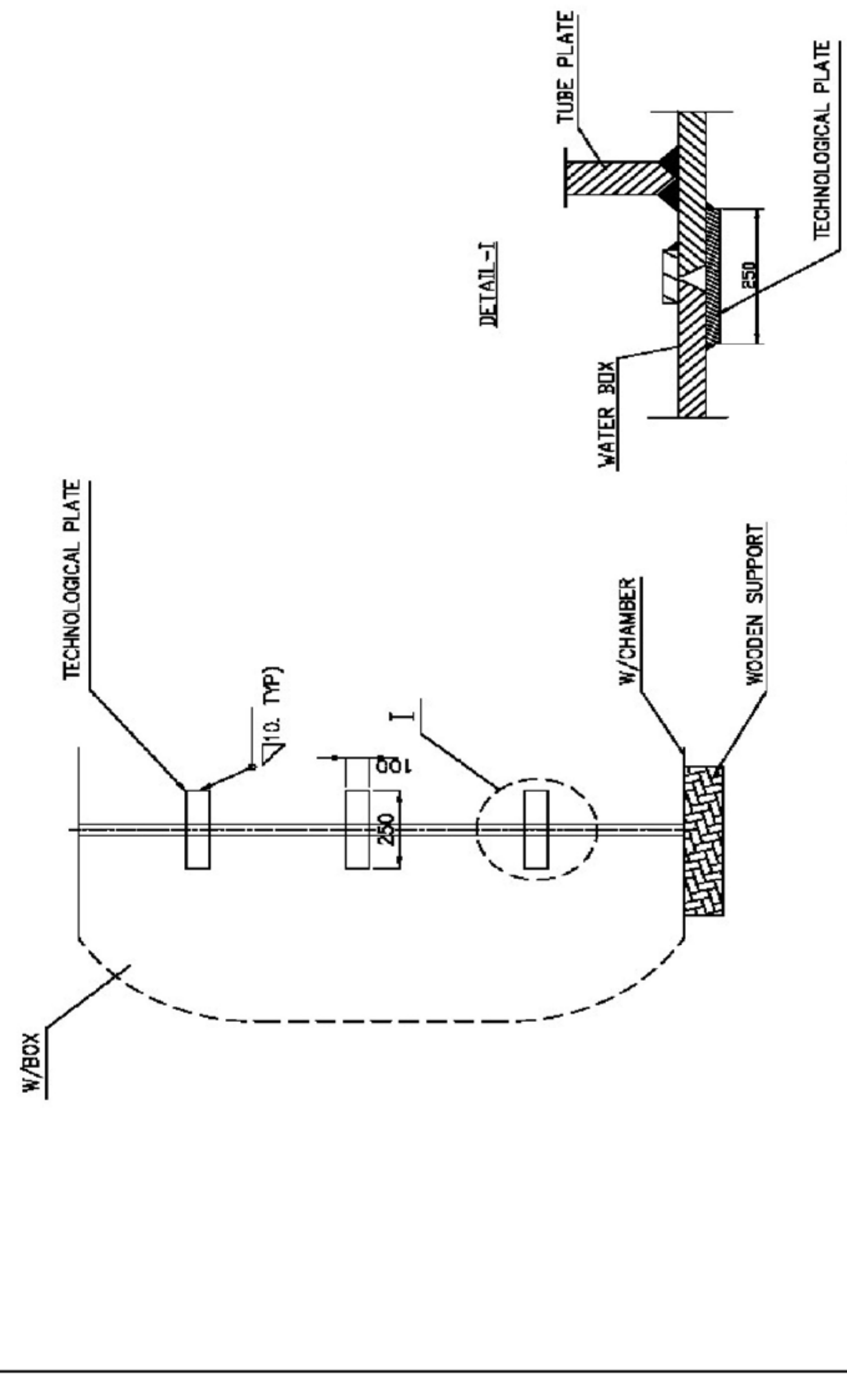


FIG-2

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.

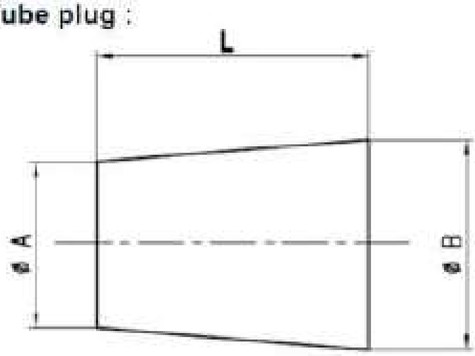
Please refer to the following "Tube End and Safety Plugging" instructions which provide the correct material and dimensions of the tapered tube plug to be used.

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.

SHEET JOINTS OF 'U' TUBE H.P. HEATER

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 <u>MATERIAL GRADES BEING USED IN STEAM TURBINE COMPONENTS</u>

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

LIST OF ANNEXURES

LIST OF TABLES

LIST OF FIGURES

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

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

पावर सेक्टर के लिए हीट ट्रीटमेंट मैनुअल

HEAT TREATMENT 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 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.

Table of Contents

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.

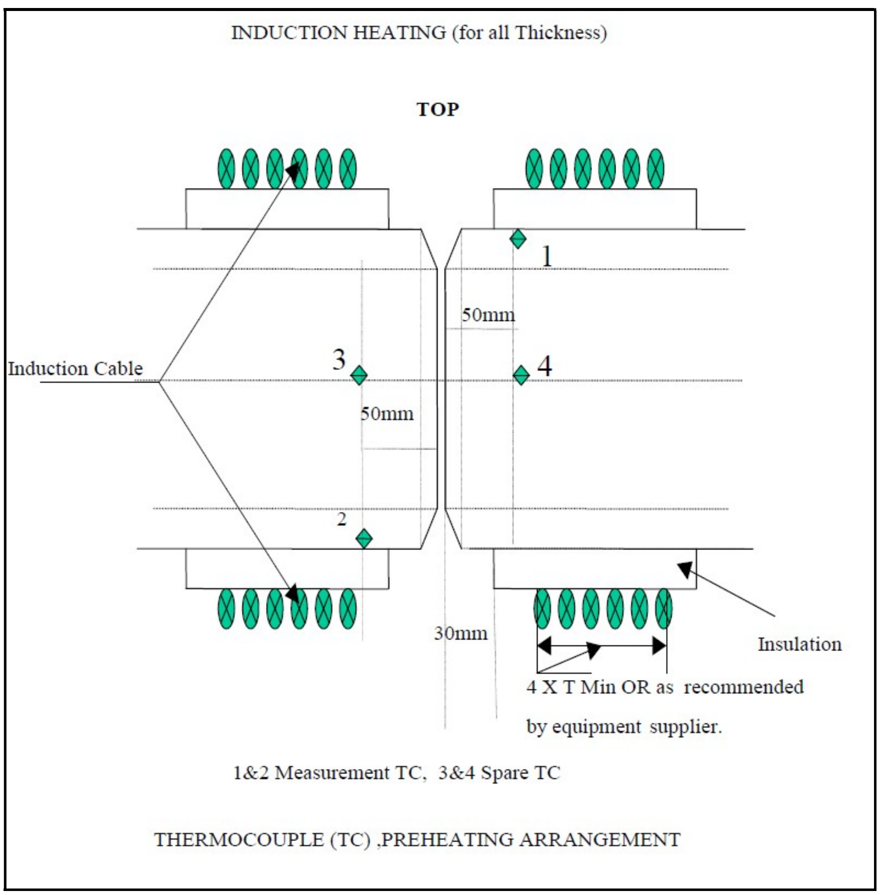


Figure 1.1: Placement of Thermocouples on P91/P92/F91/F92/C12A materials for Preheating

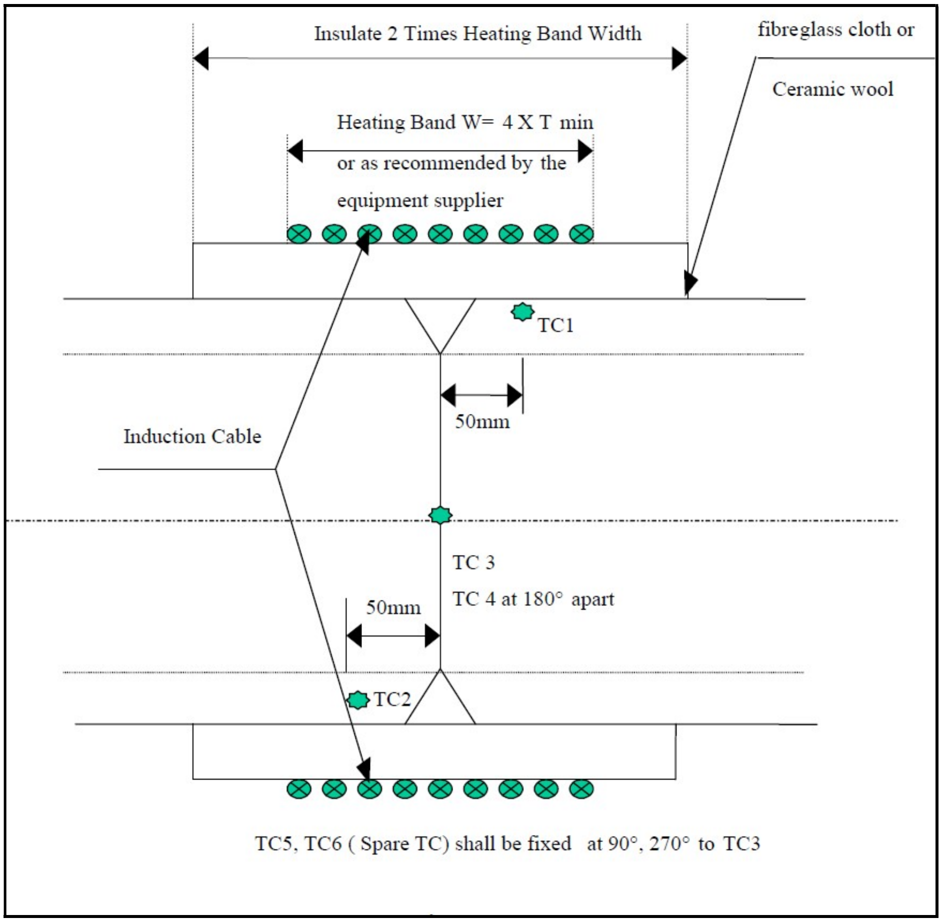


Figure 1.2: Placement of Thermocouples on P91/P92/F91/F92/C12A materials for PWHT

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.

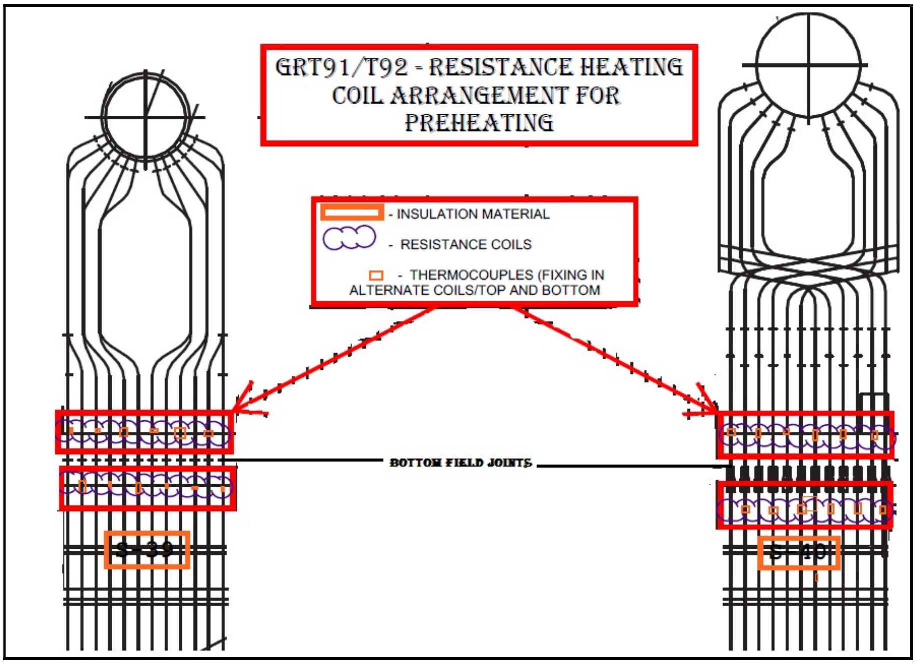


Figure 1.3: Resistance heating Coil arrangement for Preheating of T91/T92 tube assembly

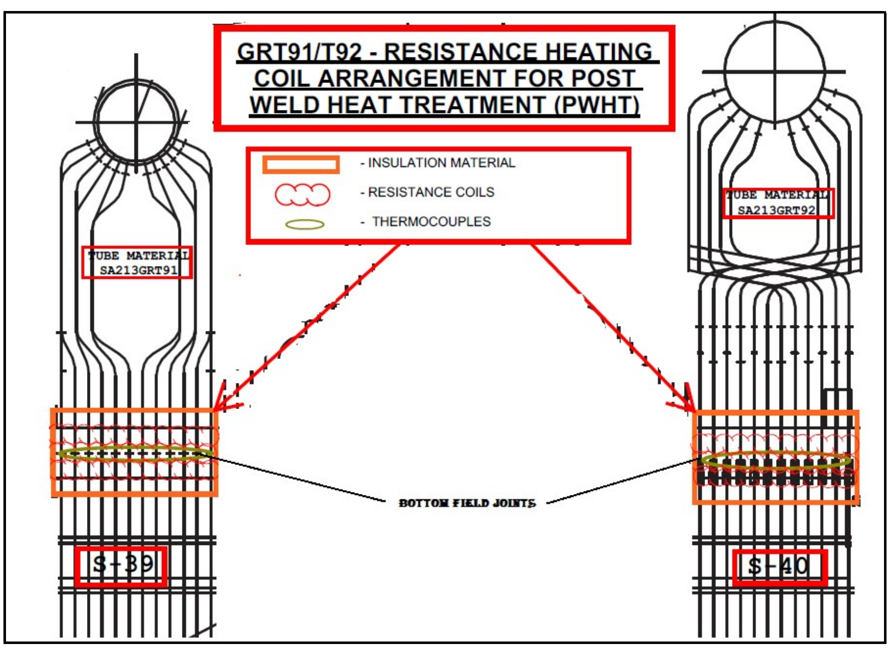


Figure 1.4: Resistance heating Coil arrangement for PWHT of T91/T92 tube assembly

3.5 **List of Tables:**

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**
				Throat ≤ 19 mm		**Throat > 19 mm**		
		Preheat °C	**PWHT °C**	**Preheat °C**	**PWHT °C**	**Preheat °C**	**PWHT °C**	
P1 Gr 1	≤ 19	Nil	Nil	Nil	Nil	Nil	595 - 625	Nil
	>19≤25	Nil	595 - 625	Nil	595 - 625	Nil	595 - 625	Nil
	>25≤75	150	595 - 625	150	595 - 625	150	595 - 625	Nil
	>75	150	595 - 625	150	595- 625	150	595 - 625	Nil
P1 Gr 2	≤9	Nil	Nil	Nil	Nil	Nil	595 - 625	Nil
	>9≤19	Nil	595 - 625	Nil	595 - 625	Nil	595 - 625	Nil
	>19	150	595 - 625	150	595 - 625	150	595 - 625	150 for 2 hrs
P4 Gr 1	All	150	640- 670*	150	640- 670*	150	640- 670*	Nil
P5 A	All	150	680 - 710	150	680- 710	150	680- 710	250 for 2 hrs
P15 E Gr1	All	220	740-770	220	740- 770	220	740- 770	NA
P15 E Gr1 + P5 A	All	220	730-760	220	730- 760	220	730- 760	NA

**** Minimum 650°C for ASME jobs***

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

P1 + P3 -	620 to 650°C	
P1 + P4 -	640 to 670°C	***Minimum 650°C for ASME jobs***
P4 + P5A-	680 to 710°C	

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

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

P. No. of Material / Material Specification	Gas Cutting		Welding		
	Thickness (mm)	Preheat °C	Thickness (mm)	Preheat (°C)	PWHT (°C)
P1 / IS 2062 E250 BR, E350 BR,E350C	≤ 50 > 50	Nil 100	≤ 38 > 38 ≤ 63 > 63	Nil 100 150	595-625 1.0 All butt welds > 50 mm thick 2.0 For Ceiling girders if thickness > 50 mm 3.0 No HT required for web to flange fillet welds.
BS EN 10025 Gr 420 N (Ceiling Girder)	All	220	All	220	620 – 650
P3 Gr 1 and Gr 2	T>25	150	All	150	620-650 a) All butt welds in tension member b) All butt welds of fabricated components > 16mm thick and fillet welds with throat thickness > 13 mm
P4 Gr 1	All	150	All	150	650-680 a) All butt welds in tension member b) All butt welds of fabricated components > 16mm thick and fillet welds with throat thickness > 13 mm
P5A Gr 1	All	150	All	150	680-710 All welds (Note 2)
P15E Gr.1	Not permitted	Not permitted	All	220	740-770

NOTE:

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

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CHAPTER -2
HEAT TREATMENT PROCEDURE - STEAM TURBINE, TURBO-GENERATOR AND AUXILIARIES

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

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

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

LIST OF ANNEXURE

LIST OF TABLES:

LIST OF FIGURES

RECORD OF REVISIONS

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

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

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

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

BHEL	**BHARAT HEAVY ELECTRICALS LIMITED** **DEPT.235 – TIRUCHIRAPALLI - 620 014** **Non-Destructive Testing**	BHE:NDT:PB:PT- 01 Revision 22 Page 1 of 10

PROCEDURE FOR LIQUID PENETRANT EXAMINATION

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

Effective from 01.01.2020

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.*

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 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 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.

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.

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.

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.

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

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 from	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

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	B.K.Sethupathy 01-01-2020	01/01/2020

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.

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^{o}C to 315^{o}C (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' 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.

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.

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 application before removing the magnetic field, to prevent high-velocity particle flow that may wash away or remove fine or weakly held indications.

14.0 LIGHTING

14.1. Visible Light Intensity

14.1.1 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.

14.1.2 Lux meter shall be calibrated at least once a year or whenever the meter has been repaired. If meter has not been used for one year it shall be calibrated before use.

14.2. Black Light

14.2.1 Black light intensity at the examination surface shall be not less than 1000 micro watt/cm square at a height of 250 mm. The black light intensity shall be measured at least once every 8 hr. and whenever the work station is changed.

14.2.2 With fluorescent particles the examination is performed in a darkened area.

14.2.3 The examiner shall be in the darkened area for at least 5 minutes prior to performing the examination for eye adaptation. Glasses or lenses worn by the examiners shall not be photochromic or exhibit any fluorescence.

14.2.4 The black light shall be warmed up for a minimum period of 5 minutes prior to use or measurement of intensity.

14.2.5 Light meters shall be calibrated at least once a year or whenever a meter has been repaired

15.0 SYSTEM PERFORMANCE CHECK (Fig.4 & 4a)

15.1. For prod magnetization with HWDC, performance sensitivity shall be checked at least once in a shift before start of the examination on a test plate that contains machined grooves to different depths. The indication of a groove at 3 mm depth from the surface of the test plate will indicate adequate sensitivity.

15.2. For electromagnetic yokes, the adequacy or direction of the magnetizing force shall be verified by positioning the 'Magnetic Field Indicator' (Fig 5) on the surface to be examined. The pattern in the indicator should be clearly developed on the surface of the block.

16.0 DEMAGNETISATION

16.1. When residual magnetism in the part could interfere with subsequent processing or usage, the part shall be demagnetized any time after completion of the examination.

17.0 EVALUATION OF INDICATION

17.1. Mechanical discontinuity at the surface would be indicated by the retention of the powder or medium.

17.1.1 All the indications are not necessarily defects, however, since certain metallurgical discontinuities and magnetic permeability variations may produce similar indications which are not relevant.

17.1.2 Any indication that is believed to be non-relevant shall be reexamined to verify whether or not actual defects are present. Surface conditioning may precede the reexamination. Non relevant indications that would mask indications of defects are unacceptable.

Relevant indications are those which result from unacceptable mechanical discontinuities.

17.2. Relevant indications are indications which result from imperfections. Relevant indications are caused by a condition or type of discontinuities that requires evaluation.

17.2.1 Linear indications are those indications in which the length is greater than three times the width.

17.2.2 Rounded indications are circular or elliptical with the length equal to or less than three times the width.

18.0 ACCEPTANCE STANDARDS AS PER ASME (Sec. I, VIII Div. 1 & 2)

18.1. Welds and Materials

18.2. 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 for evaluation.

18.3. Only indications which have dimensions greater than 1.5 mm shall be considered relevant.

18.4. All surfaces to be examined shall be free of

18.4.1 Relevant linear indications.

18.4.2 Relevant rounded indications greater than 5.0 mm

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

18.4.4 In welds joining nipples to drums, spheres or headers, all slag or porosity indications shall be investigated to assure that no leak-path exists.

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

19.0 For Power Piping (as per ASME B 31.1 Power Piping)

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

19.2. 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 unfavourable location relative to the indications being evaluated.

20.0 ACCEPTANCE STANDARD FOR STRUCTURAL COMPONENTS AS PER AWS

20.1. The magnetic Particle acceptance criteria is based on the size of the actual discontinuity and not the size of the discontinuity as indicated by the magnetic particle inspection medium. Where discontinuity cannot be visually seen (with magnification if required), after removal of the indicating medium, evaluation shall be based on size and nature of the magnetic particle indication.

21.0 Statically loaded Non-tubular connections

21.1. Cracks, Lack of Fusion, and Incomplete Penetration are not acceptable.

21.2. Undercut - for material with thickness less than 25 mm, 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. For material equal to or greater than 25.0 mm thick, undercut shall not exceed 2.0 mm for any length of weld.

21.3. Porosity - a complete joint penetration groove welds in butt joints transverse to the direction of computed tensile stress shall have no visible piping porosity. 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 10.0 mm in any linear 25.0 mm of weld and shall not exceed 20mm in any 300 mm length of weld.

22.0 Cyclically Loaded Non-Tubular Connections

22.1. Undercut - In primary members, undercut shall be no 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 1.0 mm deep for all other cases.

22.2. Porosity - 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 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 20 mm in 300 mm length of weld.

22.3. Complete joint penetration groove welds in butt joints transverse to the direction of computed tensile stress shall have NO Piping Porosity.

22.4. PIPING POROSITY - (General) is elongated porosity whose major dimension lies in a direction approximately normal to the weld surface. Frequently referred to as pin holes when the porosity extends to the weld surface.

23.0 EDGE DISCONTINUITIES IN CUT MATERIALS

23.1. No crack is acceptable.

23.2. Mill induced discontinuity

23.3. Length 25 mm and less - acceptable.

23.4. Length over 25 mm and depth up to 3 mm – acceptable. Here the depth shall be explored for 10 % of the discontinuities on the cut surface by grinding.

23.5. Length over 25 mm and depth between 3 mm and 6 mm - indications shall be removed, but filling up of this region by welding is not required.

23.6. Length over 25 mm and depth greater than 6 mm and less than 25 mm- indications shall be removed and re-welded. The method explained in 23.6(1) through (4) shall be followed for disposition.

23.6.1 Where discontinuities such as W, X or Y in figure 6 are observed prior to completing the joint, the size and shape of the discontinuity shall be determined by UT. The area of the discontinuity shall be determined by the area of total loss of back wall reflection. When tested in conformance with ASTM A 435.

23.6.2 For acceptance of W,X or Y discontinuities, the area of discontinuity(or aggregate area of multiple discontinuities) shall not exceed 4% of the cut material area(length times width) with the following exception: if the length of the discontinuity of aggregate width of discontinuities on any transvers section , as measured perpendicular to the cut material length, exceeds 20% of the cut material width, the 4% cut material area shall be reduced by the % amount of the width exceeding 20&.(For example, if a discontinuity is 30% of the cut material width, the area of discontinuity cannot exceed 3.6% of the cut material area). The discontinuity of the cut surface of the cut material shall be removed to a depth of 25 mm beyond its intersection with the surface by chipping, gouging or grinding, and blocked off by welding with a low hydrogen process in layers not exceeding 3 mm in thickness for atleast the first four layers.

23.6.3 Repair shall not be required if a discontinuity Z, not exceeding the allowable area in 23.6(2), is discovered after the joint has been completed and is determined to be 25 mm or more away from the face of the weld, as measured on the cut base-metal surface. If the discontinuity is less than 25 mm away from the face of the weld, it shall be removed to a distance of 25 mm from the fusion zone of the weld by chipping, gouging or grinding. It shall then be blocked off by welding with a low hydrogen process in layers not exceeding 3 mm in thickness for atleast the first four layers.

23.6.4 If the area of discontinuity W, X, Y or Z exceeds the allowable in 23.6(2), the cut material and the subcomponent shall be rejected and replaced.

24.0 REPAIR AND RE-EXAMINATION

24.1. Whenever an imperfection is repaired by chipping or grinding or and subsequent repair by welding is not required, 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 2 in [50 mm] beyond each end of the crack shall be removed, and rewelded.

24.2. After a defect is thought to have been removed and prior to making weld repairs, the area will be examined by suitable methods to ensure that the defect has been removed or reduced to an acceptable size of an imperfection.

24.3. Where welding is required after repair of an imperfection the area shall be cleaned and repair carried out. After repairs have been made the repaired area shall be blended into the surrounding surface so as to avoid sharp notches, crevices or corners.

24.4. After repairs have been made, the repaired area shall be re-examined by methods of examination that were originally required for the affected area.

25.0 PERSONNEL QUALIFICATIONS

25.1. 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 Level II and Evaluation by Level II / III Personnel.

26.0 POST EXAMINATION CLEANING

26.1. When the inspection is concluded, the magnetic particles shall be removed from the surface by using dry white cloth/cotton waste or any suitable means without adversely affect the part, leaving the product in a dry and clean condition.

27.0 REPORTING AND RETENTION PERIOD

27.1. The report shall include as a minimum, the data as specified in T-190(a) of Article-1, T 792 & T-793 of ASME Section V Article 7. Then report shall be reviewed and signed by NDT Level II / III and issued. All the reports will be retained for a period of 1 year or Final Inspection clearance whichever is later and reports for ASME Coded works for a period of 5 years.

****

Table 1
MAGNETIC PARTICLES USED *

Manufacturer	Brand	Method	Color
Pradeep NDT Products	Automag RD-7	Dry	Brick Red
Arora Technologies Pvt Ltd	DR 100	Dry	Brick Red
Magnaflux	8A Red	Dry	Brick Red
Pradeep NDT Products	Flawguide	Wet Fluorescent	--
MR Chemie	114HB	Wet Fluorescent	--
Ferrochem NDT	1332C/P-5	Wet Fluorescent	--
Arora technologies	Flawglo WF 10	Wet Fluorescent	--

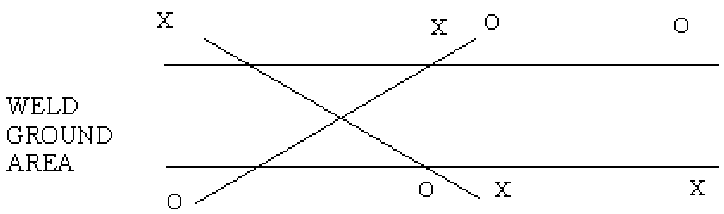
*The above Brand of MPI particles will be used or other brands may also be used with the approval of Level III / NDT.

Table 2
DEMONSTRATION RECORD FOR ESSENTIAL AND NON-ESSENTIAL VARIABLES

Sl. No	Requirement	Type of variable	Covered in the procedure as
01	Magnetizing technique	Essential	Clause 7.1-Prod- Dry particle method
02	Magnetizing current type or as previously qualified	Essential	Clause 8.1-Single phase HWDC
03	Surface preparation	Essential	Clause 5.1-As welded, as ground surface -Free from oil, grease etc.
04	Magnetic particle(Fluorescent/ visible, Color, size, wet / dry)	Essential	Clause 4.2 -Visible Dry-Brick Red
05	Method of particle application	Essential	*Clause 13.1*: Hand Powder applicators- Squeeze bulb
06	Method of excess particle removal	Essential	*Clause 13.1.2* -Gentle air stream while the current is on.

07	Minimum light intensity	Essential	*Clause 14.1.1 - 1076 lux* Source: A hand lamp with 240 V/ 09 W LED bulb white light kept at a maximum distance of 300 mm.
08	Coating thickness greater than qualified	Essential	Not used
09	Non-magnetic surface contrast enhancement when utilized	Essential	Not used
10	Performance demonstration, if required	Essential	A change of requirement in Table-3 identified as essential variable from the specified value, or range of values, Procedure shall be re-qualified by satisfactory demonstration to the AI.
11	Part Surface temp. outside of the temp range recommended by the supplier of the powder or as previously qualified	Essential	Clause 4.2-Maximum 345°C for Dry method (within recommended range by M/s Pradeep NDT Products, Pune)
12	Shape / size of object	Non-Essential	Clause 1.1:Butt and fillet welds in Steam Generator, piping, pumps, valves, Pressure Vessel and Heat Exchanger components used for Nuclear applications
13	Equipment of same type	Non-Essential	Clause 3.0- Prod type
14	Temperature (within those specified by manufacturer or as previously qualified)	Non-Essential	Clause 4.2: 17° C to 345° C for Dry method (within recommended range by M/s. Pradeep NDT Products, Pune)
15	Demagnetizing technique	Non-Essential	*Clause 16.1*- No demagnetization unless otherwise specified
16	Post examination cleaning technique	Non-Essential	*Clause 20.0*
17	Personnel qualification requirement	Non-Essential	*Clause 25.0*

X - PROD POSITION 1
D-PROD POSITION 2



FIG(1): TECHNIQUE FOR EXAMINATION OF LONG SEAMS AND CIRCUMFERENTIAL SEAMS

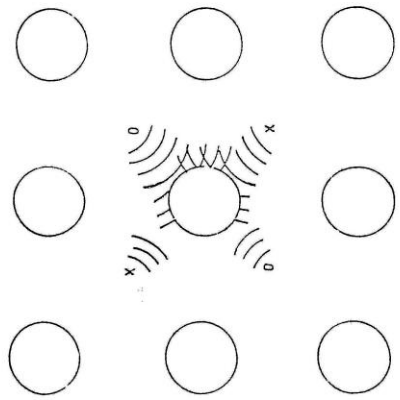


FIG (2): TECHNIQUES FOR EXAMINATION OF FILLET WELDS

0 – POSITION 1 X – POSITION 2 ARC BREAK LOCATION

NOTE:

1) Prods must be placed on Drum / Header perpendicular to plate Surface.

2) Inspection will be 100% of weld for each shot.

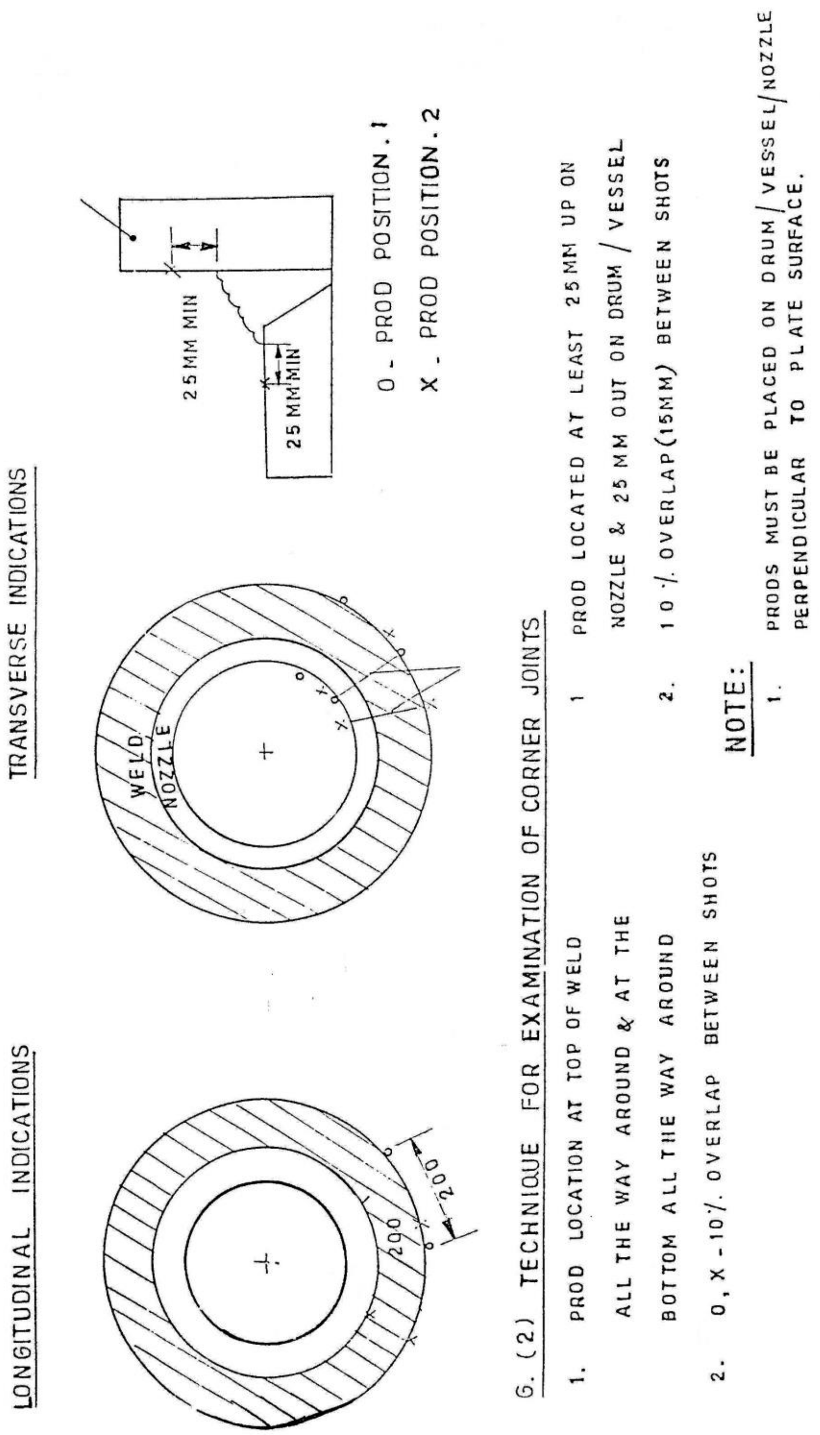
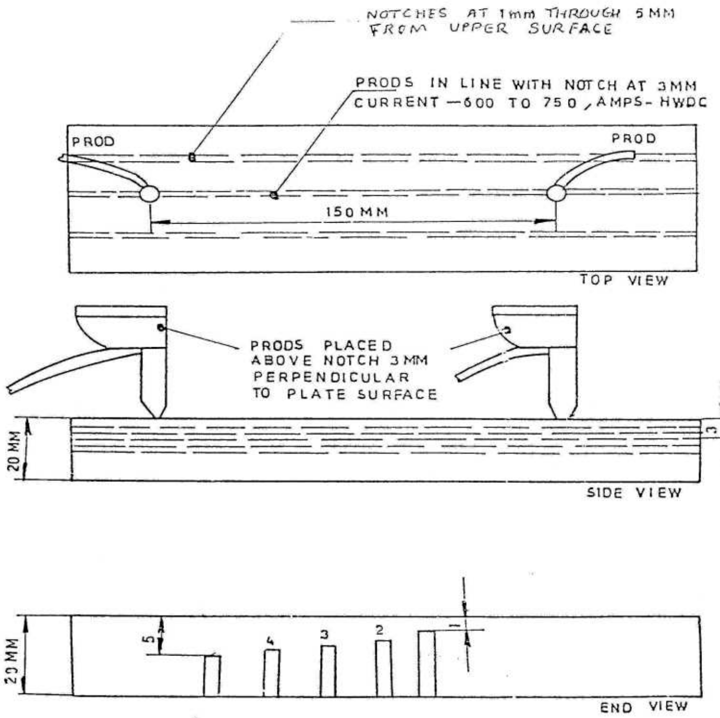
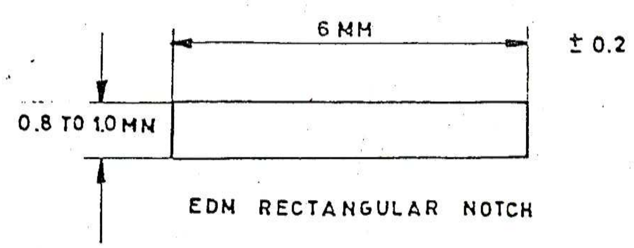


Fig (3) Technique for examination of Corner Joint



PERFORMANCE CHECK – EQUIPMENT AND DRY POWDER COMBINATION PRIOR TO TEST

FIG (4) VERIFICATION OF SYSTEM PERFORMANCE FOR PROD TECHNIQUE



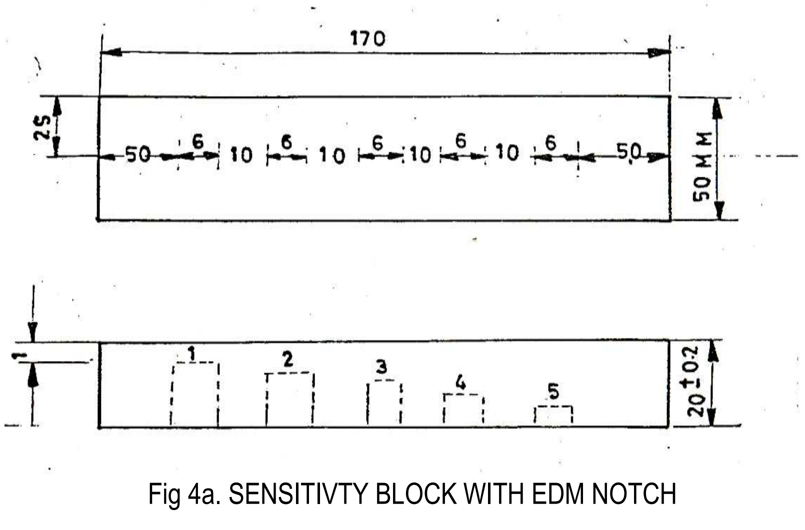


Fig 4a. SENSITIVTY BLOCK WITH EDM NOTCH

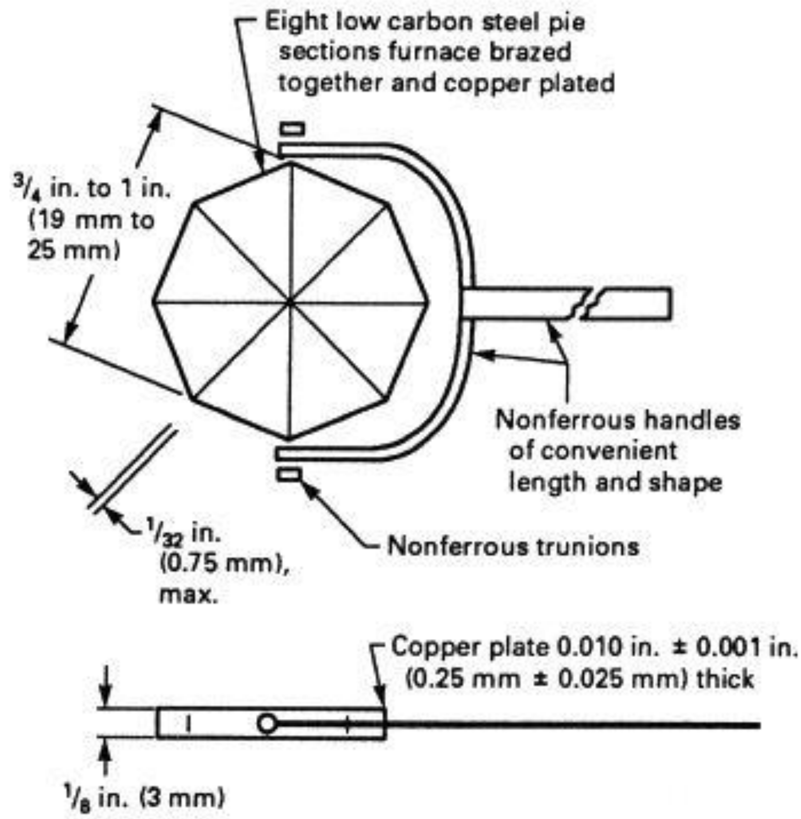


Fig (5): Pie shaped Magnetic Field Indicator

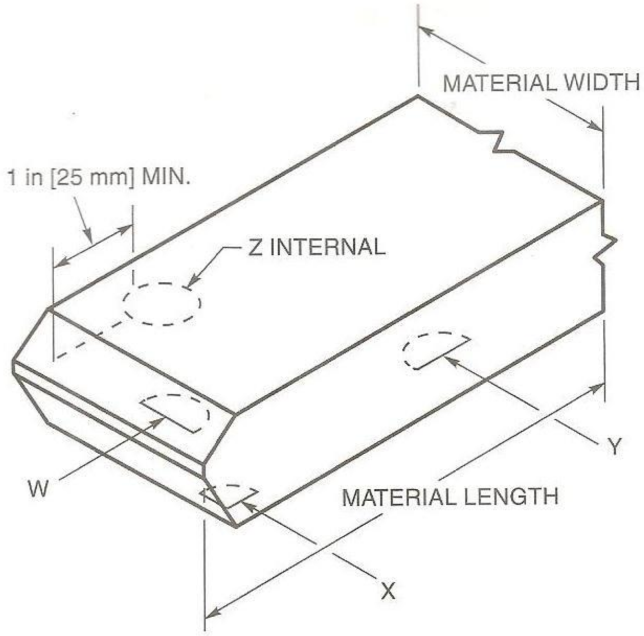


Fig (6) Edge discontinuities in cut material (See sec. 23.6)

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

Report No: Date: Call / Notification Ref:

Work Order: Material: Stage of test: Before / After HT

Part: Drawing No:

Thickness: mm Surface Condition:

Equipment: Calibration validity:

Magnetization: Circular/Longitudinal Technique: Prod/Head shot/Coil/Yoke
Method: Visible/Fluorescent/Non Fluorescent/Wet/Dry Surface Pre cleaning:

Color contrast enhancement: Lifting Power:

Prod / Pole spacing: mm current: Amps

Powder / Fluid Color : Brand:

Particle / Fluid application: Excess particle removal:

Sensitivity / Field direction check: Demagnetization: Done/Not done

Lighting Equipment: Light intensity:

Temperature of part: Deg. C Date of Testing:

Procedure & Acceptance: BHE: NDT: PB: MT- Rev

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

SAMPLE

Performed by	Evaluated by	Reviewed / Witnessed by
Level I / II	Level II / III	AI / Customer

CHAPTER 1.3

MAGNETIC PARTICLE EXAMINATION OF MATERIAL SURFACE, WELDING GROOVES AND WELD JOINTS OF X-20, P91 AND P92 MATERIALS

PROCEDURE FOR MAGNETIC PARTICLE EXAMINATION OF MATERIAL SURFACE, WELDING GROOVES AND WELD JOINTS OF X-20, 91 AND 92 MATERIALS

Prepared by	Reviewed by	Approved by	Issued by
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01.01.2020	01/01/2020	B.K. Sethupathy 01-01-2020	01/01/2020

EFFECTIVE FROM 01.01.2020

RECORD OF REVISION

Rev No	Revision Date	Details of Revision
01	27-07-1998	(a) Revised to include Fluorescent Particle Testing
02	15-03-2000	(a) Requirements of P91 added (b) Reference Modified (c) Editorial corrections made
03	08-08-2016	(a) Clause 1.2.1 revised (b) Clause 1.2.2 added (c) Clause 1.1 revised (d) Clause 2.2 revised (e) Clause 2.3 added (f) Form 235-011 added (g) Clause 8.1 revised
04	26-10-2018	(a) Clause 1.2.2 added (b) Clause 6.2 revised (c) Clause 7.2.2 modified (d) Clause 8.1 revised (e) Clause 5.1 modified (f) Clause 7.2.1 modified (g) Clause 7.2.3 modified (h) Clause 8.1 modified (i) Clause 8.2 modified (j) Clause 9.1 modified
05	03-01-2019	Procedure title modified, Clause 1.1, 1.2.2 modified, Clause 1.2.3 added, Clause 6.3 added, Clause 10.1, 10.2 and 10.3 revised
06	21-11-2019	(a) Clause 2.3 a. modified. (b) Clause 10.4 deleted.
07	01-01-2020	(a) Clause 1.2.2 modified. (b) Clause 2.3b, 2.3c modified. (c) Clause 7.1.1 modified. (d) Clause 7.2 modified. (e) Clause 9.1 modified

1.0 **SCOPE**

1.1 This procedure deals with the testing methods and acceptance standard for the magnetic particle examination of material surface, welding groove bevels, Butt and Fillet weld joints of X-20, 91 and 92 materials.

1.2 **REFERENCES**

1.2.1 AD- Merkblatt HP 5/3 / 2011

1.2.2 ***ASME Sec I & Sec V / 2019***

1.2.3 ASME B31.1 2015

2.0 **EQUIPMENT**

2.1 AC or HWDC Yoke magnet shall be used for examination.

2.2 Non fluorescent dry or wet magnetic particles of black, grey or red colour or wet fluorescent magnetic particles, suspended either in kerosene or water conditioned with suitable wetting agent shall be used. The particle used shall be of high permeability, low retentivity and of suitable sizes and shapes to produce readily magnetic particle indications. The colour of the non- fluorescent particle chosen shall be in sharp contrast to the material surface being examined.

2.3 (a) The magnetizing power of yokes shall be verified prior to use on every day the yoke is used. The magnetizing power of yokes shall be verified whenever the yoke has been damaged or repaired.

2.3 (b) Each alternating current electromagnetic yoke shall have a lifting power of at least 4.5 kg at the maximum pole spacing that will be used *with contact similar to what will be used during the examination.*

2.3 (c) Each direct current or permanent magnetic yoke shall have a lifting power of at least 18 kg at the maximum pole spacing that will be used *with contact similar to what will be used during the examination.*

2.3 (d) Each weight shall be weighed with a scale from a reputable manufacturer and stencilled with the applicable nominal weight prior to first use. weight need only be verified again if damaged in a manner that could have caused potential loss of material.

3.0 **SURFACE PREPARATION**

3.1 The surface to be examined shall be even and free of impurities. Drag lines, notches or weld beads (also arc strikes or tacks) shall be removed. A surface roughness equal to or smaller than 20 microns is desired. Undercuts, overlaps or abrupt edges and valleys in the weld metal shall be smoothly merged with the parent metal.

4.0 **TYPE OF MAGNETISATION**

Longitudinal magnetization with yoke and alternate current or half wave DC (HWDC) shall be used for examination.

4.1 Examination shall be made by continuous method, i.e. magnetizing current remains on while inspection medium is being applied.

5.1 **MAGNETIC FIELD ADEQUACY AND DIRECTION**

The Direction and Field Adequacy of the magnetic field should be checked over the area to be tested, to ensure clear visibility of indication on a Berthold type field indicator/ ASTM Pie shaped Magnetic Particle Field Indicator

5. 2 Care shall be taken to ensure that field strength is not excess at the area to be tested, as excessive field strength may cause non relevant indications of edge, draglines etc.

6.0 **CONTROL OF THE INSPECTION MEDIUM**

6.1 The characteristics of the magnetic particle dispersion is checked by using the Berthold type/ASTM Pie shaped field indicator . The reference piece shall be held at the test section (with the cross at an angle of about 45 degree for Berthold type) to the magnetization direction and during the course of magnetization the medium is sprayed. The concentration of the dispersion is considered good if the notch is clearly visible .

6.2 The wet testing method uses the liquids like kerosene or water with corrosion protective means and antifoam additives .

The concentration of the magnetic particle shall be between 1.2 to 2.4 ml per 100 ml for non-fluorescent particle method and 0.1 ml to 0 .4 ml per 100 ml for fluorescent particle method. A Pear shaped centrifuge settling tube will be used to check the concentration. Before sampling the suspension should be run through the circulating system for at least 30 min to ensure thorough mixing of all particles. The settling Time is 60 min with Petroleum distillate suspensions or 30 min with water-based suspensions before reading.

6.3 Application of wet MT on high alloyed materials shall not be carried out before PWHT.

7.0 LIGHTING

7.1 Visible Light Intensity

7.1.1 The examination area and the accumulation of magnetic particles shall be observed under adequate lighting. An intensity of ***1076*** lux is adequate. The minimum light intensity shall be 100 fc (***1076 lux***). The light intensity, natural or supplemental white light source, shall be measured with a white light meter prior to the evaluation of indications or a verified light source shall be used. Verification of light sources is required to be demonstrated only one time, documented, and maintained on file.

7. 2 Black Light (UV-A Light)

7 .2 .1 Black light intensity at the examination surface shall be not less than 1000 micro watt/ cm $^{2.}$ The black light intensity shall be measured at least once in every 8 hrs. and whenever the work station is changed. The UV-A and White Light Meter should be calibrated once in Six months.

7. 2. 2 With fluorescent particles the examination is performed in a darkened area. The Intensity of Ambient visible light in the darkened area shall not exceed 2 fc or 21.5 lux.

7. 2. 3 The examiner shall be in the darkened area for at least 5 minutes prior to performing the examination for eye adaptation. The examiner shall not wear glasses with permanent Tint or Photo Chromic (light sensitive) lenses which change colour in Sunlight.

7. 2. 4 The black light shall be warmed up for a minimum period of 5 minutes prior to use or measurement of the intensity.

8. 0 **TEST PERFORMANCE**

8. 1 The periodic checking of Magnetic Field Adequacy and Direction shall be done twice in a shift on a pie gauge. The magnetizing power of yokes shall be verified prior to use each day the yoke is used. The magnetic Yoke shall be calibrated once in six months or after any major electrical repair within a year.

8. 2 All examinations shall be conducted with sufficient field overlap to ensure 100% coverage. The following minimum periods shall be observed for a test

(i) Magnetising & rinsing (minimum 3 seconds)
(ii) post magnetising (minimum 5 seconds)
Interpretation and evaluation shall be performed during the post magnetisation period.

9.0 **PERSONNEL QUALIFICATION**

9.1 All personnel carrying out the examination and evaluation shall be qualified to as per BHE: NDT: G: CRT in line with SNT-TC-1A 2016. The testing shall be done by minimum Level-I working under Level II and Evaluation by Level II / III Personnel.

10.0 **INTERPRETATION OF MAGNETIC PARTICLE INDICATION**

10. 1 Any indication that is believed to be non-relevant shall be re-examined to verify whether or not actual defects are present. Surface conditioning may precede the re-examination. Non relevant indications that would mask indications of defects are unacceptable.

10. 2 Acceptance standard based on ASME B 31.1: -

i. Cracks ,lack of fusion and lack of penetration are not acceptable.

ii. Indications whose major dimensions are greater than 1⁄16 in. (2.0 mm) shall be considered relevant. The following relevant indications are unacceptable: -

(a) any cracks or linear indications

(b) rounded indications with dimensions greater than 3⁄16 in. (5.0 mm)

(c) four or more rounded indications in a line separated by 1⁄16 in. (2.0 mm) or less, edge to edge

(d) ten or more rounded indications in any 6 in^2 (3870 mm^2) of surface with the major dimension of this area not to exceed 6 in. (150 mm) with the area taken in the most unfavourable location relative to the indications being evaluated.

10 .3 Acceptance standard based on ASME BPVC Section I: -

All surfaces to be examined shall be free of

(a) relevant linear indications.

(b) relevant rounded indications greater than 3/16 in. (5 mm)

(c) four or more relevant rounded indications in a line separated by 1/16 in. (1.5 mm) or less, edge to edge.

11. 0 **POST CLEANING**

11. 1 When inspection is concluded, the magnetic particle residue remaining on the surface shall be removed by any suitable means leaving the product in dry and clean condition.

12. 0 **REPORTS**

12. 1 Report in the approved form No .235-011 or equivalent signed by a Level - II or Level - III shall be issued.

235-011 MAGNETIC PARTICLE TESTING REPORT

Report No	Date:	Test No.	Ref:
Material		Stage of Test:	Before SR / After SR
part		Surface Condition:	
part		Magnetisation.	Circular / Long
Work Order:		Method	Dry / Wet / HWDC / AC
Drawing No		Prod/Yoke Spacing:	
Procedure:		Demagnetisation	Done / Not done

Acceptance: As per Procedure

No	Details of Part	Quantity	Findings	Remarks

ACCEPTED		DEFECTS NOTICED
Operator's Name & Level I / I l	Approved Level II / IlI	Inspection Agency

CHAPTER 1.4

PROCEDURE FOR RADIOGRAPHIC EXAMINATION OF WELDS

BHEL	**BHARAT HEAVY ELECTRICALS LIMITED** **DEPT.235 – TIRUCHIRAPALLI – 620 014** **Non-Destructive Testing**	BHE:NDT:PB:RT- 01 Revision 23 Page 1 of 23

PROCEDURE FOR RADIOGRAPHIC EXAMINATION OF WELDS

Prepared by	Reviewed and approved by	Issued by
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01/01/2020	B.K.Sethupathy 01-01-2020	01/01/2020

Effective from 01-01-2020

RECORD OF REVISION

Rev No	Revision Date	Revision of Details
03to 06	01-06-1983 01-03-1990	Revision details are maintained separately
07	28-03-1994	Changed for its entirety to include ASME Section VIII Div I and 2
08	01-08-1996	Revised in entirety
09	25-02-1997	ProceduresBHE:NDT:PB:RT01/01,01/02and01/03 merged with this procedure and revised in its entirety
10	10-06-1997	Revised to incorporate the revision in ASME Section V/1995-1996 Addenda. Clause 16 modified
11	11-05-1998	Clauses 2.1,6.1,10.1,22.1 and 23.1 revised
12	20-03-2000	Clauses 2.0,6.1 and Annexure I modified
13	28-12-2002	Clause 4.2.1 deleted. 8.1, 10.2, 11.1.1, 13.1, 17.4, revised. Annexure I and II modified.
14	15-03-2005	2.0, 10.2, 12.3 Modified. Annexure-I Revised. Annexure III modified.
15	28-12-2006	Clause 2.1 Revised Annexure III- Figure 6 Revised.
16	30-12-2007	Clause 2.1 Revised
17	31-12-2009	Clause 2.1 Revised. Clause 19.2 Modified. Porosity Acceptance level charts added
18	15-12-2011	Clause 2.1, 2.2 Revised Clause 6.1.1 Clause 10.3, 16.5.1, 17.2.1,17.3.1 Revised Clause 18.1.7 Added
19	30-01-2015	Clauses 2.1, 2.2., 5.2.2, 6.5.2, 11.1.1, 14.2.1, 17.4.1, Annexure-I and Annexure-II revised
20	01-01-2016	Clause 2.1 revised Clause 1.1,5.2.1,6.2.1,11.1.1,22.1 modified
21	07-10-2017	Clause 5.2.1,5.2.2,6.5.2,12.3 revised. Clause 11.1.1 (a),(b) deleted. Clause 13.1.1,20.5 added
22	28-06-2018	Clause 1.1,2.1,2.2,4.1,6.4.1,6.5,6.5.1,6.5.2,8.1,13.1,21.1 revised. Annexure III column 1 revised
23	01-01-2020	Clause 2.1,4.1,5.2,8.1, 14.2.1 revised. Clause 17.2.1 modified.

1.0 SCOPE

1.1 This procedure describes the techniques and acceptance standard for Radiographic Examination of butt welds in steel (Carbon Steel, Alloy Steel, Stainless Steel etc.) and nonferrous materials up to 200 mm thickness, of boilers (drums, headers, pipelines etc.), Pressure Vessel and Heat Exchanger components.

2.0 REFERENCE

2.1 ASME Section I, V, VIII (Divn.1 & 2) 2019 Edition.

2.2 ASME B 31.1 / 2016

3.0 SURFACE PREPARATION

3.1 The weld ripples or weld surface irregularities on both outside and inside (where accessible) shall be removed by grinding or any other suitable process to such a degree that the resulting radiographic image due to irregularities cannot mask or be confused with the image of any discontinuity.

3.2 The finished surface of all welded joints may be flush with the base material or may have reasonably uniform crowns, with reinforcement not to exceed that specified in Annexure I in each face. If there is a question regarding the surface condition of the weld when interpreting radiographs, then radiographs shall be compared to the actual weld surface for determination of acceptability.

4.0 BACK SCATTER RADIATION

4.1 A lead letter 'B' of minimum 1.5 mm thick and 11 mm height shall be attached to the back of each film holder within the area of radiograph which meets the density requirements mentioned in para 17.1 to 17.3 during each exposure to determine if back scatter is exposing the film.

4.2 Excessive back-scatter: If the image of the letter 'B' appears as lighter density than the back ground, it is an indication that protection against back scattering is insufficient and that additional Lead backing shall be used.

5.0 SYSTEM IDENTIFICATION

5.1 Each radiograph shall have a permanent identification traceable to the contract, component, and weld seam or part numbers as appropriate.

5.2 In addition, BHEL symbol or name and the date of the radiography shall be plainly and permanently included on the radiograph. ***NDE subcontractor's name or symbol may also be used together with that of the Manufacturer.***

5.2.1 This identification system does not necessarily require that the information appear as radiographic images. It can be done either by placing lead numbers during radiographic exposure or vibro etching on the radiograph. This information shall not obscure the area of interest.

5.2.2 These images will appear on all the radiographs exposed individually or by panoramic exposure.

5.3 For longitudinal welds in shells or in plate formed pipes the reference for the start of the segment shall be from one end of the weld. Sufficient overlap in the film shall be given to ensure 100% coverage in radiograph.

5.4 The entire longitudinal seam shall be divided, stamped and marked into number of segments.

5.5 Any geometric imperfection that requires rework by surface conditioning (and not by welding) after initial radiography, the affected area shall be blended smooth with adjoining surfaces by grinding to avoid sharp notches, crevices or corners.

5.6.1 The blended area shall be re-radiographed with letters suffixed G1, G2, G3 etc. to the original identification number to denote the number of times the weld has undergone surface conditioning.

5.7 Letters R1, R2 etc will be suffixed to the original identification number, when radiographs are taken after repair by welding, to denote the number of times the weld has undergone repair.

5.8 Wherever retake has been performed, letters RT/(RT1), RT2 etc. will be suffixed to the original identification number.

6.0 EQUIPMENT AND MATERIALS

6.1 Film:

6.1.1 The film used for radiography shall be as per SE 1815 and type ASTM System Class I or II. Generally the following brands of film shall be used. Other brands of films may be used subject to the approval of Head / NDT.

(a) Kodak-Industrex AA 400/T 200/M
(b) Agfa Gevaert - Agfa D7/D5/D4

6.1.2 The exposed films shall be processed as per procedure BHE: NDT: PB: RT: 14

6.2 Intensifying Screens:

6.2.1 Lead Screens of minimum thickness as listed below will be used on the front and back side of the film to improve the quality of the radiograph depending upon radiation energy selected.

X-rays	upto 420 kV	0.02 to 0.25 mm
Ir.192		0.10 mm
Co.60		0.20 mm
4 MeV/6Mev Linac		0.25 mm

6.2.2 All intensifying screens shall be handled carefully to avoid dents, scratches, dirt or grease on the active surface, which might cause false indications.

6.3 Image Quality Indicator (IQI)

6.3.1 IQI shall be hole type and shall conform to SE 1025 and Table T.233.1 of ASME Section V.

6.4 Density Monitoring

6.4.1 Step wedge comparison filmstrip or a densitometer shall be used to judge the radiograph density. (Refer BHE:NDT:RT:Calib:01 for filmstrip requirements)

6.5 Facility for Viewing of Radiographs

6.5.1 The radiographs shall be viewed in a room with subdued background lighting of an intensity that will not cause troublesome reflections, shadows or glare on the radiograph.

6.5.2 Illuminators / radiograph viewers shall be used to view radiographs for interpretation. The illuminator shall provide a variable light source sufficient for the essential IQI hole to be visible for the density range specified and obtained in the radiograph. The viewing conditions shall be such that light from around the outer edge of the radiograph or coming through low-density portions of the radiograph does not interfere with interpretation. This can be taken care by masking the region around the edges of the radiograph.

7.0 CALIBRATION

7.1 Source Size

7.1.1 The technical manual or written statements of the equipment manufacturer or supplier's publication documenting the actual or maximum source size or focal spot shall be acceptable as source size verification.

7.2 Step Wedge Film and Densitometer

7.2.1 The density of step wedge comparison films and densitometer calibration shall be verified by comparison with a standard step wedge film as per procedure BHE:NDT:RT:Calib:01.

8.0 RADIATION ENERGY

8.1 The radiation energy (X-rays energy up to 6 Mev, Iridium 192, *Selenium -75 (for Close Proximity Radiography)* and Cobalt 60) employed for any Radiographic technique shall achieve the Density and IQI image requirements.

9.0 DIRECTION OF RADIATION

9.1 The direction of the central beam shall be centered on the area of interest whenever practical

10.0 GEOMETRIC UNSHARPNESS (Source to Film Distance)

10.1 Film shall be kept in close contact with the object.

10.2 Table 1 may be used as a guideline for Geometric un-sharpness.

TABLE - 1

MATERIAL THICKNESS	μ_g Max.
Under 50.0 mm	0.51 mm
Over 50.0 to 75.0 mm	0.76 mm
Over 75.0 to 100.0mm	1.02 mm
Greater than 100.0 mm	1.78 mm

Material thickness is the thickness on which the IQI is based.

10.3 Minimum source to film distance shall be kept such that the geometric unsharpness of the radiograph shall be kept as low as practical within the above range, but in any case shall not exceed 1.78 mm for Power Boiler components complying with ASME Section I or 2.0 for power piping components complying with ASME B 31.1.

10.4 Final acceptance of Radiographs shall be based on the achievement of required IQI sensitivity.

11.0 EXAMINATION - FULL RADIOGRAPHY
11.1 Radiographic technique

11.1.1 A single-wall exposure technique shall be used for radiography whenever practical. When it is not practical to use a single-wall technique, a double wall technique shall be used. An adequate number of exposures shall be made to demonstrate that the required coverage has been obtained. Two methods for Double wall technique are double wall single image technique and double wall double image technique.

11.1.2 The Real Time Radioscopy examination in lieu of Radiography for Straight Tube Butt welds shall be carried out as per the procedure BHE:NDT:PB:FT 01

12.0 EXAMINATION - SPOT RADIOGRAPHY

12.0 The total length of the weld shall be divided into equal segments of length, approximately equal to 15 cms or 30 cms. The segment where the spot is marked for examination shall be radiographed with the corresponding segment numbers.

12.2 Single wall single image technique shall be used wherever possible:

12.3 One spot shall be examined on each vessel for each 15 meters increment of weld or fraction thereof per welder or welding operator. However, for identical vessels each with less than 15 meters of weld, 15 metres increments weld may be represented by one spot examination. A sufficient number of spot radiographs shall be taken to examine the welding of each welder or welding operator.

12.4 Under condition where two or more welders or welding operators make weld layers in a joint, one spot may represent the work of all welders or welding operators.

12.5 Each spot examination shall be made as soon as practicable after completion of the increment of weld length to be examined. The minimum length of spot radiography shall be 150 mm.

13.0 LOCATION OF MARKERS

13.1 Location markers made of lead that are to appear as radiographic images on the radiograph shall be placed on the part adjacent to the weld. Their locations shall be marked and stamped on the surface of the part being radiographed in such a manner that an area of interest appearing on the radiograph will be accurately located. The location markers shall provide evidence on the radiograph that complete coverage of the weld has been obtained. Location markers shall not interfere with the interpretation of the radiograph. Location markers shall be placed as given in figures (a) to (f) given in Annexure IV.

13.1.1 Single wall Viewing : Location markers shall be placed on Source side when radiographing flat components or longitudinal joints in cylindrical or conical components/curved or spherical components whose convex side is toward the source. Location markers shall be placed film side when radiographing either curved or spherical components whose concave side is toward the source and when the “source to material” distance is greater than the inside radius. For flat components or longitudinal joints in cylindrical or conical components as an alternative location markers shall be placed on the film side when the radiograph shows coverage beyond the location markers to the extent demonstrated in Annexure IV. Location markers may be placed on either the source side or film side when

radiographing either curved or spherical components whose concave side is toward the source and the " source to material" distance equals the radius of the component.

13.2 Double wall Viewing

13.2.1 For double-wall viewing at least one location marker shall be placed on the source side surface adjacent to the weld for each radiograph - (Double Wall elliptical images with source off set for butt welds in Boiler Tubes).

14.0 SELECTION OF IQI

14.1 IQI shall be selected from either the same material group or grade as identified in SE - 1025 or from a material group or grade with less radiation absorption than the material being radiographed.

14.1.1 The designated hole IQI with essential hole shall be as specified in Annexure II / Table-5. A smaller hole in a thicker IQI or a larger hole in a thinner IQI may be substituted for any section thickness, provided equivalent Hole type IQI sensitivity as in Annexure II / Table-6 is maintained and all other requirements for radiography are met.

14.2 Weld with Reinforcement

14.2.1 The thickness on which the IQI is based is the nominal single wall thickness plus the actual weld reinforcement thickness estimated to be present on both sides of the weld (ID and OD). *The values used for the estimated weld reinforcement thicknesses shall be representative of the weld conditions* and shall not exceed the maximum specified as in Annexure I / Table 2, 3 and 4.

14.2.2 Backing rings or strip are not to be considered as part of the thickness in IQI selection. The actual measurement of the weld reinforcement is not required.

14.3 Weld without reinforcement

14.3.1 The thickness on which the IQI is based is the nominal single wall thickness. Backing rings or strips are not to be considered as part of the weld thickness in IQI selection.

14.4 Welds joining dissimilar materials or welds with dissimilar filler metal

14.4.1 When the weld material has a radiation attenuation that differs from the base material, the IQI material selection shall be based on the weld metal and be in accordance with 14.1. When the density limits of +30 % to -15% cannot be met with one IQI and the exceptional density area(s) is at the interface of the weld metal and the base metal, the material selection for the additional IQI shall be based on the base material and be in accordance with 14.1.

15.0 PLACEMENT OF IQI

15.1 Source Side IQI

15.1.1 Wherever possible, the IQI shall be placed on the source side of the part being examined.

15.2 Film Side IQI

15.2.1 Where inaccessibility prevents hand placing the IQI(s) on the source side, the IQI shall be placed on the film side in contact with the part being examined. A lead letter 'F' shall be placed adjacent to the IQI(s) but shall not mask the essential hole.

15.3 IQI Location for welds

15.3.1 The IQI will be generally placed adjacent to the weld. When placed on the weld, the identification numbers, the lead letter 'F' etc. shall not fall in the area of interest, except when geometric configuration makes it impractical.

15.4 IQI Location for materials other than welds

15.4.1 The IQI with the IQI identification, letter 'F' etc. may be placed in the area of interest.

16.0 NUMBER OF IQI

16.1 For components when one or more film holders are used for an exposure, at least one IQI image shall appear on each radiograph except as outlined below:

16.1.1 For circumferential welds in cylindrical and spherical components, where the source is placed on the axis of the weld for a single exposure (Panoramic Exposure), at least three IQI's shall be spaced approximately 120° apart,

(a) When the complete circumference is radiographed using one or more film holders, or;

.

(b) When a section or sections of the circumference, where the length between the ends of the outermost sections span 240 or more degree is radiographed using one or more film holders. additional film locations may be required to obtain necessary IQI spacing.

16.1.2 For Cylindrical or Spherical components where the source is placed on the axis of the component for a single exposure, at least three IQI(s), with one placed at each end of the span of the circumference radiographed and one in the approximate centre of the span are required under the following conditions:

(a) When the section of the circumference, the length of which is greater than 120 degree and less than 240 degree is radiographed using just one film holder, or;

(b) When a section or sections of circumference, where the length between the ends of the outermost sections span less than 240 deg., is radiographed using more than one film holder.

16.1.3 In 16.1.1 and 16.1.2 above, where sections of longitudinal welds adjoining the circumferential weld are radiographed simultaneously with circumferential weld, an additional IQI shall be placed on each longitudinal weld at the end of the section most remote from the junction with the circumferential weld being radiographed.

16.1.4 In spherical components, where other welds are radiographed simultaneously with the circumferential weld, one additional IQI shall be placed on each other weld.

16.2 When an array of components in a circle is radiographed, at least one IQI shall show on each component image.

16.3 In order to maintain the continuity of records involving subsequent exposures, all radiographs exhibiting IQI that qualify the techniques permitted in 16.1.1, 16.1.2, 16.1.3 or 16.1.4 shall be retained. Annexure V may be used as guide.

16.4 Multiple IQI

16.4.1 If the requirements of 17.2 are met by using more than one IQI, one shall be representative of the lightest area of interest and the other the darkest area of interest, the intervening densities on the radiograph shall be considered as having acceptable density.

16.5 Shims under IQI

16.5.1 A shim of material radiographically similar to the weld metal shall be placed between the part and the IQI, if needed, so that the radiographic density throughout the area of interest is within minus 15% from the radiographic density through the body of IQI adjacent to the essential hole.

16.5.2 The shim dimensions shall exceed the IQI dimensions such that the outline of at least three side of the IQI image shall be visible in the radiograph.

17.0 EVALUATION

17.1 Quality of radiographs

17.1.1 All radiographs should be free from mechanical, chemical or other blemishes such as fogging, processing defects to the extent that they do not mask or are not confused with the image of any discontinuity in the area of interest of the object being radiographed.

17.2 Radiographic density

17.2.1 ***The transmitted film density through the radiographic image of the body of the designated hole type IQI adjacent to the essential hole and the area of interest shall be 1.8 minimum for radiographs made with an X-ray source and 2.0 minimum for radiographic made with a gamma ray source.***

17.2.2 In both cases the maximum density shall be 4.0. A tolerance of ±0.05 in density is allowed for variation between the densitometer readings.

17.3 Density variation

17.3.1 If the density of radiograph anywhere through the area of interest varies by more than minus 15% or plus 30% rounded to the nearest 0.1 from the density through the body of designated hole type IQI adjacent to the essential hole within the minimum/maximum allowable density ranges specified in para 16.2.1, then an additional IQI shall be used for each exceptional area, one shall represent the lightest area and the other the darkest area of interest.

17.3.2 With shims: When shims are used, the +30% density restriction of 17.3.1 above may be exceeded, provided the required IQI sensitivity is displayed and the density limitation of 17.2 are not exceeded.

17.4 IQI Sensitivity

17.4.1 Radiography shall be performed with a technique of sufficient sensitivity to display the IQI image and 2T-hole, which are the essential indications of the image quality of the radiographs. The radiographs shall also display the identifying numbers and letters. A

thinner or thicker IQI than listed in Annexure II (Table 5) may be used if an equivalent IQI sensitivity as specified in Annexure II (Table 6)is obtained.

18.0 ACCEPTANCE - FULL RADIOGRAPHY

18.1 The following type of discontinuities shall be unacceptable:

18.1.1 Any type of crack, zone of incomplete fusion or incomplete penetration.

18.1.2 Any other elongated indication on the radiograph whose length exceeds the following:
a) 6 mm for thickness up to 19 mm.
b) 1/3 t for 't' from 19 mm to 57 mm.
c) 19 mm for 't' over 57 mm.
Where 't' is the thickness of weld excluding any allowable reinforcement. For a butt weld joining two members having different thickness at the weld, 't' is the thinner of these two thicknesses. If a full penetration weld includes a fillet weld, the thickness of the throat of the fillet shall be included in 't'.

18.1.3 Any group of aligned indications that have an aggregate length greater than 't' in a length of 12t except when the distance between successive indication exceeds 6L where 'L' is the longest indication in the group.

18.1.4 Rounded indications (whose length is less than three times the width) in excess of that shown as acceptable as in Appendix A 250 of ASME Section I or Appendix 4 of ASME Section VIII Division 1 or appendix 8 of ASME Section VIII Division 2 (all are identical), Table 7.

18.1.5 For circumferential joint in pipe, tube and headers, the thickness of the weld measured between the inside surface of the weld preparation and the outside surface of the pipe or tube shall not be less than the minimum thickness permitted by the applicable material specification for the particular size and thickness of the pipe or tube used.

18.1.6 The contour of the concavity shall be smooth and the resulting thickness of the weld, including reinforcement, shall be at least equal to the required thickness of the thinner section. Root concavity shown without abrupt change in density is acceptable provided it is not greater than 2.5 mm in depth or 20% of thinner of the two sections, whichever is minimum for components fabricated as per Section I and 0.8 mm or 10% for components fabricated as per Section VIII. Comparable outside reinforcement shall be provided whenever acceptable root concavity is present.

18.1.7 Root concavity when there is an abrupt change in density, as indicated in the radiography, is not acceptable for power piping welds.

18.2 Repaired area in a weld shall be re-radiographed using the same technique used for original radiography.

19.0 ACCEPTANCE - SPOT RADIOGRAPHY

19.1 Any zone of crack, lack of fusion or in-complete penetration are unacceptable.

19.2 Slag inclusion or cavities whose length is greater than 2/3T or 19 mm, whichever is less, where T is the thickness of the weld excluding any allowable reinforcement is unacceptable.. For all thicknesses, indications less than 6 mm are acceptable and indications greater than 19 mm are unacceptable. For a butt weld joining two members having different thickness at the weld, 'T' is the thickness of the thinner of the two sections.

19.3 **If several indications within the limitation given 19.2 above exists in a line, the welds shall be judged acceptable if the sum of the larger dimensions of all such indications is not more the 'T' in a length of 6T (or proportionately, for radiographs shorter than 6T) and if the longest indications considered are separated by at least '3L' of acceptable weld metal where L is the length of the longest indication. Any such indications shorter than 6 mm shall be acceptable for any plate thickness.**

19.4 **Rounded indications (length less than three times the width) are not a factor in the acceptability of welds not required to be fully radiographed.**

20.0 EVALUATION AND RETEST: (Spot Radiography)

20.1 **When radiograph of one spot is found acceptable, the entire weld increment represented by this radiograph is acceptable.**

20.2 **If any spot is found defective, then two additional spots shall be radiographed from the same weld increment at location away from the original spot. If additional spots are found acceptable, then the entire weld increment represented by the three radiographs is acceptable. The defective area in the first radiograph will be removed, re-welded and re-radiographed as given above.**

20.3 **If either of the two additional spots examined are found defective, then the entire increment of weld represented shall be radiographed and repaired or the entire weld shall be rejected.**

20.4 **If the entire weld is removed and re-welded based on the spot radiography result, the welded joint or weld repaired area shall be spot radiographically examined at one location in accordance with the procedure given above.**

20.5 **For original and additional spot selection AI Permission shall be obtained.**

21.0 PERSONNEL QUALIFICATION

21.1 **Personnel performing examination shall be qualified in accordance with BHE:NDT:G:CRT to at least one of the following levels.**

1) Operator - Minimum Level- I 2) Radiograph Evaluation- Minimum Level-II

22.0 RECORDING AND REPORTING

22.1 **BHEL's evaluation report shall be given in the format (Annexure VI) and shall be presented along with radiographs to External Inspector for review.**

23.0 STORAGE:

23.1 **Radiographs of Products to ASME Code Sec. I, Sec. VIII Div.1 and Div.2 and Boiler drums:**

23.1.1 **A complete set of radiographs with proper identification shall be preserved for a period of 5 years as in Quality Control Manual.**

23.2 **Radiographs of Other components:**

23.2.1 **Radiographs of header, pipe and tubular butt welds shall be retained and kept on file for a period of three years or till the final inspection, whichever is earlier.**

23.2.2 Records such as registers and reports shall be maintained till the final inspection is completed.

24.0 SAFETY

24.1 Radiography shall be performed in accordance with all applicable safety requirements as specified in BHEL's Safety Procedure BHE:NDT: G:SFT.

****

ANNEXURE I

Table 2- MAXIMUM WELD REINFORCEMENT AS PER ASME SECTION I

Weld Thickness in mm (nominal thickness of the thinner section at the weld joint)	Circumferential welds in Pipes & Tubes (mm)	Other welds (mm)
Up to 3.0	2.5	2.5
Over 3.0 to 5.0	3.0	2.5
Over 5.0 to 13.0	4.0	2.5
Over13.0 to 25.0	5.0	2.5
Over 25.0 to 50.0	6.0	3.0
Over 50.0 to 75.0	The greater of 6 mm or 1/8 times the width of the weld (in mm).	4.0
Over 75.0 to 100.0		5.5
Over 100.0 to 125		6.0
Over 125		8.0

TABLE 3- MAXIMUM WELD REINFORCEMENT AS PER ASME SECTION VIII-Division 1

Weld Thickness in mm (nominal thickness of the thinner section at the weld joint)	Category B & C Butt welds (mm)	Other welds (mm)
Up to 2.4	2.4	0.8
Over 2.4 to 4.8	3.0	1.5
Over 4.8 to 13.0	4.0	2.5
Over13.0 to 25.0	5.0	2.5
Over 25.0 to 51.0	5.0	3.0
Over 51.0 to 76.0	6.0	4.0
Over 76.0 to 102.0	6.0	5.5
Over 102.0 to 127	6.0	6.0
Over 127	8.0	8.0

TABLE 4- MAXIMUM WELD REINFORCEMENT AS PER ASME SECTION VIII-Division 2

Weld Thickness in mm (nominal thickness of the thinner section at the weld joint)	Circumferential welds in Pipes & Tubes (mm)	Other welds (mm)
< 2.5	2.5	0.8
≥ 2.5 to < 5.0	2.5	1.5
≥ 5.0 to <13.0	3.0	2.5
≥ 13.0 to <25.0	4.0	2.5

≥ 25.0 to <50.0	4.0	3.0
≥ 50.0 to <76.0	4.0	4.0
≥ 76.0 to <100.0	5.5	5.5
≥ 100.0 to <125.0	6.0	6.0
≥ 125.0	8.0	8.0

ANNEXURE II
TABLE 5 - IQI SELECTION

	IQI	
Nominal Single Wall thickness Range(mm)	**Source side Desgn.**	**Film Side Desgn.**
Up to 6.4 mm	12	10
Over 6.4 thro' 9.5	15	12
Over 9.5 thro' 12.7	17	15
Over 12.7 thro' 19.0	20	17
Over 19.0 thro' 25.4	25	20
Over 25.4 thro'38.1	30	25
Over 38.1 thro' 50.8	35	30
Over 50.8 thro'63.5	40	35
Over 63.5 thro' 101.6	50	40
Over 101.6 thro'152.4	60	50
Over 152.4 thro'203.2	80	60
Over 203.2 thro'254.0	100	80
Over 254.0 thro'304.8	120	100

Note: The radiograph should display the designated IQI and 2T-hole image

TABLE – 6 EQUIVALENT HOLE TYPE IQI SENSITIVITY (T-283 of ASME Sec.V, Article 2)

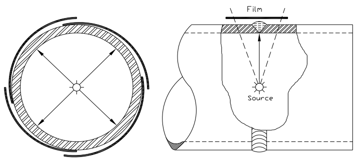
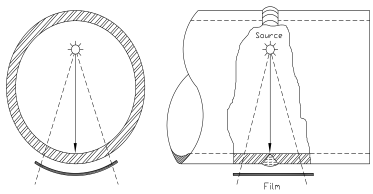
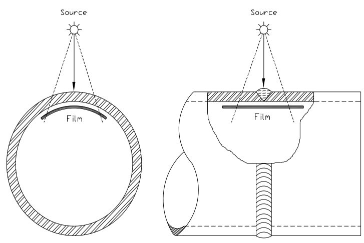
Hole Type Designation 2T - Hole	Equivalent Hole Type Designation	
	1T Hole	4T Hole
10	15	5
12	17	7
15	20	10
17	25	12
20	30	15
25	35	17
30	40	20
35	50	25
40	60	30
50	70	35
60	80	40
80	120	60
100	140	70
120	160	80
160	240	120
200	280	140

Table-7

Thickness t mm	Max size acceptable mm		Max size of non relevant indication
	Random	Isolated	
< 3	1/4t	1/3t	1/10t
3	0.79	1.07	0.38
5	1.19	1.60	0.38
6	1.60	2.11	0.38
8	1.98	2.64	0.79
10	2.31	3.18	0.79
11	2.77	3.71	0.79
13	3.18	4.27	0.79
14	3.61	4.78	0.79
16	3.96	5.84	0.79
19 to 50 incl	3.96	6.35	0.79
Over 50	3.96	9.53	1.60

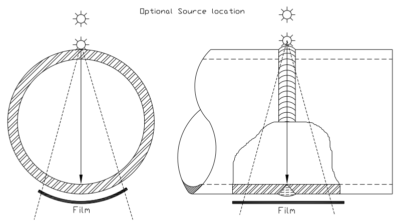
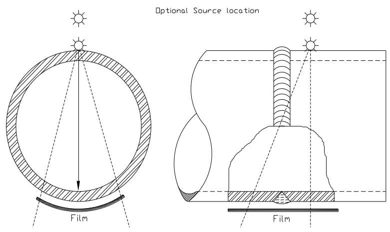
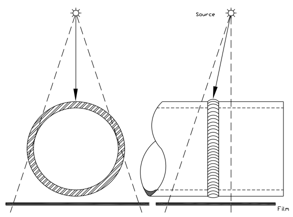
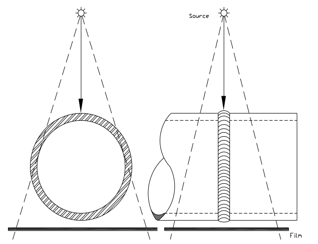
.ANNEXURE III

SINGLE WALL RADIOGRAPHIC TECHNIQUES

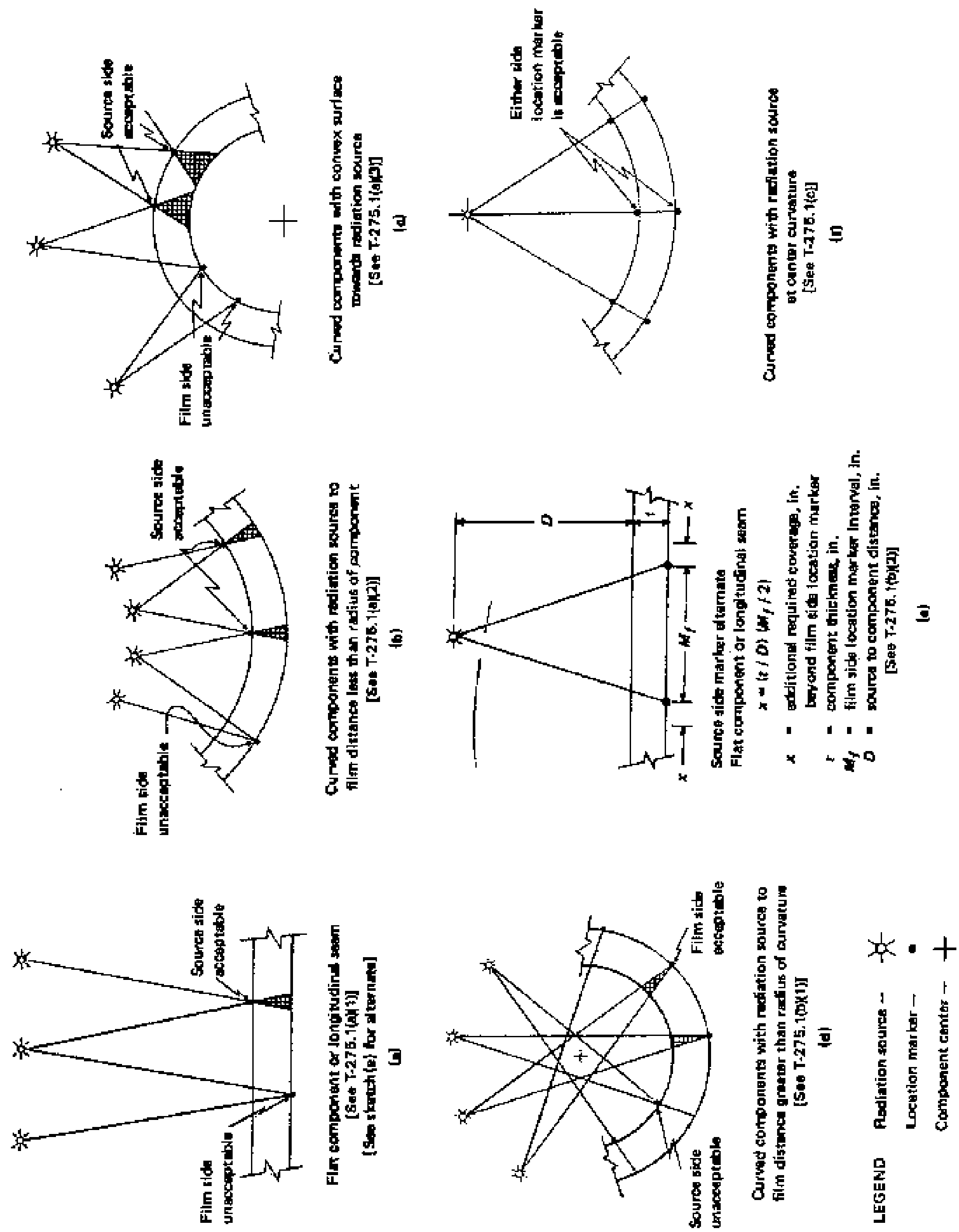
O.D	Exposure Technique	Radiograph Viewing	Source-weld-film Arrangement: End View	Source-weld-film Arrangement: Side View	IQI: Selection	IQI: Placement	Location Marker Placement
Any	Single wall	Single wall	1)Panoramic		Table 2	Source side (15.1) Film side (15.2)	Either side (13.0)
Any	Single wall	Single wall	2)Source inside – Film outside		Table 2	Source side (15.1) Film side (15.2)	Film side (13.0)
Any	Single wall	Single wall	3)Source outside – Film inside		Table 2	Source side (15.1) Film side (15.2)	Source side (13.0)

ANNEXURE III

DOUBLE WALL RADIOGRAPHIC TECHNIQUES

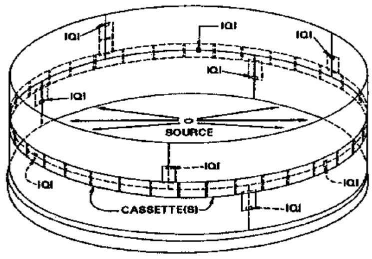
O.D	Exposure Technique	Radiograph Viewing	Source –weld-film Arrangement		IQI		Location Marker Placement
			End View	Side View	Selection	Placement	
Any	Double wall: at least 3 exposures 120° to each other for complete coverage	Single wall	 4)Double wall single image		Table 2	Source side (15.1) Film side (15.2)	Film side (13.0)
Any	Double wall: at least 3 exposures 120° to each other for complete coverage	Single wall	 5)Double wall single image- source offset		Table 2	Source side (15.1) Film side (15.2)	Film side (13.0)
<u>*89 mm or less*</u>	Double wall: at least 2 exposures 90° to each other for complete coverage	Double wall (Ellipse): Read offset source side and film side images	 6)Double wall double image		Table 2	Source side (15.1)	Either side (13.0)
<u>89 mm or less</u>	Double wall: at least 3 exposures at 60° or 120° to each other for complete coverage	Double wall: Read Super imposed source side and film side images	 7)Double wall double image-superimpose		Table 2	Source side (15.1)	Either side (13.0)

ANNEXURE IV

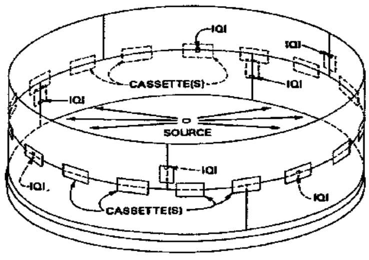

Film side unacceptable
Source side acceptable
Flat component or longitudinal seam
[See T-275.1(a)(1)]
[See sketch (e) for alternate]
(a)
Film side unacceptable
Source side acceptable
Curved components with radiation source to film distance less than radius of component
[See T-275.1(a)(3)]
(b)
Source side acceptable
Film side unacceptable
Curved components with convex surface towards radiation source
[See T-275.1(a)(3)]
(c)
Film side acceptable
Source side unacceptable
Curved components with radiation source to film distance greater than radius of curvature
[See T-275.1(b)(1)]
(d)
D
t
x
M_f
Source side marker alternate
Flat component or longitudinal seam
$x = (t / D)(M_f / 2)$
x = additional required coverage, in. beyond film side location marker
t = component thickness, in.
M_f = film side location marker interval, in.
D = source to component distance, in.
[See T-275.1(b)(2)]
(e)
Either side location marker is acceptable
Curved components with radiation source at center curvature
[See T-275.1(c)]
(f)
LEGEND
Radiation source –
Location marker –
Component center –

LOCATION MARKER SKETCHES

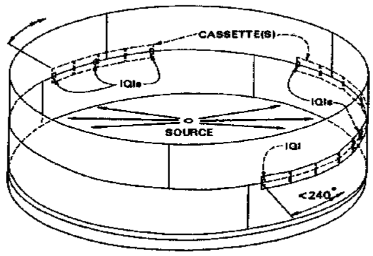
ANNEXURE V



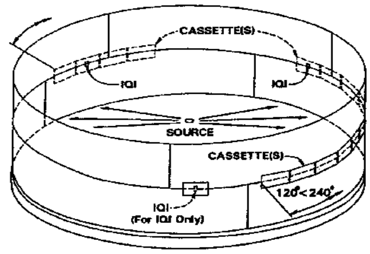
COMPLETE CIRCUMFERENCE
CYLINDRICAL COMPONENT



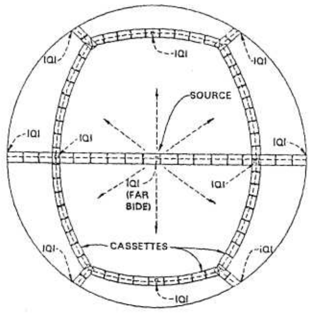
SECTION OF CIRCUMFERENCE
240 deg. OR MORE CYLINDRICAL COMPONENT
(EXAMPLE IS ALTERNATE INTERVALS)



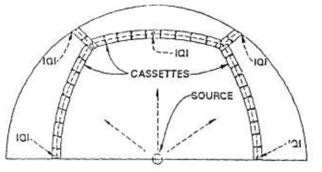
SECTION(S) OF CIRCUMFERENCE
LESS THAN 240 deg. CYLINDRICAL COMPONENT



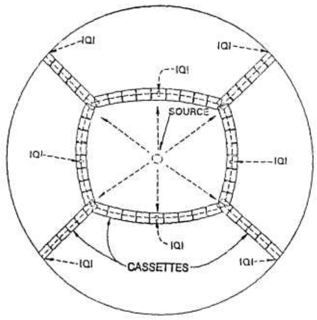
SECTION(S) OF CIRCUMFERENCE
EQUAL TO OR MORE THAN 120 deg. AND LESS THAN
240 deg. CYLINDRICAL COMPONENT

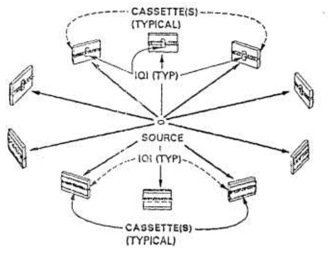


COMPLETE CIRCUMFERENTIAL WELDS SPHERICAL COMPONENT



WELDS IN SEGMENTS OF SPHERICAL COMPONENT





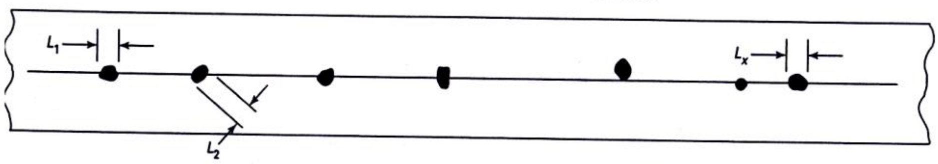
Note: Special Cases IQI Locations are Typical in All Figures.

PLAN VIEW A-A

ARRAY OF OBJECTS IN A CIRCLE

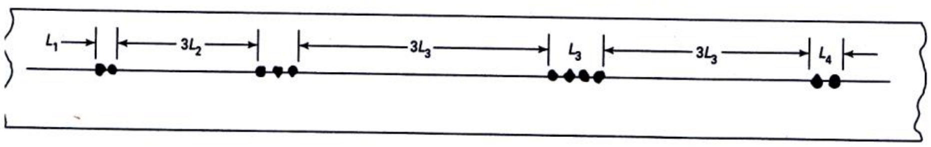
POROSITY-ACCEPTANCE LEVEL

FIG. A-250.3.4.-1 ALIGNED ROUNDED INDICATIONS



GENERAL NOTE: Sum of L_1 to L_x shall be less than t in a length of 12 t.

FIG. A-250.3.4-2 GROUPS OF ALIGNED ROUNDED INDICATIONS

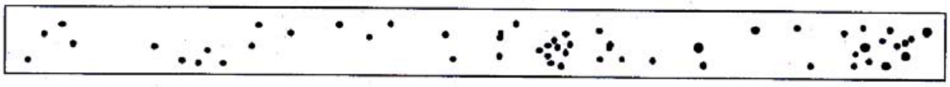


Maximum Group Length
$L = 1/4$ in. (6 mm) for t less than $3/4$ in. (19 mm)
$L = 1/3\, t$ for t $3/4$ in. (19 mm) to $2\,1/4$ in. (57 mm)
$L = 3/4$ in. (19 mm) for t greater than $2\,1/4$ in. (57 mm)

Minimum Group Spacing
$3L$ where L is the length of the longest adjacent group being evaluated.

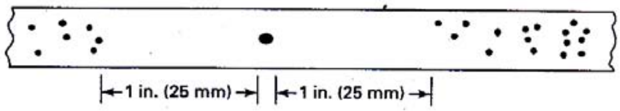
GENERAL NOTE: Sum of the group lengths shall be less than t in a length of 12 t.

FIG. A-250.3.6-1 CHARTS FOR t 1/8 in. (3 mm) TO 1/4 in. (6 mm), INCLUSIVE

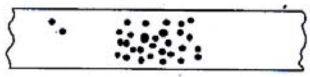


GENERAL NOTE: Typical concentration and size permitted in any 6 in. (150 mm) length of weld

(a) Random Rounded Indications



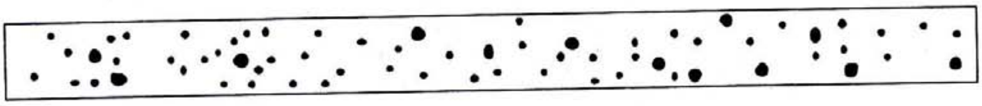
(b) Isolated Indication
(Maximum size per Table A-250.3.2)



(c) Cluster

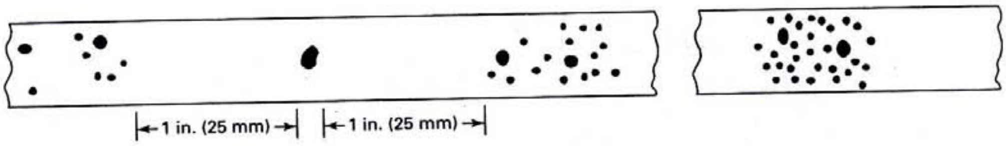
POROSITY-ACCEPTANCE LEVEL

FIG. A-250.3.6-2 CHARTS FOR t OVER $\frac{1}{4}$ in. (6 mm) TO $\frac{3}{8}$ in. (10 mm), INCLUSIVE



GENERAL NOTE: Typical concentration and size permitted in any 6 in. (150 mm) length of weld

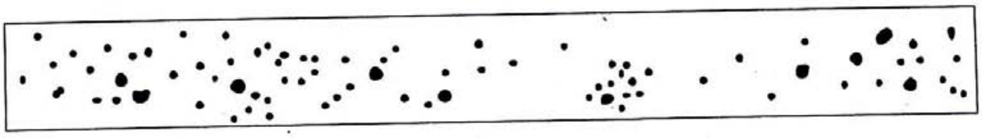
(a) Random Rounded Indications



(b) Isolated Indication
(Maximum size per Table A-250.3.2)

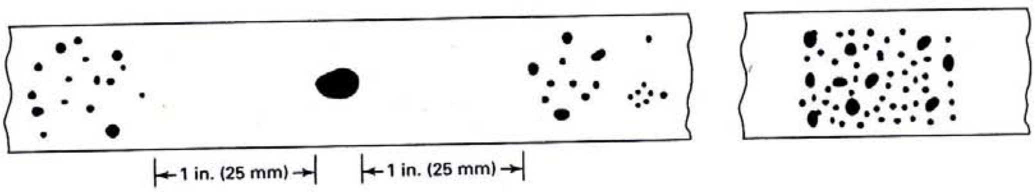
(c) Cluster

FIG. A-250.3.6-3 CHARTS FOR t OVER $\frac{3}{8}$ in. (10 mm) TO $\frac{3}{4}$ in. (19 mm), INCLUSIVE



GENERAL NOTE: Typical concentration and size permitted in any 6 in. (150 mm) length of weld

(a) Random Rounded Indications

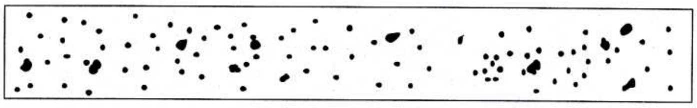


(b) Isolated Indication
(Maximum size per Table A-250.3.2)

(c) Cluster

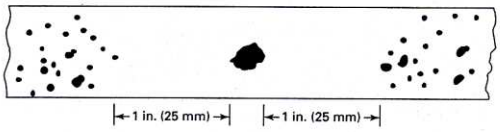
POROSITY-ACCEPTANCE LEVEL

FIG. A-250.3.6-4 CHARTS FOR t OVER $\frac{3}{4}$ in. (19 mm) TO 2 in. (50 mm), INCLUSIVE

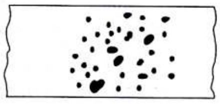


GENERAL NOTE: Typical concentration and size permitted in any 6 in. (150 mm) length of weld.

(a) Random Rounded Indications

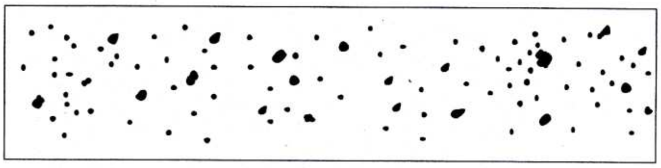


(b) Isolated Indication
(Maximum size per Table A-250.3.2)



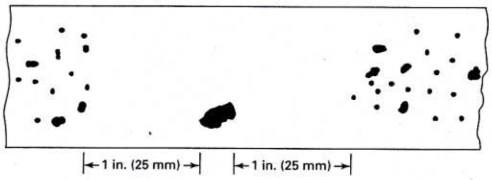
(c) Cluster

FIG. A-250.3.6-5 CHARTS FOR t OVER 2 in. (50 mm) TO 4 in. (100 mm), INCLUSIVE

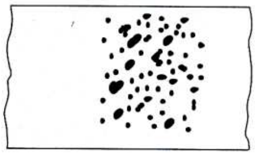


GENERAL NOTE: Typical concentration and size permitted in any 6 in. (150 mm) length of weld.

(a) Random Rounded Indications

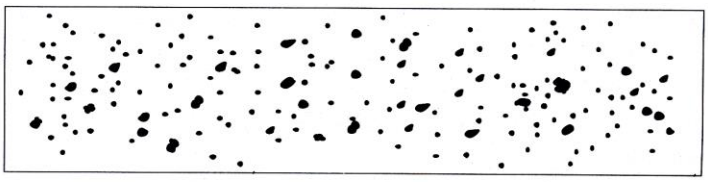


(b) Isolated Indication
(Maximum size per Table A-250.3.2)



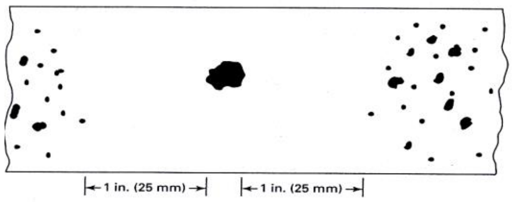
(c) Cluster

FIG. A-250.3.6-6 CHARTS FOR t OVER 4 in. (100 mm)

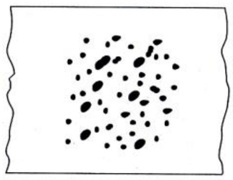


GENERAL NOTE: Typical concentration and size permitted in any 6 in. (150 mm) length of weld.

(a) Random Rounded Indications



(b) Isolated Indication
(Maximum size per Table A-250.3.2)



(c) Cluster

ANNEXURE VI

RADIOGRAPHIC REPORT CUM REVIEW FORM

Report No.:	Date:	Ref.:	Stage of Test:
Description:	Material:	Dia.: mm	Thickness: mm
W.O. No.:	Drg. No.:	DU No.:	
Pb. Screen Front/Back	Welding Process:	Weld reinforcement: mm	
Source: X- Rays/ Ir. 192/ Co.60	Source Size:	Exposure: KV: mA / Ci.mts:	
Source to Object distance: mm	Source side of object to Film Distance: mm		
IQI: ASTM Hole / Wire type:	Source side /Film side	Sensitivity:	Density:
Single/Double wall/Panoramic technique	Single/ Double wall viewing	Markers: Source / Film side	
Film Manufacturer: Agfa. / Kodak.	Film Type / Designation :		
No. of Radiographs (Exposures):	No. of films in each cassette:	Date of Evaluation:	
Procedure & Acceptance : BHE:NDT:PB / SS / VV / NU / RT			

Sl. No.	Welder No.	Radiograph No./ Joint No.	Seg. No.	Findings	Disposition (Repair/Accept)

SAMPLE

Operator Level I / II	Approved by : Level II / III	External Inspection Agency

CHAPTER 1.5

PROCEDURE FOR RADIOGRAPHIC EXAMINATION OF BUTT WELDS IN STRUCTURES

BHEL	**BHARAT HEAVY ELECTRICALS LIMITED** **DEPT.235 – TIRUCHIRAPALLI – 620 014** **Non-Destructive Testing**	BHE:NDT:SS:RT- 05 Revision 06 Page 1 of 13

PROCEDURE FOR RADIOGRAPHIC EXAMINATION OF BUTT WELDS IN STRUCTURES

Prepared By	Reviewed By	Approved By	Issued By
01-01-2020	01/01/2020	B K Sethupathy 01-01-2020	01/01/2020
S JAGADEESH LEVEL II DY. MANAGER-NDTL	RAGHAVENDRIEN R LEVEL III DY. MANAGER-NDTL	B K SETHUPATHY LEVEL III MANAGER-NDTL	R ARULPRABHU LEVEL III DGM & HEAD-NDTL

Effective from 01-01-2020

RECORD OF REVISION

Rev. No	Revision Date	Revision of Details
01	01-08-1981	Revised in its entirety
02	13-07-1993	Clauses 1.1, 2.0, 4.2, 10.1, 13.3.1 and 15.2(b) modified. Clause 11.8 added.
03	03-03-1997	Clauses 2.0, 5.0, 9.1 are modified. Clauses 11.4, 15.3 and 17 added. Editorial corrections made
04	23-10-2006	Revised in its entirety
05	20-07-2016	Clause 2.1,2.2 updated Clause 18.1 modified Clause 16.3 and Table 5 added
06	01-01-2020	Clause 2.0 modified Clause 18.1 modified Figure 5 modified to depict cases 1 to 4

1.0 SCOPE

1.1 **This procedure describes the technique and acceptance for the radiographic examination of Butt Welds of carbon steel, alloy steel and stainless steel structures used in Boilers .**

2.0 REFERENCE

2.1 AWS D1.1/ D1.1M 2015 Structural Welding Code – Steel
2.2 ASME Article 2 / Section V 2019 Edition

3.0 SURFACE PREPARATION

3.1 **Radiography can be taken in as welded condition unless Contract requirements calls for or its surface irregularities or junction between weld and base metal may cause objectionable weld discontinuities to be observed in the radiograph.**

4.0 FILM AND SCREEN

4.1 **Radiographs shall be made from films of good commercial quality and the following brands of films or equivalent shall be normally used:**

a) Kodak AA 400 / T 200 b) Agfa D7/D5/D4
c) Any other brand of film with the approval of Head / NDT

4.2 **Lead Screens-** **Front 0.1 mm for X-rays and Iridium 192**
Front 0.25 mm for Cobalt 60 and Linear Accelerator
Back screen will be of same thickness or slightly larger

5.0 QUALITY OF RADIOGRAPH

5.1 **All radiographs shall be free from mechanical, chemical or Processing Markings**

6.0 RADIOGRAPHIC DENSITY

6.1 **The optical density of the radiographs shall meet the requirements as given in the Table**

Table 1

Source	Minimum Density	Maximum Density
X-rays	1.8	4.0
Gamma Rays	2.0	4.0

7.0 BACK SCATTER

7.1 **A lead symbol ‘B’ of 2 mm thick and 12mm height, shall be kept at the back of each film cassette to check the back scattering effect and the radiograph is unacceptable if light image of the letter ‘B’ appears on a darker background of the radiograph. A dark image of “B” on a lighter background is not a cause for rejection.**

8.0 SYSTEM OF IDENTIFICATION

8.1 **The following identifications shall be available in the radiograph.**
a) Job Identification number/ Work order
b) Segment identification number
c) Date of RT,
d) Firm code No
e) Weld repair ./ rework status details(R1, R2, R3 etc, RT, GRT or MRT) if applicable,
f) Location identification markers
Location marker identification shall be marked / stamped on the surface.
These identification numbers shall be placed 20mm away from the weld edge.

10.0 RADIATION SOURCES

10.1 The radiation energy employed for any radiographic technique shall achieve the density and IQI requirement requirements.

11.0 RADIOGRAPHIC TECHNIQUE

11.1 A single-wall exposure technique shall be used for radiography whenever practical. When it is not practical to use a single-wall technique, a double wall technique shall be used .

11.2 The film shall be kept close and parallel to the back surface of the weld, to avoid enlargement and distortion of image.

11.3 The width of the film shall be sufficient to depict all portions of the weld joint including the heat affected zones and shall provide sufficient additional space for required IQI and film identification without infringing upon the area of interest in the radiograph.

11.4 Films shall have sufficient length and shall be placed to produce at least 12.5 mm of film exposed to direct radiation from the source beyond each free edge where the weld is terminated.

11.5 Welds longer than 350mm may be radiographed by overlapping film cassettes by making a single exposure or by using a single film cassettes and making separate exposures.

11.6 Edge blocks shall be used when radiographing butt welds >12 mm thickness. Fig (6)
The edge blocks shall have the following dimensions:
Length: Minimum 50 mm on each side with respect to weld center line
Thickness: Equal to or greater than the weld thickness
Width: Equal to half of thickness or 20 mm whichever is higher
Gap: 2 mm Maximum
Surface finish: 3 micrometer

12.0 GEOMETRIC UN SHARPNESS (μ_g)

12.1 Geometric un sharpness (μ_g) shall not exceed the following limitations

TABLE - 2

MATERIAL THICKNESS	μ_g Max.
Under 50.0 mm	0.51 mm
Over 50.0 to 75.0 mm	0.76 mm
Over 75.0 to 100.0mm	1.02 mm
Greater than 100.0 mm	1.78 mm

Material thickness is the thickness on which the IQI is based.

12.2 The minimum source to object distance shall be seven times the maximum thickness of the weld plus reinforcement and backing if any, under examination or the total length of the film being exposed in a single plane whichever is greater

13.0 REINFORCEMENT

13.1 When weld reinforcement is not removed, the allowable reinforcement shall not exceed 3.0 mm.

14.0 IMAGE QUALITY INDICATORS (IQI)

14.1 Hole type or wire type image Quality Indicators(IQI) made of carbon steel or type 304 stainless steel shall be used for radiography. the thickness on which the IQI based is on nominal single wall thickness plus the reinforcement permitted in 13.4.

15.0 NUMBER OF IQI

15.1 For welds joining nominally equal thickness

15.1.1 To radiograph 250 mm or greater of weld length, IQI shall be placed at the ends of the segment, one on either side of the weld.

For length less than 250 mm of weld, one IQI shall be placed at the center away from the weld. IQI shall be placed 10mm away from weld edge. Fig (1 & 2).

15.2 For welds at a transition in thickness

15.2.1 To radiograph 250 mm or greater of weld length, two IQI s on either end of the weld in thinner side and one at the centre of the thicker side weld and shall be placed 10 mm away from the weld. The IQI on the transition thickness shall be based on the maximum thickness under the IQI . Similarly for weld length less than 250 mm one IQI shall be placed on thinner side and one on thicker side. Fig(3 & 4)

16.0 SELECTION OF IQI

16.1 The essential hole size and thickness of the IQI shall be as specified below:-

Table - 3

Nominal Material Thickness range	Source side Designation of IQI	IQI Essential Hole
Up to 6.0 mm	10	4T
Over6.0 mm thro 10 mm	12	4T
Over10.0 mm thro 16 mm	15	4T
Over16.0 mm thro 20 mm	17	4T
Over20.0 mm thro 25 mm	20	4T
Over25.0 mm thro 32 mm	25	4T
Over32.0 mm thro 38 mm	30	2T
Over38 mm thro 50 mm	35	2T
Over50 mm thro 65 mm	40	2T
Over65 mm thro 75 mm	45	2T
Over75 mm thro 100mm	50	2T
Over100 mm thro 150 mm	60	2T
Over150 mm thro 200 mm	80	2T

Number of IQIs to be placed
Table- 4

	Segment length < 250 mm	Segment length ≥ 250 mm
Equal weld Thickness	1	2
Unequal weld thickness	2	3

16.2 The thickness shall be measured at the place where the IQI is placed and Shims may be used to compensate with the thickness of allowable reinforcement, provided the dimension of the shim extends 3.0 mm beyond three sides of the IQI. Backing plate shall not be considered part of the weld or reinforcement.

16.3 The essential wire type IQI shall be as specified below:-

Table - 5

Nominal Material Thickness range	Source side Maximum wire dia mm	Film side Minimum wire dia mm
Up to 6 mm	0.25	0.20
Over6 mm thro 10 mm	0.33	0.25
Over10 mm thro 16 mm	0.41	0.33
Over16mm thro 20 mm	0.51	0.41
Over20 mm thro 38 mm	0.63	0.51
Over38mm thro 50 mm	0.81	0.63
Over50 mm thro 65 mm	1.02	0.81
Over65 mm thro 100 mm	1.27	1.02
Over100 mm thro 150 mm	1.60	1.27
Over 150 mm thro 200 mm	2.54	1.60

17.0 PERSONNEL

17.1 Personnel performing examination shall be qualified in accordance with BHE:NDT:G:CRT to at least one of the following levels.
1) Operator - Minimum Level-1   2) Film Evaluation and Reporting- Minimum Level II

18.0 ACCEPTANCE- STATICALLY LOADED NONTUBULAR WELDS

18.1 The following type of discontinuities shall not be acceptable:

a. Any type of crack

b. Elongated discontinuities exceeding the maximum size of Figure 5

c. Discontinuities closer than the minimum clearance allowance of Figure 5

d. Rounded discontinuities greater than a maximum of size t / 3 (where t is the weld thickness) , not to exceed 6 mm .
However when the weld thickness is > than 50 mm, the maximum rounded indication may be 10 mm.
The minimum clearance of rounded discontinuities greater than or equal to 2.5 mm to an acceptable elongated or rounded discontinuity or to an edge or end of an intersecting weld shall be 3 times the greatest dimension of the larger of the discontinuity being considered.

e. At the intersection of a weld with another weld or a free edge (i.e., an edge beyond which no material extension exists), acceptable discontinuities shall conform to the limitations of Figure 5, Cases 1–4.

f. Isolated discontinuities such as cluster of rounded indications, having a sum of their greatest dimensions exceeding the maximum size single discontinuity allowed in Fig (5)
The minimum clearance to another cluster or an elongated or rounded discontinuity or to an edge or end of an intersecting weld shall be 3 times the greatest dimension of the larger of the discontinuities being considered.

g. The sum of the individual discontinuities each having a greater dimension of less than 2.5 mm shall not exceed 2t / 3 mm or 10 mm whichever is less, in any linear 25mm of weld . This requirement is independent of (b), (c), (d) above.

h. In-line discontinuities, where the sum of the greatest dimensions exceeds 't' in any length of 6t When the length of the weld being examined is less than '6t', the allowable sum of the greatest dimensions shall be proportionally less.

Figure 7 and 8 illustrate the application of the requirements given above.

18.2 All these radiographs shall be retained for one full year after completion of work or will be handed over to the customer as the case may be.

19.0 REPAIRS

19.1 The welds that are subjected to repairs shall be re-examined by the same procedure and technique that was employed prior to repairs.

20.0 SAFETY REQUIREMENTS

20.1 Radiography shall be performed in accordance with all applicable safety requirements In accordance with BHEL:NDT:SFT.

21.0 REPORT

21.1 All radiographs of the welds subjected to radiographic testing including any that show unacceptable quality prior to repairs and a report interpreting them shall be submitted to the inspector concerned, in the standard RT Report Form or its equivalent/latest revision.

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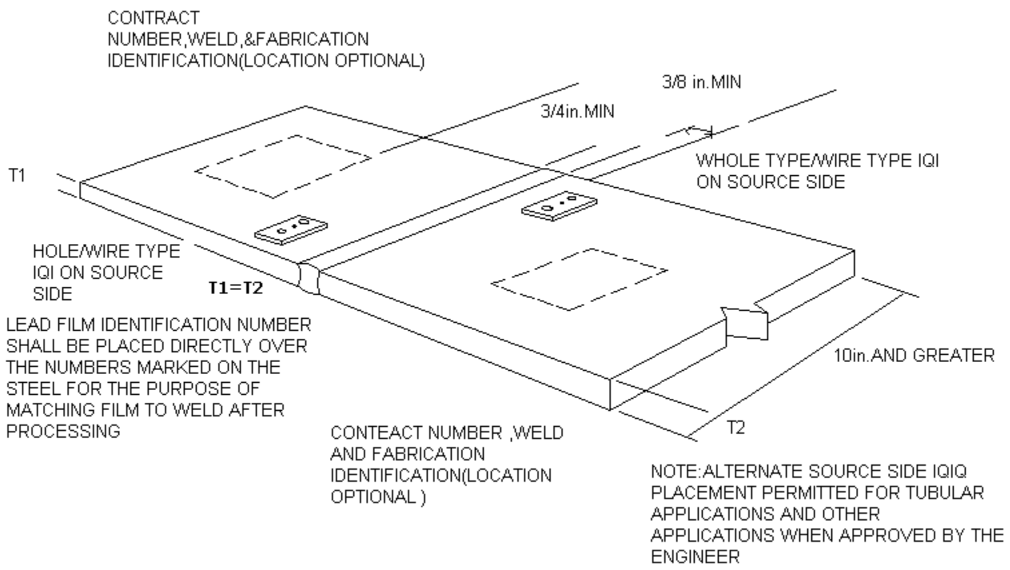


Figure (1)
RT Identification and IQI Locations on equal thickness joints of length ≥ 250 mm

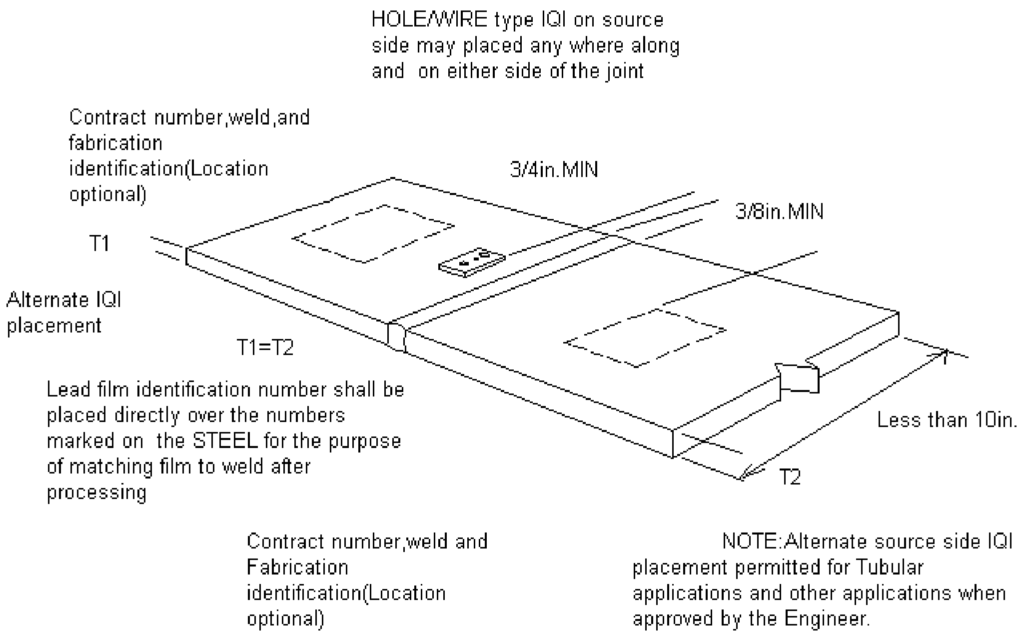


Figure (2)
RT Identification and IQI Locations on equal thickness joints of length < 250 mm

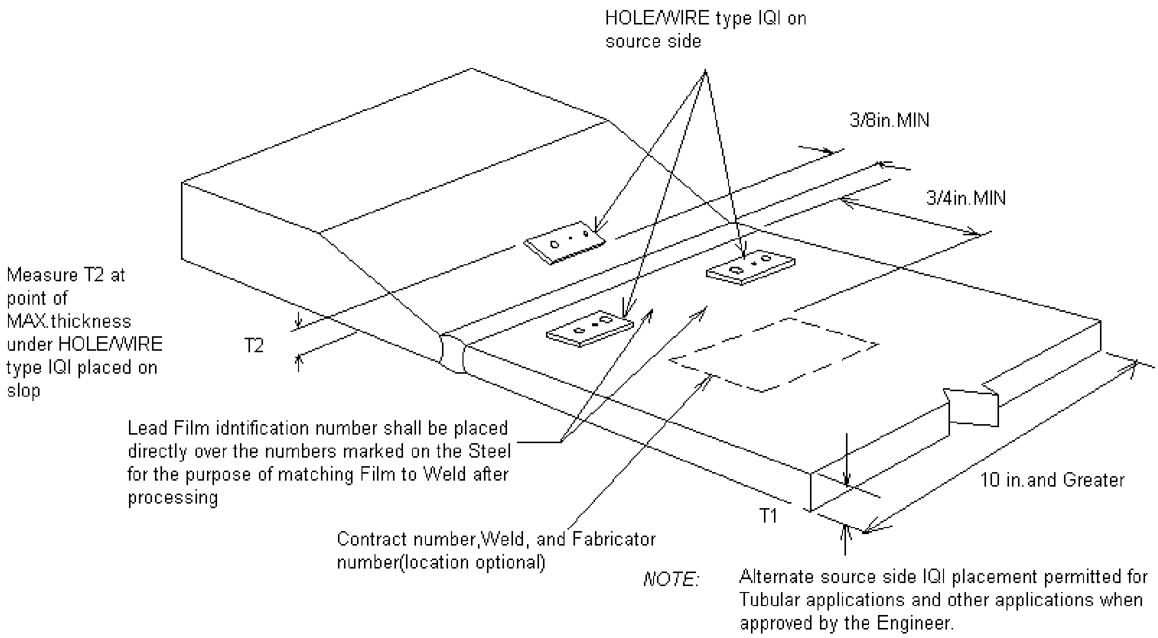


Figure (3)
RT Identification and IQI Locations on transition joints of length ≥ 250 mm

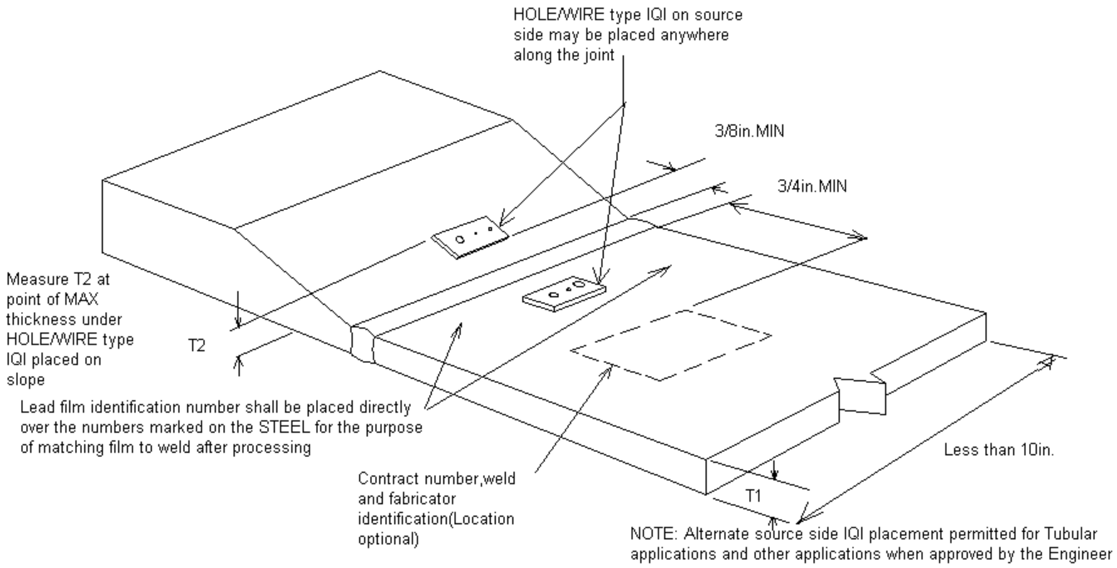
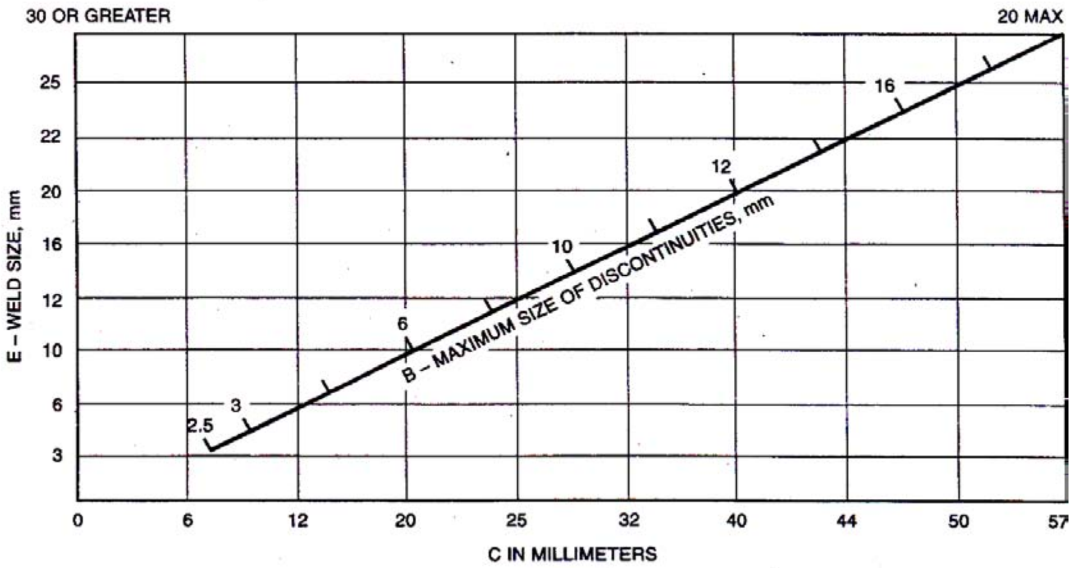


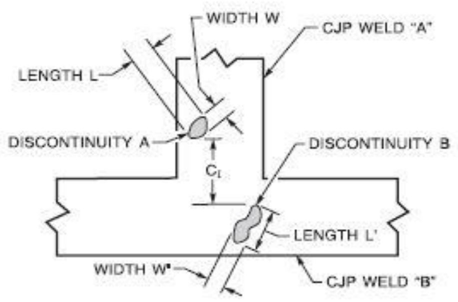
Figure (4)
RT Identification and IQI Locations on transition joints of length < 250 mm



To determine he maximum size of discontinuity allowed in any weld size, project E horizontally to B
To determine the minimum clearance allowed between edges of discontinuities of any size greater than or equal to 2.5 mm, project B vertically to C
B – Maximum allowable dimension of discontinuity   E- Weld thickness
C- Minimum clearance measured between edges of porosity or fusion type discontinuities

Figure (5) Weld Quality requirements for elongated discontinuities by RT for Statically Loaded Non tubular Structures

DISCONTINUITY A = ROUNDED OR ELONGATED DISCONTINUITY LOCATED IN WELD A
DISCONTINUITY B = ROUNDED OR ELONGATED DISCONTINUITY LOCATED IN WELD B
L AND W = LARGEST AND SMALLEST DIMENSIONS, RESPECTIVELY, OF DISCONTINUITY A
L' AND W' = LARGEST AND SMALLEST DIMENSIONS, RESPECTIVELY, OF DISCONTINUITY B
E = WELD SIZE
C_1 = SHORTEST DISTANCE PARALLEL TO THE WELD A AXIS, BETWEEN THE NEAREST DISCONTINUITY EDGES

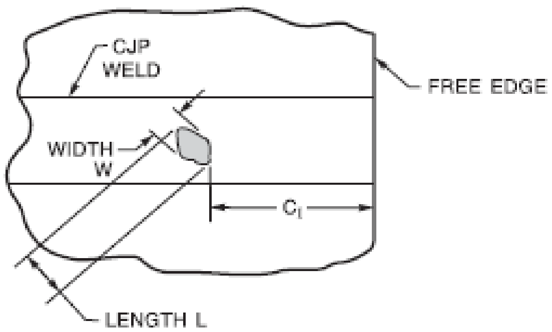


CASE I DISCONTINUITY LIMITATIONS[a]

DISCONTINUITY DIMENSION	LIMITATIONS	CONDITIONS
L	< E/3, ≤ 1/4 in [6 mm]	E ≤ 2 in [50 mm]
	≤ 3/8 in [10 mm]	E > 2 in [50 mm]
C_1	≥ 3L	(A) ONE DISCONTINUITY ROUNDED, THE OTHER ROUNDED OR ELONGATED[a] (B) L ≥ 3/32 in [2.5 mm]

[a] The elongated discontinuity may be located in either weld "A" or "B." For the purposes of this illustration the elongated discontinuity "B" was located in weld "B."

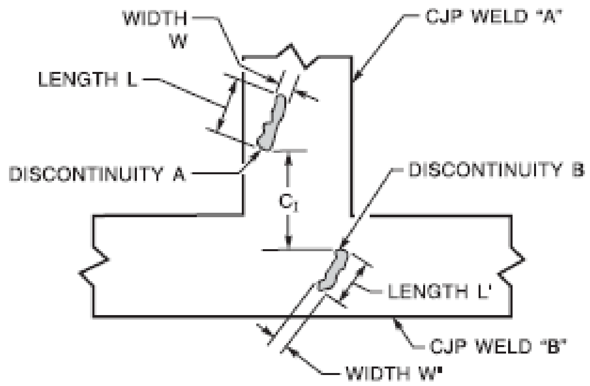
Figure 5 Case I- Discontinuity at weld intersection



CASE II DISCONTINUITY LIMITATIONS

DISCONTINUITY DIMENSION	LIMITATIONS	CONDITIONS
L	<E/3, ≤1/4 in [6 mm]	E ≤ 2 in [50 mm]
	≤3/8 in [10 mm]	E > 2 in [50 mm]
C_I	≥3L	L ≥ 3/32 in [2.5 mm]

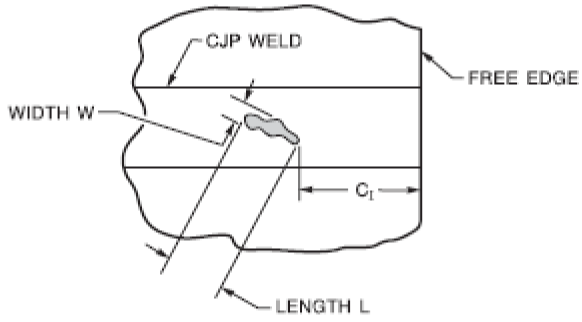
Figure 5 Case 2- Discontinuity at Free Edge of CJP Groove Weld



CASE III DISCONTINUITY LIMITATIONS

DISCONTINUITY DIMENSION	LIMITATIONS	CONDITIONS
L	≤2E/3	L/W > 3W
C_I	≥3L OR 2E, WHICHEVER IS GREATER	L ≥ 3/32 in [2.5 mm]

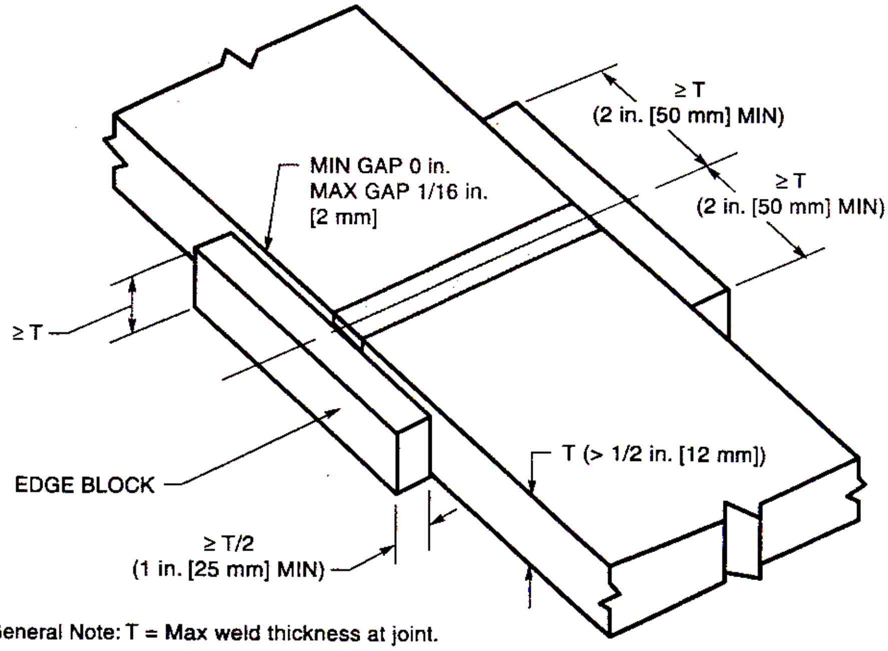
Figure 5 Case 3- Discontinuity at Weld Intersection



CASE IV DISCONTINUITY LIMITATIONS

DISCONTINUITY DIMENSION	LIMITATIONS	CONDITIONS
L	≤2E/3	L/W > 3
C_I	≥3L OR 2E, WHICHEVER IS GREATER	L ≥ 3/32 in [2.5 mm]

Figure 5 Case 4- Discontinuity at Free Edge of CJP Groove Weld



General Note: T = Max weld thickness at joint.

Figure (6) RT Edge Block

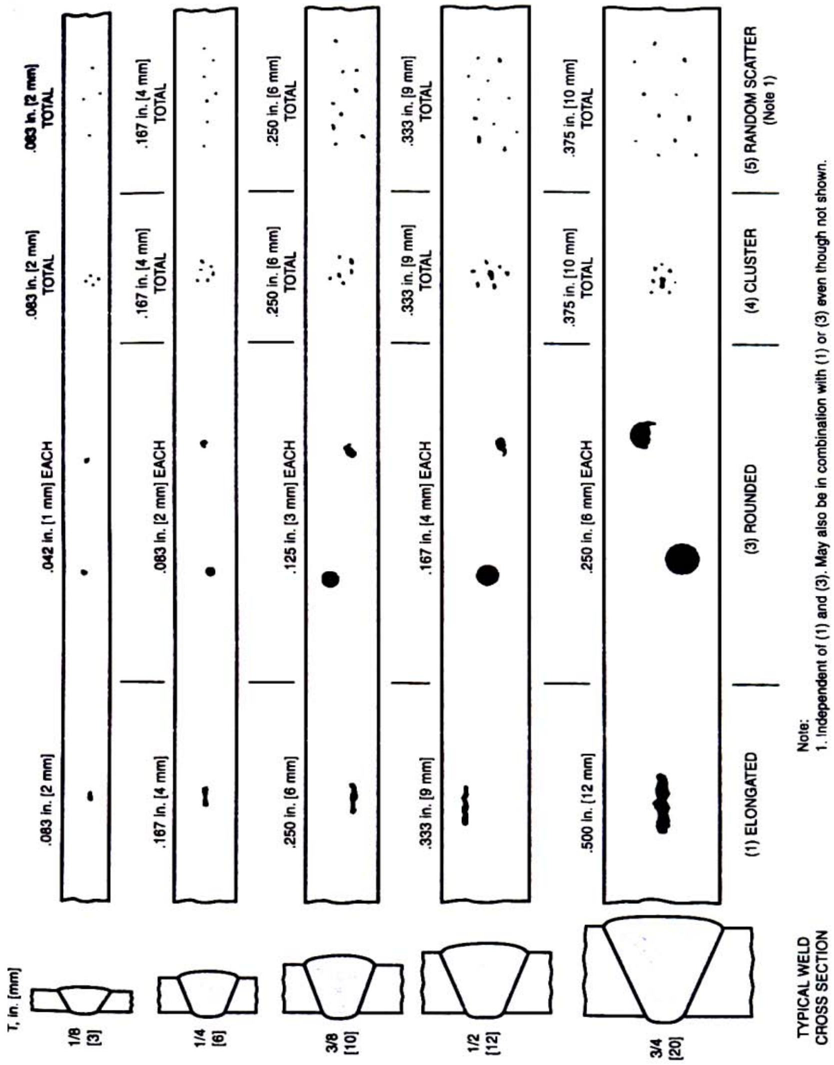
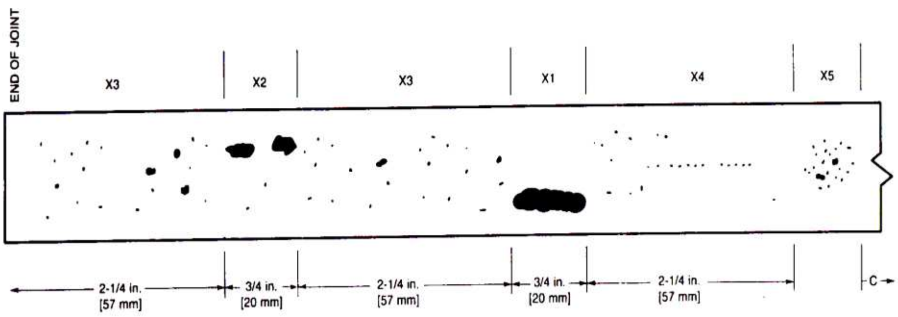


Fig (7) Maximum Acceptable RT Images



C- Minimum clearance allowed between edges of discontinuities 2.5 mm or larger
X1-Largerst permissible elongated discontinuity for 30 mm joint thickness
X2-Multiple discontinuities within a length may be handled as a single discontinuity
X3- X4 – Rounded type discontinuity less than 2.5 mm
X5-Rounded type discontinuities in a cluster. Such a cluster having a maximum of 20 mm for all pores In the cluster shall be treated as requiring the same clearance as a 20 mm long discontinuity

Interpretation: Rounded and elongated discontinuities shall be acceptable as shown. All are within the size limits and the minimum clearance allowed between discontinuities or the end of a weld joint

Fig (8) Random Acceptable Discontinuities

CHAPTER 1.6

PROCEDURE FOR ULTRASONIC EXAMINATION OF WELDS

BHEL	**BHARAT HEAVY ELECTRICALS LIMITED** **DEPT.235 – TIRUCHIRAPALLI – 620 014** **Non-Destructive Testing**	BHE:NDT:PB:UT- 01 Revision 13 Page 1 of 22

PROCEDURE FOR ULTRASONIC EXAMINATION OF WELDS

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EFFECTIVE FROM 01-01-2020

RECORD OF REVISION

Sl No.	Date	Details of Revision
06	28-03-94	Revised in entirety.
07	01-08-96	Revised in entirety.
08	01-04-97	Revised to merge and replace BHE:NDT:PB:UT:01/01,01/02,01/03, 11,13,14,16,17 & 25 to represent as a single procedure.
09	16-03-16	Revised to incorporate ASME BPV Code edition 2015, Clause 2.1, 4.1, 8.1.1, 8.1.4, 8.1.5, 8.1.6, 8.2.2, 8.5.4, 25.3 added, 21.2.1 revised, 25.3 added, Fig 1, 2, 6 revised.
10	07-10-17	Clause 4.1, 6.1 modified.
11	21-10-17	Revised in entirety.
12	01-09-2018	2.1, 2.2, 23.6.2 & Fig (16) revised.
13	01.01.2020	2.1, 2.2, 4.1, 22.5, 23.2 revised. Clause 25.0 Added.

1.0 SCOPE

1.1 This procedure defines the requirements of equipment, calibration, examination procedure and acceptance standards for ultrasonic examination of ferritic welds (carbon or alloy steel) by manual, contact method, that is required to be performed by ASME code for the following products:

a)Butt, Corner and Tee joints in components of boilers, Pressure vessels , heat- exchangers and HP / LP bypass Valves, with a dia greater than 120 mm and thickness equal to or greater than 10 mm.

b) Butt joints in pipes with Outer dia >120 mm and thickness ≥10mm.

c) Butt joints in boiler pipes / tubes dia 31.8 to 120 mm and thickness 3.6 mm to 13 mm.

2.0 REFERENCE

2.1 ASME Section I, V, and VIII Division 1 & 2 – 2019.

2.2 ASME B 31.1 / 2018

3.0 EQUIPMENT

3.1 Equipment features

3.1.1 A Digital Ultrasonic Flaw Detector of pulse - echo, Manual contact method type that responds to frequencies 1 MHz to 6 MHz and equipped with a stepped gain control of 2 dB or less shall be used as the UT instrument. The equipment setting values shall be detailed in the report.

3.2 Equipment Calibration

3.2.1 The Screen height linearity and amplitude control linearity shall be performed in accordance with BHE: NDT: UT: Calib: 1 (latest revision)at the beginning of each period of extended use or every 3 months (for Analog) and 1 year for Digital equipment, whichever is less.

3.3 Probes

3.3.1 Probes can be either single or dual transducer elements. Probes with curved contact wedges may be used to improve ultrasonic coupling in which case calibration shall be done with contact wedges used during the examination.

3.3.2 Search unit of 2 MHz to 4 MHz frequency shall be selected to produce a desirable signal- to- noise ratio (S / N) from the material to be examined at the specified sensitivity. Probes / search unit can be either single or dual transducer elements. An S / N value of at least 3 to 1 shall be usually considered to be minimum. Frequency < 2 MHz will be used to assure adequate penetration, when coarse grain structures are encountered. Crystal size 8 x 9 mm / 20 x 22 mm / dia 10 mm / dia 25 mm shall be used as per the application. Usage of any other crystal size shall be demonstrated to fulfill the requirements. To achieve proper contact, ultrasonic coupling and sensitivity on the smaller diameter surface, probes with contour contact wedges / shoes may be used in which case calibration shall be done with contact wedges / shoes used during the examination.

3.4 Couplant

3.4.1 Grease and Servo 35 oil mix will be used as couplant. The couplant used for the examination shall be the same that is used for calibration.

4.0 PERSONNEL QUALIFICATION

4.1 Personnel performing examinations shall be qualified in accordance with employer's written down document which is prepared in line with ASNT SNT – TC -1A (2016). The testing shall be conducted by minimum Level-I Personnel (Under the supervision of Level II OR Level III) or Level II and the interpretation and evaluation shall be done by minimum Level-II personnel.

5.0 SURFACE PREPARATION

5.1 As welded or ground surface shall be acceptable for the examination of the weld. The surface shall be free of dirt, scale, weld spatter, rust, paint, or any other extraneous matter that could prevent the scanning.

6.0 EXAMINATION

6.1 GENERAL EXAMINATION REQUIREMENT:

6.1.1 The entire volume of the full weld length inclusive of adjacent base metal shall be examined by moving the probe over the examination surface. During scanning the probes shall be moved to and from, with swiveling action of 10º to 15º on either side with overlap between successive scanning. Each pass of the probe shall overlap a minimum of 10 % of the crystal element dimension perpendicular to the direction of the scan. The rate of probe movement for examination shall not exceed 150 mm / sec.

6.2 STRAIGHT BEAM EXAMINATION:

6.2.1 For straight beam examination, longitudinal wave probes (0 degree) with crystal dimensions in the range of 10 to 25 mm shall be used.

6.2.2 The weld and fusion-zone of adjacent base material shall be scanned to the extent possible from one surface of the production part.

6.3 ANGLE BEAM EXAMINATION:

6.3.1 Scanning angle:

6.3.1.1 The search unit and beam angle selected shall be 45^0 or an angle appropriate for the configuration, groove angles and thickness of the weld being examined and shall be capable of detecting the calibration reflectors, over the required angle beam path.

6.3.2 Scanning Position and Directions:

6.3.2.1 Scanning shall be performed from both surfaces and from each side of the weld between 1/8 to 5/8 skip distances from the weld-centre line. (Fig 1.)

6.3.2.2 When examination is practical from one surface only, the 1/4-T volume lying below the examination surface, shall be examined from each side of the weld, by additionally positioning and moving the probe from 3/4-T to 1-T (full) skip distance. (Fig 2.)

6.3.2.3 When examination is practical from one surface and one side only two angle-beam probes shall be used. One of the angle-beam employed shall be 45 degree. The extent of limit coverage shall be noted in the examination report.

6.3.2.4 For Corner joints the scanning directions shall be such that the entire volume of the weld is scanned by angle and straight probes. (Fig 3, 4)

6.4 Angle beam / Longitudinal flaw scanning:

6.4.1 The angle beam shall be directed at 90º to the weld axis. The probe shall be manipulated so that ultrasonic energy passes through the required volumes of weld and adjacent base material.

6.5 Angle-beam/ transverse flaw scanning:

6.5.1 Scanning with weld reinforcement: If the weld cap is not machined or ground flat, the examination shall be performed from the base material on both sides of the weld cap. While scanning parallel to the weld axis, the angle beam shall be directed from 0 deg. to 60 deg. with respect to the weld axis in both axial directions, with the angle beam passing through the required examination volume.

6.5.2 Scanning without weld reinforcement: If the weld cap is machined or ground flat, the examination shall be performed on the weld. While scanning, the angle beam shall be directed essentially parallel to the weld axis in both axial directions. The search unit shall be manipulated so that the angle beam passes through the required examination volume.

6.6 Scanning sensitivity:

6.6.1 The scanning shall be performed at a gain setting + 6 dB of the primary reference level. If detection and evaluation of all indications exceeding 20 % of FSH required, scanning shall be performed at +14 dB. Evaluation shall be performed with respect to primary reference level.

7.0 REPAIR

7.1 Repaired welds in all the above materials shall be re-examined by the same procedure used for original testing.

8.0 REPORT

8.1 A detailed report duly signed by a minimum Level II NDE personnel shall be issued in the approved format.

6.8.2 The reports shall be retained for a minimum period of Five years for products made as per ASME Section I and Section VIII Div 1 and 2.

9.0 POST EXAMINATION CLEANING

9.1 After the examination is over the couplant applied on the surface shall be removed, if the residue couplant could interfere the further use of the test piece.

10.0 BUTT WELDS IN BOILER DRUMS, PRESSURE VESSELS AND VALVES

10.1 BASIC CALIBRATION BLOCK:

10.1.1 The material from which the block is fabricated shall be of the same product form and material specification or equivalent P-Number grouping of the materials being examined with similar Heat treatment conditions. P-No.s. 1, 3, 4, 5A through 5C, and 15A through 15F materials are considered equivalent. The material selection shall be based on the material on the side of the weld from which the examination will be conducted. If the examination will be conducted from both sides, calibration reflectors shall be provided in both materials.

10.1.2 The finish on the surfaces of the block shall be representative of the surface finishes on the production material.

10.1.3 The temperature difference between the examination and basic calibration block surfaces shall be within 14 degree C.

10.1.4 For examination in materials where the examination surface dia is greater than 500 mm, either a block of essentially the same curvature or a flat basic calibration block shall be used.(Fig. 5)

10.1.5 For materials with examination surface diameter 500 mm or less, the basic calibration block shall be curved. A single curved basic calibration block may be used to calibrate, examination of surfaces, in the range of 0.9 to 1.5 times the basic calibration block diameter. (Fig. 6)

10.1.6 The block thickness shall be as per Fig. (5). When the block thickness ± 25 mm spans two of weld thickness ranges in the table in Fig.5, the block's use shall be acceptable in those portions of each thickness range covered by 25 mm of the calibration bloc thickness. (E.g. A calibration block with thickness 38 mm could be used for weld thickness of 13 mm to 64 mm).

10.1.7 In cases such as single sided access welds (corner), if the calibration block detailed in Figure 5 does not provide the necessary sound path distances to the reference reflectors to provide distance-amplitude correction (DAC) that will fully cover the area of interest for the straight beam technique, a second calibration block is required whose thickness (T) and reference reflector locations are based on the sound path distance that provides for coverage of the area of interest.

10.1.8 No point on the DAC curve shall be less than 20% of full screen height (FSH). When any portion of the DAC curve will fall below 20% FSH, a split DAC shall be used. The first calibration reflector on the second DAC shall start at 80% ± 5% FSH. When reflector signal-to-noise ratio precludes effective indication evaluation and characterization, a split DAC should not be used.

10.2 Calibration Confirmation

10.2.1 When any part of the examination system is changed, a calibration check shall be made on the calibration block to verify that distance range points and sensitivity settings satisfy the requirements of 8.3. A calibration check on at least one of the basic reflectors in the basic calibration block shall be made at the finish of each examination, every 4 hrs. During the examination and when examination personnel are changed.

10.3 Confirmation Acceptance values

10.3.1 Distance range points: If any distance range point has moved on the sweep line more than 10% of the distance reading or 5% of full sweep, whichever is greater, then the sweep range calibration shall be corrected and recorded. All recorded indications since the last valid calibration shall be re-examined with corrected calibration and their values changed on the data sheets.

10.3.2 Sensitivity settings: If any sensitivity setting has changed by more than 20% or 2 dB of its amplitude, correct the sensitivity calibration and record. If the sensitivity setting has decreased, all the data sheets since the last calibration or calibration check shall be considered invalid. A new calibration shall be made and recorded. The invalid areas covered shall be re-examined. If the sensitivity setting has increased, all recorded indications since the last valid calibration or calibration check shall be re-examined and their values shall be changed on the data sheets or re-recorded.

11.0 SCANNING ADJACENT BASE MATERIAL

11.1 The scanning of adjacent base material shall be performed with straight-beam probe to detect reflectors that might affect interpretation of angle beam results. Locations and areas of such reflectors shall be recorded. This adjacent base material examination is not to be used as acceptance - rejection examination.

12.0 TECHNIQUES FOR ANGLE BEAM CALIBRATION

12.1 SWEEP RANGE:

12.1.1 The Sweep range is calibrated using IIW Block. The multiple reflection signals from 100 mm quadrant in IIW block are adjusted such that first reflection coincides with 5th division and 2nd signal at 10th division for 200 mm range. Similar settings shall be done for the different sweep ranges according to the thickness and skip distances used for scanning (Fig 7)

12.2 DISTANCE AMPLITUDE CORRECTION (DAC): Fig (8)

12.2.1 The probe is to be positioned for maximum response from the SDH, which gives the highest amplitude

12.2.2 The sensitivity control is to be adjusted to get an indication of 80% of full screen height (FSH) and the peak is to be marked on the screen.

12.2.3 The probe is to be positioned from another SDH for maximum response without altering the gain settings.

12.2.4 The peak point is to be marked on the screen.

12.2.5 The third SDH is positioned and the peak point is marked on the screen.

12.2.6 The 3/4T SDH is positioned for maximum amplitude after the beam bounces back from the opposite surface. The peak point is to be marked on the screen.

12.2.7 All the screen marks are to be connected for the required DAC

12.3 CALIBRATION CORRECTION FOR RECTANGULAR NOTCHES:

12.3.1 The probe shall be positioned for maximum amplitude from the notch on the opposite surface and the peak of the indication marked with an 'X' on the screen. The opposition surface notch may give an indication 2 to 1 above DAC for 45 degree shear wave, but only ½ DAC for a 60º shear wave. Therefore, the indication from the notch shall be considered when evaluating reflectors at the opposite surface. (Fig 9)

12.3.2 When a vessel or other component with a thickness of 13 mm or less and a diameter equal or less than 500 mm, the angle beam calibration for DAC may be performed as given in 17.1.

13.0 STRAIGHT BEAM CALIBRATION

13.1 The Sweep range is calibrated using IIW Block. The multiple reflection signals from 25 mm thickness in IIW block are adjusted such that first reflection coincides with 2.5 division, 2nd signal at 5th division, 3rd signal at 7.5 division and 4th signal at 10th division for a range of 100 mm. Similar settings shall be done for the different sweep ranges according to the thickness and skip distances used for scanning. (Fig. 10.)

13.2 Distance Amplitude Calibration (DAC) for Straight beam shall be done as in 10.2.1 to 10.2.5 and 10.2.7. (Fig. 11.)

14.0 NOZZLE SIDE WELD FUSION ZONE AND ADJACENT NOZZLE PARENT METAL EXAMINATION

14.1 CALIBRATION BLOCK

14.1.1 The calibration block configuration shall be as in figure (15).The block size and the reflector location shall be adequate to perform calibrations to cover the nozzle side weld fusion zone and the adjacent nozzle parent metal

14.1.2 Thickness: The calibration block shall be the maximum thickness of the nozzle wall adjacent to the nozzle weld plus 19 mm.

14.1.3 Curvature: For examination of nozzles with an inside diameter equal to or less than 500 mm, the contact surface of the calibration block shall have the same curvature or be within the range of 0.9 to 1.5 times the diameter (Fig 6).

14.1.4 Calibration reflectors: the calibration reflectors shall be side drilled holes that are in accordance with the requirements of figure (5).

14.1.5 Alternative calibration blocks may be used for similar types of examination, provided the sound path distance(s) to the block's reflector(s) is (are) within 6 mm of what is required and the side drilled hole is the same or a smaller diameter than what is required.

14.1.6 Calibration confirmation as per 8.3 shall be ensured.

14.2 EXAMINATION-specific requirements:

14.2.1 The requirements of clause 6, are applicable. The full circumference of the nozzle shall be scanned to cover the entire nozzle side fusion zone of the weld plus 25 mm beyond the weld toes. The search unit may be moved either circumferentially around or axially across the examination zone, as shown in figures 3 and 4. The screen range shall cover as a minimum, 1.1 times the full thickness of the nozzle wall. Nozzles that cannot be fully examined (e.g., restricted access that prevents hand placement of the search unit) shall be noted in the examination report.

15.0 EVALUATION:

15.1 Any imperfection which causes an indication in excess of 20% DAC shall be interpreted to determine the identity, shape and locations of all such imperfections to characterize them for their nature and type.

15.2 Indications that are determined to originate from metallurgical structure such as weld metal to austenitic clad interface shall be classified as spurious indications.

15.3 To classify an indication as geometric, reflected coordinates are to be verified and plotted and a cross sectional sketch of the weld shall be prepared showing the reflector position and surface discontinuities such as root and counter-bore.

16.0 RECORDING:

16.1 All indications having signal amplitudes equal to and above 50% of the reference level shall be recorded.

17.0 FLAW SIZING: Fig. (12)

17.1 Indications from discontinuities that remain from 100% DAC to 30% of DAC, the length of the reflector shall be obtained by recording the position and location along the lengths of the weld as determined by 50% level of maximum amplitude for each end of reflector (6 dB drop).

17.2 Indications that exceed the reference level the length of the reflector shall be determined by recording the position and location along the lengths of the weld until the maximum amplitude echo just falls below the 100% DAC reference response curve (0 dB drop).

18.0 ACCEPTANCE STANDARD:

18.1 Indications characterized as cracks, lack of fusion of incomplete penetration are not acceptable regardless of length.

18.3 Indications from other imperfections are not acceptable if the indications exceed the reference level and have lengths which exceed

a) 6 mm for `t' up to 19 mm,
b) 1/3t for t from 19 mm to 57 mm
c) 19 mm for t over 57 mm
Where `t' is thickness of weld excluding any allowable reinforcement.

18.3 For a butt weld joining two members having different thickness at the weld 't' is the thinner of the thickness. If a full penetration weld includes a fillet weld, the thickness of `throat' of the fillet shall be included in `t'.

19.0 WELDS IN PIPES WITH OUTER DIAMETER > 120 MM AND THICKNESS ≥ 10 MM

19.1 The basic calibration block configuration and reflectors (notches) shall be as shown in Fig 13. Thickness, T, shall be ± 25% of the nominal thickness of the component to be examined. The block size and reflector locations shall be adequate to perform calibrations for the beam angle(s) and distance range(s) to be used.

19.2 For examination in materials where the examination surface dia is greater than 500 mm, either a block of essentially the same curvature or a flat basic calibration block shall be used.(Fig. 13). For materials with examination surface diameter 500 mm or less, the basic calibration block shall be curved. A single curved basic calibration block may be used to calibrate, examination of surfaces, in the range of 0.9 to 1.5 times the basic calibration block diameter. (Fig. 6).

19.3 The surface finish of the calibration block shall be representative of the surface finish of the piping.

19.4 Calibration confirmation as per 8.3 shall be ensured.

20.0 ANGLE BEAM CALIBRATION:

20.1 The angle beam shall be directed toward the notch that yields the maximum response. The gain control shall be set so that this response is 80% ± 5% of full screen height. This shall be the primary reference level. The search unit shall then be manipulated, without changing instrument settings, to obtain the maximum responses from the calibration reflectors at the distance increments necessary to generate a three-point distance-amplitude correction (DAC) curve. Separate calibrations shall be established for both the axial and circumferential notches. These calibrations shall establish both the distance range calibration and the distance amplitude correction.

21.0 ANGLE BEAM EXAMINATION:

21.1 Scanning angle:

21.1.1 For angle beam examination one shear wave angle beam probe of 45º shall be generally used. Other beam angles 60º or 70º will be used when it is appropriate to the configuration of piping being examined, its thickness and groove angle employed for welding. (Fig 14)

21.1.3 For angle beam examination the crystal dimensions shall be selected appropriate to the contact examination surface and generally be in the range of 8 mm to 35 mm.

21.2 Scanning Position and Directions:

21.2.1 Scanning shall be performed from outer surface only and from each side of the weld between 1/3 to one full skip distance.

21.2.3 When examination is practical from one surface and one side only two angle beam probes shall be used. One of the angle-beam employed shall be 45 degree.

22.0 EVALUATION:

22.1 Any imperfection which causes an indication in excess of 20% DAC shall be interpreted to determine the identity, shape and locations of all such imperfections to characterize them for their nature and type.

22.2 Indications that are determined to originate from surface conditions such as weld root geometry, counter-bore, and weld reinforcement shall be classified as 'geometry indications'.

22.3 Recording:

22.3.1 All indications having signal amplitudes equal to and above 50% of the reference level shall be recorded.

22.4 Flaw length measurement:

22.4.1 The measurements shall be made as in 15.0

22.5 ACCEPTANCE STANDARD:

a. Indications characterized as cracks, lack of fusion & incomplete penetration are not acceptable regardless of length.

b. Indications from other imperfections are not acceptable if the indications exceed the reference level and have lengths which exceed

   a)6 mm for `t' up to 19 mm,
   b)1/3t for t from 19 mm to 57 mm
   c)19 mm for t over 57 mm

c. Where `t' is thickness of weld excluding any allowable reinforcement.

d. For a butt weld joining two members having different thickness at the weld 't' is the thinner of the thickness. If a full penetration weld includes a fillet weld, the thickness of `throat' of the fillet shall be included in `t'.

23.0. WELDS IN PIPES / TUBES OUTER DIA (OD) ≤ 120 mm

23.1. This procedure is applicable to induction pressure welds (IPW) & fusion welds in boiler tubes for the purpose of detecting radial-type defects having their major dimension circumferentially relative to the tube axis.

23.2. <u>BASIC CALIBRATION BLOCK</u>

23.2.1. The basic calibration block shall be a section of the pipe / tube with an outer diameter (OD) within 0.9 to 1.5 times the OD of the test pipe / tube, and thickness within $\pm$ 25 % of that of the test pipe / tube. The material of the block shall meet the requirements specified in clause 10.1.1.

23.2.2. The calibration reflectors shall be circumferential notches on both the inner and outer surface. The calibration reflectors shall be of length ≥ 25 mm, depth 8%T minimum to 11%T maximum (where T is the thickness of the test pipe). Notch width shall be maximum 6 mm.

23.2.3. The notches in the calibration piece shall be kept clean. If contaminated by Couplant or accumulated dirt the notches shall be cleaned by washing with a stream of water directed into and along the notch and rinsed with acetone, or other rapid drying solvent.

23.3. <u>ANGLE BEAM CALIBRATION:</u>

23.3.1. The angle beam probe shall be directed toward ID notch that yields the maximum response, adjusting the instrument settings to 80% of full screen height (FSH), in half node if practicable or in 1.5 skip or more so that this indication appears around 50 % of the time-base. The left end of the gate shall be adjusted to this position on the CRT.

23.3.2. The probe shall be then positioned at distance necessary to resolve the OD notch and the right end of the gate shall be adjusted to this sweep position on the CRT. The gate length just established will be the area for acceptance or rejection of indication when combined with the proper transducer position. The OD notch shall be used as reference to establish the gate length only.

23.4. <u>ANGLE BEAM SCANNING:</u>

23.4.1. Only longitudinal flaw scanning shall be performed from outer surface and from each side of the weld up to 2 skip distances using 70 deg. shear-wave probe.

23.5. <u>EVALUATION:</u>

23.5.1. Indications that are determined, by careful evaluation of the examination area, to originate from surface conditions such as weld root geometry, counter-bore, weld reinforcement, mismatched upset on ID and OD they shall be classified as geometry indications.

23.5.2. Indications contained within the OD upset may be removed and re-examined provided the OD reinforcement has not been reduced below the specified minimum wall thickness.

23.6. <u>ACCEPTANCE STANDARD:</u>

23.6.1. Any flaw-indication exceeding the primary reference shall be unacceptable.

23.6.2. On Induction Pressure welded tube joints, UT need not be carried out in case if visually unacceptable joints found viz. Offcentre > 1.5 mm, Peak, Melt, Overlap and Mismatch on OD (as shown in Fig.16) and are not acceptable.

23.6.3. Any indication arising out of root geometry which gives echo response at any level with respect to primary reference and only one side of weld scanning is acceptable.

24.0 POST CLEANING:

24.1 When post cleaning is required by the procedure, it should be conducted as soon as practical after evaluation and documentation using a process that does not adversely affect the part.

25.0 Record Retention:

25.1 The Records of reports signed by min. Level II/III shall be retained for the period of 5 years for components fabricated as per ASME Sec-I and 3 years for components of ASME SEC-VIII.

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Table-1
ESSENTIAL AND NON- ESSENTIAL VARIABLES

Sl. No	Requirement	Type of variable	Applicable clauses in the procedure
01	Weld configuration to be examined-Thickness, dimension, base material product form	Essential	Clause 1.1 & 5.1
02	Surface from which examination performed	Essential	Clause 6.2.2,6.3.2
03	Technique	Essential	Straight beam, Angle beam(contact) Clause 6.2,6.3
04	Angle and mode	Essential	Clause 6.2.1 & 6.3.1.1
05	Search unit type, frequency and dimensions	Essential	Clause 3.3.2, 6.2.1
06	Special search unit when used	Essential	Clause 3.3.2
07	Ultrasonic instrument	Essential	Clause 3.1
08	Calibration blocks and techniques	Essential	Clause 8, 12,17,18, Fig. 5,6,13,14 & 15
09	Direction and extent of scanning	Essential	Clause 6.1, 6.2, 6.3
10	Scanning (Manual)	Essential	Clause 6.1
11	Method for discriminating geometry and flaw	Essential	Clause 13.3
12	Method of sizing indications	Essential	Clause 15
13	Computer enhanced data acquisition	Essential	Not Applicable
14	Scan overlap(decreased only)	Essential	Clause 6.1
15	Personnel performance requirement	Essential	Clause 4.1
16	Personnel qualification requirement	Non Essential	Clause 4.1
17	Surface condition	Non Essential	Clause 5
18	Couplant: brand name or type	Non Essential	Clause 3.4
19	Post examination cleaning technique	Non Essential	Clause 24.1
20	Automatic alarm and recording equipment	Non Essential	Not applicable.
21	Records including minimum calibration data to be recorded (e. g-Instrument settings)	Non Essential	Equipment setting values & calibration data covered in the report

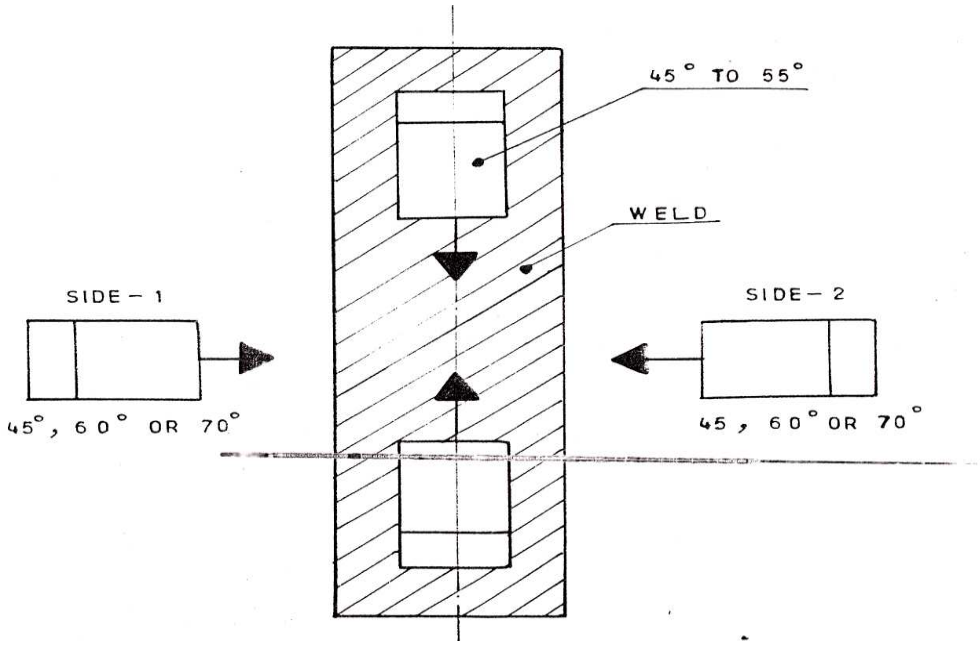
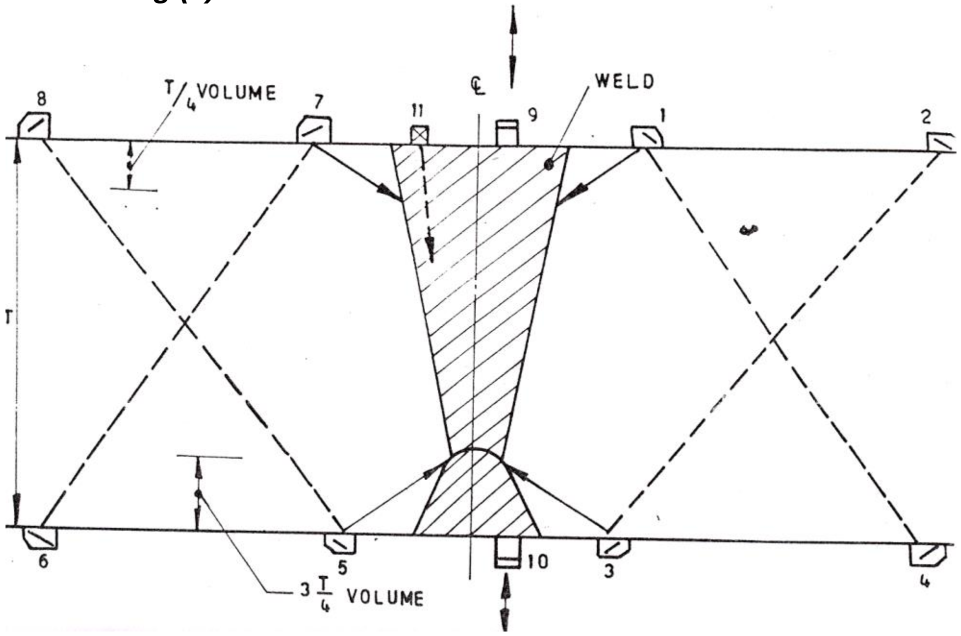


Fig (1): SCANNING DIRECTION FOR ANGLE BEAM



<u>Probe position</u>: 1 to 8: scanning perpendicular to weld axis- angle beam
9 & 10: scanning along weld axis- angle beam
11 : straight beam scanning

<u>Evaluation area</u>: ¼ TO 5/4 T on sweep line

Fig (2): SCANNING DIRECTIONS AND EVALUATION AREAS FOR BUTT WELDS

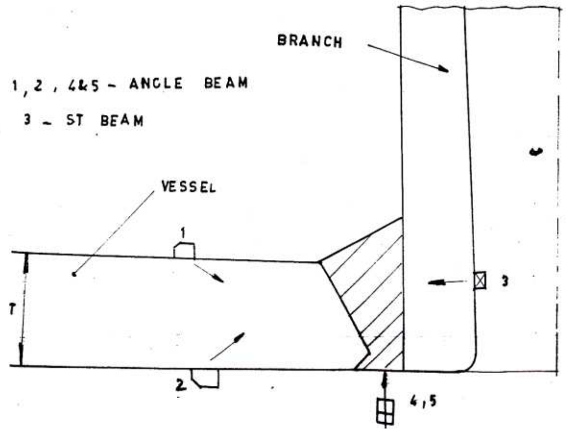


Fig (3): ***SCANNING DIRECTIONS FOR FULL PENETRATION CORNER WELDS (SET – THROUGH)***

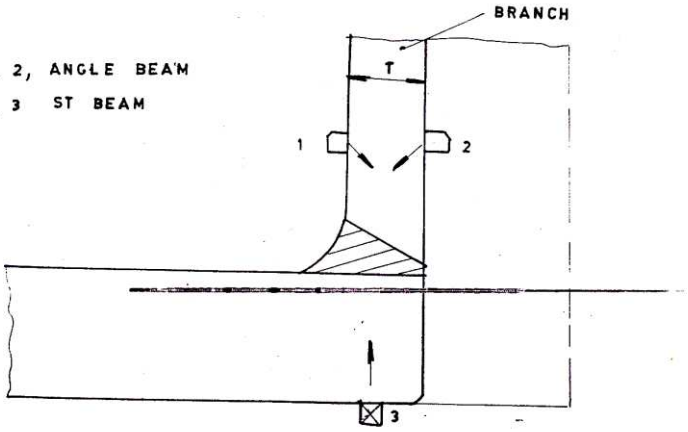
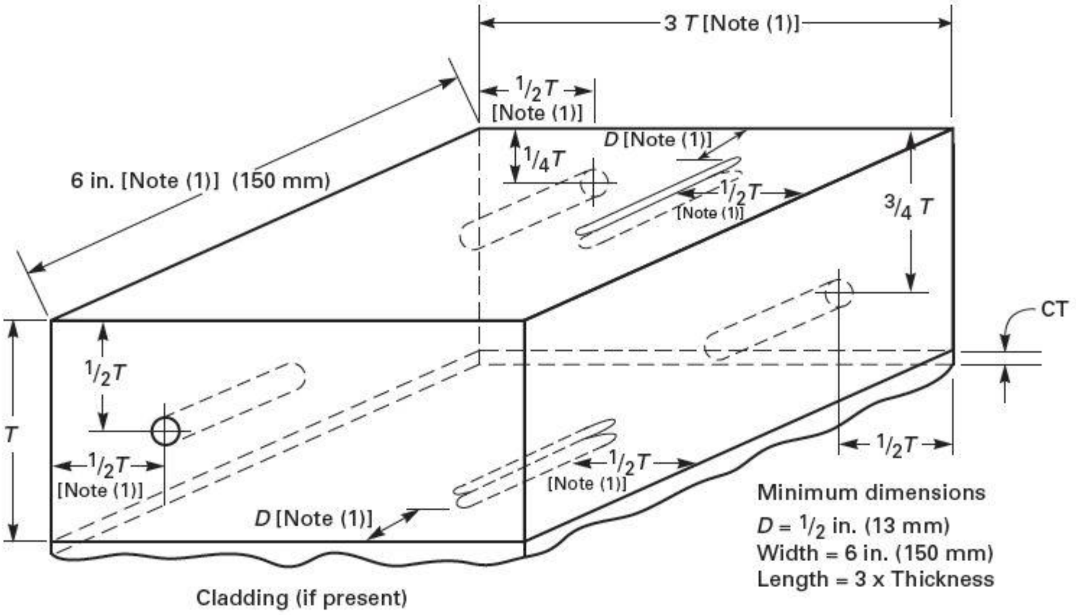


Fig (4): ***SCANNING DIRECTIONS FOR FULL PENETRATION CORNER WELDS (SET- ON)***



Wall Thickness (t) (mm	Calibration Block Thickness (T) mm	Hole Diameter-mm
Up to 25	19 or t	2.5
Over 25 through 50	38 or t	3
Over 50 through 100	75 or t	5
Over 100	T ± 25	For each increase in weld thickness of 50 mm or fraction thereof over 100 mm, the hole diameter shall increase 1.5 mm.

Notch Dimensions	
Notch Depth (mm)	1.6% T to 2.2 %T
Notch Width (mm)	6 mm Maximum
Notch Length	25 mm minimum

GENERAL NOTES:

(a) Holes shall be drilled and reamed to a minimum length of 38 mm, essentially parallel to the examination surface.

(b) For components equal to or less than 500 mm in diameter, calibration block diameter shall meet the requirements of Clause 8.1. Two sets of calibration reflectors (holes, notches) oriented 90 deg. from each other shall be used. Alternatively, two curved calibration blocks may be used.

(c) The tolerance for hole diameter shall be ±0.8 mm. The tolerance for hole location through the calibration block thickness (i.e., distance from the examination surface) shall be ±3 mm.

(d) For blocks less than 19 mm in thickness, only the 1/2T side-drilled hole and surface notches are required.

(e) All holes may be located on the same face (side) of the calibration block, provided care is exercised to locate all the reflectors (holes, notches) to prevent one reflector from affecting the indication from another reflector during calibration.

(f) When cladding is present, notch depth on the cladding side of the block shall be increased by the cladding thickness, CT (i.e., 1.6% T + CT minimum to 2.2% T + CT maximum).

(g) Maximum notch width is not critical. Notches may be made by EDM or with end mills up to 6.4 mm in diameter.

(h) Weld thickness, t, is the nominal material thickness for welds without reinforcement or, for welds with reinforcement, the nominal material thickness plus the estimated weld reinforcement not to exceed the maximum permitted by the referencing Code Section. When two or more base material thicknesses are involved, the calibration block thickness, T, shall be determined by the average thickness of the weld; alternatively, a calibration block based on the greater base material thickness may be used provided the reference reflector size is based upon the average weld thickness.

NOTES:

(1) Minimum dimension.

Fig (5):NON-PIPING CALIBRATION BLOCKS

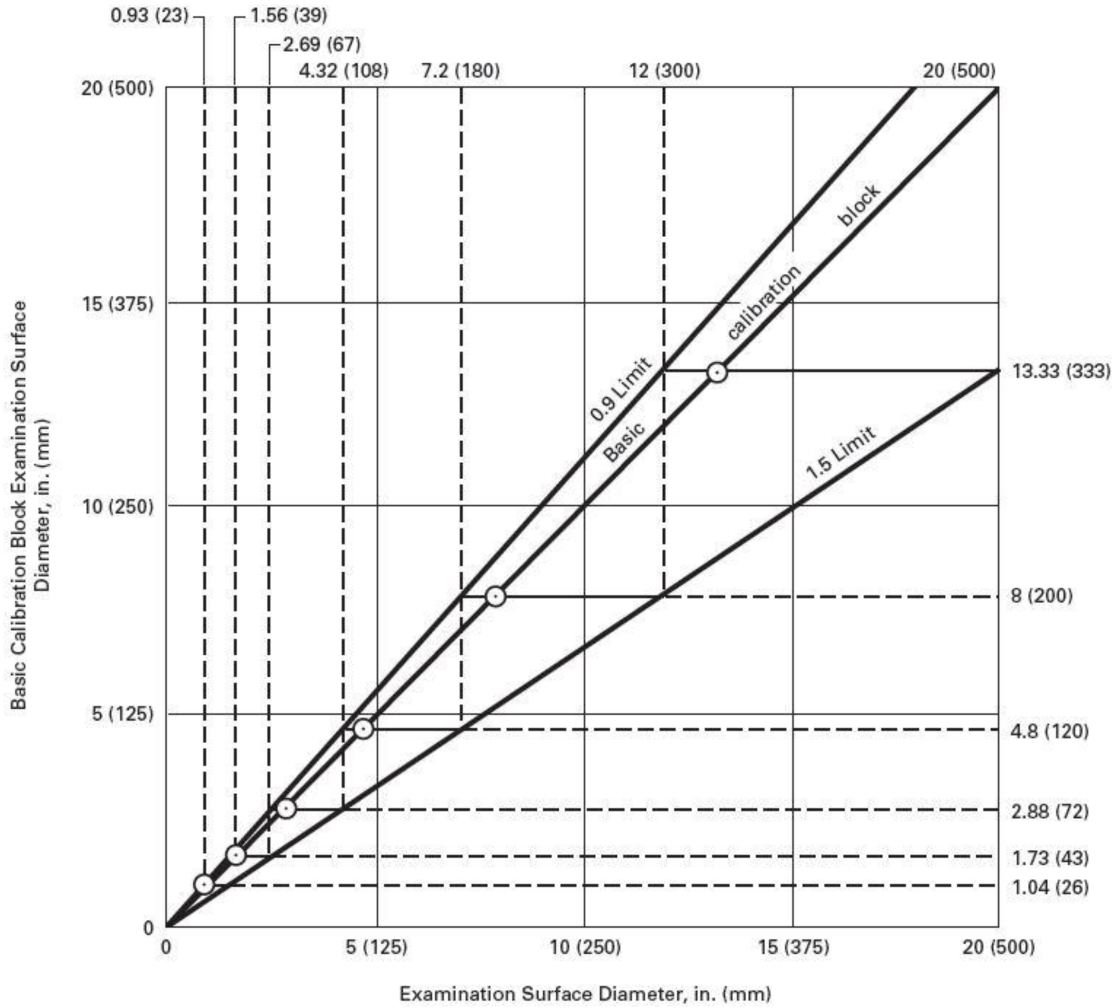


Fig (6): RATIO LIMITS FOR CURVED SURFACES

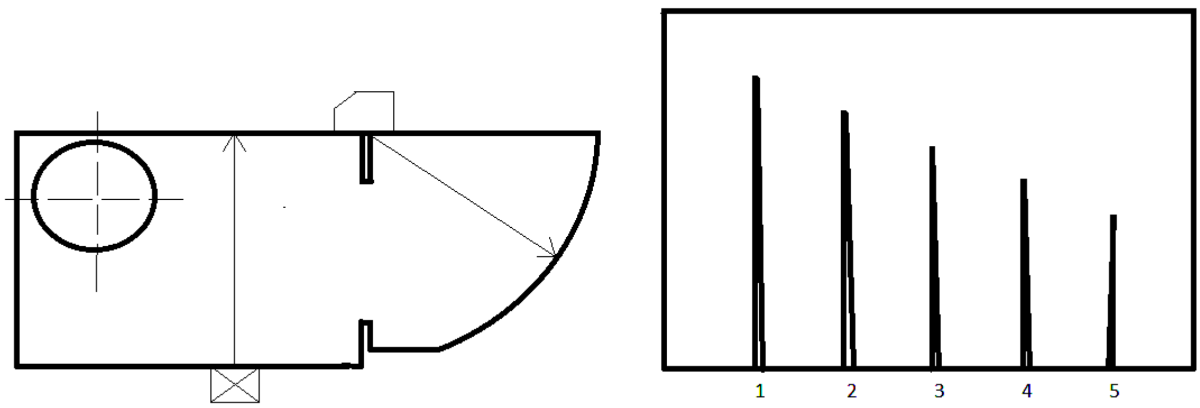


Fig (7): SWEEP RANGE (ANGLE BEAM)

SENSITIVITY AND DISTANCE-AMPLITUDE CORRECTION (SIDE-DRILLED HOLES)

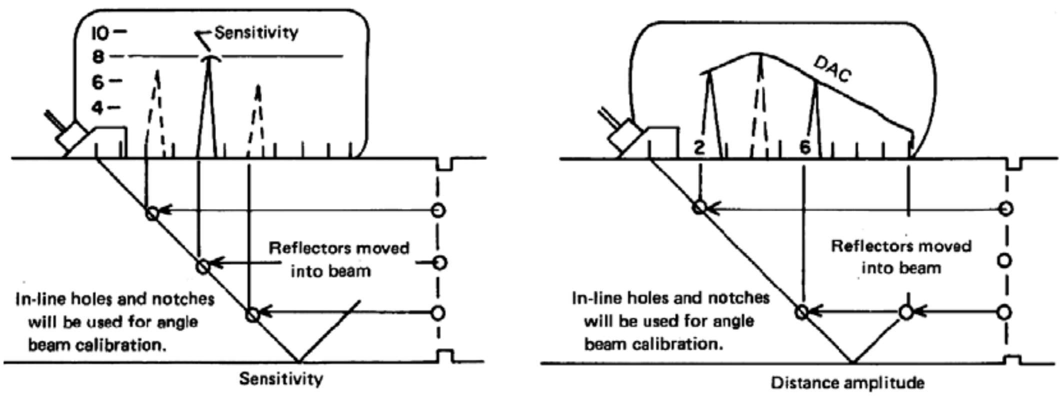


Fig (8): ***DISTANCE-AMPLITUDE CORRECTION (ANGLE BEAM)***

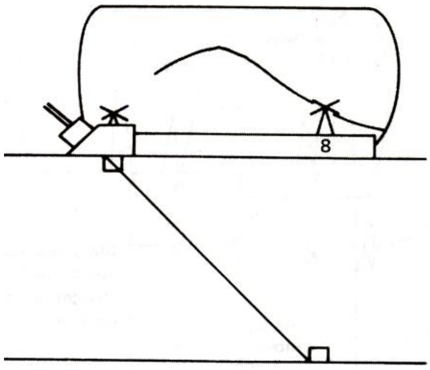


Fig (9) :(ANGLE BEAM) PLANAR REFLECTIONS

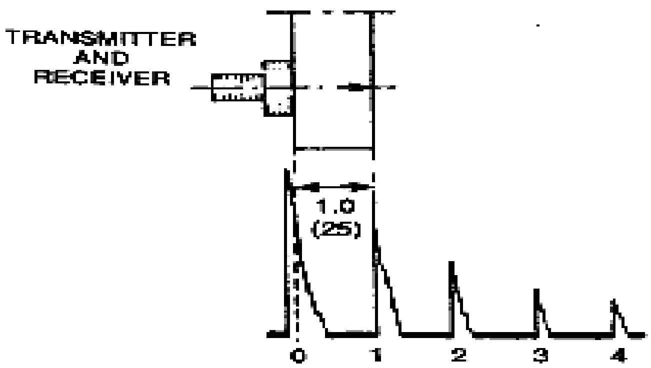


Fig (10): SWEEP RANGE (STRAIGHT BEAM)

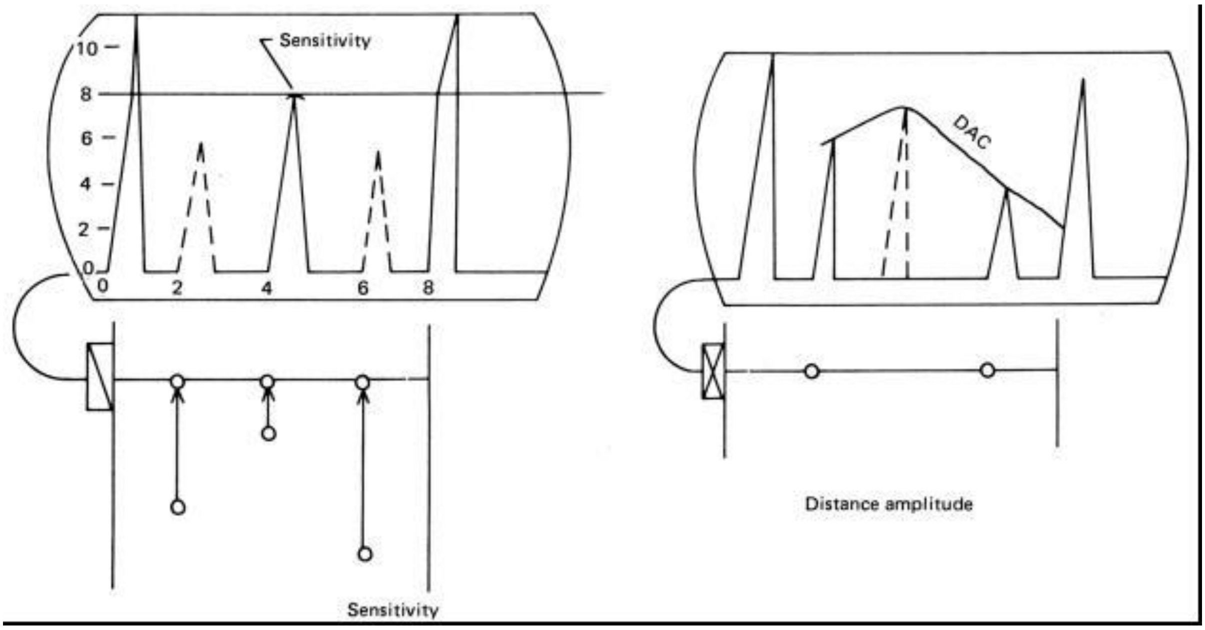


Fig (11): Sensitivity and Distance Amplitude Correction

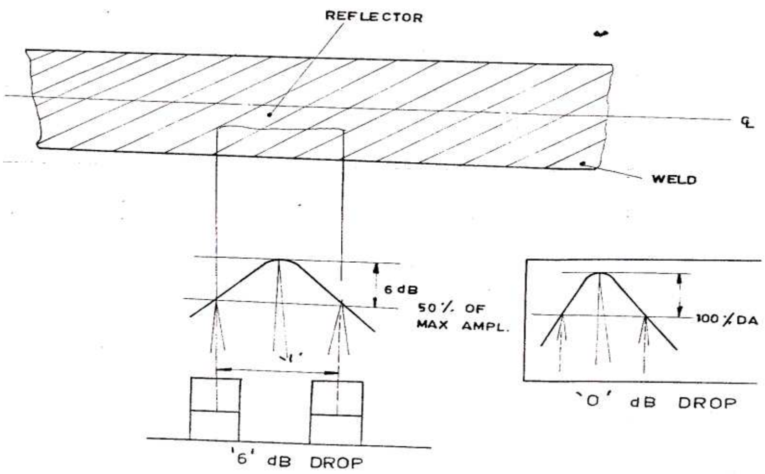
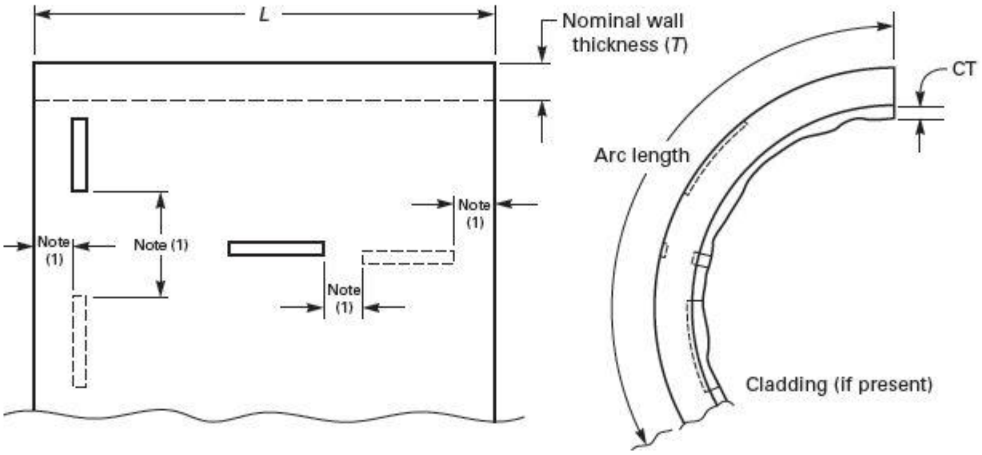


Fig (12): MEASUREMENT OF LENGTH OF REFLECTOR



General Notes:

(a) The minimum calibration block length, L, shall be 200 mm or 8T, whichever is greater.

(b) For OD 100 mm or less, the minimum arc length shall be 270 deg. For OD greater than 100 mm, the minimum arc length shall be 200 mm or 3T, whichever is greater.

(c) Notch depths shall be from 8% T minimum to 11% T maximum. Notch widths shall be 6 mm maximum. Notch lengths shall be 25 mm minimum.

(d) Maximum notch width is not critical. Notches may be made with EDM or with end mills up to 6 mm in diameter.

(e) Notch lengths shall be sufficient to provide for calibration with a minimum 3 to 1 signal-to-noise ratio.

(f) Two blocks shall be used when a weld joining two different thicknesses of material is examined and a single block does not satisfy the requirements of Clause 17.

(g) When a flat block is used as permitted by Clause 17.2, the two axial notches may be omitted and the block width may be reduced to 100 mm provided the I.D. and O.D. notches are placed on opposite examination surfaces of the block. When cladding is not present, only one notch is required provided each examination surface is accessible during calibrations.

NOTE: (1) Notches shall be located not closer than 1/2T or 1/2 in. (13 mm), whichever is greater, to any block edge or to other notches.

Fig (13).CALIBRATION BLOC FOR PIPE

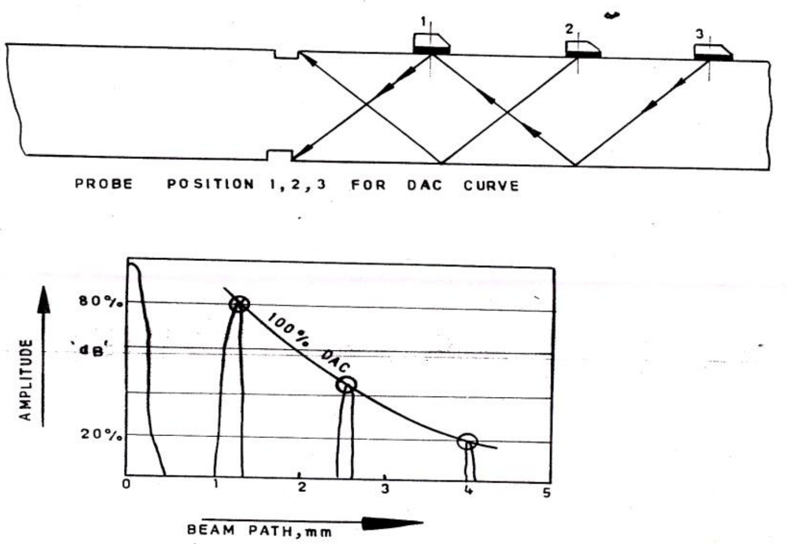
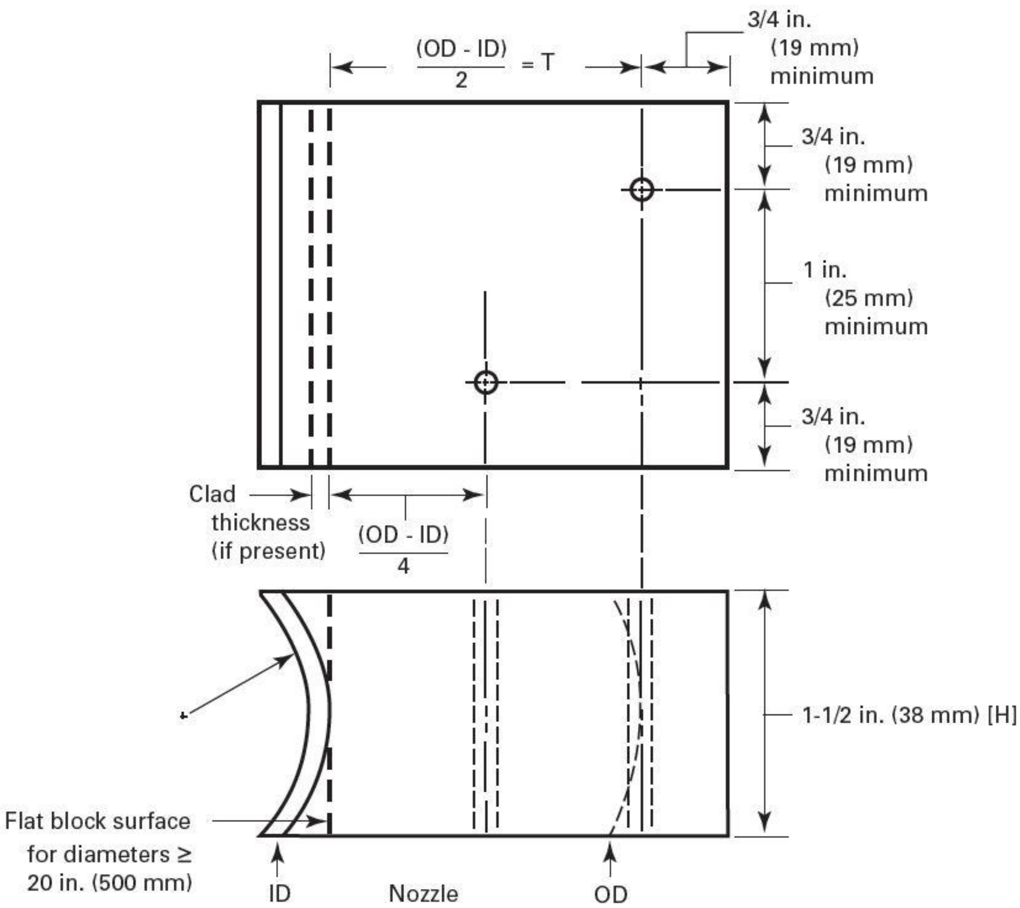


Fig (14): DISTANCE AMPLITUDE CORRECTION (ANGLE BEAM)



Calibration block wall thickness(mm)	Hole location 5/8 T	Hole location 6/8 T	Hole location 7/8 T
>50 through 75		X	
>75	X		X

GENERAL NOTES:
(a) The thickness (T) of the calibration block (OD – ID)/2 shall be selected for the maximum nozzle wall thickness under the nozzle attachment weld.
(b) Side-drilled holes shall be drilled and reamed the full height [H] of the block.
(c) The diameter of the side-drilled holes shall be selected for the maximum nozzle wall thickness per (a) above and Fig (5).
(d) For nozzle side examinations, when the wall thickness of the calibration block exceeds 50 mm, additional side-drilled holes shall be placed in the block as required in the table below.

Fig (15): Calibration block-nozzle side weld fusion zone and adjacent nozzle parent metal examination

__Fig (16): Surface Conditions over which UT need not be carried out__

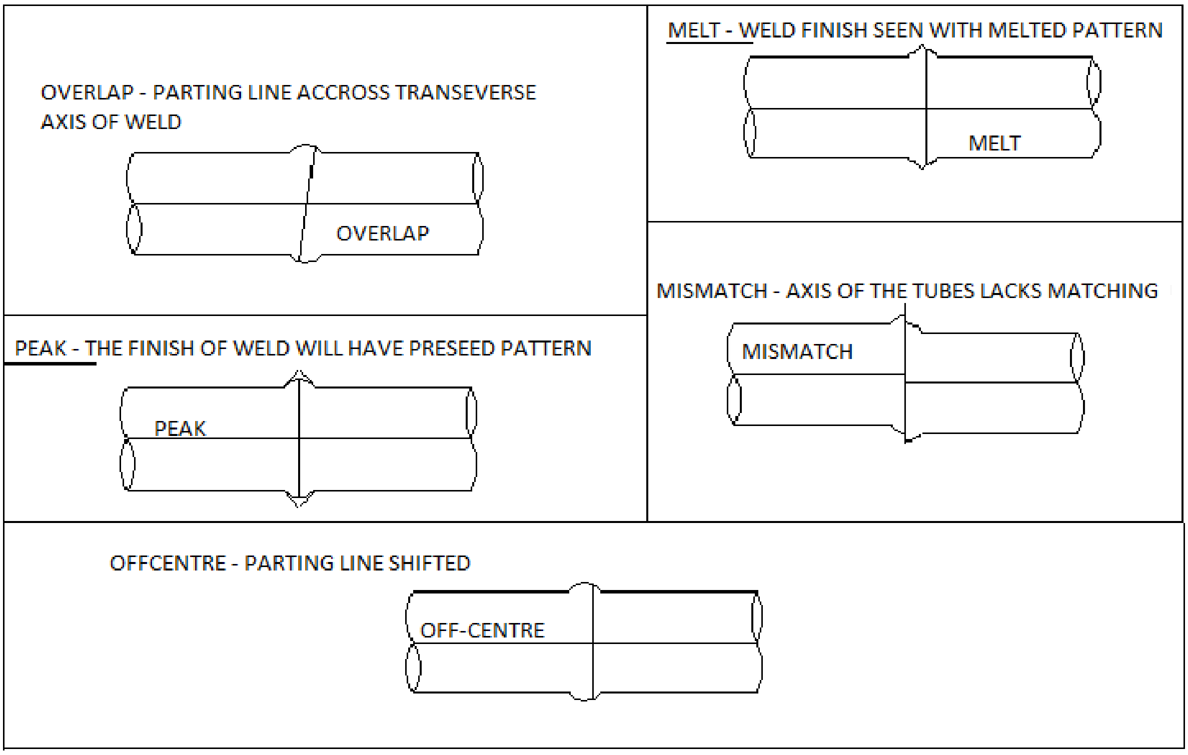


FIG:16

NOTE:

(1).Off-Centre,>1.5 mm, Peak, Melt, Mismatch and overlap are not acceptable
(2).UT need not to be done in case if IPW tube is found to be having such unacceptable defects mentioned in point No 1 above.

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CHAPTER 1.7

ULTRASONIC EXAMINATION OF BUTT WELDS IN X-20, P91 AND P92 PIPES

BHEL	BHARAT HEAVY ELECTRICALS LIMITED DEPT.235 – TIRUCHIRAPALLI – 620 014 Non-Destructive Testing	BHE: NDT: PB: UT- 21 Revision 09 Page 1 of 13

ULTRASONIC EXAMINATION OF BUTT WELDS IN X-20, P91 and P92 PIPES

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EFFECTIVE FROM 01.01.2020

RECORD OF REVISION

Rev. No.	Revision Date	Revision of Details
01	01-04-90	***********
02	01-09-97	Revised in entirety
03	15-03-2000	Revised to include P 91 material. Editorial corrections made
04	4-07-2000	8.4.1.1- Straight beam examination of base metal added. 9.2.3-weld geometry records added.
05	18.01.2010	1.1. 2.1, 3.2, 8.3, 8.4.1 modified Fig 9 added
06	05-06-2012	Title changed. 1.1,2.1,5.2,8.3 and 11.2 modified. 8.2.1 added. Figures 10,11,12 added.
07	16-07-2016	Clause 2.1,4.1,15.1,3.3.1 Revised
08	14-08-2018	Clause 2.2 revised
09	01-01-2020	Clause 2.2 & 4.1 revised

1.0 SCOPE

1.1. This procedure defines the requirements of equipment, calibration, examination procedure and acceptance standards for ultrasonic examination of butt welds, corner welds, Tee welds, fillet welds in X-20, P91 and P92 pipes of dia 120mm to 900 mm and thickness between 10 mm to 150 mm.

2.0 REFERENCE DOCUMENTS

2.1. AD-Merkblatt 2000 HP 5/3 –2011 edition
2.2. ASME-Section-V 2019 Edition

3.0 EQUIPMENT

3.1. The examination shall be conducted by manual contact testing. The equipment shall be of pulse - echo type with A-scan presentation that generates and receives frequencies in the range of 1 MHz to 5 MHz.

3.2. Analog or Digital equipment of Krautkramer /Germany or equivalent make will be used.

3.3. EQUIPMENT CALIBRATION

3.3.1. The Screen height linearity and amplitude control linearity shall be performed in accordance with ASME Sec V Article 4 Mandatory Appendix I & II at the beginning of each period of extended use or every 3 months for analog instrument and one year for digital instrument whichever is less.

3.4. PROBES

3.4.1. The nominal frequency of the probe shall be 4 MHz for thickness less than or equivalent to 40 mm and 2 MHz for thickness greater than 40 mm.

3.4.2. The crystal dimensions will be 8 x 9 mm or 20 x 22 mm and shall be appropriate to the examination surfaces ensuring adequate contact for transmission of ultrasonic vibrations.

3.4.3. Probes with curved contact wedges may be used to improve ultrasonic coupling in which case calibration shall be done with contact wedges used during the examination.

3.5. COUPLANT

3.5.1. Oil, Grease - oil mix or glycerine will be used as couplant. The couplant used for the examination shall be the same as that used for calibration.

4.0 PERSONNEL QUALIFICATION

4.1. Personnel performing examinations shall be qualified in accordance with employer's written down document which is prepared in line with ASNT SNT – TC -1A (2016). The testing shall be conducted by minimum Level-I Personnel & the interpretation and evaluation shall be done by minimum Level-II personnel.

5.0 SURFACE CONDITION

5.1. The probe-to-specimen contact area shall be free from weld spatter, rust, scale, grooves/depressions and other contaminations, which might interfere with probe-to-specimen contact.

5.2. To facilitate the detection of transverse flaws, the weld reinforcement shall be smoothly ground to ensure that there is proper contact between the probe and weld metal and with adjacent parent metal.

6.0 BASIC CALIBRATION BLOCK: Fig (1) and (2)

6.1. The basic calibration block will be a section of the pipe of same nominal size, schedule, heat treatment and material specification or equivalent P-number grouping. Separate calibration blocks shall be used to examine longitudinal and transverse flaws.

6.2. The surface finish of the calibration block shall be representative of the surface finish of the piping. The block width shall be a minimum of 50 mm.

6.3. The basic calibration reflectors shall be 3 mm dia cylindrical holes drilled through the entire width of the block as shown in the sketch.

6.4. A square notch of size 1 mm x 1 mm shall be used to adjust the sensitivity for detection of flaws in the root area and to furnish proof of form echoes in welds at root.

7.0 DISTANCE AMPLITUDE CORRECTION (DAC) - FIG (3) and (4)

7.1. DAC shall be established with basic calibration reflectors. The peak of the indications is marked on the screen and extended to cover the entire examination range for 3/8 to full skip distance between 80% to 20% of Full Screen Height (FSH). This is the reference response (PRR) level.

8.0 EXAMINATION

8.1. The ultrasonic test shall be performed after the last heat-treatment of the production weld.

8.2. The examination shall be performed with TWO angle beam probes. One of the beam angles (incident angle from entry surface) for testing shall be 45 degrees and the other either 60 or 70 depending on the weld configuration.

8.3. The scanning shall be performed from outer surface and from each side of the weld by moving the probes from 3/8th to one-vee sound path (full skip) distances. If only one side is accessible, testing within the stated scope takes place on one side only. In the case of nozzle welds, wherever scanning distance is insufficient, it can be also be done from inside of the nozzle (Fig 9).

8.4. Area of base-metal coverage - FIG (5)

8.4.1. The entire volume of the weld inclusive of adjacent base metal (heat-affected zone) shall be scanned by moving an angle-beam probe over the examination surface to appropriate distances. The evaluation range includes the entire skip distance in the case of smaller beam angle and includes half skip distance in the case of large beam angle. The adjacent base metal on both sides of the weld, to be included for scanning is: 10 mm for weld thickness (t) less than or equal to 30mm;1/3 't' for 't' greater than 30 mm and less than or equal to 60 mm and 20 mm for 't' greater than 60 mm.

8.4.2. The entire area of base metal inclusive of heat affected zone on both sides of the weld on which the angle-beam probe is employed for examination shall be examined using a straight-beam probe to detect reflectors that might affect interpretation of angle-beam results and is not used for acceptance -rejection examination. Location and areas of such reflectors shall be recorded.

8.5. During scanning the probes shall be moved to and fro, with swiveling action of 10 degrees to 15 degrees on either side with overlap between successive scanning. Each pass of the probe shall overlap a minimum of 10% of the crystal element dimension perpendicular to the direction of the scan. (FIG 5).

8.6. The rate of probe movement for examination shall be less than or equal to 150 mm/sec.

8.7. LONGITUDINAL FLAW SCANNING

8.7.1. The angle beam shall be directed at 90 degrees to the weld axis. The probe shall be manipulated so that ultrasonic energy passes through the required volumes of weld and adjacent base material as in 8.4.

8.8. TRANSVERSE FLAW SCANNING

8.8.1. The incident beam angle shall not be less than 45 degrees.

8.8.2. The angle beam shall be directed essentially parallel to the weld axis and the probe shall be manipulated so that the angle beam passes through required volumes of weld and adjacent base metal as in 8.4. The probe shall be rotated 180 degree and examination repeated.

8.9. ROOT FLAW SCANNING

8.9.1. For the evaluation of "Root Flaws" the amplitude response level from 1mm deep notch located at ID surface shall be compared with "PRR level". If the amplitude response is less than DAC, the gain setting shall be further increased to equalise DAC. If the response level is greater than DAC no further correction necessary.

8.10. EXAMINATION SENSITIVITY

8.10.1. For scanning, sensitivity settings shall be further increased by 6 dB and evaluation shall be performed at Primary Reference Response Level.

8.11. RECORDING LIMIT

8.11.1. All indications that equal or exceed 50 % of DAC, for longitudinal flaw scanning & 25% of DAC, for transverse flaw scanning at PRR Level shall be recorded.

9.0 EVALUATION OF ECHOES- FIG (6) and (7)

9.1. Indications that are determined to originate from surface conditions or weld shapes such as weld reinforcement, root protrusion, counter-bore, mismatched upset on ID and OD shall be assessed to identify and classify them as 'geometry indications'.

9.2. CONTROL MEASURES FOR GEOMETRY INDICATIONS

9.2.1. Response from 1 mm x 1mm square notch shall be employed for verification and accurate determination of projection distances involved during examination.

9.2.2. The following conditions related to indications obtained and which are assessed in line with 9.2.1, as a 'geometry indications due to shape' are acceptable. The verification shall be demonstrated over the total length of the reflector.

a) Mismatch / counter-bore: The reflector does not indicate an echo when scanned from the other side of weld

b) Excess penetration or Root-concavity: The echoes are received from both sides of the weld, that may be from the edges of a root-reinforcement or root-concavity with an overlap or a gap greater than 3mm between the locations of projected surface distances.

9.2.3. Weld geometry records will be made available at the time of examination.

10.0 LENGTH DIMENSIONING: FIG (8)

10.1. When the height of the indication from discontinuity exceeds the recording level, the length shall be obtained by 6 dB (50%) drop method for weld thickness less than or equal to 40 mm and by 12 dB (25%) drop method for weld thickness greater than 40 mm.

10.2. The lengths equal to and less than 10 mm shall be recorded as 10 mm. Other lengths measured shall be recorded in steps of 5 mm.

10.3. The measured length of Longitudinal flaw, as above, may be corrected for

a. Beam spread;

b. Projection of measured length of the defect to the outer surface.

10.4. Higher frequency/special probes may be used for assessment of flaws and flaw length measurement.

11.0 ACCEPTANCE STANDARD FOR LONGITUDINAL FLAW

11.1. All indications that exceed the primary reference level are not acceptable.

11.2. Indications from imperfections are not acceptable if the indications exceed 50% of the primary reference response level and have lengths which exceed

a. 20 mm for 't' greater than 10 mm and less than or equal to 20 mm

b. 25 mm for 't' greater than 20 mm and less than or equal to 40 mm

c. 30 mm for 't' greater than 40 mm and less than or equal to 60 mm

d. 40 mm for 't' greater 60 mm and less than or equal to 120 mm

e. 50 mm for ‘t’ greater than 120 mm

where ‘t' is thickness of weld excluding any allowable reinforcement.

11.3. In any '6t' length of weld the aggregate length of indications shall not exceed ‘1.5 t' for thickness upto 60 mm and '2t' for thickness greater than 60 mm.

11.4. f the distance between successive indications is less than twice the length of the longer indication, the two indications in question shall be considered as continuous and evaluated as in 11.2.

11.5. For a butt weld joining two members having different thickness at the weld, 't' is the thinner of the thickness. If a full penetration weld includes a fillet weld, the thickness of 'throat' of the fillet shall be included in 't'.

12.0 ACCEPTANCE STANDARD FOR TRANSVERSE FLAW

12.1. All indications that exceed 50% DAC are unacceptable. Between 25% and 50% of DAC, only 3 indications of length upto 10 mm are permissible per meter of weld as transverse flaws.

13.0 POST CLEANING:

13.1. After the examination is over the couplant applied on the surface shall be removed, if the residue couplant on the surface applied could interfere the further use of the test piece.

14.0 REPAIR:

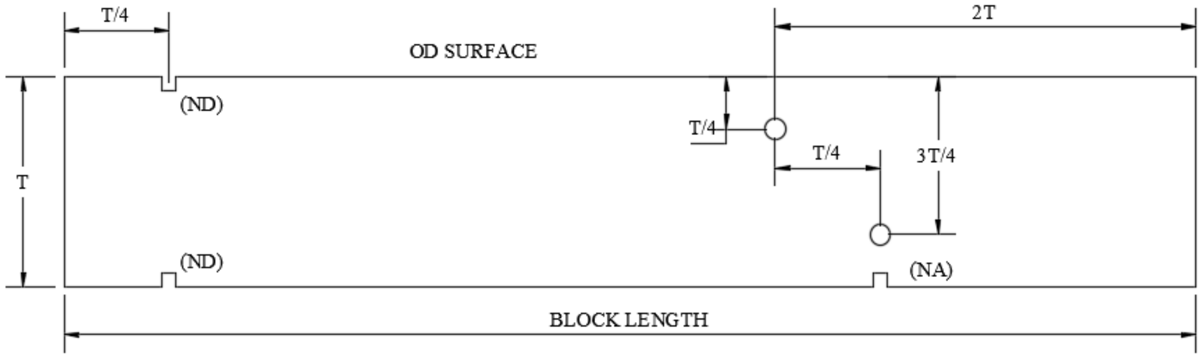
14.1. Repaired welds in shall be re-examined by the same procedure used for original testing.

15.0 REPORT:

15.1. A detailed report duly signed by a minimum Level II NDE personnel shall be issued in accordance with T-491 & T-492 of Article 4 ASME Sec V.

15.2. The records made in the inspection register shall be retained till manufacturing is completed, unless otherwise required.

****



CALIBRATION BLOCK 1 (L)

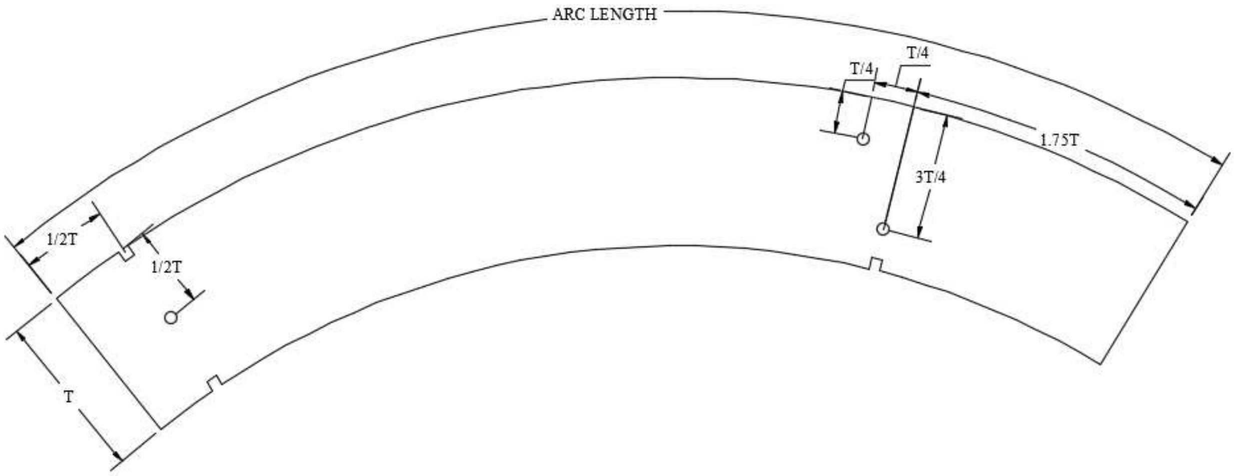
(SECTION OF PIPE PARALLEL TO PIPE AXIS)

3 mm CYLINDERICAL HOLE

ND 1mm x 1 mm NOTCHES(DIN)

NA 10% T DEEP NOTH

Fig (1)



CALIBRATION BLOCK 2 (T)

(SECTION OF PIPE PERPENDICULAR TO PIPE AXIS)

FIG (2)

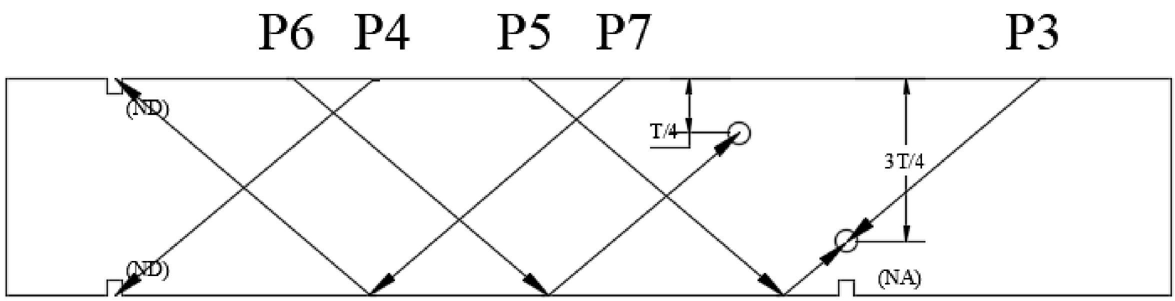


FIG (3) ANGLE BEAM CALIBRATION: AXIAL SCAN

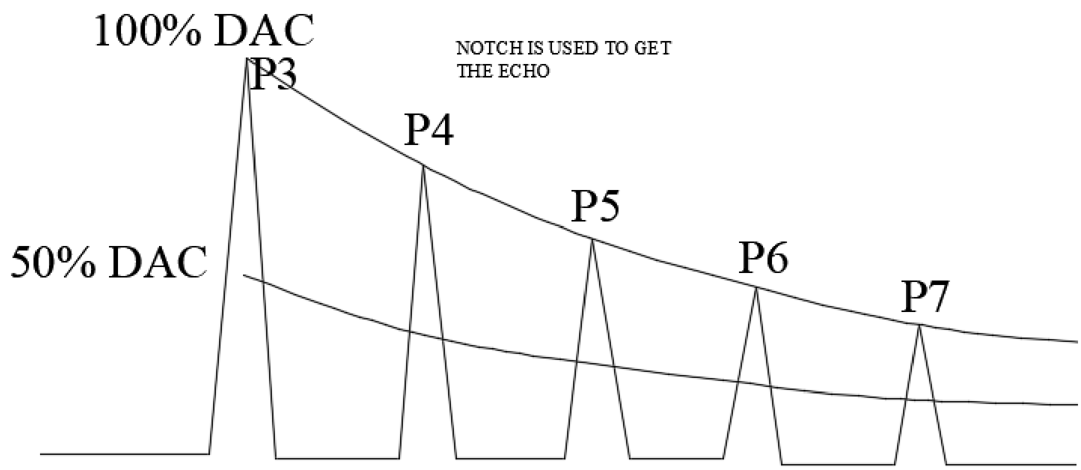


FIG (4) DAC FOR AXIAL SCAN

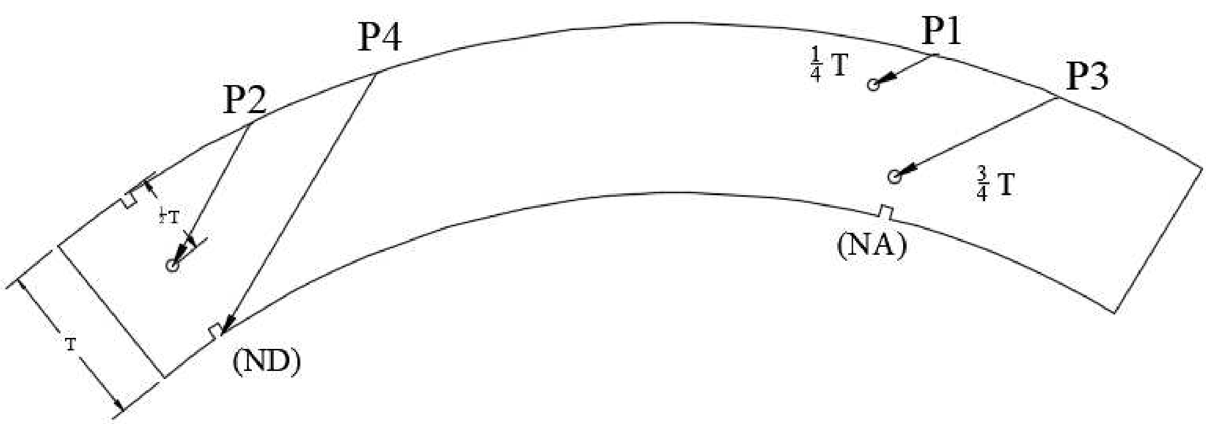


FIG (5) ANGLE BEAM CALIBRATION: CIRCUMFERENTIAL SCAN

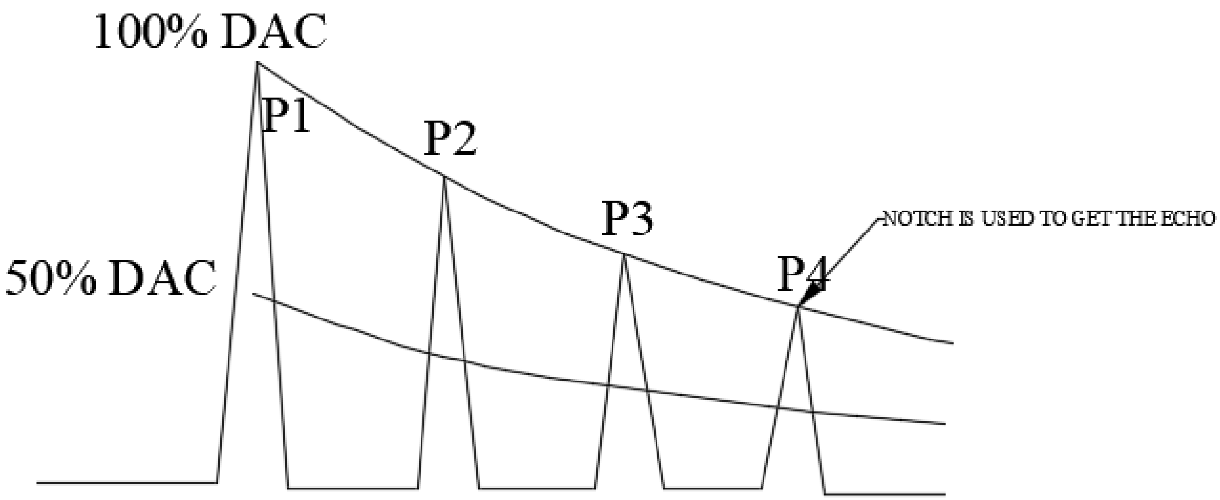
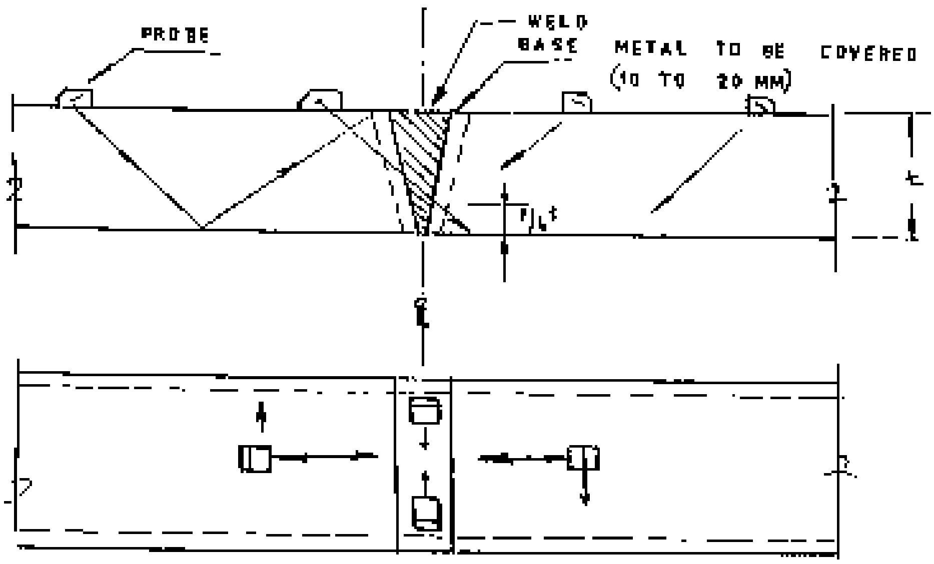
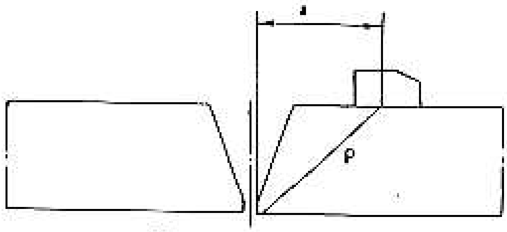


FIG (6) DAC FOR CIRCUMFERENTIAL SCAN



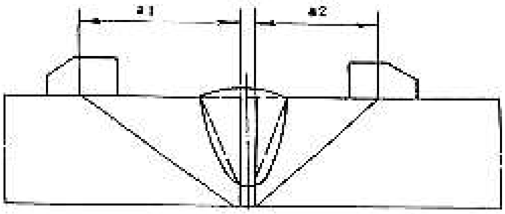
OVERLAP 10% SWIVELLING 10 to 15 Degrees

FIG (5) SCANNING DIRECTIONS

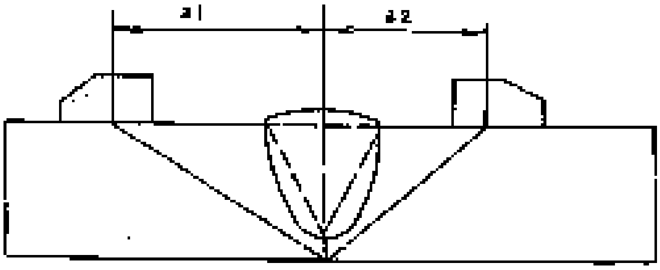


a = PROJECTION LENGTH

P = SOUND BEAM PATH

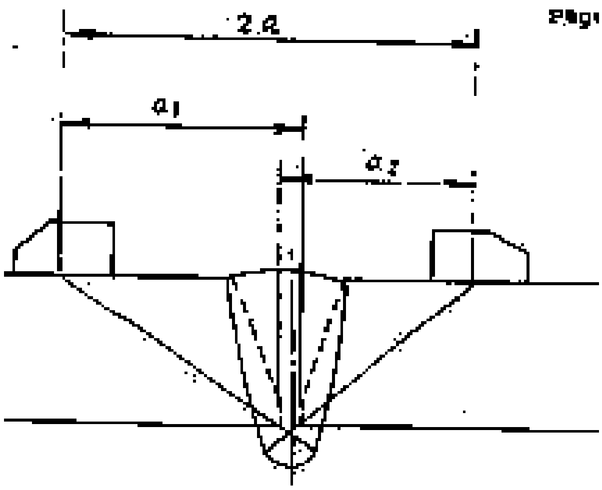


a1 and a2 INCOMPLETE ROOT PENETRATION

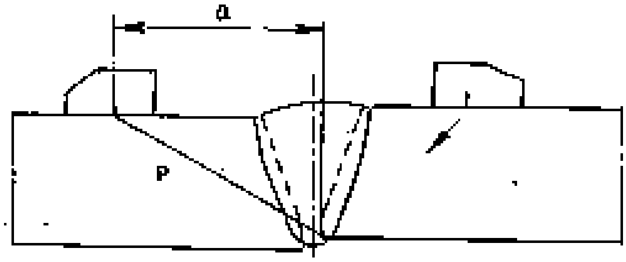


a1 and a2 TIGHT INCOMPLETE ROOT PENETRATION

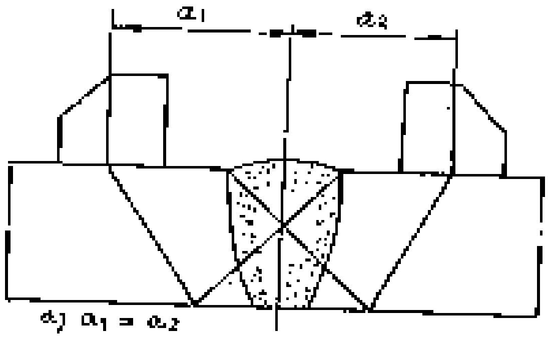
Fig (6)



EXCESSIVE ROOT PENETRATION (a1+a2)=2a = >2MIN



LINEAR MIS ALIGNMENT



EXCESSIVE REINFORECEMENT (Fig 7)

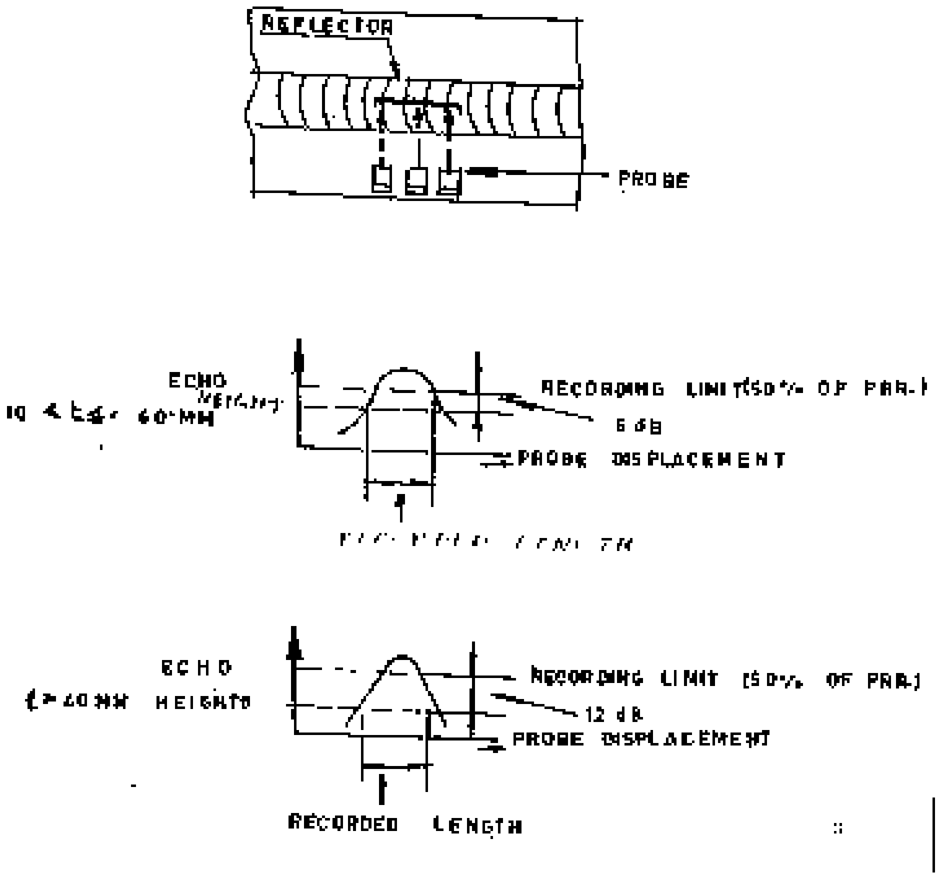
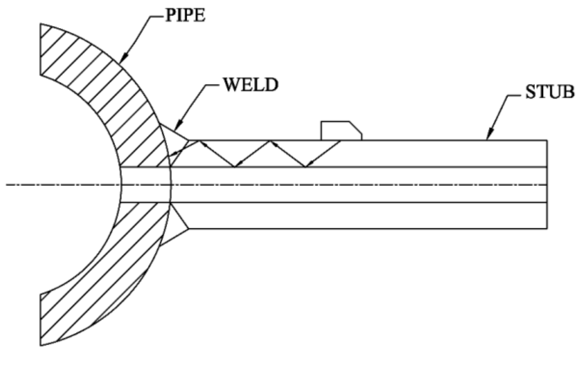


FIG (8) DETERMINATION OF LENGTH OF REFLECTOR



Fig(9) FILLET WELD EXAMINATION

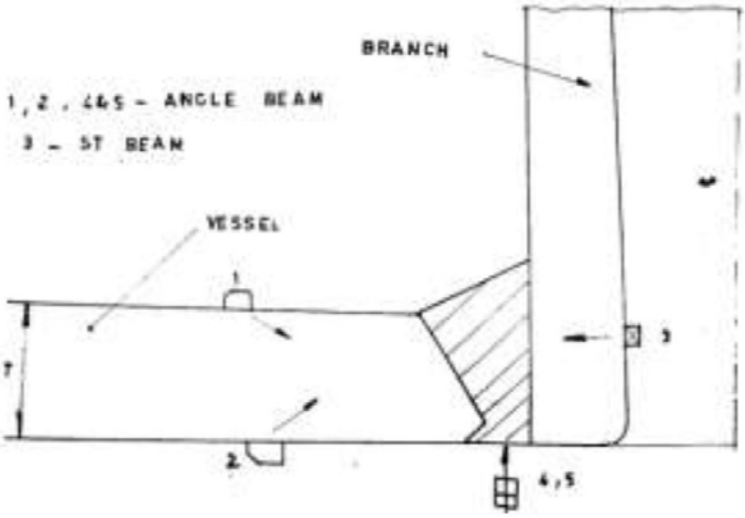


Fig. 10. SCANNING DIRECTION- FULL PENETRATION CORNER WELD (SET-THROUGH)

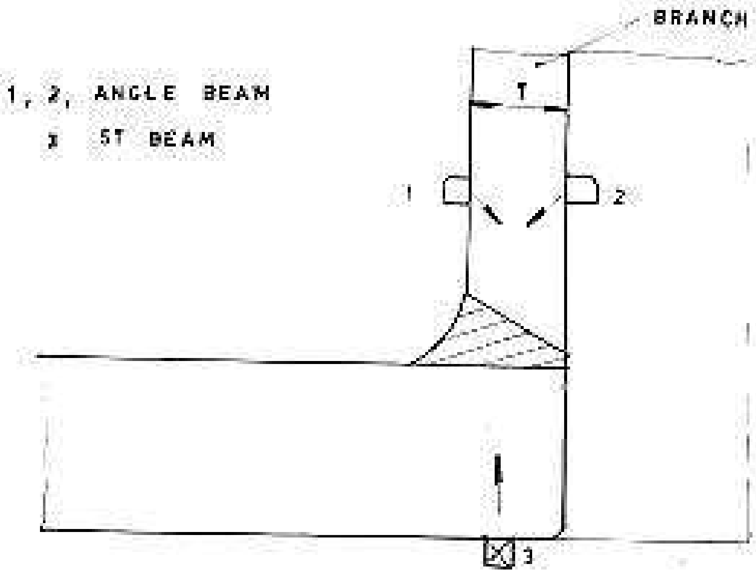


Fig.11. SCANNING DIRECTIONS FULL PENETRATION CORNER WELDS (SET-ON)

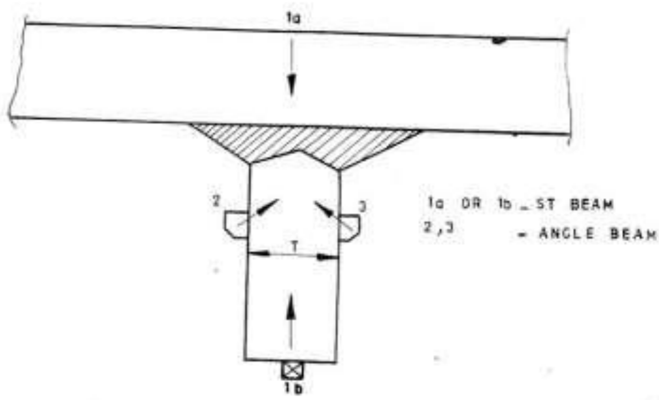


Fig.12. SCANNING DIRECTION FOR 'T' WELDS (ATTACHMENT)

CHAPTER 1.8

PROCEDURE FOR CALIBRATION OF PULSE-ECHO ULTRASONIC TESTING SYSTEMS

BHEL	**BHARAT HEAVY ELECTRICALS LIMITED** **DEPT.235 – TIRUCHIRAPALLI – 620 014** **Non-Destructive Testing**	BHE:NDT:UT:CALIB- 01 Revision 08 Page 1 of 10

PROCEDURE FOR CALIBRATION OF PULSE-ECHO ULTRASONIC TESTING SYSTEMS

Prepared By	Reviewed By	Approved By	Issued By
01-01-2020	01/01/2020	B.K. Sethupathy 01-01-2020	01/01/2020
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Effective from 01-01-2020

RECORD OF REVISION

Rev. No	Revision Date	Revision of Details
01 & 02	****	Kept separately
03	21-07-1997	Editorial corrections reflecting Addenda 1996
04	26-12-2006	2.1 Revised 5.2 Modified 10.1 Modified Figure numbers 1 to 4 rearranged
05	30-12-2011	2.1 Revised 9.2 Revised 9.3 Added
06	29-07-2013	Clause 1.0, 2.1, 3.2, 9.2 Revised Clause 9.4 Added Report Format Revised
07	01-01-2016	Clause 2.1 and Table 1 revised
08	01-01-2020	Clause 2.1, 2.2, 6.2, 7.1 revised

Sl.No.	*Table Of Contents*	*Page No.*

1.0 Scope

1.1. This procedure describes the method of Calibration of Pulse-echo, manual contact method Ultrasonic testing equipment with A-scan display.

2.0 REFERENCE DOCUMENTS

2.1. ASME - Section V - 2019

2.2. SE317-16

3.0 Equipment

3.1. Ultrasonic Testing Equipment.

3.2. 4MHz Miniature Normal and Angle Beam Probe, and basic calibration block, shall be used for calibration. The calibration block shall be of similar metallurgical structure and possess the same attenuation characteristics as that of the material under test. For contact examination the temperature difference of the examination surface and the calibration block surface shall be within 14 degree C.

4.0 Linearity of Time Base

4.1. Linearity of the time base shall be checked using Normal probe on IIW block or any other basic calibration block.

4.2. The linearity shall be verified for 100mm, 250mm and 500mm range.

4.3. 100mm range shall be verified with N-23 or 4 MHz miniature normal probe with the IIW block or any of the basic calibration blocks. 4 echoes will be obtained from 25mm side. 1st echo and 3rd echo will be made to coincide with 25mm and 75 mm of the time base. Then 2nd and 4th echo will automatically align with 50mm and 100 mm mark.

4.4. For 250mm range, using delay control, the leading edge of first echo will be adjusted to the '0' division of the time base. If the 6th echo remains on 10th division, the range is linear.

4.5. The procedure as in 4.4 will be repeated for 500 mm range, with first echo on '0' division and 11th echo on 10th division.

4.6. The non-linearity of the time-base shall not be greater than 2% of the full scale range or ± one minor sub-division of the chosen range of the time base (fig-1&fig.-2).

5.0 Verification of Screen Height Linearity

5.1. A straight-beam search unit having the nominal frequency 2MHz or 4 MHz, shall be used. The search unit shall be positioned over the depth resolution notch in the IIW Block so that the signal from the notch is 40% of the screen height, and the signal from the 100mm back surface is 80% of screen height, to give 2:1 ratio.(Fig.3).

5.2. Without moving the search unit, the gain setting is decreased in 2 dB step and the height of notch signal and back reflection are to be recorded. The reading of notch echo shall be 50%

of back reflection echo within 5% of full screen height. The setting and readings shall be established to the nearest 1% of full screen height.

6.0 Verification Of Amplitude-Control Linearity

6.1. Drilled holes shall serve as basic calibration reflectors. The depth, location and diameter of the holes shall be as given in Fig.4. Alternatively, any other conventional reflector from any calibration block may be used with straight or angle beam.

6.2. To verify the amplitude control linearity, an angle beam search unit is positioned as shown in Fig.4, and beamed towards the 1/2t hole in the basic calibration block. The indication is peaked on the screen to 80 %. With the decrease and increase of dB as shown in the table-1 below. The amplitude of the corresponding echo is noted. The indications must be within the specified limits.

TABLE - 1

Indications set at % of full screen	dB control change	Indication limit % of full screen
80%	-6 dB	35 to 45%
80%	-12dB	*15 to 25%*
40%	+6 dB	*65 to 95%*
20%	+12dB	*65 to 95%*

The setting and readings must be estimated to the nearest 1% full screen.

7.0 Sensitivity

7.1. The sensitivity of the equipment shall be checked with an angle beam probe by detecting the 1.5 mm side drilled hole in the IIW block. Sensitivity shall also be checked with a straight beam probe by placing on the surface of the plastic insert of IIW Calibration block and verifying the number of full- screen bottom echoes visible on the screen. At the full-gain setting, if necessary, the number of echoes shall be not less than the numbers shown below for the appropriate frequency range.

Frequency Range MHz	Minimum number of full screen bottom echoes
1.0 to 2.0	3
2.0 to 5.0	2

8.0 CHECKING OF RESOLUTION

8.1. The search unit and apparatus combined shall be capable of clearly resolving two or more echoes reflected from defects situated close to one another. When the search unit (normal probe) is position over the depth resolution notch in IIW block, the reflection is from 85, 91 and 100mm.

8.2. The echoes from 91 and 100mm shall be kept equal to 80% of screen height. If the falling edge of the first echo is within 20% of the full screen (the first major division of the vertical scale) the resolution is satisfactory. Patterns of good and poor resolution are shown in Figure-5.

9.0 Frequency Of Calibration

9.1. During calibration if the linearity is not within the limits mentioned above, the equipment will be sent for rectification.

9.2. Verification of vertical scale linearity, amplitude control linearity and linearity of time-base shall be performed every 3 months for analog and every one year for digital equipment, or whenever the unit has under gone major repairs or maintenance, or the accuracy of the equipment is suspected.

9.3. When the equipment is lost, damaged, or found to be out of calibration, the validity of previous measurement, inspection or test results and the acceptability of items previous inspected or tested shall be evaluated.

9.4. The normal and angle beam probes along with the cables used shall be checked before the use.

10.0 Report and Retention Period

10.1. A report in the prescribed format shall be generated after calibration and issued to the custodian of the equipment. All the reports are to be retained for a period of three years from the date of calibration.

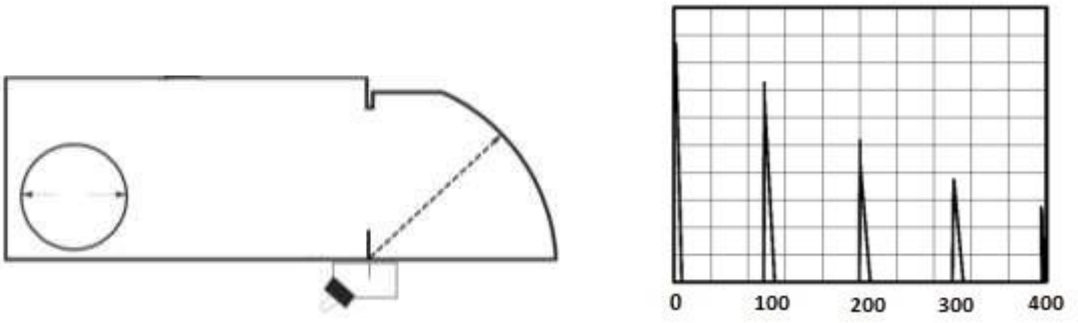

Fig 1 CALIBRATION FOR HORIZONTAL LINEARITY-ANGLE BEAM

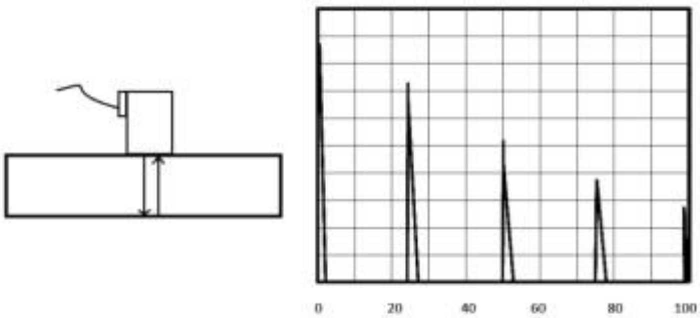

Fig 2 CALIBRATION FOR HORIZONTAL LINEARITY-NORMAL BEAM

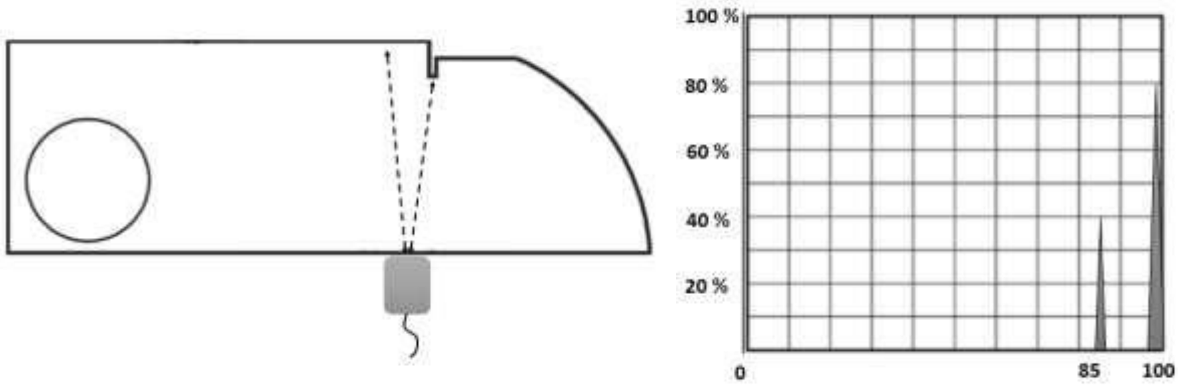

Fig. 3 CALIBRATION FOR SCREEN HEIGHT LINEARITY

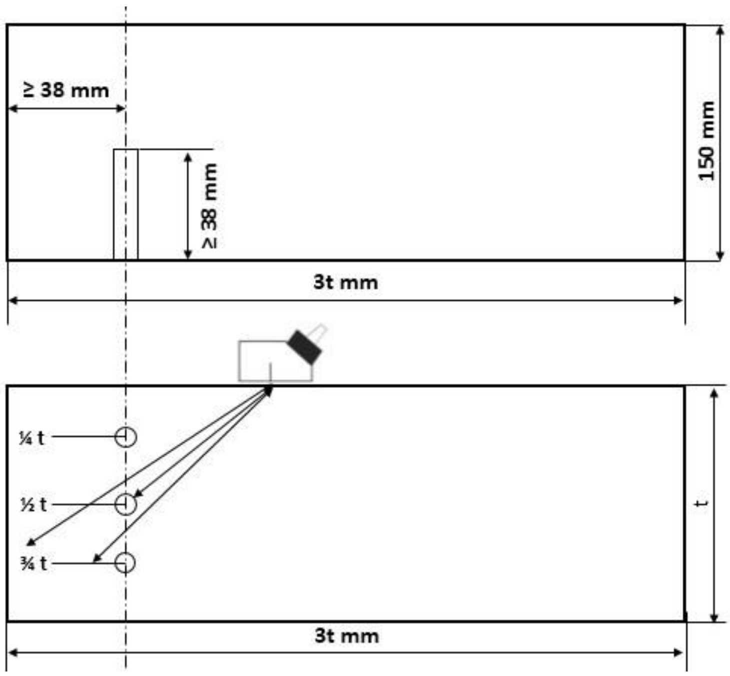

Fig 4 CALIBRATION BLOCK FOR AMPLITUDE CONTROL LINEARITY

Thickness ‘t’ in mm	Calibration Block thickness ‘T’ in mm	Hole depth(mm)	Hole Dia(mm)
Over 50 thru 100 Over 100 thru 150 Over 150 thru 200	75 mm ot ‘t’ 125 mm or ‘t’ 175 mm or ‘t’	≥ 38 ≥ 38 ≥ 38	4.75 6.25 7.50

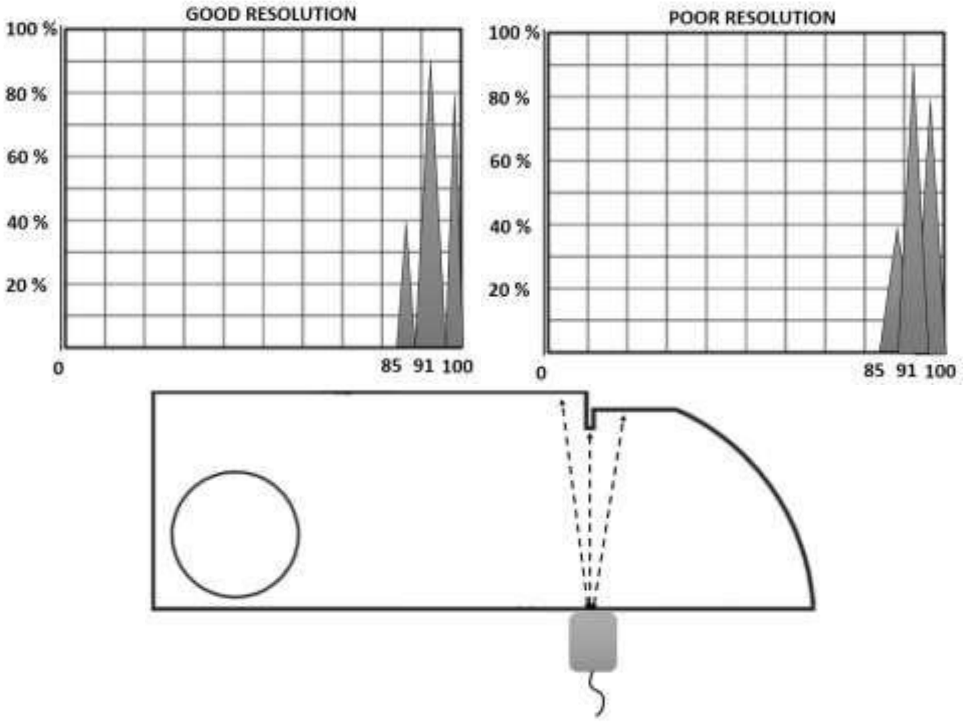

Fig 5 RESOLUTION PATTERN

Ultrasonic Test
Calibration Report

Area :
Type : Digital/Analog
For :

A: Equipment Details

01. Unit Model :
02. Serial No :
03. Make :

B: Calibration Details

04. Procedure Ref : BHE:NDT:UT:CALIB:01 Rev 08.
05. Date of Calibration :
06. *Validity of Calibration* :
(If the equipment has undergone any repair during the intervening period then the validity is not applicable.)

C: Calibration Data:

07. *Probe*:	Frequency	Size
Straight:	4MHz	mm
Angle:	2MHz	mm

08. Verification of screen height linearity:

dB value of larger height indication	1st Larger indication (a%)	2nd Smaller indication - Actual (b%)	2nd smaller indication- Expected (c%)	Deviation (Difference of b& c)
X=__dB X-2dB X-4dB X-6dB X-8dB X-10dB X-12dB				

Note: Deviations within ±5% of FSH are acceptable.

09. Verification of amplitude control linearity:

Indication set at % of full screen	dB control change	Indication Limits	Actual readings % of Full screen
80%	-6dB	35% to 45%	
80%	-12dB	*15% to 25%*	
40%	+6dB	*65% to 95%*	
20%	+12dB	*65% to 95%*	

10. Linearity of Time Base:

Range	Reading	Echo Positions				
		1	2	3	4	5
100	Actual					
	Expected					
	Deviation					
250	Actual					
	Expected					
	Deviation					
500	Actual					
	Expected					
	Deviation					

Note: Deviation ±2% of range or ± one minor sub division is acceptable.

11. *Resolution* :

12. Sensitivity :

13. Remarks :

14. *Recommendation for Rectification* : Not Required /Required

Calibrated By
(Level-II)

Accepted By
(Level-II/III)

CHAPTER 1.9

ULTRASONIC EXAMINATION OF WELD JOINTS IN STRUCTURALS

ULTRASONIC TESTING OF WELD JOINTS IN STRUCTURALS

Prepared By	Reviewed &Approved By
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01-11-2017	01/11/17

EFFECTIVE FROM 01-11-2017

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ISSUED TO	ISSUED ON	CONTROL NO.	ISSUED BY

RECORD OF REVISION

Rev. No	Revision Date	Revision of Details
01	23-10-2006	Clause 12.0 modified
02	01-07-2016	Clauses 1.0, 2.1, 3.1, 4.2.1, 9.2, 9.3, 9.5.1, 18, Annexures A, B (B.1.6, B.3.1, B.3.2, B.3.11, B.4.0, B.4.1, B. 4. 2), C, Revised. Captions for Figures (1), (2), (3), 4(a), 4(b), 5, 6 added. Notes Added in Figure (6). Clauses B.4.3, B.4.3 (Annexure B) removed.
03	01-11-2017	Clause 13.3 removed. Clauses 17.1.1 modified.

1.0 SCOPE

This procedure describes the Ultrasonic testing method for butt welds in Steel structures (thickness > 8 mm *and < 200 mm both inclusive*) where radiography with Ir-192 is not feasible at site. *This procedure shall not be applicable to tube-to –tube T, Y, K connections.*

2.0 REFERENCE

2.1 AWS D1.1 / D1.1.M 20*15- Structural welding code -Steel*

3.0 PERSONNEL QUALIFICATION

3.1 Personnel shall be trained and certified as Level II as per SNT-TC-1A of ASNT. *The qualification of the personnel shall include a specific and practical examination as per the requirements of this procedure or referencing code.*

4.0 EQUIPMENT

4.1 Ultrasonic equipment shall be of pulse echo A-scan type and operate in 1-6 MHz Frequency range.

4.2 CALIBRATION

4.2.1 The equipment shall be qualified as per annexure B at the following interval

- Gain control check –2 months.
- Horizontal Linearity – *2 months.*
- Internal Reflection - every 40 hours of equipment use.
- *Angle beam search units (Index point, Angle)-8 hours of use.*
- *Instrument / search unit combinations(Resolution for normal/angle beam)-prior to initial use*
- *Range, Sensitivity calibration for testing-Just prior to at the location of the first weld tested*

4.2.2 Equipment shall have a calibrated gain control adjustable to 1 or 2 dB step over a range of 60 dB. The accuracy of the gain setting shall be within +or- 1 dB.

4.2.3 Display Range

4.2.3.1 The dynamic of the display shall be such that a difference of 1 dB of amplitude can be easily detected on the display.

5.0 PROBES / TRANSDUCERS

5.1 STRAIGHT BEAM PROBES

5.1.1 Probes shall be Rounded or Square.

5.1.2 Crystal area shall be between 323 Sq mm and 645 Sq mm.

5.1.3 Resolution shall be good.

5.2 ANGLE PROBES

5.2.1 The transducer and angle wedge may be of an integral unit or two separate elements.

5.2.2 Probe shall be square or Rectangular.

5.2.3 Crystal width may be between 15 to 25 and height between 15-20 mm

5.2.4 Transducer frequency shall be between 2 to 2.5 MHz.

5.2.5 Angle of the probe shall be 70°, 60° or 45° with +/- 2° tolerance.
5.2.6 The distance between edge of probes and index point shall not exceed 25 mm.

6.0 REFERENCE STANDARDS.

6.1 IIW block shall be the standard block used for distance calibration and Sensitivity calibration.

6.2 Use of corner reflection for calibration shall be prohibited.

7.0 SURFACE PREPARATION.

7.1 All surfaces shall be free from weld spatters, dirt, grease, oil, paint, loose-scales etc.

8.0 COUPLANT.

8.1 Couplant to be used shall be glycerin, grease, oil, or grease and oil mixture.

8.2 Couplant used for calibration and testing shall be the same.

9.0 RANGE SETTING.

9.1 Calibration and testing shall be made with Nil reflection level. (Reject/clipping/suppression control shall be turned off)

9.2 Calibration for Sensitivity and range setting shall be done *by the UT operator just prior to and at the location of the first weld tested.*

9.3 Recalibration shall be done after
- Change of operator.
- *2 hours of interval.*
- Probe change.
- Battery change.
- Cable change.
- Power failure.

9.4.1 STRAIGHT BEAM TESTING OF BASE METAL.

9.4.2 Range setting shall be made by keeping the probe on face A (Fig 1.) of base metal and sweep adjusted for a distance of at least 2 Plate thickness.

9.4.3 From defect free location the back wall echo shall be adjusted using gain control for a height of 50% to 75 % Full Screen Height (FSH).

9.5 ANGLE BEAM RANGE SETTING.

9.5.1 The angle probe shall be placed in position D on IIW block (*Refer Fig. 2*) and sweep adjusted to have indications at 100 mm, 200 mm, 300 mm, etc. according to the probe angle and thickness of weld to be tested.

10.0 ZERO REFERENCE LEVEL (‘b’ on ultrasonic test report).

10.1 The probe shall be placed on position ‘A’ (fig 2) on IIW block and focused towards 1.59mm hole to attain a height of 50% of Full screen height by adjusting gain control. This gain shall be used as Zero Reference gain “b” in the report.

11.0 TESTING PROCEDURE

11.1 X-line -weld centerline on the Butt Weld shall be marked as X line to mark the defect location.

11.2 Y- line -to identify face A to measure the location, a ‘y’ line shall be drawn at the start of the weld.

11.3 Inaccessibility

11.3.1 If testing is not possible due to lamination in parent metal one of the following shall be used as an alternate.

- Weld shall be ground flush.
- Testing from face A and B shall be performed.
- Other angles may be used.

11.4 All butt joints shall be tested from each side of the face. Corner and T joints shall be from one side of the weld axis.

11.5 The scanning pattern shall be as in (fig3).

11.6 All welds shall be tested for entire volume and HAZ in 2 crossing directions wherever possible.

11.7 Probe swelling of 10° shall be given during scanning as in A in (Fig3).

11.8 The scanning towards the weld as in B (Fig 3) shall be such that the entire volume is covered.

11.9 Progression distance ‘C’ shall be ½ of probe width.

11.10 Flush ground weld transverse scanning shall be as in D(Fig 3)

11.11 For ungrounded weld, pattern ‘e” shall be used for Transverse scanning at angle of 15° maximum.

12.0 TESTING ANGLE, SCANNING FACE & THICKNESS COVERAGE SELECTION.

Table-1

Material Thickness, in [mm]

Weld Type	5/16 [8] to 1-1/2 [38]		>1-1/2 [38] to 1-3/4 [45]		>1-3/4 [45] to 2-1/2 [60]		>2-1/2 [60] to 3-1/2 [90]		>3-1/2 [90] to 4-1/2 [110]		>4-1/2 [110] to 5 [130]		>5 [130] to 6-1/2 [160]		>6-1/2 [160] to 7 [180]		>7 [180] to 8 [200]	
		*		*		*		*		*		*		*		*		*
Butt	1	O	1	F	1G or 4	F	1G or 5	F	6 or 7	F	8 or 10	F	9 or 11	F	12 or 13	F	12	F

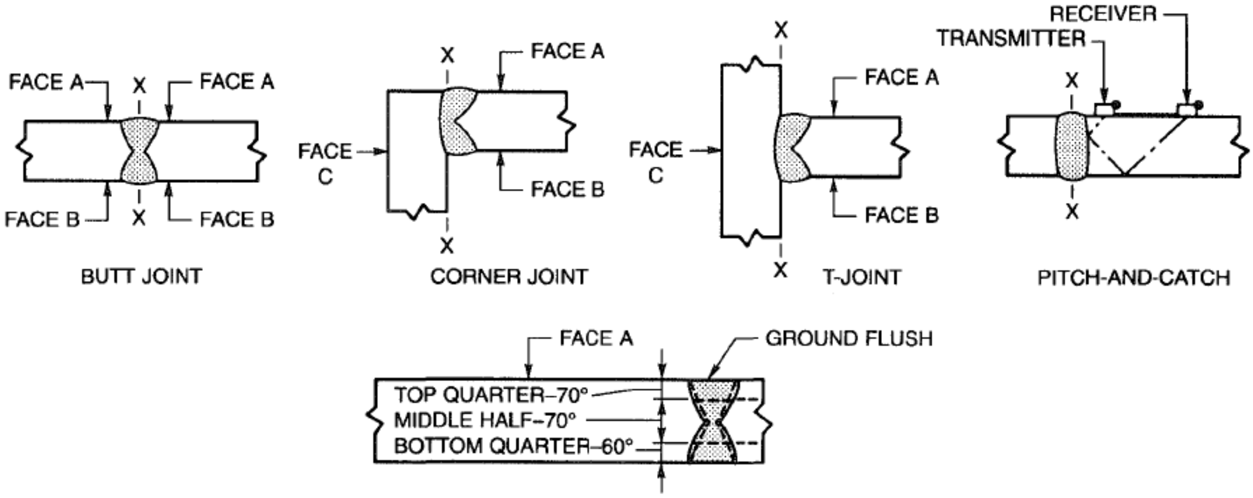


Fig (1)

General Notes

- Wherever possible all examinations shall be from Face A and Leg 1(0-1/2 skip) unless specified.
- Root areas of single groove weld which have backing not requiring removal, shall be tested in leg 1 and Face A opposite to Backing
- If weld is un-ground, Testing in Leg 2 or 3 shall be done.
- Testing in leg 3 shall be done when thickness or geometry prevents full coverage of weld.
- On Tension welds in cyclically loaded structures, top quarter shall be tested from Face A in leg 2 or from Face B in leg 1.
- The weld face shall be flush ground for procedure 1G, 6, 8, 9, 12, 14, 15

PROCEDURE LEGEND

Table-2

	AREA OF WELD THICKNESS		
	Top Quarter	Middle Half	Bottom Quarter
01	70º	70º	70º
02	60º	60º	60º
03	45º	45º	45º
04	60º	70º	70º
05	45º	70º	70º
06	70º G A	70º	60º
07	60º B	70º	60º
08	70º G A	60º	60º
09	70º G A	60º	45º
10	60º B	60º	45º
11	45º B	70º **	45º
12	70º G A	45º	70º G B
13	45º B	45º	45º
14	70º G A	45º	45º
15	70º G A	70º A B	70º G B

LEGEND

X :Check from Face A
G :Grind weld face flush
O :Not required
A Face :The face of material from which the initial scanning done
B Face :Opposite to Face A
C Face :The face opposite the weld on the connecting member of a T or Corner joint.
* :Required only where display reference height indication noted at the weld metal-base metal interface

** : Use 400 or 500 mm range
P : Pitch and Catch shall be conducted
F : weld metal-base metal interface indication shall be further evaluated with either 70, 60 or 45 probe.

13.0 SCANNING LEVEL

13.1 Statically loaded Non-tubular welds

Table-3

Beam Path in mm	Above Zero Reference dB
Up to 65 mm	14
65-125mm	19
125-250mm	29
250-380mm	39

13.2 Cyclically loaded Non-tubular welds

Table-4

Beam Path in mm	Above Zero Reference dB
Up to 65 mm	20
65-125mm	25
125-250mm	35
250-380mm	45

14.0 ATTENUATION FACTOR

14.1 Attenuation factor ‘C’ value in dB shall be calculated as follows

C= (Beam path in inches –1 inch) x 2
e.g. Beam path 115 mm = 4½”
C= (4½”-1”) x 2= 3½” x 2=7
C=7dB

dB less than ½ rounded to the lower level and greater than ½ to the higher level

15.0 INDICATION RATING

15.1 When an indication noticed during scanning, the maximum indication from the discontinuity shall be set to 50% of FSH (Zero reference level) and the gain value is registered as indication level “a” dB.

15.2 The indication rating “d” = a – b - c dB.

16.0 LENGTH OF DISCONTINUITIES

16.1 Straight beam

16.1.1 The boundary of the laminar discontinuities shall be found by 6 dB drop method.

16.2 Angle beam scanning

16.2.1 After attaining the maximum peak from the discontinuity, the probe shall be moved either sides of the indications to drop to 50% (6dB)of the original height. The length between the probe centers on either side is the discontinuity length.

17.0 EVALUATION AND RECORDING

17.1.1 Each weld discontinuity shall be accepted or rejected based on its indication rating and length in accordance with table 5 for statically loaded Non Tubular and Table 6 for cyclically loaded Non Tubular structures.

17.2 Indications which are within 6 dB inclusive of the minimum reflectable rating shall be recorded in the report.

18.0 ACCEPTANCE CRITERIA

18.1 Statically Loaded Non-tubular welds

18.1.1 For web to flange welds, acceptance of discontinuities detected by scanning movements other than ‘e’ may be based on the weld thickness equal to the actual web thickness plus 25 mm.
18.1.2 Discontinuities detected by scanning pattern ‘e’ shall be evaluated for the actual web thickness.
18.1.3 Weld thickness is the nominal thickness of the thinner of the two parts being welded.
18.1.4 Class A (large discontinuities): Any indication in this category not acceptable regardless of length.
18.1.5 Class B (Medium discontinuities):20 mm and above length not accepted
18.1.6 Class C (Small discontinuities):50 mm and above length not accepted.
18.1.7 Class D (Minor discontinuities): Any indication regardless of length and location accepted.

Table-5

Discontinuity Severity Class	Weld Size[a] in inches [mm] and Search Unit Angle										
	5/16 through 3/4 [8–20]	> 3/4 through 1-1/2 [20–38]	> 1-1/2 through 2-1/2 [38–65]			> 2-1/2 through 4 [65–100]			> 4 through 8 [100–200]		
	70°	70°	70°	60°	45°	70°	60°	45°	70°	60°	45°
Class A	+5 & lower	+2 & lower	–2 & lower	+1 & lower	+3 & lower	–5 & lower	–2 & lower	0 & lower	–7 & lower	–4 & lower	–1 & lower
Class B	+6	+3	–1 0	+2 +3	+4 +5	–4 –3	–1 0	+1 +2	–6 –5	–3 –2	0 +1
Class C	+7	+4	+1 +2	+4 +5	+6 +7	–2 to +2	+1 +2	+3 +4	–4 to +2	–1 to +2	+2 +3
Class D	+8 & up	+5 & up	+3 & up	+6 & up	+8 & up	+3 & up	+3 & up	+5 & up	+3 & up	+3 & up	+4 & up

[a] Weld size in butt joints shall be the nominal thickness of the thinner of the two parts being joined.

General Notes:

- Class B and C discontinuities shall be separated by at least 2L, L being the length of the longest discontinuity, except that when 2 or more such discontinuities are not separated by at least 2L, but the combined length of discontinuities and their separation distance is equal to or less than the maximum allowable length under the provision of class B or C, the discontinuity shall be considered s a single acceptable discontinuity.
- Class B and C discontinuities shall not begin at a distance less than 2L, from weld ends carrying primary tensile stress, L being the discontinuity length.
- Discontinuity detected at scanning level in the root face area of CJP double groove welds shall be evaluated using an indication rating 4 dB more sensitive than described in 15.2 when such welds are designated as “ Tension welds”(Subtract 4 dB from the indication rating ‘d’). This shall not apply if the weld is back coughed to remove the root face and MT used to verify that the root face has been removed.
- ESW or EGW: Discontinuity detected at scanning level which exceeds 50 mm in length shall be suspected as being piping porosity and shall be further evaluated by Radiography.
- For indications that remain on the display as search unit is moved towards and away from the discontinuity (scanning movement “b”) may be indicative of planar discontinuities with significant through- throat dimensions.

18.2 Cyclically Loaded Non-tubular Welds

18.2.1 For web to flange welds, acceptance of discontinuities detected by scanning movements other than 'e' may be based on the weld thickness equal to the actual web thickness plus 25 mm.

18.2.2 Discontinuities detected by scanning pattern 'e' shall be evaluated for the actual web thickness.

18.2.3 Class A (large discontinuities): Any indication in this category not acceptable regardless of length.

18.2.4 Class B (Medium discontinuities):20 mm and above length not accepted

18.2.5 Class C (Small discontinuities):50 mm and above length in middle half or 20 mm in top or botton quarter of weld thickness not accepted

18.2.6 Class D (Minor discontinuities): Any indication regardless of length and location accepted.

Table-6

Discontinuity Severity Class	Weld Size[a] in inches [mm] and Search Unit Angle										
	5/16 through 3/4 [8–20]	> 3/4 through 1-1/2 [20–38]	> 1-1/2 through 2-1/2 [38–65]			> 2-1/2 through 4 [65–100]			> 4 through 8 [100–200]		
	70°	70°	70°	60°	45°	70°	60°	45°	70°	60°	45°
Class A	+10 & lower	+8 & lower	+4 & lower	+7 & lower	+9 & lower	+1 & lower	+4 & lower	+6 & lower	–2 & lower	+1 & lower	+3 & lower
Class B	+11	+9	+5 +6	+8 +9	+10 +11	+2 +3	+5 +6	+7 +8	–1 0	+2 +3	+4 +5
Class C	+12	+10	+7 +8	+10 +11	+12 +13	+4 +5	+7 +8	+9 +10	+1 +2	+4 +5	+6 +7
Class D	+13 & up	+11 & up	+9 & up	+12 & up	+14 & up	+6 & up	+9 & up	+11 & up	+3 & up	+6 & up	+8 & up

[a] Weld size in butt joints shall be the nominal thickness of the thinner of the two parts being joined.

General Notes:

- Class B and C discontinuities shall be separated by at least 2L, L being the length of the longer discontinuity, except that when 2 or more such discontinuities are not separated by at least 2L, but the combined length of discontinuities and their separation distance is equal to or less than the maximum allowable length under the provision of class B or C, the discontinuity shall be considered s a single acceptable discontinuity.
- Class B and C discontinuities shall not begin at a distance less than 2L from weld ends carrying primary tensile stress, L being the discontinuity length.
- Discontinuity detected at scanning level in the root face area of CJP double groove welds shall be evaluated using an indication rating 4 dB more sensitive than described in 15.2 when such welds are designated as " Tension welds"(Subtract 4 dB from the indication rating 'd'). This shall not apply if the weld is back gouged to remove the root face and MT used to verify that the root face has been removed

19.0 IDENTIFICATION OF REJECTED AREA.

19.1 Unacceptable discontinuity on weld shall be marked by paint or punching and the depth shall be noted side by.

20.0 REPORT

20.1 The test report as in annexure "A" shall be issued by Level II / III personnel and submitted to the Customer/ Inspection Agency.

21.0 REPAIR

21.1 The repaired area shall be tested and results shall be recorded as above in the report form clearly mentioning the status i.e., after 1st repair or 2nd repair.

ANNEXURE A
REPORT FORMAT

Work Order / Joint Number | Report No.

Weld Identification | Material Thickness

Weld Joint | Weld Process

Quality requirement | Section No

Remarks

Line No	Ind. No	Angle	Face	Leg	Ind.Level	Ref.Level	Attn. Factor	Ind. Rating	Length	Beam path	Depth from Face A	Display		Evaluation	Remarks
												X	Y		

We, the undersigned, certify that the statements in this record are correct and that the welds were prepared and tested in conformation with the requirements of Section 6, Part F of AWS D1.1/ D1.1M , 20*15*, Structural Welding Code- Steel.

Test Date | Manufacture / Contractor

Inspected by | Authorised by

Date

ANNEXURE B
EQUIPMENT QUALIFICATION PROCEDURE

B.1 HORIZONTAL LINEARITY

B.1.1 Probe: 2 MHz- Accuracy 2%
B.1.2 Bloc: IIW
B.1.3 Range: 500 mm
B.1.4 Normal probe shall be kept in position E (Fig 2) to get 5 reflections. First and Fifth reflections shall be set at 2nd and 10th divisions on CRT by adjusting sweep and delay controls
B.1.5 Each indication shall be adjusted to 50% FSH using gain control for each intermediate indication 2, 3 and 4 to coincide with respective positions within 2% of total range or ± 1 division.
B.1.6 *In the case of qualification with angle beam transducer (shear wave), it is necessary to double the shear wave distance ranges to be used in applying this procedure. (E.g. The use of a 250 mm screen calibration in shear wave would require a 500 mm screen calibration for this procedure.)*

B.2 dB ACCURACY
B.2.1 Probe- Straight Beam- 2MHz
B.2.2 Bloc- Distance and Sensitivity 'DS' Reference Bloc (Fig 2)

B.3 PROCEDURE
B.3.1 To get the required ±1% accuracy in reading the indication height, the vertical screen height shall be graduated at 2% *intervals for Analog units, or 2.5 % intervals for instruments with Digital amplitude read out at horizontal mid screen height*. The graduation will be marked on the screen from 60% to 100% screen height.
B.3.2 The normal beam is coupled to DS bloc at position "T". *(Fig. 2)*
B.3.3 50 mm back reflection set at horizontal mid screen by using sweep and delay controls.
B.3.4 Gain is adjusted to have the height exactly above 40% of FSH.
B.3.5 Probe shall be moved to position "U" until the indication is exactly at 40% screen height.
B.3.6 Gain is increased by 6 dB and the height shall be exactly 80% theoretically.
B.3.7 The dB reading shall be recorded in Row 'a' under column 1and actual screen height in Row 'b' under column 1 in the calibration report. (Annexure C)
B.3.8 Probe is moved further towards "U" till the indication is fixed at 40%.
B.3.9 The gain is increased further 6 dB, i.e. totally 12 dB and recording of the gain in row 'a' and actual height in row 'b' under column 2 shall be done.
B.3.10 Operation shall be repeated till the full range of the gain control is reached (60 dB minimum).
B.3.11 Values in Rows 'a' and 'b' shall be applied to the following equation to calculate the corrected dB reading in Row 'c', *or to the "Nomograph" described in B4.0*.

$$dB_2 - dB_1 = 20\, log\, \frac{\%_2}{\%_1}$$

or

$$dB_2 = dB_1 + 20\, log\, \frac{\%_2}{\%_1}$$

Where, dB1=Row 'a'
dB2=Row 'c'
$\%_1$=Row 'b'
$\%_2$=Average of Row 'b' disregarding first and last 3 values

B3.12 dB error in row 'd' = ± (a-c)
B3.13 Collective dB error 'e' is established by starting with dB error 'd' nearest to 0.0, collectively add the dB error 'd' values horizontally, placing the sub totals in Row 'e'.
B3.14 Moving horizontally, left and right from the average % line, find the space in which largest and smallest collective dB error remain at or below 2 dB. The number of horizontal spaces of movement counted and 1 is subtracted from it and the balance is multiplied by 6. This dB value is the acceptable range of unit.

B4.0 GRAPHICAL REPRESENTATION (*NOMOGRAPH*)

B4.1 The following notes apply to the use of the nomograph.

B4.1.1 Rows a, b, c, d and e are on certification sheet, Annexure C

B4.1.2 The A, B, and C scales are on the nomograph, (Example in Figure (6))

B4.1.3 (3) The zero points on the C scale shall be prefixed by adding the necessary value to correspond with the instrument settings; i.e., 0, 10, 20, 30, etc.

B4.2 Procedure for using the nomograph.

B4.2.1 A straight line between the decibel reading from Row "a" applied to the C scale and the corresponding percentage from Row "b" applied to the A scale shall be extended.

B4.2.2 The point where the straight line from step 1 crosses the pivot line B as a pivot point for a second straight line shall be used.

B4.2.3 A second straight line from the average % point on the A scale through the pivot point developed in step 2 and on to the dB scale C shall be extended.

B4.2.4 This point on the C scale is indicative of the corrected dB for use in Row "c."

B5.0 INTERNAL REFLECTION

B5.1 After calibrating the equipment for straight or angle beam, the probe is removed.

B5.2 The calibrated gain is increased to 20 dB more than the reference gain.

B5.3 The screen area beyond 12 mm beam path and above reference level height shall be free from any indication.

B6.0 INDEX POINT

B6.1 Probe shall be coupled at ‘D’ on IIW block (Fig 2).

B6.2 Reflected indication from the 100 mm quadrant is maximized. The point at which the probe coincides with the slot marking on IIW bloc shall be the Probe index value.

B7.0 PROBE ANGLE.

B7.1 Probe is coupled in position ‘B’ on IIW bloc for 40º to 60º or in ‘C’ position for 60º to 70º.

B7.2 Probe is moved back and forth and focused towards the Perspex and maximized. The probe index shall be compared with the angle marking on the bloc. ± 2º tolerance is allowed.

Model
ANNEXURE C

ULTRASONIC UNIT CALIBRATION REPORT- AWS

Ultrasonic Unit Model : USN52R Serial No : 12358
Probe Size : 25 mm Dia Type : Normal beam Frequency: 2MHz
Calibration Date: *02-07-2016* Interval : 2 Months Method : AWS D1.1
Block Sl.No :01

Horizontal Linearity
Range: 0-100 mm Back-wall echo from 25 mm side

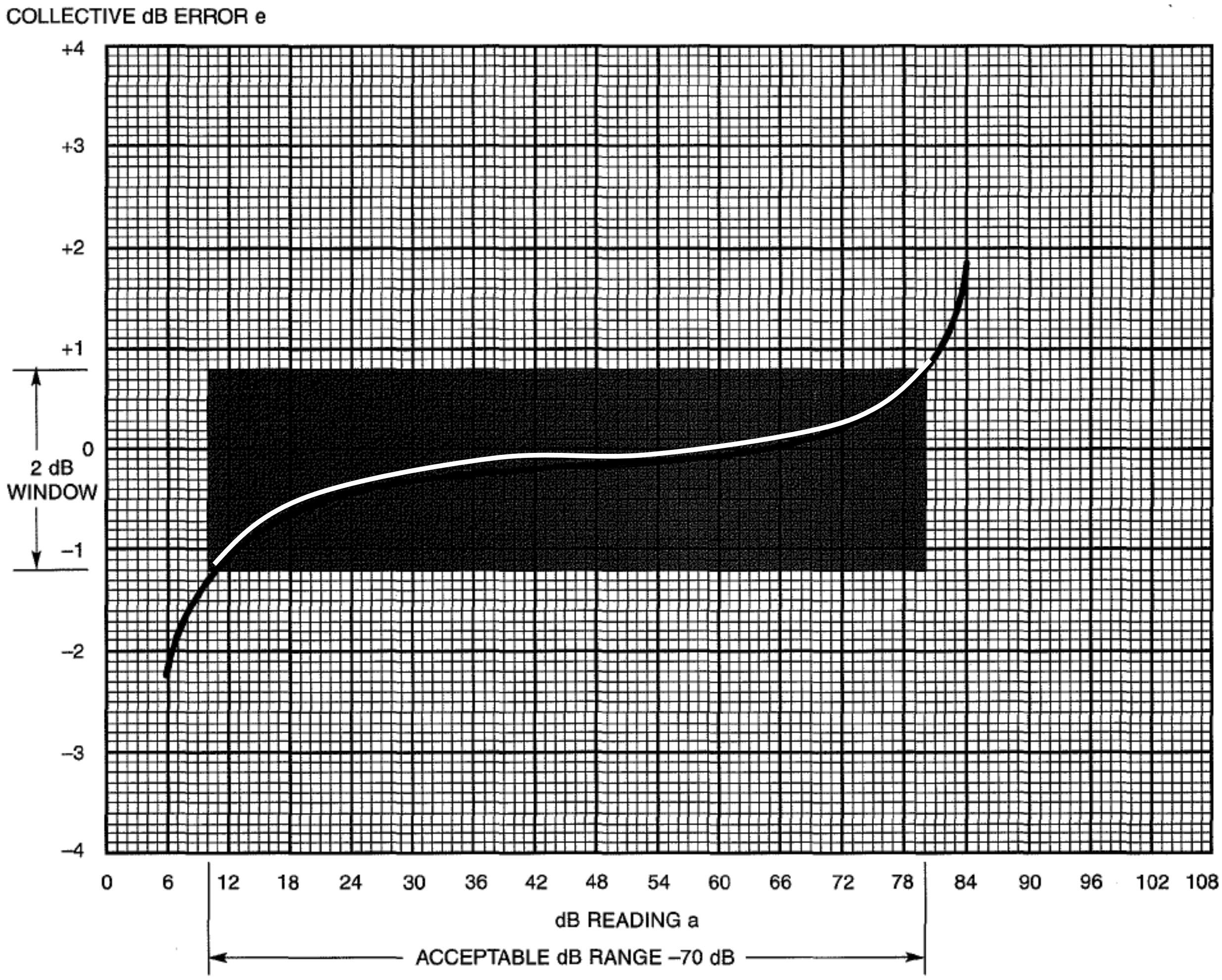
Reflection No.	ECHO		Deviation
	Actual	Expected	
01	25	25	NIL
02	52	50	2 %
03	75	75	NIL
04	100	100	NIL

Row		1	2	3	4	5	6	7	8	9	10	11	12	13
a	dB reading	6	12	18	24	30	36	42	48	54	60	66	72	80
b	Display Height	69	75	75	77	77	77	77	78	77	78	79	80	81
c	Corrected reading	7.1	12.3	18.3	24.1	30.1	36.1	42.1	48	54.1	60	65.9	71.8	77.7
d	dB error	-1.1	-0.3	-0.3	-0.1	-0.1	-0.1	-0.1	0.0	-0.1	0.0	+0.1	+0.3	+0.6
e	Collective dB error	-2.2	-1.1	-0.8	-0.5	-0.4	-0.3	-0.2	-0.1	-0.1	0.0	+0.1	+0.3	+0.6

Accuracy Required: Minimum allowable range :
%$_2$ (Average) :
Equipment : Acceptable / Not Acceptable for use
Total Quality Range: dB to dB = dB Total error dB(from chart)
Total Quality Range: dB to dB = dB Total error dB(from Annexure D)

Calibrated by: Level: Location:

ANNEXURE D – GRAPHICAL REPRESENTATION



THE CURVE ON FORM M-9 EXAMPLE IS DERIVED FROM CALCULATIONS FROM FORM M-8.
THE SHADED AREA ON THE GRAPH ABOVE SHOWS THE AREA OVER WHICH THE EXAMPLE UNIT QUALIFIES TO THIS CODE.

Note: The first line of example of the use of Form M-8 is shown in this example.

Fig (1). dB Accuracy evaluation -AWS

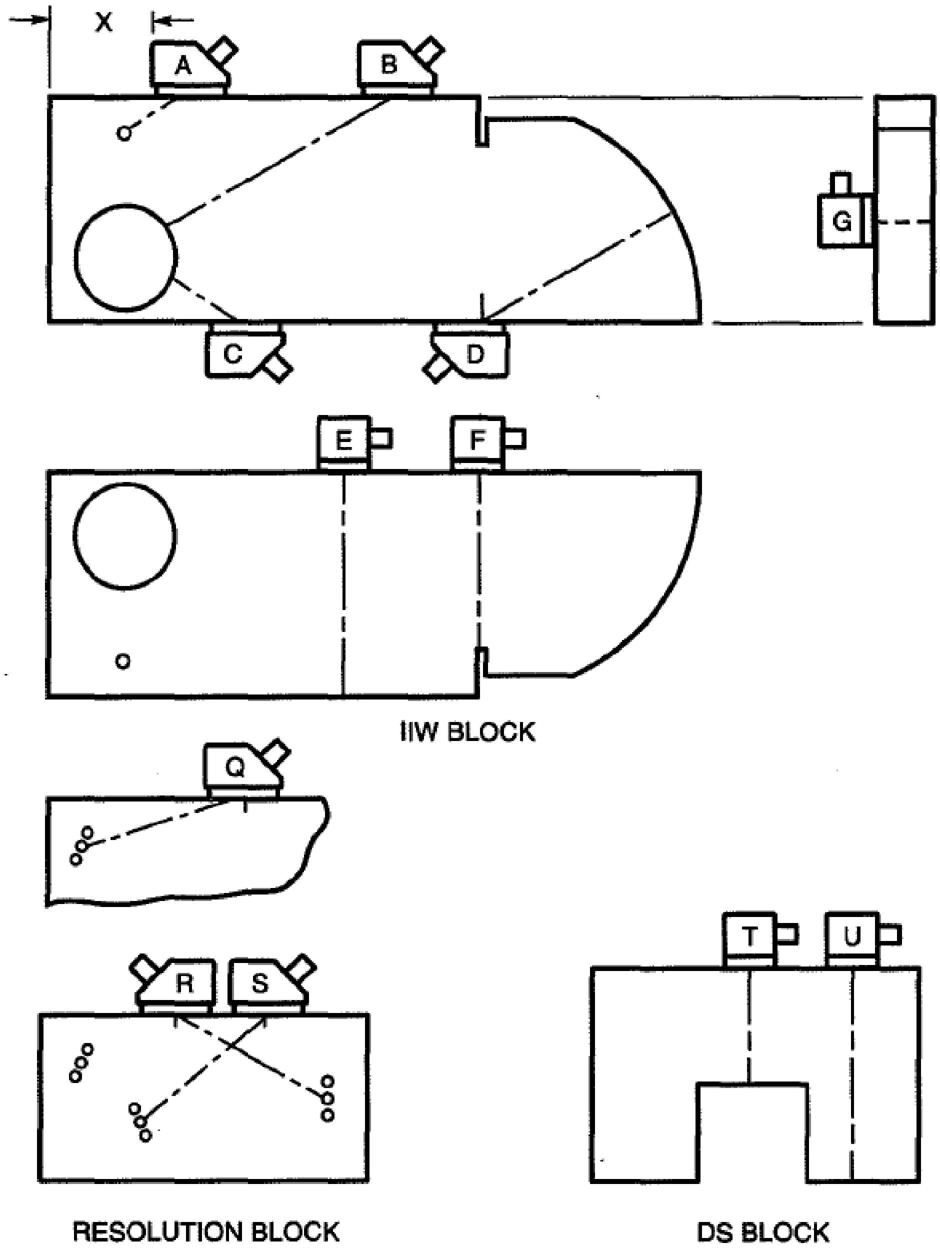


Fig (2). *Typical transducer positions with annotations*

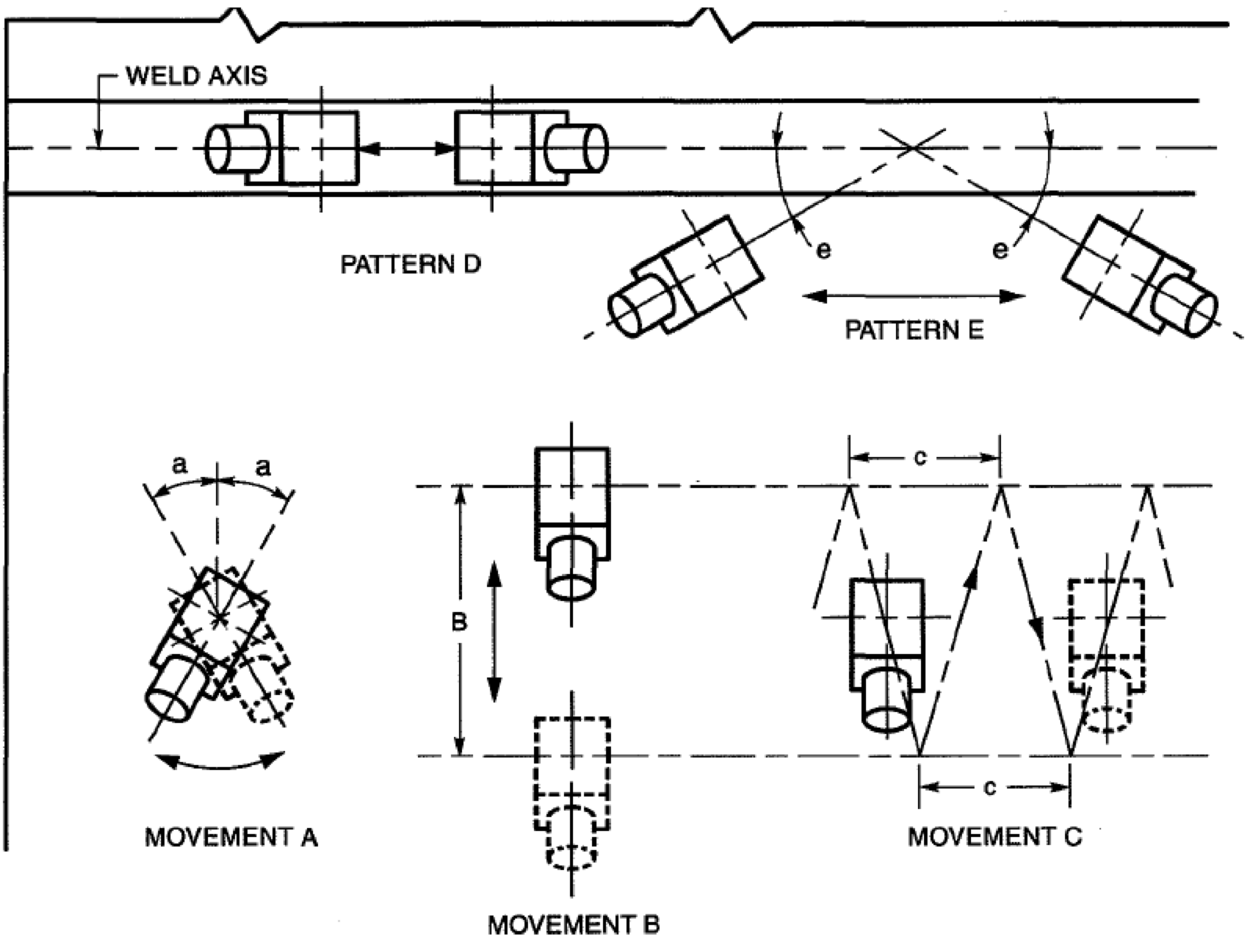


Fig (3) *Plan view of UT scanning patterns*

Notes:

- Testing patterns are all symmetrical around the weld axis with the exception of pattern D, which shall be conducted directly over the weld axis.
- Testing from both sides of the weld axis shall be made wherever mechanically possible.

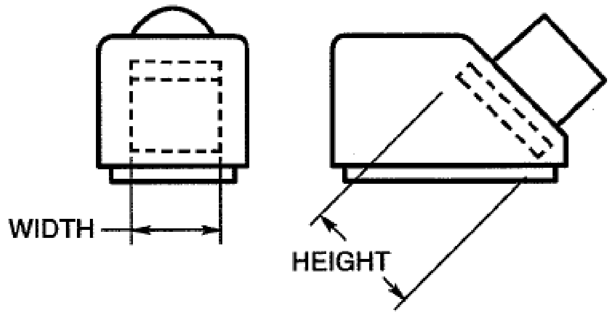


Fig (4) a-Transducer crystal

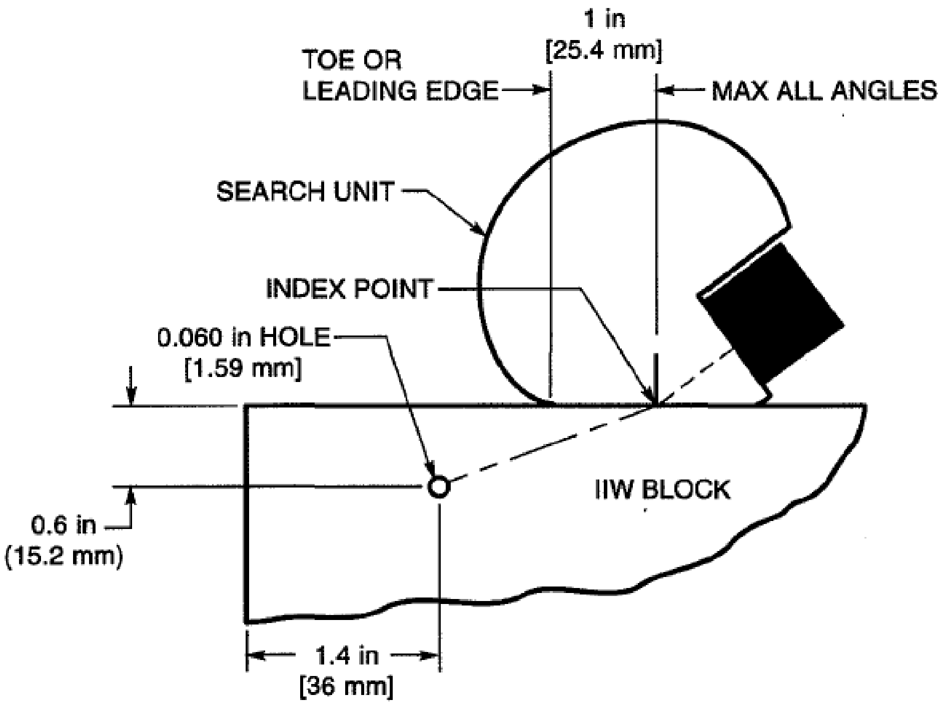
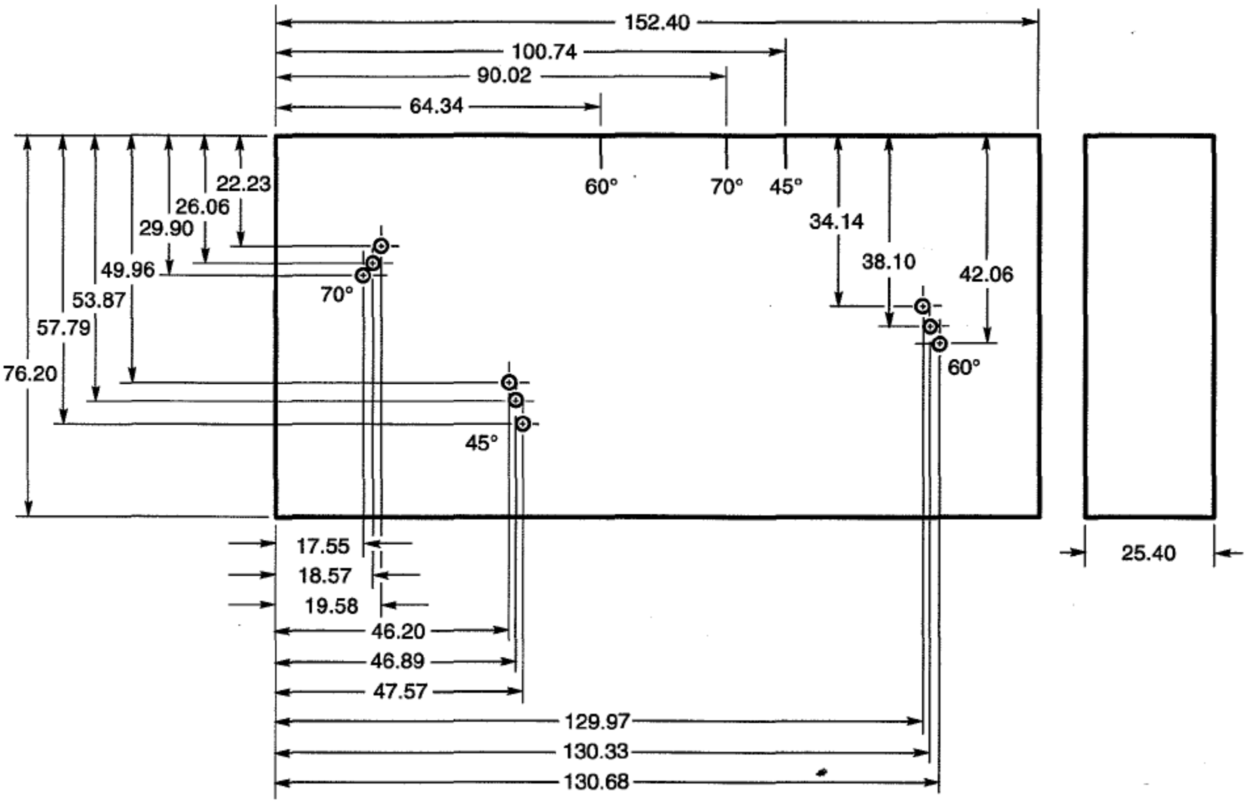


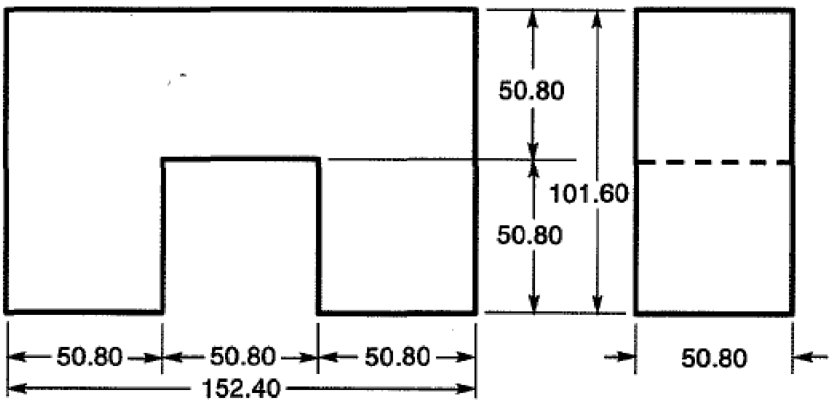
Fig (4) b-Qualification procedure of search unit using IIW reference block



Note: All holes are 1.59 mm in diameter.

DIMENSIONS IN MILLIMETER:

RC – RESOLUTION REFERENCE BLOCK



TYPE – DISTANCE AND SENSITIVITY REFERENCE BLOCK

Fig (5). *Qualification blocks*

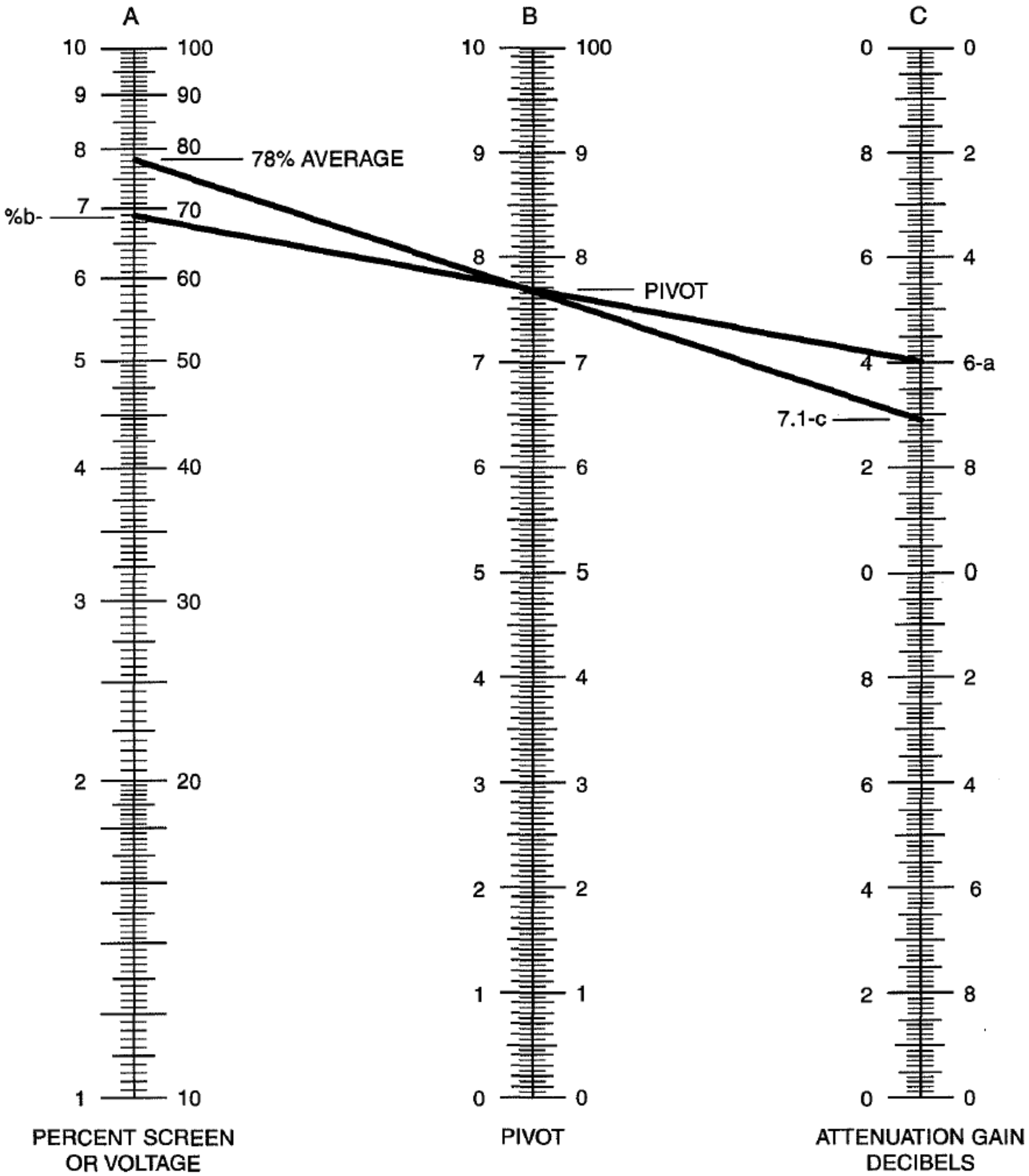


Fig (6). *Example for use of Decibel (Gain or Attenuation) values nomograph-AWS*

NOTES:

1. *The 6 dB reading and 69% scale are derived from the instrument reading and become dB_1"b" and $\%_1$ "c", respectively.*
2. *$\%_2$ is 78 - constant.*
3. *dB_2 (which is corrected dB "d") is equal to 20 times X log $\left(\frac{78}{69}\right)$ + 6 or 7.1.*

CHAPTER 1.10

PROCEDURE OF DEMAGNETISATION OF FERRITIC STEEL MATERIALS SUBJECTED TO MAGNETIC PARTICLE EXAMINATION

BHEL	**BHARAT HEAVY ELECTRICALS LIMITED** **DEPT.235 – TIRUCHIRAPALLI – 620 014** **Non-Destructive Testing**	BHE: NDT: PB:MT: DEMAG:01 Revision: 01 Page 1 of 4

PROCEDURE FOR DEMAGNETISATION OF FERRTIC STEEL MATERIALS SUBJECTED TO MAGNETIC PARTICLE EXAMINATION

Prepared by	Reviewed by	Approved by	Issued by
Vishnu Kumar P Level II Sr. Engineer-NDTL	Deepesh V Level III Sr. Manager-NDTL	B.K. Sethupathy Level III Manager-NDTL	R Arul Prabhu Level III DGM & Head-NDTL
01-01-2020	01/01/2020	B. K. Sethupathy 01-01-2020	01/01/2020

EFFECTIVE FROM 01-01-2020

RECORD OF REVISION

Rev. No	Revision Date	Revision of Details
00	01-01-2016	New issue
01	01-01-2020	Clause No.2.1,3.1,5.1 revised 2.2,4.14 added

1.0 SCOPE

1.1 This procedure describes the techniques for demagnetization of pipe/tube structures in the ferritic steel materials subjected to Magnetic Particle examination.

1.2 This procedure is called for when Demagnetization is required only if specified in the drawings / specification/ purchase order or when any one or a combination of the following undesirable effects of the residual magnetism of the test object are anticipated.

1.2. a. May cause chips, filing, scale, etc. to adhere to the surface affecting subsequent machining operations, painting, or plating.

1.2. b. May affect the sensitive instruments if the part is used in locations near to them.

1.2. c. May affect / interfere the subsequent welding or plating process planned on the test object.

1.2. d. May affect the further magnetic particle examinations on the part.

2.0 REFERENCE

2.1 ASME BPVC Section V , 2019.

2.2 ASTM E-709

2.3 BHE: NDT: PB: MT:01

3.0 TYPE OF MAGNETISATION

3.1 Longitudinal magnetization technique using Alternating current, with value of 5000 to 10000 Ampere-Turns shall be used..

4.0 PROCEDURE

4.1. Use Residual field indicator at one end of pipe and measure the residual field

4.2. Note reading and direction of field +ve or –ve.

4.3. Wrap insulated welding cable 5 turns-clockwise on the OD surface of pipe 50 to 100 mm away from pipe end as shown in figure 1.

4.4. One cable end to be connected to + terminal of Power source / welding generator /MT Equipment. The other end to -ve terminal

4.5. Complete electrical circuit and pass 400 amps current for 2 to 3 seconds

4.6. Reduce the current gradually to zero or minimum

4.7. Measure the residual field at the same end of the pipe

4.8. If demagnetization is effective the reading will come closer to “0”

4.9. Change the polarity of cables attached to the Power source / welding generator / MT Equipment or Wrap the insulated cable (5 turns) in anticlockwise direction

4.10. Pass current slightly excess of 400 Amps

4.11. Reduce the current gradually to 0 Amps in One minute

4.12. Measure the residual field at the same end of the pipe

4.13. Repeat the process till the Gauss meter shows residual field value 3 gauss or less, as shown in figure 2.

4.14. Alternatively the technique of withdrawing the part or coil may be used.

5. PERSONNEL QUALIFICATION

5.1 Demagnetization process shall be performed by at least Level I qualified personnel and acceptance through reporting shall be done by at least a Level II qualified personnel in MT as per SNT-TC-1A 2016 or BHEL's approved written practice for NDT personnel training and certification.

6. REPORTING

6.1 The demagnetization shall consist the following information, as a minimum.

a. Dimensional as well as material details of the test object.
b. Current- type and value
c. Gauss meter reading the beginning and end of the test.
d. Personnel performed and approved the report.

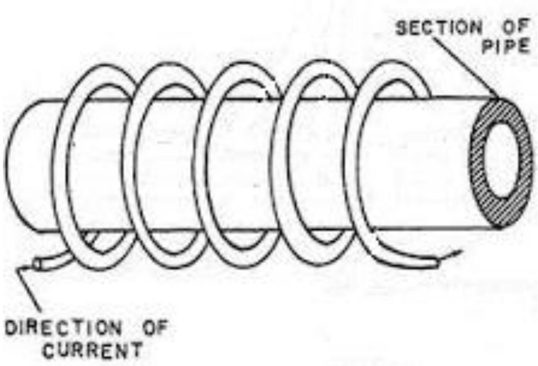


Figure 1. Demagnetization technique

Figure 2. Gauss meter

CHAPTER 1.11

PROCEDURE FOR SAFE WORK PRACTICES IN ENCLOSED RADIOGRAPHY INSTALLATIONS AND IN OPEN FIELD RADIOGRAPHY

PROCEDURE FOR SAFE WORK PRACTICES IN ENCLOSED RADIOGRAPHY INSTALLATIONS AND IN OPEN FIELD RADIOGRAPHY

Prepared By	Reviewed By	Approved By
01-01-2020	01/01/2020	01/01/2020
Jagadeesh.S Deputy Manager Level II Radiation Safety Officer NDTL	R.Raghavendrien Deputy Manager Level III Radiation Safety Officer NDTL	R.Arulprabhu Dy General Manager Head NDTL

Effective from 01.01.2020

RECORD OF REVISION

Rev. No	Revision Date	Record of Revision
01	21.03.2000	2.1 AERB Safety Guide No.SG/IN 3 included 4.6 Revised and modified
02	29.12.2000	Restructured New clauses added &Revised in entirety
03	29.03.2002	2.1 AERB Safety Code No.AERB /SC/IR 1 Included 3.2 Included Restructured Revised in entirety & Annexure included
04	11.06.2012	2.1 Year included 3.2 Restructured 4.7 included 5.1 Restructured 7.8 Restructured 8.1.2 Restructured 8.2.4 Re structured 8.3.1 Name of contact person and Phone no changed 8.3.2 Phone no's changed 9.8 included 10.1 Restructured Annexure Restructured
05	15.12.2014	8.3.2 Name of contact person and Phone no changed
06	16.08.2016	3.1 Modified 4.7 Modified 8.1 & 8.3 Modified 10.1 Modified Annexure modified
07	01.01.2020	2.1,3.1,4.1 &7.5 Modified 8.3.1 & 8.3.2 Name of contact person and Phone no changed Clause 11 added

1.0 SCOPE:

1.1 **This procedure describes the safe work practices to be followed in enclosed Radiography installations and in Open Field Radiography**

2.0 REFERENCE:

2.1 **AERB Safety code for Industrial Radiography AERB / RF- IR /SC–1 (REV 1).**

3.0 PERSONNEL:

3.1 **All Radiography cameras must be operated only by certified radiographers, Safety site in Charges or Radiation Safety Officers. All radiography personnel (certified radiographers/site incharges /Radiation safety officers) should be registered as a radiation professional in ELORA (e – licensing of radiation applications) portal of AERB.**

3.2 **All radiation workers must be enrolled in 'Personnel Monitoring Service' of BARC and their instructions shall be followed. Each radiation worker shall wear Personnel monitoring badge during radiography work. In case of suspected over exposure to radiation, the personnel dose shall be evaluated as per clause 8.2.4. The TLD cards are changed every month and used cards sent to Personnel monitoring service of BARC or its Agency for evaluation and dose reporting.**

4.0 ISOTOPE RADIOGRPHY OPERATION:

4.1 **Radiography must be carried out only with a "type approved radiography camera" duly approved by AERB. A calibrated Radiation survey meter should always be available during entire radiography process.**

4.2 **A log book must be maintained for each radiography hall / site / source to record the date of radiography, model and Serial number of camera / X-ray equipment, Survey meter used strength of source, name of the radiographer, location of radiography, exposure time in Ci.minutes. or mA mts. and total number of exposures.**

4.3 Movement of camera from one location to another must be recorded and signed by Safety site in charge and Radiation Safety Officer shall inspect the logbook and counter sign once in a month.

4.4 The Safety Site in charge shall measure the maximum and minimum readings on the surfaces of the camera and enter in the logbook once in a month. This enables to check the shielding integrity of the camera.

4.5 Before operation, it shall be ensured that the camera is in safe condition. Any malfunction in the camera and its accessories shall be brought to the notice of the concerned Safety site in charge, by the radiographer.

4.6 While using remote controlled cameras, it shall be ensured with survey meter that the source is retrieved safely back into the camera, after the exposure is completed.

4.7 The cameras are always stored in AERB approved storage pits and locked when not in use. The keys are stored in a place accessible only to Safety Site Incharges/RSOs. The certified radiographers will take the key from Incharges and use cameras for radiography. After the work is completed, return back the cameras to storage pit, lock the storage pit and return the key to the Incharges.

5.0 RADIOGRAPHY IN ENCLOSURES

5.1 Unauthorized entry into the radiography hall should be prohibited.

5.2 A warning lamp must be provided at the entrance. A radiation zone monitor must be installed at a suitable location near the entrance to indicate the radiation level in the exposure hall.

5.3 Wherever possible the radiation beam should be directed towards areas of minimum occupancy and must not be pointed towards doors, windows, and control panel.

5.4 While carrying out the radiography in open top enclosures, it shall be ensured that the red warning lamps on the four corners of the hall are switched on.

6.0 OPEN FIELD RADIOGRAPHY:

6.1 **The radiography work must be carried out only under the supervision and guidance of the Safety site in charge.**

6.2 **All operations should be planned in advance and executed in minimum possible time.**

6.3 **Radiography camera should be moved to the site along with Radiation survey meter.**

6.4 **As far as possible, field radiography should be carried out when there is minimum occupancy. The area around the field radiography site should be cordoned off so that the radiation at the cordon off does not exceed the permissible level for members of public.**

6.5 **Radiation warning symbol in English and in local language must be displayed at cordon off distance. Red warning lights must be displayed during night along the cordon off at the point of entry.**

6.6 **The concerned radiographer must be available at the site very near to the cordoned area throughout the exposure. Entry of unauthorized persons into these cordoned areas during exposures should be strictly prohibited.**

6.7 **After termination of each exposure, it is to be ensured that the source is safely retrieved back into the camera.**

6.8 **Proper collimators should be used to limit the radiation beam to the job to be radio graphed.**

7.0 CONTROL MEASURES TO REDUCE EXPOSURE TO IONIZING RADIATION

7.1 **Radiography shall be performed as far as practicable in approved radiography enclosures by trained and certified radiographers.**

7.2 **The enclosures where X-rays, Ir-192 and Co-60 sources are employed for examination shall be kept closed when ‘not in use ‘and ‘during exposures’.**

7.3 **Entry of non-occupational workers to these areas shall be restricted with ‘NO ENTRY’ posters or boards.**

7.4 **The enclosures shall not be used as a ‘freeway’.**

7.5 Wherever possible, Radiation beam should be directed to area of examination making use of cones, diaphragms and collimators etc and the part placed in such a manner that the' beam' is directed towards area of minimum occupancy.

7.6 Only one radiography source should be used at a time in any enclosure.

7.7 The key for operating the X-ray machine and locking system of the isotope cameras shall be under the custody of the certified radiographer, performing the operation.

7.8 The radiation levels outside the boundary shall not exceed 0.02 m Sv (2 mR) per week, as permitted for general public.

7.9 The leakage radiation level of the isotope camera containing the radioactive sources shall be verified before and after each operation to ensure the source is in its safe position inside the camera.

7.10 After the exposure is over the source shall be verified for its safe location inside 'S' conduit and the selector ring at the rear of the camera shall be brought to lock position, and then the guide tubes shall be removed and the shipping plug inserted.

7.11 The isotope cameras should be returned to source storage enclosures and locked or kept in areas earmarked for this purpose at the end of each shift.

7.12 The shielding integrity of isotopes camera shall be verified once in a month by RSO / Safety site in charges.

7.13 The guide tubes and associated accessories shall be checked on a day today basis by certified radiographers / Site in charges / radiation safety officer and defects rectified appropriately or discarded.

7.14 No repairs are permitted in isotope cameras or its locking mechanism when an 'active source 'is secured inside.

8.0 RADIATION EMERGENCY:

8.1 The procedure to be followed in case of emergency is detailed in Emergency Preparedness and Response Plan the gist of which is as follows:

8.1.1 Cordon off the area with the help of survey meter to prevent unauthorized entry.

8.1.1 All efforts to bring back the source into the camera shall be followed

8.1.3 If all efforts to restore the source back to the camera have failed, shield the source with lead sheet, lock the installation and inform the incident / accident to Radiation Safety Division, AERB, Mumbai – 94.

8.2 EMERGENCY PREPARDNESS DURING RADIOGRAPHY:

8.2.1 When a source is stuck in the camera guide tube or when a source pencil has fallen or is misplaced or lost, or damaged or broken resulting in the source remaining in an unshielded condition, a radiation emergency is created. In such circumstances, the following action should be taken by the Safety site in charge / RSO. No person other than RSO / Safety site in charge should be asked to handle the radiation emergencies.

8.2.2 The Safety site in charge should immediately cordon off the area in which the source is known to be present or suspected to be present, and restrict the entry of persons into the area. The Safety site in charge should locate the source within a reasonable time using appropriate radiation monitoring instruments.

8.2.3 When all efforts to locate the source have failed and when the source cannot be brought to its safe shielded position, competent authority should be informed immediately giving essential details of the emergency and action being taken. Necessary assistance should be sought from RSD, AERB, Mumbai – 94.

8.2.4 If any person is suspected to have received high radiation exposure, his personal monitoring badge should be immediately sent to Personnel Monitoring service of BARC or its service provider for urgent evaluation. The suspected individual should be subject to medical examination by a qualified doctor. Such medical examination should include blood examination (RBC, WBC& Platelet count) and general physical examination. The general physical condition of the suspected person should be observed and if any symptoms that can be attributed to radiation should emerge, the person should be brought to BARC Hospital at Mumbai for detailed examination and treatment.

8.3 List of names and phone numbers to be contacted in the event of Emergency should be displayed at work centers.

8.3.1 RSD, AERB, Mumbai –94

Ph.: 022-25572989, 90, 91,93,94,95, 2599 0100

8.3.2 BHEL:

1. **R.Arulprabhu: 0431-2575590, Mobile 9442502921**
2. **R.Raghavendrien: 0431-2575632 , Mobile 9489202949**
3. **Jagadeesh.S: 0431-2578393, Mobile 9944615047**

The contact numbers are displayed in the work centers.

9.0 SAFE TRANSPORT OF GAMMA RADIOGRAPHY SOURCES:

9.1 All gamma radiography sources are supplied in a sealed capsule and attached securely to a Teleflex cable. The capsule is shielded in a camera and this is loaded in a sturdy wooden box. The wooden box which is in sound condition is provided with spacers for preventing free movement of the shielded container inside, during transport. The outer container must be provided with strong handles to facilitate easy handling and must be closed. This is referred to as the package.

9.2.1 The radiation level on the external surface of the package must be monitored using an appropriate calibrated radiation survey meter and the maximum level recorded. Care must be taken that the camera is securely locked to prevent movement of the source during transport.

9.2.2 The Transport index defined as the number expressing the maximum radiation level in mR / hr at one metre from the external surface of the package and is determined by means of a radiation survey meter.

9.2.3 Based on the maximum permissible surface leakage levels the package shall be labeled with Yellow II or Yellow III.

9.2.4 If the maximum level at the external surface of the package is more than 5 µ Sv per hr (0.5 mrem /hr) but not more than 0.5 mSv/ hr (50 mrem/hr) and if the transport index is not greater than 1, then the package is described as CATEGORY II YELLOW.

9.2.5 If the maximum level in the above case is between 0.5 mSv/hr (50mr/hr.) and 2 mSv / hr. (200mr/hr) and the transport index is between 1and 10 then the package is described as

CATEGORY III YELLOW.

9.3 **The package must be declared as a radioactive consignment in the transport documents.**

9.4 **While booking the cargo a certificate must be issued by the consignor to the effect that the package containing a radioactive material has been properly packed, marked, and labeled and the consignment is in conformity with requirements stipulated by competent authority.**

9.5 **If the package gets involved in an accident during transportation, the consignor and Radiation Safety Division, AERB, Mumbai must be informed within 24 hours and the package must be forwarded for transport only after obtaining the clearance from RSD, AERB, Mumbai.**

9.6 **Additional conditions as may be specified by the competent authority in the interest of radiological safety must be duly adhered to.**

9.7 **The decayed sources are safely disposed by Board of Radiation and Isotope Technology, Mumbai, when the cameras are sent for replenishment.**

10 MEDICAL CHECKUP:

10.1 **Radiography personnel will be medically examined at least once in three years or whenever any direction is received from BARC, based on the Personnel monitoring badge recordings.**

10.2 **Any of the medical reports as in 10.1 reveals that the operator has received more radiation than permitted; BARC's advice will be followed for further course of action.**

10.3 **Medical checkup details shall be retained by the Occupational Health Services.**

11 SUBCONTRACTING OF RT WORKS:

11.1 **Subcontracting agency shall possess a valid license for possession and operation of radiography exposure devices for industrial radiography.**

11.2 **Agency should possess adequate number of radiographers to carry out radiography. Each agency operating in site/Unit should have at least one site charge/ radiation safety officer.**

11.3 Movement of radiography source from one site to another shall be done only with the prior approval of Atomic Energy Regulatory Board through ELORA portal.

11.4 Site/Unit is required to provide storage facility for the radiography sources as per AERB guidelines and assist radiography agency in getting necessary approvals through ELORA.

11.5 Radiography agency shall obtain prior permission from site engineer for carrying out open field radiography. Open field radiography should be carried out only after evacuation of non- radiography personnel from the radiation zone.

11.6 TLD Dose reports of all radiation personnel shall be maintained.

ANNEXURE

PERMISSIBLE LEVELS LISTED AS PER AERB GUIDE LINES

1. **THE CUMULATIVE EFFECTIVE DOSE OVER A BLOCK OF 5YEARS SHALL NOT EXCEED 100 mSV WITH THE MAXIMUM LEVEL FOR A SINGLE YEAR NOT EXCEEDING 30 m SV. THAT IS, THE AVERAGE ANNUAL DOSE LIMIT SHALL NOT EXCEED 20 m SV**

2. **AT 5CMS FROM SURFACE OF EXPOSURE DEVICE, THE MAXIMUM PERMISSIBLE LEAKAGE LEVEL SHALL NOT EXCEED 0.5 mSV /Hr FOR PORTABLE TYPES AND 1.0 mSV/Hr FOR MOBILE TYPES**

CHAPTER 1.12

PROCEDURE FOR APPROVAL OF NDT AGENCIES

BHEL	**BHARAT HEAVY ELECTRICALS LIMITED** **DEPT.235 – TIRUCHIRAPALLI – 620 014** **Non-Destructive Testing**	BHE: NDT: G- 005 Revision 003 Page 1 of 5

PROCEDURE FOR APPROVAL OF NDT AGENCIES

Prepared by	Reviewed by	Approved by	Issued by
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01/01/2020	01/01/2020	B.K.Sethupathy 01-01-2020	01/01/2020

With effect from 01-01-2020

RECORD OF REVISION

Rev. No	Revision Date	Revision of Details
001	21-03-2000	Clause 7 added.
002	28-03-2015	Clause 2.1 Modified
		Clause 3.3 Modified
		Clause 3.6 Modified
		Clause 3.10 Modified
		Clause 3.14 Modified
		Clause 4.3, 4.4 added
		Clause 5.3, 5.4 added
		Clause 6.2, 6.3 added
		Annexure-I,II & III added
003	01-01-2020	Clause 3.1 Modified
		Clause 3.15 Added.

1.0 SCOPE

1.1 This procedure describes the requirements to be fulfilled by a NDT Agency to get approval from BHEL to carry out NDT - viz Radiography, Ultrasonic Testing, Magnetic Particle Testing and Liquid Penetrant Testing on their products.

2.0 GENERAL REQUIREMENTS

2.1 Registered in Small Scale Industries and IBR (if Applicable) shall be obtained.

2.2 Trained, experienced and certified personnel qualified as Level I / II / III as per SNT-TC-1A of ASNT or BSEN 473 of EN through ISNT or its Accredited Agencies or through approved third Party Inspection Agencies like Lloyds etc should be employed.

2.3 The personnel should have sufficient experience in testing of welds/castings/forgings/plates and should be capable to interpret the given procedure and carry out the test.

2.4 Those equipment's require calibration should have been calibrated and recalibrated in stipulated intervals.

2.5 Calibration and Reference Blocks should be available wherever applicable.

2.6 Film and other consumables used shall be BHEL approved brands.

3.0 REQUIREMENTS FOR RADIOGRAPHY

3.1 Approval from BARC for the Site and to carry out Radiography (in the enclosure as well as open field) should be obtained.

3.2 BARC certified Radiation Safety Officer/Site in charge / RSO should be available.

3.3 Should possess minimum 2 Nos. of Remote Operating Type Iridium 192 Source, preferably one should be Tech/Ops/Amersham.

3.4 Each Radiation source should have an experienced BARC Certified Radiographer Level I to operate the camera.

3.5 In addition, there should be personnel certified to Level II to monitor the activities.

3.6 All the radiation workers should be enrolled with Film Badge Services of BARC.

3.7 Radiation safety equipment's and monitoring equipment's like Survey meter should be available for each source.

3.8 Well maintained and air conditioned dark room should be available, preferably with temperature controlled film processing device.

3.9 High Intensity illuminator with intensity control should be available.

3.10 Calibrated ASTM Image Quality Indicators(IQI), minimum 6 Nos. in each designation and ASTM wire type IQIs should be available.

3.11 Sufficient flexible cassettes with 0.2 mm thick lead screen should be available.

3.12 Lead sheets of thickness 1 mm and 2 mm should be available.

3.13 All safety precautions laid down by AERB should be strictly followed.

3.14 Calibrated Density Strip / Densitometer shall be made available for use.

3.15 If required, agency has to demonstrate and establish various parameters for the quality of radiograph (eg: Image density, sensitivity, source size, source to film distance, geometric unsharpness etc.,) to the satisfaction of NDTL/BHEL Trichy.

4.0 REQUIREMENTS FOR ULTRASONIC EXAMINATION

4.1 Should have Analogue or Digital type Pulse Echo A Scan equipment.

4.2 Probe shall be available in various frequencies (particularly 2 MHz and 4 MHz) and various angles (Normal, 45 degree, 60 degree, 70 degree) of single crystal and double crystal construction. In each type there should be spare probes to meet any eventualities. Probes shall be from reputed manufacturer.

4.3 Calibrated Equipment shall be used for testing.

4.4 Trained, experienced and certified personnel qualified in Ultrasonic testing as given clause 2.2 shall be engaged for testing and interpretation.

5.0 REQUIREMENTS FOR MAGNETIC PARTICLE EXAMINATION

5.1 Should have portable AC/HWAC equipment delivering current of minimum of 1000 amps and portable AC/DC electromagnetic yokes.

5.2 Calibrated Equipment/ Ammeters shall be used for testing.

5.3 Should be capable of testing with visual and fluorescent magnetic particles.

5.4 Trained, experienced and certified personnel qualified in Magnetic testing as given clause 2.2 shall be engaged for testing and interpretation.

6.0 REQUIREMENTS FOR LIQUID PENETRANT EXAMINATION

6.1 Should be capable of testing with Visual and fluorescent penetrants.

6.2 Only Approved brand of chemicals shall be used for testing.

6.3 Trained, experienced and certified personnel qualified in Penetrant testing as given clause2.2 shall be engaged for testing and interpretation.

7.0 VALIDITY AND RENEWAL

7.1 The validity of the NDT Agencies engaged by Outsourced Firms will be renewed at the end of every two years based on the following:

7.1.1 Assessments made in every six months

7.1.2 IBR Approval.

7.1.3 Feedback or complaints, Audit checks and others if any.

7.2 If any NDT Sub contractor was not engaged by any fabrication unit within a period of 2 years, the NDT Sub contractors name will be deleted from the approved list.

7.3 Approved list of NDT sub contractors will be circulated to Outsourcing, Valves subcontracting and Valve purchase, FBC & HRSG and QC/OLI departments.

CHAPTER 1.13

MAGNETIC PARTICLE EXAMINATION OF PIPE BENDS

	BHARAT HEAVY ELECTRICALS LIMITED **DEPT.235 – TIRUCHIRAPALLI – 620 014** **Non-Destructive Testing**	BHE:NDT:PB:MT- 02 Revision 02 Page 1 of 5

MAGNETIC PARTICLE EXAMINATION ON PIPE BENDS

Prepared By	Reviewed By	Approved By	Issued By
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Effective from 01-01-2020

RECORD OF REVISION

Rev. No	Revision Date	Revision of Details
00	10-01-2010	New issue
01	16-07-2016	1.2.1,1.2.2,9.1 revised
02	01-01-2020	1.1,1.2.1,1.2.2,8.1,9.1,12.1 revised

1.0 SCOPE

1.1 This procedure describes the method, techniques and acceptance standards for Magnetic Particle Examination on Bends of Carbon steel, Alloy Steel and P91 Pipes. This procedure is used only for detection of Transverse Defects arising during hot bending in the bend area.

1.2 REFERENCES

1.2.1 ASME Section V -2019

1.2.2 ASME B 31.1/ 2018

2.0 EQUIPMENT

2.1 Equipments generating half-wave rectified direct current shall be used for examination.

3.0 SURFACE PREPARATION

3.1 The surface to be examined shall be even and free from scales/undulations, Drag lines, notches etc.

4.0 TYPE OF MAGNETISATION

4.1 Longitudinal magnetization induced by Coil winding over the part using half wave DC (HWDC) shall be used.

4.2 Examination shall be made by dry continuous method, i.e. magnetising current remains on while inspection medium (dry powder) is being applied.

5.0 MAGNETIC FIELD STRENGTH

5.1 The strength of the magnetic field should be checked over the area to be tested to ensure Clear visibility of indication on a berthold type field indicator/ASTM Pie shaped Magnetic Particle Field Indicator.

6.0 LONGITUDINAL MAGNETIZATION TECHNIQUE:

6.1 Magnetization by this method is produced by passing current through a multi-turn cables or coils that is wrapped around the part or section of the part being examined. This produces a longitudinal magnetic field parallel to the axis of the coil.

7.0 CURRENT SELECTION

7.1 If the area to be magnetized exceeds beyond 225 mm on either side of the coil's center, field adequacy shall be demonstrated using a magnetic field indicator or artificial flaw shims

7.2 The magnetizing current shall be 1200 ampere-turns to 4500 ampere-turns. The field adequacy shall be demonstrated using a magnetic field indicator or artificial flaw shims.

8.0 TESTING METHOD

8.1 The bend portion of the pipe shall be marked.

8.2 The insulated magnetic equipment cable shall be wrapped (one or two windings) on the OD surface of the pipe and one end of the cable to be connected to the common terminal of the equipment and the other end to HWDC terminal.(Fig 1)

8.3 The current has to be selected as in 7.2.

8.4 After passing the required current and magnetizing the part , the field adequacy checked using Berthold type field indicator/ASTM Pie shaped Magnetic Particle Field Indicator and the magnetic powder shall be applied on the part while the current is on.(Fig 2)

8.5 Indication, if any, shall be observed and recorded.

8.6 The cable winding shall be moved to the adjacent areas and testing continued.

9.0 LIGHTING

9.1 The examination area and the accumulation of magnetic particles shall be observed under natural or supplemental white light of intensity minimum 100 fc (1076 lx).

10.0 TEST PERFORMANCE

10.1 Ammeter shall be calibrated at least once a year, or after each time it has been subjected to major electrical repair, periodic overhaul or damage.

10.2 Any test area shall overlap by 40 to 50mm.

10.3 Interpretation and Evaluation shall be performed during the post magnetization period.

11.0 DEMAGNETIZATION

11.1 After completion of the testing in the bend portions, the residual field present on the shall be measured with Residual Field Indicator or Gauss Meter.

11.2 If the meter shows + or – field level, demagnetization shall be carried either using the demagnetization facility provided in the Equipment or by changing the polarity and reducing the current and reversing the part or coil.

11.3 The residual field level present after each demagnetization operation shall be measured and the process repeated till the residual field level reaches 3 gauss or below.

12.0 PERSONNEL QUALIFICATION

12.1 Personnel performing examination and evaluation shall be qualified in accordance with BHE:NDT:G:CRT which is in line with SNT-TC-1A 2016.

1) Testing - Minimum Level- I
2) Evaluation and Report issue - Minimum Level II

13.0 INTERPRETATION OF MAGNETIC PARTICLE INDICATION

13.1 Transverse Indications irrespective of the length are not acceptable.

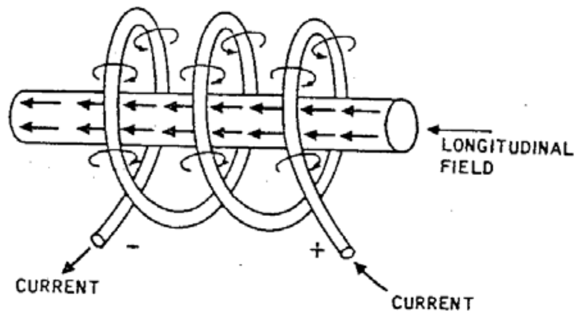
14.0 POST CLEANING

14.1 When inspection is concluded, the magnetic particle residue remaining on the surface shall be removed by any suitable mean leaving the product in dry and clea**n condition.**

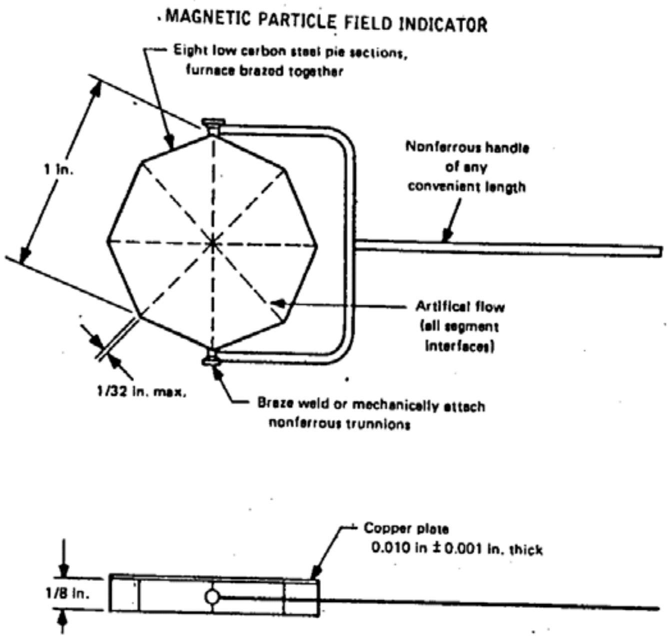
15.0 REPORT AND STORAGE

15.1 Report in the approved format signed by a Level-II or Level-III shall be issued. All the reports will be retained for a period of 1 year or Final Inspection clearance whichever is later.

****



(Fig 1) LONGITUDINAL- COIL(SOLENOID) METHOD



(Fig 2) BERTHOLD PENETRAMETER / FIELD INDICATOR

CHAPTER 1.14

PROCEDURE FOR FILM PROCESSING, FILM STORING AND STORAGE OF RADIOGRAPHS

PROCEDURE FOR FILM PROCESSING, FILM STORING AND STORAGE OF RADIOGRAPHS

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

Effective from 01-01-2020

RECORD OF REVISION

Rev.No	Date	Revision of Details
01	28-12-2008	Clause 2.1 Revised, Clause 10.1 revised
04	06-11-2015	Clause 2.1
05	01-01-2020	Clause 2.1 Revised, Clause 2.2,2.3 added

1.0 SCOPE

1.1 This procedure describes the method of storing unexposed films, storage of radiographs, manual deep tank processing and auto-processing of exposed X-ray films.

2.0 REFERENCE

2.1 ASTM E94 – 2010

2.2 ASME SEC V ARTICLE 2 2019

2.3 ASTM E999 – 2015

3.0 STORAGE OF FILMS

3.1 Unexposed films shall be stored in as cool a place as possible and stored in such a manner that they are protected from the effects of light, pressure, excessive heat and humidity.

3.2 Films shall not be stored in the immediate proximity of X-ray processing solutions or storage area of gamma source and shall be protected from damaging fumes or vapors or penetrating radiation.

3.3 Storage of films should be on 'First in' 'first out' basis.

4.0 MANUAL FILM PROCESSING (Deep-Tank)

4.1 Processing shall be carried out under subdued light of a color to which the film is relatively insensitive.

4.2 The processing room as well as the accessories and equipment shall be kept clean. The thermo-meters, film hangers shall be thoroughly washed in clean water immediately after use .

4.3 All tanks shall be cleaned thoroughly before putting solutions into them. Any solutions spilled at any time shall be wiped at once .

4.4 The safe-lights employed for film loading and processing in the dark room shall be periodically checked, once in a month, for its effect on the radiographic films as below:

a) A strip of X-ray film 10x20 cms. long shall be placed in total darkness at the same distance at which the films are normally loaded prior to exposures.

b) The safe light under examination only shall be switched on for 2 minutes after covering the film for a length of 25 mm with a piece of opaque card-board. The above operation shall be repeated for 4 & 8 minutes with 25 mm
additional incremental lengths each time. The exposed film shall be processed and dried. The measured fog density in any area of the affected film shall not exceed 0.3.

5.0 DEVELOPMENT

5.1 Before start of development the developer solution shall be thoroughly stirred and the temperature shall be measured and recorded. The development temperature shall be between 18°C and 26°C.

5.2 The development times as in Table -1 shall be followed based on measured temperature.

TABLE-1 :DEVELOPMENT TEMPERATURE AND TIME

Temperature	Development time- minutes	
	Minimum	Maximum.
18 deg. C / 64 deg. F	6	9
20 deg. C / 68 deg. F	5	8
22 deg. C / 72 deg. F	4	6
24 deg. C / 75 deg. F	3.5	5
26 deg. C / 82 deg. F	2.5	3.5

5.3 The film to film or film to edges of the tank shall be separated to a distance of 13 mm from each other.

5.4 The hanger frames shall be continuously agitated in 2 directions for about 15 secs.

5.4 The films shall be moved vertically and horizontally for 5 seconds each minute during development.

6.0 STOP PATH

6.1 After development is complete the films are allowed to drain above the developer tank for 2 to 3 sec. and shall be immersed immediately in acid stop bath for 30 sec.

6.2 If acid water bath is not used, films shall be rinsed in running water or in clean water in an intermediate tank with vigorous agitation for 30 seconds.

7.0 REPLENISHMENT

7.1 The liquid level in the developing tank shall be maintained to its original level as well as the activity of the solution shall be maintained everyday prior to start of development as follows:

7.2 Based on number of films processed the previous day, for every 8 sheets of 30 x 40 cm films, 300 ml. of developer shall be removed and then approx. 600 ml. of replenisher solution shall be added into the developer tank.

7.3 The quantity of replenisher shall be added to a maximum of 4 times the volume of the developer tank i.e.90 Lit. The developer solution shall be discarded after developing approx.725 sheets of 30 x 40 cm with periodic replenishment or at the end of three months whichever is earlier.

8.0 FIXING

8.1 The films shall not touch one another in the fixer solution. The films shall be agitated vertically for about 10 seconds and again at the end if first minute and every 2 minutes during the course of fixation.

8.2 Films shall be fixed for double the time required to clear the emulsion but not more than 15 minutes. Disappearance of the opalescent milkiness is referred as 'clearing time' which is normally 2 to 3 minutes.

8.3 The fixer solution shall be discarded after approx. 725 sheets of 30 x 40 cm films are fixed or at the end of three months whichever is earlier.

9.0 WASHING

9.1 The films shall be washed in running water for 15 minutes and placed in the wash tank near the outlet end and then moved in the direction of the inlet.

10.0 WETTING AGENT

10.1 The films are immersed for 30 seconds in a solution of wetting agent after the final wash.

11.0 DRYING :

11.1 All films shall be preferably dried in a drying cabinet or in dust free room with ambient temperature with air circulated by a fan. Drying temperature in a cabinet shall be a maximum of 60 °C .

12.0 AUTOMATIC PROCESSING OF FILMS

12.1 The solution deposits shall be wiped from rollers which lie above the solution level with a damp cloth. When the developer temperatures becomes steady the temperature shall be measured and recorded each day before the day's processing operation begins.

13.0 FILM FEEDING

13.1 Three rolls of the rollers-transport system shall be always in contact with the film to maintain proper travel through the processor. Films shall be fed into the processor making it certain they are straight and parallel to the side of the feed-tray. A time lapse of 30 sec. shall be followed between consecutive feedings. Multiple films shall have a space between them to avoid overlapping. Table 2 gives number of films that can be processed at a time.

TABLE-2

FILM SIZE	NO OF FILMS
30X40 Cms.	1
15x40 Cms.	2
10x40 Cms.	3

14.0 TRANSPORT SYSTEM

14.1 The films shall be transported by a system of rollers by a constant speed motor. The rollers shall produce vigorous uniform agitation of the solution at the surface of film.

15.0 RECIRCULATION SYSTEM

15.1 Re-circulation of the developer and fixer solutions shall uniformly mix the processing and replenisher solutions maintaining them at constant temperature. The solutions shall be thoroughly mixed and agitated at the surface of the film moving through the tanks so that the films are constantly bathed in fresh solution. Re-circulation and replenishment for wash-water also shall be accomplished.

16.0 REPLENISHMENT SYSTEM

16.1 The solutions shall be replenished at the rate proper for the type or types of film being processed and the average density of the radiograph.

16.2 Table 3 shows the replenishment rates per minute per 30x40 cms. size for different brands of films for an average film density of 2.0.

TABLE-3 :REPLENISHMENT RATES.

DEVELOPER	FIXER	WATER
50 - 55 mL.	90 - 95 ML.	1.9 - 2.0 LIT.

16.3 Replenishment rates shall be measured accurately and checked periodically once in a month.

17.0 DRYER SYSTEM

17.1 The drying temperature shall be set for the lowest possible temperature consistent with good drying.

TABLE-4: PROCESSING AND DRYING TEMPERATURES.

Developer	25 to 30 deg C
Fixer	25 to 31 deg C
Wash water	27 to 30 deg C
Dryer	40 to 45 deg C

18.0 STORAGE OF RADIOGRAPHS

18.1 Radiographs should be stored in a clean dust free room. Radiographs shall be arranged in definite order of control number year wise for easy identification traceable to applicable products.

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CHAPTER 1.15

GENERAL PHASED ARRAY ULTRASONIC PROCEDURE FOR BUTT WELD JOINTS IN TUBULAR COMPONENTS

General Phased Array Ultrasonic Examination Procedure for butt weld joints in Tubular components

Effective Date 13-02-2020

		13-02-2020	13/02/2020	13-02-2020	13/02/2020
00	13-02-2020	Prepared By (BHEL)	Reviewed By (BHEL)	Approved By (BHEL)	Issued By (BHEL)
		Dilip Kumar Singh	V Deepesh	B K Sethupathy	R Arulprabhu
Rev No.	Date	Sr.Engr./NDTL/ PAUT L-II	Sr. Manager/NDTL/ Level-III	Manager/NDTL/ Level-III	DGM/NDTL-HOD/Level-III

1.0 Scope

This procedure describes the requirement and application of Semi-Automated Phased Array Ultrasonic Examination for detection and evaluation of discontinuities within butt weld of tubular products and its effective heat affected zone. This procedure shall be used in combination with specified scan plan and demonstrations approved by UT-Level III with PAUT level II. This procedure is applicable for Carbon and alloy steel tubes with minimum thickness 6 mm (note-1) and outer diameter ranging from 21 mm to 114 mm (note-1).

Note1: For additional range (Greater/Lower for OD/Thickness and different Material grade) examination requirements, this procedure shall be utilized only with proper demonstration qualification on mock up blocks by detecting defects as mentioned by referencing code. ASME sec V art IV Mandatory appendix IX. All qualification shall be approved and accepted by a UT Level III with PAUT level II. Also, it to be noted that for very low thicknesses defect characterization is quite difficult. So, in that case procedure will be used as GO/No GO basis only.

2.0 Purpose

This procedure shall apply to the general aspect of ultrasonic examination of welds using Phased Array technique**. Omni scan MX/MX2/X3** or **equivalent** Phased Array equipment shall be used coupled with Scanner. Any other Phased Array acquisition unit coupled with suitable scanner may be used on successful validation as per mandatory requirement mentioned in ASME Sec-V (2019 edition).

Main objective of this procedure is to;

- Monitor the performance of the equipment
- Configuring the display and data acquisition parameters (Technique Sheet of scan plan)
- Calibration of time base and sensitivity (Wedge Delay, Sensitivity and TCG etc.)
- Description of the recording criteria
- Identification and layout of the components to be tested
- Surface condition required
- Details of the equipment used and volumes covered
- Detection and evaluation of discontinuities in weld metal and HAZ

3.0 Reference

The following documents shall be referred in conjunction with this procedure:

- **BHE: NDT: G: CRT;** BHEL's Written Practice for Training, Examination, Qualification & Certification of NDE Personnel
- **SNT-TC-1A, 2016;** Personnel Qualification and Certification in Nondestructive Testing
- **ASME SEC V (2019 edition);** ASME Boiler and Pressure Vessel Code-Nondestructive Examination

- **ASME SEC I (2019 edition);** Rules for Construction of Power Boilers
- **ASME SEC VIII, Div-1 (2019 edition)**; Rules for Construction of Pressure Vessels
- Equipment Operating Manual

4.0 Table of Essential Variables for Qualification of Procedure

Requirement Requirements of an Ultrasonic Examination Procedure	Essential Variable	Nonessential Variable
Weld configurations to be examined, including thickness Dimensions and base material product form (pipe, plate, etc.)	v	
The surfaces from which the examination shall be performed	v	
Technique(s) (straight beam, angle beam, contact, and/or immersion)	v	
Angle(s) and mode(s) of wave propagation in the material	v	
Search unit type(s), frequency (ies), and element size(s)/shape(s)	v	
Special search units, wedges, shoes, or saddles, when used	v	
Ultrasonic instrument(s)	v	
Calibration [calibration block(s) and technique(s)]	v	
Directions and extent of scanning	v	
Scanning (manual vs. automatic)	v	
Method for discriminating geometric from flaw indications	v	
Method for sizing indications	v	
Computer enhanced data acquisition, when used	v	
Scan overlap (decrease only)	v	
Personnel performance requirements, when required	v	
Personnel qualification requirements		v
Surface condition (examination surface, calibration block)		v
Couplant : brand name or type		v
Post examination cleaning technique		v
Automatic alarm and/or recording equipment, when applicable		v
Records, including minimum calibration data to be recorded (e.g., instrument settings)		v
Requirements of a Phased Manual Raster Scanning Examination Procedure Using Linear Arrays		
Search unit (element size and number, and pitch and gap dimensions)	v	
Focal range (identify plane, depth, or sound path)	v	
Virtual aperture size (i.e., number of elements, effective height, and element width)	v	
Wedge angle	v	
Range of element numbers used (i.e., 1, 126, 10, 50, etc.)	v	
Element incremental change (i.e., 1, 2, etc.)	v	

Angular range used (i.e., 40 deg 50 deg, 50 deg 70 deg, etc.)	v	
Angle incremental change (i.e., deg, 1 deg, etc.)	v	
Requirements of a Phased Array Linear Scanning Examination Procedure Using Linear Arrays (E Scan & S Scan)		
Search unit(s) (element pitch, size, number, and gap dimensions)	v	
Focal range(s) (identify plane, depth, or sound path as applicable)	v	
Virtual aperture size(s) (number of elements, element width, and effective height)[Note (2)]	v	
Wedge natural refracted angle	v	
Scan plan	v	
Weld axis reference point marking.		v
Rastering angle(s)	v	
Aperture start and stop element numbers	v	

Note 2 Effective height is the distance from the outside edge if the first to last element used in the focal law.

Following to be done to qualify the procedure:

a) Complete UT system (Method, Technique, Search units, instrument, all test parameters & conditions etc.) shall be capable of detecting and sizing the reference reflectors & indication throughout the 100% volume.
b) For procedure qualification, the qualification block(s) shall be prepared and shall contain a minimum of three flaws, oriented to simulate flaws parallel to the production weld's fusion line as follows:
   i) One surface flaw on the side of the block representing the component O.D. surface (sensitivity calibration block having OD notch can be used),
   ii) One surface flaw on the side of the block representing the component I.D. surface (sensitivity calibration block having ID notch can be used),
   iii) One subsurface flaw (Side drilled hole at middle thickness, or weld samples having side wall lack of fusion etc. can be used.)
c) Procedure has to be pre-qualified by performing a specific demonstration examination in accordance to the requirements T-150 of Article-1 ASME code Section-V & T-421.2 of ASME code Section-V. Procedure qualification also include the validation of calibration standard/blocks and characterization of recordable signals (if any). All records for the same shall be documented.
d) A change of requirement in Table identified as essential variable from the specified value, or range of values, specific procedure/scan plan shall be re-qualified, established and revised.
e) A change of requirement in above Table identified as non-essential variable from the specified value, or range of values would require revision of the procedure.

5.0 Safety

All personnel are responsible for ensuring that they perform their job in a safe and professional manner, while adhering to the BHEL`s safety regulations, in addition they will also adhere to any statutory requirements along with any project specific safety requirements.

6.0 Personnel Qualification

Personnel performing non-destructive testing to this specification shall be qualified and certified in accordance with NDE written practice for Training, Examination, Qualification & Certification of NDE Personnel as PAUT Level-II minimum.

Personnel who acquires the data, scan the job, does the calibration and analyze Phased Array data shall be trained on same specific technique and certified as NDE PAUT level II. However, data evaluation and analysis shall be performed by a NDE PAUT Level II or NDE Level III.

7.0 Preparation of Examination Area & Surface

Scanning surface should be free from any spatter, foreign materials, paint and any roughness that would interfere with the free movement of the search unit.

Scribe/reference line shall be marked at least on one side of joint configuration before starting the welding.

Maximum Surface roughness of scanning surface area shall be less than 1/3rd of notch depth. Where accessible, prepare the surface of the deposited weld metal so that it merges into the surfaces of the adjacent base materials; however, the weld may be examined in the as-welded condition, provided the surface condition does not interfere with valid interpretation of indications.

Generally, parent material has been tested using normal beam for planar flaw (e.g. lamination) during various stages of fabrication. Raw material records shall be referred. If it is taken care in raw material stage or chance of lamination is not there in the components, then it is not required. If the record is not available then prior to start of the Phased Array Inspection, the base metal distance up to scanning area and its HAZ area shall be scanned using normal beam probe.

The temperature difference between the calibration block and examination surface shall be within 14 degrees Celsius.

The ultrasonic examination area shall include the volume of the weld, plus the lesser of 1 in. (25 mm) or t on each side of the weld. Alternatively, examination volume may be reduced to include the actual heat affected zone (HAZ) plus 1/4 in. (6 mm) of base material beyond the heat affected zone on each side of the weld, provided the following requirements are met:

a) The extent of the weld HAZ is measured and documented during the weld qualification process.

b) The ultrasonic (UT) transducer positioning and scanning device is controlled using a reference mark (paint or low stress stamp adjacent to the weld) to ensure that the actual HAZ plus an additional 1/4 in. (6 mm) of base metal is examined.

8.0 Weld Identification

Weld joints shall be identified with Joint No. This unique joint numbering system shall be recorded as part of the file storage data. On the prepared area for inspection there will be a “ZERO” reference index and/or position numbers on the weld with paint marker, arrow indicating the direction of scanning. Same direction shall be maintained during the scan of similar type of joints.

9.0 Inspection Equipment and Accessories

9.1 Acquisition Unit & Software

Omni scan MX/MX2/X3 **or equivalent Phased Array inspection unit** which can be operated in pulse echo and/or pitch catch mode, shall be used in association to this procedure. It should contain 16/32 independent pulsar/receiver channels and shall handle up to 256 focal laws at a time. In general, the 16:128 modules can be effectively used up to 40 mm thickness which is the maximum thickness under the scope of this procedure. Also, the system shall be capable of generating B-Scan, C-Scan, S-Scan display along with A-scan. Equipment shall be capable of operation at frequencies over the range of 0.5 MHz to 21 MHz equipped with a calibrated stepped gain controls in units of 1dB or less and shall be with digitization of A-scans at a digitizing frequency of 100 MHz Also, equipment shall have option for onboard focal law generation software, various groups (Linear, Sectorial, compound) which can be generated according to the applicable scan plan. The real-time monitoring of the S-scan and C- scan data while doing scanning will ensure that proper data has been collected. The scanned data shall be stored in an external storage device, flash card or USB memory stick and it shall be transferred to a PC/Laptop and analysis of scanned data can be done with the help of OmniPC software or equivalent software. For information, OmniPC is PC-based software used for design, data acquisition, and visualization of ultrasonic signals. For offline analysis of the data a PC with Tom view or Omni PC software can be used. Data can be copied and analyzed remotely using this set up. ES Beam Tool software/ NDT setup Builder software can be used for making scan plan and ensuring 100% coverage of the weld region.

9.2 Scanner, Scanning and Data Acquisition Details:

These tools are adaptable with various wedges and phased array probes to suit any inspection procedures regardless of thickness & material. Examination shall be performed by one of the following techniques:

a) Manual/ semi-automated scanning using semi-automated scanner(s),
b) automated scanning using automated scanner(s)

For the purpose of above, Industrial one axis scanner or XY scanner etc. shall be used for the examination. Refer the table in next page for selection of scanner. Encoded scanners shall be used to improve quality, reliability and performance of data acquisition. Encoded systems shall be equipped with real-time displays to display one or more views of data being collected during the scan. This feature will be used only for assessment of data quality as the scan is progressing and may allow for one or more channels to be monitored. Welds scanned using encoded techniques may be scanned in sections provided that there is an overlap of data collected and the overlap between scans is identified in the encoded position with respect to the weld reference start position (minimum 50 mm overlap is required if more than one subsequent scanning to be done to complete the full weld length scan for example 9000-mm long weld may be scanned in two to complete the full weld length scan a for example, parts; one from 0 to 5000 mm and the second from 450 to 900mm).

Probes shall be mounted on the scanner. The major characteristic of the scanner is its capacity to bend in the center. This allows the scanner to fit on smaller/larger diameter and also to bring the force of the spring-loaded arm in the radial direction of the component for better stability of the wedge, and therefore, optimum data acquisition. Refer below table for recommended Scanner Model:

Inspection Technology	Model (Note*)	Axis		Manual	Motorized	Area Coverage
		One-Axis scanner	X-Y Scanner			
Phased Array	COBRA SCANNER	✓	-	✓	-	21 mm to 114 mm

Note * Any other Phased Array acquisition unit coupled with suitable scanner may be used on successful validation as per mandatory requirement mentioned in ASME Sec-V (2019 edition).

In general Cobra Scanner with the Omni Scan PA flaw detector, shall be used to perform circumferential weld inspections on small-diameter pipes. The COBRA holds up to two PA probes for inspections on tubes/pipes. This spring-loaded scanner is designed to clasp carbon steel and stainless steel tubes/pipes of various diameters using multiple link. The COBRA scanner is characterized by its smooth rolling encoded movement, which enables precise data acquisition. Aperture overlap for linear groups shall not be more than 50% of effective aperture height, and for sectorial groups angular increments shall not be more than 1 degree. In the scan axis, a minimum of 25 mm shall be given as overlap in order to ensure full coverage of the weld. Shear wave ultrasound shall be used for the angle beam inspection. Scanning shall be done at a maximum of 6 dB higher than the primary reference level sensitivity. Scan index distances shall be selected as specified in the scan plan (refer appendix). Generally, if required, for lamination/planar flaw, parent normal beam scan shall be done if required (refer clause 7.0)

	BHARAT HEAVY ELECTRICALS LIMITED TIRUCHIRAPPALLI – 620 014 Non-Destructive Testing General Phased Array Ultrasonic Examination Procedure for butt weld joints in Tubular Components	Doc. No	PAUT_Tubular_Joints_01
		Rev. No	00
		Rev. Date	13.02.2020
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9.3 Search Unit and Wedges

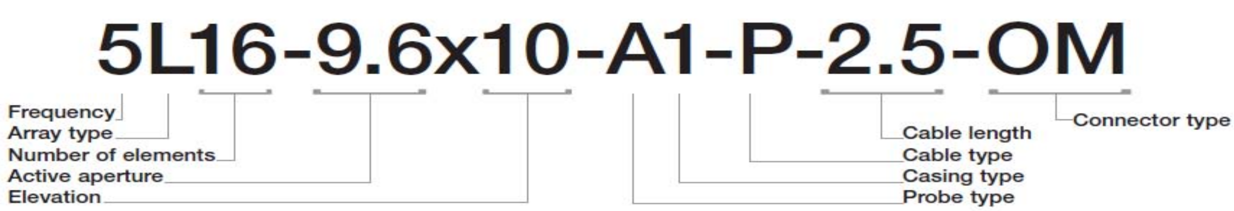
The Phased array probe frequency and size shall be determined by the pertinent parameters for the approved scan plan. Ultrasonic transducers configurations shall be selected in such a way that it shall cover the full volume of the weld. It will depend upon thickness and profile, location etc. of the weld joint. In general, 7.5/5MHz Phased array probes with 16 to 64 elements can be selected. However, the based on the actual joint profile, thickness etc. details a scan plan shall be made and same shall be approved by Level III with PAUT level II. Phased array probes shall be mounted on a wedge of suitable material and refracting angle as to be compatible to provide required beam steering.

Wedges shall have a provision for irrigation hole to provide uniform couplant while scanning.

The complete details of the phased array search units and wedges shall be specified in scan plan. (refer the sample Annexure: 1).

Probes shall be mounted on a wedge of suitable material and refracting angle as to be compatible to provide required beam steering.

Typical probe identification and probe nomenclature which is used by manufacturer are given below:



GLOSSARY USED TO ORDER PHASED ARRAY PROBES (Typical options shown)

Frequency
- 1.5 = 1.5 MHz
- 2.25 = 2.25 MHz
- 3.5 = 3.5 MHz
- 5 = 5 MHz
- 7.5 = 7.5 MHz
- 10 = 10 MHz

Array type
- L = linear
- A = annular
- M = matrix probe (1.5D, 2D)
- CV (ROC) = convex in azimuth
- CC (ROC) = concave in azimuth
- CCEV (ROC) = elevation focused

Number of elements
Example:
- 16 = 16 elements

Active Aperture
Active aperture in mm.
Refer to page vi for details.

Elevation
Elevation in mm
Example:
- 10 = 10 mm

Probe type
- A = angle beam with external wedge
- NW = near-wall
- PWZ = weld inspection angle beam
- W = angle beam with integrated wedge
- I = immersion
- DGS = DGS inspection/Atlas (AVG probe)
- AWS = AWS inspection

Casing type
Casing type for a given probe type

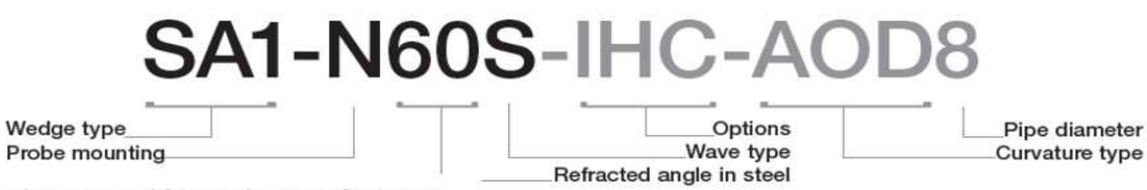
Cable type
- P = PVC outer
- M = metal armor outer

Cable length
Cable length in m
- 2.5 = 2.5 m
- 5 = 5 m
- 10 = 10 m

Connector type
- OM = OmniScan® connector
- HY = Hypertronics™ connector
- OL = OmniScan Connector with conventional UT channel on element 1 (LEMO® 00 connector)

This procedure shall use the following Phased Array Probes & Wedges as mentioned in below table:

Probe Model	Weld	Typical Application Use		Additional Information
		Manual	Automated	
A15	√			Low-profile design. Well suited for boiler tubes, thin-walled/small pipes and applications with minimal height clearance. Compatible with the COBRA* scanner.
A31	√		√	Primary probe for carbon steel weld inspections ranging from 3 mm to 26mm(0.12 in. to 1.02 in.) thickness.
A32	√		√	Primary probe for carbon steel weld inspections ranging from 12 mm to 60 mm(0.47 in. to 2.36 in.) thickness.



Glossary used for Wedge Specification:

Wedge type
- SA00 = wedge for angle beam probe type A00
- SA0 = wedge for angle beam probe type A0
- SA1 = wedge for angle beam probe type A1
- SA2 = wedge for angle beam probe type A2
- SA3 = wedge for angle beam probe type A3
- SA4 = wedge for angle beam probe type A4
- SA5 = wedge for angle beam probe type A5
- SA10 = wedge for angle beam probe type A10
- SA11 = wedge for angle beam probe type A11
- SA12 = wedge for angle beam probe type A12
- SNW1 = wedge for near-wall probe type NW1
- SPWZ1 = wedge for PipeWIZARD probe type PWZ1
- SPWZ3 = wedge for PipeWIZARD probe type PWZ3

Probe mounting
- N = normal
- L = lateral (90° skew)

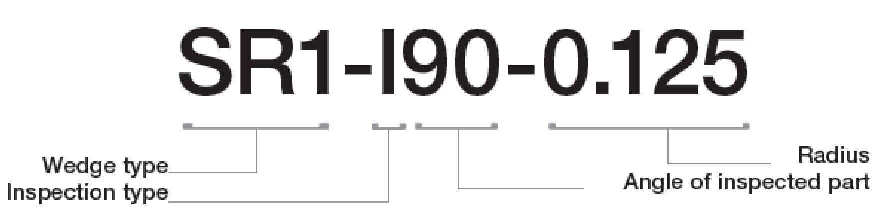
Refracted angle in steel
- 0 = 0°
- 45 = 45°
- 55 = 55°
- 60 = 60°

Wave type
- S = shear wave
- L = longitudinal wave

Options
- IHC = Irrigation, scanner attachment points, and carbide wear pins
- IHC-C = Irrigation, scanner attachment points, and composite wear pins
- WP5 = Water pocket 0.005 in.

Curvature type
- AOD = Axial outside diameter (circumferential scan)
- COD = Circumferential outside diameter (axial scan)

Pipe diameter
Measured external pipe diameter in in.



Glossary used for curved wedge specification:

Wedge type
- SR1 = wedge for curved probe type R1
- SR4 = wedge for curved probe type R4
- SR5 = wedge for curved probe type R5

Inspection type
- I = internal
- E = external

Angle of inspected part (°)
- 81 = 81°
- 90 = 90°
- 98 = 98°

Custom angles can be ordered.

Radius
Radius in in.
- ADJ = adjustable radius

Standard Axial Outside Diameter (AOD) Wedge Curvature values		
External Diameter mm(in.)	**Curvature Range**	
	Minimum mm (in.)	**Maximum mm(in.)**
WEDGE TYPE: SA1,SA2,SA3,SA4,SA5,PWZ1,SPWZ3,S11,S12,S13		
2	45.7 (1.8)	50.8 (2)
2.25	50.8 (2)	57.1 (2.25)
2.5	57.1 (2.25)	63.5 (2.5)
3	63.5 (2.5)	76.2 (3)
3.25	76.2 (3)	82.5 (3.25)
3.5	82.5 (3.25)	88.9 (3.5)
4	88.9 (3.5)	101.6 (4)
4.5	101.6 (4)	114.3 (4.5)
5	114.3 (4.5)	127 (5)
6	127.0 (5)	152.4 (6)
7	152.4 (6)	177.8 (7)
8	177.8 (7)	203.2 (8)
10	203.2 (8)	254.0(10)
12	254.0 (10)	304.8 (12)
16	304.8 (12)	406.4 (16)
22	406.4 (16)	555.8 (22)
30	558.8 (22)	762.0 (30)
FLAT	762.0 (30)	Up to flat
WEDGE TYPE: SA10*,SA11*,SA12*,SA14*SA31,SA32		
2.375	50.8 (2)	60.3 (2.375)
2.875	60.3 (2.375)	73.0 (2.875)
3.5	73.0 (2.875)	88.9 (3.5)
4	88.9 (3.5)	101.6 (4)
4.5	101.6 (4)	114.3 (4.5)
5.563	114.3 (4.5)	141.3 (5.563)
6.625	141.3 (5.563)	168.3 (6.625)
8.625	193.7 (7.625)	219.0 (8.625)
10.75	219.0 (8.625)	273.0 (10.75)
12.75	273.0 (10.75)	323.8 (12.75)
16	323.8 (12.75)	406.4 (16)
24	406.4 (16)	609.6 (24)
FLAT	609.6 (24)	Up to flat

10.0 Computerized Imaging technique

The major attribute of Computerized Imaging Techniques (CITs) is their effectiveness when used to characterize and evaluate indications; however, CITs may also be used to perform the basic scanning functions required for flaw detection. Computer-processed data analysis and display techniques are used in conjunction with automatic or semiautomatic scanning mechanisms to produce two and three-dimensional images of flaws, which provides an enhanced capability for examining critical components and structures. Computer processes may be used to quantitatively evaluate the type, size, shape, location, and orientation of flaws detected by ultrasonic examination.

11.0 Couplant

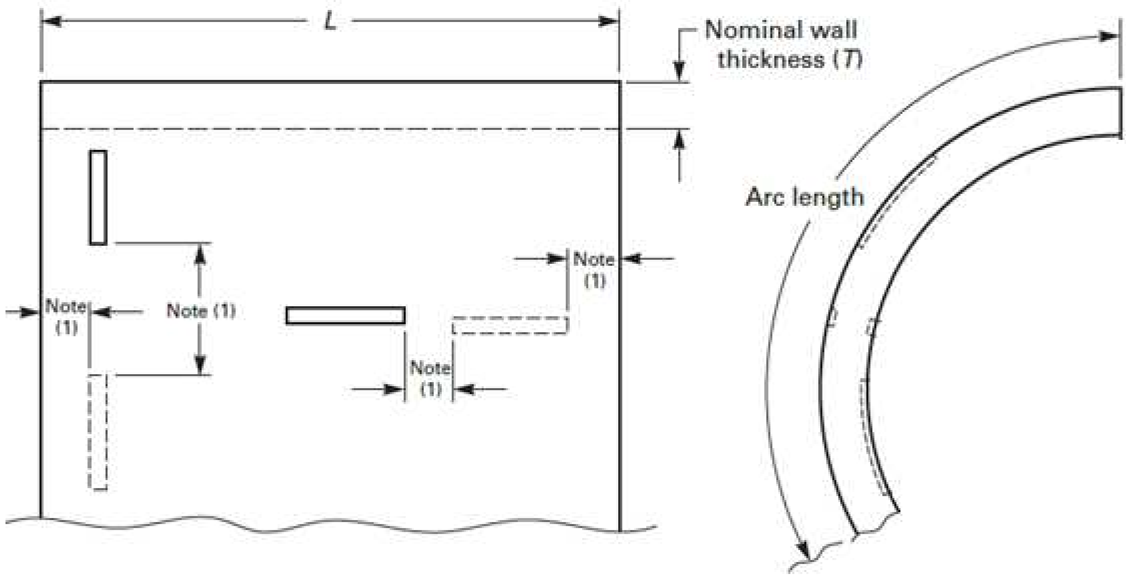
Acoustic coupling shall be obtained by using a medium (oil, grease, cellulose, water) suitable for the purpose. In this procedure water (up to 50°C) shall be used to promote acoustic coupling, however, no residue will remain on the work-piece surface after the water has been evaporated. Couplant to be used during the calibration shall be used for scanning on actual job. The temperature differential between the calibration block and examination surfaces shall be within 25°F (15°C).

12.0 Calibration Blocks

The inspection system shall be calibrated using standard calibration blocks and reference blocks. Following details shall be ensured:

a) **Material, Heat Treatment, Curvature & Surface finish**: The material from which the block is fabricated shall be of the same product form and material specification or equivalent P-Number grouping as one of the materials being examined. For the purposes of this paragraph, P-Nos. 1, 3, 4, 5A through 5C, and 15A through 15F materials are considered equivalent. Generally, the compared specimen (calibration Standard/reference block) shall of the same product form, nominal diameter, thickness, nominal composition, surface conditions, acoustical properties and heat treatment condition as the product being examined. When the block material is not of the same product form or has not received the same heat treatment, it may be used provided it meets all other block requirements and a transfer correction for acoustical property differences is used. All these details shall be reported for the validation of calibration standard/Block. The finish on the scanning surfaces of the block shall be representative of the scanning surface finishes on the component to be examined.

b) **Reflectors:** The standard reflector shall be as per article 4 of ASME Section V. Specific detailed drawing with the tolerance for the calibration standard/Block shall be attached scan plan.



General Notes:

i) The minimum calibration block length(L), shall be adequate enough to take care of scanner as well as probe setup required for calibration. Generally, minimum calibration block length(L) preferred is 500 mm.

ii) Arc length shall be 360 deg/full section to take care of sensitivity calibration as well as scanner block requirement. However, if in some cases machining of reflectors is very difficult then in that case separate block for sensitivity and scanner block for demo can be made. In case of separate block, for OD 100 mm or less, the minimum arc length shall be 270 deg and for OD greater than 100 mm, the minimum arc length shall be 200 mm or 3T, whichever is greater.

iii) Notch depths shall be from 8% T minimum to 11% T maximum.

iv) Notch widths shall be 6 mm maximum. Notch lengths shall be 25 mm minimum. Maximum notch width is not critical. Notches may be made with EDM or with end mills up to 6 mm in diameter.

v) Minimum Notch lengths and maximum notch width shall be sufficient to provide for calibration with a minimum 3 to 1 signal-to-noise ratio.

vi) For dissimilar material/thickness: Two blocks shall be used, if single block does not satisfy the requirements.

vii) Notch(groove) height> 3 times the surface roughness of the block, Block/reflector flatness < 0.5° and Maximum block thickness variation < 0.10 T Component.

viii) Reflectors transverse to the weld seam is required only when cross-defects (such as transverse cracking) is suspected, the requirement of the same can be established during welding process qualification.

ix) Schematic figure of sample calibration block is mentioned in Annexure-II.

Note:1 Notches shall be located not closer than T or 1 in. (25 mm), whichever is greater, to any block edge or to other notches.

C) Quality: Prior to fabrication, the block material shall be completely examined with a straight beam search unit. Areas that contain an indication exceeding the remaining back-wall reflection shall be excluded from the beam paths required to reach the various calibration reflectors. The same shall be recorded. The standard defects shall be machined by very precise machining process in such a way that the indications of each of them are separate and distinct without any mutual acoustic interface or amplification. The calibration block shall be long enough to simulate the handling of the product being examined through the examination equipment. All upset metal, burrs, etc., adjacent to the reference notches shall be removed.

Calibration Standard/Block shall be able to produce minimum SNR value 3:1 with the actual test speed condition. Also, signal from each reflectors have to be clearly distinguishable.

Measurements may be made by optical, replicating, or CMM techniques. Tolerance shall be also specified for the dimensions in the drawing of blocks.

The all actual dimension of the calibration standard/Block including reflectors shape & size details shall be checked and shall be reported. These dimensions shall be also witnessed & certified (once) by the Inspector. However, the detailed documented record shall be made available to the inspector and shall be part of final documentation.

13.0 Calibration

13.1 Equipment Calibration

Phased Array System Linearity verification shall be done as per Article 23, SE- 2491 of ASME Section V. The results of these checks recorded in the ultrasonic instrument linearity forms and are kept as a part of the inspection record. Instrument linearity checks are conducted on a twelve-month cycle.

Prior to the start of shift operator need to carry out an element check and ensure that probe is in working condition and ensure that no more than 10% of elements are inactive and no two adjacent elements are inactive.

13.2 Encoder Calibration

Encoder calibration check shall be performed at intervals not to exceed one month or prior to first use thereafter, by moving the encoder a minimum distance of 20 in. (500 mm). The display distance shall be within 1% of the actual distance moved.

Steps for Encoder Calibration

a) Encoder calibration shall be done to ensure the positional accuracy of the encoder.
b) Mark a distance of minimum 500 mm, and move the encoder through this distance. The value shown by the encoder shall be within +/- 1 % of the moved

distance. If the values are outside the acceptable range, then encoder calibration shall be performed.

c) Move the encoder through a known distance, enter the distance value in the system and calibrate.
d) The system will automatically calculate the resolution of the encoder.
e) Move the encoder to a known distance after the calibration to make sure that the encoder is showing positional accuracy within the acceptable range.

13.3 Velocity & Wedge Delay Calibration

The wedge delay calibration shall be carried out for both linear scan and as well as sectorial scan. The velocity & wedge delay calibration can be carried out in sound path (using 50mm, 100mm radius of IIW V1 block) mode or true depth (using SDH's) mode with known reflector having fixed sound path or depth respectively. Peak up this signal from the calibration reflector and scan the phased array probe backwards and forwards through all the different angles or focal laws. When the signal for all angles and focal laws lies within the threshold, Omni scan system dynamically adjusts delay setting to correctly indicate radius (depth).

Steps for Velocity Calibration:

a) Velocity calibration shall be used for determining the accurate sound velocity in the test Material.
b) Holes or reflectors at different depth shall be used for calibrating velocity.
c) Input the known depth values of the reflectors to the machine and peak up the signals from
d) corresponding reflectors.
e) After recording these points, upon calibrating the machine will calculate the value of sound velocity in the material.

Steps for Wedge Delay:

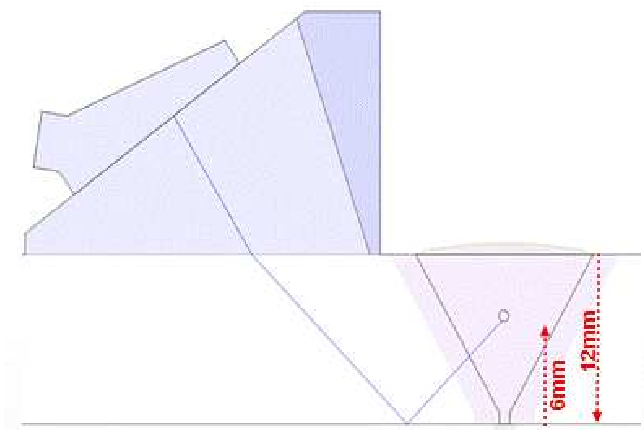
a) Wedge delay calibration shall be used for the true depth with all the angles used in each group.
b) Holes or surfaces (for zero degree) shall be used for calibrating wedge delay.
c) Peak up the signal from the reference reflector and scan the probe back and forth to catch the reflector echo through all the focal laws in the group
d) After calibrating, the system will calculate the respective wedge delays and will make the necessary adjustments so that the system will show the correct depth of reflectors from there on.

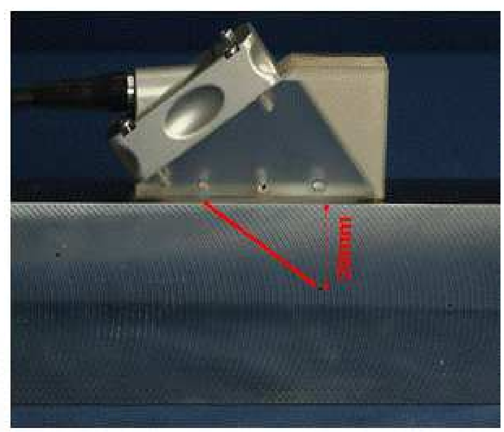
13.4 Sensitivity Calibration

The Sensitivity Calibration will provide the required gain adjustment for each refracted angle or focal law used in a group. All individual beam in the examination shall be calibrated to provide the measurement of distance and amplitude correction over the sound path employed in the examination. This shall include the applicable compensation for the wedge sound path variations and wedge attenuation effects. Focal law to be used during the examination shall be used for calibration. Sensitivity calibration is done to equalize the amplitude of all focal laws in each group. Basic idea is to make sure all focal laws will give same amplitude for same reflector.
Typically, ID/OD notch or SDH of the reference block shall be taken as reference reflector within the zone of material to be examined.

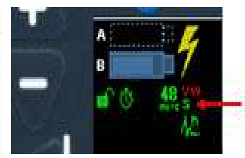
Steps for sensitivity Calibration

a) Select a reflector, within the depth range of examination. In general depth (or beam travel) of reflector has to at least 1.5 times the skip thickness in true depth. For example, refer the figure below:





a) Ensure range is sufficient for all the focal laws (for example 40-70 degrees),
b) Peak up the signal from this reflector, and adjust the amplitude to 80% of FSH.
c) Scan the probe back and forth over the reflector with consistent pressure and coupling such that all the focal laws catch the reflector.
d) After calibrating for sensitivity, system will calculate the compensatory gain and all the focal laws will show the same amplitude range within 80% +/-5% of FSH.
e) Calibrate option may be selected repeatedly until all laws are within tolerance.
f) Finally, select option accept and a green S will appear indicating sensitivity calibration is completed. For example, refer the figure:



g) Already stored calibration files shall be re-verified on the reference block before performing the actual examination to take care of any change in the test components such as probe, cables, instruments, every day before start of the inspection, when examination personnel are changed etc.

13.5 TCG Calibration

A Time Corrected Gain (TCG) shall be used to compensate the attenuation of sound in the material within the sound paths utilized during examination. TCG to be done to equalize the amplitude of all A-scans or focal laws over the sound path range with a series of calibration targets. Generally, it should be a 3 point TCG. This shall be digitally recorded and documented. TCG calibration wizard uses the same interface as the sensitivity calibration with the exception that it does not allow a negative gain correction and it can be used as successive calibration reflectors/targets. The reflectors/targets used for TCG calibration should cover the entire range of the area of interest for the inspection. TCG calibration has to be carried out for all scan plans in a multi group option while using phased array probe.

Steps for TCG Calibration

a) Depending upon scan plan, two or more reflectors at different depths shall be used for calibrating TCG according to the range requirements.
b) Place the phased array probe perpendicular to the reflector’s axis. Move the phased array probe forward and backward to equal the amplitude for all the focal laws and angles and plot the first point.
c) Peak the signal from the respective reflectors and adjust the gain to obtain 80% of amplitude from the reflector.

d) The same process is repeated to set the response from each reflector for each focal law and will be adjusted to 80% of full screen height with 5% tolerance level, by automatically calibrating the compensatory gain.
e) Once all the points (generally three) are picked the TCG can be accepted.
f) Once the TCG is done, the system will show same amplitude for same sized reflectors within the calibrated depth range. Same can be cross checked before acceptance of the TCG. Refer the figure below:

g) Once TCG is accepted, it shall be stored with all parameter such as job Thickness, OD, Job No. etc. for proper identification and retrieval.
h) Already stored calibration files shall be re-verified on the reference block before performing the actual examination to take care of any change in the test components such as probe, cables, instruments, every day before start of the inspection, when examination personnel are changed etc.
i) In case of any practical difficulties faced on notch calibration for very lower thickness/diameter component, the same shall be reported to level III and PAUT II for the obtaining the further decision.

13.6 Calibration Confirmation

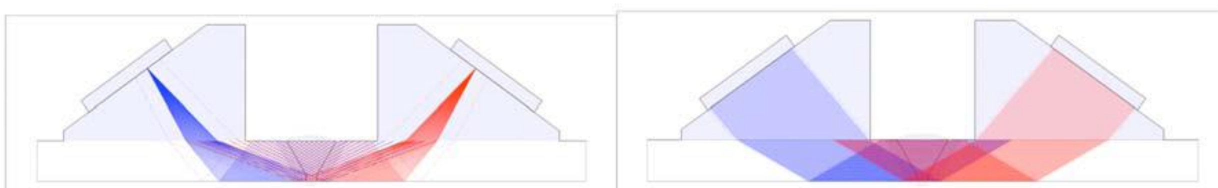
A calibration checks on at least one of the reflectors in the basic calibration block or a check using a simulator shall be performed at the completion of each examination or series of similar examinations, and when examination personnel (except for automated equipment) are changed. If any sensitivity setting has changed by more than 20% or 2 dB of its amplitude, correct the sensitivity calibration and note the correction in the examination record. If the sensitivity setting has decreased, all data sheets since the last valid calibration or calibration check shall be marked void and the area covered by the voided data shall be reexamined. A logbook for the same shall be maintained by the performer and reviewed by the inspector.

14.0 Scan plan

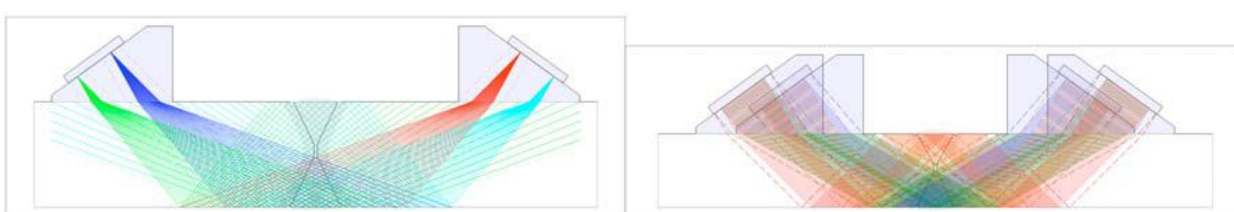
A documented examination strategy or scan plan shall be provided showing transducer placement, movement, and component coverage that provides a standardized and repeatable methodology for weld acceptance. The scan plan shall also include ultrasonic beam angle used, beam directions with respect to weld centerline, weld geometry, number of zones and vessel volume examined for each weld. The specific documentation shall be made.

Scan plan shall provide clear view of scanning, helping to clearly convey weld coverage, HAZ coverage and probe position, in addition to critical dimensions. The beam set parameters dialog displays a visual representation of the transducer elements that are used to form the beam set. These all achieved with the help of ES-Beam software tool and NDT Setup Builder. The scan plan, in combination with the written procedure, shall address all requirements of Table IV-421.

For thin butt welds (S and E Scans) should be examined from both sides of the weld and preferably from the bevel opening side (when access permits). For thin wall sections, a single probe stand-off may be possible for linear scanning if the probe parameters are adequate for full volume coverage.



For thick butt welds (S and E Scans) should be examined from both sides of the weld and preferably from the bevel opening side (when access permits). For thick wall sections, multiple probe stand-offs or multiple focal law stand-offs will be required for linear scanning to ensure full volume coverage.



The sample detailed scan plan for inspection of full volume for given weld geometry and thickness are given in Annexures. Depending upon the actual job configuration, weld bevel profile etc. specific scan plan shall be made and shall be approved by level III for the examination.

Note: It may be required to change the scan plan parameters depends on actual job configuration, weld bevel profile etc. The same shall be verified with demonstration/qualification block to ensure the full coverage.

15.0 Examination Coverage and Scanning

The required volume of the base material and weld to be examined shall be scanned from outer surface using a linear scanning technique with encoder. Each linear scan shall be parallel to the weld axis and at a constant standoff distance with the beam oriented perpendicular to the weld axis. Scanning mechanisms shall be used to maintain a constant distance and alignment between the index points of the probes. Scanning mechanisms can either be motor or manually driven with encoder. They shall be guided by means of a suitable guiding mechanism (steel band, belt, automatic track following systems, guiding wheels etc.). Restricted access welds like single side access and T-Joints shall have to be dressed for its weld cap and examined from single side. During inspection over this dressed weld surface, if data acquisition is not acceptable due to missing data lines, then the weld cap shall be removed for inspection. A maximum sampling of 1mm shall be set for and be used between A-scans collected for thickness up to 50mm. A 2mm resolution can be used for thicknesses more than 50mm. Scanning speed shall not exceed 150 mm/sec. Also, scanning speed will be limited by mechanical ability to maintain acoustic coupling and by the system's electronic ability to ensure full wave forms are captured without missing data points. Missing of data lines shall not exceed 2 data lines per inch or 5% (whichever is less) of the total acquisition with adjacent data shall not be missed. Generally, equipment has the capability of rewriting the data while observed loss of data. The encoder is retrieved back to home position whenever data is missed. Missing data is represented by black lines in the display. Between two consecutive scans there should be and overlap of 50mm. Repaired weld area shall be rescanned with an overlap of minimum 50mm at the start and end of the scan.

For material thickness 8 in. (200 mm) or less, the ultrasonic examination area shall include the volume of the weld, plus the lesser of 1 in. (25 mm) or t on each side of the weld. Alternatively, examination volume may be reduced to include the actual heat affected zone (HAZ) plus 1/4 in. (6 mm) of base material beyond the heat affected zone on each side of the weld, provided the following requirements are met:

a) The extent of the weld HAZ is measured and documented during the weld qualification process.
b) The ultrasonic (UT) transducer positioning and scanning device is controlled using a reference mark (paint or low stress stamp adjacent to the weld) to ensure that the actual HAZ plus an additional 1/4 in. (6 mm) of base metal is examined.

A documented examination strategy or scan plan shall be provided showing transducer placement, movement, and component coverage that provides a standardized and repeatable methodology for weld acceptance. The scan plan shall also include ultrasonic beam angle.

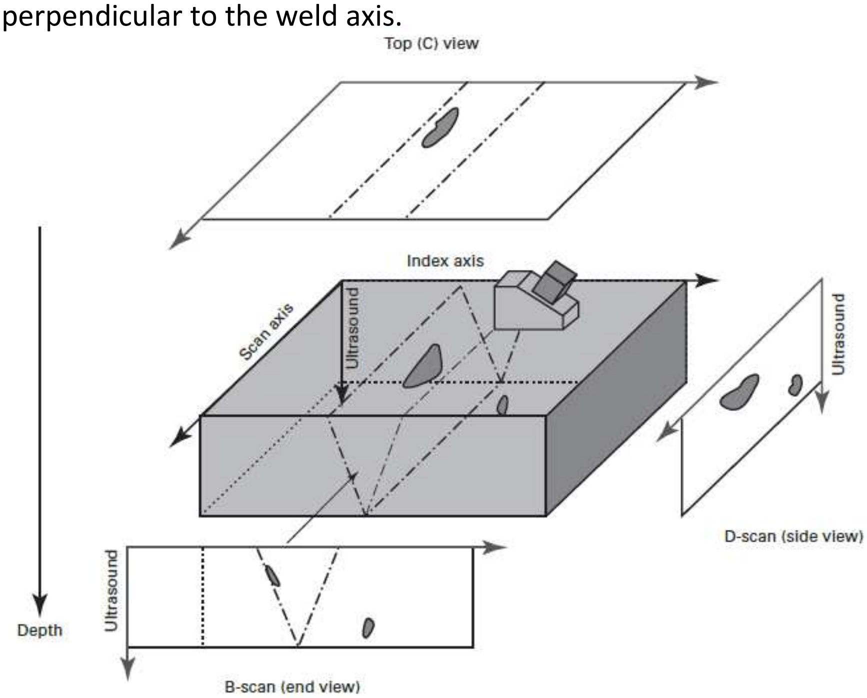
For reflectors transverse to the weld seam, manual shear wave UT should be utilized and the indications originating from actual discontinuities shall be recorded. **This is applicable only when**

cross-defects (such as transverse cracking) is suspected, the requirement of the same can be established during welding process qualification. If required, Manual Pulse-Echo UT examinations are performed along flush ground welds in longitudinal direction; this will be demonstrated by identifying the transverse discontinuity in the validation block. Scanning in both directions along the weld (e.g. Clockwise & counter clock wise for a circumferential seam) is applicable. If the weld cap is not machined or ground flat, the examination shall be performed from the base material on both sides of the weld cap. While scanning parallel to the weld axis, the angle beam shall be directed from 0 deg to 60 deg with respect to the weld axis in both axial directions, with the angle beam passing through the required examination volume.

Prior to scanning, calibration data shall be recorded and stored. The Restricted access welds like T-Joints shall have to be dressed for its weld cap and examined. During inspection over this dressed weld surface, if data acquisition is not acceptable due to missing data lines, then the weld cap shall be removed for inspection.

A maximum sampling of 1mm shall be set for and be used between A-scans collected for thickness up to 50mm. A 2mm resolution can be used for thicknesses more than 50mm. Scanning speed shall not exceed 150 mm/sec. Scanning speed will be limited by mechanical ability to maintain acoustic coupling and by the system's electronic ability to ensure full wave forms are captured without missing data points. Scanning speed shall not exceed that qualified. Missing of data lines shall not exceed 5% of the total acquisition with adjacent data shall not be missed. Omni Scan equipment has the capability of rewriting the data while observed loss of data. The encoder is retrieved back to home position whenever data is missed.

Each linear scan shall be parallel to the weld axis and at a constant standoff distance with the beam oriented perpendicular to the weld axis.



16.0 Recording and Evaluation

A-scan data shall be recorded for the area of interest in an unprocessed form with no threshold, at a minimum digitization rate of five times the examination frequency.

For amplitude base technique all indications greater than 20% of the reference level shall be investigated to the extent that they can be evaluated in terms of the acceptance criteria of the referencing Code Section.

Missing lines in the display shall not exceed 5% of the scan lines to be collected, and no adjacent lines shall be missed

For welds joining two different thickness of material, material thickness shall be based on the thinner of the two materials.

It is recognized that not all ultrasonic reflectors indicate flaws, since certain metallurgical discontinuities and geometric conditions may produce indications that are not relevant. Included in this category are plate segregates in the heat-affected zone that become reflective after fabrication. Under straight beam examination, these may appear as spot or line indications. Under angle beam examination, indications that are determined to originate from surface conditions (such as weld root geometry) or variations in metallurgical structure in austenitic materials (such as the automatic-to-manual weld clad interface) may be classified as geometric indications. The identity, maximum amplitude, location, and extent of reflector causing a geometric indication shall be recorded. [For example: internal attachment, 200% DAC, 1 in. (25 mm) above weld center line, on the inside surface, from 90 deg to 95 deg] The following steps shall be taken to classify an indication as geometric:

(a) Interpret the area containing the reflector in accordance with the applicable examination procedure.

(b) Plot and verify the reflector coordinates. Prepare a cross-sectional sketch showing the reflector position and surface discontinuities such as root and counterbore.

(c) Review fabrication or weld preparation drawings. Other ultrasonic techniques or nondestructive examination methods may be helpful in determining a reflector's true position, size, and orientation.

EVALUATION LEVEL

Distance–Amplitude Techniques: All indications greater than 20% of the reference level shall be investigated to the extent that they can be evaluated in terms of the acceptance criteria of the referencing Code Section.

Non-distance–Amplitude Techniques: All indications longer than 40% of the rejectable flaw size shall be investigated to the extent that they can be evaluated in terms of the acceptance criteria of the referencing Code Section.

EVALUATION OF LAMINAR REFLECTORS

Reflectors evaluated as laminar reflectors in base material which interfere with the scanning of examination volumes shall require the angle beam examination technique to be modified such that the maximum feasible volume is examined, and shall be noted in the record of the examination

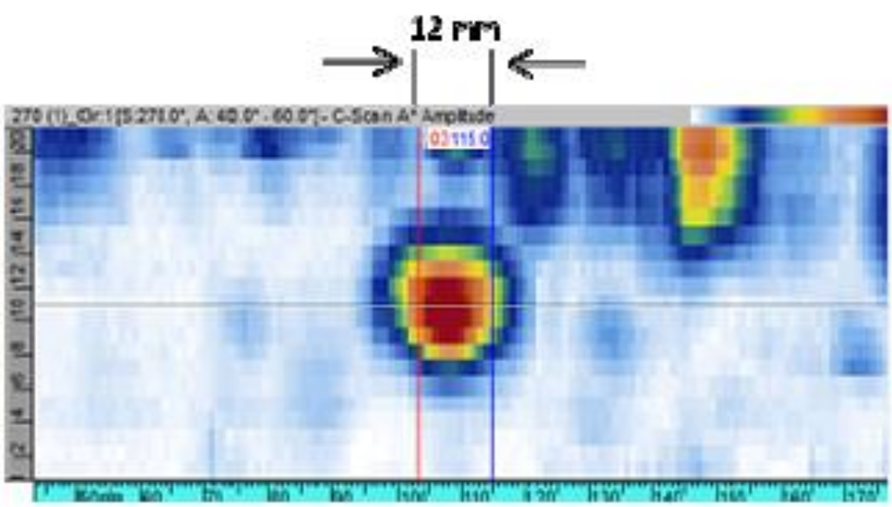
ALTERNATIVE EVALUATIONS

Reflector dimensions exceeding the referencing Code Section requirements may be evaluated to any alternative standards provided by the referencing Code Section

16.1 Relevant Indications

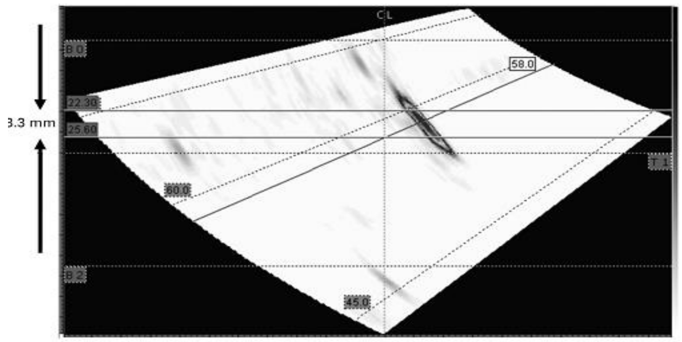
Signals that are determined to result from welding flaws shall be assessed according to the acceptance criteria.

Flaw Length: Flaw lengths parallel to the surface can be measured from the distance encoded C-scan images using amplitude drop (e.g., -6 dB Drop) techniques by placing the vertical cursors on the extents of the flaw displayed on the C-scan display. Below mentioned image shows an example of cursors used for length sizing.

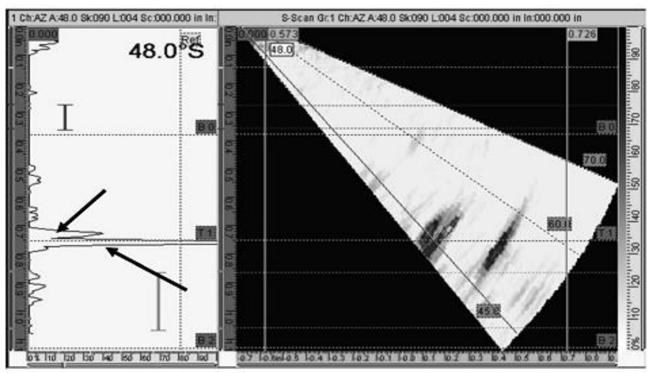


Flaw Height: Flaw height normal to the surface can be measured from the B-, E-, or S-scan images using **(a)** amplitude drop, **(b)** tip diffraction techniques.

(a) Using amplitude drop techniques, the horizontal cursors are placed on the displayed flaws upper and lower extents. Below mentioned image shows an example of cursors used for height sizing with the amplitude drop technique.



(b) Using tip diffraction techniques the horizontal cursors are placed on the upper and lower tip signals of the displayed flaw. Below mentioned image shows an example of cursors used for height sizing with the tip diffraction technique.



17.0 Flaw Evaluation and Acceptance Criteria

For lower thickness where categorization of imperfections by type (surface and sub-surface) and their size (i.e. length and through wall height) is not possible then workmanship acceptance standard shall be followed otherwise fracture mechanics based shall be followed. Same shall be ensured during demonstration and scan plan qualification.

Workmanship:

A standard for acceptance of a weld based on the characterization of imperfections by type (i.e. Crack, Incomplete fusion, Incomplete penetration, or Inclusion) and their size (i.e. length).

a) Indications characterized as cracks, lack of fusion & incomplete penetration are not acceptable regardless of length.

b) Indications from other imperfections are not acceptable if the indications exceed the reference level and have lengths which exceed
   i) 6 mm for `t' up to 19 mm,
   ii) 1/3t for t from 19 mm to 57 mm
   iii) 19 mm for t over 57 mm

   Where `t' is thickness of weld excluding any allowable reinforcement.

c) For a butt weld joining two members having different thickness at the weld 't' is the thinner of the thickness. If a full penetration weld includes a fillet weld, the thickness of `throat' of the fillet shall be included in `t'.

Fracture Mechanics:

A standard for acceptance of a weld based on the categorization of imperfections by type (i.e. surface or subsurface) and their size (i.e. length and through wall height).

Acceptance Criteria:

Flaws shall be evaluated for acceptance using the applicable criteria and with the following additional requirements:

(a) For surface connected flaws, the measured through-wall dimension, a, shall be compared to the value of "a" as determined from the applicable flaw acceptance criteria.

(b) For subsurface flaws, the measured through wall dimension, 2a, shall be compared to twice the value of "a" as determined from the applicable flaw acceptance criteria table.

(c) Surface Connected Flaws:

Flaws identified as surface flaws during the UT examination may or may not be surface connected, as shown in Figures 1 through 5. Therefore, unless the UT data analysis confirms that that flaw is not surface connected, it shall be considered surface connected or a flaw open to the surface. If the flaw is surface connected, the requirements above still apply; however, in no case shall the flaw length, ℓ, exceed the acceptance criteria in the applicable Construction Code for the method employed.

(d) Multiple Flaws:

(1). Discontinuous flaws shall be considered a singular planar flaw if the distance between adjacent flaws is equal to or less than S as shown in Figure 2.

(2). Discontinuous flaws that are oriented primarily in parallel planes shall be considered a singular planar flaw if the distance between the adjacent planes is equal to or less than 1/2 in. (13 mm). (Refer to Figure 3.)

(3). Discontinuous flaws that are coplanar and nonaligned in the through-wall thickness direction of the component shall be considered a singular planar flaw if the distance between adjacent flaws is equal to or less than S as shown in Figure 4.

(4). Discontinuous flaws that are coplanar in the through-wall direction within two parallel planes 1/2 in. (13 mm) apart (i.e., normal to the pressure retaining surface of the component) are unacceptable if the additive flaw depth dimension of the flaws exceeds those shown in Figure 5.

(e) Subsurface Flaws.

Flaw length (*l)* shall not exceed 4*t.*

(j) The nameplate shall be marked under the Certification Mark by applying UT to indicate ultrasonic examination of welded seams required to be inspected in accordance with Section I or Section XII.

(k) This Case number shall be shown on the Manufacturer's Data Report, and the extent of the UT examination shall be noted.

Flaw Acceptance Criteria for 1/2 in. (13 mm) To Less than 1 in. (25 mm) Thick Weld

	a/t	***ℓ***
Surface flaw	≤0.087	≤0.25 in. (6.4 mm)
Subsurface flaw	≤0.143	≤0.25 in. (6.4 mm)

GENERAL NOTES:

(a) *t* = the thickness of the weld excluding any allowable reinforcement. For a butt weld joining two members having different thickness at the weld, *t* is the thinner of these two thicknesses. If a full penetration weld includes a fillet weld, the thickness of the throat of the fillet weld shall be included in *t.*

(b) A subsurface indication shall be considered as a surface flaw if the separation (*S* in Figure 1) of the indication from the nearest

surface of the component is equal to or less than half the through dimension (2*d* in Figure 1, sketch [b]) of the subsurface indication.

Flaw Acceptance Criteria for 1 in. (25 mm) To 12 in. (300 mm) Thick Weld

Aspect Ratio, a/ ℓ	1 in. (25 mm) ≤ *t* ≤ 21/2 in. (64 mm)		4 in. (100 mm) ≤ *t* ≤ 12 in. (300 mm)	
	Surface Flaw, *a/t*	Subsurface Flaw, *a/t*	Surface Flaw, *a/t*	Subsurface Flaw, *a/t*
0.00	0.031	0.034	0.019	0.020
0.05	0.033	0.038	0.020	0.022
0.10	0.036	0.043	0.022	0.025
0.15	0.041	0.054	0.025	0.029
0.20	0.047	0.066	0.028	0.034
0.25	0.055	0.078	0.033	0.040
0.30	0.064	0.090	0.038	0.047
0.35	0.074	0.103	0.044	0.054
0.40	0.083	0.116	0.050	0.061
0.45	0.085	0.129	0.051	0.069
0.50	0.087	0.143	0.052	0.076

Flaw Acceptance Criteria for 1 in. (25 mm) To 12 in. (300 mm) Thick Weld (Cont'd)

GENERAL NOTES:

(a) *t* = thickness of the weld excluding any allowable reinforcement. For a butt weld joining two members having different thickness at the weld, *t* is the thinner of these two thicknesses. If a full penetration weld includes a fillet weld, the thickness of the throat of the fillet weld shall be included in *t.*

(b) A subsurface indication shall be considered as a surface flaw if separation (*S* in Figure 1) of the indication from the nearest surface of the component is equal to or less than half the through thickness dimension (2*d* in Figure 1, sketch [b]) of the subsurface indication.

(c) If the acceptance criteria in this table results in a flaw length, ℓ, less than 0.25 in. (6.4 mm), a value of 0.25 in. (6.4 mm) may be used.

NOTE:

(1) For intermediate flaw aspect ratio *a/ℓ* and thickness *t* (21/2 in. [64 mm] < *t* < 4 in. [100 mm]) linear interpolation is permissible.

Flaw Acceptance Criteria for Larger than 12 in. (300 mm) Thick Weld

Aspect Ratio, a/ ℓ	Surface Flaw, a		Subsurface Flaw, a	
	in	mm	in	mm

0.00	0.228	5.79	0.240	6.10
0.05	0.240	6.10	0.264	6.71
0.10	0.264	6.71	0.300	7.26
0.15	0.300	7.62	0.348	8.84
0.20	0.336	8.53	0.408	10.4
0.25	0.396	10.1	0.480	12.2
0.30	0.456	11.6	0.564	14.3
0.35	0.528	13.4	0.648	16.5
0.40	0.600	15.2	0.732	18.6
0.45	0.612	15.5	0.828	21.0
0.50	0.624	15.8	0.912	23.2

GENERAL NOTES:

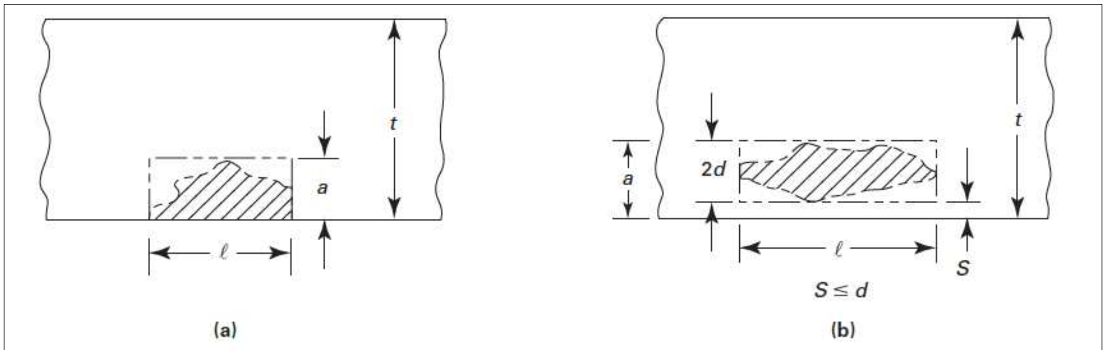
(a) For intermediate flaw aspect ratio, a/ℓ linear interpolation is permissible.

(b) t = the thickness of the weld excluding any allowable reinforcement. For a butt weld joining two members having different thickness at the weld, t is the thinner of these two thicknesses. If a full penetration weld includes a fillet weld, the thickness of the throat of the fillet weld shall be included in t.

(c) A subsurface indication shall be considered as a surface flaw if separation (S in Figure 1) of the indication from the nearest surface of the component is equal to or less than half the through thickness dimension ($2d$ in Figure 1, sketch [b]) of the subsurface indication.

Figure 1

Single Indications



Surface Indications

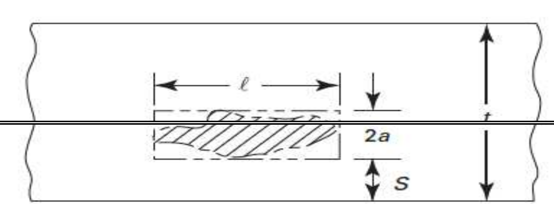


Figure 2

Multiple Planar Flaws Oriented in Plane Normal to Pressure Retaining Surface

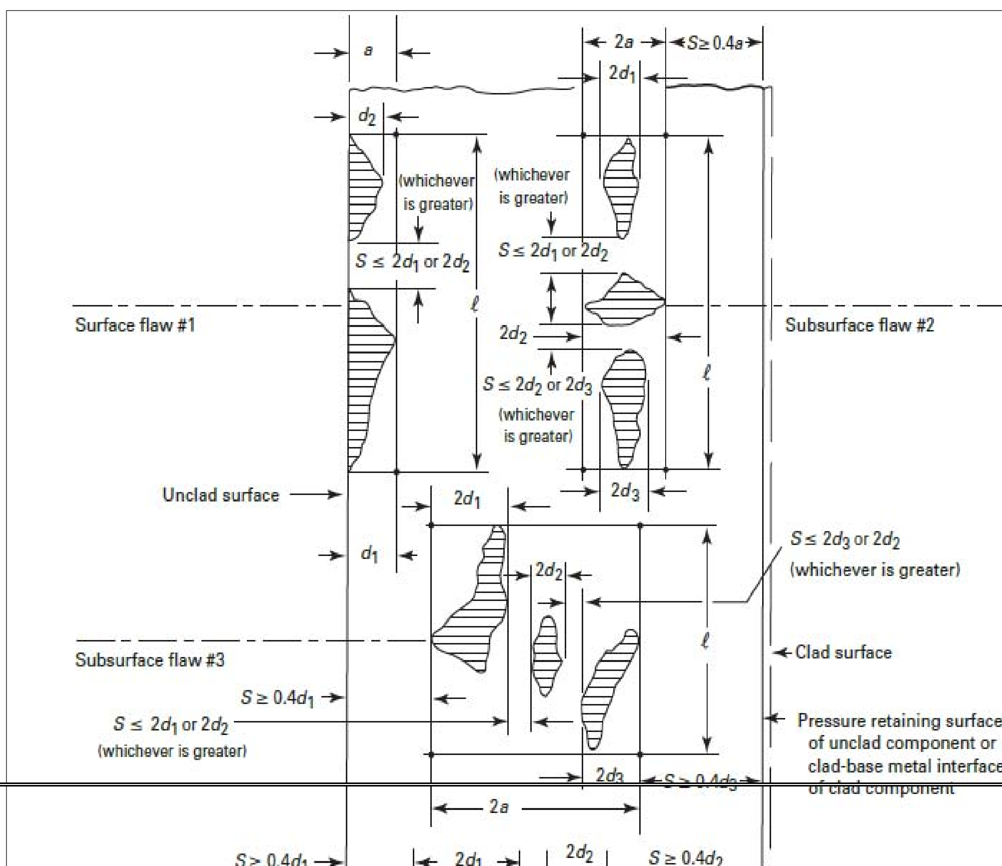


Figure 3

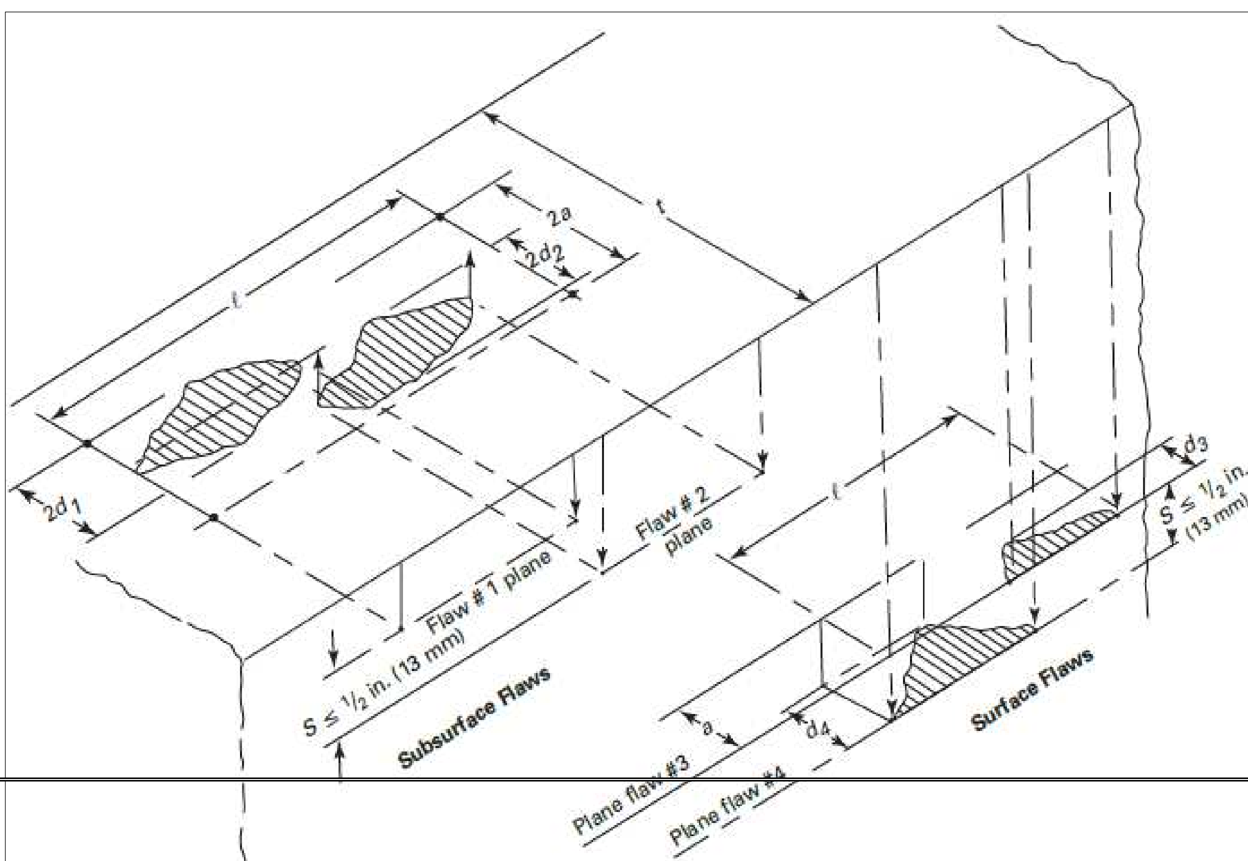

t
2a
2d2
ℓ
2d1
Flaw # 1 plane
Flaw # 2 plane
S ≤ 1/2 in. (13 mm)
Subsurface Flaws
ℓ
d3
S ≤ 1/2 in. (13 mm)
a
d4
Surface Flaws
Plane flaw #3
Plane flaw #4

Figure 4

Nonaligned Coplanar Flaws in Plane Normal to Pressure Retaining Surface (Illustrative Flaw Configurations)

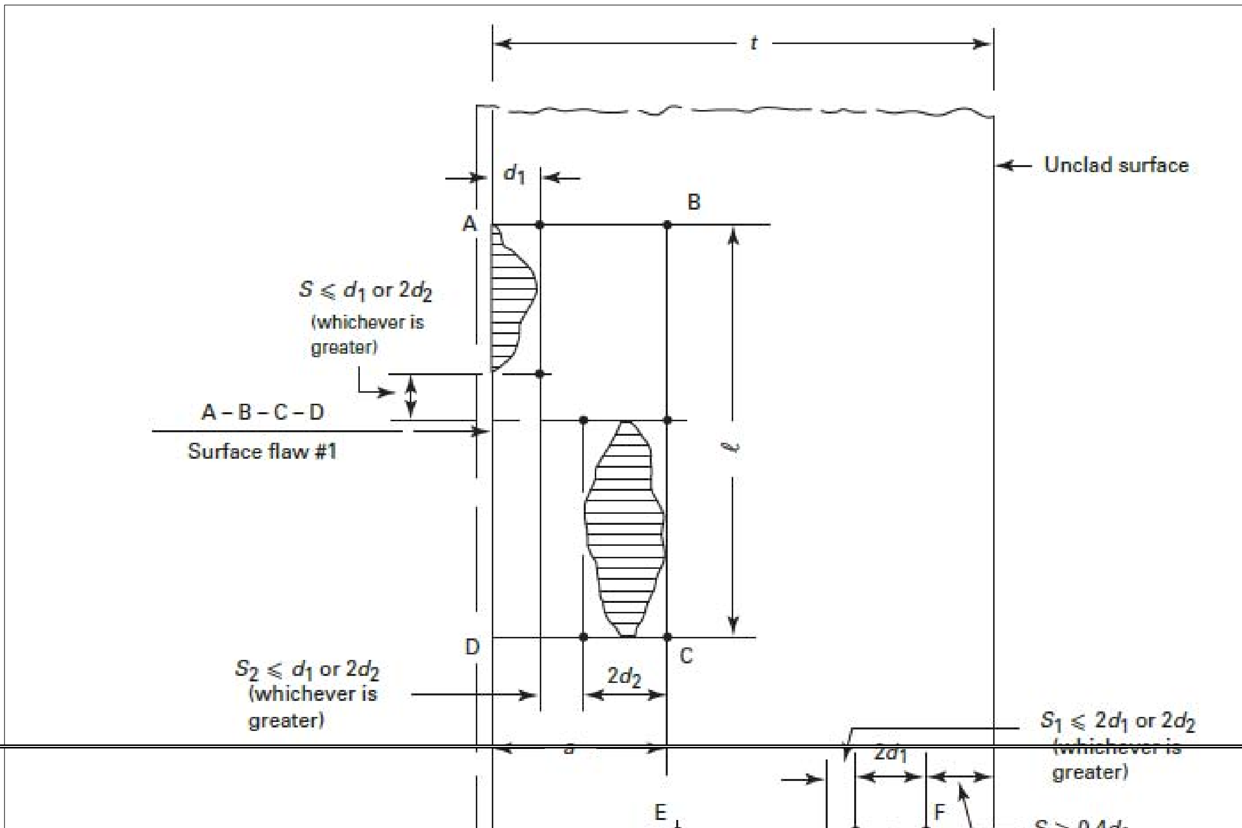
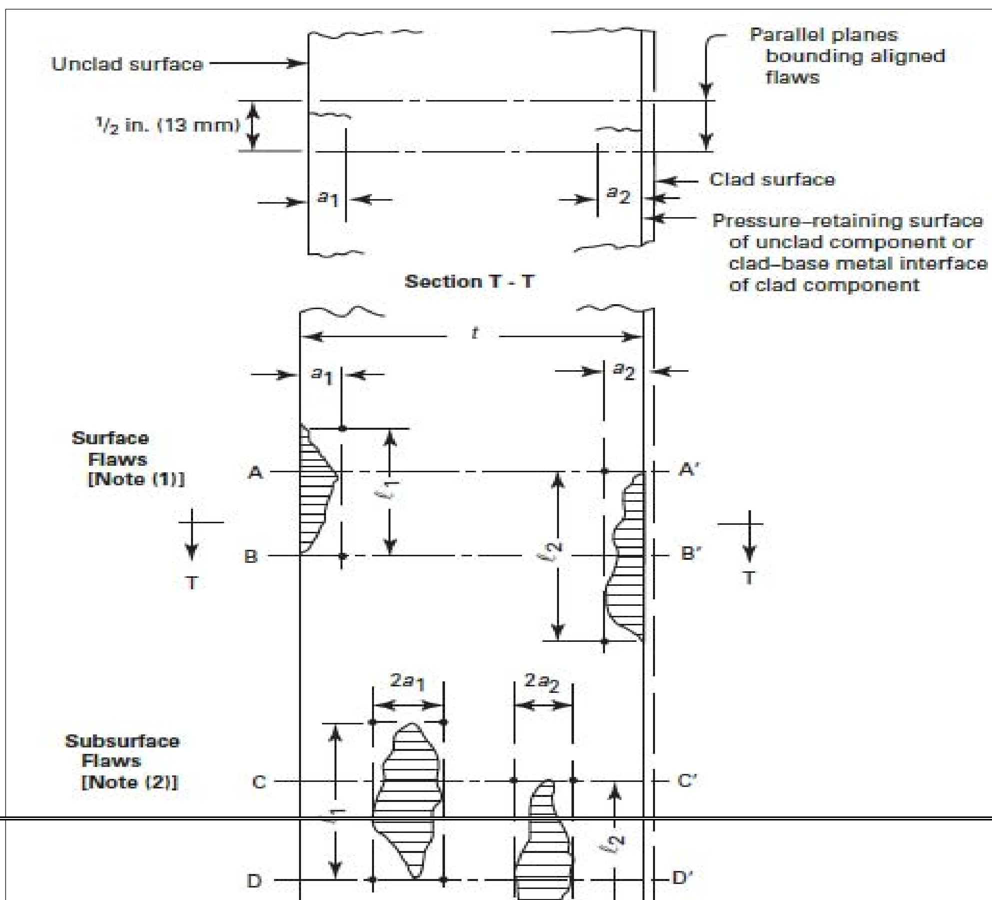


Figure 5

Multiple Aligned Planar Flaws



GENERAL NOTE: In the Notes below, the flaw depth dimensions a_s and a_e are the allowable flaw standards for surface and subsurface flaws, respectively.

NOTES:

(1) This illustration indicates two surface flaws. The first, a_1, is on the outer surface of the component, and the second, a_2, is on the inner surface: $(a_1 + a_2) \leq (a_s + a'_s)/2$ within planes A-A′ and B-B′

(2) This illustration indicates two subsurface flaws: $(a_1 + a_2) \leq (a_e + a'_e)/2$ within planes C-C′ and D-D′

(3) This illustration indicates two surface flaws and one subsurface flaw:
(a) $(a_1 + a_3) \leq (a_s + a'_e)/2$ within planes E-E′ and F-F′
(b) $(a_1 + a_2) \leq (a_s + a_e + a'_s)/3$ within planes F-F′ and G-G′
(c) $(a_2 + a_3) \leq (a'_s + a_e)/2$ within planes G-G′ and H-H′

18.0 Reporting

For each Phased Array examination report, the following information shall be included:
(a) Procedure identification and revision
(b) Ultrasonic instrument identification (including manufacturer’s serial number);
(c) Search unit(s) identification (including manufacturer’s serial number, frequency, and size)
(d) Beam angle(s) used
(e) Couplant used, brand name or type
(f) Search unit cable(s) used, type and length

(g) Special equipment when used (search units, wedges, shoes, automatic scanning equipment, recording equipment, etc.);
(h) Computerized program identification and revision (when used)
(I) Calibration blocks identification
(j) Simulation block(s) and electronic simulator(s) identification (when used)
(k) Instrument reference level gain and, if used, damping and reject setting(s);
(l) Calibration data [including reference reflector(s), indication amplitude(s), and distance reading(s)]
(m) Data correlating simulation block(s) and electronic simulator(s), when used, with initial calibration
(n) Identification and location of weld or volume scanned
(o) Surface from which examination was conducted, including surface condition;
(p) Map or record of reject able indications detected or areas cleared
(q) Areas of restricted access or inaccessible welds;
(r) Examination personnel identity and, when required by referencing Code Section, qualification level
(s) Date of examination

Report Format

BHEL	BHARAT HEAVY ELECTRICALS LIMITED TIRUCHIRAPPALLI - 620 014 PHASED ARRAY EXAMINATION REPORT	Report No	
		Date	
		Format No.	
Job No		Client	
Procedure & Rev No		cont No & Unit No	
Acceptance Std		Drawing No	

INSTRUMENT DETAILS

Manufacturer	Equipment Serial No	Calibration Due Date	Model

Probe	Probe Serial	Frequency(MHz)	Size	Cable Type &Length	Couplant	Brand	Type

Scanner Used	Calibration Block Id	Software	Accessibility
			◻ Accessible ◻ Not Accessible

SCAN PLAN DETAILS

Group No.	Probe	Wedge	Probe Index/PCS(mm)	Start Element	Angle(°)	Skew

PHASED ARRAY PROBE DETAILS

Probe	Frequency	Number of Elements	Pitch	Element numbers used for focal laws	Mode of transmission	Method of sensitivity standardization	virtual aperture used

PHASED ARRAY WEDGE DETAILS

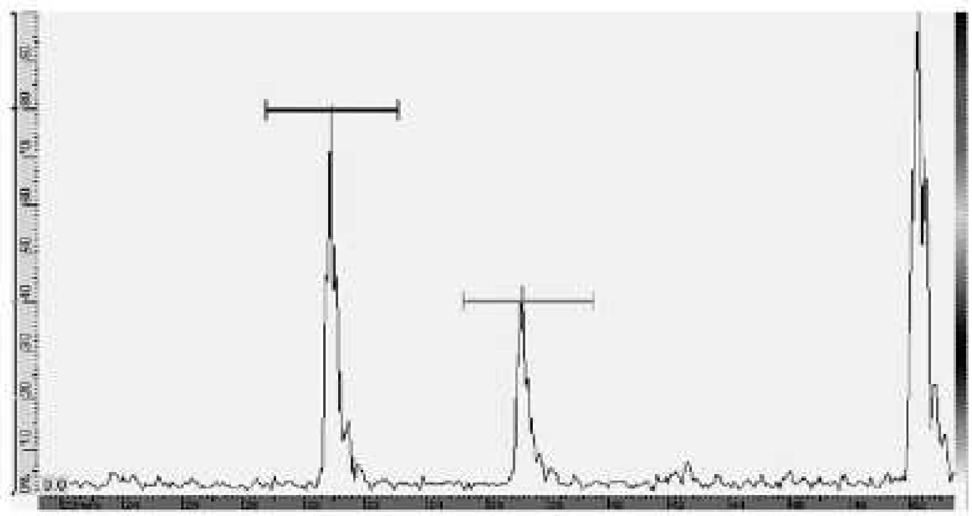
Wedge	Velocity	Incident angle	Dimension	Reference dimension to first element	Encoder used	Recommended wedge angular range from manufacturer

CALIBRATION DETAILS

Annexure-I

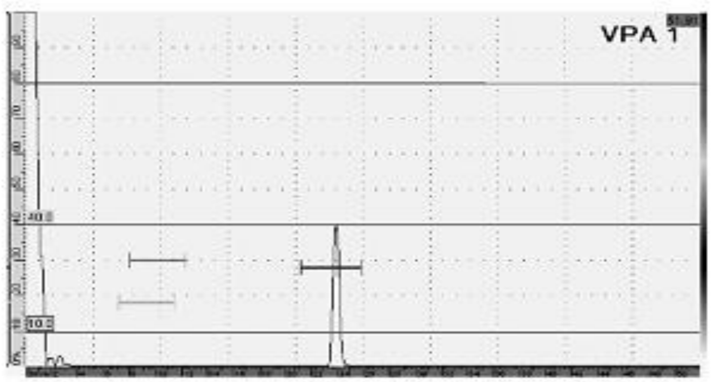
System Calibration

DISPLAY HEIGHT LINEARITY



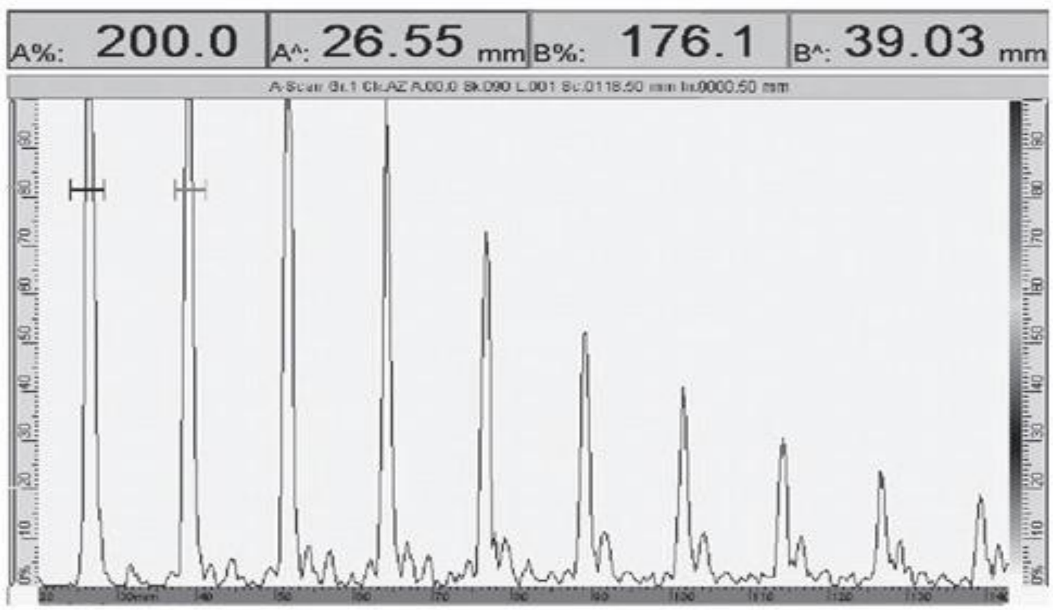
1. With the phased array instrument connected to a probe (shear or longitudinal) and coupled to any block that will produce two signals as shown in fig.6 adjust the probe such that the amplitude of the two signals are at 80% and 40% of the display screen height.
2. Increase the gain using the receiver gain adjustment to obtain 100% of full screen height of the larger response. The height of the lower response is recorded at this gain setting as a percentage of full screen height.
3. The height of the higher response is reduced in 10% steps to 10% of full screen height and the height of the second response is recorded for each step.
4. Return the larger signal to 80% to ensure that the smaller signal has not drifted from its original 40% level due to coupling variation. Repeat the test if variation of the second signal is greater than 41% or less than 39% FSH.
5. For an acceptable tolerance, the response from the two reflectors should bear a 2 to 1 relationship to within •}3% of full screen height throughout the range 10% to 100% (99% if 100% is saturation) of full screen height.
6. The results are recorded on an instrument linearity form.

AMPLITUDE CONTROL LINEARITY



1. A16/64 phased-array instrument has 16 pulsers and receivers that are used to address up to 64 elements. Each of the pulser-receiver components is checked to determine the linearity of the instrument amplification capabilities.
2. Select a flat (normal incidence) linear array phased array probe having at least as many elements as the phased array ultrasonic instrument has pulsers.
3. Using this probe, configure the phased-array ultrasonic instrument to have an electronic raster scan. Each focal law will consist of one element and the scan will start at element number 1 and end at the element number that corresponds to the number of pulsers in the phased-array instrument.
4. Couple the probe to a suitable surface to obtain a pulse-echo response from each focal law. The back wall echo from the 25-mm thickness of the IIW block or the back wall from the 20-mm thickness of the custom linearity block provides a suitable target option. Alternatively, immersion testing can be used.
5. Select Channel 1 of the pulse-receivers of the phased-array instrument. Using the A-scan display, monitor the response from the selected target. Adjust the gain to bring the signal to 40 % screen height.
6. Add gain to the receiver in the increments of 1 dB, then 2 dB, then 4 dB and then 6 db. Remove the gain added after each increment to ensure that the signal has returned to 40 % display height. Record the actual height of the signal as a percentage of the display height.
7. Adjust the signal to 100 % display height, remove 6-dB gain and record the actual height of the signal as a percentage of the display height.
8. Signal amplitudes should fall within a range of 63 % of the display height required in the allowed height range of verification report.
9. Repeat the sequence from 5 to 7 for all other pulse-receiver channels.
10. For instruments having 10- or 12-bit amplitude digitization and configured to read amplitudes in a gated region to amplitudes greater than can be seen on the display, a larger range of check points can be used. For these instruments the gated output instead of the A-scan display would be verified for linearity.

TIME-BASE LINEARITY (HORIZONTAL LINEARITY)



1. Configure the phased array instrument to display an A-scan presentation.
2. Select any compression wave probe and configure the phased-array instrument to display a range suitable to obtain at least ten multiple back reflections from a block of a known thickness. The 25-mm wall thickness of the IIW block is a convenient option for this test.
3. Set the phased-array instrument analog-to-digital conversion rate to at least 80 MHz
4. With the probe coupled to the block and the A-scan displaying 10 clearly defined multiples as illustrated in Figure above, the display software is used to assess the interval between adjacent back wall signals.
5. Acoustic velocity of the test block, determined using the methods described in E494, is entered into the display software and the display configured to read out in distance (thickness).
6. Using the reference and measurement cursors determine the interval between each multiple and record the interval of the first 10 multiples.
7. Acceptable linearity may be established by an error tolerance based on the analog-to-digital conversion rate converted to a distance equivalent. For example, at 100 MHz each sample of the time base is 10 ns. For steel at 5900 m/s each sample along the time base (10 ns) in pulse-echo mode represents 30 m. A tolerance of •}3 timing samples should be achievable by most analog-to digital systems. Some allowance should be made for velocity determination error (~1%). Typically, the errors on the multiples should not exceed •}0.5 mm for a steel plate.

PHASED ARRAY ULTRASONIC INSTRUMENT LINEARITY VERIFICATION REPORT

Location:		Date:	
Operation:		Standard: ASME Sec - V, ARTICLE 23, SE-2491	
Instrument:		Couplant:	
Pulser Voltage (V): Low	Pulse Duration (ns):	Receiver (band) :	Recever Smoothing: On
Digitization Frequency (MHz): 100 MHz		Averaging: 1	

Display Height Linearity			Amplitude Control Linearity		
Large (%)	Small Allowed Range	Small Actual (%)	Indication Height	dB	Allowed Range
100	47 - 53		40	+ 1	42 - 47
90	42 - 48		40	+ 2	48 - 52
80	40		40	+ 4	60 - 66
70	32 - 38		40	+ 6	77 - 83
60	27 - 33		40	- 6	47 - 53
50	22 - 28				
40	17 -23				
30	12 - 18				
20	7 - 13				
10	2- 8				

Sample

Amplitude Control Linearity Channel Results: (Note any channels that do not fall in the allowed range)

Channel (Add more if required for 32 or 64 pulser - receiver units)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

Time Base Linearity (for 25 mm IIW block)										
Multiple	1	2	3	4	5	6	7	8	9	10
Thickness	25	50	75	100	125	150	175	200	225	250
Measured Interval										
Allowed deviation ± 0.5 mm (Yes / No)										

	Verified by	Reviewd By
Name		
Position		
Signature		
Date		

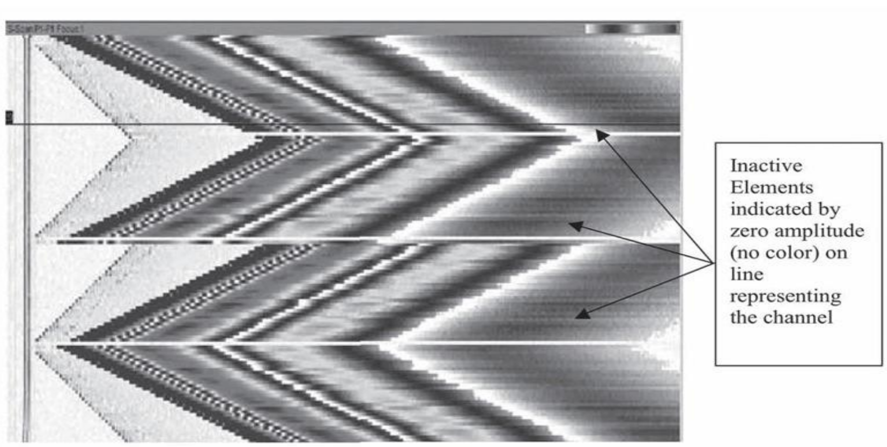
DETERMINATION OF PHASED-ARRAY ELEMENT ACTIVITY

This assessment is used to determine that all elements of the phased-array probe are active and of uniform acoustic energy.

1. Connect the phased-array probe to be tested to the phased-array ultrasonic instrument and remove any delay line or refracting wedge from the probe.
2. Acoustically couple the probe to the 25-mm thickness of an IIW (International Institute of Welding) block with a uniform layer of couplant. This may be accomplished by a contact-gap technique such that the probe-to-block interface is under water (to ensure uniform coupling). Alternatively, an immersion method using a fixed water path may be used and the water-steel interface signal monitored instead of the steel wall thickness.

3. Configure an electronic scan consisting of one element that is stepped along one element at a time for the total number of elements in the array. (This should ensure that the pulser-receiver number 1 is used in each focal law or if the channel is selectable it should be the same channel used for each element). Set the pulser parameters to optimize the response for the nominal frequency of the probe array and establish a pulse-echo response from the block back wall or water path to 80% display height for each element in the probe.
4. Observe the A-scan display for each element in the array and record the receiver gain required to achieve the 80% signal amplitude for each element.
5. Note and record any elements that do not provide a back wall or water path signal (inactive elements).
6. If a prepackaged program is available for checking element activity, this can be used as an alternative.

FIG. A3.1 CONTINUITY DISPLAY FOR PHASED-ARRAY INSTRUMENT OR CABLE



7. Data collected is used to assess probe uniformity and functionality. Comparison to previous assessments is made using the same instrument settings (including gain) that were saved to file. The receiver gains to provide an 80% response should be within a range of •}2 dB of any previous assessments and within •}2 dB of each other.
8. The total number of inactive elements and number of adjacent inactive elements in a probe should be agreed upon and identified in a written procedure. This number may be different for baseline and in-service verifications. Some phased-array probes may have several hundred elements and even new phased-array probes may be found to have inactive elements as a result of manufacturing difficulties ensuring the electrical connections to elements with dimensions on the order of a fraction of a millimeter.
9. The number of inactive elements allowed should be based on performance of other capabilities such as focusing and steering limits of the focal laws being used. No simple

rule for the number of inactive elements can be made for all phased-array probes. Typically, if more than 25% of the elements in a probe are inactive, sensitivity and steering capabilities may be compromised. Similarly, the number of adjacent elements allowed to be inactive should be determined by the steering and electronic raster resolution required by the application.

10. Stability of coupling is essential for the comparison assessment. If using a contact method and the assessment of elements produces signals outside the •}2 dB range the coupling should be checked and the test run again. If still outside the acceptable range the probe should be removed from service and corrected prior to further use. The test using a fixed water path to a water/steel interface will reduce coupling variations.
11. Prior to removing the probe from service the cable used for the test should be exchanged with another cable, when possible, to verify that the inactive elements are not due to a bad cable.
12. Cable continuity adapters can be made that allow the multi-strand connectors to be tested independently. These adaptors can be connected to the phased-array instrument directly to verify that all output channels are active or they can be connected to the probe end of the cable to indicate the continuity of the individual co-axial connectors in the interconnecting cable.

PROBE ELEMENT ACTIVITY CHART: ENTER RECEIVER GAIN FOR 80% FSH

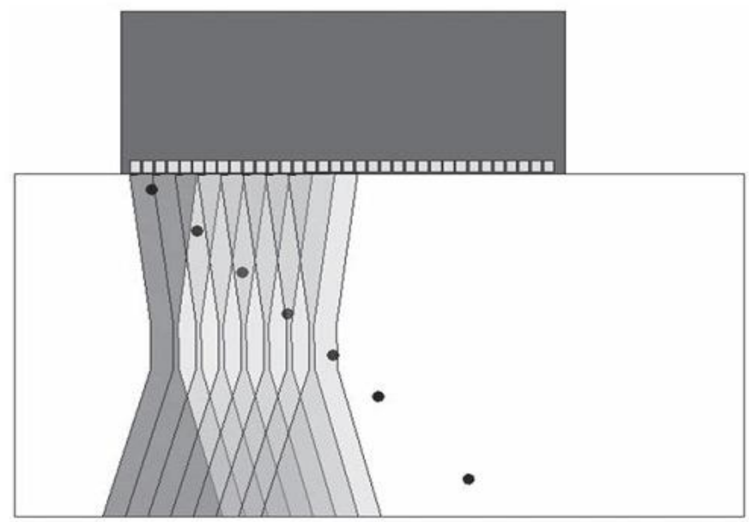
Element	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Gain																
Active([sqcap]) Inactive (x)																

DETERMINATION OF PHASED-ARRAY BEAM PROFILE

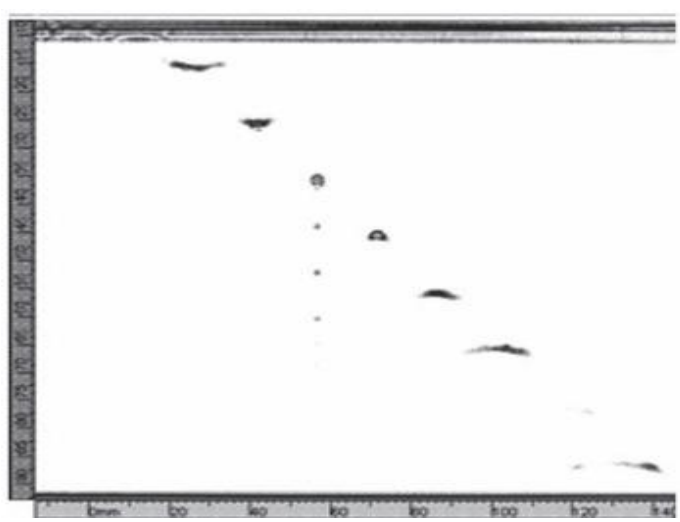
This assessment is used to determine beam profiles of phased-array probes. Either immersion or contact probe applications.

1. Linear-array probes have an active plane and an inactive or passive plane. Assessment of the beam in the active plane should be made by use of an electronic scan sequence for probes with sufficient number of elements to electronically advance the beam past the targets of interest. For phased-array probes using a large portion of the available elements to form the beam the number of remaining elements for the electronic raster may be too small to allow the beam to pass over the target. In this case it will be necessary to have encoded mechanical motion and assess each focal law along the active plane separately.

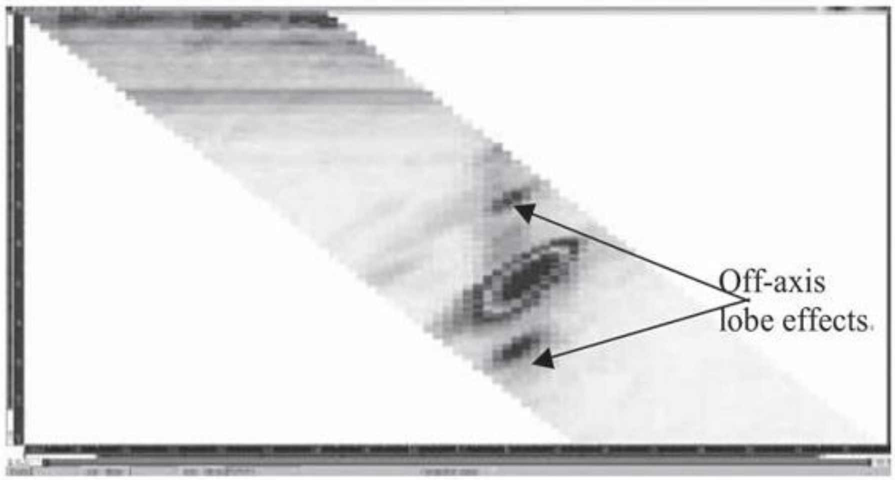
2. Side-drilled holes should be arranged at various depths in a flaw-free sample of the test material in which focal laws have been programmed for. Using the linear scan feature of the phased-array system the beam is passed over the targets at the various depths of interest. The electronic scan is illustrated schematically in below figure.



3. Data collection of the entire waveform over the range of interest shall be made. The display shall represent amplitude as a color or grayscale. Time or equivalent distance in the test material shall be presented along one axis and distance displaced along the other axis. This is a typical B-scan as illustrated in below figure.



4. Data display for an electronic scan using a phased-array probe mounted on a wedge can be similarly made using simple orthogonal representation of time versus displacement or it can be angle corrected as illustrated in below figure.



5. Resolution along the displacement axis will be a function of the step size of the electronic scan or, if the scan uses an encoded mechanical fixture the resolution will be dependent on the encoder step-size used for sampling.
6. Resolution along the beam axis will be a function of the intervals between the target paths. For highly focused beams it may be desirable to have small differences between the sound paths to the target paths (for example, 1 mm or 2 mm).
7. Beam profiling in the passive plane can also be made. The passive plane in a linear-array probe is perpendicular to the active plane and refers to the plane in which no beam steering is possible by phasing effects. Beam profiling in the passive direction will require mechanical scanning.

Waveform collection of signals using a combination of electronic scanning in the active plane and encoded mechanical motion in the passive plane provides data that can be projection-corrected to provide beam dimensions in the passive plane.

Typical Scan Plan

Annexure 1

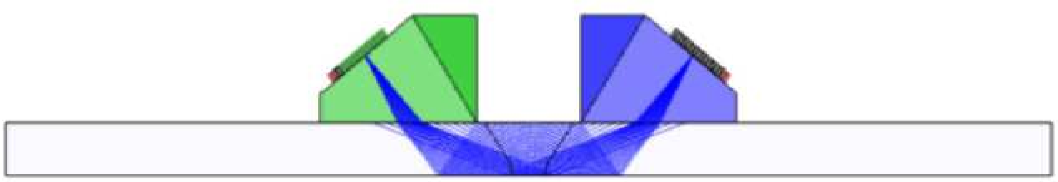
SCAN PLAN DETAILS

Sl.No	Material	Thickness & Dia (mm)	PAUT						
			Probe	Wedge	Index	Aperture element	Start element	Last element	Angle in (degrees)
1	SA213 T 91 & T 23	4.5 & 5.5 Ø63.5	7.5CCEV35-16-A15	SA15-N60S-IH-7.5CCEV35-16-A15 (AOD 2.875)	±6	16	5	12	41-70

Annexure 2

SCAN PLAN IMAGES

Scan plan view 4.5mm & 5.5mm thickness (1st leg)



Note: A documented examination strategy (scan plan) shall be provided showing search unit placement and movement that provides a standardized and repeatable methodology for the examination. Scan plan shall include beam angles and direction with respect to the weld axis reference point, weld geometry and number of zones. Scan plan provides clear view of scanning, helping to clearly convey weld coverage, HAZ coverage and probe position, in addition to critical dimensions. The beam set parameters dialog displays a visual representation of the transducer elements that are used to form the beam set. Varying the focus of the beam is the capability of PA instrument, but generally focusing is not the norm for weld inspection. Beam spread visualization allows more accurately see the beam coverage and near field visualization ensures that any focusing being performed is within the near field. True Depth, Projection and Half Path focus types can be visualized in the workspace and documented as a technique report. These all is achieved with the help of NDT Setup Builder. The scan plan for inspection of full volume of given weld geometry and thickness are given in Annexure: 1

Note: 1. Scan plan given above may require modification based on the actual field conditions to achieve optimum inspection results.

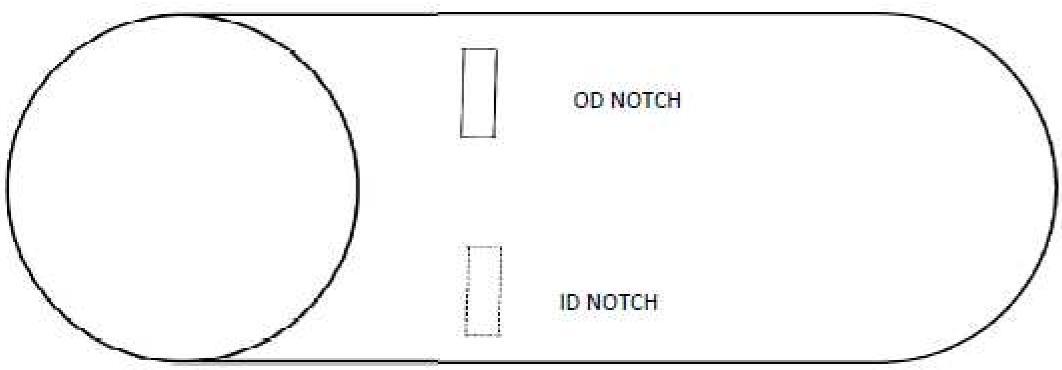
2. For single side access welds (pipe to fitting welds) weld shall be flushed/ground and scan from top of weld or from third leg whichever is possible.

Annexure III

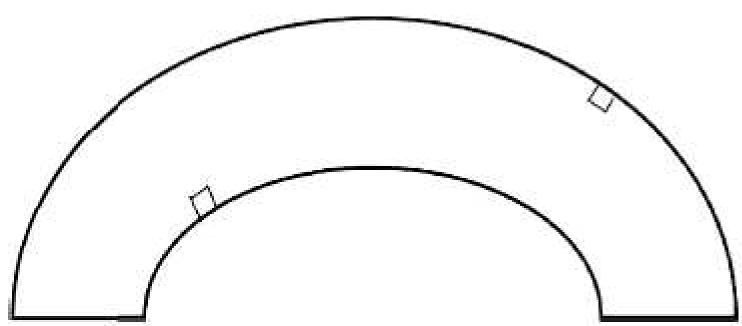
CALIBRATION / DEMONSTRATION BLOCK DETAILS

	Calibration Block Details	
Material	**Pipe details**	**Notch Details:**
SS 213 T91 & T23	Dia -63.5 mm	Length- 30mm
	Thickness- 4.5/5.5 mm	Width-6mm
	Length- 1000 mm	Depth-0.5mm

Side View



Cross sectional View



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CHAPTER 2.0

INSTRUCTIONS FOR ACCESSING NDE PROCEDURES FOR PRESSURE VESSELS, HEAT EXCHANGERS, MILLS, GAS TURBINES AND PIPING

(HPEP HYDERABAD)

Instructions for accessing NDE Procedures for Pressure Vessels, Heat Exchangers, Mills, Gas Turbines and Piping (HPEP Hyderabad)

These documents are restricted as per Corporate Document Repository System and can be accessed from repository only after an access request is approved by the Owner of the document.

Instructions for Accessing Documents Listed Below:

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2. Login to document repository through SSON.
3. Select "Document Administration". In the next dropdown select "Field Quality- Product Specific Standard Documents".
4. In case rights to document repository (or for the specific sub-category) has not been allotted to the individual, request may be raised vide e-mail to Head QLY of the region for the document.
5. Head QLY Region or his representatives having access to the document on the document repository may follow Steps 2 and 3.
6. Procedure to be identified in the document repository by using a search string from the table below (Document Title or Document No.). Request may be raised for access on the document repository. Request will go to the document owner.
7. The Document Owner shall verify the current revision of the document and give access rights to the requesting individual.
8. In case if the document is downloaded and issued by Head QLY, Region or his representative, the document shall be issued to site user after including proper control instructions.
9. If the access rights are not received within 24 hrs of making the request or if there is an urgent need for the document, Head QLY, region may request Head QLY, Hyderabad through e-mail with a copy to Head, CQ&BE, New Delhi.

Product	Sl No	Document No.	Document Title
PRESSURE VESSELS, HEAT EXCHANGERS, MILLS	1	HYQC:NDE:01	NDE Procedure for liquid penetrant examination
	2	HYQC:NDE:12	NDE Procedure for magnetic particle examination
	3	HYQC:NDE:19	NDE procedure for radiographic examination of welds
	4	HYQC:NDE:23	NDE procedure for ultrasonic examination of butt welds
GAS TURBINES AND PIPING	1	HYQC:NDT:30	NDE Procedure for liquid penetrant examination of welds
	2	HYQC:NDT:31	NDE Procedure for Magnetic particle examination
	3	HYQC:NDT:27	NDE Procedure for Radiographic examination of welds
	4	HYQC:NDT:28	NDE Procedure for Ultrasonic examination of Plates
	5	HYQC:NDT:29	NDE Procedure for Ultrasonic examination of Welds

CHAPTER – 3.0
NDE PROCEDURES FOR STEAM TURBINE, TURBO-GENERATORS AND AUXILIARIES

(HEEP, HARIDWAR)

NDE for site welds of Steam Turbine, Turbo-Generator and Auxiliaries supplied by BHEL HEEP, Haridwar.
Please refer the following Plant Standards

Sl. No.	Plant Standard	Title
1	HW0620099	Welding-Fusion welded joints in steel, nickel, titanium and their alloys-Quality levels for imperfections
2	HW0850199	Non-Destructive testing of welded joints
	Part 1	General Principles
	Part 2	Requirements on test procedures
	Part 2.4	Hardness Testing
	Part 10	Part specific information on Heat Exchangers
	Part 11	Component specific data for piping

CHAPTER 4.0

BUS DUCT: ACCEPTANCE STANDARD FOR WELDS IN ALUMINIUM (RADIOGRAPHIC QUALITY)

CFP RUDRAPUR

ACCEPTANCE STANDARD WELDS IN ALUMINUM RADIOGRAPHIC QUALITY

1.0 Scope:

This procedure covers the requirements of radiographic testing and acceptance standards for welds in aluminum such as aluminum flexible connection, enclosures and conductors, etc.

2.0 Surface condition:

As welded

3.0 Procedure:

In general, the testing procedure shall be as per ASME, Section V, Article 2.

3.1 Extent of radiographic examination – As indicated in the relevant drawings or as agreed between BHEL and client.

3.2 Radiation source – X rays

3.3 Film – ASTM class 1 or 2, such as Kodak C5, Agfa – Gaevart D7, NDT 65, 70 or equivalent.

3.4 Film density – shall be between 1.8 to 3.0.

3.5 Technique – Single wall, single image or any other suitable technique as per ASME Section V, if necessary.

3.6 Radiographic Quality level – shall be determined by using ASME Penetrameters or wire penetrameters to DIN 54109 or IS 3657.

Penetrameter sensitivity in case of wire penetrameters shall be 2% or better.

Penetrameters shall be placed towards the source side.

4.0 Acceptance standards:

Any of the following imperfections are unacceptable:

4.1 Any type of crack

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4.2 Zone of incomplete fusion or penetration, which exceed 10% of the weld length of the joint. In longitudinal or transverse butt weld, where full penetration is intended by the weld procedure some lack of penetration is acceptable. The total length of weld with lack of penetration shall not exceed 10% of the overall weld length. At no place shall weld penetration be less than 90% of the thickness of the material. Continuous occurrence of lack of penetration is permitted, but shall not exceed 50 mm in any 500 mm length of weld.

4.3 Inadequate weld dimensions, root cavity (shrinkage) and incompletely filled groove, greater than 10% effective throat thickness.

4.4 Excess penetration shall be permitted provided it does not exceed 25% of the wall thickness or 4 mm whichever is smaller.

4.5 Weld reinforcement: Build up in excess of 25% of the effective throat thickness shall be dressed. Any reinforcement shall be substantially symmetrical about the center – line of the weld and shall be of smooth contour blending smoothly at the toes with the parent material.

4.6 Undercutting and over lapping greater than 10% effective throat thickness.

4.7 Elongated cavities and / or worm holes exceeding 3 mm dia or equivalent area in length provided the limitations on porosity are met with.

4.8 Copper, tungsten or oxide inclusions greater than $t/4$ or 3 mm dia or its equivalent area whichever is smaller.

4.9 Crater pipes exceeding 25% effective throat thickness or 3 mm whichever is smaller.

4.10 Porosity: Scattered porosity not exceeding 0.5 % by volume is acceptable. In general, the size of the pores shall not exceed 0.8 mm dia but occasional 1.6 mm dia pores may be acceptable, provided the following limits are not exceeded:

i) Where pore size is 0.4 mm or less, upto 150 t pores may be permitted in 1000 mm sq area of radiograph.

ii) Where pore size is 0.8 mm dia or less, upto 19 t pores may be permitted in 1000 mm sq area of radiograph.

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iii) Where pore sizes are generally 0.8 dia or less but occasional 1.6 mm dia pores are present, upto 9 t. pores of 0.8 mm dia may be permitted in 1000 sq mm area of radiograph, provided the number of pores up to 1.6 mm in dia does not exceed t.

iv) However, visible surface porosity > 1 mm dia is not acceptable.

Note:
1. In all cases t = thickness in mm of the thinnest section of the weld under examination.

2. Unacceptable weld defects shall be repaired in accordance with the original welding procedure. All repairs shall be 100% respected in accordance with original testing procedure.

3. It is observed, in case of aluminum flexible connections, at the joining zone of aluminum foils to weld metal, a curvilinear type of indication parallel to the longitudinal axis of the welds is observed in general on the film.

It is mentioned in ASME section VIII (1988) para UL W 54
"In case of pressure vessels, parts that are fabricated using layered sections welded to solid sections (similar to aluminum flexible connection), layer wash penetrates slightly into layered sections during welding, resulting in an indication as mentioned above. Such indications are not taken into consideration while interpreting the film".

The above statement needs to be taken into consideration, while interpreting welds in aluminum flexible connection, in the region where foils are welded to weld metal.

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CHAPTER 5.0

PROCEDURE FOR KEROSENE LEAK TESTING

CHAPTER:5.1 KEROSENE LEAK TESTING

1.0 SCOPE :

1.1 This procedure provides details of methods to conduct leak testing using kerosene as penetrant.

1.2 This procedure may be applied for non-pressure parts welds like those in air and flue gas ducts.

2.0 PROCEDURE:

2.1. Weld shall be thoroughly cleaned by hand wire brush or rotary wire brush to remove oil, grease, slag and rust.

2.2. Weld shall be visually inspected and Unacceptable defects if any shall be repaired by grinding and welding.

2.3. Kerosene leak test shall be carried out only at room temperature.

3.0 TESTING

3.1 The weld surface shall be applied with wet/pasty chalk (mixed with water) and dried.

3.1.1 Kerosene shall be sprayed on the other (root) side of weld. The kerosene penetrates through crevices or cracks/ pin holes and is absorbed by dry chalk powder showing up as a dull patch/indication on the bright chalk surface.

3.2 Alternatively weld surface may be wetted with wet (soaked in kerosene) cotton waste or cloth.

3.2.1 In such cases wet/pasty chalk shall be applied on the other (root) side of the weld. This shall be completed before applying kerosene.

3.3 The side on which chalk is applied shall be visually examined for indications of kerosene absorption (sweating/wetting) after 5 minutes of kerosene application. Indications noticed if any shall be repaired as given below.

4.0 REPAIRS

4.1 Leaking spots (indication) shall be marked for repair.

4.2 Repairs shall be carried out by grinding and welding.

4.3 Repaired areas shall be retested as per clause 3.0

5.0 CLEANING

5.1 After testing / retesting is completed the chalk powder and traces of kerosene shall be cleaned off from the welds.

RECORD OF REVISIONS

Sl No	Rev No	Chapter No.	Details of Revision	Date of Revision
1	1	General	All pages revised to include current Rev No., revised Page No. and Date of Issue	10.02.2020
2	1	Table of Contents	Revised as per Contents of Revision No. 1	10.02.2020
3	1	1.1	Current Revision No. 22 updated	10.02.2020
4	1	1.2	Current Revision No. 24 updated	10.02.2020
5	1	1.3	Current Revision No. 07 updated	10.02.2020
6	1	1.4	Procedure No. BHE:NDT:PB:RT-1 Rev 01 included and BHE:NDT:PB:RT-1 Rev 02 removed as it has been obsoleted.	10.02.2020
7	1	1.5	Current Revision No. 06 updated	10.02.2020
8	1	1.6	Current Revision No. 13 updated	10.02.2020
9	1	1.7	Current Revision No. 21 updated	10.02.2020
10	1	1.8	Current Revision No. 08 updated	10.02.2020
11	1	1.9	Current Revision No. 03 updated	10.02.2020
12	1	1.10	Current Revision No. 01 updated	10.02.2020
13	1	1.11	Current Revision No. 07 updated	10.02.2020
14	1	1.12	Chapter Added	10.02.2020
15	1	1.13	Chapter Added	10.02.2020
16	1	1.14	Chapter Added	10.02.2020
17	1	1.15	Chapter Added	10.02.2020
18	1	2.0	Instructions for accessing NDE Procedures For Pressure Vessels, Heat Exchangers , Mills , Gas Turbines And Piping Added	10.02.2020
19	1	2.1 – 2.9	Chapters removed. Documents made available at online document repository system. Instructions for accessing included in Chapter 2.0	10.02.2020
20	1	3.0	Chapter revised to include reference to current procedures.	10.02.2020
21	0		First Issue of the Document, issued after major changes to Document No PSQ-NDEM-COM-2010 (discontinued hereafter)	24.10.2016

GUIDELINES FOR SELECTION OF NDE AND HEAT TREATMENT AGENCIES AT SITE

(to be deployed by BHEL's E&C Associates)

Bharat Heavy Electricals Limited

Power Sector Eastern Region

Kolkata - 700091

Doc. No. : PP-QLY-AA-DC-106/01-20

Rev. No. : 0

PSER : QLY & BE	**Guidelines for Selection of NDE and Heat Treatment Agencies at Site** (to be deployed by BHEL's E&C Associates)	Doc. No. : **PP-QLY-AA-DC-106/01-20** Rev. No. : 0, Date : 14/09/2020 Page **1** of **9**

Title : Guidelines for Selection of NDE and Heat Treatment Agencies at Site
(to be deployed by BHEL's E&C Associates)

Prepared By Committee	Smarak Kumar Sahoo / Dy Engr. (Member)	
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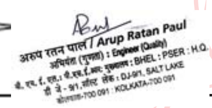
	Arup Ratan Paul / Engineer (Convener)	 Digitally signed by ARUP RATAN PAUL DN: c=IN, o=BHARAT HEAVY ELECTRICALS LIMITED, ou=BHEL-PSER-HQ, postalCode=700091, st=West Bengal, 2.5.4.20=b6355c0e40c2ad6bdcd8bf4ead57fc91a7d353fa88668896bf74b6a564865593, cn=ARUP RATAN PAUL Date: 2020.09.14 17:24:20 +05'30'
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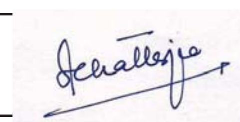
Approved By	Head/ QLY & BE	 Digitally signed by SUMANTA CHATTERJEE DN: c=IN, o=BHARAT HEAVY ELECTRICALS LIMITED, ou=BHEL-PSER-HQ, postalCode=700091, st=West Bengal, 2.5.4.20=b8585eb2e62f6511c82073907e19d5[illegible]8fa875666724bfa32fed52c3c0d8bcded, cn=SUMANTA CHATTERJEE Date: 2020.09.14 17:25:36 +05'30'

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SL. NO.	REFERENCE OF SHEETS REVISED	REVISION NO. & DATE	REMARKS
01	All	0, Dtd.: 14/09/20	New guidelines developed. Valuable comments / guidelines from CQ&BE and QA-Trichy incorporated in the document.

1.0 Object

Object of the guidelines is to enable BHEL engineers to make informed decision regarding selection/acceptance of NDE & Heat Treatment agencies; those are deployed by BHEL's E&C associates at site and to evaluate the performance of the agencies.

2.0 General Guidelines

A. BHEL's E&C associates have to take prior permission/approval before deployment of NDE & Heat Treatment agencies at site. All relevant documents along with the filled-up format as per Annex-A & Annex-B to be submitted by BHEL's E&C associates.

B. The personnel, proposed by the agency for NDE, should have sufficient experience in testing of welds/castings/forgings/plates and should be capable to interpret the given procedure and carry out the test. Trained, experienced and certified personnel qualified as Level I / II / III (as required) as per SNT-TC-1A of ASNT or BSEN 473 of EN through ASNT / ISNT / CSWIP or its Accredited Agencies should only be deployed.

C. The personnel, proposed by the agency for Heat Treatment job, should have sufficient experience in heat treatment of welds/castings/forgings/plates and should be capable to interpret the given procedure and carry out the test.

D. On receipt of proposal along with all necessary supporting documents from E&C associates at site, concerned BHEL Erection engineer & BHEL FQA engineer shall jointly review the proposal and record the details of the accepted agencies as per Annex-C and share with the Construction manager and Head/ Quality & BE/ BHEL-PSER HQ.

E. The FQA engineer shall also take necessary clearance / acceptance from customer, if required, before acceptance of the proposed agency and maintain a record for that. If customer approval is not required, prior intimation shall be given to the customer through memo.

F. The NDE / Heat Treatment agency shall meet the requirements of this document plus any additional qualification requirements specified in latest revision of the BHEL NDE Manual (AA/CQ/GL/011 Part III-NDEM), as applicable.

G. Based on the feedback from BHEL FQA engineers, a controlled list (with revision number & date) of accepted NDE & Heat Treatment agencies with their BHEL-approved personnel shall be maintained by PSER-HQ Quality department and this list shall be uploaded in PSER intranet portal.

H. Monthly performance of the accepted agency/s shall be monitored by BHEL FQA Engineer and the evaluation report to be sent to Head/ Quality & BE/ BHEL-PSER HQ, in MSQR.

I. The agency may be disqualified/debarred on following grounds:

   i. if a re-inspection of material or a recheck of NDE / Heat Treatment data shows significant variation from the agency's report, as determined by BHEL FQA engineer

   ii. if a significant discrepancy or issue (*viz.* or malpractices like usage of modified/ manipulated Reports/ Charts, other fraudulent activity) is noted during the process audit / routine site inspection..

   iii. if any of the agency's BHEL-approved personnel has changed without taking prior approval from BHEL FQA In-charge.

iv. if the equipment mobilised by the agency no longer meets the requirements for approved usage.

v. if the Agency is not able to ensure re-qualification of his personnel/ equipment on expiry of certification or is not able to replace such personnel/ equipment in time with permission of the FQA.

J. The debarred / disqualified agency may apply for re-acceptance only after three months with a written clarification of its previous misconduct and corrective action taken to avoid occurrence of the same incidence. A standing committee of FQA Engineers shall be constituted by Head/Quality & BE/PSER, which shall scrutinise the documents

K. If, for any of the above reasons, the agency is debarred / disqualified, the same shall be immediately intimated by BHEL FQA engineer to Head/ Quality & BE/ BHEL-PSER Site CM and Main Sub-Contractor with intimation for immediate replacement.. The same shall be updated in controlled list of accepted agencies.

L. This guideline does not specifically provide any recommendation for safety measures to be taken during NDE & Heat Treatment work. Suitable safety analysis & hazard identification is to be done at site as per the project HSE manual & standard OCP.

3.0 Specific Guidelines for selection of NDE Agency for PAUT (Phase Array UT)

A. The NDE agency should have executed at least 30% of the proposed work quantity in a single job. In case, multiple agencies are proposed to be deployed, each agency should have executed at least 30% of proposed quantity in a single job. The necessary documents (*viz.* copy of Work Order, End User Performance Certificate, *etc.*) for above to be produced by agency.

B. The Agency to submit their organizational setup, supervision arrangement and list of resources to be deployed at site.

C. For PAUT, the agency shall be capable of mobilising the PAUT equipment & accessories and manpower as follows –

i. **PAUT equipment**: Omni scan MX/MX2/X3 or equivalent Phased Array equipment shall be used coupled with Scanner (16:68 or higher configuration), having

- Weld inspection features including setting up of weld profile.
- Multi grouping capability.
- Capability of using two PAUT probes simultaneously. Necessary adapter/splitter (if required) for attaching two probes for simultaneously working should be available for inspection.
- Operation with battery.
- A-scan, B-scan, C-scan, S-scan, Linear scan, Sectional scan
- Calibration: Velocity, Wedge delay, Sensitivity, TCG, DAC, Encoder calibration features.
- Data analysis and report building
- Encoder recognition.

- Probes: At least two numbers of low profile suitable PAUT probes for (MS and Alloy Steel) of 7.5 -10 Mhz frequency,16-32 element with more than 2 meters of cable length. The probes shall have couplant supply mechanism (passage of couplant) to test surface & required accessories for the same.
- Suitable probes for SS to be made available for inspection of SS joints.
- For Circumferential weld Inspection of Small-Diameter Pipes Advanced semi-automated scanning equipment/ Cobra scanner

ii. **Wedges:** Specially designed wedges to fit in the above probes and having reference angle of 50 to 60 Degree sheer wave in steel will be required. Wedges should have suitable contour to fit around required range of tubes OD (NORMALLY 25 TO 100mm).

iii. **Scanner:** A manual/automated scanner capable for scanning of required OD (normally 25 mm to 100 mm) tubes. The scanner should have encoder with it for precise data acquisition. The scanner should be able to hold two low profile phased array probes and wedges, as mentioned above for complete inspection of the weld in one rotation of the scanner. The design of scanner, probe & wedges shall allow complete inspection of circumferential weld on tube having gap more than 15 mm with any adjacent tubes, supports and structures etc.

iv. **Manpower**: The NDE agency shall deploy minimum two persons for performing non-destructive testing. They shall be qualified and certified in accordance with NDE written practice for Training, Examination, and Qualification & Certification of NDE Personnel as PAUT Level-II. The personnel who acquires the data, scan the job, does the calibration and analyse Phased Array data shall be trained on same specific technique and certified as PAUT level II. However, data evaluation and analysis shall be performed by a PAUT Level II or UT Level III. The necessary document/certificate for above to be produced by agency.

D. **Test Plan / Scan Plan:** The agency shall be capable of submitting the written inspection procedure for PAUT of weld complying with the requirement of latest BHEL NDE Manual (AA/CQ/GL/011 Part III-NDEM), duly approved by a UT Level-III person. The procedure / test plan shall be qualified at site as per latest BHEL NDE Manual (AA/CQ/GL/011 Part III-NDEM).

E. **Calibration:** Velocity, wedge delay, sensitivity, TCG, encoder calibration shall be performed by PAUT operator before inspection and as per frequency of code. Verification shall be done by BHEL FQA engineer regarding competency of the personnel deployed by the agencies, prior to start of job.

F. **Reference block:** Tubes with similar dia & wall thk (within 10% as per code) and circumferential notches/groves shall be used as reference block. The reference block should have length not less than 200 mm. It should have two circumferential grooves/notches (one each on ID & OD) having depth of 10% of wall thickness. 1 to 1.5 mm width & length between 25 to 50 mm. These two grooves should be located at opposite ends of the tube. The notches should be separated from adjacent tube edge by about 50 mm. These two grooves should be located at opposite ends of the tube. The notches should be separated from adjacent tube edge by about 50 mm. The length of reference block and location of reflectors (notches/grooves) should comply the requirement of calibration for angle beams. Agency to take tube samples in advance so that Machine calibration work can be completed before start of work.

G. **Data Storage:** The calibration data and inspection data should be in the equipment and should be available for verification. Inspection data file to be stored by giving identifiable marking for reporting & interpretation. Agency must be capable to hand over data in suitable media (DVD / Flash Drive).

H. **Test Result:** The test result submitted by the agency for each tested tube should provide information on type of defects (like lack of penetration, porosity, lack of fusion etc), their location, length, height, depth etc. The final report with above information to be given in an excel sheet along with PAUT inspection data file & images for all the tested joints. Sample copy of test result of previous job to be submitted by the agency.

4.0 Specific Guidelines for selection of NDE Agency for RT (Radiography Test)

A. The NDE agency should have executed at least 30% of the proposed work quantity in a similar single job. In case, multiple agencies are proposed to be deployed, each agency should have executed at least 30% of proposed quantity in a similar single job. The necessary documents (*viz.* copy of Work Order, End User Performance Certificate, *etc.*) for above to be produced by agency.

B. Agency will submit their organizational setup, supervision arrangement and list of radiography sources to be deployed at site.

C. Agency to submit the documents of BARC / AERB Level- I & II personnel for doing RT & Interpretation of films, respectively. Personnel's skill & capability will be reviewed by FQA before engaging them in job.

D. The agency shall comply with all safety norms as per BARC/AERB & agency must submit source movement authorization for the subject site from BARC/AERB before start of work. The source movement within the site shall also be maintained by the agency in the log book. The agency shall fulfil all the safety precautions as per statutory requirements including Radiological safety at their own cost.

E. **Manpower & Resources:**

i. For a single unit, The agency shall deploy one BARC/AERB certified site in-charge and minimum of two numbers of BARC/AERB qualified Level-I radiographers for deployment of each number of source and one number of Trained, experienced and BARC/AERB qualified RT Level-II film interpreter. Personnel's skill & capability will be reviewed by FQA before engaging them in job.

ii. Agency shall mobilize one full time Radiation Safety Officer (RSO) and one site in-charge at site and maintained as per BARC and BHEL OCP guidelines.

iii. For a single unit, the NDE agency shall have permission from BARC/AERB for mobilizing a minimum of two radioactive sources (as per contractual guidelines) of sufficient strength all the time (minimum of 10 Curie). The source should be replaced immediately after decay to 10 Curie. Agency shall be capable to arrange additional source on emergency.

iv. The Agency has to submit the decay chart and all records regarding movement of the source.

v. The agency should be responsible for security of their source in the plant or during movement of camera at site.

vi. All employees of the agency to use TLD badges & pocket dosimeters while doing radiography testing at site. Also submit annual dose report of radiation workers.

vii. The agency to calculate cordon-off distance & provide 'Radiography warning sign boards & symbols' with cordon-off rope & warning alarm while carrying out the radiography.

viii. Radiography team to be available at site round the clock

ix. Equipment, Film and other consumables used shall be BHEL approved brands.

F. Agency has to demonstrate and establish various parameters for the quality of radiograph (*e.g.* Image density, sensitivity, source size, source to film distance, geometric unsharpness etc.,) to the satisfaction of BHEL.

5.0 Specific Guidelines for selection of NDE Agency for UT & MPI

A. The NDE agency should have executed at least 30% of the proposed work quantity in a similar single job. In case, multiple agencies are proposed to be deployed, each agency should have executed at least 30% of proposed quantity in a similar single job. The necessary documents (viz. copy of Work Order, End User Performance Certificate, etc.) for above to be produced by agency.

B. Agency will submit their organizational setup, supervision arrangement and list of resources to be deployed at site.

C. For a single unit, the NDE agency shall deploy a minimum of two number Digital type Pulse Echo A Scan UT equipment (preferably of OLYMPUS, EINSTEIN-II & Krautkramer) along with required calibration block at site.

D. For a single unit, the NDE agency shall deploy a minimum of two numbers of Trained, experienced and certified Level-I UT technicians and one number of Trained, experienced and certified Level-II Interpreter in UT.

E. For a single unit in MPI work, the NDE agency shall deploy a minimum of two sets of magnetic yokes, pie indicators, iron oxide particles, colour contrast, etc. Should have portable AC/HWAC equipment delivering current of minimum of 1000 amps and portable AC/DC electromagnetic yokes. Calibrated Equipment/ Ammeters shall be used for testing. The equipment should be capable of testing with visual and fluorescent magnetic particles.

F. The agency shall deploy a minimum of two numbers of Trained, experienced and certified Level-I technician in MPI and one number of Trained, experienced and certified Level-II Interpreter in MPI.

6.0 Specific Guidelines for selection of Heat Treatment Agency

A. The NDE agency should have executed at least 30% of the proposed work quantity in a similar single job. In case, multiple agencies are proposed to be deployed, each agency should have executed at least 30% of proposed quantity in a similar single job. The necessary documents (viz. copy of Work Order, End User Performance Certificate, etc.) for above to be produced by agency.

B. Agency will submit their organizational setup, supervision arrangement and list of resources to be deployed at site. This must coresponf to the requirement mentioned in Sl. No. F

C. The T & P's for Resistance Heating being deployed by Heat Treatment agency at site *viz.* PID Control Heating panels, Thermocouples, heating elements, Recorders shall be of renowned make/ branded having provision for digital display (*e.g.* temperature, Amp/ Voltage *etc.*), calibrated and in good working condition. Also to be noted that insulation being used should be in workable condition.

D. The T & P's for Induction Heating being deployed by Heat Treatment agency at site *viz.* Induction Heating equipment, induction cables, Thermocouples, auto-recorders shall be of renowned make/ branded having provision for digital display (e.g. temperature, Amp/ Voltage etc.),calibrated and in good working condition. The Induction heating equipment should be inverter type (IGBT H Bridge) and output frequency should be 7.5-10 KHz. Also, to be noted that insulation being used should be in workable condition.

E. Guidelines of BHEL Heat Treatment manuals shall also be referred.

F. The agency shall be capable of mobilising required number of machines and against each machine one experienced operator & one technician-cum-electrician must be deployed. One experienced supervision staff must be engaged by the agency exclusively for HT job. Qualification of the supervision staff shall be minimum Diploma in Mechanical/ Metallurgical engineering. The competency of operator & condition of equipment must be verified at site, as elaborated in Sl. No. H.

G. The agency should have capability of mobilising flexible ceramic pads as & when advised by BHEL.

H. One trial Heat Treatment must be conducted by BHEL engineers before acceptance of the HT equipment and the manpower, to assess the competency of the deployed persons and the condition of the machinery. The thickness & material to be selected based on the maximum thickness & material to be heat treated at site. All results to be recorded by BHEL engineer for future reference. The following are to be monitored and assessed -

1) For resistance heating process:
   - i. Equipment's condition and calibration documents
   - ii. Competency of the operator to follow SR job card instruction/ WPS instruction
   - iii. Competency of the operator for selection of Resistance coil gauge
   - iv. Wrapping skill of the operator for single tube/pipe
   - v. Wrapping skill of the operator for bunching of tubes
   - vi. Insulating skill of the operator
   - vii. Competency of the operator for Thermocouple fixing skill
   - viii. Competency of the operator for Programming of PID controller
   - ix. Competency of the operator for selection of ROH/ROC
   - x. Performance after completion of PWHT

2) For Induction heating process:
   - i. Equipment's condition and calibration documents
   - ii. Competency of the operator to follow SR job card instruction/ WPS instruction
   - iii. Competency of the operator for Induction coil/ annealing cable rotation

iv. Wrapping skill of the operator for single tube/pipe
v. Insulating skill of the operator
vi. Competency of the operator for Thermocouple fixing skill
vii. Competency of the operator for programming in auto controller of IHE
viii. Competency of the operator for selection of ROH/ROC
ix. Performance after completion of PWHT
x. Competency of the operator to download PWHT graph from auto controller recorder

One mock power failure shall be staged during the trial process to verify readiness of the agency & BHEL's E&C associate for contingency. Acceptability shall depend on the hardness achieved (as measured by UCI machine)

7.0 Revision of this Guidelines

A. Revision in this Guideline, as may be felt from time to time, shall be decided by the standing committee of FQA Engineers constituted by Head/Quality & BE/BHEL-PSER.

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Annex-A

Application for approval of NDE / Heat Treatment Agency at …………………..…………………………….
(Name of Project)

Name of the NDE / Heat Treatment Agency : …………………………………………………………………

Address : …………………………………………………………………

Name of the Proprietor : …………………………………………………………………

PAN / TIN of agency : …………………………………………………………………

Contact No. : …………………………………………………………………

Email address : …………………………………………………………………

1. Details of Qualified / Certified NDT Personnel (ASNT / ISNT)
(*Including BARC certified Radio grapher-RT-1, Site In-charge-RT-2, RSO*)

Sl. No.	Name	NDT Method	Level	Date of first Certification	Certificate Valid upto	Certifying Authority

2. Details of Heat Treatment Personnel

Sl. No.	Name	Qualification	Previous Experience

3. Details of NDE / HT Equipment proposed to be mobilised

Sl. No.	Equipment (Make/Model)	Type (RT/ UT/ MPI/ PAUT/ HT)	Quantity	Specification / Rating	Calibration Status	Capacity of the Equipment

4. Details of Previous work done (in past 3 years):

Sl. No.	Project Name & Customer	Type of Job (RT/ UT/ MPI/ PAUT/ HT)	Number Tube Joints completed	Number of Pipe Joints Completed

………………………………………………………………… …………………………………………………………………

Signature of the Owner of the Agency & seal   Signature of BHEL's E&C Associate & seal

Note : Applicant shall submit supporting documents along with this application and fill the Annex-B

Annex-B

Check list for Annex-A

Note : Applicant shall fill the following details and no column shall be left blank		
Sl. No.	***Description***	
A.	Name of the Proposed Agency	
B.	Quantum of job being proposed for the agency	
C.	Copy of agencies Govt. Registration	Page no.
D.	Duly filled in Annex-A	Page no.
E.	Certificates for Individuals as mentioned in Sl. No. 1 of Annex-A (Not applicable for HT agency)	Page no. from ….. to …..
F.	AERB approval certificate (for RT agency Only)	Page no. from ….. to …..
G.	Supporting documents for previous work Experience as mentioned in Sl. No. 2 of Annex-A	Page no. from ….. to …..
H.	Supporting documents for previous work Experience as mentioned in Sl. No. 3 of Annex-A	Page no. from ….. to …..

………………………………………………………………………

Signature of BHEL's E&C Associate & seal

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Annex-C

Agencies Authorised for conducting NDE / Heat Treatment at ………………..………………….………

(Name of Project)

Date : ……………………………….

Proposed By (Name of BHEL E&C Associate) : ……………………………………………………………………………………..

SL. No	Name & Address of Agency	Type of Job (RT/ UT/ MPI/ PAUT/ HT)	Name of the Persons	Method	Level	Certificate Valid upto	Contact Person, Contact number

Tick (√) applicable

1. Credentials of the above agencies have been reviewed as per Guideline and found acceptable.
2. Trial Heat Treatment has been performed by the HT agency and found to be satisfactory
3. The agencies' personnel have been interviewed and found to possess knowledge of the process & equipment

……………………………………………………………………… ………………………………………………………………………

(BHEL Erection Engineer) (BHEL FQA Engineer)

Distribution:

1. Construction Manager / BHEL Site
2. Head / Quality & BE, BHEL-PSER