TECHNICAL LITERATURE

MANUFACTURING AND SKILL DEVELOPMENT

महाराष्ट्र शासन

सत्यमेव जयते

BOILER™ INDIA 2022

14 | 15 | 16 SEPTEMBER

CIDCO Exihibition & Convention Centre

MUMBAI | INDIA

india.boilerworldexpo.com

Shri. Eknath Shinde
Hon. Chief Minister
Maharashtra State

अप्राप्यं नाम नेहास्ति धीरस्य व्यवसायिनः।

"There is nothing unattainable to the one who has courage and who works hard."

Maharashtra has always been the most industrious state and has maintained this position since long. Maharashtra is looked up as the leader in the agricultural sector, Industrial production, trade, transport system and education. The state capital is the commercial capital of India and is emerging as a global financial hub. Maharashtra is a pioneer in small scale industries and boasts of the largest number of special export promotion zones. Maharashtra has a large base of skilled and industrial labour. GOM has already decided to spend more than Four Lakh crores in the next three years on agriculture, health, human resource, transport and industry. Industries find Maharashtra an ideal destination for its knowledge based and manufacturing sectors.

Boilers are a very important part of the Industrial development. Maharashtra being more vigilant and sensitive in nature for safe and healthy practices look forward to the development ensuring adequate safety. With this preview and context, this present network and progress driven platform of Boiler India, 2022 has been made available. This futuristic opportunity presented needs to be utilized by one and all.

Wishing the best to the convention!!!

Jai Hind!!!

Jai Maharashtra!!!

Shri. Devendra Fadnavis
Hon. Deputy Chief Minister,
Maharashtra State

कल्पयति येन वृत्तिं येन च लोके प्रशस्यते सद्भिः।
स गुणस्तेन च गुणिना रक्ष्यः संवर्धनीयश्च॥

"The skill that sustains livelihood and which is praised by all should be fostered and protected for your own development."

Maharashtra is the economic power of the country and with the present post covid scenario it is expected to grow in larger proportions. The growth in the GSDP is expected to be at 18% against the 12% achieved this FY 21-22. Industrial sector shoulders as much as 46% of this responsibility. In line with the strong initiative's made by the Central government for the increase in the "Ease of Doing Business", Maharashtra is keen and devoted on this front. The Government of Maharashtra has chalk marked an 18% increase in the budget to enable the growth in both the urban and the rural development.

With the global competition in investment attraction, facilitation has been increased by the Government of Maharashtra. It has become imperative to provide seamless facilitation and world-class infrastructure to the industry and this unique convention is an important step in this direction. The work taken by the Department of Labour and Directorate of Steam Boilers to provide single platform for the Manufacturers and end users is a measure to boost the Industrial reach and develop an ease of accessibility towards the growth that Government of Maharashtra has sworn to. The growth is bifold with the manufacturers exposed to wider products and the Users getting a wide bouquet of products to choose from.

Looking forwarded to the success of the event and hence the State and Nation as a whole.

Dr. Suresh (Bhau) Dagadu Khade
Hon. Minister, Labour
Maharashtra State

अभ्यासादेव कौशलम्।

"It is work that makes a man workman."

Maharashtra's industrial growth has gone hand in hand with the Human resource development of the State. Maharashtra is very progressive on front of professional education with a very strong base for highly intellectual and skilled manpower. Development of the society requires an all-around growth of manpower with given situation of dropout of school Students before reaching to high school, owing to different reasons, Maharashtra has developed full functional skill development society with a rigid framework instituted ensuring growth in the skill set. Directorate of Steam Boilers in this direction has contributed immensely by providing technical and skilled Boiler Attendants, Boiler Operation Engineers and super skilled Welders to the Boiler Industry.

Boilers are a very important and economical utility used in a wide variety of applications across the industry. The Directorate of Steam Boilers is setup as the primary institute entrusted with the responsibility against failures and hence any loss to the society or rather the nation as a whole. Using resourcefulness, the department is promoting the skill development to a higher level and most importantly to the under privileged strata of the society too. This present consortium is again another ingenuity of the department, leading to bring together all the different facades of the business together. Wishing good to the Boiler India 2022 initiative and great success.

Smt. Vinita Vaid Singal (IAS)
Principal Secretary, Labour
Maharashtra State

Department of Labour Maharashtra as always is a trend setter for the Nation. Maharashtra's industrial landscape has shown continuous upward movement. The onus of the above not only falls on the Stakeholders, management and the workers but also on the approach of the bureaucracy. Maharashtra has a very strong vision for the safety of the work force and this reflects in the failure figures with regards to the amount of establishments.

Boilers have a very big contribution towards the development of the industry and the society as a whole. Every facet of the industry utilizes the steam power be it the basic electricity production, pharma, FMCG sector, Glass manufacturing, to the service hospitality sector. The extremely powerful Boilers installations required more strict laws to ensure safety. Directorate of Steam Boilers, Maharashtra is not only a enforcing agency but also a developer of the holistic approach. With the immense success of the past endeavour in 2020, "Boiler India 2022" promises to be scaled up to multifold. The concentration on bringing such a big industry consisting of global market leaders, prime suppliers, dealers, accomplished academicians, experienced technocrats and service providers in this convention benefits the commercial capital of India.

Looking forward to the wonderful interaction during this convention.

Vinita Singal

Dhawal P. Antapurkar
Director of Steam Boilers,
Maharashtra State, Mumbai

यथा होकेन चक्रेण न रथस्य गतिर्भवेत्। एवं
परुषकारेण विना दैवं न सिद्‌धयति ।।

"Just like a Chariot cannot Move with one Wheel, we cannot attain our Destiny without Hard work and Effort"

Steam Boiler have an ancient origin and have been widely used since. The utilization of boilers is on a very wide scale.

Boiler inspections in India have completed 152 years. Two serious accidents in 1869 led the foundation of present form of the Directorate The directorate has taken up the job of ensuring safety at a multi fold level. Boiler safety starts from the primary stage of construction, raw material selections, strict inspections of all manufacturing stages, correct erection, commissioning and use with appropriate and mandatory manpower deployment in the complete life cycle of the boiler.

It gives me immense pleasure to bring forth this new edition of "Boiler India 2022". The remarkable success of the event in March 2020 motivated us to go global, post the covid scenario. This year event promises to bring together the sophisticated and state of the art technologies in both the producer and the user ends. Looking forward to a fruitful interaction between all the stake holders in building of a safe work environment, stronger Industry and stronger Nation.

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METALLURGY FOR HIGH PRESSURE & TEMPERATURE APPLICATIONS

By Mr. Asutosh Khandelwal, Mr. Satish Tilva,
Mr. Swarajya Kumar, L&T-MHI Power Boilers Pvt. Ltd.

Name: Asutosh Khandelwal
Organisation: L&T-MHI Power Boilers Pvt. Ltd.
Designation: Head Quality
Education: B.Tech. (Mechanical Engineering) - GB Pant University, M.E. (Welding Technology) - IIT Roorkee

Leading the Quality Team at L&T MHI Power Boilers. Implementing Company's Vision and Mission w.r.t Quality. Meeting the Customer's need & expectations w.r.t Quality, Overall Performance of Manufacturing & Site Quality, Monitoring and Development of vendors. Hands on experience on advance welding processes viz. Auto TIG, Orbital, ESSW, PAW. Handled various metallurgies viz. CS, AS, SS, Duplex, Super Duplex, Aluminium, Nickel alloys, Titanium etc.

Successfully implemented the advance NDT technique e.g., PAUT, Computed Radiography at the L&T MHI Power Boilers. Successfully established the NABL accredited Testing Laboratory at L&T MHI Power Boilers. Established the various quality procedures at manufacturing works / site locations as per the Japanese requirements and Indian conditions.

Established welding and QA/QC procedures for the critical metallurgies e.g., Grade 92, Code Case 2328 and dissimilar joints. Obtained various prestigious certification for L&T MHI Power Boilers e.g., METI (for exporting to Japan), ASME, PED and IBR. Developed the welding procedures for DHDS reactors, High alloy steel, nonferrous steel at Godrej.

Name: Satish Tilva
Organisation: L&T-MHI Power Boilers Pvt. Ltd.
Designation: Head – QA / QC/ NDT
Education: B.E. Production – Saurashtra University

Name: Swarajya Kumar
Organisation: L&T-MHI Power Boilers Pvt. Ltd.
Designation: Manager QA / QC and lab
Education: B.Sc. Engg. Mechanical) from Bhagalpur University

Introduction

The current thrust is of thermal power development in the country is on supercritical units so as to improve the conversion efficiency and reduce carbon footprint.

L&T-MHI Power Boilers Private limited is a joint venture company with the manufacturing facility for Super Critical boilers (Forced Flow Steam Generators) in collaboration with Mitsubishi Power System Limited, Japan. The joint venture is in the business of design, engineering, procurement, manufacturing, erection and commissioning of Super Critical Boilers and all incidental activities for this business. L&T-MHI Power Boilers is also having the manufacturing capacity of coal pulverisers and Heavy castings.

Supercritical technology with the pressure of 225-300 kg/cm2 and main steam/ reheat steam temperatures of 600/610^{0}C is an established and proven technology with over 500 supercritical units operating worldwide and reliability & availability of supercritical units being at par with that of subcritical units. However, there are critical metallurgies where utmost care is required at the time of manufacturing for trouble free operation.

Abstract

As the reduction of CO_2 emissions becomes an important issue worldwide, in the boiler plant for power generation, the improvement for high power generation efficiency, namely steam condition, is one of the solutions. With the improvement of steam conditions, there is a substantial development in material grades with higher creep strength. Desired performance of these materials is due to the certain microstructure. Hence, retaining this microstructure is very much important during manufacturing.

SA 213 UNS 30432 is widely used in most of the Superheater and Reheater coils. This material is stronger at high temperature (superior creep strength) and more resistant to steam oxidation than ferritic heat resistant steel, and for this reason, the former is used mainly for high-temperature parts of power generation boilers.

There is a need of performing Heat-treatment after subsequent forming operations of this material for obtaining the required service life. Various trials have been conducted for establishing the desired Heat-treatment parameters. This paper describes

- Stresses associated with cold working deformation of stainless steel
- Impact of deformation on the operational life of tubes
- Solution treatment methods and parameters

- Metallurgical acceptance criteria

Further SA213 UNS30432 is used at various locations in the super critical boiler. This material is welded to other ferritic steels (such joints being referred to as dissimilar welded joints, at the interface between the high- and low-temperature sections of the boilers). There is an impact of welding parameters and post weld heat treatment on the properties of weld metal and Heat Affected Zone. Various trials have been conducted for establishing the desired welding parameters for obtaining the desired properties of these dissimilar joints. This paper describes

- Problems associated with Dissimilar metal welds
- Method to overcome these problems including welding parameters and Heat-treatment parameters
- Testing and metallurgical acceptance

LATEST TRENDS IN JOINING TECHNOLOGY AND PROBLEMS FACED ON SHOP FLOOR

By Dr. Renu Gupta - L&T Heavy Engineering, Powai
Dr. Krishnan Shivraman, L&T

Name: Dr. Renu N. Gupta

Organisation: L&T Heavy Engineering

Designation: Head - Design for Manufacturing

Education: B.E. (Metallurgy) from IIT-Roorkee, Ph. D. from IIT-Mumbai

Currently, as Head - Design for Manufacturing at L&T Heavy Engineering, I lead the team of experts providing support in engineering & fabrication of complex process plant and nuclear plant equipment.

During my 18 years splendid association with L&T, I have been the key member in developing welding and heat treatment technology for many of the national importance projects like ISRO PSLV/ GSLV Launch vehicles, NPCIL pressurized heavy water and fast breeder reactors.

In the beginning of my career at Godrej in early 2000, I was instrumental in indigenization of the Russian manufacturing technology for BrahMos missile along with DRDO.

Name: Dr. Krishnan Shivraman

Organisation: L&T Ltd.

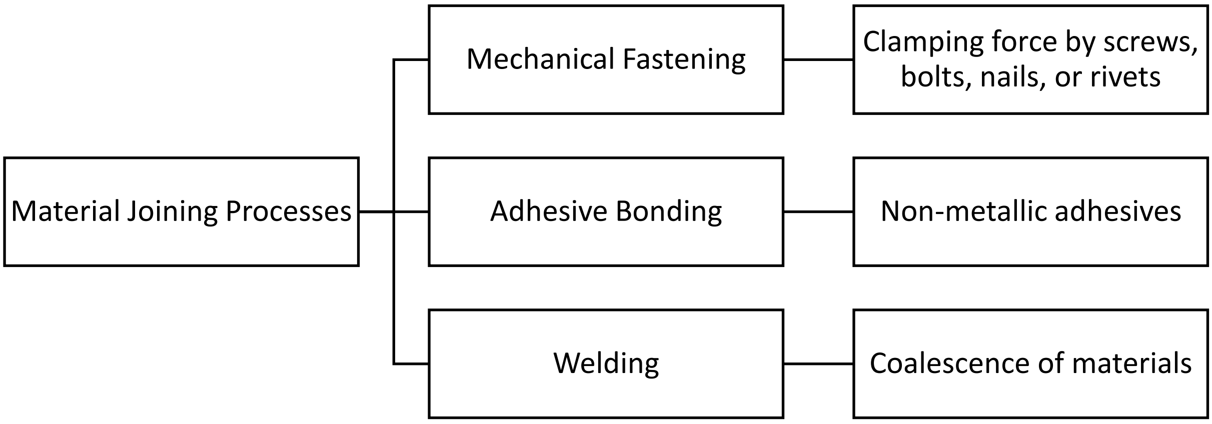
Designation: Sr. DGM Manufacturing Technology

Education: PhD IIT - Bombay

Heading the welding, metallurgy and supply chain function of MRU, HEIC. With over 21 years of experience, my achievements include

- Best National Welding Engineer (2008)
- Young Technologist Award (2012)
- Dynamic Welding Engineer Award (2019)
- Vice Chairmen – Indian Institute of Welding Mumbai Branch

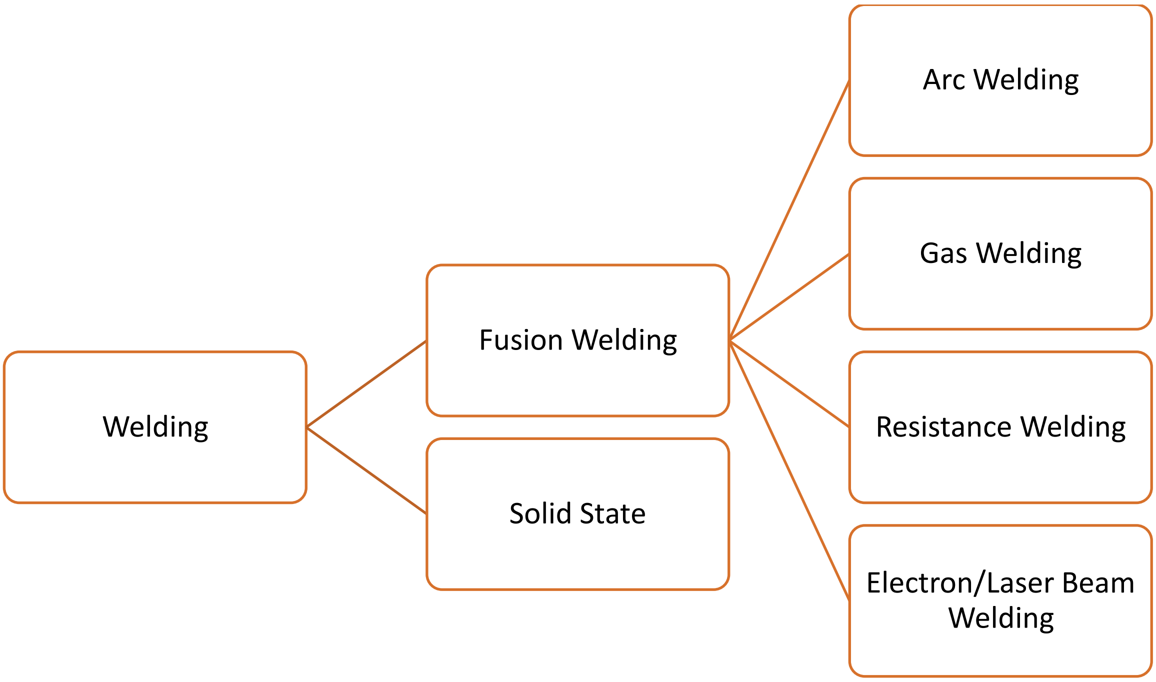
Material Joining Processes



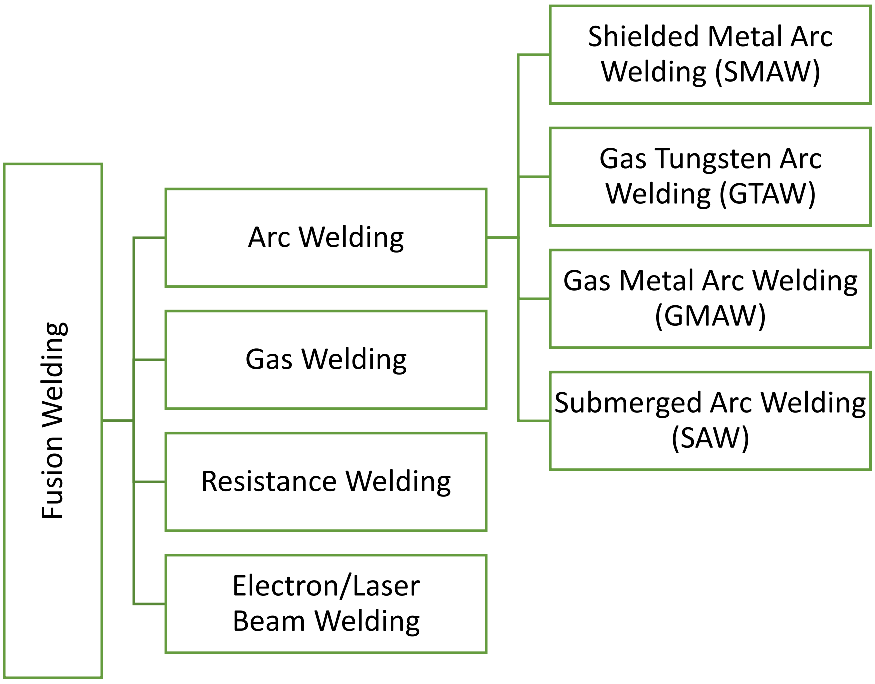
Welding

Welding: A joining process that produces coalescence of materials by heating them to suitable temperature with or without the application of pressure, and with or without the use of a filler material.

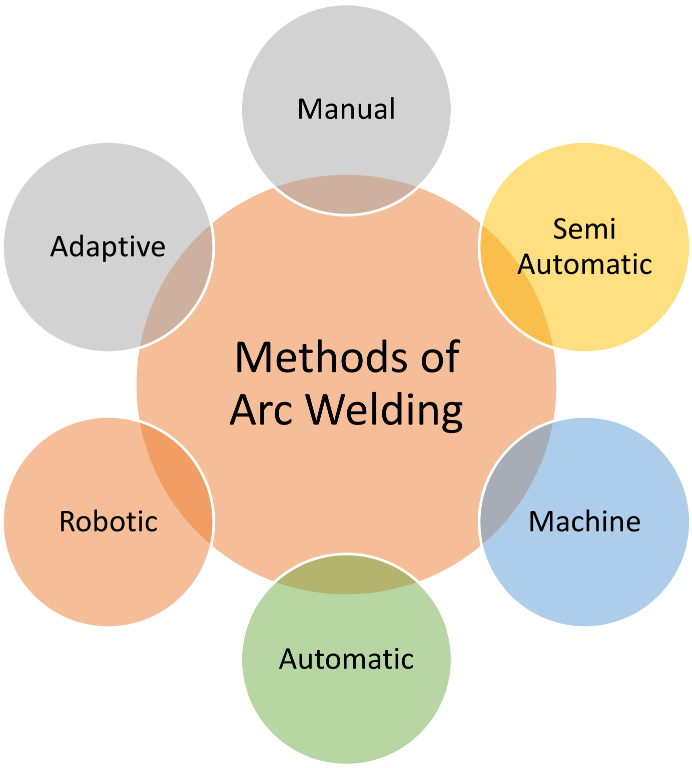
Coalescence: Melting together of base metal and filler metal or of base metal only.



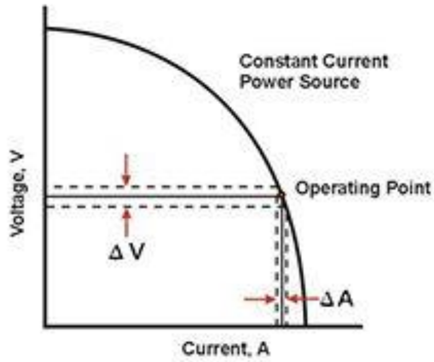
Fusion Welding



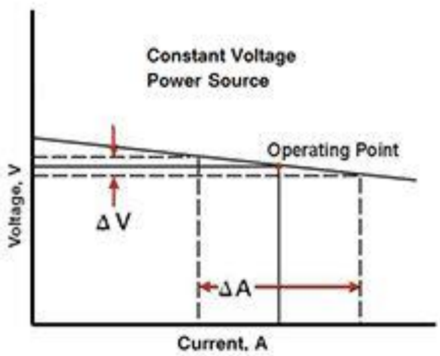
Methods of Arc Welding



Welding Power Source



- Welding Power Source
  - Direct Current
    - Constant Current Welding Processes: SMAW, GTAW, SAW
    - Constant Voltage Welding Processes: GMAW, FCAW, SAW
  - Alternating Current

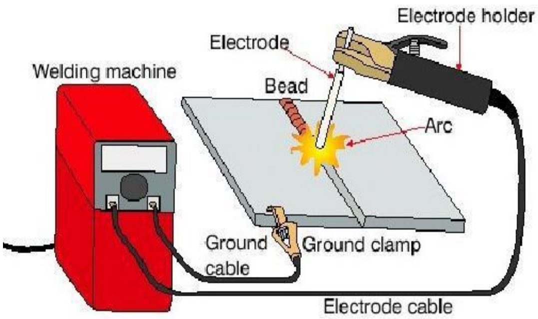


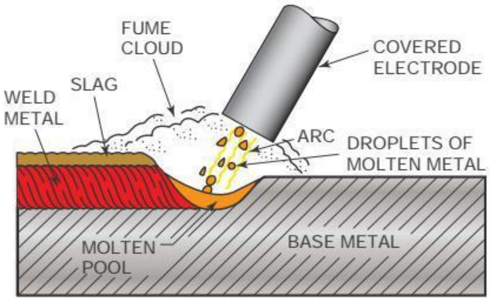
Shielded Metal Arc Welding (SMAW)

Arc welding process with an arc between covered electrode and the weld pool

SMAW Equipment

Welding Power Source: CC
Polarity: DCEN/DCEP/AC



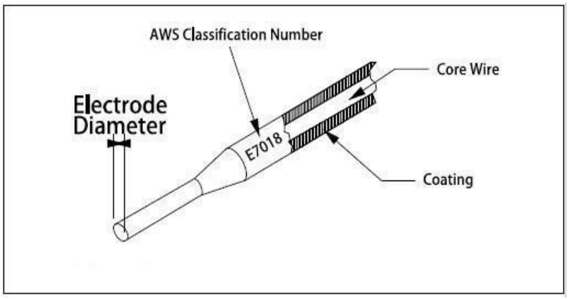


Shielded metal arc welding.

SMAW Filler Metal

Electrodes for SMAW Consist of

- Core Wire
- Flux Coating



Functions of covering of electrodes

- Shield the arc from atmosphere by shielding gas from decomposition of certain ingredients of the coating
- Deoxidizer for scavenging and purifying the deposited weld metal
- Slag formers to protect the deposited weld metal from oxidation
- Ionizing elements to make the arc more stable
- Provide alloying element to improve the strength and physical properties of the weld metal

Advantages

1. Lower Equipment Cost - Simple and inexpensive equipment
2. Lightweight and Portable
3. Built in Shield - No exterior shielding gas is needed
4. Versatile - Can be used with variety of different material and in different position

Disadvantages

1. Lower Productivity
2. Less Deposition
3. More number of start-stop points
4. Spatter and slag clean up

Gas Tungsten Arc Welding (GTAW)

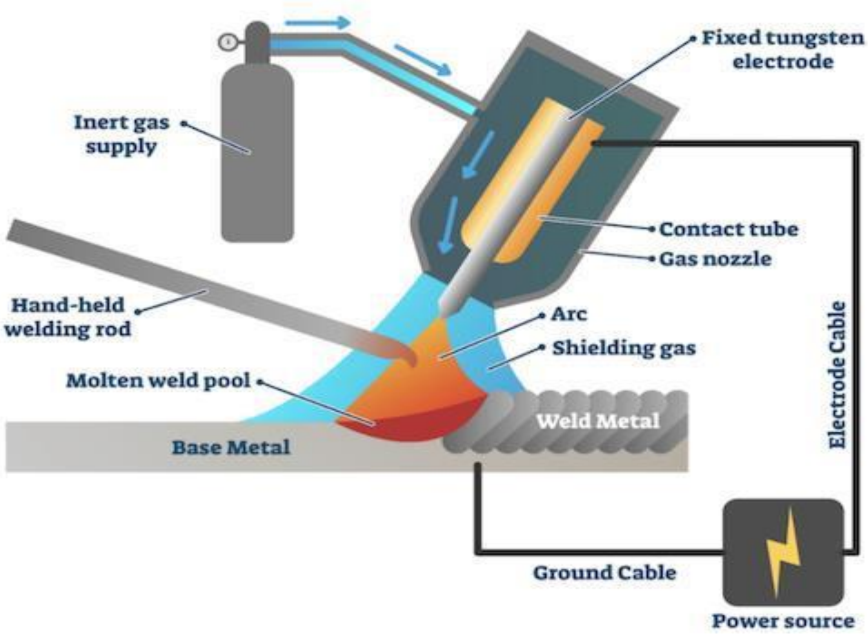
Arc welding process that uses an arc between a tungsten electrode (non-Consumable) and the weld pool

GTAW Equipment

Welding Power Source: CC
Polarity: DCEN/AC
Shielding Gas: Ar or He

Methods of Application

	Torch Control	Filler Metal feed
Manual	By hand	
Semi-Automatic	By hand	Equipment
Automatic	Equipment	Equipment



Tungsten Electrode and Filler Metals

Tungsten Electrode

- Highest Melting Point: 3410°C
- The Classification and Colour code are listed

Filler Metal

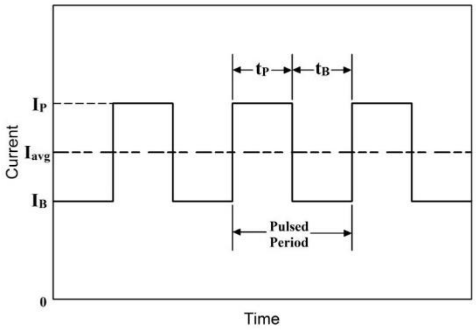
- Bare Solid (Rods and Spools)
- Available in size range 0.8-2.4 mm

Tungsten Electrode Color Codes

AWS classification	Defined	Color
EWP	Pure tungsten	Green
EWCe-2	2% Ceria	Orange
EWLa-1	1% Lanthana	Black
EWTh-1	1% Thoria	Yellow
EWTh-2	2% Thoria	Red
EWZr-1	0.15–0.40% Zirconia	Brown
EWG	Other	Gray

Pulsed GTAW

1. Welding Current continuously changes between two levels
2. Peak Current Heating and Fusion
   Background Current Cooling & Solidification
3. Reduces Heat Input, increase travel speed and gives consistent quality
4. Controls distortion on thinner material



Advantages

- Clean and High quality welds
- Welds wide ranges of metals
- No spatter or slag, sparks, or smoke
- Allows welding in all position

Disadvantages

1. Lower deposition rate
2. Requires high level of operator skill
3. High Level of UV rays
4. Requires good eye and hand coordination to achieve quality weld in Manual GTAW
5. Requires precise part location and fit-up in automatic GTAW

Gas Metal Arc Welding (GMAW)

Arc welding process that uses an arc between a continuous filler metal electrode and the weld pool

GMAW Equipment

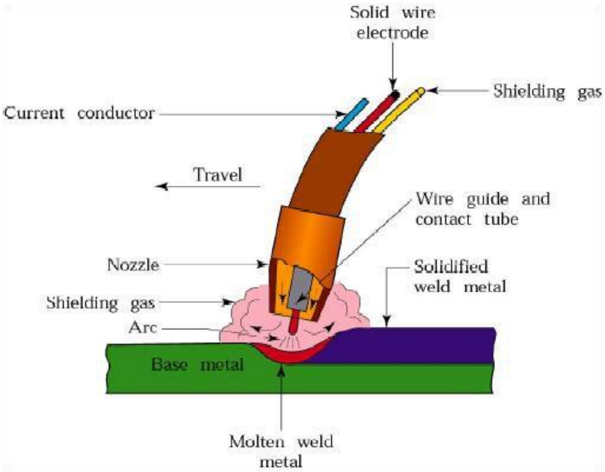
Welding Power Source: CV

Polarity: DCEP

Shielding Gas: Inert Gases (Ar, He)
Active Gases (CO_2, Ar + CO_2)

Methods of Application

	Torch Control	Filler Metal Feed
Semi-Automatic	By Hand	Equipment
Automatic	Equipment	Equipment



Wire Feeder and GMAW Torch

Wire Feeder

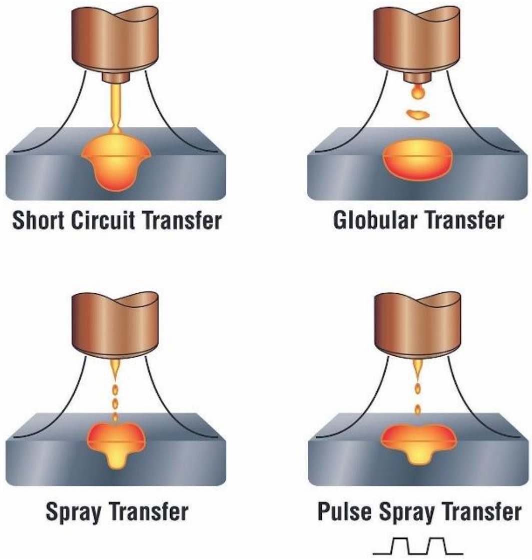
- Drives the electrode wire the wire Spool through cable and gun to welding arc
- Constant Speed wire feeder is used with constant voltage power source

GMAW Torch

- Carry electrode wire, welding current, and shielding gas to the welding arc
- Consist of
    - Nozzle – Directs flow of shielding gas
    - Contact tip – Guides wire and transfer welding current to the electrode wire
- Can be either Air cooled or Water cooled

GMAW – Metal Transfer

Metal Transfer refers to the transfer of molten metal from the electrode across the arc to form weld deposit.



Advantages

- High deposition rate
- High Production factor (No slag removal and Continuous electrode)
- Low hydrogen weld deposit
- No stub end losses or wasted man hours caused by changing electrodes.

Disadvantages

- Need shielding gas so welding in windy condition can be difficult
- No Slag so out of position welds are sometimes more difficult
- Chances of lack fusion if welding parameters and technique is not
- controlled
- Welding torch is difficult to get into tight place

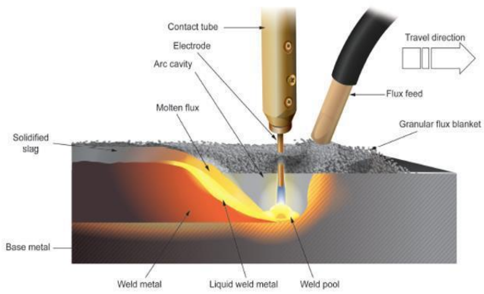
Submerged Arc Welding (SAW)

Arc welding process that uses an arc between a bare consumable electrode wire and the workpiece submerged under cover of granular fusible and molten flux. filler metal electrode and the weld pool.

Welding Power Source: CC or CV
Polarity: DC or AC

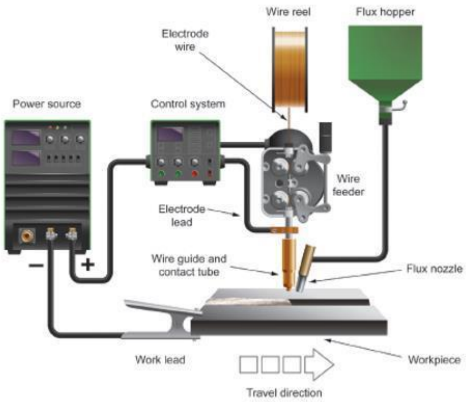
Methods of Application

Machine or Automatic



SAW System consist of

1. Welding Power Source
2. Wire feeder and control System
3. Welding torch and Cable assembly
4. Flux hopper and feeding mechanism
5. Flux recovery System
6. Travel Mechanism
7. Electrode wire
8. Flux



Electrode wire

1. Diameter ranges from 1.6 mm to 5 mm
2. LAS/CS wire copper coated to protect it from atmospheric corrosion and increase current carrying capacity

Flux

1. Consist of a granular mineral compound
2. Types of fluxes: Fused, bonded, and mechanically mixed
3. Classified based on mechanical properties of the weld deposit produced in combination with specific types of electrodes

Advantages

1. High deposition rates and high arc on times when fully automated.
2. Minimal welding fume, no weld spatter and no visible arc

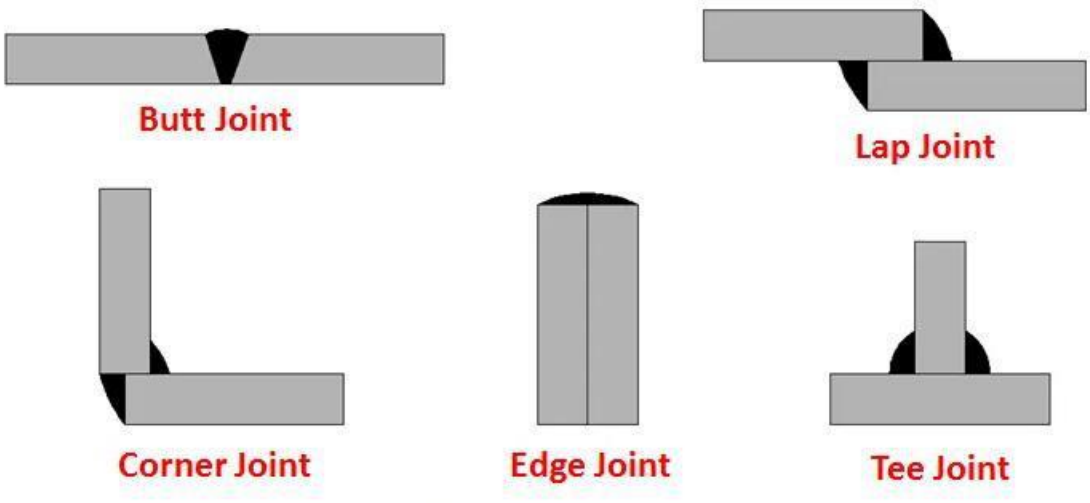
3. Unused flux can be recovered, recycled and reused.
4. If metallurgically acceptable, single pass welds can be made in relatively thick plates.

Disadvantages

1. Welding is limited to positions 1F, 1G, and 2F. Horizontal butt welds can be made but special devices are required to support the flux.
2. Requires separate flux handling systems and slag removal between passes.
3. Not realistically applicable to thin materials

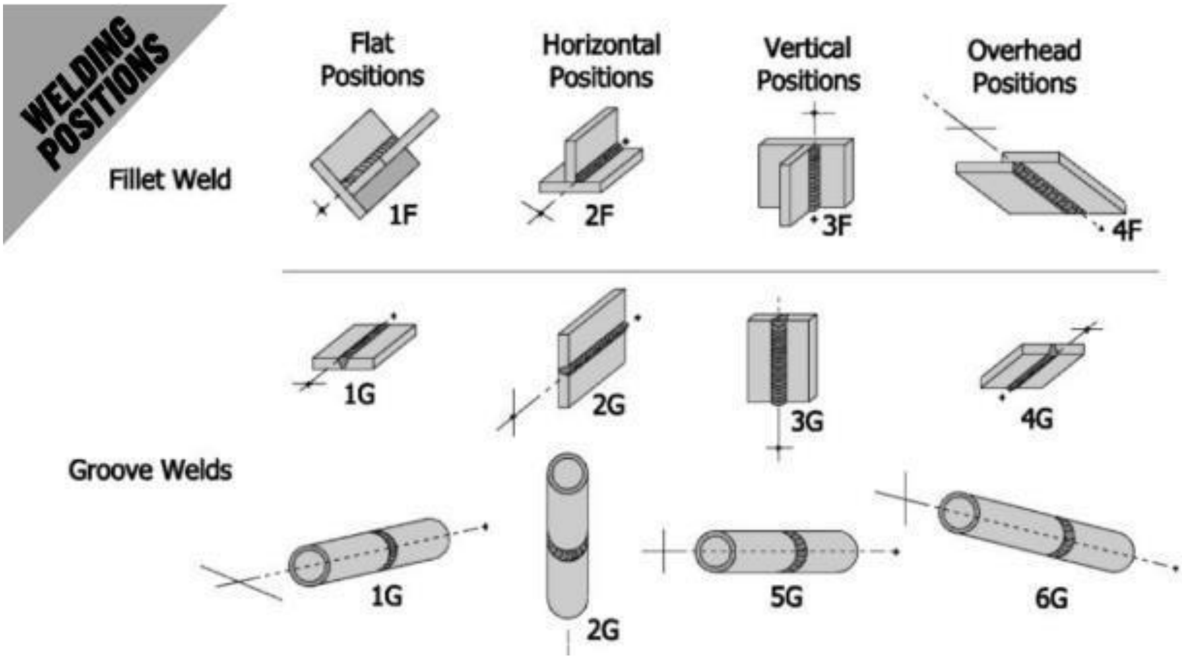
Types of Weld Joints

Welding joints is an edge or point where two or more metal pieces or plastic pieces are joined together.



Welding Position

In order to help welder to understand the location of the weld to be made, a number and letter system is used to indicate the type and position of the weld.



Welding Codes and Standards

Standard:

Standard can be defined as a set of technical definitions and guidelines that functions as instructions for designers, manufacturer, operator, or users of equipment. e.g., AWS D1.1, API 1104, etc.

Code:

A standard becomes code when it has been adopted by one or more governmental bodies and is enforceable by law, or when it has been incorporated into business contract. e.g., ASME BPVC, B31.3. B31.1, etc.

Specification:

Specification cover requirements for voluntary adoption and no enforcement is meant unless they are agreed upon between procuring agency and contractor as spelled out in purchase order.

Welding Procedure Specification

WPS (Welding Procedure Specification) is a written document to provide direction for making production welds which will meet code requirements.

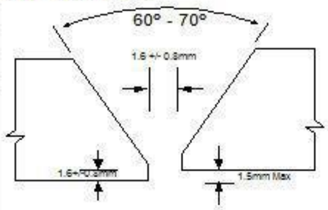
Welding Procedure Specification

Client:	**Mobil**	Project:	**221010Goatee**	REF No.	**WPS 6 R1**
Procedure Description:	**12" Heavy Wall Offshore Tie-in**			0290/1/WPS5	
Material:	**AS3679.1 Grade 250API 5L X65**	Diameter:	**168.3**	Thickness:	**18.3**
Position:	**6G**	Clamp Type:	**Internal**		
Preheat °C (Min):	**100**	Interpass °C (Max):	**300**		

	ROOT	HOT PASS	FILL & CAP
Welding Process	SMAW	SMAW	SMAW
Welding Direction	Vertical Down	Vertical Down	Vertical Down
Filler	Lincoln SA70+	Lincoln SA70+	Bohler BVD90M
Polarity	DC +ve	DC +ve	DC +ve
Shielding Gas	N/A	N/A	N/A
Purge Gas	N/A	N/A	N/A

Pass No	Filler Size (mm)	Amps	Volts	Speed (mm/sec)	Heat Input (kJ/mm)
1	3.2mm	70-130	18-33	3.3-6.6	0.4-0.8
2	4.0mm	110-210	18-35	2.9-6.8	0.6-1.3
FILL	4.0mm	145-260	16-27	1.6-7.0	0.6-2.2
CAP	4.0mm	130-230	16-26	1.8-5.3	0.6-1.7

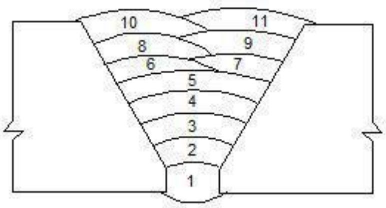
Weld Preparation



NOTES

1. API Std 1104BP3094-SP-PL-3010R1
2. Clamp removal stage : **100% completion of root (external clamp may be used in the event of a breakdown – removed after 50% minimum completion of the root.)**
3. Time lapse between root and second pass : **16 Minutes**
4. Time lapse between second pass and 1st fill : **12 Minutes**
5. Minimum number of passes before pipe movement : **2 passes**
6. Minimum number of passes before break in welding : **3 passes**
7. Minimum Number of welders- **Root & second pass: 2 , Fill & Cap : 1**
8. Method of cleaning : **Grinder / Wire brush**
9. Method of Preheat : **Gas Torch**
10. Qualification reference number : **48280/PP/WP6 R1**

Pass Location



Company Welding Engineer Approved .... **Approved for Client** ....

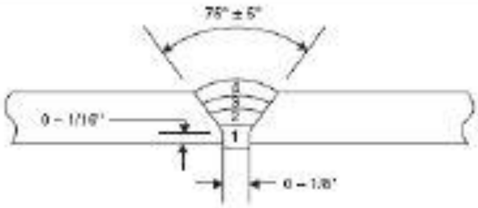
Procedure Qualification Record

PQR (Procedure Qualification Record) is record of welding data used during welding of test coupon and of test results.

QW-483 SUGGESTED FORMAT FOR PROCEDURE QUALIFICATION RECORDS (PQR)
(See QW-200.2, Section IX, ASME Boiler and Pressure Vessel Code)
Record Actual Variables Used to Weld Test Coupon

Company Name: DCR Engineers, Inc
Procedure Qualification Record No.: PP001-1 Date: 10-10-14
WPS No.: PP001-1
Welding Process(es): GTAW/SMAW
Types (Manual, Automatic, Semi-Automatic): Manual

JOINTS (QW-402)



Passes 1 & 2: GTAW
Rest: SMAW

Groove Design of Test Coupon
(For combination qualifications, the deposited weld metal thickness shall be recorded for each filler metal and process used.)

BASE METALS (QW-403)
Material Spec.: SA 106
Type/Grade, or UNS Number: Grade B
P-No.: 1 Group No.: ___ to P-No.: 1 Group No.: ___
Thickness of Test Coupon: .218
Diameter of Test Coupon: 2"
Maximum Pass Thickness:
Other:

POSTWELD HEAT TREATMENT (QW-407)
Temperature: NA
Time: NA
Other:

GAS (QW-408)

	Gas(es)	Percent Composition (Mixture)	Flow Rate
Shielding	Argon	WELD Grade	
Trailing			
Backing			
Other			

FILLER METALS (QW-404)

	GTAW	SMAW
SFA Specification	5.18	5.1
AWS Classification	E 70S-2	E 7018
Filler Metal F-No.	6	4
Weld Metal Analysis A-No.	1	1
Size of Filler Metal	3/32, 1/8	3/32, 1/8, 5/32
Filler Metal Product Form		
Supplemental Filler Metal		
Electrode Flux Classification		
Flux Type		
Flux Trade Name		
Weld Metal Thickness		
Other		

ELECTRICAL CHARACTERISTICS (QW-409)
Current: Direct
Polarity: GTAW-Straight SMAW-Reverse
Amps.: 70-225 Volts: 7-29
Tungsten Electrode Size:
Mode of Metal Transfer for GMAW (FCAW):
Heat Input:
Other:

POSITION (QW-405)
Position of Groove: 6G
Weld Progression (Uphill, Downhill): Uphill
Other:

TECHNIQUE (QW-410)
Travel Speed: 1-11 ipm
String or Weave Bead: Both
Oscillation:
Multipass or Single Pass (Per Side): Multipass
Single or Multiple Electrodes: Single
Other:

PREHEAT (QW-406)
Preheat Temperature: 50°F
Interpass Temperature: 500°F
Other:

QW-483 (Back)

PQR No. DP001-1

Tensile Test (QW-150)

Specimen No.	Width	Thickness	Area	Ultimate Total Load	Ultimate Unit Stress, (psi or MPa)	Type of Failure and Location

Guided-Bend Tests (QW-160)

Type and Figure No.	Result
FACE No. 1 QW-462.3 (a)	Satisfactory
FACE No. 2 QW-462.3 (a)	Satisfactory
Root No. 1 QW-462.3 (a)	Satisfactory
Root No. 2 QW-462.3 (a)	Satisfactory

Toughness Tests (QW-170)

Specimen No.	Notch Location	Specimen Size	Test Temperature	Impact Values			Drop Weight Break (Y/N)
				ft-lb or J	% Shear	Mils (in.) or mm	

Comments ______

Fillet-Weld Test (QW-180)

Result — Satisfactory: Yes ____ No ____ Penetration into Parent Metal: Yes ____ No ____

Macro — Results ______

Other Tests

Type of Test ______

Deposit Analysis ______

Other ______

Welder's Name John Doe Clock No. 507-56-7477 Stamp No. PDC

Tests Conducted by Industrial Testing Inter. Inc. Laboratory Test No. JR613.1

We certify that the statements in this record are correct and that the test welds were prepared, welded, and tested in accordance with the requirements of Section IX of the ASME Boiler and Pressure Vessel Code.

Manufacturer or Contractor DCR Engineers, Inc.

Date 3/5/14 Certified by Duncan C. Richardson

(Detail of record of tests are illustrative only and may be modified to conform to the type and number of tests required by the Code.)

Basic steps in Qualification of a Procedure

1. Prepare Preliminary WPS
2. Prepare and Weld a suitable test coupon using WPS
3. Conduct required NDT and Destructive Testing
4. Evaluate results of Testing
5. Document results on PQR
6. Issue approved PQR
7. Issue approved WPS for production weld

PQR-WPS Variables Considered

- Base Metal
- Welding Process
- Filler Metal
- Type of Current/Range
- Voltage
- Heat Input
- Travel Speed
- Joint design and Tolerances
- Joint and Surface preparation
- Welding Details
- Electrode Size, Passes, Weave
- Position
- Post Weld Heat Treatment
- Shielding Gas details

Need to check specific code for the list of essential variables

Welding Performance Qualification

Welder Performance Qualification test are intended to determine the ability of welder to deposit sound weld using qualified welding procedure specification

Variables:

- Welding Process
- Filler Metal
- Position
- Joint Details

- Thickness
- Technique

Duration of Qualification:

Inactivity of 6 month requires requalification (as per ASME IX)

FORM QW-484A SUGGESTED FORMAT A FOR WELDER PERFORMANCE QUALIFICATIONS (WPQ)
(See QW-301, Section IX, ASME Boiler and Pressure Vessel Code)

Welder's name John Doe Identification no. 525-94-2834

Test Description

Identification of WPS followed PJ001 ☐ Test coupon ☐ Production weld

Specification and type/grade or UNS Number of base metal(s) ______ Thickness ______

Testing Variables and Qualification Limits

Welding Variables (QW-350)	Actual Values	Range Qualified
Welding process(es)	GTAW	GTAW
Type (i.e.; manual, semi-automatic) used	Manual	Manual
Backing (with/without)	Without	With or Without
☐ Plate ☐ Pipe (enter diameter if pipe or tube)		
Base metal P-Number to P-Number	P1 to P1	P1, P8 to P8
Filler metal or electrode specification(s) (SFA) (info. only)		
Filler metal or electrode classification(s) (info. only)		
Filler metal F-Number(s)	6	6
Consumable insert (GTAW or PAW)		
Filler Metal Product Form (solid/metal or flux cored/powder) (GTAW or PAW)		
Deposit thickness for each process		
Process 1 ______ 3 layers minimum ☐ Yes ☐ No		
Process 2 ______ 3 layers minimum ☐ Yes ☐ No		
Position qualified (2G, 6G, 3F, etc.)		
Vertical progression (uphill or downhill)	uphill	uphill
Type of fuel gas (OFW)		
Inert gas backing (GTAW, PAW, GMAW)		
Transfer mode (spray/globular or pulse to short circuit-GMAW)		
GTAW current type/polarity (AC, DCEP, DCEN)	DCEP	DCEP

RESULTS

Visual examination of completed weld (QW-302.4) ______

☐ Transverse face and root bends [QW-462.3(a)] ☐ Longitudinal bends [QW-462.3(b)] ☐ Side bends (QW-462.2)

☐ Pipe bend specimen, corrosion-resistant weld metal overlay [QW-462.5(c)]

☐ Plate bend specimen, corrosion-resistant weld metal overlay [QW-462.5(d)]

☐ Pipe specimen, macro test for fusion [QW-462.5(b)] ☐ Plate specimen, macro test for fusion [QW-462.5(e)]

Type	Result	Type	Result	Type	Result
FACE A QW-462.3(a)	Accept	FACE B QW-462.3(a)	Accept	ROOT A QW-462.3(a)	Accept
				ROOT B QW-462.3(a)	Accept

Alternative Volumetric Examination Results (QW-191): ______ RT ☐ or UT ☐ (check one)

Fillet weld — fracture test (QW-181.2) ______ Length and percent of defects ______

☐ Fillet welds in plate [QW-462.4(b)] ☐ Fillet welds in pipe [QW-462.4(c)]

Macro examination (QW-184) ______ Fillet size (in.) ____ × ____ Concavity/convexity (in.) ______

Other tests ______

Film or specimens evaluated by ______ Company ______

Mechanical tests conducted by Industrial Testing Inter. Inc. Laboratory test no. 633.2

Welding supervised 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 of Section IX of the ASME BOILER AND PRESSURE VESSEL CODE.

Organization DCR Engineers, Inc.

Date 3-12-14 Certified by ______

BOILER DESIGN OPTIMISATION THROUGH SAFETY ASPECTS

By Mr. R. S. Jha, Mr. Pramaod Shigarkanthi
Thermax Ltd. C & H

Name: R. S. Jha
Organisation: Thermax Ltd.
Designation: Head of Innovation
Education: B. Tech in Mechanical engineering (IIT- BHU), M. Tech in Energy system (IIT- Bombay)

Over 25 years of experience Mr. Jha is responsible for development of new products and introduction of new Technology.

Name: Pramod Mallikarjun Shigarkanthi
Organisation: Thermax Ltd.
Designation: Senior Manager- Engineering
Education: Qualification: B.E. (Mechanical Engineering.), MIT - Pune

Heading Detailed Engineering (Product PU- Heating SBU) at Thermax Ltd. 8 years of experience in boiler manufacturing and 18 years in detail engineering. Area of interests are assimilating different pressure vessel codes.

Failure modes of the boiler

- Higher membrane stress
- Higher stress concentration
- Exposure to higher temperature (Water level control)
- Poor water quality
- Thermal stress
- Overheating
- Poor circulation/ Dry-out
- Erosion
- Corrosion
- Overfiring

IBR 1950 and EN 12953-3(2016) comparison

IBR 1950	EN 12953-3 (2016)
As per IBR 1950, in integral furnace boiler, for both oil and gas fuel, Maximum heat input in a single furnace is limited to 12 MW	As per EN12953-3(2016), in integral furnace boiler, Maximum heat input in a single furnace is limited to 18 MW for oil fuel and 23.4 MW for gas fuel. Higher heat input has been derived from the calculation of heat flux corresponding to the design metal temperature of the furnace for the minimum diameter and length of the furnace. Higher heat input for the gas fired boiler has been deduced from the non-luminous radiation and lower heat flux of a gas fired boiler. Lower heat transfer in gas fired boiler is considered in the calculation of tube wall temperature. Boilers with heat input between 14 to 18 MW for fuel oil and heat input between 18.2 to 23.4 for gas require detailed calculation of heat flux and metal temperature.
Maximum furnace diameter < 1800 mm	Maximum furnace diameter < 2000 mm

	It allows furnace diameter up to 2000 mm, but it requires stress calculation by FEA.
No constraints on stiffener ring pitch and position.	It constrains the use of stiffener in high heat flux zone
Does not specify Minimum required furnace length for given furnace heat input	EN12953-3(2016), Figure no 2 specifies Minimum required furnace length for given furnace heat input

For Boilers with heat input between 14 to 18 MW for fuel oil and heat input between 18.2 to 23.4 for gas, EN 12953-3(2016) mandates additional operating requirements as listed below.

- More Stringent operating conditions must be specified such as improved water quality requirements in addition to the requirements of EN 12953-10:2003, shorter maintenance and/or inspection intervals.
- Temperature monitoring of the furnace shell
- Monitoring of the conductivity of the boiler water shall be in accordance with EN 12953-6:2011, Improvement in the circulation during start-up.
- More stringent start up conditions such as limitation of the heating rate in the cold start up

Boiler design-Metal temperature calculation

- Allowable stress calculation
- Thermal stress calculation
- Heat generation
- Heat transfer area (Furnace diameter & length)
- Heat flux calculation
- Luminous vs non-luminous flame
- Tube wall temperature- Velocity
- Tube plate temperature (Velocity and Ligament)

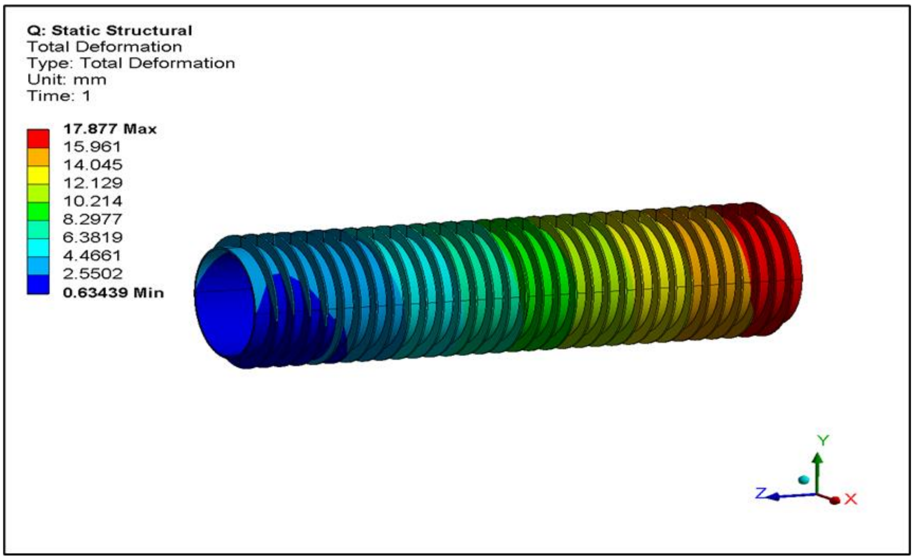
Boiler design-Thermal stress

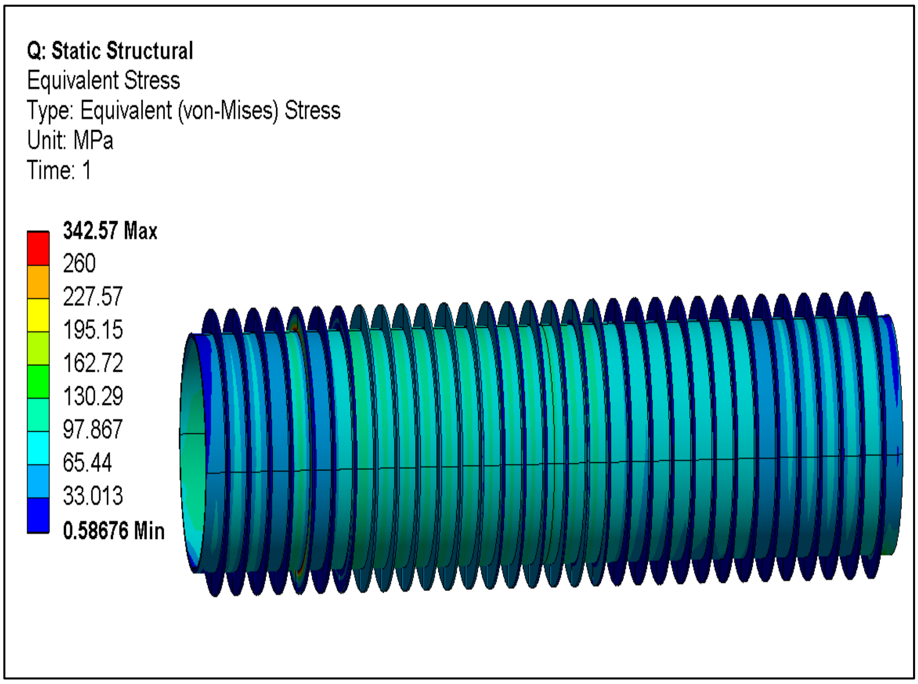
- Same tube plate connected with furnace, first pass convective tubes, second pass convective tubes & boiler shell.
- These surfaces are exposed to different temperature conditions.
- Differential Thermal expansion

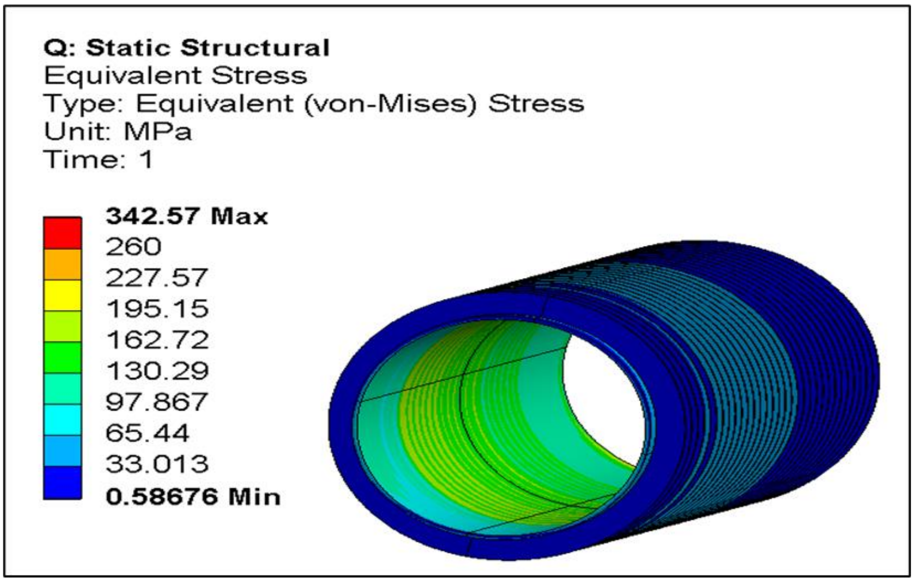
- Thermal stress
- Higher tensile stress in tubes or shell near to furnace due to higher expansion and rigidity of furnace
- Compression stress in furnace due to lower thermal expansion of neighbouring tubes and shell
- Compression stress in tubes near the shell due to lower thermal expansion of shell

Thermal stress - Furnace design

- Higher breathing space for stiffener furnace as it can't absorb differential expansion (EN)
- Minimum distance between tube plate and stiffener to avoid stiffener in high temperature zone (EN)
- Consequence of furnace failure is very high in stiffener furnace as it can damage tube plate section




Q: Static Structural
Equivalent Stress
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 1
342.57 Max
260
227.57
195.15
162.72
130.29
97.867
65.44
33.013
0.58676 Min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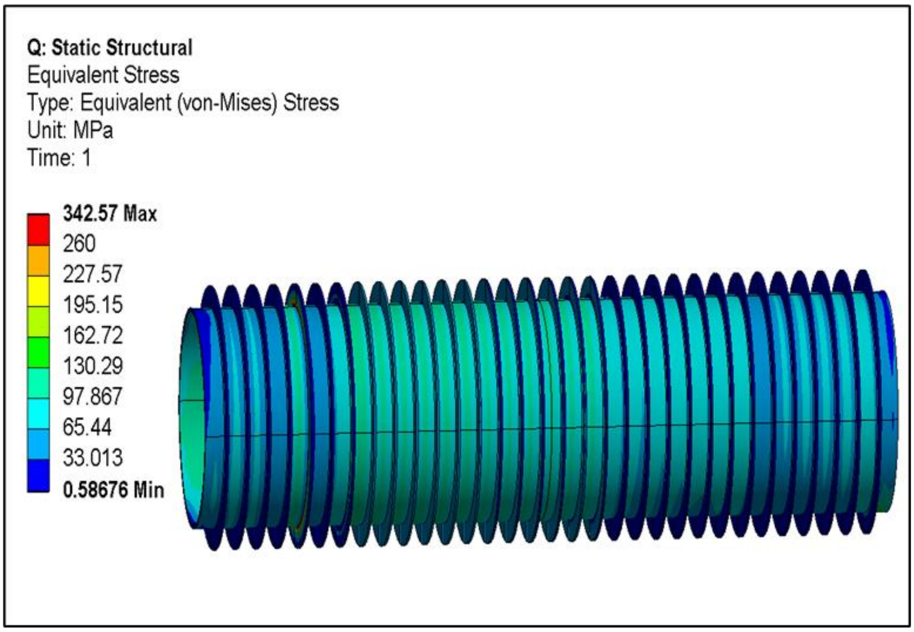
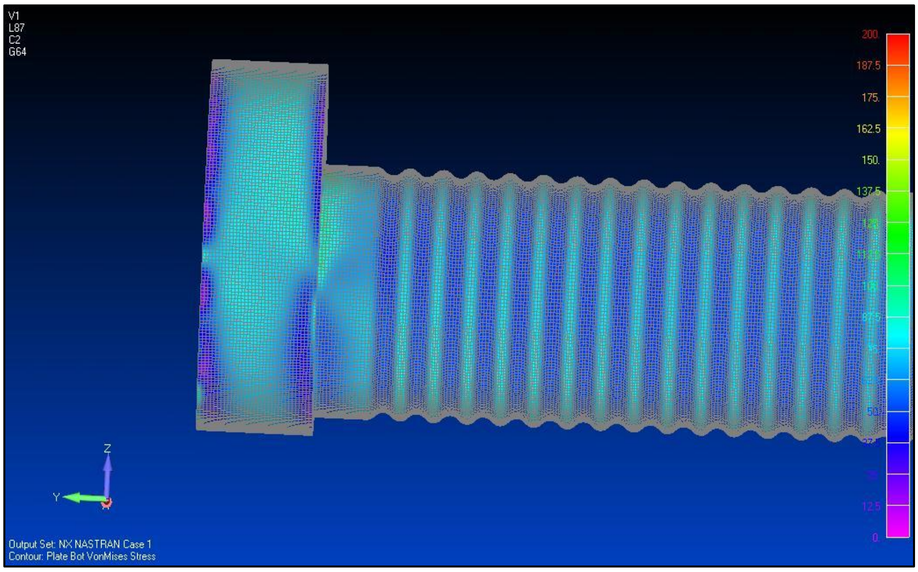
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 1
342.57 Max
260
227.57
195.15
162.72
130.29
97.867
65.44
33.013
0.58676 Min

Thermal stress - Furnace design

Stiffener furnace vs Corrugated furnace stress comparison



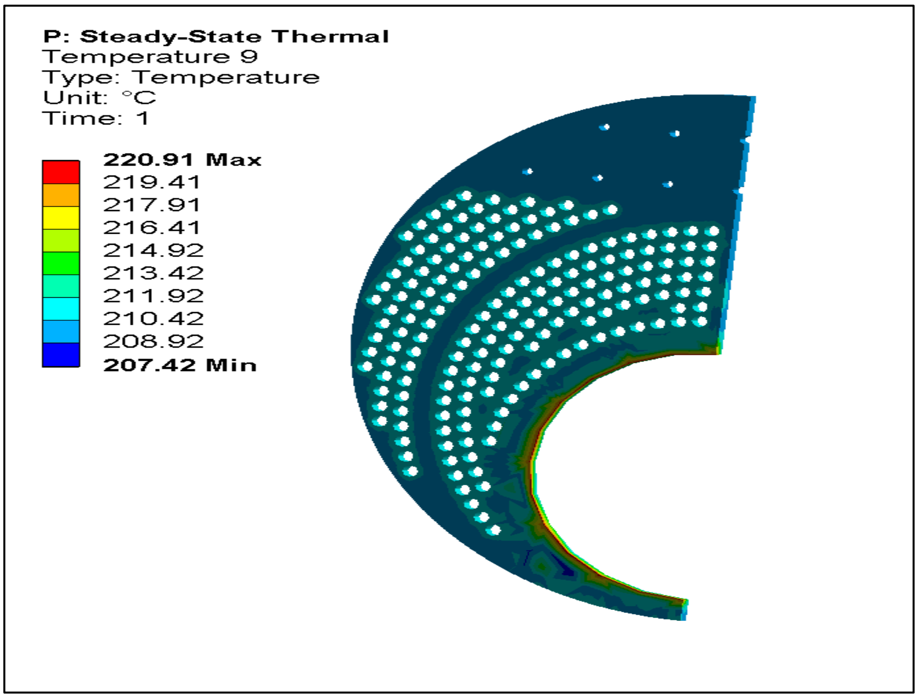
Stiffener furnace Stress - 80-230 MPa



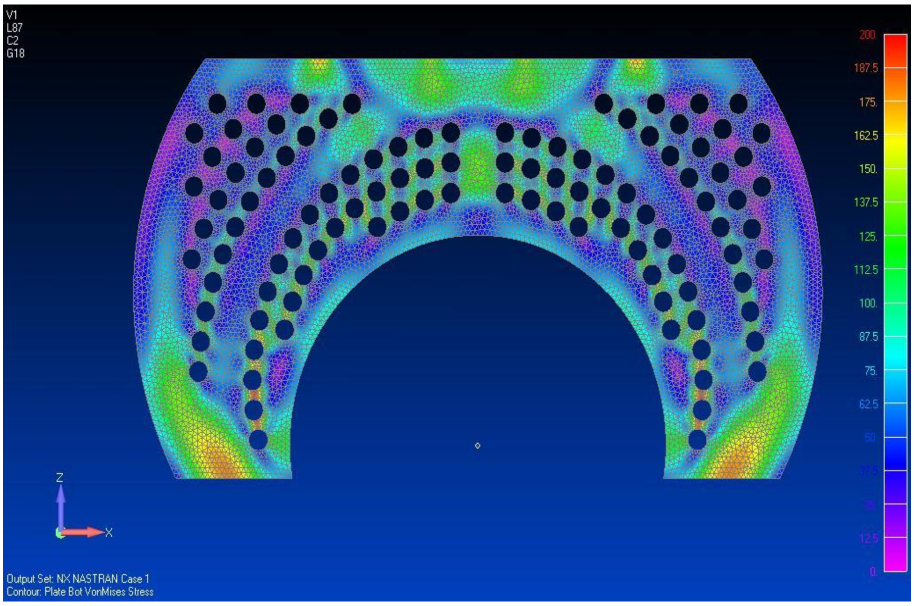
Corrugated furnace Stress - 50-80 MPa

Thermal stress - Furnace design

Stiffener furnace vs Corrugated furnace stress comparison

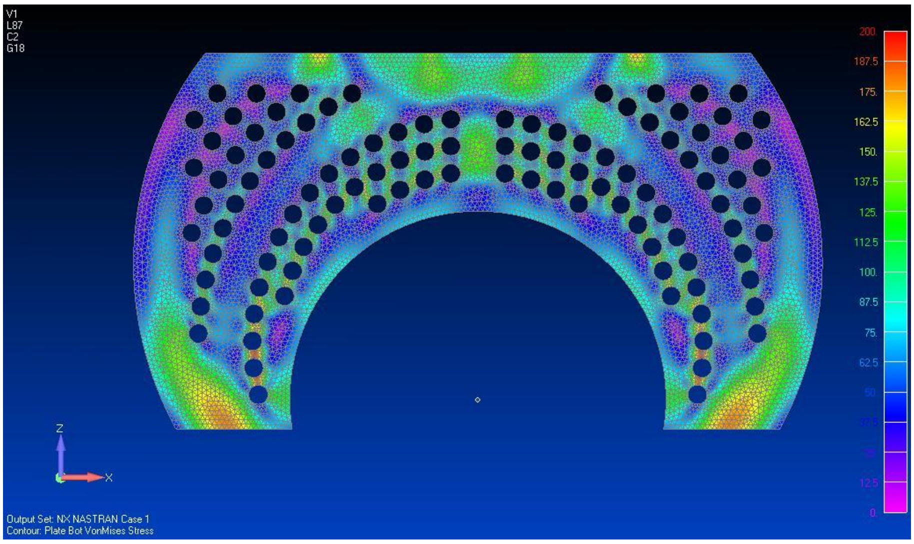


Stiffener furnace - High stress concentration near furnace



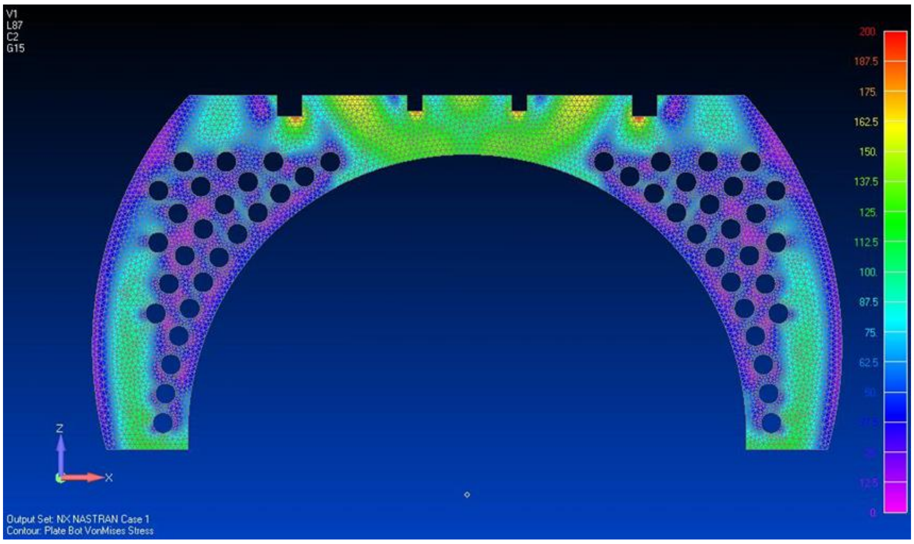
Corrugated furnace - High stress concentration near furnace

Thermal stress - Breathing space



stress- 110- 150 MPa

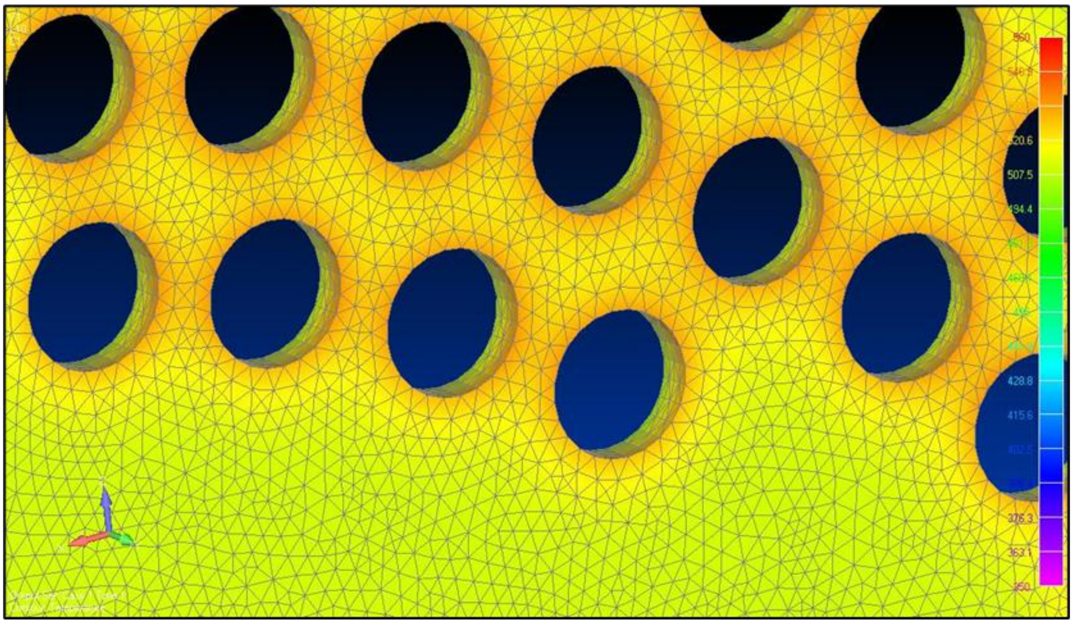
Differential expansion can be the reason of high stress in lower tube



Stress- 40-80 MPa

Higher stress in tubes near to shell

Tube plate cracking - Temperature profile on tube plate



Temperature variation - 230 ^{0}C to 262 ^{0}C

Influencing parameters

- Furnace exit temperature
- Fuel- Luminous vs non-luminous flame
- Velocity
- Ligament
- Constraints on velocity
- Increase in ligament
- Conversion from Oil to gas - Case study

Stresses in the boiler

- Membrane stress (Pm)
- Local membrane stress -Membrane stress including discontinuity (PL)
- Bending stress (Pb)
- Secondary Membrane plus Bending including thermal stress (Q)
- Peak (F)

Design by formula

- Primary membrane stress (Pm)
- Bending stress (Pb)

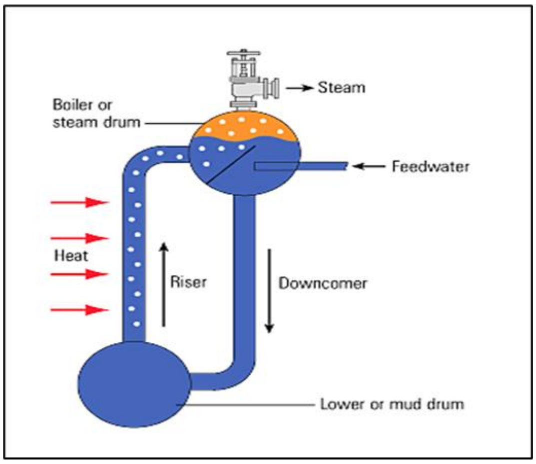
Design by Analysis

Stress Classification (PD5500)	Allowable Stress Intensity (wrt Design Stress f)	Allowable Stress Intensity
General primary membrane f_m	f	$2/3\ \sigma_y$
Local primary membrane f_L	$1.5\,f$	σ_y
Primary membrane plus bending $(f_m + f_b)$ or $(f_L + f_b)$	$1.5\,f$	σ_y
Primary plus secondary $(f_m + f_B + f_q Q)$ or $(f_L + f_b + f_q)$	$3\,f$	$2\ \sigma_y$

ASME, Section- VIII, Div-2, Part-5

Boiler design - Circulation

- Natural circulation
- Circulation ratio
- Driving head & flow resistance

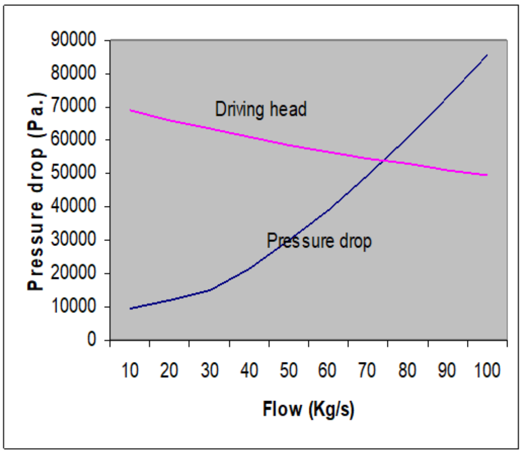


Failure mode

1. Departure from nucleate boiling
2. Flow regime and void fraction
3. Phase stratification
4. Two phase flow instability

Design criteria

- Tube entry velocity (Flow stratification limit on mass flow rate, Tube inclination)
- Void fraction (percentage of steam by volume in steam water mixture)
- Steam quality at the outlet (Dry-out, Critical heat flux)



Circulation design - Flow regime

- Sub cooled boiling
- Saturated nucleate boiling (Bubbles distributed in complete tube cross section)
- Saturated forced convective boiling (Annular flow or annular mist flow)
- Post dry-out (Mist flow)

Circulation design - Void fraction

- Void fraction (Steam volume fraction)
- Void fraction as an indicator of flow regime
- Void fraction as a design criteria

Circulation design - Departure from nucleate boiling

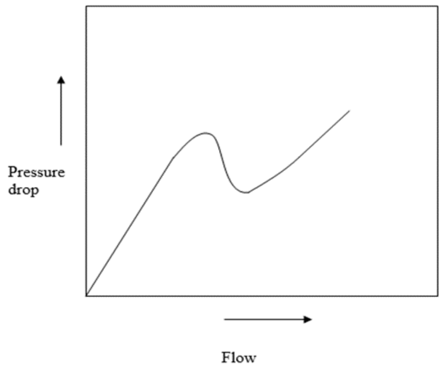
- Critical heat flux (> 4 X 10 5 W/m2)
- Critical mass flux (< 4 X 10 5 W/m2)

Dryness fraction as a function of mass flux

Circulation design - Phase stratification

- Phase stratification - Phase separation with smooth interface under gravity.
- It can induce dry-out
- Minimum entry velocity
- Factor affecting stratification
    - Inclination angle (0° / 10°)
    - Steam quality (Critical mass flux)
- Common area - IBH tubes, top section of MP tubes

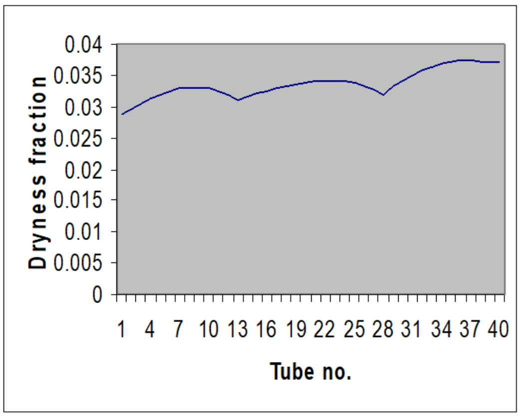
Circulation design - Two phase flow Instability



- Flow oscillation
- Poor circulation ratio & higher dryness fraction
- Accelerate dry-out process
- Cyclic loading

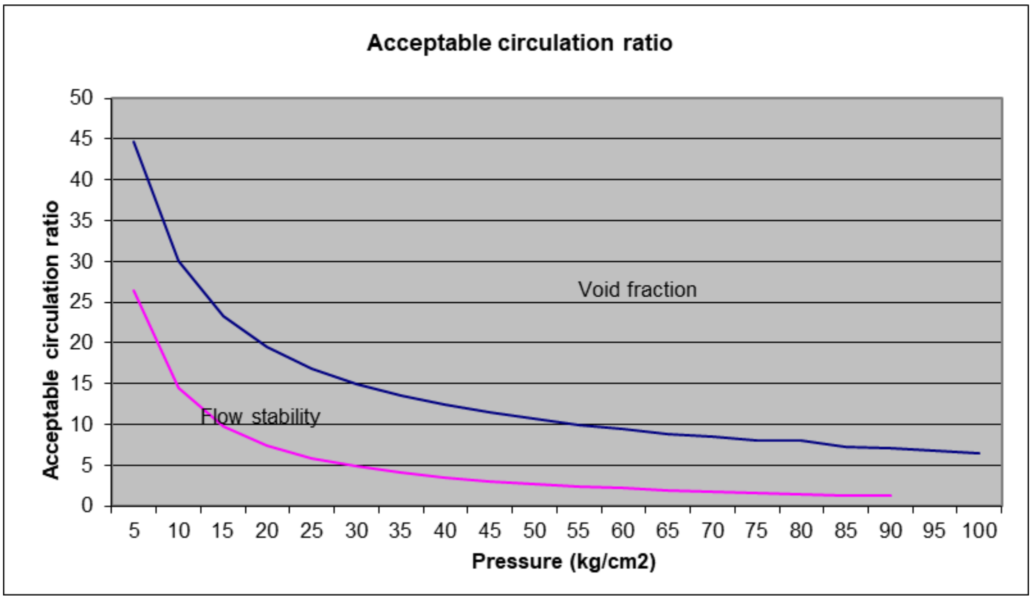
Circulation design - Maldistribution

- Common circulation ratio
- Maldistribution
- Merging & separation
- Momentum
- Uneven heat transfer



Dryness fraction variation among MP tubes

Circulation design - Circulation ratio



- Circulation ratio as a design criteria
- Void fraction & two phase flow instability
- Effect of pressure on design circulation ratio

Boiler design - Erosion

- Erosion is primarily function of Flue gas velocity, relative hardness of ash particle and collision angle
- This can be expressed as follows: $E = kf(\theta)v^n$
- Where K is the function of relative hardness of heat transfer surface and ash
- Erosion in IBH, Convective tubes, Heat recovery units, Dust collection equipment
- Role of velocity in erosion
- Velocity constraints in water tube design and fire tube design
- Soot blower may induce erosion in the boiler
- The design velocity has become lower with time to improve the reliability of the boiler
- Role of circulation in erosion

Boiler design - Corrosion

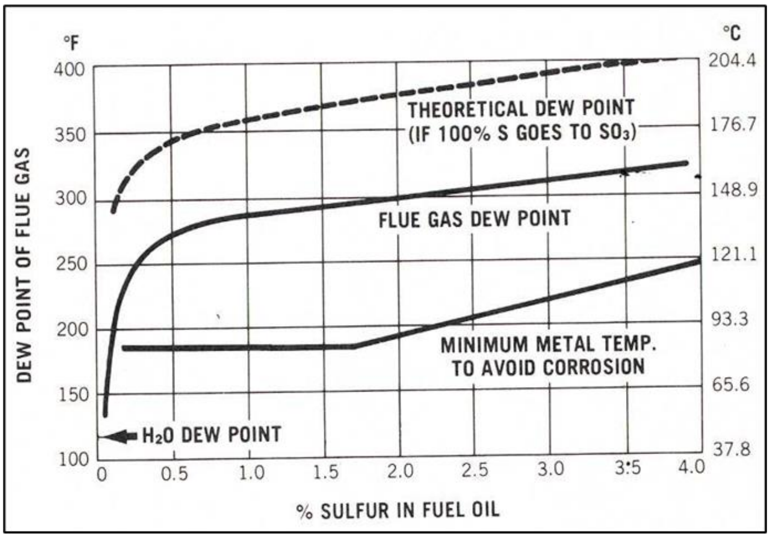
- High temperature corrosion
- Low temperature corrosion

High temperature corrosion - Fuel oil

- Vanadium attack
  Saturation temperature for V2O5- 600°C & Na_2SO_4 - 700 to 800°C
  V_2O_5 in presence of Na_2SO_4 (Sodium Vanadate)
    - Absorbs ambient oxygen and supply to metal
    - Removes protective layer of Iron Oxide
- Sulphide attack by Na_2SO_4 (liberated Sulphur reacts with metal, Na_2CO_3 formed)

Low temperature corrosion - Fuel oil

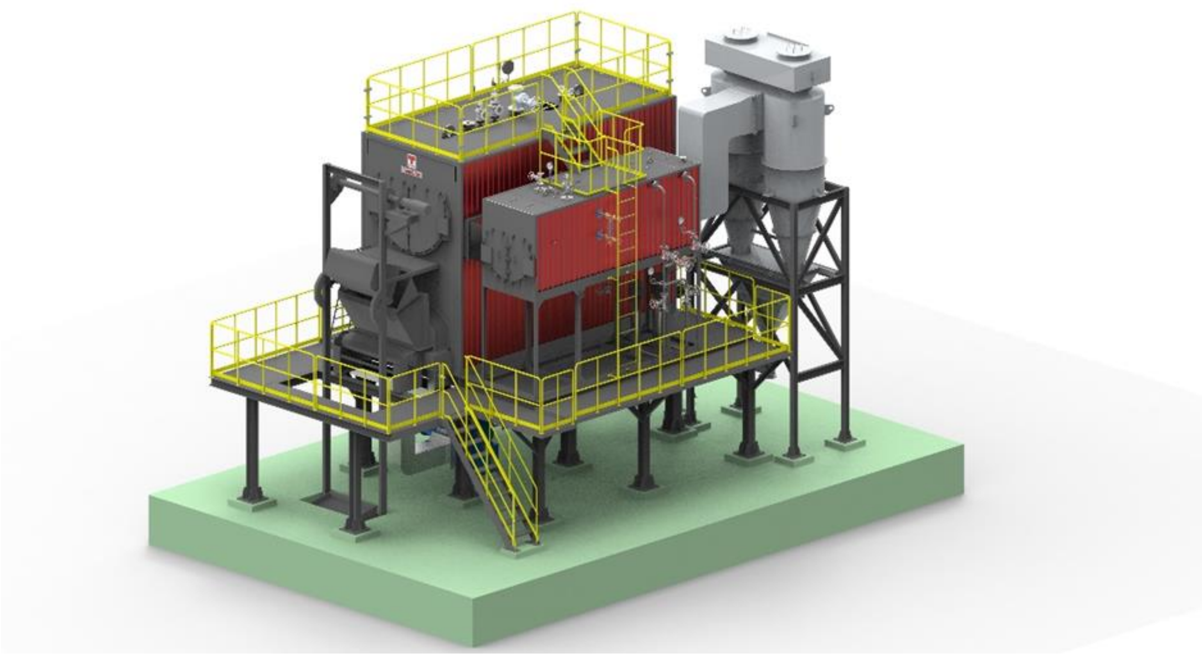
- Low end corrosion
- Condensation of sulfuric acid at the heat transfer surface (Governed by the sulfuric acid dew point temp. and metal temp



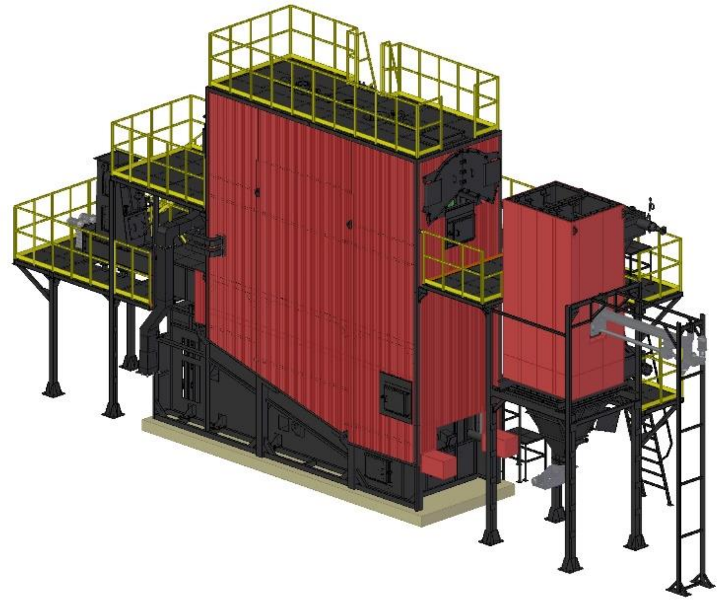
Corrosion - Solid fuel

- First and second layer are formed by melting Na_2SO_4 and K_2SO_4.
- As the deposition surface is wet with molten salt, deposition of salt and fly-ash takes place.
- As the thickness increases, temperature increases and goes beyond the saturation temperature and only fly ash gets deposited.
- The deposited Na_2SO_4 and Fe_2O_3 reacts with flue-gas SO_3 and forms complex $Na_2Fe(SO_4)_3$.
- This lower melting point and reacts with Fe.

Our key products

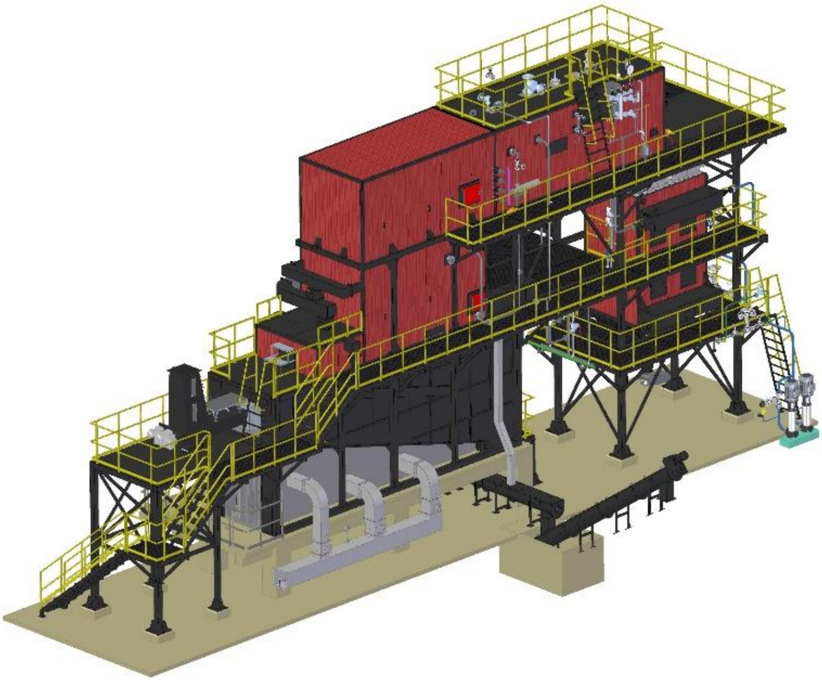


CBCG- Packaged chain grate boiler

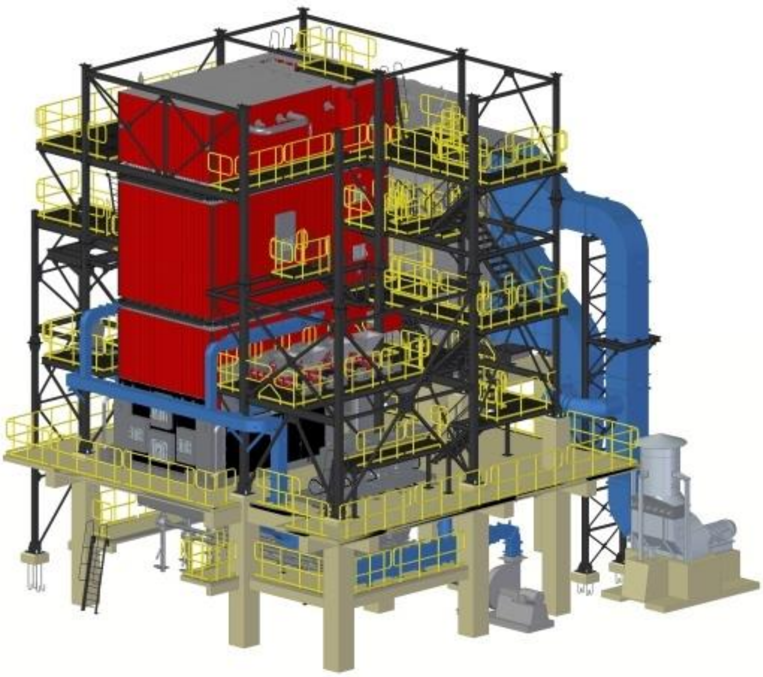


UPRG - Ultra-compact universal biomass boiler

CBUFS - Package Underfeed stoker boiler



CPRG - Hybrid reciprocating biomass boiler



BDF- Fluidised bed Bi-drum boiler &
BDRG- Reciprocating grate Bi-drum boiler

IMPORTANCE OF QUALITY SYSTEM IN BOILER MANUFACTURING AS PER INTERNATIONAL CODE

By Mr Parthapratim Brahma, TWI India Pvt Ltd.

Name: Parthapratim Brahma
Organisation: TWI India Ltd.
Designation: Mentor
Education: BE (Mechanical) Bengal Engineering College, Calcutta University, M Tech (Production Science & Technology) IIT, Kharagpur

As mentor help developing new engineering services to suit the Indian boiler & pressure vessel industry, expand training and certification in welding, NDT, Risk Based Inspection, Code and Standards

More than 39 years of experience in shipbuilding, boiler & Pressure vessel manufacturing industry as Welding Engineer, Surveyor, IRCA Registered Lead Auditor, trainer and mentor. Retired from Lloyd's Register as Area Technical & Quality Manager for South Asia Middle East and Africa. 26+ years of experience as ASME Authorised Inspector and Supervisor in Code construction of boilers and pressure vessels for various industry sector like power, oil & gas, chemical, food and engineering industry.

- Professional qualification in as ASME Authorised Inspector Supervisor
- Publication of papers and presentation at various conferences and forums like IIW, Petrosafe, Boiler India, ASNT, ISNT and other institutes on welding, NDT, ISO3834, ASME
- Member Central Boiler Board,
- Member International Working Group, ASME Sec I
- Controller of Authorisation, Training Management Board of ISNT

Abstract

Boilers and pressure vessels are manufactured and inspected in accordance with code and standards to comply with regulatory and contractual requirements. However, it is a common knowledge that not all of such pressure equipment perform uniformly to the desired quality level although certain stages verified during construction according to stipulated code of construction. Reliance on quality control and inspection alone will not help achieve the right quality which is the collective output of all processes involved during manufacturing. Focus must shift to 'how we do' from 'what we check'. A well-established quality system will help interlinking the key processes, measure the output of each process and continually improve the processes to make them more efficient. As a result, the products not only meet the regulatory needs but also achieve the desired quality level consistently and perform reliably.

Introduction

Boilers and pressure vessels are manufactured globally following certain code and standards as normally stipulated by the national regulatory body at the location of installation. The requirements are typically established by way of a contract placed on the manufacturer by the buyer/user which details the scope, specification and selection of national/international codes of construction. Construction codes do specify minimum requirements to follow in respect of design, materials, fabrication process, inspection and testing, certification to ensure safe operation. Often contracts stipulate requirement of independent inspection either by a third party inspection authority or by buyer's representative. The manufactures do prepare a "quality control plan" or "inspection and test plan" to list out the stages of inspection and intervention by its own QC and external inspection authority. Such quality control plans undergo review by the inspection authority and often by the buyer's representative before start of fabrication.

Verification at planned stages by QC and external inspectors certainly would justify reason for accepting those stages verified but may not necessarily confirm compliance with all aspects of code construction. The big question remains whether limited intervention through QC approach can assure the integrity of manufacturing processes, the right use of competency, materials, tools and techniques? Can we assure the integrity of the whole design by checking a few sampled calculations? Can we confirm that the materials used are from known source with demonstrable traceability to its source? Are we in a position to confirm that production welding was indeed made using the right weld procedure with right parameters and consumables as established by qualification? What is the reliability of the test we witness?

Fig 1

A mere quality control and inspection based system can't assure all above aspects to a satisfactory level. The inspection based system can identify defects to the extent those are detectable and offer reactive approach towards correcting defects (*Fig 1*). Such arrangements don't offer credible opportunity to learn from mistakes, reach the root of a failure and take effective corrective action so that the mistakes aren't repeated again. Whereas a Quality System or Quality Programme can help the manufacturer of boiler and pressure vessels to identify key processes, establish controls for desired output of each process and finally integrating those to assure products with consistent quality and reliability for intended use.

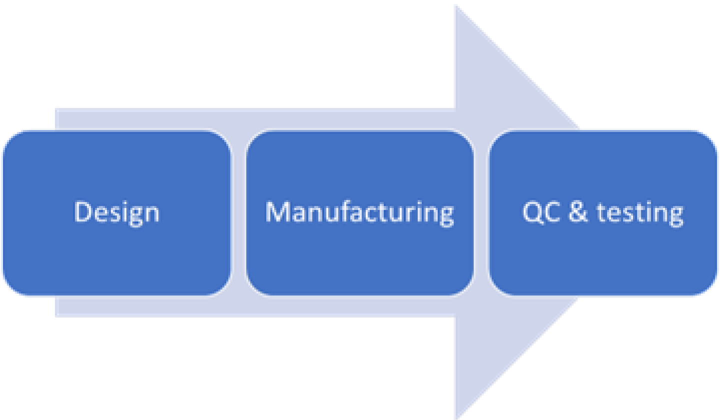
What is a Quality System

A "Quality System" is an organization's blueprint: it identifies its business model and processes, provides details about how its people will work together to get things done, and establishes measurable norms (some call objectives) for performance so that weak links are identified and improvements made.

A product is a collective output of a set of business processes. Some of the processes are considered key processes for the purpose of determining level of quality, meeting customer and regulatory requirements and compliance with the construction codes. For example, in a boiler manufacturing company the processes of sales, design, material procurement, manufacturing, quality control, testing and even despatch could play an important role in achieving overall product quality. Question may be raised as to how a sales process might influence the quality of a boiler manufactured to IBR Code. The simple explanation is that if the design specifications, site information, customer requirements, regulatory needs are well clarified at the contracting stage, there is greater opportunity to do it right first time and less likelihood of alteration and rework at manufacturing stage. Similarly, a design process is not all about calculating thicknesses of the pressure part according to Code but to take care of the whole boiler as a product to ensure safe operation, its structural integrity and guaranteed performance, for the operational conditions received as design input.

All processes are interconnected and interdependent as output of one can influence the succeeding process. For example, a good fabrication drawing with accurate construction details, right manufacturing method, tolerances based on shop capability as output of design process would certainly help ease of manufacturing and improve the productivity. It is therefore essential to focus on each key process and improve upon them so that collectively those would deliver an improved product. A well-established quality system would help integrate the business processes thereby assuring quality including compliance with code and standards at every stage without much dependence on surveillance based approach.

Fig 2



Quality system or quality programme is about defining the key processes and establish suitable controls to manage those processes effectively. Some time output of a process can't be assessed qualitatively as direct measurement of quality is not possible . Such processes are called "special process" like welding, painting etc. Therefore process control is crucial for such processes to achieve consistent quality output. Let's have a look at some of the elements in process control.

Process can be defined as a set of actions or steps or activities undertaken in order to achieve a particular outcome based on given input. Like for example, let's consider fabrication process which has multiple actions or operations to convert a piece of metal plate to a pipe. The input here is the drawing /specification of pipe giving size and shape and the raw material plate. Now the fabrication process will involve several activities like marking, cutting to shape, rolling/forming, welding, heat treatment etc. Each of these activities need to be managed in such a manner that the end result would meet the requirement of specification and we shall get a good quality pipe. It is important to note here that the drawings and materials also should have come through controlled processes to ensure the right quality of the end product pipe.

There are four major controls available to manage a process for desirable output (see Fig 3):

1. Process, procedures, techniques
2. Technology
3. People
4. Organisation culture

Process, procedures, techniques are tools to control a particular activity or group of activities. Typically, these are documented instructions describing how to perform an activity. Technology contributes to process improvement, accuracies, repeatability in operations by way of automation or use of advance technology. People are the key in managing any process. The skill and competency of people would possibly have larger impact on level of quality output. Lastly the organisation culture which encourage people to work in a team and complement each other for a significant output.

An Organisation must find a balance between these four mechanisms for optimal control of a process. Control mechanisms described above are interdependent and therefore the degree of application of a particular mechanism would depend on others. For an example a process managed by highly qualified and competent people may not need many documented work instructions to perform their tasks compared to a situation where available skill is of average nature.

Now once the controls are in place, measurable objectives may be set to monitor the performance of the process and its effectiveness to achieve desired output. This is a crucial part in process control as it offers the opportunity to identify root cause of a problem and fine tune by taking corrective steps to eliminate root cause. This is much different approach from just correcting a defective item as is usual in inspection based system. Quality system with process-based approach would facilitate elimination of a root cause thereby improving the process with less defective output.

Role of people in Quality system

Often, we hear that a well-established quality system doesn't depend on people. It is not entirely true as the effectiveness of a quality system would depend on people who operate within the system. The role, responsibility and authority of people at all level must be well clarified commensurate with their competency for a quality system to function efficiently. There are three categories of people in a quality system:

a) “Performer” like designer, recruiter, shop production supervisor, material procurement personnel, welder, radiographer etc.
b) “Verifier” like QC personnel, internal auditor etc.
c) “Knower” like managers, senior management, finance

In a quality control based programme more emphasis is usually given to the “verifier” who are given the task of verifying each and every piece of work done by others. It is not only time consuming but also has certain limitation in verifying all aspects of construction particularly those involving special processes. Moreover, it adds to the cost of quality as time and efforts are spent on detecting defective items, rework and repair of those items.

Quality can be built by the “performer” of an activity and therefore a strong quality system will have equal focus on those who perform work be it a drawing preparation, purchase order issue, storage of materials, manufacturing a dished head or conducting non-destructive testing. Quality system would capture these activities and identify corresponding controls including responsibility and authority. A good record keeping is an essential part of a efficient quality system.

The “knowers” are the people who take decisions based on available data. A good quality system would promote measurement of performance and supply of credible data to management for efficient resource planning and investments on technology etc.

Quality System requirements by International Boiler Codes

Recognised International codes for boiler construction such as ASME Sec I, EN 12952, EN 12953, AD 2000, TRD (Technical Regulations for Boilers in Germany) all have requirement for manufacturers to operate documented quality system. European Code for water tube boiler EN 12952 Part 5, Annexure F has described the quality management system for the manufacturers to address various elements like Quality Manual, Document Control, Organisation, Design, Purchasing, Manufacturing, Examination, field assembly. This section further referenced ISO9001 and ISO3834-2 &3 as the Quality Management System standards to comply with by the Manufacturers. ISO9001 is the Quality Management System Standard providing a generic structure to manage the key business processes seeking continual improvement. There is a great focus on leadership and management accountability towards quality and meeting regulatory requirements. ISO 3834 series is set of Quality System standards specific to manufacturing organisations using fusion welding of metallic materials.

ASME Boiler code has very specific requirements for the boiler manufacturers to implement a quality control system and its evaluation by ASME designee during assessments. Let us look at how a quality system is defined by ASME Sec I, Rules for Construction of Power Boilers.

"**PG-105.4 Quality Control System**. *Any Manufacturer or Assembler holding or applying for a Certificate of Authorization shall demonstrate a quality program that meets the requirements of ASME CA-1 and establishes that all Code requirements including material, design, fabrication, examination (by the Manufacturer), and inspection for boilers and boiler parts (by the Authorized Inspector) will be met."*

CA-1 is the standard for Conformity Assessment by ASME International. It is noteworthy that the emphasis is on demonstrating the quality system to ensure that all code requirements are met.

ASME Sec I, A 301 has described the requirement of a written quality system which shall be made available to the ASME designee during his audit. A written documented quality system consists of a Quality Manual supported by Quality Procedures and Instructions. The Boiler Manufacturer or Assembler has the freedom to prepare the Quality Manual and procedures to suit its organization, operations, products and complexities. The outline of written Quality System is provided in A 302 of Sec I. Let us discuss these elements in brief.

1. Authority & Responsibility: The role responsibility and authority of people involved in the quality system shall be clearly documented. Persons involved directly with quality control functions shall have well defined authority and organizational freedom to identify quality problem and initiate action to avoid those.
2. Organization: An organization chart to show the relationship between the management and other functionaries like engineering, purchase, manufacturing, QC to reflect the actual organization structure. The purpose is to identify the organizational groups and associate them with relevant functions for which they are responsible. This helps create a synergy between the functions and achieve compliance with code at all appropriate stages.
3. Drawings, Design calculations and specification control: The manufacturer shall have a documented procedure to ensure that current approved documents are used for ordering materials, manufacturing, inspection etc. Also, the purpose of a system to ensure that design documentations are prepared by authorized and competent personnel.
4. Materials Control: The Quality system shall describe how materials are ordered, received, and stored with accurate traceability. The controls shall be established to ensure receipt

of correct materials with identification marking and test reports as required by code. Correct issue of materials to shop also needs to be addressed.

5. Examination and Inspection programme: The quality system shall address adequately how fabrication process carried out, QC inspection carried out with documented evidence of stages being complied with code and standards. The Authorized Inspector (AI) who provides the designated oversight, shall have the right to identify stages for his "Hold" and "Witness" inspection.
6. Non Conformities Control: The manufacturer shall have documented process to identify non conformities at any stage of construction and a systematic method to correct those non conformities with the agreement of AI. The item can only be considered for Code required stamping and certification only after closing out all non-conformities satisfactorily.
7. Welding Control: The quality system must address a process to qualify welding procedure and welder performance qualification as per Sec IX and other part of the Code. The qualification and responsibility of those involved with qualification shall be adequately addressed. The process shall also describe how production welding will be controlled to ensure code compliance.
8. Non Destructive Examination (NDE): The Quality system shall describe the NDE methods and procedures which are to be used during boiler construction as per Sec I. The system shall address how NDE personnel and procedures are qualified and certified before use.
9. Heat Treatment: The quality system must address the methods, controls and verification process to ensure that Code required heat treatments are completed.
10. Calibration: Measuring instruments and test gauges used for Sec I Boiler construction must be calibrated with required accuracy according to recognised national standards and ASME Code.
11. Record Retention: The Manufacturer's Quality system shall describe the type of records to retain as objective evidence and duration to demonstrate how compliance with Code was made. Such records are subject to review by ASME Designee and Authorised Inspection Agency.
12. Sample Forms: The documented system shall have identified controlled formats which are to be used for recording various activities in Code construction
13. Inspection of Boilers and Boiler parts: section shall describe inspection by the Authorized Inspector, how Manufacturer's representatives will coordinate and arrange for his inspection as per code. The AI and his Supervisor shall have full access to all documents and site of fabrication during Code construction. The AI must be provided with the copy of current Quality Manual for his review and acceptance before start of a Code job.

14. Pressure relief device: this section is meant for boiler safety valves manufacturer to describe how code compliance would be ensured with required oversight by a Certified Individual.
15. Certification: This section shall describe how documents are reviewed and authorized / approved for release within the organisation. If any different method other than written signatures are used, the quality system must describe the procedure to ensure the integrity of approval and authorisation process.

Indian Boiler Regulation

Indian Boiler Regulations-1950 has set of administrative and technical regulations which are to be complied with during construction and installation of a Boiler in India. According to Boiler Act 1923, the manufacturer of boiler must make such facilities available at its premises which are essential for meeting the regulations specified in IBR and for the verification Competent Person. Regulation 4(c) stated that boiler manufacturer must carry out manufacturing activities under the supervision of a Competent Person. At places like Reg 248 mentioned about certain capability of manufacturer in respect of welding machines, non-destructive and other testing, heat treatment etc. Also described the scope of inspection witness for the Competent Person including drawing approval. However, there is no specific mention about a quality system and its implementation by allocating responsibility and authority for various functions within a manufacturing organisation. It is therefore important for the Inspecting Authority and Competent Persons to encourage the manufacturer to implement a quality system in similar line with international codes to ensure integrity of the functions with adequate process control. Such quality system would not only help the manufacturer perform its activities efficiently but also support the inspection by Competent Persons in a more robust manner to ensure compliance with regulations. The Inspecting Authority may perform initial and periodic assessment to ensure continuity in the system with improvements.

Conclusion

A well-established Quality System will allow for good control over key processes and improve efficiency by optimizing resources. It will help the manufacturer by bringing more transparency in working processes and thereby accountability of people responsible for the process. The process of quality control and statutory inspection will be more effective and reliable when backed up by a documented system and records generated during operations. It is the time for Indian boiler industry to recognise that “Quality” of a product depends on how it is ‘built’ and not how it is ‘inspected’.

RISK BASED INSPECTION AND FITNESS FOR SERVICE

By Mr. Mehran Izadkhah
TWI, Malaysia

Name: Mehran Izadkhah
Organisation: TWI, Malaysia
Designation: Global Riskwise Engineering Product Manager, Asset Integrity Management
Education: Bachelor of Science (Honours), Chemical Engineering, University of Tehran, Iran

Mehran started his career with Iranian Offshore Oil Company in 2006 with some prior field experience and worked for around two years on offshore platforms as a Site Engineer. He then joined TWI Central Asia in January 2009. His site experience and the support from TWI led him to gain more responsibilities in asset integrity engineering of oil and gas production facilities. Since then, he has been responsible for risk-based inspection, damage mechanism identification, fitness-for-services in accordance with API 579, repair and maintenance relating to production equipment and offshore structural integrity assessment, as well as pipeline external/internal corrosion direct assessments, over 3000 km pipeline integrity assessment, materials selection, corrosion control, cathodic protection, protective coatings, and failure investigations.

Mehran was involved in developing procedures, methodologies and software algorithms for a fully quantitative probability of failure and semi-quantitative consequence of failure for Onshore/Offshore Gas/Liquid pipelines following the requirements of relevant pipeline standards. Mehran and his colleagues published an article in “World Pipeline Magazine” in October 2018 named “A Game of Risk and Consequence” regarding the Risk assessment approach for onshore pipeline systems.

He also wrote an article with ADMA OPCO to develop a probabilistic study on the dead legs in ADMA’s process plants and offshore facilities subjected to internal thinning, presented at ADIPEC Exhibition in 2017.

With over fourteen (14) years of experience, he is now the Global RiskWISE Software Product Manager. Mehran leads and manages developments of TWI’s RBI and Integrity management software, supporting customers to maintain the integrity of their assets.

Introduction to Risk Based Inspection (RBI)

The inspection approaches for power plants, boilers and heat recovery systems, structures and machinery are usually determined by custom industry practices based on prescriptive codes and health and safety legislation. The inspection frequency, methods employed, and locations examined were determined by the type of equipment with little consideration given to its age, specific duty or likely damage. Ever-growing operational experience and a better appreciation of plant ageing and associated hazards have led the industry to adopt a risk-informed approach to inspection planning. These modern-day approaches require specifying an inspection appropriate to manage the risk of failure within regulatory expectations.

The risk-based inspection involves developing a scheme of inspection based on knowledge of the risk of failure. The critical element in the process is to perform risk analysis for the asset. Risk analysis includes the assessment of the likelihood (probability) of failure due to flaws, damage, deterioration or degradation and an assessment of the consequences of such failure.

The information gained from this process is then used to identify:

a) the type of damage that may potentially be present
b) where such damage could occur
c) the rate at which such damage might evolve
d) where failure may lead to catastrophe.

Areas at high risk usually have credible damage mechanisms combined with high consequences from structural failure, the release of hazardous substances or stored energy. A suitable inspection scheme will deploy techniques at a frequency that provides adequate confidence about the condition, taking the damage mechanisms and the reliability of the inspection techniques into consideration.

Risk-based inspection can generally be utilised in any industry sector. However, there has been most interest from the power and petrochemical sectors. Some of the examples reflecting the need, approach and benefits of RBI implantation may include:

A report on best practices for risk-based inspection as a part of plant integrity management. [www.hse.gov.uk/research/crr_pdf/2001/crr01363.pdf] published by the UK Health and Safety Executive in 2006.

The RIMAP project to develop risk-based inspection and maintenance procedures for European Industry launched by the European Commission in 2000. [Jovanovic A, Overview of the RIMAP project and its deliverables in the area of power plants, IntJPVP, vol 81, issues 10 and 11, pp815-824, 2004]

The American Petroleum Institute (API) has published recommended practice and a base resource document for risk based inspection relevant to refineries [API Recommended Practice 580 and Base Resource Document 581].

Industry sees RBI as a way to obtain economic benefits from extended run lengths and as means of using inspection resources effectively through the use of suitable automated NDT techniques and/or thoughtfully developed non-invasive inspection schemes. Regulatory pressure will ensure that the process of RBI is carried out rigorously so that inspection decisions are based on adequate information and expertise. However, in some industry sectors (e.g., nuclear) with very high consequences of failure, an approach to assure safety based only on RBI may not be entirely tenable.

In addition, RBI is a risk assessment and management tool that focuses on risk management topics which are not entirely addressed in other organisational risk management efforts, such as process hazards analyses, IOWs, or reliability-centred maintenance. Integration of these risk management efforts, including RBI, is the key to a successful risk management program.

RBI produces equipment inspection and maintenance plans that identify the actions that should be taken to provide reliable and safe operations. An RBI effort can give input for an organisation's annual planning and budgeting to define the staffing and funds required to maintain equipment operation at acceptable performance and risk levels [API Recommended Practice 580 and Base Resource Document 581].

Implementation Approach

The Risk Based Inspection (RBI) can be applied qualitatively, quantitatively or using an aspect of both, i.e. semi-quantitative. Each approach provides a systematic way to screen for risk, identify areas of potential concern and develop a prioritised list for more in-depth inspection or analysis. Each approach covers calculations of the Probability of Failure (POF) and the Consequence of Failure (COF) at the equipment level. The complexity of the risk calculation is a function of the number of factors that can affect the risk. In general, RBI focuses on a systematic determination of relative risks.

TWI is one of the world's leading organisations for RBI implementation. It regularly contributes to standard committees towards developing various RBI methodologies for various equipment and structures such as Pipelines, Jacket legs, Well conductors etc. TWI supports its clients in developing and implementing Asset Integrity Management plans, including RBI, Inspection, high-level Fitness for Service, Root Cause Analysis and life extension approaches.

TWI provides RBI software as well as implementation for different types of equipment. Our main core RBI software - RiskWISE® - since its start of development in late 1990s remains as a RBI and Risk-Based Management (RBM) engineering software designed in accordance with industry-accepted and proven concepts of RBI and RBM. It covers the concepts detailed in API Recommended Practice (RP) 580 – Risk Based Inspection (RBI) and API RP 581 – Risk Based Inspection Technology. The user-friendly software has been designed by plant personnel to help improve your safety and facilitate increased run times while reducing expensive outage costs.

RiskWISE® automates the fully quantitative methods and procedures of risk-based inspection (RBI) in process plants, according to API RP 580, API RP 581 and semi-quantitative assessment as per industry best practice. It is used to enable the facility operators or owners to establish an optimum inspection strategy, inspection programs; and make maintenance decisions. The software development incorporates years of experience and expertise in inspection. It aligns with the requirements of relevant standards, including API 581, API RP 580 and ASME.

Providing a fully quantitative risk-based inspection assessment platform as per API RP 581:2016, RiskWISE uses a regularly updated database to include all relevant damage mechanisms along with guidance to help the integrity engineers formulate the probability and consequences of failure.

Boilers are one of the assets with a variety of failure mechanisms. Understanding these mechanisms will help power plant owners significantly reduce the number of required inspections while managing the risk of the whole plant in a cost-effective approach.

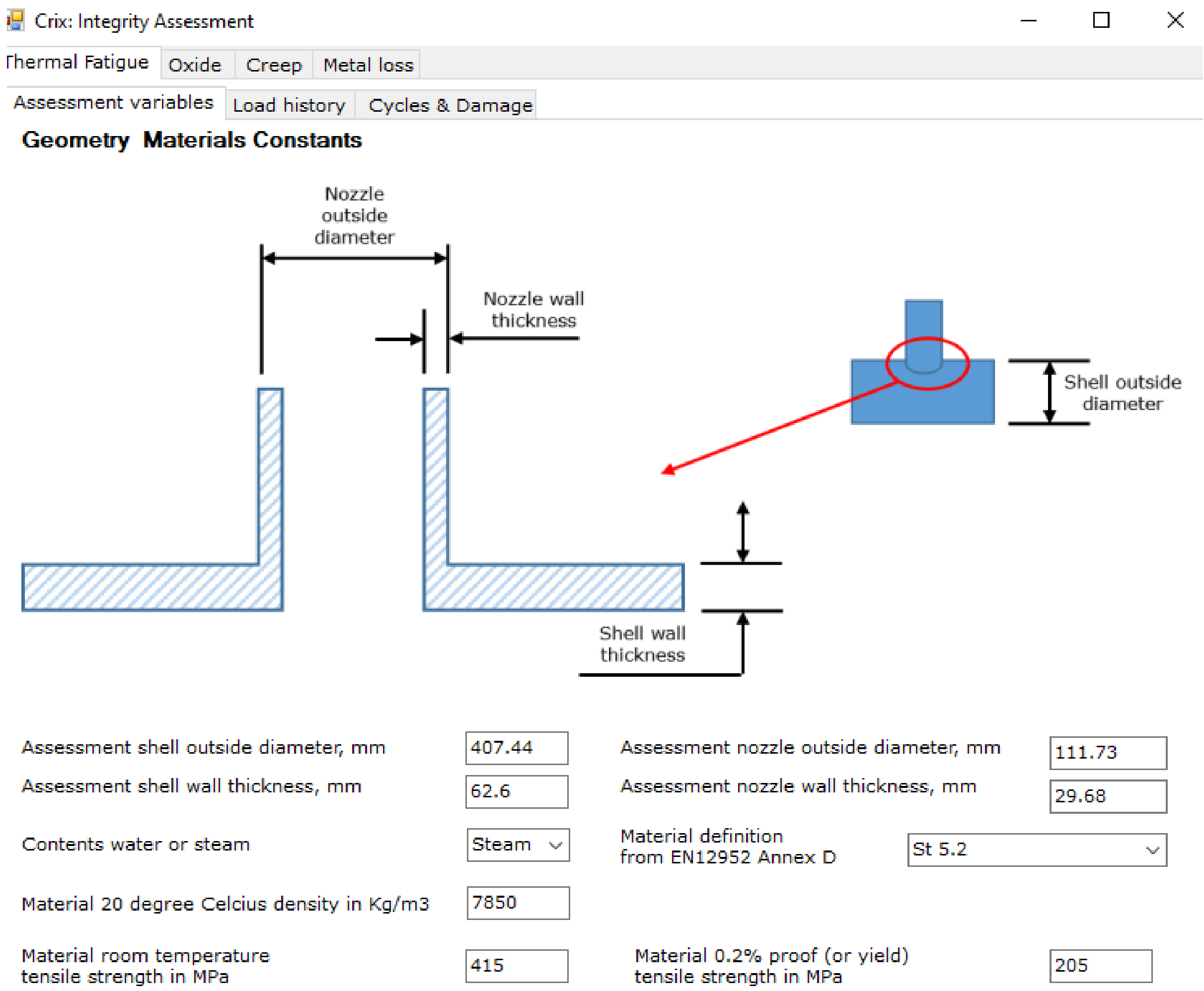
Executing the inspection and detailed assessment of boilers and boiler components gave TWI vast experience and knowledge to develop specific RBI methodologies quantitatively and semi-quantitatively for boilers and their components. This methodology covers all specific damage types in boiler components and heat recovery units, which are not addressed in API 581. Using this methodology, TWI together with its collaboration has developed a software called “POWER-RBI” to assess the risk and help the power plant owners to maintain the plant risk to the desired level. POWER –RBI will help the plant owners to:

- Avoid forced boiler outages and improve planned outage work
- Manage asset-related documents, P&IDs, MRBs, P&ID tagging and results

- Map and predict failures using available standards models
- Manage inspections and automate the flow of information/work
- 2D/3D visualisation of the Corrosion Monitoring Locations (CMLs)
- Inspection planning based on Damage mechanisms
- Flexible RBI methodology based on the availability of data

To ensure all boiler threats are addressed in the methodology, all types of damage mechanisms were addressed in both Semi, and fully quantitative RBI approaches in POWER-RBI. The main damage mechanisms are:

- General thinning
- Localised tube thinning
- Caustic SCC
- Chloride Stress Corrosion Cracking
- External chloride stress corrosion cracking
- Thermal fatigue
- Long-term and Short-term Creep
- Creep-fatigue
- Mechanical fatigue
- Low alloy steel embrittlement
- Softening
- Flow-induced turbulence damage
- Mechanical excitation



In addition to the RBI approach, a recently developed application called Crix to calculate the remaining life of the components for Creep, Thermal Fatigue and oxidation, and metal loss will be presented.

INFORMATION ABOUT APPENDIX 'J' OF IBR

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Mr. Imran Mujawar, Steam Boilers, M.S. Mumbai

Name: Hrishikesh Vilas Bawane
Organisation: Thermax Ltd.
Designation: Manager- Quality
Education: DME, AWS - CWI, CWIT - Pune

Head SHOP Quality, Receipt & Shipping, DT & NDT Lab, IBR Cell (Product PU- Heating SBU) at Thermax Ltd. More than 25 years of experience in Boiler Quality. Lead Auditor, welding Inspector.

Name: Imran Ibrahim Mujawar
Organisation: Directorate of Steam Boilers, Govt. of Maharashtra
Designation: Deputy Director
Education: Master's of Technology in Thermal from Maulana Azad National Institute of Technology, Bhopal (formerly REC Bhopal). Bachelor's degree in Mechanical Engineering from Government college of Engineering, Aurangabad.

Work as Deputy Director in Regional office of the Joint Director of Steam Boilers, Pune for effective implementation of The Boilers Act 1923, Indian boiler regulations 1950, Maharashtra Boiler Rules 1962, Maharashtra Economiser Rules 1965.

- Successfully commissioned Unit-7 250 MW Thermal Power plant of MSPGCL, Parli TPS, Tq- Parli, Dist- Beed.
- Successfully implemented "Mukhya Mantri Saur Krishi Vahini Yojana" in Latur district while working in MSPGCL, Latur solar project division.
- Topper from Maulana Azad National Institute of Technology, Bhopal in M-Tech thermal.
- Invited from Sandipani Technical Campus (Faculty of engineering) Kolpa, Tq. Dist. Latur as an Industry Expert for "VCRP-2016" to conduct Technical interview of participants from Latur, Osmanabad, Beed, Nanded district in year 2016.
- Invited from Vilasrao Deshmukh Foundation's School of polytechnic, Latur for delivering seminar on "Thermal Power plant" in year 2015.

Abstract

As Boiler operate under extreme pressure and temperature fluctuations, small undetected problem during manufacturing of the boiler and its pressure parts could lead to a catastrophic failure, resulting in an explosion and loss of property or life. Therefore, boiler and its components must be sufficiently inspected to ensure that the materials, manufacturing, and testing conform to the requirements of the Indian Boiler Regulations-1950. Appendix – J of the said regulations will describe the mandatory stages for inspection during manufacturing of the boiler and its components and pressure parts.

General

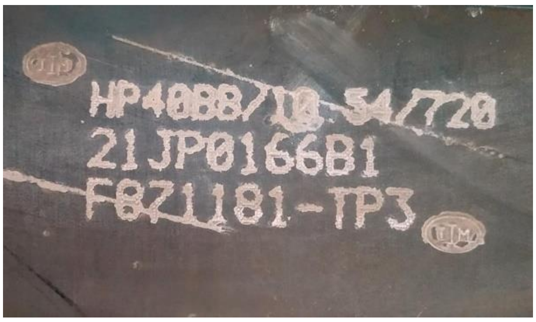
- The Inspecting Authority/Competent Person shall have access to the works of the manufacturer at all reasonable times and shall inspect the manufacture of the boiler at least at the following stages and may reject any part that does not comply with the requirements of the Indian Boiler Regulations, 1950.
- In case of any doubt, the Inspecting Authority/Competent Person may examine at any stage other than the stages stipulated below.
- The manufacturer shall give prior notice to the Inspecting Authority/Competent Person before reaching each stage.
- Before undertaking any of the stage inspections, the Inspecting Authority/ Competent Person shall satisfy himself that the testing equipment/instrument has been properly calibrated.

Stages of Inspection During Manufacture

A) Shell Type Boilers

a) When the materials are ready for identification with the relevant material test certificates at boiler maker's works.

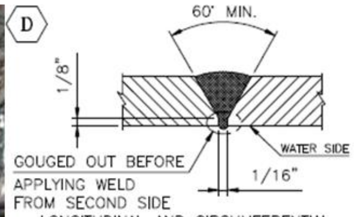
i) In laying out and cutting the plates, the plate identification mark shall be located so as to be clearly visible after the boiler part is completed. If the plate's identification mark is unavoidably cut out, it shall be transferred by the manufacturer to another part of the component to the satisfaction of the Inspecting Authority/Competent Person.



Material Identification

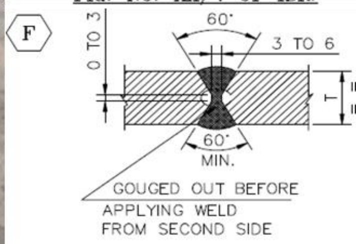
ii) The Inspecting Authority/Competent Person shall identify weld test plate material if production weld tests are required.

b) When the Shell plate and end plates have been formed with plate edges prepared for welding and test plates are attached.



LONGITUDINAL AND CIRCUMFERENTIAL WELDING SEAM FOR SHELL, CUT FURNACE, FURNACE,IRC, FUEL PIPE & ACCESS RING

FIG. NO. XII/4 OF IBR



LONGITUDINAL & CIRCUMFERENTIAL WELDING SEAM FOR SHELL,FURNACE, I.R.CHAMBER & STIFFNER RING.

FIG. NO. XII/5 OF IBR

c) When the welding of main cylindrical shell is completed and checked for circularity.

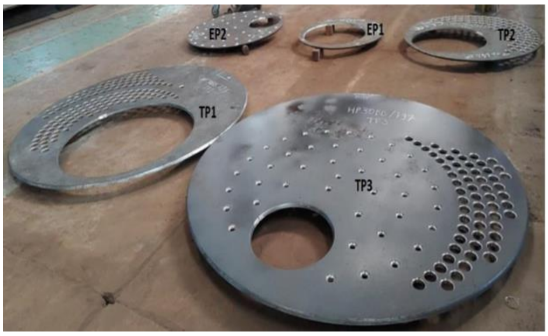
Alignment/Offset (Reg.no.541)

L-Seam - 10% of t & shall not exceed 3mm

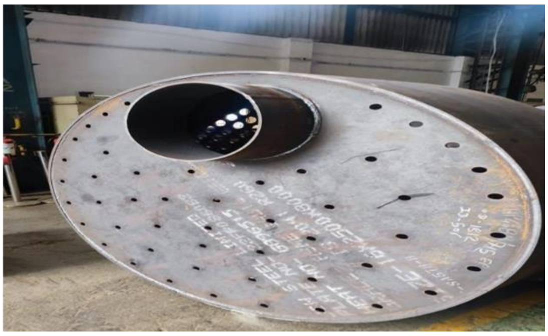
C-Seam - 10% of t & shall not exceed 4.8mm

d) To examine radiographs and/or reports of non-destructive testing.

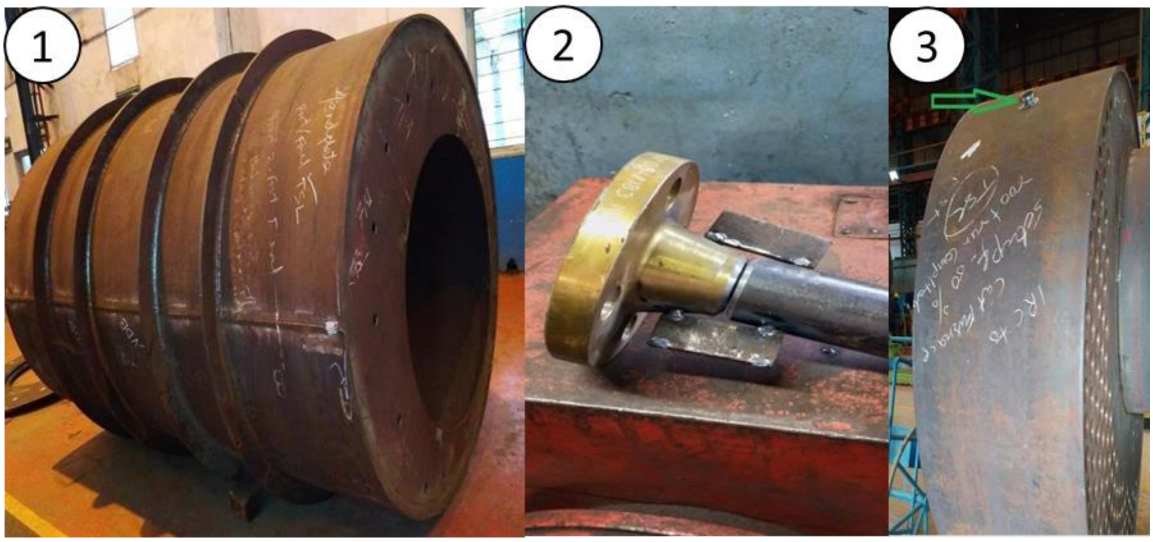
e) When openings have been prepared and stand pipes and similar connections including end plates have been tack-welded in position and subsequently on completion.



TP1, TP2, TP3, EP1 & EP2 ground i/s



IRC to TP2 and EP2setup, Access ring to EP2

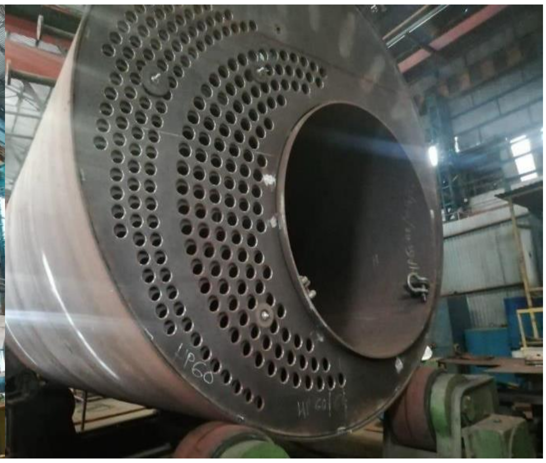


(1) EP1 to Furnace shell setup & Stiffener Ring Set-up
(2) Pipe to Flange Setup or Blowdown pipe to flange
(3) Coupling Setup

TP1 To Furnace Shell setup

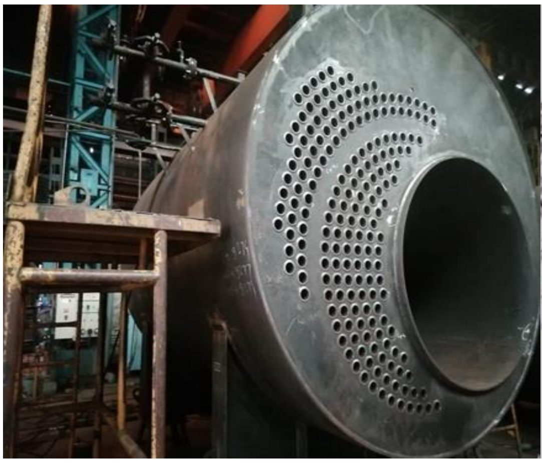
TP3 to access ring Setup

Nozzle to Shell, Manhole, Headhole Setup



Penetration of TP1and TP3 to main shell along with Gusset setup

f) When welding of drum or shell is completed and to check the records of heat-treatment when heat treatment is required under these regulations.



Full Welding clearance before stress relieving

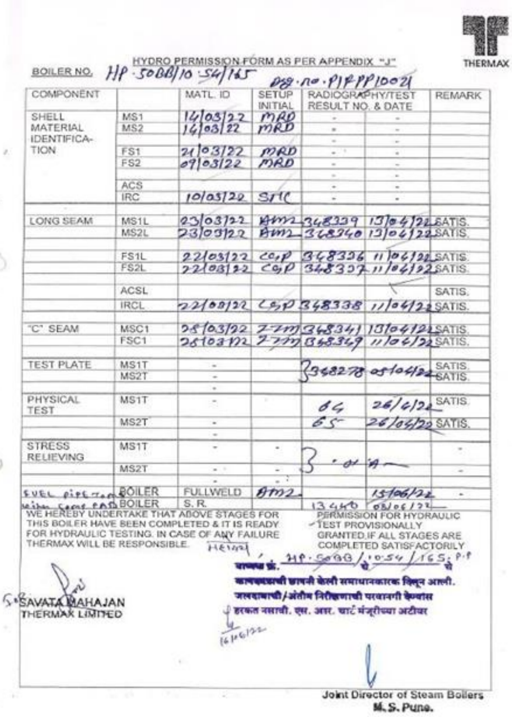
Pre-Ruboff

g) When weld test specimens have been prepared from the test plate, previously selected to witness the required testing.

i) 02 Nos - Bend Sample (F & R)
ii) 01 Nos -Transverse Tensile
iii) 01 Nos -Macro & Micro
iv) 01 Nos - All Weld Sample
v) 03 Nos - V notch Impact sample

h) During hydraulic test, followed by external and internal examination and stamping.
Hydro pressure=1.5 times design pressure
Required pressure gauge range = 1.5 to 4 times of hydro pressure

OC Readings and deflections at end plates during hydraulic test			
	At 0 Kg/cm2	At W.P. Kg/cm2	At hydro press Kg/cm2
Shell - 1			
Shell - 2			


THERMAX

HYDRO PERMISSION FORM AS PER APPENDIX "J"

BOILER NO. HP 50BB/10 54/165 Drg. no. P1FPP1002

COMPONENT		MATL. ID	SETUP INITIAL	RADIOGRAPHY/TEST RESULT NO. & DATE		REMARK
SHELL MATERIAL IDENTIFICATION	MS1	14/03/22	MRD	-	-	
	MS2	14/03/22	MRD	-	-	
	FS1	21/03/22	MRD	-	-	
	FS2	09/03/22	MRD	-	-	
	ACS			-	-	
	IRC	10/03/22	SMC	-	-	
LONG SEAM	MS1L	23/03/22	AMM	348339	13/04/22	SATIS.
	MS2L	23/03/22	AMM	348340	13/04/22	SATIS.
	FS1L	22/03/22	COP	348336	11/04/22	SATIS.
	FS2L	22/03/22	COP	348337	11/04/22	SATIS.
	ACSL					SATIS.
	IRCL	22/03/22	CSP	348338	11/04/22	SATIS.
"C" SEAM	MSC1	25/03/22	TTM	348341	13/04/22	SATIS.
	FSC1	25/03/22	TTM	348349	11/04/22	SATIS.
TEST PLATE	MS1T	-		348278	05/04/22	SATIS.
	MS2T	-				SATIS.
PHYSICAL TEST	MS1T	-		64	26/4/22	SATIS.
	MS2T	-		65	26/04/22	SATIS.
STRESS RELIEVING	MS1T	-	-			-
	MS2T	-	-			-
FUEL pipe...	BOILER	FULLWELD	AMM		15/06/22	-
	BOILER	S. R.		13440	08/06/22	

WE HEREBY UNDERTAKE THAT ABOVE STAGES FOR THIS BOILER HAVE BEEN COMPLETED & IT IS READY FOR HYDRAULIC TESTING. IN CASE OF ANY FAILURE THERMAX WILL BE RESPONSIBLE.

PERMISSION FOR HYDRAULIC TEST PROVISIONALLY GRANTED IF ALL STAGES ARE COMPLETED SATISFACTORILY

HP 50BB/10.54/165

हरकत नसावी. एस. आर. चार्ट मंजूरीच्या अटीवर

16/06/22

S. SAVATA MAHAJAN
THERMAX LIMITED

Joint Director of Steam Boilers
M. S. Pune.

Hydro permission

Hydro test followed by final inspection

B) Water Tube Boilers

Welded drums, headers, separators and vessels:

a) When the materials are ready for identification with the relevant material test certificates at boiler maker's works;

i) In laying out and cutting the plates, the plate identification mark shall be located so as to be clearly visible after the boiler part is completed. If the plate's identification mark is unavoidably cut out, it shall be transferred by the manufacturer to another part of the component to the satisfaction of the Inspecting Authority / Competent Person.

ii) The Inspecting Authority/Competent Person shall identify weld test plate material if production weld tests are required

b) When the plates are formed to cylindrical shape with the edges prepared for welding and set up in readiness for commencement of welding and attachment of test plates.

c) When the welding of the main cylindrical shell is completed, the shell checked for circularity and the radiographic or ultrasonic test reports, records are available for scrutiny.

d) When the end plates are ready for identification with the mill certificate, formed to shape with weld edges prepared and set on to the cylindrical shell in readiness for the circumferential welding operation.

e) When the welding of the end plates to the drum or the header is complete and the radiographs or ultrasonic examination records are available for scrutiny.

f) When each drum or header is prepared to receive any compensation plates and attachments, and when at least 10% of each type of branch of tube stub is set up ready for welding.

Header to pipe/stub setup

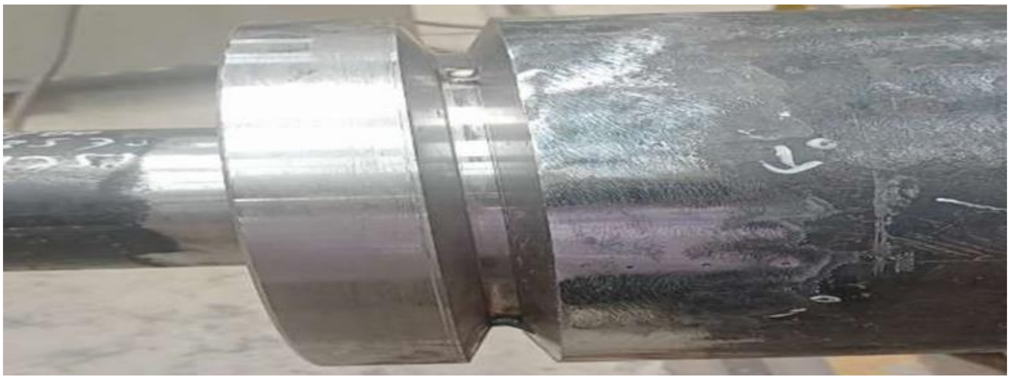
g) When all welding on each drum or header is complete, the Inspecting Authority/Competent Person will check the records of heat treatment, and mark off of specimens for preparation and testing from test plates.

h) During non-destructive examination, after stress relieving, on alloy steel drums and carbon steel drums with carbon content exceeding 0.25 % or thickness more than 100 mm.

i) During hydraulic test followed by final examination and stamping.

Seamless drums, headers, separators and vessels:

a) When materials are ready for identification with the relevant material test certificates, also when each cylinder is prepared for forming, or welding of separate end closures and to identify test plate material
b) When the end plates are ready for identification with the mill certificate, formed to shape with weld edges prepared and set on to the cylindrical shell in readiness for the circumferential welding operation



Header to end plate setup

c) When the welding of the end plates to the drum or the header is complete and the radiographs or ultrasonic examination records are available for scrutiny.
d) When each drum or header is prepared to receive any compensation plates and attachments, and when at least 10% of each type of branch of tube stub is set up ready for welding.
e) When all welding on each drum or header is complete, the Inspecting Authority will check the records of heat treatment, and mark off of specimens for preparation and testing from test plate.
f) During non-destructive examination, after stress relieving, on alloy steel drums and carbon steel drums with carbon content exceeding 0.25 % or thickness more than 100 mm.
g) During hydraulic test followed by final examination and stamping.

C) Tubular and piping components

a) When the tubes or pipes are ready for identification with the relevant material test certificates at the boiler makers' works.

Ovality of Bend	10% Max. For Cold Bend 15% Max. For Hot Bend	$\frac{D\ Max. - D\ Min.}{D\ Nom.} X100$ $\frac{37.40 - 35.80}{38.01}$ X100 = 4.20 %

Ovality of bend

Departure from circularity shall not exceed,

10 % - when Bend performed in single bending operation

15 % - When bend which are hot pressed after primary bending

Minimum Thickness on Extrados as Per Calculation	$= \frac{100}{\left(\frac{4R}{D}+2\right)} \%$ = 13.8 % = 3.15 mm	R (Bend Radius) - 50 mm D (Tube OD) - 38.1 mm Specified thk of tube - 3.66 mm Actual Minimum Thickness Observed = 3.54 mm

Minimum thickness calculations

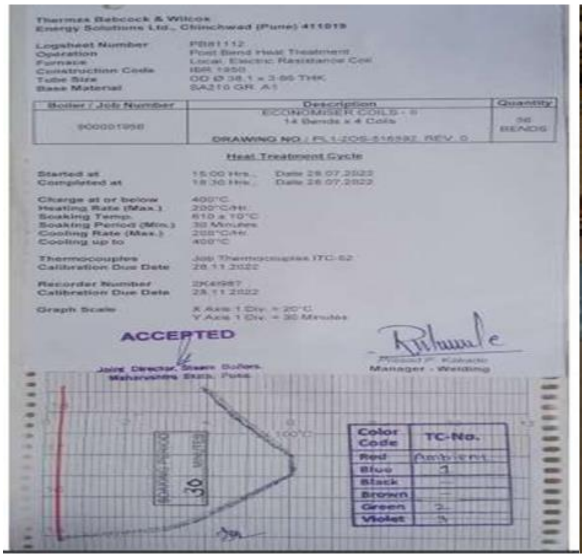
If % thinning is more than 25% then PBHT required.

If OD less than 141.3 mm (5.5 Inch) & R/OD <= 1.5 PBHT required.

If OD more than 141.3 mm (5.5 Inch) & R/OD <= 2.5 PBHT required

R- mean radius of bend to the centre line of tube.

b) When all welding of tubes or pipes and their attachments are complete and the non-destructive examination and stress relieving report/records are available for scrutiny.



Thermax Babcock & Wilcox
Energy Solutions Ltd., Chinchwad (Pune) 411019

Logsheet Number PB81112
Operation Post Bend Heat Treatment
Furnace Local Electric Resistance Coil
Construction Code IBR 1950
Tube Size OD Ø 38.1 x 3.66 THK
Base Material SA210 GR. A1

Boiler / Job Number	Description	Quantity
900001958	ECONOMISER COILS - II 14 Bends x 4 Coils DRAWING NO. / PL1-2OS-516592 REV. 0	56 BENDS

Heat Treatment Cycle

Started at 15.00 Hrs., Date 28.07.2022
Completed at 18.30 Hrs., Date 28.07.2022

Charge at or below 400°C
Heating Rate (Max.) 200°C/Hr.
Soaking Temp. 610 ± 10°C
Soaking Period (Min.) 30 Minutes
Cooling Rate (Max.) 200°C/Hr.
Cooling up to 400°C

Thermocouples Job Thermocouples ITC-62
Calibration Due Date 28.11.2022

Recorder Number 2K4987
Calibration Due Date 28.11.2022

Graph Scale X Axis 1 Div. = 20°C
Y Axis 1 Div. = 30 Minutes

ACCEPTED
Joint Director, Steam Boilers, Maharashtra State, Pune

Manager - Welding

Color Code	TC-No.
Red	Ambient
Blue	1
Black	—
Brown	—
Green	2
Violet	3

Post Bend heat treatment

c) During hydraulic test followed by final examination and stamping.

D) Inspections and tests to be carried out at Steel Makers' Works Foundry/Forging Units and the pipe and tube makers' works by the Inspecting Authority/Competent Person

a) Steel Makers Works

For manufacture of the billets, ingots, slabs, blooms, plates, bars, concast bars or any other material to be used in the construction of the boilers:

i) Checking of the chemistry of steel as per regulations.

ii) When ready for non-destructive examination and selection of mechanical test specimen after heat treatment.

iii) Testing, final examination and stamping.

Note: Notwithstanding anything specified above where the steel is made by the Well-known Steel Maker as recognised under the Indian Boiler Regulations, 1950 by the Central Boilers Board these tests will be carried out and certified by the Steel Makers themselves and the records maintained.

b) Pipe and Tube Makers

i) Identification of materials with relevant material test certificates.

ii) When ready for non-destructive examination and selection of mechanical test specimens after heat treatment.

iii) When specimen is tested and pipes/tubes are ready for hydraulic tests.

iv) Final inspection and stamping.

Note: Notwithstanding anything specified above, when the pipes/tubes are manufactured by well-known pipes/tubes makers recognised under the Indian Boiler Regulations, 1950 by the Central Boilers Board, all the above stages of inspections shall be carried out and certified by the manufacturers of pipes and tubes themselves and records maintained.

c) Forging Units

i) Checking of the chemistry of steel as per regulations.

Samples for Testing

ii) When ready for non-destructive examination and selection of mechanical test specimen after heat treatment.

iii) Testing, final examination and stamping.

Note: Notwithstanding anything specified under the Indian Boiler Regulations, 1950 by the Central Boilers Board then tests will above, when the forgings are made by well-known forging units as recognised be carried out and certified by the Forges themselves and all records are maintained properly.

d) Foundry Units

i) Checking of the chemistry of molten metal

ii) Verification of heat number and stamping of test bars

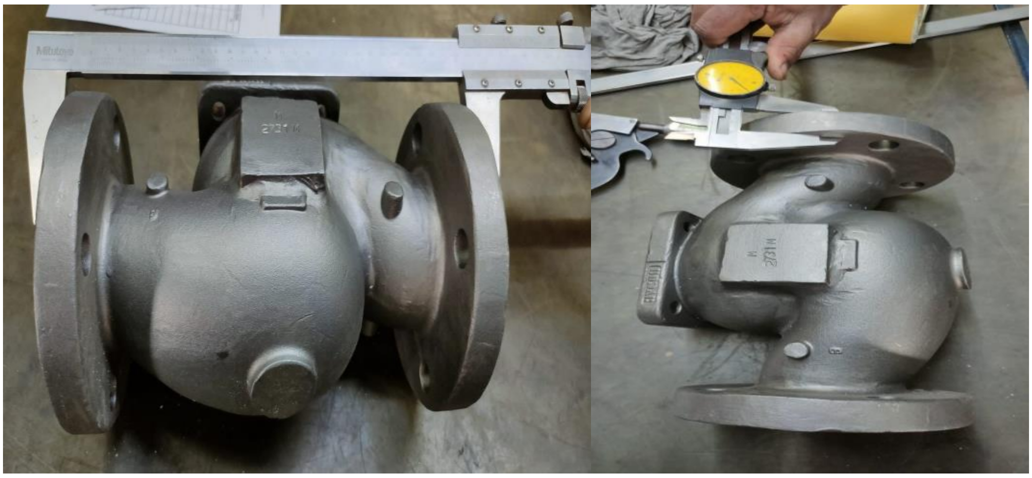
Samples for testing

iii) Verification of non-destructive examination report and heat treatment reports/records, mechanical testing, final examination & stamping.

Note: Notwithstanding anything specified above, when the castings are made by well-known foundry units as recognised under the Indian Boiler Regulations, 1950 by the Central Boilers Board then tests will be carried out and certified by the Foundries themselves and all records are maintained properly.

e) Valves and Mountings

i) Identification of materials with the relevant material test certificates. During this stage raw material along with relevant material test certificates, approved drawings will be checked, raw material should be free from any defects, dimensions should be as per drawings, also valve body shall be clearly marked to indicate the direction of flow etc.

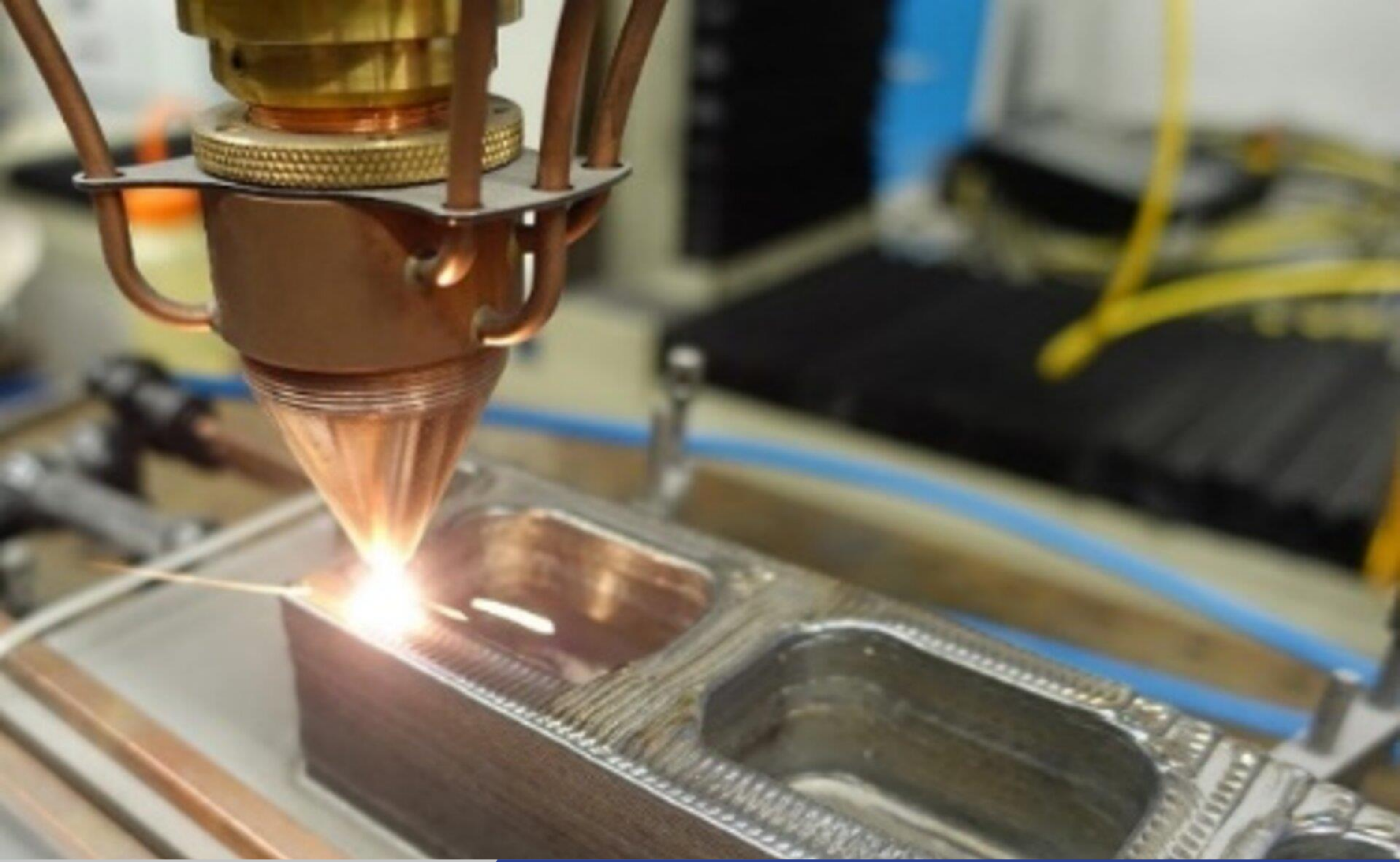


Raw material identification

ii) Hydraulic test and stamping

During this stage number of valves and fittings shall be made available to the competent person (excluding mechanical test) shall be as per Reg.290 (e)., Hydraulic testing shall be as per Reg. 290 (a).

Hydro test and final inspection



LATEST MANUFACTURING FACILITIES AND ADDITIVE MANUFACTURING

Mr. Mangesh Ashtekar
Forbes Marshall Pvt. Ltd

Name: Mangesh Ashtekar
Organisation: Forbes Marshall
Designation: Head Industrial Engineering
Education:
M Tech (Manufacturing Management),
BE Mechanical, MBA Finance,
BITS Pilani, Pune University

Industrial Engineering, Product Packaging, Capital Equipment, Plant layouts, Automation, Ind 4.0.

- Proud to be part of Forbes Marshall's Chakan, Pune Green Field Project
- Forbes Marshall Singapore factory commissioned during difficult covid period
- Worked on numerous manufacturing cell development as well as manufacturing layout projects of Forbes Marshall & its Joint Venture companies
- Developed various Material Storage, Material Handling Systems as well as Welding Automation & Special Purpose machines along with Corp Engg team
- Represented Forbes Marshall in India's first ZED Cluster (Zero Defect Zero Effect) by CII+ACMA
- Instrumental in developing Mobile based Suggestion Scheme app in 2016 for Forbes Marshall
- Ind 4.0 welding machine monitoring system for Boiler factory
- Published technical papers, case studies at forums of CII, IIIE, INSSAN, QCFI, ISE
- Hon Secretary Indian National Suggestion Scheme INSSAN – Western India Chapter
- Hon Vice Chairman Indian Institution of Industrial Engineering, IIIE Pune Chapter
- ASQ Certified Six Sigma Black Belt
- Fellow Indian Institution of Industrial Engineering
- TRIZ Level 1 Certification
- Certified TQM Professional from JUSE – Union of Japanese Scientists & Engineers. Trained under Noriaki Kano of the famous 'Kano Model'

Additive Manufacturing (AM)

Additive Manufacturing (AM) refers to a process by which digital 3D design data is used to build up a component in layers by depositing material. (Ref: The International Committee F42 for Additive Manufacturing Technologies, ASTM)

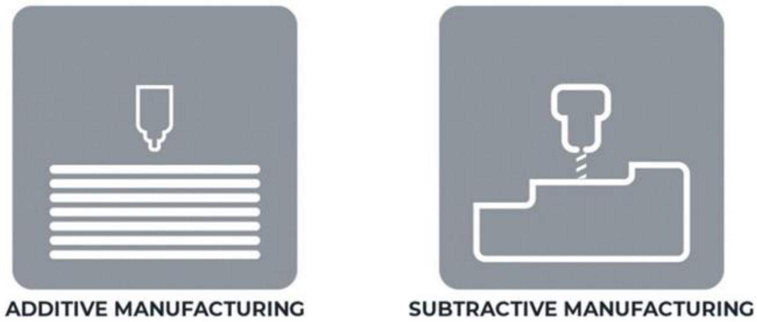
What You See Is What You Build (WYSIWYB) Process

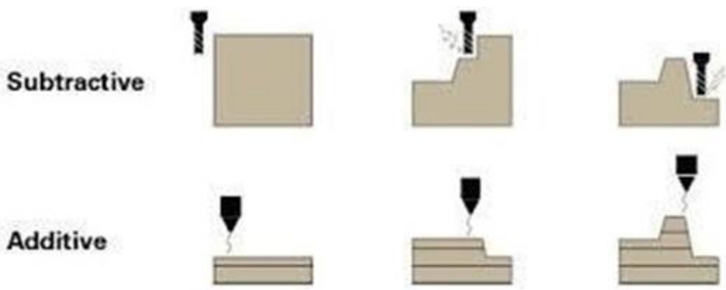
- the use of a computer 3D modelling software (Computer Aided Design or CAD),
- machine equipment and
- layering material.

Once a CAD sketch is produced, the AM equipment reads in data from the CAD file and lays downs or adds successive layers of liquid, powder, sheet material or other, in a layer-upon-layer fashion to fabricate a 3D object.

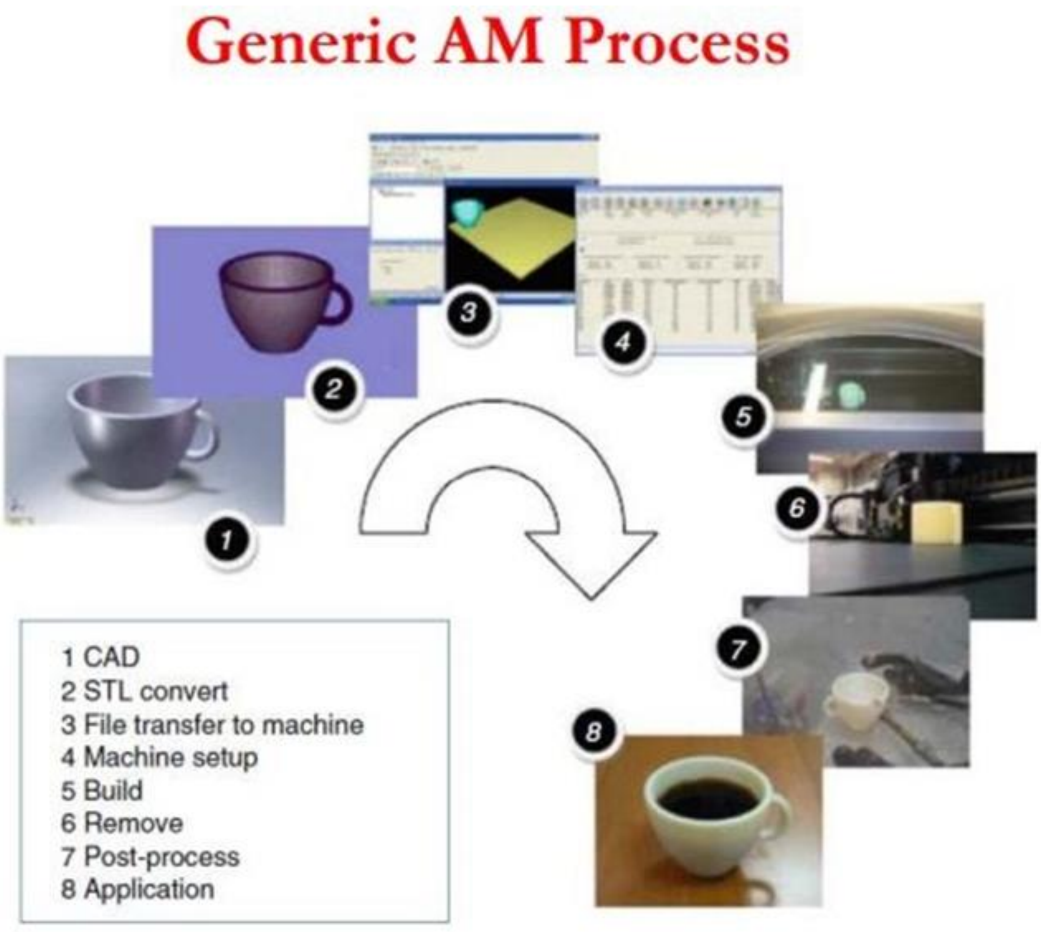
The term AM encompasses many technologies including subsets like 3D Printing, Rapid Prototyping (RP), Direct Digital Manufacturing (DDM), layered manufacturing and additive fabrication.

Additive manufacturing adds material. Subtractive manufacturing takes it away.





	Additive Manufacturing	Subtractive Manufacturing
Intricate Shape Creation	Easy	Difficult
Material Wastage	Very Less	More
Production Rate	Slower	Faster
Cost Effectiveness	More	Expensive
Finished Product Quality Reliability	Less	More
Training	Easy	Difficult



Source: Gibson, Additive Manufacturing

Benefits of Additive Manufacturing (AM)

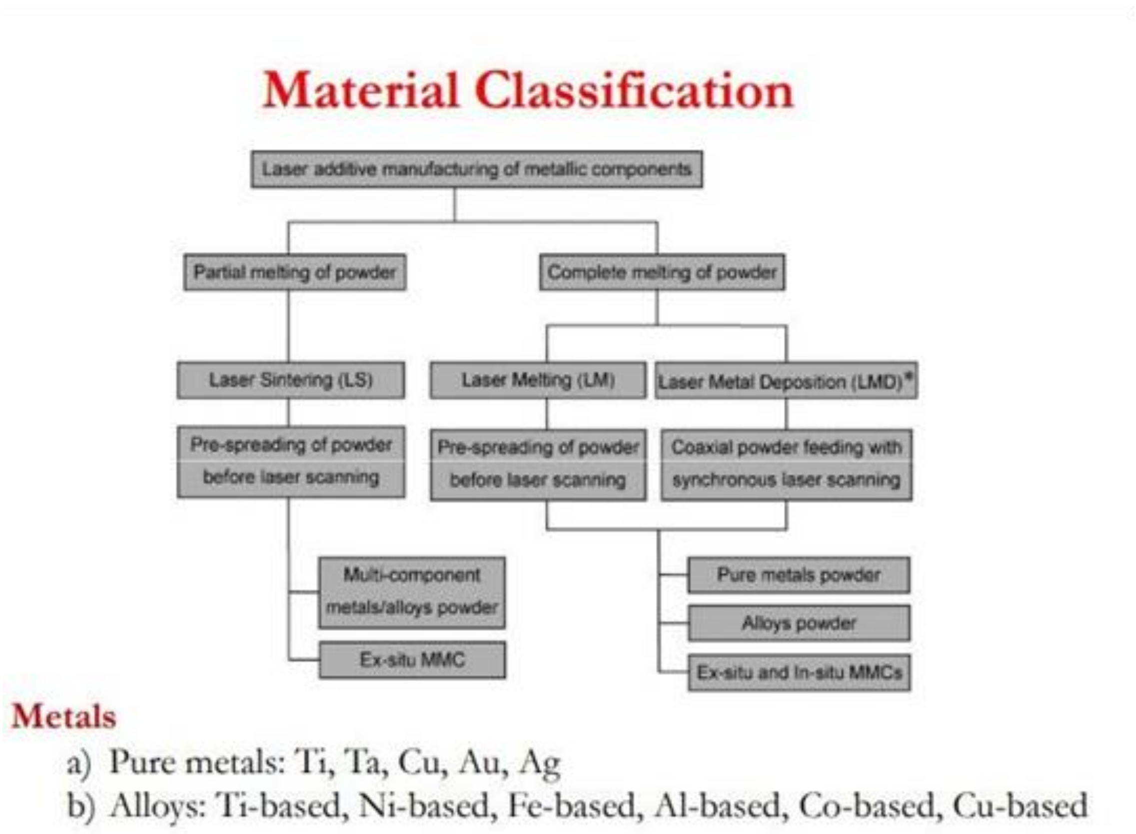
Green technology

Additive manufacturing technology builds the product in layers, reducing material waste and consumption. The waste generated in the process is reused in manufacturing and does not lose any of its properties.

Speed of design and flexibility

AM allows quick design changes without compromising pricing and the short lead times. AM is also very cost efficient for manufacturing smaller batches.

Additive Manufacturing (AM) Materials



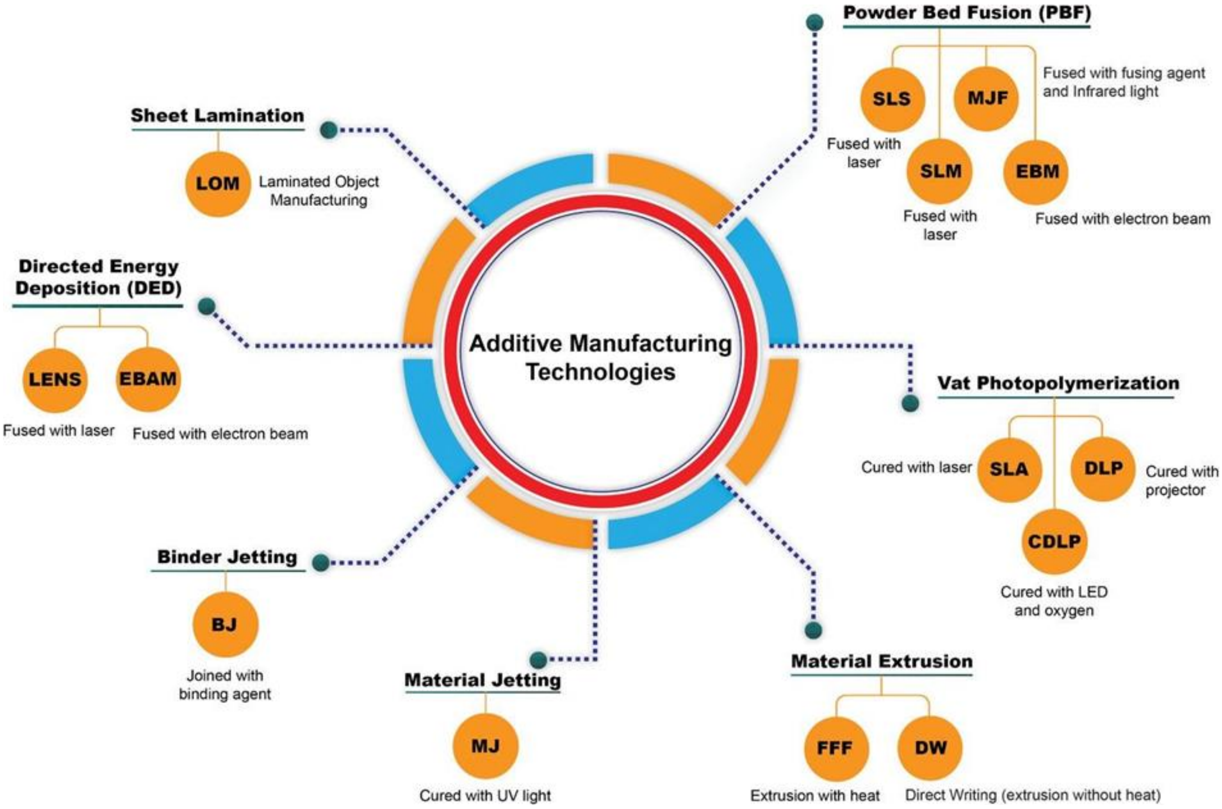
Material Development

- novel ferritic steel, named HiperFer (High Performance Ferrite), which was designed for increased fatigue strength. (Equivalent to SS316L)
- This ferritic, laves phase-strengthened, stainless steel could be used for a wide range of structural components in power and (petro)chemical engineering at maximum temperatures ranging from about 580 to 650 °C.
- This material benefits from in situ heat treatment and counteracts process-related defects by "reactive" crack obstruction mechanisms, hampering both crack initiation and crack propagation.
- In this way, increased fatigue resistance and safety can be achieved.

3D printing technologies spectrum

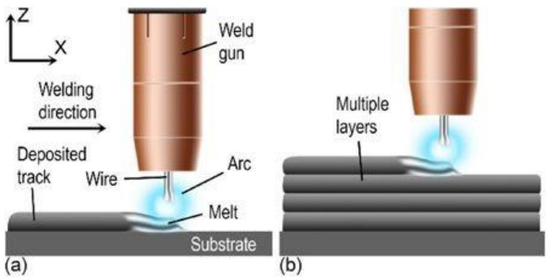
Plastic	Metal
Stereolithography (SLA)	Powder Bed FUsion
Selective Laser Sintering (SLS)	Direct Energy Deposition
Fused Deposition Modeling (FDM)	Binder Jetting
Digital Light Process (DLP)	Bound Powder Extrusion
Multi Jet Fusion (MJF)	
PolyJet	
Direct Metal Laser Sintering (DMLS)	
Electron Beam Melting (EBM)	

Additive Manufacturing (AM) Technologies



Wire Arc Additive Manufacturing (WAAM)

- Wire arc additive manufacturing is a wire-based process. It uses the gas metal arc welding process (GMAW)
- WAAM has high deposition rate (up to 4 Kg/Hr with steel materials)



The welding process needs to be sufficiently low energy such that when a new layer is applied, the existing layers do not melt again. In other words, the process needs to be as "cold" as possible.

The weld layers need to be continuous, spatter-free, and consistent. If any flaws were to occur, these would be replicated in each subsequent layer.

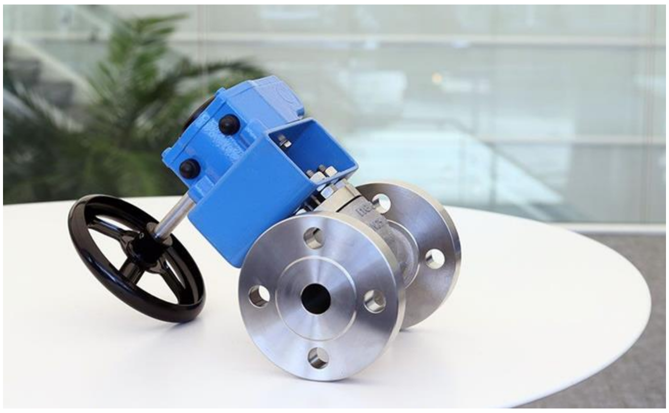
Additive manufacturing - Next generation industrial valves

Ramén Valves are one of the first valve manufacturers in the world to offer control valves in titanium grade 5 using additive manufacturing (AM).

EBM (Electron Beam Melting) is the process of producing parts by successive melting of layers of material rather than removing material. Each layer is melted to the exact geometry defined by a 3D computer model. The process provides a solid material whose properties is better than casted material and comparable to forged material. No residual stresses No heat treatment (of titanium)

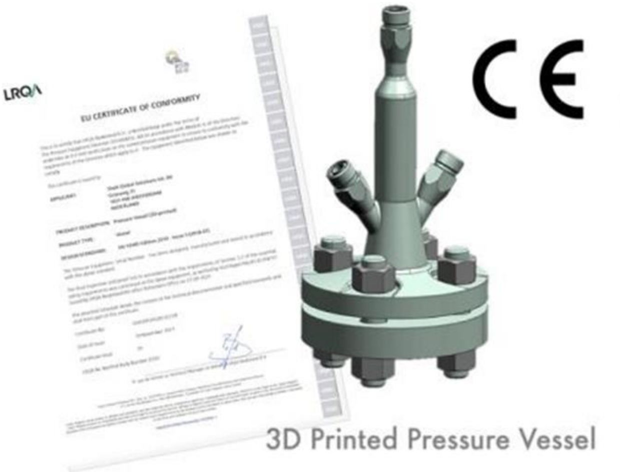
3D Printed Control Valve & Internals

3D printing can improve valve performance, reduce noise and deliver optimised solutions for customers' unique applications.



first-ever valve with 3D printed valve body for field testing by Valmet (former Neles)

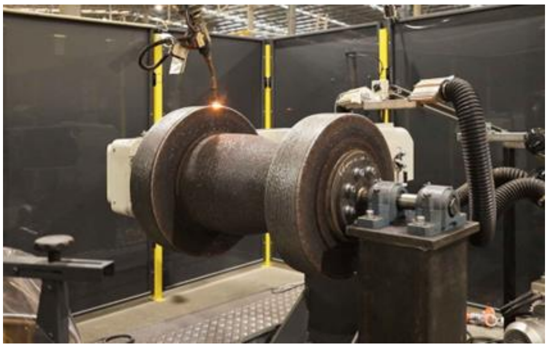
3D Printed Pressure Vessel by Shell Receives CE Certification



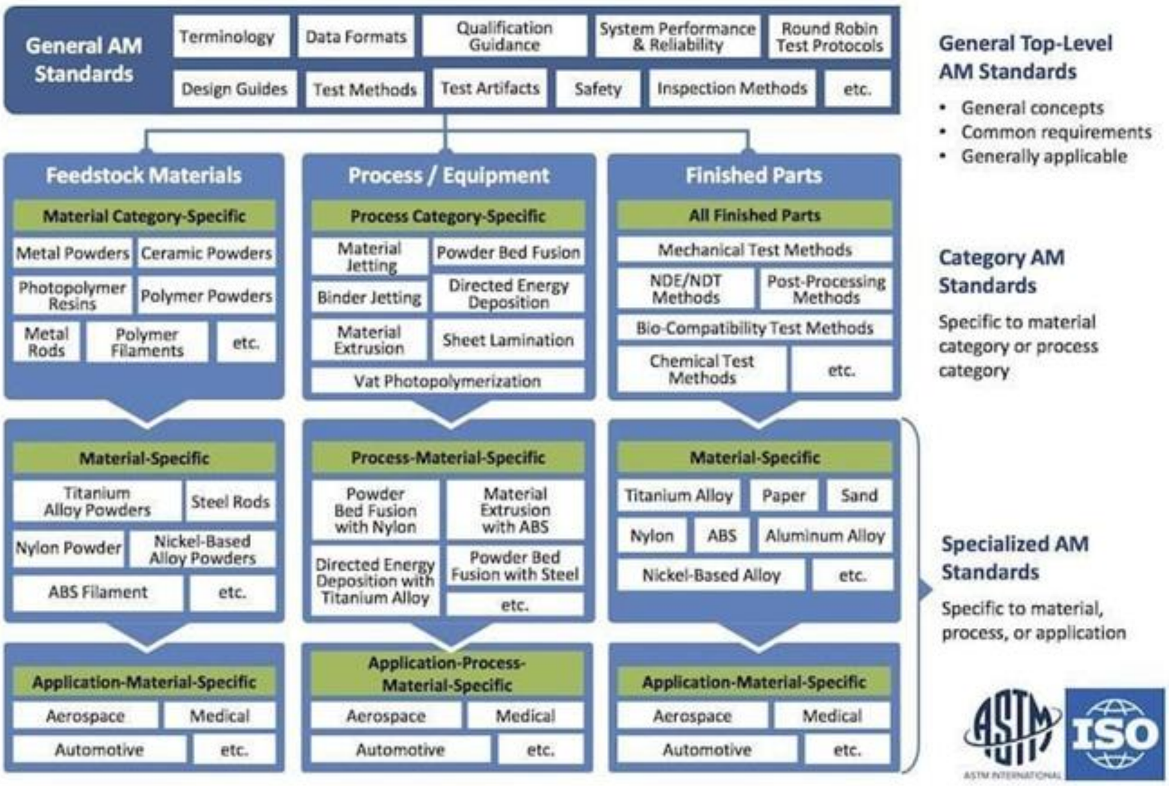
The vessel was manufactured through Powder Bed Fusion at the Energy Transition Campus in Amsterdam and is designed for pressures up to 220 bar.

ExxonMobil Orders "World's Largest" 3D Printed Pressure Vessel from AML3D

Australian metal additive manufacturing (AM) firm, AML3D, has announced a $190,000 purchase order for a high-pressure piping vessel, from global oil megalith ExxonMobil. Specifically, ExxonMobil's Asia Pacific division has ordered what AML3D touts as the "world's largest" metal 3D printed commercial pressure vessel.



Additive Manufacturing Standards Structure



National Strategy for AM

The National Strategy for Additive Manufacturing aspires to enhance India's AM market share to 5% of Global market with a target to add nearly US$ 1Bn to the GDP by 2025. This growth will aspire to achieve the following specific targets:

The strategy would address key sector specific technical challenges for making 3D printing economically viable for MSMEs, which include:

(i) Properties of the materials
(ii) Limited types of options on AM suitable materials
(iii) Process technology and performance
(iv) Limited in-process, in-situ monitoring mechanism
(v) Qualification & certification of AM processes and parts
(vi) Part accuracy
(vii) Surface finish of contoured surfaces
(viii) Fabrication speed
(ix) Build volumes/part size
(x) Data formats
(xi) AM Standards

In house experimentations

- Metal 3D printed mechanism parts for steam powered condensate pump
- Polymer 3D printing for aesthetic and from evaluation
- Polymer 3D printing for design validation

Metal 3D printed mechanism parts for steam powered condensate pump

We have done 3D printing of metal components in SS 316. The components were internal components of the mPump and were not subjected to pressure force. Out of the 3 components we printed one was a press part and the other two were casting components which were finished by using a machining process.

Observations, for the 3D metal printed components

1. The finishing of holes in the press part was not as expected. We may have undulation inside the hole.
2. Close tolerances achieved by traditional machining cannot be achieved by a 3D printing process. We need to keep machining allowances in 3D printed components and get them machined after the printing, which still needs traditional processes like fixtures and machining.
3. The surface finish in 3D metal is as good as sand cast components.
4. In terms of strength, the property may vary according to material or 3D printing technique.

IMPORTANCE OF NON PRESSURE PARTS FOR SAFE AND EFFICIENT OPERATION OF BOILERS

By Mr. Abhay Patil & Mr. Santosh Asangi
ThyssenKrupp

Name: Abhay Ramrao Patil
Organisation: thyssenkrupp Industries India Pvt. Ltd.
Designation: Director - Energy Division
Education: M. Tech - Structural Engineering, Bachelor of Engineering - Mechanical (VRCE, Nagpur, India)

27 years in Boiler & Heaters Industry, started as Design Engineer with a leading Boiler Manufacturing company in India, worked in leadership roles across Business Management, Proposal & Detail Engineering and Operations.

- Played a pivotal role in technology upgradation & scaling of Boilers like largest capacity CFBC & AFBC Boilers, which become industry standard for various Cement plants. HRSG to 9FA, BFG Boilers to 10 times.
- Instrumental for establishing port facility & developing modularized designs for enhancing export business. Received prestigious innovation award for Export modular HRSG design.
- P&L leader, directly responsible for thyssenkrupp's Global Energy Business
- Established turnaround and growth strategy for tkII Energy business by various strategic initiatives in product design, market expansion and by adding new products to the portfolio through in-house R&D and through strategic collaborations like MOU B&W for multiplied product basket of Boiler Technologies
- Contributed to business expansion & achieving market leadership for tkII Energy business by Starting portfolio for AI-based solutions for power plants and material handling systems, improving performance by predictive maintenance and remote operation & monitoring
- Patent holder on the various Boiler Design components
- Prominent speaker on Boiler Technologies & have presented multiple technical papers at various international forums & seminars
- Co-Chair for ASME (IWG India) code India Chapter

Name: Santosh Asangi
Organisation: thyssenkrupp Industries India Pvt. Ltd.
Designation: Sr. Vice President
Education: Bachelor of Engineering - Mechanical, Diploma in Business Management, College of Engineering, Pune

30+ years, 25 years in Boiler industry, Proposal & Application engineering.

- Implemented 45+ captive power plants using fossil fuels, waste heat resource.
- Implemented two Gas Turbine co-generation plants.
- Implemented 1st 100% paddy straw fired biomass boiler in India

Why Non- Pressure parts are equally important?

Boiler pressure parts supplied in India are designed as per Indian Boiler Regulations, 1950 and there is check and approval of IBR authority at every stage of Engineering, Procurement, Manufacturing and Erection, which ensures operational safety.

Non Pressure Part thus becomes responsibility of Manufacturer & User to supply and maintain and ensure no adverse effect on Boiler operation.

Non-pressure parts equally contribute to successful Boiler installation and are to be designed keeping operational safety as a motto.

Non-Pressure parts in any Boiler

1. **Structure: Columns, Support Girders, Beams, Bracings, Railings, Staircases, Ladders, Access platforms, Grills, Canopy**

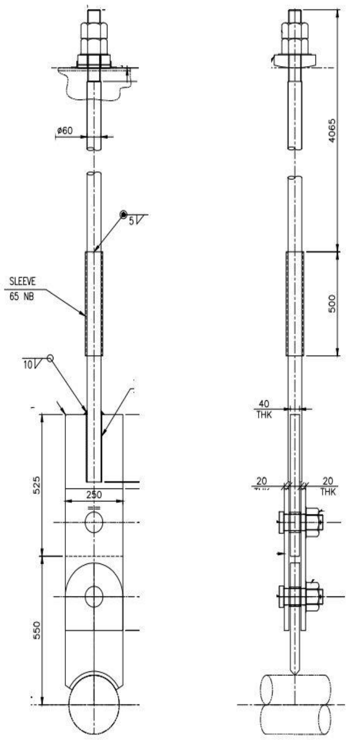
   For Indian Installations, follow IS 800 for steel structure design, IS 875 for Wind speed and IS 1983 for earthquake design.

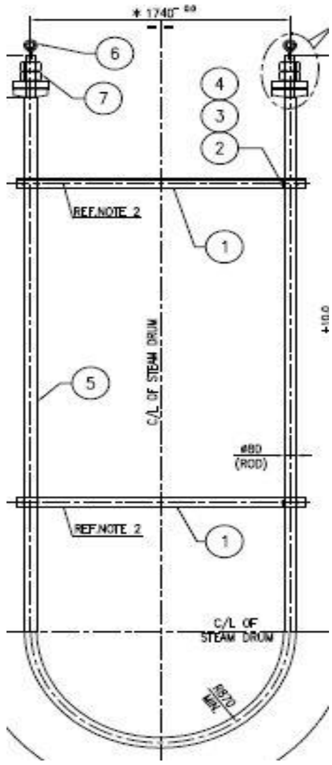
   Columns, Heavy Girders shall have lifting arrangement for safe erection. Column sections shall be selected such that proper access for painting is available. Bolted connections are preferred as it saves erection time. Chances of welding miss outs are avoided. Skilled manpower like Welder is not required. And overall Quality is better than welded connections. Cost factor shall be accommodated by the User considering advantages of bolted connection.


   Angle of Staircases shall be limited to 37°. Railings shall have height of 1100 mm up to 30 m and 1500 mm above it for safety reasons. Proper access to all manholes and Instruments shall be provided. Every level Platform shall have minimum two accesses from safety point of view. If due to layout constraints two staircases are not possible, provide escape ladder at least at one end. Electro forged Gratings with self-tapping screws have better quality than traditional welded type. Canopy shall be designed in such a way that it avoids rain ingress in working area.

2. Pressure Part Supports: Rigid or Spring Supports

   Mostly high-pressure boilers are top supported boilers. Small capacity and biomass boiler having special furnaces are bottom-supported boilers. In Top supported boilers, calculation of pressure part weight, expansions are important to design supports. High temperature and Pressure piping like Main Steam lines are Stress analysed in Software like CAESAR and necessary supports are provided accordingly. Critical lines like Steam line connecting to turbine Flanges require experience of line behaviour at high temperature and Routing with spring supports is done accordingly.





3. **Steam Drum Internals**

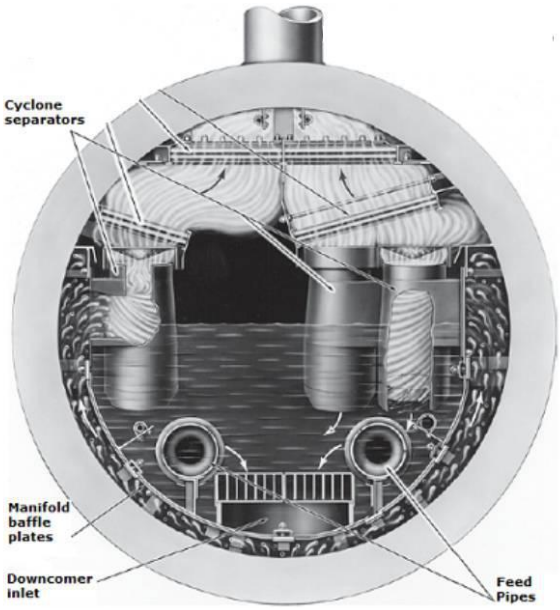
In any High pressure boiler, Steam drum is a part where feed water and saturated steam from furnace walls is collected.

Feed water is fed through pipe across the steam drum length. Holes on these pipes are oriented such that proper distribution, mixing with HP dosing and no obstruction to separated water from Saturated steam is achieved.

Cyclone separators, Scrubbers are provided to separate water from Saturated steam and this steam is passed to Superheaters. Life of Superheater depends upon efficiency of Separators.

Blow down connections, HP dosing are also part of Drum Internal.

Drum internal play's vital role in maintaining steam quality and enhancing Superheater life

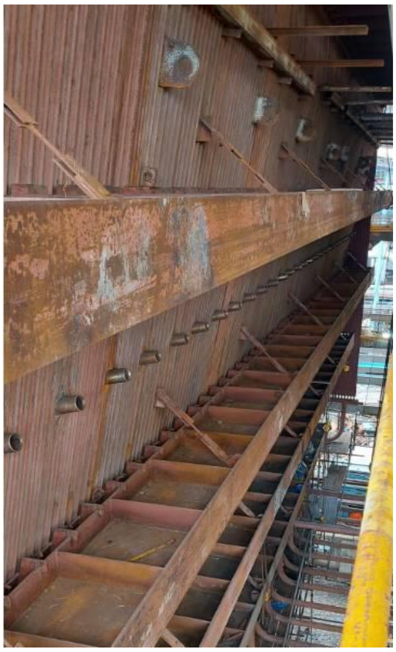


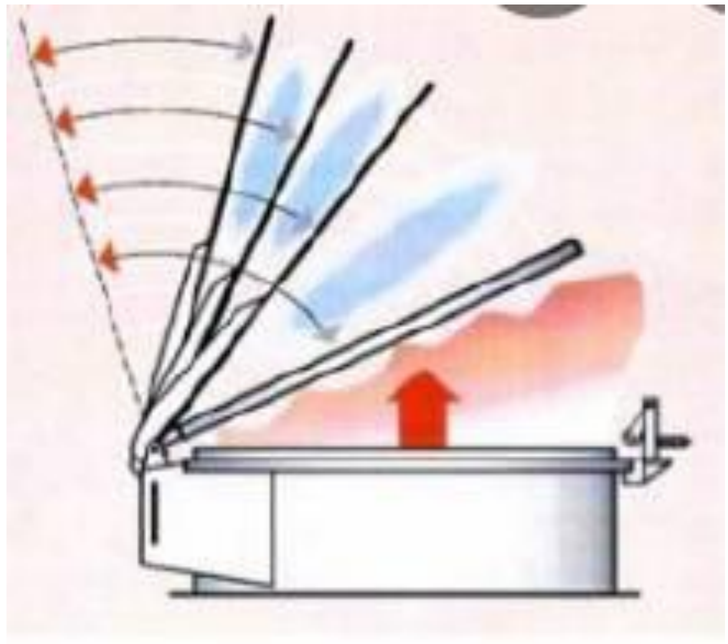
4. **Buckstay, Explosion doors, Emergency vents**

Buckstay: Boiler Furnace water wall panels are slender and try to buckle outside due to furnace pressure. Buckstay form a flexible support around the 4 furnace walls which allows thermal expansion and at the same time restrict any buckling of water wall panel. These are specially designed structural sections attached to furnace without any welding and simple pin holding arrangement is provided. As per NFPA guidelines, design pressure is selected to size the Buckstay member cross section.

Explosion Doors: In case of sudden pressure rise in furnace due to explosion or implosion, buck stays may not save furnace damage. Explosion doors designed for specific pressure gets open due to actual pressure rise and saves pressure parts from any Damage.

CO vent: In CFBC boilers during sudden blackout condition, these vents help to evacuate CO accumulated in Furnace Wind box.





5. **Fuel Silos, Bunkers, Fuel Feed Chutes**

   Sizing of bunker is very important for any plant operation. Many times, water volumes of bunker are not fully utilized if feeding from conveyor is not designed in proper way.

   Circular Silos are better for coal flow compared to Rectangular Bunkers and choking of Coal in rainy seasons is minimized. Air Blasters are commonly used for this purpose

   For Coal feed chute, wear resistant material, refractory lining is provided for better availability.

6. **Ducting and it's auxiliaries**

Ducting sizing is maintained according to the required Air or Flue gas velocity. Round ducting works better than conventional rectangular ducting where flue gas contains more ash content. Round Cross-section with slope avoids ash accumulation.

Fixed and sliding support shall be ensured during erection at site. Welding of supports shall be checked on regular basis.

Expansion bellows, Dampers, Special supports need regular maintenance. Ensure there are Drains provided where chances of condensate are there. Adequate Manholes and Vents are required for safe working during erection and shutdowns

7. **Furnace or duct refractory**

Important Terms defining the Boiler Refractory property:

- Refractoriness: It is a property at which a refractory will deform under its own load and it is generally determined by the composition of material used to make a refractory.
- Porosity: It is the property to resist against chemical attack (usually by fuel and water). A low value of porosity means high strength and good thermal conductivity.

- Refractory Strength: It is the resistance of the refractory to compressive loads, tension and shear stresses.
- Specific gravity: The specific gravity is associated with the weight of the refractory after application. A higher specific gravity will have more strength.
- Spalling: Spalling is a type of defect, also known as fracture of refractory, which is caused by excessive thermal and/or mechanical load on the refractory.
- Permanent Linear change (PLC) on reheating: Permanent change in the property of the refractory mostly caused by high temperature.
- Thermal conductivity: It indicates the general heat flow characteristics of the refractory
- Thermal expansion: An important factor determining the ability of refractory product to expand during high temperature and contract during cooling
- Bulk density: It is measured as weight of a given volume of the refractory and relates to apparent porosity of the material used. A refractory with higher bulk density is better in quality.
- Abrasion Resistance: Resistance of refractory to the surface wear caused by the mechanical action of moving solids.

Apart from above properties, design and spacing of refractory holding anchors is important. Any refractory sample shall be checked and approved before using it at any installation. Application method and dry out cycles to be followed as per recommendation.

8. Insulation and Cladding

- Thermal insulation is required for Boiler and its auxiliaries for safety purpose. Insulation thickness is calculated as per IS 14164.

- Selection of Insulation holding Anchors, Anchor Pitch, Washers, MOC suitable to operating temperature, other special attachments play a vital role in Insulation application and its performance.
- New insulation material giving lesser thickness and better surface temperature are available in market and are to be used than conventional material.
- For better aesthetics, coloured cladding is used now a days than conventional plain aluminium cladding.



IBR DOCUMENTATION FOR BOILER & BOILER COMPONENTS MANUFACTURING

By Mr. Vinod. M. Barmate, Mr. B. S. Bhamare, Mr. Navindra Kambre, Mr. P M Kadam, Mrs. Savita Wayal
Steam Boilers, M.S. Mumbai

Name: Vinod. M. Barmate
Organisation: Steam Boilers, M.S. Mumbai
Designation: Joint Director

Name: B. S. Bhamare
Organisation: Steam Boilers, M.S. Mumbai
Designation: Ex-Sr. Technical Assistant

Name: Navindra Kambre
Organisation: Steam Boilers, M.S. Mumbai
Designation: Technical Officer

Name: P M Kadam
Organisation: Steam Boilers, M.S. Mumbai
Designation: Technical Assistant

Name: Savita Wayal
Organisation: Steam Boilers, M.S. Mumbai
Designation: Technical Assistant

Objectives

Any product coming under the purview of the Indian Boiler Regulations 1950, and manufactured under the supervision of an Inspecting Authority, has to undergo, broadly in the following three Steps

1. Designing and preparation of manufacturing drawings of the product, and subsequently get the same approved before commencement of manufacture.
2. To complete the manufacturing of the product along with inspection at every stage.
3. To prepare proper certificate/s depending upon the type of the product, and get the same endorsed /certified by the Inspecting Authority.

Hence it can be stated that, the time (optimum) required to manufacture a product and get the same certified, will be the combined time required for all above stages. Any mistake or error occurring in preparation of the drawings or the certificates, and therefore, a rectification thereof, will only add-up to the optimum time, thereby delaying the output.

The purpose of this session is therefore to minimize this delay by guiding the personnel engaged with the activity of preparation of the drawings and documents. This can even ensure that the time required for preparation of drawings and documents will be less, in case of such personnel. Also, this can further help in reducing the time required for scrutiny by the Technical Branch, thereby reducing the optimum time itself, as a result of a combined effect.

Hence to arrive at an ideal stage or a full extent correctness in preparation of the drawings and documents hereby provides guidelines regarding:

1. Presentation of drawing
2. Preparation of the respective certificate/s for the product, as per regulations.
3. Computation of fee as prescribed for scrutiny, for both approval and certification in above cases.

Presentation of Drawings

Preparation of a drawing is the first stage of any given manufacturing activity. The drawing should be such that, it exhibits all the views of the product with dimensions in the sketches supported by sectional views for better understanding. Sketches of welding details, individual parts, sub-assemblies etc. shall be shown. In addition, the following requirements should be fulfilled.

1. The Design and Manufacturing Code if differs to IBR 1950, Ex, ASME/TEMA/International Code with Sufficient Proof should be mentioned in the drawing.
2. The parameters such as Design/Working Pressure and Temperature, Hydraulic Test Pressure, Heat Transfer Area, Evaporation Capacity etc. should be mentioned. In case of vacuum conditions arising during operation of the plant, the same shall be mentioned.
3. For all drawings a Bill of Material, should be presented in a tabular form, covering all the parts used in the construction, with their respective material of manufacture, quantity required, and any other specific detail if necessary.
4. A table of Nozzle Schedule in case of boilers, boiler components, tanks, heat exchanger and vessels for each opening on the shell and end connections shall be given. The table should include nomenclature, size, quantity and the type of connection for mounting.
5. Hence to arrive at an ideal stage or a full extent correctness in preparation of the drawings and documents hereby provides guidelines regarding:
6. Presentation of drawing
7. Preparation of the respective certificate/s for the product, as per regulations.
8. Computation of fee as prescribed for scrutiny, for both approval and certification in above cases.

General Recommended Standard Paper Sizes for Drawings

SR.	PRODUCT / DESCRIPTION	SIZE
1	Assembly of a very large size Water Tube Boiler	A-0
2	Shell Type Boiler/ Pressure Vessels/ Heat Exchanger	A-1
3	Small Industrial Boiler	A-2
4	Boiler Components	A-1, A-2, A-3, A-4
5	Valves	A-2, A-3
6	Fittings	A-3, A-4
7	Piping Systems or Layouts	A-1, A-2, A-3, A-4

CHECK LIST FOR DRAWING APPROVAL		
NAME OF FIRM : ____________________ **JOB TITLE : ____________________** **JOB NO: ____________ DRG NO :____________**		
SR. NO.	DESCRIPTION	✓IF APPLICABLE
01	COVERING LETTER OF DRAWING DETAILS ON FIRM'S LETTER HEAD	
02	APPROPRIATE FEES FOR DRAWING APPROVAL PAID AS PER IBR 1950, AT WEBSITE www.gras.mahakosh.gov.in TO CONCERN DIVISIONAL OFFICE.	
	MAIN DRAWING	
03	DRAWING WITH ALL DIMENSIONS / REQUISITE SECTIONAL VIEWS / ALL PART NO. MENTIONED, NOZZLES DETAIL, WELDING FIGURES / SIGN SPACE Etc.	
	TITLE BOX / NAME PLATE	
04	MAKER'S NAME / MANUFACTURER NAME	
05	CLIENT NAME / SITE DETAILS	
06	DRAWING NO. WITH REVISION / ALTERATION NO.	
07	MODEL NO. / JOB NO.	
08	DESCRIPTION OF BOILER COMPONENT/ PRESSURE PART	
09	DRAWING SCALE MENTIONED	
10	NAME, SIGN & CONTACT NO. OF PERSON RESPONSIBLE FOR DRAWING PREPARATION, CHECKING & APPROVAL	
	DESIGN DATA	
11	DESIGN & CONSTRUCTION CODE	
12	DESIGN PRESSURE	
13	WORKING PRESSURE	
14	HYDRUALIC TEST PRESSURE	
15	DESIGN METAL TEMP.	
16	SATURATION TEMP OF STEAM	
17	EVAPORATION CAPACITY	
18	HEATING SURFACE AREA	
19	NAME OF COMPONENT GIVING LEAST WORKING PRESSURE	
	BILL OF MATERIAL	
20	PART NO,PART NAME, MATERIAL SPECIFICATION, SIZE , QTY Etc.	
	NOTES	
21	ALL DIMENSIONS TO BE SHOWN	
22	NOTES TO BE MENTIONED FOR DT/NDT/UT, HEAT TREATMENT,SHOP/SITE JOINTS	
23	MIN UTS & ALLOWABALE STRESS VALUES OF MATERIAL USED	
	WELD DETAILS	
24	WELDING FIGURES AS PER IBR 1950	
*IF ANY OF ABOVE IS NOT APPLICABLE, PUT 'N.A' IN YES COLUMN		
NAME & SIGNATURE OF MAKER/REPRESENTATIVE : DATE :		

CHECK LIST FOR PRESSURE PART CALCULATION-(SHELL TYPE BOILER)

NAME OF FIRM : ____

JOB TITLE : ____

JOB NO: ______________________ **DRG NO :**__________________

SR. NO.	DESCRIPTION	*YES
01	BOILER SHELL	
02	FURNACE	
03	CUT FURNACE	
04	IRC SHELL	
05	ACCESS RING	
06	STIFFENERS RINGS / BOWLING HOOPS	
07	PITCH OF TUBES	
08	END PLATES BOILER FRONT & REAR TUBE PLATES IRC FRONT & REAR TUBE PLATES	
09	FLAT PLATE MARGIN	
10	BREATHING SPACE	
11	WIDE WATER SPACES BETWEEN AND AROUND TUBE NESTS	
12	TUBES UNDER EXTERNAL PRESSURE	

CHECK LIST FOR PRESSURE PART CALCULATION-(SHELL TYPE BOILER)

SR. NO.	DESCRIPTION	*YES
13	STAY TUBES	
14	STAY BARS	
15	GUSSETS	
16	MANHOLE COMPENSATION	
17	STAND PIPE CALCULATIONS	
18	SAFETY VALVES CALCULATIONS	
19	HEATING SURFACE AREAS CALCULATION	
20	VOLUMETRIC CAPACITY CALCULATION (SMALL INDUSTRIAL BOILER)	

*IF ANY OF ABOVE IS NOT APPLICABLE, PUT 'N.A' IN YES COLUMN

NAME & SIGNATURE OF MAKER/REPRESENTATIVE :
DATE :

CHECK LIST FOR PRESSURE PART CALCULATION-(WATER TUBE TYPE BOILER)

NAME OF FIRM : ____

JOB TITLE : ____

JOB NO: ___________________________ DRG NO :______________________

SR. NO.	**DESCRIPTION**	***YES**
01	STEAM DRUM / WATER DRUM SHELL	
	WITH LIGAMENT EFFICIENCY – LONGITUDINAL,CIRCUMFERENTIAL & DIAGONAL	
	WITH COMPANSATION FOR OPENING	
02	DISHED ENDS WITH COMPANSATION FOR OPENING	
03	MANHOLE RINGS AND COVERS	
04	STAND PIPES THICKNESS	
05	RISERS / DOWNCOMERS	
06	BOILER BANK TUBES	
07	WATER WALL PANELS – TUBES, HEADERS & END COVERS	
08	EVAPORATOR ASSEMBLY	
09	BED COIL ASSEMBLY	
10	SUPER HEATER ASSEMBLY	
	TUBES, HEADERS, END COVERS WITH DESIGN METAL TEMP.	

CHECK LIST FOR PRESSURE PART CALCULATION-(WATER TUBE TYPE BOILER)

SR. NO.	DESCRIPTION	*YES
11	INTEGRAL ECONOMISER ASSEMBLY – TUBES, HEADERS & END COVERS	
12	INTEGRAL PIPING	
i)	INTEGRAL ECONOMISER OUTLET HEADER TO STEAM DRUM SHELL	
ii)	FINAL SUPER HEATER OUTLET HEADER TO MAIN STEAM STOP VALVE	
13	HEATING SURFACE AREA CALCULATIONS	

*IF ANY OF ABOVE IS NOT APPLICABLE, PUT ‘N.A’ IN YES COLUMN

NAME & SIGNATURE OF MAKER/REPRESENTATIVE :
DATE :

Date :	JOB CARD FOR WATER TUBE BOILER

Manufacturer name :

Construction Code: IBR Design Metal Temperature: ______(DEG.C) Design Pressure : ____________(KG/CM^2) Working Pressure: ___________(KG/CM^2) Hydro Pressure: _____________(KG/CM^2)	Boiler No: _______________________ Drawing No.: _____________________ Heating Surface Area: _________M^2 FEES PAID : Rs._____________

RAW MATERIAL INSPECTION

Part.No Item Description Material Thk Size (L x W) Material Specs.	QTY.	Plate No. / Heat No	Date of Inspection	Signature			C/S by Dir./ Jt.Dir.
				Maker QC	Dy.Dir	Jt.Dir	
1 SHELL PLATE 12 THK. 5378 X2500 SA516 GR 70							
2 SHELL PLATE 12 THK. 5378 X1500 SA516 GR 70							
3 DISHED END 12 THK BLANK SIZE 4300 X 2500 SA516 GR70							
4 FORGED MANHOLE RIM 45 THK 4300 X 2500 SA516 GR70							
5 MANHOLE COVER 53 THK. 4300 X 2500 SA516 GR70							
6 PIPE (DOWN COMER) 250 NB SCH 100 362 X --- PIPE SA106 GR B							
7 PIPE (RISER) 200 NB SCH 120 307 X --- PIPE SA106 GR B							

Date :	JOB CARD FOR WATER TUBE BOILER
Manufacturer name :	

Construction Code: IBR Design Metal Temperature: ______(DEG.C) Design Pressure : ____________(KG/CM^2) Working Pressure: ___________(KG/CM^2) Hydro Pressure: _____________(KG/CM^2)	Boiler No: ________________________ Drawing No.: ______________________ Heating Surface Area: _________M^2 FEES PAID : Rs._____________

WELD SETUP INSPECTION

WELD SETUP INSPECTION	QTY	Date of Inspection	Signature			C/S by Dir./ Jt.Dir.
			Maker QC	Dy.Dir	Jt.Dir	
1 TO 1 (Butt joint with RT) SHELL PLATE TO SHELL PLATE						
34 TO 34 (Butt joint with RT) SHELL PLATE TO SHELL PLATE						
3 TO 1 (Butt joint with RT) DISHED END 1700 I.D. x 12 THK TO SHELL PLATE						
2 TO 3 (Butt joint with RT) SHELL PLATE TO DISHED END 1700 I.D. x 12 THK						
3 TO 4 (Fillet/Branch joint) DISHED END 1700 I.D. x 12 THK TO FORGED MANHOLE RIM 45 THK						
1 TO 21 (Fillet/Branch joint) SHELL PLATE TO PIPE (VENT STUB)						
1 TO 17 (Fillet/Branch joint) SHELL PLATE TO PIPE						
1 TO 22 (Fillet/Branch joint) SHELL PLATE TO PIPE (SPARE)						
22 TO 23 (Fillet/Branch joint) PIPE (SPARE) TO FLANGE						
34 TO 8 (Fillet/Branch joint) SHELL PLATE TO PIPE (STEAM O/L)						
15 TO 16 (Butt joint with RT) PIPE (THERMAL SLEEVE) TO PLATE						
16 TO 14 (Fillet/Branch joint) PLATE TO PIPE (CHEMICAL DOSING)						

Date :	JOB CARD FOR WATER TUBE BOILER
Manufacturer name :	
Construction Code: IBR Design Metal Temperature: ______(DEG.C) Design Pressure : ____________(KG/CM^2) Working Pressure: ___________(KG/CM^2) Hydro Pressure: ____________(KG/CM^2)	Boiler No: _________________________ Drawing No.: _______________________ Heating Surface Area: _________M^2 FEES PAID : Rs._____________

STAGE INSPECTION	QTY	Date of Inspection	Signature			C/S by Dir./ Jt.Dir.
			Maker QC	Dy.Dir	Jt.Dir	
FULL WELDING INSPECTION						
SAMPLE BEND INSPECTION						
RT ACCEPTANCE	REPORT NO & DATE					
PTC ACCEPTANCE	REPORT NO & DATE					
HEAT TREATMENT CHART ACCEPTANCE INTERMEDIATE SR AS PER REG 251 (IF APPLICABLE)	CHART NO & DATE					
RUB-OFF SHEET						
HYDRAULIC TEST INSPECTION						
FINAL INSPECTION						

MANUFACTURING

After Drawing approval

SR. NO.	DESCRIPTION
01	MATERIAL IDENTIFICATION/ RAW MATERIAL INSPECTION ➢ With accepted Material Test certificates
02	WELD SETUP INSPECTION STAGE ➢ Preparation As per IBR Fig. ➢ Followed by DT/ NDT/Heat treatment as per IBR
03	FULL WELDING INSPECTION STAGE
04	HYDRAULIC TEST INSPECTION
	FINAL INSPECTION
05	PREPARATION OF MAKER'S CERTIFICATE
06	SUBMISSION OF MAKERS PAPERS FOR APPROVAL & GET FINAL FOLDER

STEPS OF MANUFACTURING

1
MATERIAL IDENIFICATION

2a
WELD SETUP

2b
DT/ NDT/ HEAT TREATMENT

3
FULL WELDING INSPECTION

4
HYDRAULIC TEST / FINAL INSPECTION

5
PREPARATION OF MAKER'S CERTIFICATE

6
SUBMISSION OF MAKERS PAPERS FOR APPROVAL & GET FINAL FOLDER

CHECK LIST FOR HYDRAULIC PERMISSION AS PER APPENDIX 'J' OF IBR 1950

NAME OF FIRM : ____
JOB TITLE : ____
JOB NO: _____________________________ DRG NO :_______________________

SR. NO.	DESCRIPTION	*YES
01	INSPECTION FEES PAID DETAILS, ATTACHED	
02	JOB CARD DULY COUNTERSIGNED BY DIRECTOR / JT. DIRECTOR, ATTACHED	
03	PROVISIONALLY APPROVED DRAWINGS WITH BACK SIDE CHANGES COUNTER SIGNED BY INSPECTING OFFICER	
04	ACCEPTED MATERIAL TEST CERTIFICATES WITH CONSUMPTION RECORD	
05	ACCEPTED FIRST BEND REPORT (IN CASE OF TUBE BENDING)	
06	ACCEPTED ALL RADIOGRAPHY TEST RREPORTS	
07	ACCEPTED ALL HEAT TREATMENT CHARTS	
08	ACCEPTED ALL PHYSICAL & CHEMICAL TEST REPORTS (PTC)	
09	RUB-OFF SHEET, ATTACHED	
10	FOLDER OF OUTSIDE CONSTRUCTED PARTS, ATTACHED	

*IF ANY OF ABOVE IS NOT APPLICABLE, PUT 'N.A' IN YES COLUMN

NAME & SIGNATURE OF MAKER/REPRESENTATIVE :
DATE :

Submission of Makers Papers

1. Covering Letter with mentioning details of Makers paper
2. Check List duly filled.
3. Appropriate construction/inspection Fees paid for job as per IBR 1950 at website www.gras.mahakosh.gov.in to concern IBR Dept.
4. Related IBR Forms as per IBR regulation. e.g. Form II(1), Form III, III C etc.
5. Supportive Documents as per check-list for folder approval
6. As Built drawing incorporated with back side changes (if any) endorsed by competent person

CHECK LIST:WHILE SUBMITTING MAKER'S CERTIFICATE (FOLDER) IN IBR FORM FOR APPROVAL

NAME OF FIRM : ____

JOB TITLE : ____

JOB NO: _________________________ **DRG NO :**____________________

SR. NO.	DESCRIPTION	*YES
01	Inspection Fees Details, Attached	
02	Job Card Duly Countersigned By Director / Jt. Director, Attached	
03	Provisionally Approved Drawings , Attached	
04	As Built Drawings With Back Side Changes Duly Incorporated, Attached	
05	Accepted Material TC With Consumption Record, Attached	
06	Accepted First Bend Report (In Case Of Tube Bending) , Attached	
07	Accepted All Radiography Test Reports, Attached	
08	Accepted All Heat Treatment Charts, Attached	
09	Accepted All Physical & Chemical Test Reports (PTC), Attached	
10	Rub Off Sheet, Attached	
11	Folder Of Outside Constructed Parts, Attached	
12	Hydro/Final Inspection Permission Taken. (Permission Letter) , Attached	
13	Details of Drums/ Shells, Headers, Tube Plate, Headhole, Manhole, Etc Are Properly Incorporated In Respected Form Are Checked (FORM III)	
14	Details of No.of Tubes/ Sections, Material Of Constructed Parts, Maker, Competent Person Remarks, Thickness, Uts Limit, El% Limit, Gauge Length, Heat/Plate No, Nozzle Connections Etc Are Properly Incorporated in respective form are checked. (FORM VIII)	
15	Details of Size of Boiler Diameter, Length & Volumetric capacity etc, are properly incorporaed in respective Form are checked (FORM XVII)	
16	Details of Material & Qty of Constructed Parts, Heat no/ Plate no., Maker , Chemical compositions Its Chemical Composition, Mechanical properties, U.T.S, Y.S, EL %, Name of Inspecting Authority etc Are Properly Incorporated In Respective Forms Checked (FORM IV A)	
17	Certificates In Relevant Forms For Mountings & Fittings For Boiler having Capacity less than 20 Tons/hr, are attached (AS PER IBR-4-c(vii))	

*IF ANY OF ABOVE IS NOT APPLICABLE, PUT 'N.A' IN YES COLUMN

NAME & SIGNATURE OF MAKER/REPRESENTATIVE :

DATE :

CHECK LIST FOR SUBMISSION OF FORM III-C (VALVES, MOUNTINGS & FITTINGS)

NAME OF FIRM : ____
CERTIFICATE NO: ____
DRG NO :____

Sr. No.	DESCRIPTION	YES *
1	Inspection Fees Details, attached.	
2	Job Card Duly Signed by Competent Person / Joint Director.	
3	Approved Drawing Attached.	
4	Accepted Material Test Certificate with Consumption Record, Attached.	
5	Accepted All Radiography Test Report Attached.	
6	Accepted All Heat Treatment Charts, Attached.	
7	Accepted All Physical & Chemical Test Report (PTC) Attached.	
8	Hydro / Final Inspection Report Attached.	

* If any above is not applicable, put ' N.A.' in Yes column.

Name & Signature of Maker/Representative:
Date:

Check list For Registration Inspection permission of new Boiler / Economiser

NAME OF FIRM : ____
NEW BOILER /ECONOMISER MAKER'S NO:________________________
DRG NO :____

Sr. No.	Description	Yes*
1	Online Application for Registration of new Boiler / Economiser duly filled at site: (www.maitri.mahaonline.gov.in / www.lms.mahaonline.gov.in / www.aaplesarkar.mahaonline.gov.in) is attached	
2	Requisite fees Challan for Registration of new Boiler / Economiser is attached	
3	Maker's Certificates in requisite IBR Forms along with As Built Drawings signed by Inspecting Authority are attached	
4	Endorsed copies of Certificates of Mountings & Fittings in IBR Forms are attached	
5	Design calculation sheets of all Pressure Parts is attached	

* If any of above is not applicable, put ' N.A.' in Yes column

Name & Signature of Maker/Representative:

Date:

Check list For Registration Inspection permission of new Boiler / Economiser

NAME OF FIRM : ____
NEW BOILER /ECONOMISER MAKER'S NO:___________________________
DRG NO :____

Sr. No.	Description	Yes*
1	Online Application for Registration of new Boiler / Economiser duly filled at site: (www.maitri.mahaonline.gov.in / www.lms.mahaonline.gov.in / www.aaplesarkar.mahaonline.gov.in) is attached	
2	Requisite fees Challan for Registration of new Boiler / Economiser is attached	
3	Maker's Certificates in requisite IBR Forms along with As Built Drawings signed by Inspecting Authority are attached	
4	Endorsed copies of Certificates of Mountings & Fittings in IBR Forms are attached	
5	Design calculation sheets of all Pressure Parts is attached	

* If any of above is not applicable, put ' N.A.' in Yes column

Name & Signature of Maker/Representative:

Date:

POWER GENERATION THROUGH MUNICIPAL WASTE, PROBLEMS FACED

By Mr. Sachin Sangamnerkar
Urja Disha Boiler Technologies, Pune

Name: Sachin Sangamnerkar
Organisation: Urja Disha Boiler Technologies, Pune
Designation: Technology Head
Education: B.E. (Mechanical), Govt. College of Engineering, Karad, M.E. Master of Engineering (Design Engineering, Mechanical), Walchand College of Engineering.

Conceptualization to commissioning of various types of Heat transfer equipments. Thermal and hydraulic design of fired boilers (stoker/afbc), unfired boilers. Mechanical design and detailing, proposal engineering, estimation, trouble shooting of fired heaters, fired boilers & waste heat and process integrated boilers.

- Trained at STRUTHERS WELLS CORPORATION, USA for Fired Heaters and
- Waste Heat boiler design.
- Trained at Petro Chem Development Co Inc- for designing of fired Heaters.
- Worked for ME Engineering at UK in 2003 for 6 month, for there various waste heat boiler designing.
- Visited USA & Europe (UK, Germany, Finland) for Fired heater & Boiler business.
- Worked with various process licensers like KTI, UOP etc and various EPC contractors like Bectel, EIL (India), UHDE, KPG, Hyundai, Samsung etc, for fired heaters.
- Worked with various EPC contractors like UHDE, Kaverner, Hyundai, Samsung, Stork, KTI, Bectel, Prichard, B&V, Rolls Royce, EIL, etc for boilers
- Worked for various technologies with partners like Oschatz, Lentjes, IBB, KEU, Alstom (German Shack) of Germany, Tamentec of Finland, Struthers Wells, Aqua Chem, Alstom (American Shack) of USA, Alstom & Mitchell Engineering of UK. Hurtey Petrochem of France. West of Australia.
- Worked with Thailand, Malaysia, Indonesia, Philippines, Vietnam, Bangladesh, Sri Lanka, Honduras, Columbia customers

Use of Municipal Solid Waste (MSW) as fuel for electricity generation (Waste to Power) is well proven concept in most developed countries. Typically, Indian town of 1L population generates 100 ton per day MSW and has potential to generate 1MWh electricity, which can fulfill +30% need of house hold demand. WTP project have lot many tangible and intangible benefits like reduction in dump yard lands, reduction in garbage volume, excess transportation of garbage through cities. It will also help to reduce pressure and expenses of local authorities for garbage management & additional work and expenses of health department etc. It will help to maintain better natural ecology as garbage's restrict water percolation, barrier for sun and air contact with land. India is having more than 100 cities with population more than 5L and total contributes to 25% of population (@25 Cr) +20000 MW power generation through MSW is possible. 5MW to 15MW units can be most viable plants for India. India is trying to establish techno commercially viable MSW based WTP since 2000. Few WTP plants are showing encouraging results but have many challenges and need more contribution from all segments associated with these plants including law makers, local authorities, technologist, operators, society etc.

Non consistency of MSW (fuel) is major challenge for steady power generation. MSW is mixture of various types of waste and do not possess uniformity of composition in terms of "ultimate" "proximate" analysis. It contains house hold kitchen waste, packing material, papers, plastics, glass, metals, construction debris, house hold electronic waste, garden waste, woody material etc. Few are combustible and few are not. Few are very wet and few dry. Composition of waste changes home to home, area to area, city to city, season to season etc. They get mixed at home, during transport & at dump yard before goes to WTP. Ash percentage can change from as low 5 to as high +50, moisture as low 10 to as high +50. It is big challenge to design combustion system to handle wide variation in fuel character to deliver uniform heat for steady power generation.

MSW can have very high percentage of non-combustibles like glass, metals, construction debris, sand, stones etc. Their sizes and shapes are also non uniform. It is big challenge to remove such unwanted non-combustible items from total waste. Segregation of such material needs very special equipment with high redundancy, trained man power and equipment are capital intensive and also consume good power. Majority of equipment need to be sourced from outside. Local authority can play very major role to establish system of "segregation at source" and "transport and dump" accordingly at dump yard. Wet and dry combustible and recyclable material can be separated at home. Awareness program will be key to success.

Plastic is main part of waste and comes from various sources with various composition and sizes. Plastic brings chlorine into MSW. Chlorine is highly corrosive at high temperature and has major impact on metallurgy of boiler parts at high temperature zone. Combustion system parts, fuel feeding arrangement, support and seals in high temp zone are always vulnerable. Higher metallurgy makes these parts more costly and need to source from outside.

SKILL REQUIREMENT AND OPPORTUNITIES IN BOILER MANUFACTURING & BOILER OPERATIONS

By Mr. G. T. Choughule
Steam Boilers, M.S. Mumbai

Name: G T Choughule
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Consultancy in Boiler Field. Presently working as Lawyer in District and Session Court in Ambajogai, Dist.Beed (M.S.). Twenty nine years' experience in Directorate of Steam Boilers Maharashtra State on Dy. Director of Steam Boilers and Joint Director of Steam Boilers at Various divisions in Maharashtra and retired in the year 2013.

We all know about the Boiler. It means the vessel in which water is boiled out and boring water is converted into steam. Thus, steam produced is used for various purposes. such as in power plant to produce the electricity, in sugar plant to produce the product of sugar, in chemical plant to produce the chemicals, in pharmaceutical plants to produce the medicinal products etc. It means it is the main media which is used to produce the products through some prescribed process. Now, we come to know the importance of steam in day today use. But the steam is produced in vessel which is manufactured as per acceptable codes of manufacture. It is to observe the safety of the equipment and human being. So, safety is first and then the question of operator to operate the equipment Boiler safely arises. For that also there is statutory requirement of the operator.

We know the various types of Boilers manufactured now, a day's right from one tonne per hour generating capacity to 2225 tonnes per hour generating capacity and roughly working pressure from 7 kg/cm^2 to 350 kg/cm^2 respectively. So, there is a classification of Boilers on pressure rating. For example, low pressure Boilers, medium pressure Boilers and high pressure Boilers. The limitations of low pressure Boilers are up to 17.5 kg/cm^2 working pressure and that of medium pressure Boilers is up to 45kg/cm^2 and high pressure Boilers are above 45 kg/cm^2 working pressure irrespective of tonnage of steam produced. The capacity of steam generation in the all above classes is limited by the design parameters. Apart from the above classifications there is very important class of Boilers which is called the supercritical / ultra-supercritical Boilers. The working pressure of Boilers is reached up to 350 kg/cm^2 Present days ultra-pressure critical / super critical technology is predominant. But there are limitations of materials, operations of such type of Boilers. Skilled and trained manpower is required to operate and maintain these types of Boilers. In India, first time super critical Boiler is installed at Mundra in Gujrat State Mundra port by Adani power. So, the Boiler technology in olden days of riveted structure and now it is advancement in Boiler technology up to supercritical Boiler including its materials of manufacture.

Now the challenges of Boiler operations and maintenance are before us. We will see how the manpower skill development is there as per type of Boiler, its pressure and capacity. we are going to discuss the mandatory requirement of man power in Boiler operation and maintenance as per its classifications.

A. **Low Pressure, small industrial Boilers working pressure normally up to 17.5.1 kg/cm2**

   Manpower requirement:

   a. Fireman/Assistant Fireman /water man: who is assisting to second class Boiler attendant. The Boiler may be solid fired / oil fired or gas fired.

b. Second class Boiler Attendant: It is mandatory that the Boiler / Boilers of total heating surface up to 200 m2 can take charge of running Boilers. He has to look after the Boiler operation safety and timely regular maintenance. He is responsible and accountable to tire management directl3z. His responsibility is to supply the steam to the plant process without any disturbances.
c. First Class Boiler Attendant: Up to 200 m2 first class Boiler attendant is not mandatory as per heating surface criteria, but he can take the charge of any capacity of Boiler below total heating surface of battery of Boilers or single Boiler up to 1000 m:. He will be assisted by second class Boiler attendant and in turn with fireman.
d. Boiler Operation Engineer: Boiler operation Engineer is not required to hold the charge of small industrial Boilers up to 200 m2 heating surface or even up to 1000 m2. But in any organizations, engineer is there to look after Engineering

Payment Schedules: The payment schedules of the above manpower is roughly mentioned as follows:

a. Fireman/Assistant Fireman/Water man: is in the range of Rs. 15000/-
b. Second class Boiler attendant: The payment schedule is up to Rs. 20000 -
c. First Class Boiler attendant: The payment schedule.is up to Rs. 30000i- p.m. depending on their service length and type of Boiler experience.
d. Boiler Operation Engineer: The payment schedule of the Boiler Operation Engineer is in the range of up to Rs. 35000 to 45000 p.m. initially and it increases with the service experience and by post they reaches to managerial level in the technical department.

B. Medium Pressure Boilers: (Above 17 .54 kg/cm2 upto 45 kg/cm2 working pressure)
Manpower Requirement:

a. Fireman/Assistant Fireman/Water man: may be required or may not be required depending on type of Boiler and its capacity of steam generation.
b. Second class Boiler attendant: Second class Boiler attendant is required and he is working under first class Boiler attendant. Sometimes he may have to work on the post of firemen waterman etc. as per the organization structure. But as per the statutory requirement he is second class Boiler attendant certificate holder.
c. First Class Boiler attendant: He can take the charge on the Boiler of which heating surface of one or more Boilers of which total heating surface is up to 1000 m2 rating.
d. Boiler operation Engineer: He can be in charge of Boiler house in which there may be Boilers in battery more than one. At many places he is called the utility

engineer. (BoE) can be in charge of Boilers of which heating surface is more than 1000 m2. In some organizations utility engineer may behaving BOE certificate or he may have not it. He is in charge of all machineries in the plant including Boiler house.

Payment Schedules: The payment schedule of all above manpower is already mentioned as per Boilers mentioned above up to 17.54 kg/cm2

C. **High Pressure Boilers: (Range is upto 150 Tonnes/hr. generating capacity and working pressure up to 150 kg/cm2)**

Manpower Requirement:

a. Fireman/Assistant Fireman/Water man: As such this post is not there but for example in sugar factory Boilers fireman is called Waterman. In other high pressure Boiler companies he is called the casual worker. Waterman is eligible to appear for second class Boiler examination.
b. Second class Boiler attendant: He is employed and carrying the work of Bagasse feeding to Boiler. Sometimes he is also performing the duty of waterman also.
c. First Class Boiler attendant: First class Boiler attendant is directly holding the charge of Boilers of Boilers in shift up to total heating surface of the Boilers is up to 1000 m2 and above he is assisting to Boiler operation Engineer.
d. Boiler operation Engineer: Boiler Operation Engineer is holding the charge of Boiler or Boilers having total Heating surface more than 1000 m2. It is statutory requirement. He looks after the maintenance work as well as all activities related with Boiler start up. Boiler shut down and safe operation of the Boiler and he has control over the start working under him. Sometimes he also works on DCS system in control room, depending on the capacity and working pressure of Boilers. He is promoted up to the General Manager (Technical) and so on.

Payment Schedules: The payment schedule of all above manpower is already mentioned as per Boilers mentioned above up to 17.54kg/cm2.

D. Super Critical /Ultra Super Critical Boilers: (660 MW capacity and above capacity and working pressure above 222k/cm2)

In India many super critical Boilers are in use before decade period. The first super critical Boiler is installed at Mundra Port in Gujrat of 660 MW capacity five number of units. Also, there is Tata Power having Five numbers of units each of 810 MW Capacity. All above units are working above 250 kg/cm2 working pressure. At Tiroda in Maharashtra there are Five numbers of units having capacity 660 MW each of Adani Power.

Skilled Manpower Requirement:

a. It requires trained professional for erection, operation and maintenance.
b. Operation and maintenance personnel's need specialized training in the field of metallurgy, chemistry and operation and maintenance of super critical units.
c. Skilled manpower as above should be retained.
d. Training should be conducted through simulators.
e. Exposure of personnel's to O & M practices of similar units through workshops, seminars, sharing of best practices, association during overhauls of super critical.

The trained manpower should have the knowledge of unit start up, shut downs, routine operations, infrequent procedure and emergency handling. He should have confidence and verification of operating procedures, study and tuning of control loops. There are simulator programs. For Ex.: NTPC has simulator at Noida for 660 MW generating capacity.

Qualified and trained engineers are employed in this sector of power. The Engineer is basic requirement of recruitment, in mechanical, Electrical field. Then, Engineers are trained for respective sections in power sector

Payment Schedule:

a. Engineer: Since all Engineers are qualified and trained, they get good packages of salary and facilities.
b. Boiler Attendants: Sometimes, there are good opportunities of requirement

Boiler Manufacturing and Operation skill requirement sources

Sr. No .	Name of Course	Duration	Course Type	Entry Qualification	Objective of syllabus	Employment opportunities	Availability of Course
1	Certificate course in Boiler attendant	2 Year	Full time	S.S.C. Pass	1) Awareness of safety precaution. 2) Knowledge of engineering skill, use of tools in assembly 3) Awareness of chemical plant 4) Awareness of maintenance of boiler and steam turbine in chemical plant. 5) Awareness of basic fitting, turning & machinery.	The trainee will either to be able to take up jobs with agencies which develop, maintain, repair operation & maintenance of boiler & steam turbine. Work as or with working experience will be in a position to start his own independent business Tentative Payment 15000-18000 p.m.	MSBVE (Maharashtra State Board of Vocational education 1) At. Adarsh Shikshan Prasarak Mandal At.Chanai Parisar Ambajogai Dist.Beed (1r4.5.) pin 431 51 7 2) Krushival skills Development vocational Training Center Islampur, Ta. Walwa Sanglipin 415409
2	Fireman practical Work on boiler	2 Year	Full time	S.S.C. Pass	Practical experience of boiler operation & maintenance	During practical experience of 2 years payment of rupees 12000/- to 15000/-month is paid (Tentative)	In Any industry where Boiler is in working
3	IInd class Boiler Attendant	2 Year	Full time	S.S.C. Pass	Fireman to appear for Ist class Boiler Attendant	Practical experience of boiler operation & maintenance of higher heating surface area Tentative. Payment of Rs.15000-18000P.M.	In Any industry where Boiler is in working
4	Ist Class Boiler Attendant	-	Full Time	IInd Class Boiler Attendant	Practical experience of boiler operation & maintenance of higher heating surface area (Rating of boiler above 200 m2 & up to 1000 m2	Available Payment Rs.20000 to 27000/ month is paid (Tentative)	In Any industry where Boiler is in working

5	Boiler Operation Engineer	2 Year	Full Time	D.M.E. with 5 years experience in boiler operation & maintenance or B.E. (Mech.) B.E. (Electrical) B.E. (Production) B.E. Electrical & Electronics) with 2 years experience in boiler operation & maintenance.	Theory papers 1) Boiler Technology 1 2) Boiler Technology 2 3) Engineering Drawing Each paper of 100 marks and oral examination on work examination on work experience for 100marks. Aggregate passing Marks 50%	Employment as B.O.E. Engineer on Boiler having heating surface more than 1000m2 and further opportunities of promotion as assistant manager, Deputy manager, Manager and upto general manager in organization like M.N.C. Tentative payment Rs.40000/ month and above.	In Any industry where Boiler is in working
6	Diploma Course in Welding Technology	2 Year	Full time	S.S.C. Pass	To get Knowledge of different metal .joining processes & their applications. To understand metal cutting methods, special welding processes, equipment's & accessories and their applications, To get knowledge of different welding machines and their control. To understanding m/c drawing. To prepare drawing. To prepare drawing using CAD, Awareness of safety	The student can get jobs in fabrication industries or with working experience will be in a position to start his own independent Business. tentative Payments 1 2000-1 5000 /1\4	MSBVE in any institute or Govt. ITI in Any city

7	Diploma Course in General Fitter cum Mechanic	2 Year	Full time	S.S.C. Pass	To get Knowledge of Engineering. Skill, use of fitters hand tools, measuring tools, simple marking out according to simple blue print, filing, hack sawing and chipping, Drill holes, counter bores and spot face, sharpen drill. Knowledge of plumbing assembly, Male simple jigs and fixtures, Dismantle and assemble simple machine parts & accessories, Repair broken gear tooth, To understating Engineering. Drawing, To prepare Drawing using CAD, Awareness of safety precaution	The Student can get jobs with agencies which produces machine parts or with working experience will be in a position to start his own independent Business. Tentative Payment 1 5000-1 8000 PI\I.	MSBVE in any institute or Govt. ITI in Any city
8	Diploma course in Electrical / engineering Diploma course in Lineman	2 Year	Full time	S.S.C. Pass	1) To develop professional competence in the field of electrical. 2) To train the students to acquire skills and mastery in the use of electrical circuits. 3) To train the students to repair or rewinding and test the different electrical equipment. 4) To prepare for self and wage employment. 5) To prepare competent electrical technicians for small scale industry.	The students can get job in industries, with work experience he could start his own business. Tentative payment: 15000-18000 p.m.	MSBVE in any institute or Govt. ITI in Any city
9	Certificate course in Electrician	2 Year	Full time	S.S.C. Pass	To understand basic of electricity to understand and use various electrician hand tool, To perform various task related to Electric fitting of residential and commercial building.	work as electrician in electricity board, various industrial, organizations, and commercial organizations, can start own electrician practice. Tentative payment Rs. 20000 25000 per month	MSBVE in any institute or Govt. ITI in Any city

10	Diploma Course in Architect, Draftsman	2 Year	Full time	S.S.C. Pass	To get knowledge of building construction to understanding Building Drawing, To prepare Estimate, To prepare Building Drawing on CAD, To prepare Architectural	Office of Architect, office of consultant civil Engineer, office of Builder, any civil Engineering firm, his own practice as Architectural Draughtsman and steam piping drawings, boiler construction drawings Boiler. Lay-out drawings. Tentative payment Rs.20000 to 25000/month	MSBVE in any institute or Govt. ITI in Any city
11	Insulation of Boiler & Pipeline	-	-	-	insulation of steam piping & boiler special work	In Boiler field Tentative payment Rs. 12000 to15000/ Month	in any boiler manufacturing & steam pipe fabrication work in any boiler manufacturing & steam piping manufacturing industries
12	Steam Piping fabricator	-	-	As per welder qualification	Fabrication in steam power plant	In boiler field Tentative payment Rs. 12000 to 1 5000/ Month	In any boiler manufacturing & steam pipe fabrication work in any boiler manufacturing & steam piping manufacturing industries

MANDATORY PHYSICAL & CHEMICAL TESTING DURING MANUFACTURING

By Mr. Avinash Tambewagh, Mr. Ganesh Sonawane
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Name: Avinash Shankarrao Tambewagh
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Designation: Technical Head (Advanced Testing Division)
Education: Bachelor's in engineering (B.E. Metallurgy) - Government College of Engineering, Pune

The entire advanced testing department of Fatigue test (ASTM E466, ASTM E606) and Fracture toughness tests like KIC, JIC, CTOD testing at room temperature & at sub-zero temperature as per ASTM E399, E1820, E647, BS 7448, ISO 12135, ISO 15653 etc. Successfully handled many special & Tailor-made tests in Fracture appearance, Fatigue & Fracture Toughness for NAVY & Defence Projects.

The HCF & LCF, Slip Test for reinforcement bar coupler/Mechanical splices as per ASTM A1034, IS16172, ISO 15630 etc. & Accelerated Creep Ruptured Test (ACRT) as per ASTM E139 & API standards by using of Larson-Miller parameter. Successfully handled the ACRT for Aramco-Yanbu Refinery for his RLA (using Omega Method) study. Has handled FCGR Testing as per EN 13674, ISO 12108 for JSPL for his Railway applications - Track-Rail product.

Undertakes Organizing & Handling all Third-Party Inspection under LRIS, BVIS, IRS, NTPC, TOYO, ONGC, BHEL-CQS, TPL, QUEST, IL, ABS, Multitex, GESCO, DNV, TUV, NPCIL, BARC, EIL, UDHE, FEDO, IBR, L&T, IQC, A Four Associates, Joshi & Associates, ICIS, NCPL, HPCL, Stewarts & Lloyds, Met Scan, QSS, HDO, KPGIL. Successfully organized several second & third-party audits and Audit for integrity of plant behalf of MECON.

30 years' experience in Manufacturing, Rolling, Inspection and Testing. Rewarded in Alloy Steel & Cast Iron Foundry for valuable contribution for control in rejection of impeller of Chemical Handling Centrifugal Pumps.

Quality of material must check before putting in application. Why????

- Product quality is of the greatest importance to every manufacturing company.
- Quality products equal satisfied customers, a smooth manufacturing process and a healthy company bottom line.
- Saving the time and hence economy.
- On time delivery to customer.
- It helps to control the inventory.
- And most important SAFETY.

What is Material Testing?

Materials testing is a broad term that refers to the use of analytical testing techniques to identify the chemical composition, Physical & Mechanical characteristics of a materials. When it comes to quality control, manufacturers often use material testing to find the cause of defects or product failures that can lead to quality and safety issues. Some very common material tests are:

- Tensile Test.
- Hardness Test.
- Impact Test.
- Flattening, Flaring & Bend Test.
- Macro & Microstructure characterization. Etc.

Let's move to IBR requirements:

In this session we will cover the Mechanical & Chemical Testing requirements of Materials / Component as per Indian Boiler Regulations – 1950. (Nineteenth Edition, 2021)

The following Regulation has been covered in this session.

A) Steel plates, Rivets, Section and Bars in carbon steel.
B) Cold Drawn Seamless Carbon Steel Boiler, Superheater And Heat Exchanger Tubes For Design Metal Temperature Not Exceeding 454 °C.
C) Forged product.
D) General Grey Iron Castings (Grade A)
E) Tests on Welded Seams.
a) Class I Boilers – Plates.

b) Class II Boilers – Plates.

F) Periodic Check Test (Reg.98)

A) Steel plates, Rivets, Section and Bars in carbon steel.

Branding:

a) Every plate, section and bar shall be clearly and distinctly marked by the maker in two places with the number of identification mark by which they can be traced to the charge from which the material was made. As an alternative the rivet bars may be bundle and tabbed to enable the material to be traced to the cast of steel from which they are made.

b) Every plate shall also be stamped by the steel maker as provided in IS: 2002. The following information shall necessarily be provided:

1. Name of the manufacturer.
2. Specification:
3. Heat No.
4. Plate No.
5. Stamp.

A) Steel plates, Rivets, Section and Bars in carbon steel.

1. Chemical Analysis: (Reg.10)

(a) The steel shall not contain more than 0.05 per cent of Sulphur or Phosphorus.

(b) When the material is required for flame cutting and/or welding, the carbon content shall not exceed 0.30% and special precautions shall be taken when the carbon content exceeds 0.26%.

(c) When steels are intended for service temperatures over 700°F the silicon content shall be not less than 0.10% or alternatively, the material shall pass the proof test for creep quality of carbon steel plates of boiler quality.

(d) Material shall comply the basic chemical composition as recommended in product specification.
For example: Chemical & Mechanical properties requirements as per IS 2002 as below.
IS 2002: Steel plates for pressure vessels for intermediate and high temperature service including boilers.

Table 1 Chemical Composition

(*Clause* 6.1)

Sl No.	Grade	Carbon Percent *Max*	Manganese Percent *Max*	Silicon Percent	Sulphur Percent *Max*	Phosphorus Percent *Max*
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	1	0.18	0.50-1.20	0.15-0.35	0.040	0.035
ii)	2	0.20	0.50-1.20	0.15-0.35	0.040	0.035
iii)	3	0.22	0.50-1.20	0.15-0.35	0.040	0.035

NOTES

1 Carbon content over the maximum specified shall be increased by:

a) For plates over 25 mm up to and including 65 mm thick — 0.02 percent *Max*; and

b) For plates over 65 mm thick — 0.04 percent *Max*.

2 Total aluminium content shall not exceed 0.020 percent for all thicknesses.

3 Nitrogen content, shall not exceed 0.012 percent. This should be ensured by the manufacturer by occasional check analysis.

4 Residual copper shall not exceed 0.10 percent.

5 Whenever any alloying elements are added for achieving strength, maximum carbon equivalent shall not exceed 0.44 for steels used for welding.

Carbon equivalent (CE) based on ladle analysis:

$$CE = \frac{C + Mn}{6} + \frac{Cr+Mo+V}{5} + \frac{Ni+Cu}{15}$$

Selection of test pieces (Reg.14)

All test pieces shall be selected by the Inspecting Officer and tested in his presence, and he shall satisfy himself that the conditions herein described are fulfilled.

Tensile Test pieces (Reg.15)

The tensile strength and percentage elongation shall be determined from test pieces of gauge lengths preferably equal to Lo=5.6 √A0. Alternatively, other gauge length may be used, provided the %Elongation is expressed as the equivalent value on a gauge length of Lo=5.6 √A0.

For round specimen gauge length shall be 5d0.

For plate thickness exceeding 60mm, test pieces shall be taken from the exterior third of the plate cross section. Wherever practicable, the rolled surface shall be retained on two opposite sides of the test piece.

Number of Tensile Tests (Reg.17)

a) Plates: One tensile test piece shall be cut from each plate as rolled.

b) Sections (Angle, tee, rivet, and stay bars): One tensile test shall be made from each 15 or part of 15 bars rolled of each section or diameter from the same charge, but not less than two tensile tests shall be made unless the total number of bars rolled from the same charge is 8 or less than 8 and the bars of the same section or diameter, in which case one tensile test shall suffice.

Tensile Test Specimen:

Flat / Rectangular Specimen

Round Specimen

Tensile Test Specified requirements (Chapter II):

Plates of carbon steel shall conform to one of the following four grades of tensile strength: -

(i) 37 to 45 kgf/mm²
(ii) 42 to 50 kgf/mm²
(iii) 47 to 56 kgf/mm²
(iv) 52 to 62 kgf/mm²

Bend Test (Reg.19):

Number of Bend Tests (Reg.20):

(a) Plates: A bend test shall be taken from each plate as rolled. The bend test from shell plates, butt straps and other plates which have not to be flanged or worked in the fire or which when in use are not to be exposed to flame shall be cold bend test.
(b) Angle Bars: A cold bend test shall be made from each angle bar rolled, provided that the cold bend test need not be carried out if basic material specification does not call for it.
(c) Stay Bars: A cold bend test shall be made from every 15 stay bars as rolled from each charge.

Bend Test (Reg.19):

a) Test pieces shall be sheared lengthwise or crosswise from plates or bars and shall not be less than 1½ inches (≈ 38 mm) wide, but for small bars the whole section may be used. For rivet bars bend tests are not required.

b) For cold bend tests the test of plates of all grades of steel, the test piece shall withstand, without fracture, being cold through 180° around a mandrel, the internal radius is equal to that shown in below table:

Tensile Strength	Internal Radius/Mandrel Radius
36 to 49 kgf/mm2	1T
41 to 57 kgf/mm2	1T
45 to 64 kgf/mm2	1.5T

'T' is thickness of bend specimen.

Bend Test Specimen:

Before bend

After bend

B) Cold Drawn Seamless carbon steel boiler, superheater and heat exchanger tubes for design metal temperature not exceeding 454 °c.

1. Chemical Analysis:(Reg.36 b)

Steel shall confirm the following limits of Chemical composition ():

Grade	%C	%Mn	%Si	%S	%P
TA	0.06-0.18	0.27-0.63	0.25 max.	0.035 max.	0.035 max.
TB	0.27 max*.	0.93 max	0.10 min.	0.035 max.	0.035 max.
TC	0.35 max*.	0.29 – 1.06	0.10 min.	0.035 max.	0.035 max.

*For TB and TC for each reduction of 0.01% below the specified Carbon maximum, an increase of 0.06% Manganese above the specified maximum will be permitted up to maximum of 1.35

Selection of Tubes for Test (Reg.37):

Two per cent of the tubes of each thickness and diameter and only one for every 100 or part thereof above 400 tubes of such similar size shall be made available to the Inspecting Officer for testing to the extent of such numbers.

(a) The tensile strength of the material cut from finished tubes shall conform to one of the following five grades namely,

- (i) 31 to 41 kgf/mm^2
- (ii) 36 to 46 kgf/mm^2
- (iii) 41 to 51 kgf/mm^2
- (iv) 46 to 56 kgf/mm^2
- (v) 50 to 62 kgf/mm^2

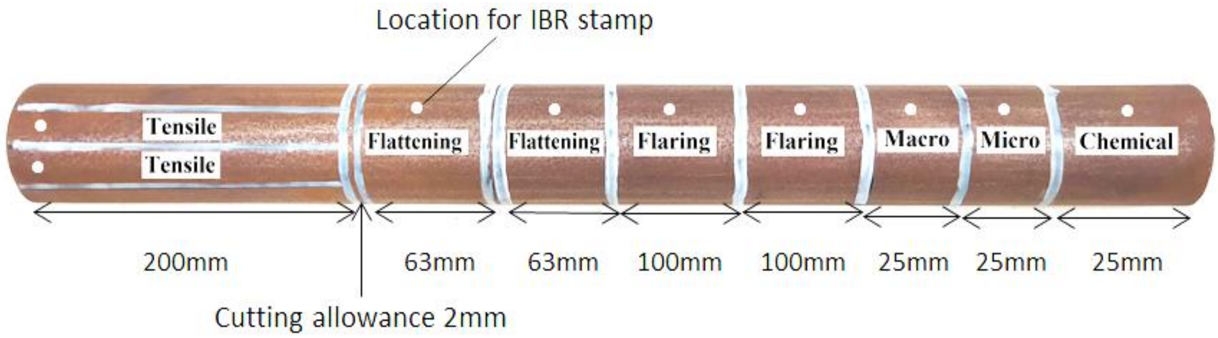
(b) Tensile test may be carried out on full section of the tubes up to the capacity of the machine.

(c) All specimens shall be tested at room temperature.

(d) Minimum 2 tubes for first 100 tubes and 1 per 100 or part thereof for tubes over 100 numbers.

Identification and marking of the Tube/Pipe sample:

All test pieces shall be selected by the Inspecting Officer and tested in his presence, and he shall satisfy himself that the conditions herein described are fulfilled. To avoid the delay in testing the sample drawn by Inspecting Officer shall be identified with hard stamping as suggested in below sketch. Sample size required: Full section x 700 mm.



Tensile and Hardness Tests (Reg.38):

The test specimen shall comply with the following requirements. The hardness test may be carried out on the wall cross section or on a flat outside surface of tube sample.

Grade	Yield Strength Mpa (kg/mm²) min.	Tensile Strength Mpa (kg/mm²) min.	%Elongation on GL = 50 mm, min.	Hardness (Max.) HB	
				HRB	HB
TA	180 (18.5)	325 (33.1)	35		137
TB	255 (26.1)	415 (42.2)	30	79	143
TC	275 (28.2)	485 (49.3)	30	89	179

Tensile and Hardness Tests (Reg.38):

(a) The upper yield point at room temperature shall be not less than 50 per cent of the specified minimum tensile strength at room temperature.

(b) The minimum values of the stress at proof limit 0.2 per cent at elevated temperature Et of the material may be calculated by multiplying the specified minimum tensile strength at room temperature R20 by the ratio Et/R20.

(c) Minimum values for the ratio of the stress at proof limit 0.2 per cent at elevated temperature Et to the minimum specified tensile strength at room temperature R20 of carbon steel tubes.

Temperature	**250 °C**	**275 °C**	**300 °C**	**325 °C**	**350 °C**	**375 °C**	**400 °C**	**425 °C**
Et/R20	0.40	0.38	0.36	0.34	0.33	0.32	0.31	0.30

The breaking elongation in % shall be not less than (100-Rm) /C

where C = 2.2 for only gauge length of L=5 do or 5.65 (Ao)1/2

do = original diameter of the round test piece.

Ao = original cross section of the rectangular test piece.

NOTE:C=1.9 for gauge lengths of 4 Ao

Tensile Test Specimens:

Tube / Pipe Reduced Section Flat Specimen

Full Section Tube Tensile Test Specimen

Flattening Tests (Reg.39):

A ring not less than 63 mm in length cut from one end of each selected tube shall be flattened between two parallel flat surfaces to a distance between the plates (H) as calculated by the formula given below without showing any sign of a crack or flaw:

$$H = \frac{(1+C)a}{C + \frac{a}{D}}$$

Where a = thickness of tube (mm)

D = outside diameter of the tube (mm)

C = a constant as given below

C = 0.09 for steel having a specified minimum tensile strength from 31 kgf/mm^2 up to and including 35 kgf/mm^2.

C = 0.07 for steel having a specified minimum tensile strength over 35 kgf/mm^2 up to and including 42 kgf/mm^2

C = 0.05 for steel having a specified minimum tensile strength over 42 kgf/mm^2 up to and including 50 kgf/mm^2.

C = 0.03 for steel having a specified minimum tensile strength over 50 kgf/mm^2 up to and including 62 kgf/mm^2.

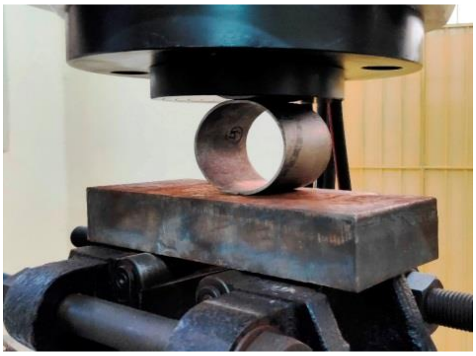
Bend Test (Reg.44 b):

For pipe of outside diameter 60.3 mm and under, bend test shall be conducted. A sufficient length of pipe shall stand being bent cold through 90° around a cylindrical mandrel, the diameter of which 12 times the nominal diameter of the pipe without developing cracks.

Flattening Test Specimen (Reg.39):

Before Flattening

After Flattening

Flanging & Drift Expanding Test (Reg.40):

(a) The tube shall withstand either the flanging test or the drift expanding test, at the option of the manufacturer.

(b) **Flanging test:**- A test piece cut from the end of a tube in a plane perpendicular to the axis
of the tube shall show no crack or flaw after flanging to the specified outside diameter as given in the table below:

(c) **Drift Expanding / Flaring test**: - A test piece cut approximately 100 mm from the end of a tube in a plane perpendicular to the axis of the tube shall show no crack after expanding by a mandrel having an included angle of 30°, 45° or 60° at the option of the manufacturer to increase the outside diameter.

Additional Test before rejection (Reg.41):

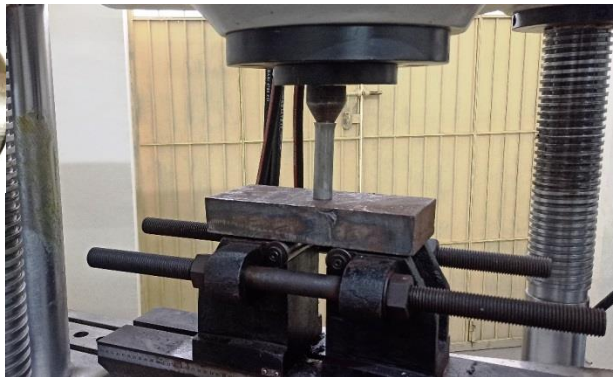
If any one or more tests specified in these regulations (Reg. 38, 39 & 40) fail, two further tests of same kind may be made on TWO other tubes of the same batch. If the repeat tests are satisfactory the tubes shall be accepted. Should either of the tubes fail in any test, the batch of tubes represented may be reheat-treated. If any failure in repeat tests, the batch of tubes which the test pieces represent shall be rejected.

Flanging & Drift Expanding Test (Reg.40):

The Mouth of the flare has been expanded to the percentages given below, without cracking:

Ratio of inside diameter to outside diameter	Minimum expansion of inside diameter %
0.9	21

0.8	22
0.7	25
0.6	30
0.4	39
0.5	51
0.3	68



C) Seamless Forged Drums (Reg.235):

I) Forging:

The forging, shall be made from a solid cast ingot, punched, bored or trepanned, or alternatively, hollow, cast ingots may be used. The resultant wall in the case of the solid cast ingot, or the wall of hollow ingot as cast shall be reduced in thickness by at least one-half in the process of forging.

1. Chemical Analysis (Reg.236) : The steel shall not contain more than 0.050 per cent of sulphur or of phosphorus.

2. Mechanical Tests

Selection of test pieces (Reg.240):

a) All test pieces shall be selected by the Inspecting Officer and shall be tested in his presence, and he shall satisfy himself that the conditions herein prescribed are fulfilled.

b) Tensile Test Pieces: The tensile strength and percentage elongation shall be determined from round test pieces with gauge lengths of 5 do.

c) **Tensile Test:** The tensile strength and percentage elongation shall be determined from round test pieces with gauge lengths of 5 do.

I) The tensile strength of different grades of material shall be within the limits specified as below

(i) 37 to 45 kgf/mm2

(ii) 42 to 50 kgf/mm2

(iii) 47 to 56 kgf/mm2

(iv) 52 to 62 kgf/mm2

(II) The upper yield point at room temperature shall be not less than 50% of the specified minimum tensile strength at room temperature.

III) The breaking elongation in percentage shall be not less than as per (N-Rm)/C

Where Rm: Tensile strength at room temperature in kgf/mm^2

N : a quality index of 100 for plate thickness up to 50 mm or 95 for plate thickness over 50mm.

C : 2.2 for only gauge lengths of L=5 do or L=5.65/ √Ao

Where Lo : gauge length

Ao : Original diameter of the round test piece.

NOTE : C is 1.9 for gauge lengths of 4 √Ao for test piece.

Bend test pieces (Reg.240 D)

d) Bend Test (Reg. 240 E)

Bend test pieces shall be of rectangular section 1 inch wide by ¾ inch thick. The edges shall be rounded to a radius of 1/16 inch. The test pieces shall be bent over the thinner section.

The test pieces shall, when cold, be capable of being bent without fracture, through an angle of 180°, the internal radius of the bend being not greater than that specified in table below :

Blank size	Internal Radius of bend (in inches)
Up to 32	⅜
Above 32 and up to 36	½
Above 36 and up to 38	¾

Additional tests before rejection (Reg. 241):
Should either a tensile or bend test fail, two further tests of the type which failed may be made on test pieces cut from the same test rings. If the results obtained from these retests are satisfactory, the drum shall be accepted, provided that in other respects it fulfils the conditions of this Chapter. If these re-tests do not give satisfactory results the drum represented may be re-heat-treated together with the remainder of the test rings and presented for further testing. In all cases where final re-tests do not give satisfactory results, the drum represented by the test pieces which fail shall be rejected.

Discard (Reg.242):
Sufficient discard shall be made from the top and bottom of each ingot to ensure soundness in the portion for forging.

Forging (Reg.243):
The forging, shall be made from a solid cast ingot, punched, bored or trepanned, or alternatively, hollow, cast ingots may be used. The resultant wall in the case of the solid cast ingot, or the wall of hollow ingot as cast shall be reduced in thickness by at least one-half in the process of forging.

D) General Grey Iron Castings - Grade A (Reg.86)

(a) Process of manufacture:

The castings shall be cast from metal melted or refined in any metallurgical plant other than an iron ore smelting furnace, for the use of which furnace permission in writing must be received from the Inspecting Authority.

(b) Chemical Composition.

The composition of the iron as cast shall be left to the discretion of the manufacturer but the maximum percentage of phosphorus or sulphur or both may be specified by the Inspecting Authority, if he so desires.

Provision of test bars (Reg.87):

a) The Inspecting Authority shall state at the time of enquiry whether he requires tensile or transverse tests, or both, and he may also specify cast-on bars where the design of the casting and method of running permit.

b) When the test bars are cast separately, they shall be poured at the same time and from the same ladle, or metal as the casting or castings they represent. The number of test bars specified in Regulation 92 shall be applicable to all castings of each melt.

d) When the bars are cast-on, the mould for the casting and the mould for the test piece shall be joined together in such a manner that the liquid metal fills both moulds at the same operation.

e) All test bars shall be cast in green sand or dry sand or in loam moulds according as to whether the casting or castings they represent are moulded in green sand, or in loam or dry sand, respectively. The test bars shall not be subjected to any heat treatment after leaving the moulds.

Dimensions of Test Bar (Reg.88)

(a) Transverse Test Bars: The transverse test bars of the diameter specified by the Inspecting Authority according to the main cross-sectional thickness of the casting represented, shall conform to the following dimensions:

Diameter of Test Bar (in inch)	Limits of Diameter (in inch)	Overall Length (in inches)	Main cross-sectional thickness of castings Represented (in inches)
0.6	+0.045	10	Not exceeding 3/8
0.785	+0.065	15	Over 3/8 and not exceeding ¾
1.2	+0.090	21	Over 3/4 and not exceeding 1 ⅛

1.6	+0.10	21	Over 1 1/8 and not exceeding 1 ⅝
2.1	+0.10	27	Over 1 ⅝

Mechanical test:

Transverse test (Reg.90):

A transverse test bar cast in accordance with **Regulation 88(a)** must when placed on supports set at the distance shown in column 2 of the following table sustain a load applied at the center of not less than that shown in column 3 and must show before rupture a deflection not less than that shown in column 4. The supports and the point of application of the load shall be rounded to a radius of not less than ⅛ inch.

Diameter of Test Bar (in inches)	Distance between supports (in inches)	Minimum braking Load Grade A (in lbs)	Minimum deflection Grade A (in inches)
0.6	9	530	0.07
0.875	12	1,185	0.10
1.2	18	1,950	0.15
1.6	18	4,280	0.12
2.1	24	6,660	0.15

Dimensions of Test Bar (Reg.88)

(b) Tensile Test Bars: The tensile test bars of the diameter specified by the Inspecting Authority, according to the main cross-sectional thickness of the casting represented shall conform to the dimensions shown in the following **table**. Bars may be tested with either plain or screwed ends.

TABLE

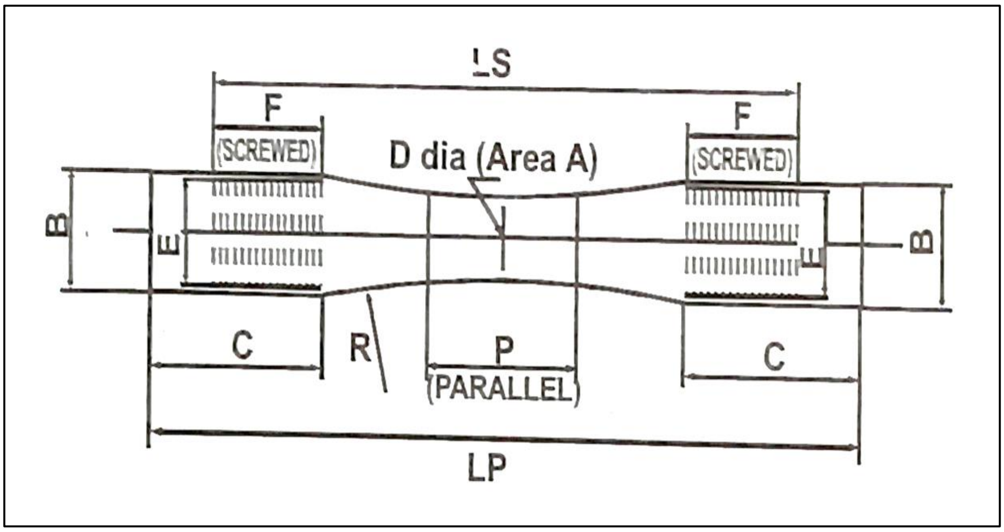
Diameter as cast	Gauge diameter	Area	Min. parallel length	Min. radius	Min. length of plain ends	Screwed ends		Approximate minimum overall length		Main cross-sectional thickness of casting represented
						Size	Min. length	Plain ends	Screwed ends	
B	D	A	P	R	C	E	F	LP	LS	
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
0.6	0.399	0.125	1	1½	1½	½ S.P. 9/16 S.F. p/16 S.W.	9/16	4½	3	Not exceeding 3/8
0.875	0.564	0.25	2	3½	1½	¾ S.F. 7/8 S.W.	¾	7-1/16	4-13/16	Over 3/8 and not exceeding ¾
1.2	0.798	0.50	2	3½	2	1½ S.F. 1½ S.W.	1½	8¼	5-7/8	Over ¾ and not exceeding 1½
1.6	1.128	1.00	2	3½	2½	1½ S.F. 1½ S.W.	1½	9-1/32	7¼ 7¼	Over 1½ and not exceeding 1-5/8
2.1	1.596	2.00	2	3½	3½	2 S.F.	2	11¼	8¼	Over 1-5/8

Mechanical test:

Tensile test (Reg.91).

A tensile test bar machined to the dimensions shown in Regulation 88 (b) and tested with either plain or screwed ends must show a breaking strength of not less than that shown in the following table:

Diameter of Test Bar (in inches)	Minimum Ultimate Tensile Stress(in Tons/in²)
0.6	12.5
0.875	12.0
1.2	11.0
1.6	10.5
2.1	10.0



Screwed end Tensile Specimen

Mechanical test:

Number of Transverse & Tensile Test (Reg.92):

The number of tests required for each batch of castings shall be in accordance with the following Table:

Group	Weight of Casting	No. of test specimen.
1	Up to 28 lbs	One test for each 30 cwt of castings or part thereof
2	Over 28 lbs to and up to 1 cwt.	One test for each 2 tons of castings or part thereof
3	Over 1 cwt to and up to 1 ton	One test for each 4 tons of castings or part thereof
4	Over 1 ton to and up to and important castings, where mutually agreed upon.	One test for each 4 tons of castings or part thereof or for each casting weighing 4 tons or more

Mechanical test:

Additional tests (Reg.93):

The additional tests to be carried out before a casting or batch of castings is rejected shall be in accordance with the following table

Test Piece	Event	Conditions
1st	If this fails	Second test piece shall be tested.
2nd	If this passes	The batch or separate casting represented shall be accepted
	If this fails	The batch or separate casting represented shall be rejected

Provided always that in the case of failure of both test pieces if either show obvious defects a third test piece may be taken from a broken casting or a piece may be cut from a usable casting for further testing as follows:

Test Piece	Event	Conditions
3rd	If this passes	The batch or separate casting represented shall be accepted
	If this fails	The batch or separate casting represented shall be rejected

E) Tests on Welded Seams (Reg.561):

Test Plates (Reg 561 a):

Test plates to represent all welded seams shall be attached at each end of each longitudinal seam in tension. These shall be of a size sufficient for the preparation of the test pieces specified. In the case of shell plates up to an including 16 feet in length the test plate may be located at one end only (see Figure XII/58). Where the shell is formed in two or more rings, the staggered longitudinal seam shall be regarded as a continuous longitudinal seam provided the welding be effected in one reasonably continuous operation and by the same operator or operators. The material for the test plates shall be cut from the respective plate or plates forming the appropriate seam.

Where there are circumferential seams only or where the method of welding the circumferential seams differs from that employed for the longitudinal seams, the method of providing the test plates shall be decided by the Inspecting Authority.

Test Plate Welded Coupon

Tests on Welded Seams (Reg.561):

Test Plates (Reg 561 a):

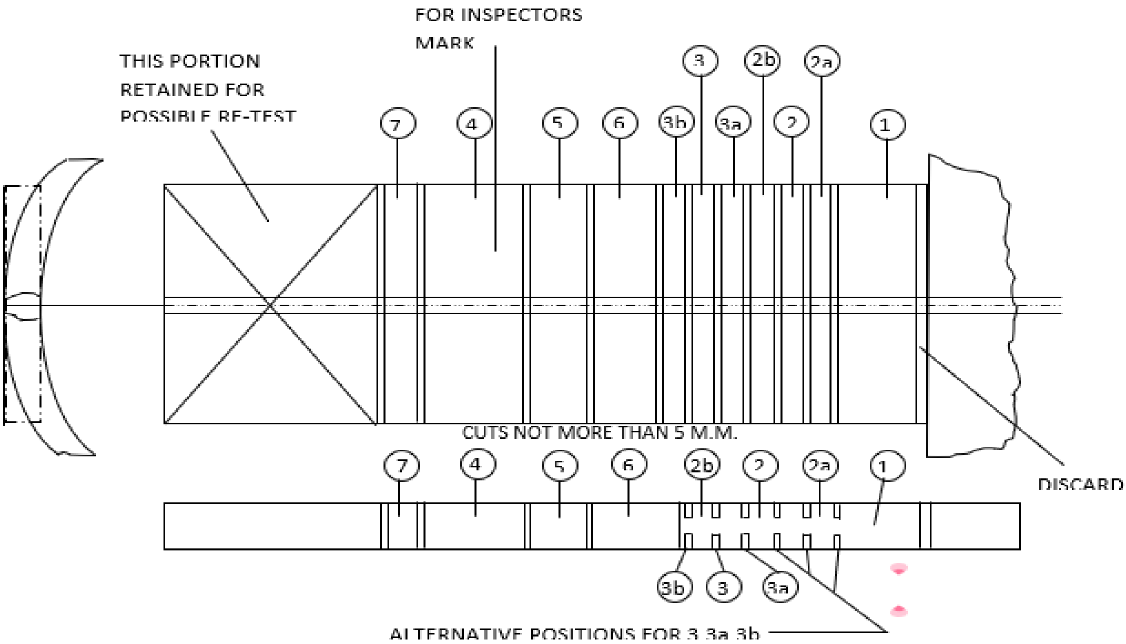


FIG.XII/58 – Details of Test Plates

Tests for Class I Boilers: (Reg 561 B):

I) Specimens for the following tests shall be selected from the test plate or plates and stamped by the Inspecting Officer for identification (see Figures XII/58 and XII/59):

1. One tensile test specimen for the welded seam.
2. One all weld metal tensile test specimen.

3. Two bend test specimens.
4. Two impact test specimens.
5. One specimen from each test plate for macro and micro examinations.
6. Additional tests before Rejection.

1.) One tensile test specimen for the welded seam. : (Reg 561 B):

a) Welded Joint:

(i)The dimensions of the reduced tensile section shall be as shown in the FIG.XII/60 (A). The width of the reduced section shall be at least 25 mm

(ii) If the thickness of the plate does not exceed 30 millimeters, the thickness of the specimen shall be equal to the plate thickness and the plate surface of the specimen shall be machined to take away the surface irregularities of the plate and the weld.

(iii) If the plate thickness exceeds 30 millimeters, the tensile test shall be carried out on several reduced section specimens, each having a thickness of at least 30 millimeters and width at the effective cross-section of at least 25 millimeters. These specimens shall be taken out of the test piece in such a way that the tensile test covers the whole thickness of the weld joints as shown in FIG.XII/60 (B). The tensile strength shall not be less than the lower limit specified for the plate.

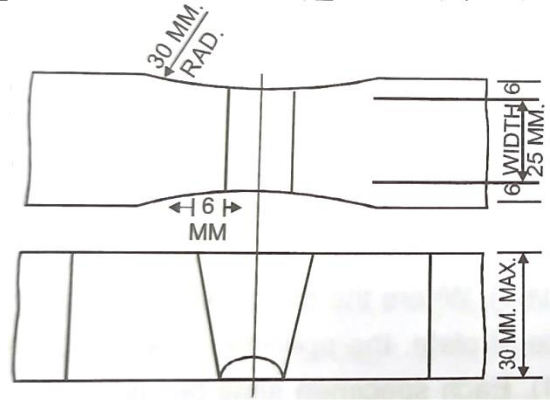
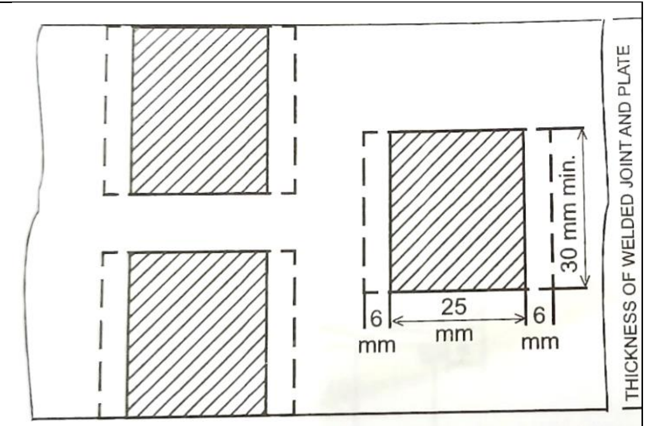
	

FIG.XII/60 (A) – Reduced Section Tensile Specimen	**FIG.XII/60 (B) – Reduced Section Tensile Specimen in Thick Plate**

2.) One all weld metal tensile test specimen:

The dimensions of the weld metal tensile test specimen shall be these given in FIG.XII/63. The diameter shall be the maximum possible consistent with the cross section of the weld but in no case more than 20 millimeters, the gauge length shall be equal to five times the diameter. The tensile strength shall not be less than the lower limit specified for the plate. The elongation shall not be less than 20 per cent on a gauge length of four times the square root of the cross-sectional area of the specimen, and the reduction in area not less than 35 per cent.

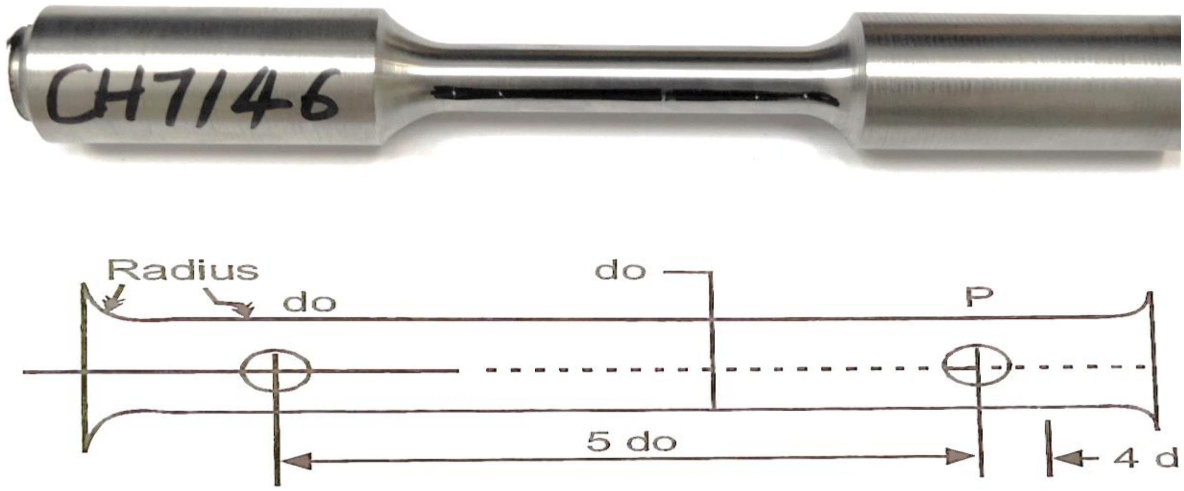


FIG.XII/63 : Tensile Test all Weld Metal

3.) Two bend test specimens:

Cold Bend Tests:

One specimen shall be tested with the outer surface of the weld in tension, and the other with the inner surface in tension. The specimens shall be rectangular in section and shall be cut out transversely to the weld to have a width not less than one-and-a half times the thickness of the plates. The sharp corners of the specimens shall be rounded to a radius not exceeding 10% of the thickness of thespecimen.

Where the plate thickness does not exceed 1 ¼ inches, the thickness of the specimen shall be equal to the full thickness of the test plate. Where the plate thickness exceeds 1 ¼ inches, the specimen shall in all cases have a thickness of at least 1 ¼ inches. The specimen to be tested with the outer surface of the weld in tension shall be prepared by cutting to waste the metal local to the inner surface of the weld, so that the desired specimen thickness is obtained (FIG. XII/64).

The specimen to be tested with the inner surface in tension shall be prepared by cutting to waste the metal local to the outer surface of the weld so that the desired specimen thickness is obtained (see Figure XII/64). Where the thickness of the plate permits, both specimens may be cut from the same piece of plate, the specimens being in the plate one above the other (FIG.XII/64). Each specimen shall be mounted with the weld midway between the supports set apart at a distance not more than 5.2 times the thickness of the specimen and pushed through the supports with a former having a diameter equal to three times the thickness of the specimen.

Cold Bend Tests:

On completion of the test no crack or defect at the outer surface of the specimen shall be greater than 1/16 inch measured cross the specimen or 1/8 inch measured along the length of the specimen. Premature failure at corners of the specimen shall not be considered cause for rejection.

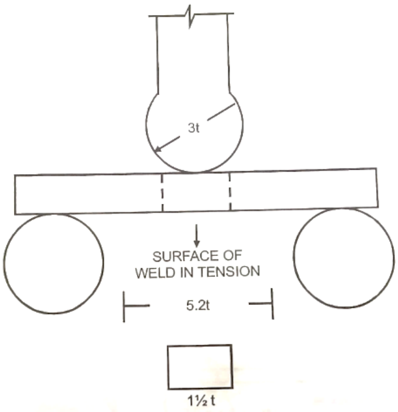


FIG.XII/66

4.) Two Impact Tests Specimens: (Reg 561 B):

Impact Test:

The impact test specimens are to be one of the two types and dimensions are one of two types and dimensions shown in FIG.21A and 21B, the notch shall be contained in the weld metal at approximately the axis of the weld and the axis of the notch is to be perpendicular to the surface of the plate.

The test shall be carried out as follows:

For V-Notch as well as U-Notch specimen at temperature 20 ± 2 °C. in the case of V-Notch specimen, the machining of the bottom of the notch shall be done very carefully. The choice between U-Notch and V-Notch specimen shall be at the discretion of the **Inspecting Authority.**

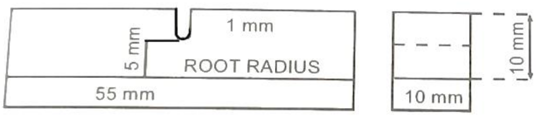


FIG.21A

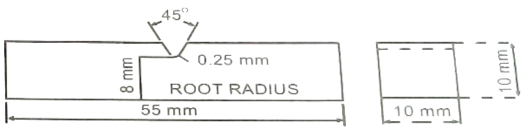
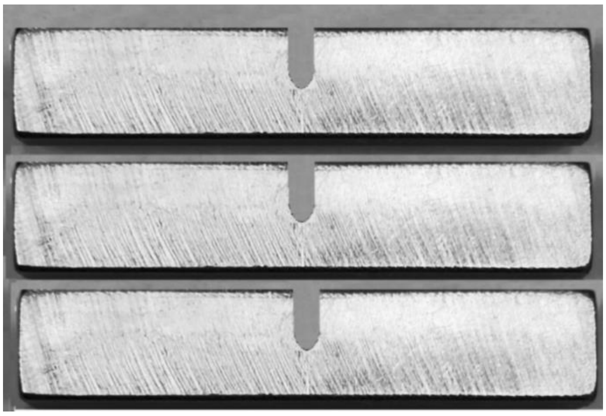


FIG.21B



U-Notch

V-Notch

Two Impact Tests Specimens: (Reg 561 B):

Impact Test:

The minimum result to obtained from the impact test pieces shall be:

Type of notch	Specified minimum requirement
U-Notch specimen	5.50kgfm/cm²
V-Notch	3.46kgfm/cm²

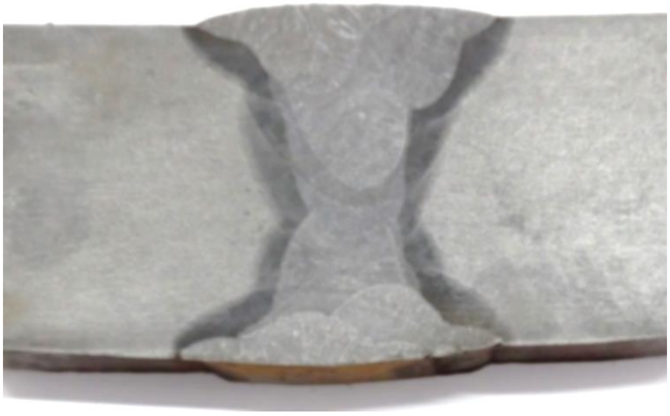
Note: above values are equivalent to 2.76 kgfm divided by sectional area below the notch.

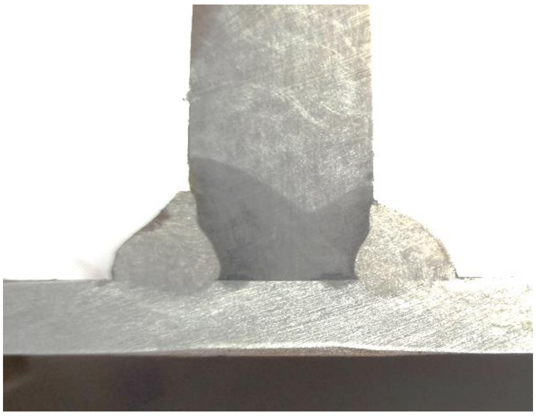
5.) Macro and Micro examination:

Specimen of the full thickness of the plate and not less than 13 mm wide shall be provided from each set of test plates for the purpose of macro and micro examinations.

Micro-etching of a complete cross-section of the weld including the heat affected zone, should show satisfactory penetration, fusion and absence of significant inclusions or other defects.

Should there be any doubt as to the condition of the weld as shown by macro-etching, the area concerned is to be microscopically examined for defect investigation.

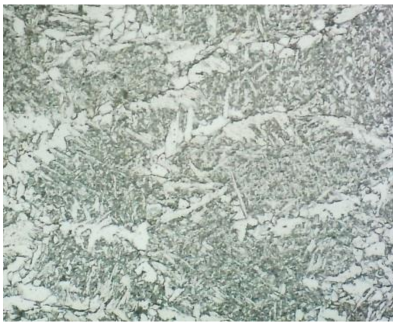




Macro-etch : Butt weld

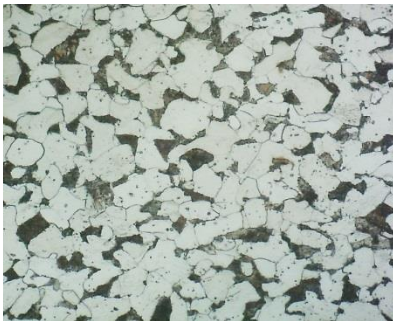
Macro-etch : Fillet Weld

5.) Macro and Micro examination:



Microstructure: Location weld

Microstructure: Location HAZ



Microstructure: Location Base

6.) Additional tests before rejection:
Any of the test specimens taken in accordance with this Regulation fail to meet the specified requirements, retests shall be allowed for each specimen that fails as follows: Where any result of the tensile test is not less than 90% of the specified figure, one retest shall be made. Where any result falls below the 90% , two retests shall be made.

Where bend specimen fails to meet the specified requirements, two retests shall be made.

If an impact test fails to meet the specified requirements, two retest shall be taken from the test plate, one on each side 0f the final specimen and separate from it by not more than 5 millimeters.

If it be found there is insufficient metal to permit the preparation of specimens for retest from the remainder of the test plate from which the original specimen was taken, the specimen for retest may be cut from the test plate relating to the opposite end of the same longitudinal seam.

should any of additional tests fail to meet the specified requirements the welded seams represented by these tests shall be rejected.

Tests for Class II Boilers: (Reg 561 C):

I) from each longitudinal seam test pieces shall be selected for the following tests and stamped by the Inspector for identification.

1. One tensile test specimen for the welded seam.
2. One bend / One Reverse bend test specimens.
3. One nick-break test specimen.
4. Additional tests before Rejection.

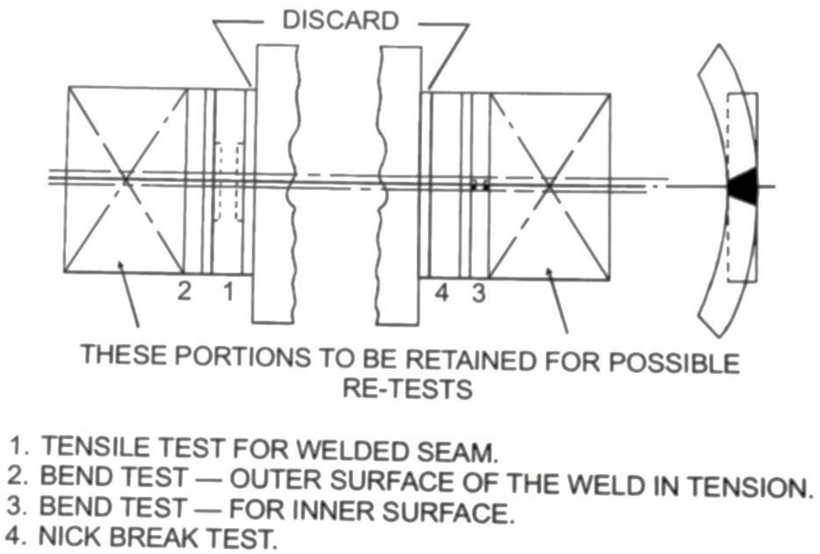


FIG. XII/65

The disposition of the specimen shall be in accordance with the sketches in FIG. XII/65. The remainder of each test plate shall be retained for retests if required.

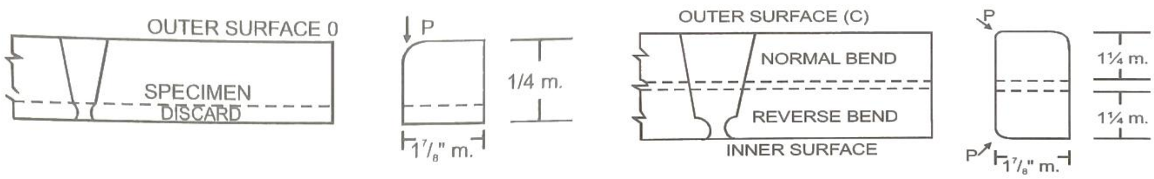
1. One tensile test specimen for the welded seam:

The dimensions of the test specimen shall be in accordance with the sketch in FIG. XII/60. Specimen 1a, and the specimen shall be cut out transversely to the welded seam. When the capacity of the available testing machine does not allow the full specimen to be tested, two narrower tensile specimens shall be substituted. These specimens shall be the full thickness of the plate at the welded joint and their breadth shall be as great as the testing machine will reasonably allow, provided the effective cross-sectional area of the test piece is not less than 1 ½ square inches (see Figure XII/60 Specimen 1b). The tensile strength of the welded joint specimen shall be not less than the lower limit specified for the plate.

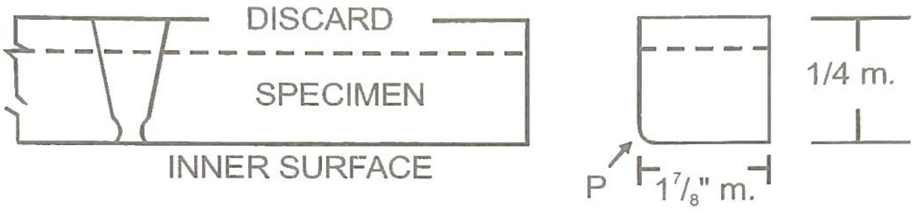
2. One bend / One Reverse bend test specimens:

One specimen shall be tested with the outer surface of the weld in tension, and the other with the inner surface in tension. The specimens shall be rectangular in section and shall be cut out transversely to the weld so to have a width not less than one-and-a-half times the thickness of the plate. The specimen to be tested with the outer surface of the weld in tension shall be prepared by cutting to waste the metal local to the inner surface of the weld, so that the desired specimen thickness is obtained (see A. Figure XII/64). The specimen to be tested with inner surface in tension shall be prepared by cutting to waste the metal local to the outer surface of the weld so that the desired specimen thickness is obtained (see B. Figure XII/64). Where the thickness of the plate permits both specimens may be cut from the same piece of plate, the specimens being located in the plate one above the other (see C. Figure XII/64).

Each specimen shall be mounted with the weld midway between the supports set apart at not more than 5.2 times the thickness of the specimen and pushed through the supports with a former having a diameter equal to three times the thickness of the specimen. One completion of the test no crack or defect at the outer surface of the specimen shall be greater than 1/16 inch measured across the specimen, or 1/8 inch measured along the length of the specimen. Premature failure at corners of the specimen shall not be considered cause for rejection.



Outer Surface Bend Specimen



Inner Surface Bend Specimen

3. One nick-break test specimen:

This specimen shall have a width not less than one-and-a half times its thickness and the slot shall be cut in each side of the specimen through the center of the weld and perpendicular to the outer face of the boiler.

The specimen shall then be broken in the weld and the fracture shall reveal a sound homogeneous weld substantially free from **slag inclusions, porosity, and coarse crystallinity**.

4.Additional tests before Rejections:

If any of the test specimens should fail, two retests shall be made, and both shall meet the specified requirements.

F) Periodic Check Test (Reg.98).

The following Periodic Check Tests on each brand of electrodes shall be carried out:-

(a) Periodic check tests consist of a selection of the tests prescribed under **Reg.95 and 97** and they shall be repeated at intervals of not more than 6 months to provide evidence that the electrodes currently produced continue to possess the properties recorded in the initial tests.

(1) All-weld tensile test with any two sizes of electrodes within the limits prescribed in clause (a) **of Reg.95.**

(2) One Tee joint fillet weld hot cracking test as prescribed in clause (b) **of Reg.95**.

(b) For deep penetration butt-welding electrodes, one transverse tensile test specimen and two transverse bend test specimens shall be prepared and tested as prescribed in **Reg.96** and the specimens shall show that a complete penetration has been achieved.

(c) For deep penetration fillet welding electrodes one cruciform fillet weld tensile test shall be taken as prescribed in **Regulation 97(1)** and the two outer discards from the test pieces shall show a minimum penetration beyond the root as required under **Reg.97(2).**

F) Periodic Check Test (Reg.98).

The following initial tests on each brand of electrodes shall be carried out:

(1) Parent metal for test plates:

The parent metal used in preparing test pieces and test specimens shall be mild steel of welding quality in the normalized condition (this condition is optional in the case of all-weld metal tests) with an ultimate tensile stress of not less than 28 and not more than 32 tons per square inch and an elongation of not less than 20 percent on standard test piece.

(2) All-weld metal test:

Method of preparation of test pieces shall be described in Reg.98 (2) & All-weld test pieces shall be prepared as shown in FIG. 1 (Reg.98 (2)). The test specimen shall not be subjected to any mechanical or thermal treatment other than that required herein.

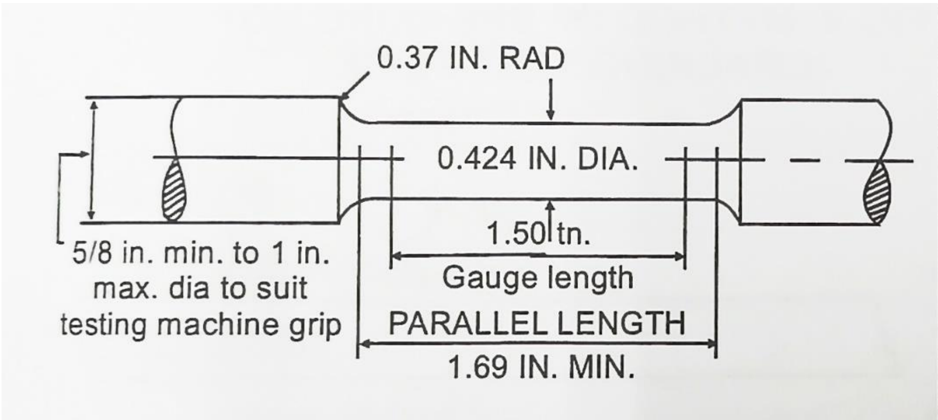
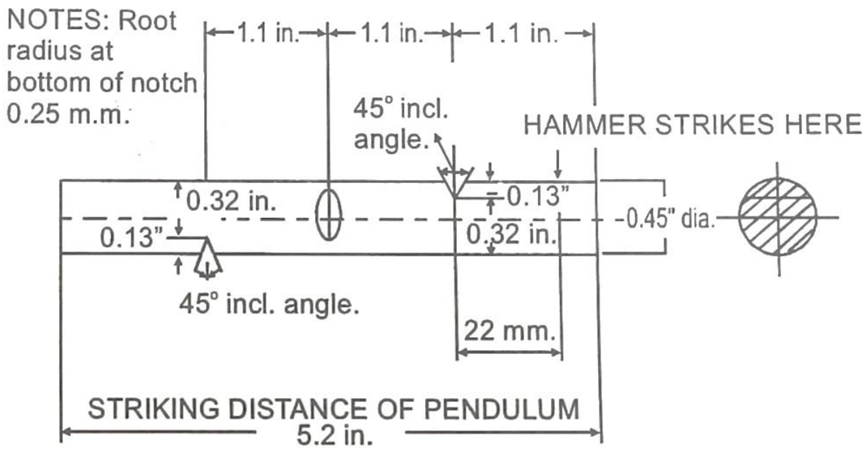


FIG.1(a): Tensile test specimen

(3) Impact Test Specimen :

The Izod impact test specimens shall be machined from the weld metal test pieces to the dimensions given in FIG. 2 care being taken that the longitudinal axis of the test piece coincides with the center line of the weld and mid-thickness of the plate. The temperature of the test specimen at the time of testing shall not be less than 50°F (10°C).



(4) Hot Cracking Test:

A 6 inches x 4 inches x ½ inch plate shall be welded to a second plate 6 inches x 6 inches x ½ inch in the form of a close square Tee joint as shown in FIG.3. The edge of the first plate abutting the surface of the second shall be prepared by machining or grinding. The gaps between parts after tack welding at the ends shall not exceed 0.01 inch.

Two fillet welds 5 inches long and ¼ inch in leg length shall be deposited in the flat position with a single 6 S.W.G. (or 0.2 inch) electrode, using the maximum current of the range recommended by the manufacturer. The test piece shall be so positioned that the slope and the rotation of the weld are zero. The second weld shall be started at that end where the first run was finished after time interval of 4 to 5 seconds. The slag shall be removed after the test piece is cooled in still air to the room temperature. The surfaces of the weld shall be visually examined for cracks.

The second plate shall be slit and the welds broken open as shown in FIG.4. The weld shall not show any evidence of hot cracking as indicated by oxidation or temper colouring of the surface of the fractures.

Hot Cracking Test:

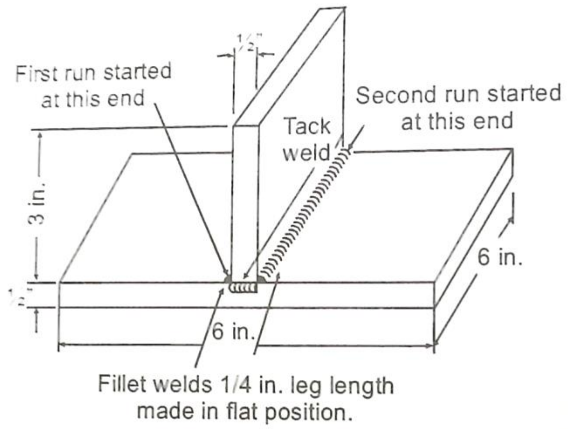


FIG.3: Method of making Hot Cracking Test Piece.

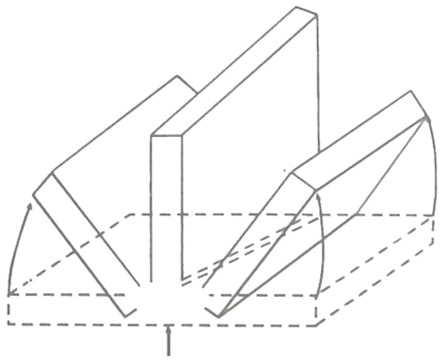


FIG.4: Method of Breaking Hot Cracking Test Piece.

(5) Transverse Tensile & Bend Tests:

The transverse tensile and bend test pieces shall be made as shown in FIG.5 by butt-welding together two ½ inch plates of suitable length and not less than 6 inches in width. The Plate edges shall be prepared to form a single Vee joint the details of which shall be as follows: (see FIG.5(a))

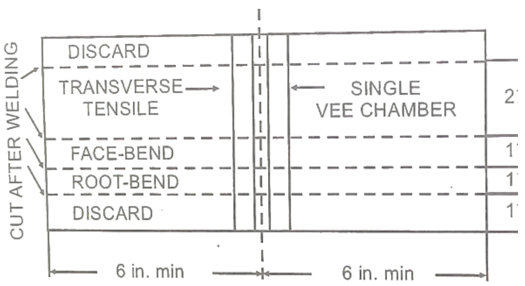
Angle between fusion faces 60° - 70°.

Root face1/8 inch.

Maximum gap 1/8 inch.

The welding procedure in making out the test pieces shall be according to the position of welding as in Table 1: Welding procedure for preparation of Transverse tensile test & Bend Test pieces. (Reg.98 Table 1)

Transverse Tensile & Bend Tests



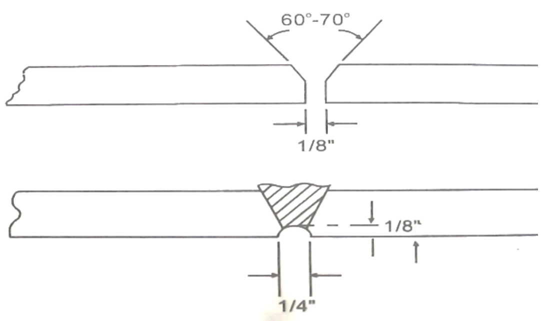


FIG.5 Method of Making Transverse Tensile & Bend Specimens.

FIG.5 (a) Grooving in Preparation for Deposition of Backing Run

(6) Transverse Tensile Tests:

Transverse tensile test specimens shall conform to the dimensions given in Figure 6*. The upper and lower surfaces of the weld shall be filed, ground or machined level with the respective original surfaces of the plates. Where the surfaces of the plates are not level with each other the metal may be cut away to bring them approximately level, provided that the thickness of the plate is not reduced by more than a total of 0.04 inch.

The test specimens shall then be tested for tensile test.

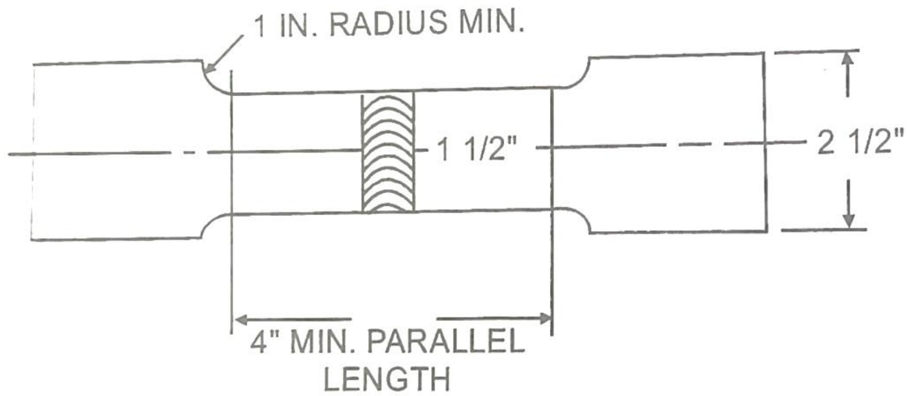


FIG. 6: Dimensions of Transverse Tensile Specimen

(7) Transverse Bend Tests:

The bend test specimens shall be 1½ inches in width. The upper and lower surfaces of the weld shall be filed, ground or machined level with the respective original surfaces of the plates, with the proviso as in item (6) above. Tool marks should be avoided as they lead to location of stress and may cause premature failure. For this reason, the direction of machining of the surfaces should be along the specimens and transverse to the weld. The sharp corners of test specimens shall be rounded to a radius not exceeding 1/20 inch. The test specimens shall be bent through an angle of 180° over former having a diameter equal to three times the thickness of the specimen, as shown in FIG.7. One test specimen shall be tested with the face of the weld in tension and one with the root of the weld in tension.

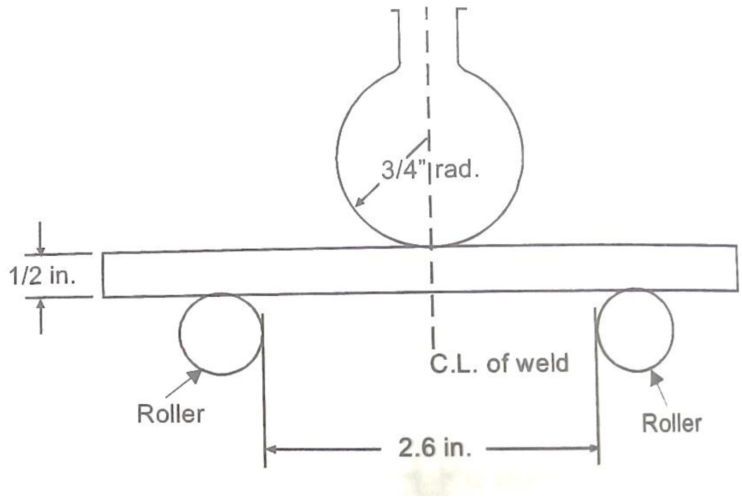


FIG. 7: Method of Carrying Out Bend tests

(8) Cruciform Fillet Weld Tensile Test:

Normal Penetration Electrodes:

The specimens shall be prepared as shown in Figure 8*. Care shall be taken that the center lines of two vertical plates are in the same plane. The parent metal used shall be at a temperature between 50° - 100°F (10° - 38°C) immediately before depositing the first run of weld metal. The test specimens shall not be subjected to any mechanical or thermal treatment, other than what is given in this appendix. The plates shall be so placed that each weld shall be deposited in the appropriate welding position, using the procedure specified in Table 2: Welding procedure for preparation of cruciform fillet weld Tensile Test pieces for Normal penetration electrodes. As per Reg. 98 Table 2

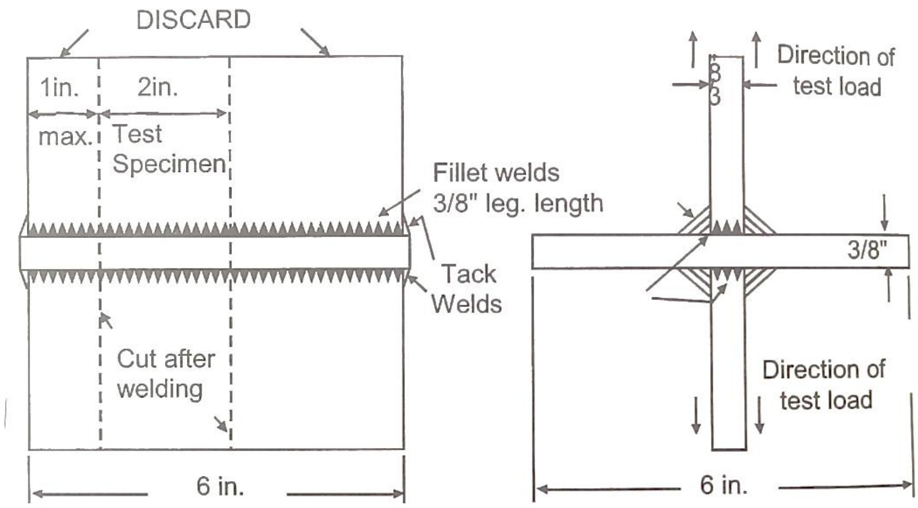


FIG.8: Method of making Cruciform Fillet Weld Test Specimen

A SNEAK PEEK AT ASME SECTION-I, CONSTRUCTION OF POWER BOILERS

By Mr. Jayaram Vattappilly
Hartford Steam Boiler Inspection and Insurance Company

PG-27 CYLINDRICAL COMPONENTS UNDER INTERNAL PRESSURE - A Notable Difference.

ASME Section I, 2021 Edition

PG-27.2.2 Piping, Drums, Shells, and Headers. Based on strength of weakest course.

$$t = \frac{PD}{2SE + 2yP} + C \quad \text{or} \quad \frac{PR}{SE - (1 - y)P} + C$$

$$P = \frac{2SE(t - C)}{D - 2y(t - C)} \quad \text{or} \quad \frac{SE(t - C)}{R + (1 - y)(t - C)}$$

See PG-27.4.1, PG-27.4.3, and PG-27.4.5 through PG-27.4.8.

PG-27.3 Symbols. Symbols used in the preceding equations are defined as follows:

C = minimum allowance for threading and structural stability (see PG-27.4.3)
D = outside diameter of cylinder
E = efficiency (see PG-27.4.1)
e = thickness factor for expanded tube ends (see PG-27.4.4)
P = maximum allowable working pressure (see PG-21)
R = inside radius of cylinder; for pipe, the inside radius is determined by the outside radius minus the nominal wall thickness
S = maximum allowable stress value at the design temperature of the metal, as listed in the tables specified in PG-23 (see PG-27.4.2)

$$\boxed{\sigma_h = \frac{PR}{t}}$$

ASME Section I, 2021 Edition

y = a coefficient having values as follows:

	Temperature, °F (°C)							
	900 (480) and Below	950 (510)	1,000 (540)	1,050 (565)	1,100 (595)	1,150 (620)	1,200 (650)	1,250 (675) and Above
Ferritic	0.4	0.5	0.7	0.7	0.7	0.7	0.7	0.7
Austenitic	0.4	0.4	0.4	0.4	0.5	0.7	0.7	0.7
Alloy 800, 801	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.7
800H, N08811	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.7
825	0.4	0.4	0.4	...	...	...	...	...
N06230	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.7
N06022	0.4	0.4	0.4	0.4	0.5	0.7	0.7	0.7
N06025	0.4	0.4	0.4	0.4	0.5	0.7	0.7	0.7
N06045	0.4	0.4	0.4	0.4	0.5	0.7	0.7	0.7
N06600	0.4	0.4	0.4	0.4	0.5	0.7	0.7	...
N06601	0.4	0.4	0.4	0.4	0.5	0.7	0.7	...
N06625	0.4	0.4	0.4	0.4	0.4	...	...	...
N06690	0.4	0.4	0.4	0.4	0.5	0.7	0.7	...
Alloy 617	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.7
S31803	0.4	...	...	...	...	...	...	...

What does the y factor do to the equation in PG-27.2.2 mentioned in the previous slide ?

y factor is introduced in Section I to take into account of the reduction of stress due to redistribution when the temperature is in the creep region.

243. Determination of maximum allowable working pressure

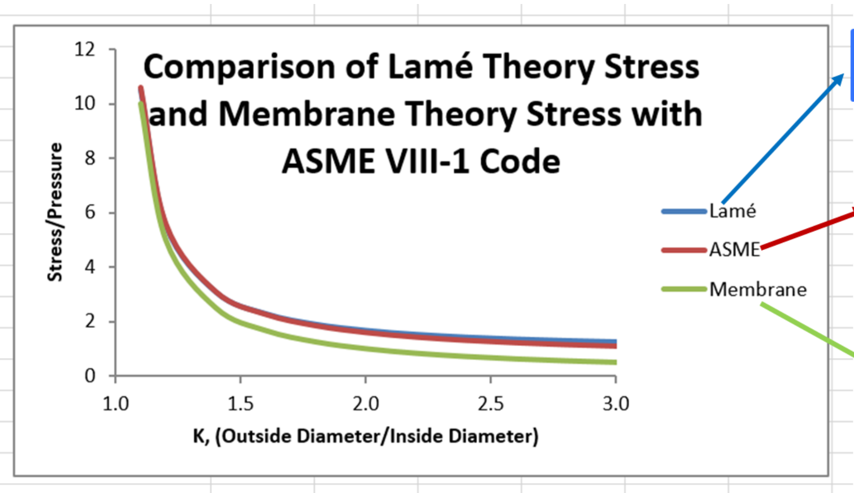
(a) Shells - The maximum allowable working pressure of shells shall be determined by the following formula: -

$$P = \frac{2fE(T-0.75)}{D+(T-0.75)}$$

$$S = \frac{PR}{t}$$

Where,

T	is thickness in mm,
D	is maximum internal diameter in mm,
P	is maximum allowable working pressure in kg/cm^2 (g),
f	is maximum permissible working stress as prescribed in Regulation 145 or 229 whichever is applicable in kg/cm^2 at the working metal temperature,
E	is Efficiency factor for fusion welded shells as given in table below, is 1.00 for seamless shells or shells made from seamless tubes, is Efficiency of ligaments between holes or openings in shell expressed as a fraction.
0.75	is the additive thickness in order to take corrosion into account.



$$\sigma_h = \frac{p_i r_i^2 - p_o r_o^2}{r_o^2 - r_i^2} + \frac{(p_i - p_o) r_o^2 r_i^2}{(r_o^2 - r_i^2) r^2}$$

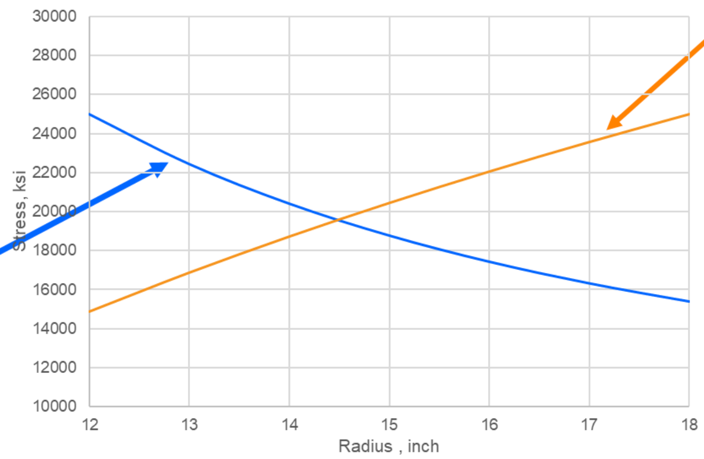
$$t = \frac{PR}{SE-0.6P} \quad \text{or} \quad P = \frac{SEt}{R+0.6t}$$

$$P = \frac{2SE(t-C)}{D-2y(t-C)} \quad \text{or} \quad \frac{SE(t-C)}{R+(1-y)(t-C)}$$

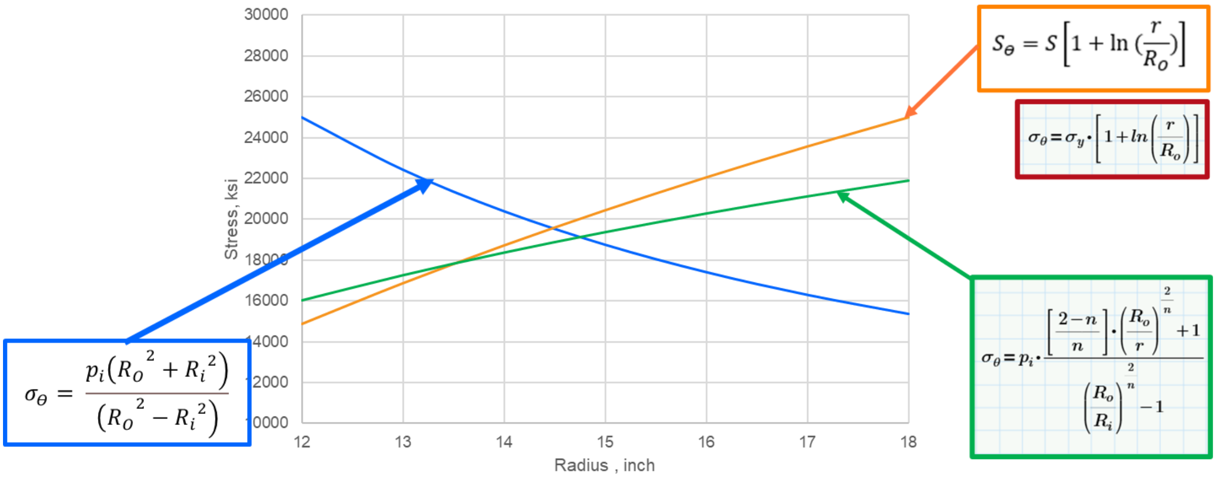
$$S = \frac{PR}{t}$$

$$S_\Theta = S\left[1 + \ln\left(\frac{r}{R_O}\right)\right]$$

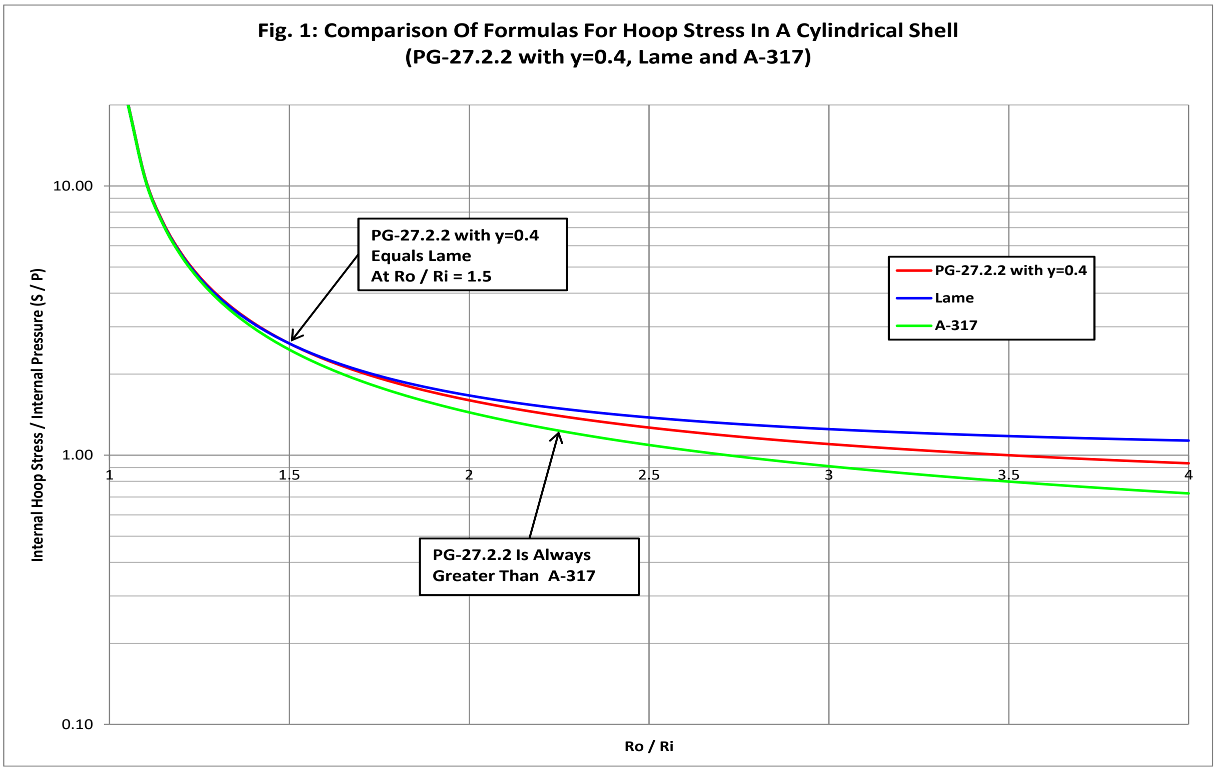
$$\sigma_\theta = \sigma_y \cdot \left[1 + ln\left(\frac{r}{R_o}\right)\right]$$



$$\sigma_\Theta = \frac{p_i\left(R_O{}^2 + R_i{}^2\right)}{\left(R_O{}^2 - R_i{}^2\right)}$$



Y factor is introduced in Section I to take into account of the reduction of stress due to redistribution when the temperature is in the creep region.



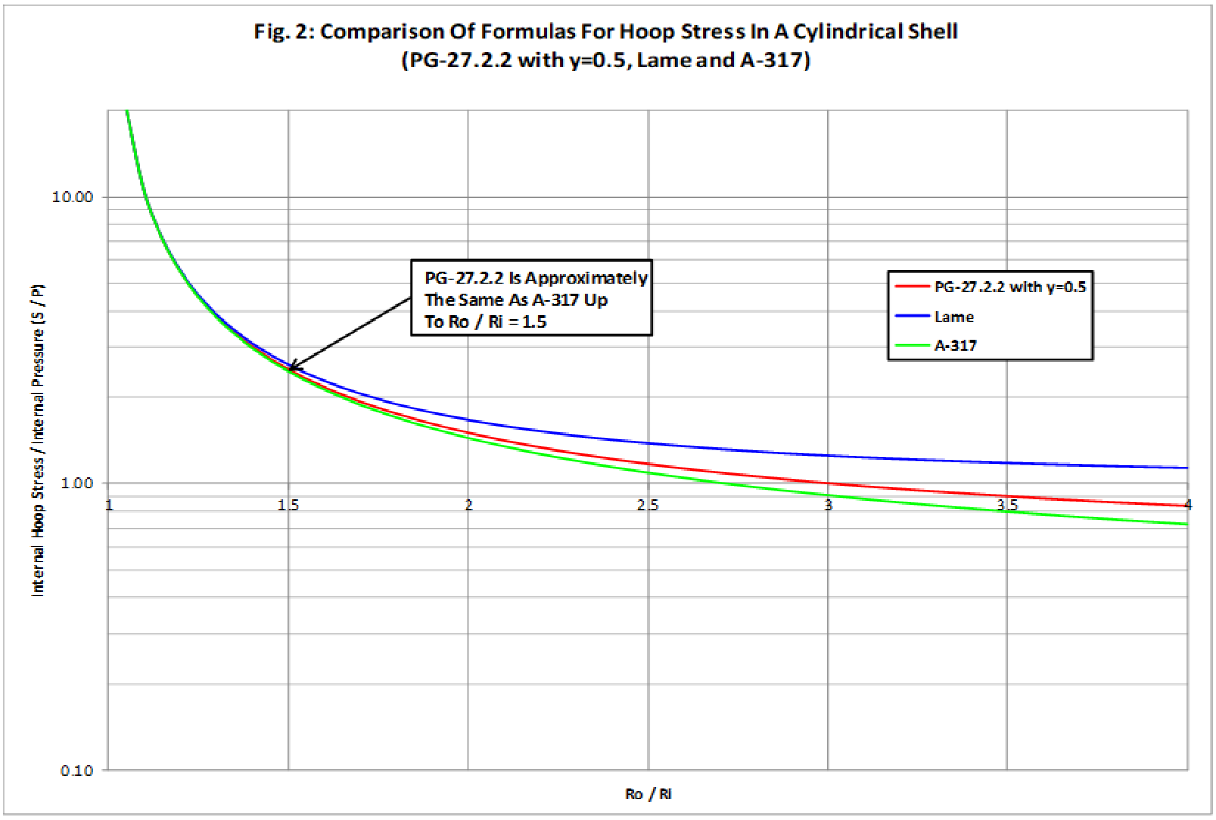


Fig. 2: Comparison Of Formulas For Hoop Stress In A Cylindrical Shell
(PG-27.2.2 with y=0.5, Lame and A-317)
10.00
1.00
0.10
Internal Hoop Stress / Internal Pressure (S / P)
1
1.5
2
2.5
3
3.5
4
Ro / Ri
PG-27.2.2 Is Approximately The Same As A-317 Up To Ro / Ri = 1.5
PG-27.2.2 with y=0.5
Lame
A-317

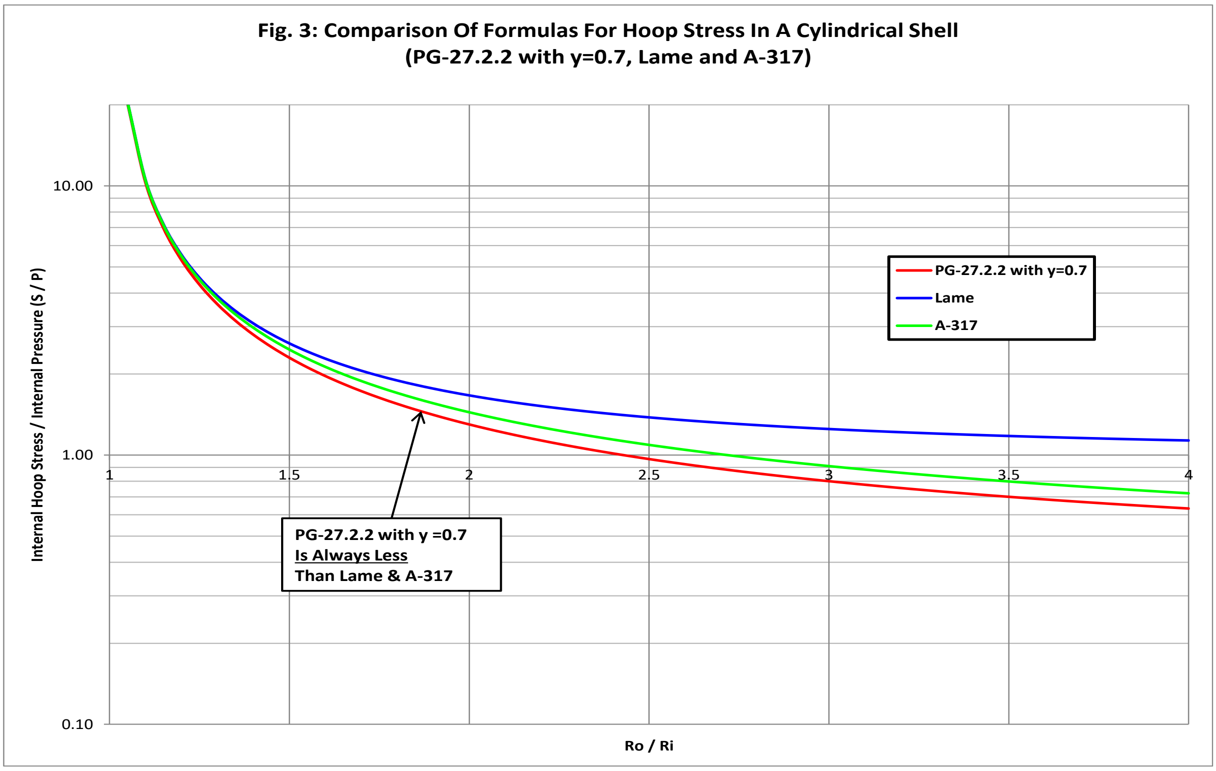
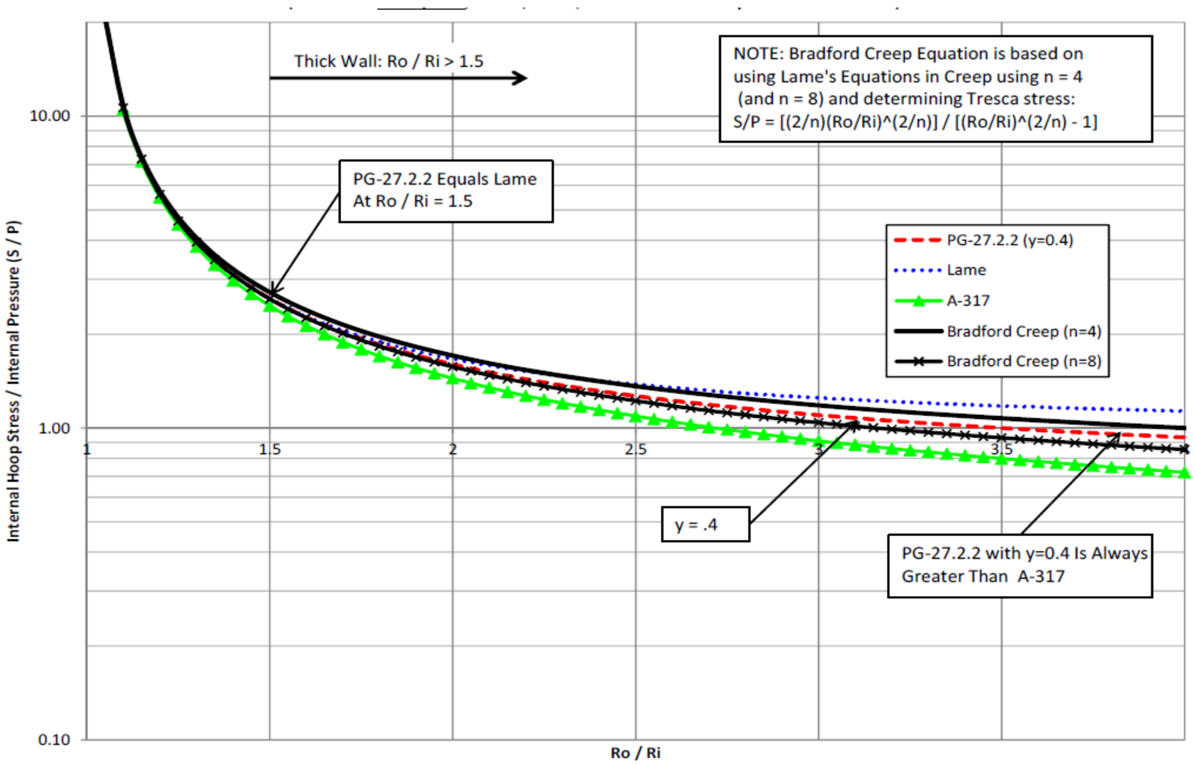
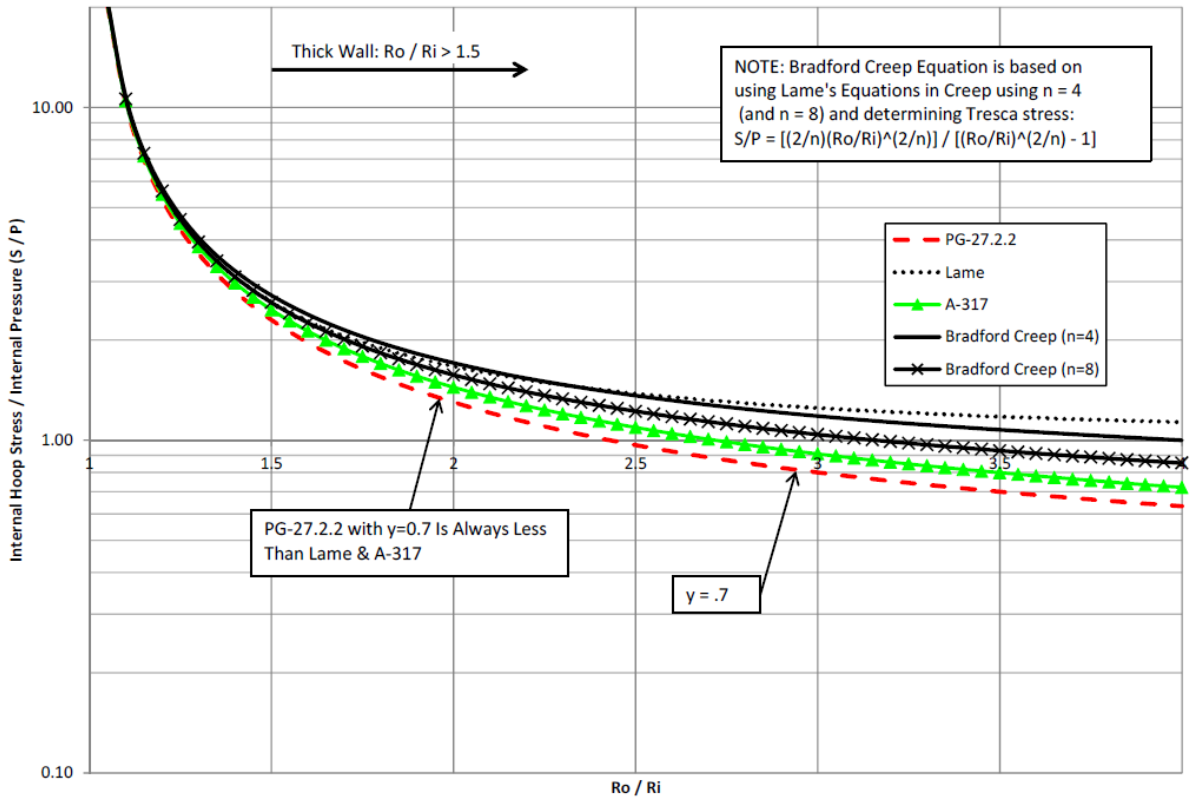


Fig. 3: Comparison Of Formulas For Hoop Stress In A Cylindrical Shell
(PG-27.2.2 with y=0.7, Lame and A-317)
10.00
1.00
0.10
Internal Hoop Stress / Internal Pressure (S / P)
1
1.5
2
2.5
3
3.5
4
Ro / Ri
PG-27.2.2 with y=0.7
Lame
A-317
PG-27.2.2 with y =0.7
Is Always Less
Than Lame & A-317


Thick Wall: Ro / Ri > 1.5
NOTE: Bradford Creep Equation is based on using Lame's Equations in Creep using n = 4 (and n = 8) and determining Tresca stress: S/P = [(2/n)(Ro/Ri)^(2/n)] / [(Ro/Ri)^(2/n) - 1]
PG-27.2.2 Equals Lame At Ro / Ri = 1.5
PG-27.2.2 (y=0.4)
Lame
A-317
Bradford Creep (n=4)
Bradford Creep (n=8)
y = .4
PG-27.2.2 with y=0.4 Is Always Greater Than A-317
Internal Hoop Stress / Internal Pressure (S / P)
Ro / Ri
10.00
1.00
0.10
1
1.5
2
2.5
3
3.5


Thick Wall: Ro / Ri > 1.5
NOTE: Bradford Creep Equation is based on using Lame's Equations in Creep using n = 4 (and n = 8) and determining Tresca stress: S/P = [(2/n)(Ro/Ri)^(2/n)] / [(Ro/Ri)^(2/n) - 1]
PG-27.2.2
Lame
A-317
Bradford Creep (n=4)
Bradford Creep (n=8)
PG-27.2.2 with y=0.7 Is Always Less Than Lame & A-317
y = .7
Internal Hoop Stress / Internal Pressure (S / P)
Ro / Ri
10.00
1.00
0.10
1
1.5
2
2.5
3
3.5

PART PA , ALTERNATIVE RULES FOR BOILER CONSTRUCTION - What is in it for me?

PART PA
ALTERNATIVE RULES FOR BOILER CONSTRUCTION

PA-1 GENERAL

Components designed and constructed to the rules of Section VIII, Division 2 may be installed in a Section I boiler, provided all other requirements of Section I are satisfied by a Section I certificate holder and the requirements of Part PA are met.

PA-2 CODE BOUNDARIES AND INTERFACES

The design and fabrication of components shall be per Section VIII, Division 2. The interface between Section VIII, Division 2 components and other parts of the Section I system shall be of welded construction and shall also meet the thickness requirements of Section I.

(21) PA-3 DESIGN SPECIFICATION AND DESIGN REPORT

When required by Section VIII, Division 2, a Certified User's Design Specification and Certified Manufacturer's Design Report shall be provided for the component.

PA-4 CONSTRUCTION

PA-4.1

Layered construction as permitted in Section VIII, Division 2 is not permitted in Section I construction.

PA-4.2

Components constructed of Section VIII, Division 2 rules shall have all joints of Category A in accordance with Type No. 1, and all joints of Category B in accordance with Type No. 1 or 2.

PA-5 MATERIALS

Materials shall comply with Section I, PG-5.5 and shall be limited to those permitted by both Section I and Section VIII, Division 2 and to the design temperature limits of Section VIII, Division 2.

PA-6 HYDROSTATIC TEST

The shop hydrostatic test pressure(s) shall be the larger of the test pressures determined by Section VIII, Division 2 and Section I, PG-99.1. The equivalent stress limits due to hydrostatic testing of the Section VIII, Division 2 components shall not exceed those prescribed by Section VIII, Division 2. After installation into a power boiler, such components shall also be subjected to that system's hydrostatic test.

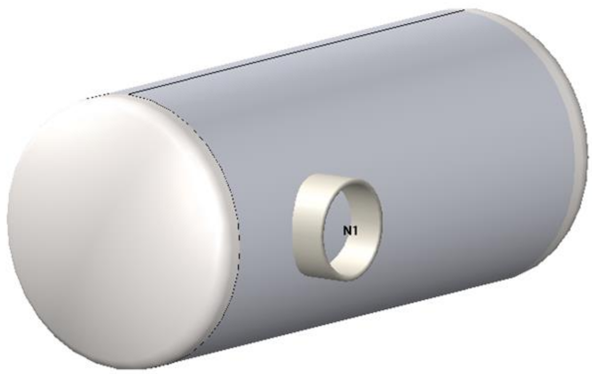
PA-7 DATA REPORTS AND STAMPING (21)

PA-7.1

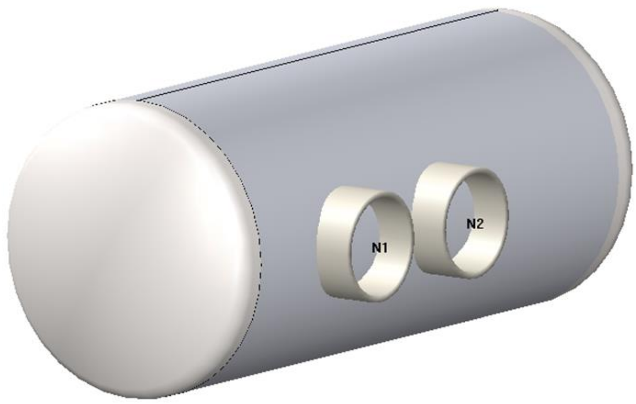
Components constructed to Section VIII, Division 2 rules shall be stamped with the Certification Mark with "U2" Designator and additional marking as required by Section VIII, Division 2. Section VIII, Division 2, Form A-1, Manufacturer's Data Report for Pressure Vessels, shall be completed for documentation. A Section VIII, Division 2 nameplate shall be furnished and marked "Section I, Part PA."

PA-7.2

Form A-1, Manufacturer's Data Report for Pressure Vessels, shall be included in the Section I Master Data Report for the completed boiler unit (see PG-113) and shall state "Components designed and constructed to Section VIII, Division 2, as permitted by Part PA."



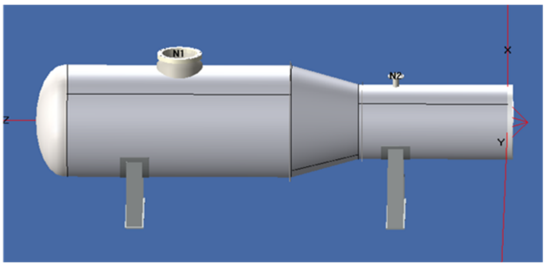
- P = 350 psi
- OD = 48”, t = ½”
- Nozzle N1
  - 18” OD,
  - t_n=1.062”
- ***N1 doesn’t meet UG-37*.**
- **$A_{required}$ = 7.1263 in^2**
- ***$A_{available}$ = 3.0548 in^2***



- P = 350 psi
- OD = 48”, t = ½”
- Nozzles N1 & N2
  - 18” OD,
  - t_n= 1.062”
- *Fully compensated as is. Moreover, N1 and N2 centerlines can be as close as 25.375” which is roughly 20% less than VIII-1 rules*

Design label	Data
Design Pressure	2MPa(g)/ FV
Design Temperature	250°C
Material of construction (Shell, cone, dish, flat head)	SA-738 Gr B
Material of construction (Nozzles)	SA-335 P12

Case Study 1: Design of vessel



Material	Allowable per Div 1	Allowable per Div 2 Cl. 1	Allowable per Div 2. Cl 2
SA-738 Gr. B $\|_{250°C}$ 23	168 MPa	195 MPa	222 MPa
SA-335 P12 $\|_{250°C}$	114 MPa	116 MPa	116 MPa

The stress is yield controlled

Case Study 1: Shell thickness calculation (Internal pressure) - SA-738 B

ASME Section VIII Div 1

Design thickness, (at 250 °C) Appendix 1-1

$$
\begin{aligned}
t &= P*R_o / (S*E + 0.40*P) + \text{Corrosion} \\
&= 2{,}000*750 / (168{,}000*0.85 + 0.40*2{,}000) + 0 \\
&= \underline{10.45} \text{ mm}
\end{aligned}
$$

ASME Section VIII Div 2 Cl.1

4.3.3.1 Design Thickness for Internal Pressure	
$t_d = D / 2 * (\exp[P / (S*E)] - 1) + \text{Corrosion}$	(4.3.1)
Operating Hot & Corroded	
$t_d = 1{,}480 / 2 * (\exp[((2{,}000 + 0) / 1000) / (195*0.85)] - 1) + 0 =$	8.98 mm
Operating Cold & Corroded	
$t_r = 1{,}480 / 2 * (\exp[((2{,}011.84 + 0) / 1000) / (195*0.85)] - 1) =$	9.04 mm

ASME Section VIII Div 2 Cl.2

4.3.3.1 Design Thickness for Internal Pressure	
$t_d = D / 2 * (\exp[P / (S*E)] - 1) + \text{Corrosion}$	(4.3.1)
Operating Hot & Corroded	
$t_d = 1{,}484 / 2 * (\exp[((2{,}000 + 0) / 1000) / (222*0.85)] - 1) + 0 =$	7.91 mm
Operating Cold & Corroded	
$t_r = 1{,}484 / 2 * (\exp[((2{,}000 + 0) / 1000) / (244*0.85)] - 1) =$	7.19 mm

Observation:

Code	Thickness	Reduction
Div. 1	10.45 mm	
Div. 2 Cl1	8.98 mm	14.1%
Div. 2 Cl2	7.91 mm	24.3%

Case Study 1: Ellipsoidal dish thickness calculation (Internal pressure)- SA-738 Gr B

ASME Section VIII Div 1

Factor K		
K = (1/6)*[2 + (D / (2*h))^2]		
Corroded	K = (1/6)*[2 + (1,479.16 / (2*369.79))^2]	1
New	K = (1/6)*[2 + (1,479.16 / (2*369.79))^2]	1

Design thickness for internal pressure, (Corroded at 250 °C) Appendix 1-4(c)

t = P*D_o*K / (2*S*E + 2*P*(K - 0.1)) + Corrosion
= 2,000*1,500*1 / (2*168,000*0.85 + 2*2,000*(1 - 0.1)) + 0
= 10.37 mm

Calculate correction factor
Substitute values in the empirical relations

ASME Section VIII Div 2 Cl 1

Operating Hot & Corroded	
k = 1,484 / (2*371) =	2
r = 1,484*(0.5 / 2 - 0.08) =	252.28 mm
L = 1,484*(0.44*2 + 0.02) =	1,335.6 mm
0.7 ≤ L / D = 1,335.6 / 1,484 = 0.9 ≤ 1	OK
r / D = 252.28 / 1,484 = 0.17 ≥ 0.06	OK
20 ≤ L / t = 1,335.6 / 7 = 190.8 ≤ 2,000	OK
β_{th} = arccos[(0.5*1,484 - 252.28) / (1,335.6 - 252.28)] =	1.1017
ϕ_{th} = (1,335.6 * 6.87)$^{1/2}$ / 252.28 =	0.3796
R_{th} = (0.5*1,484 - 252.28) / cos[(1.1017 - 0.3796)*180 / π] + 252.28 =	904.89 mm
C_1 = 0.692*252.28 / 1,484 + 0.605 =	0.7226
C_2 = 1.46 - 2.6*252.28 / 1,484 =	1.018
P_{eth} = 0.7226*189.0E+06*6.87^2 / (1.018*904.89*(904.89 / 2 - 252.28)) =	34,927.65 kPa

Iterative analysis
Assume value for t

ASME Section VIII Div 2 Cl 1

C_3 = S_y =	333 MPa
P_y = 333,000*6.87 / {1.018*904.89*(904.89 / (2*252.28) - 1)} =	3,128.64 kPa
G = 34,927.65 / 3,128.64 =	11.1638
P_{ck} = {(0.77508*11.1638 - 0.20354*11.1638^2 + 0.019274*11.1638^3) / (1 + 0.19014*11.1638 - 0.089534*11.1638^2 + 0.0093965*11.1638^3)} * 3,128.64 =	6,273.9 kPa
P_{ak} = 6,273.9 / 1.5 =	4,182.6 kPa
P_{ac} = 2*195,000*1 / (1,335.6 / 6.87 + 0.5) =	2,000 kPa
P_a = min[4,182.6 , 2,000] - 0 =	2,000 kPa
t_d = 6.87 + 0 = 6.87 mm	

Case Study 1: Ellipsoidal dish thickness calculation (Internal pressure)- SA-738 Gr B

ASME Section VIII Div 2 Cl 2

$C_3 = S_y =$	333 MPa
P_y = 333,000*6.04 / {1.018*920.35*(920.35 / (2*252.62) - 1)} =	2,611.99 kPa
G = 25,605.35 / 2,611.99 =	9.803
P_{ck} = {(0.77508*9.803 - 0.20354*9.803^2 + 0.019274*9.803^3) / (1 + 0.19014*9.803 - 0.089534*9.803^2 + 0.0093965*9.803^3)} * 2,611.99 =	5,200.16 kPa
P_{ak} = 5,200.16 / 1.5 =	3,466.77 kPa
P_{ac} = 2*222,000*1 / (1,337.4 / 6.04 + 0.5) =	2,000 kPa
P_a = min[3,466.77 , 2,000] - 0 =	2,000 kPa
t_d = 6.04 + 0 = 6.04 mm	

Observation:

Code	Thickness	Reduction
Div. 1	10.37 mm	
Div. 2 Cl1	6.87 mm	33.7%
Div. 2 Cl2	6.04 mm	41.7%

Case Study 1: Cone thickness calculation (Internal pressure)

ASME Section VIII Div 1

Design thickness, (at 250 °C) App 1-4(e) (Large End)

t = P*D_o / (2*cos(α)*(S*E + 0.40*P)) + Corrosion
= 2,000*1,500 / (2*cos(15.5241)*(168,000*0.85 + 0.40*2,000)) + 0
= 10.84 mm

ASME Section VIII Div 2 Cl 2

4.3.4.1 Design Thickness for Internal Pressure		
t_d = D / (2*cos[α]) * (exp[P / (S*E)] - 1) + Corrosion		(4.3.2)
Operating Hot & Corroded		
Left	t_d = 1,481.32 / (2*cos[15.5241]) * (exp[((2,000 + 0) / 1000) / (222*0.85)] - 1) + 0 =	8.19 mm
Right	t_d = 981.32 / (2*cos[15.5241]) * (exp[((2,000 + 0) / 1000) / (222*0.85)] - 1) + 0 =	5.43 mm

ASME Section VIII Div 2 Cl 1

4.3.4.1 Design Thickness for Internal Pressure		
t_d = D / (2*cos[α]) * (exp[P / (S*E)] - 1) + Corrosion		(4.3.2)
Operating Hot & Corroded		
Left	t_d = 1,479.24 / (2*cos[15.5241]) * (exp[((2,000 + 0) / 1000) / (195*0.85)] - 1) + 0 =	9.32 mm
Right	t_d = 979.24 / (2*cos[15.5241]) * (exp[((2,000 + 0) / 1000) / (195*0.85)] - 1) + 0 =	6.17 mm

Observation:

Code	Thickness	Reduction
Div. 1	10.84 mm	
Div. 2 Cl1	9.32 mm	14.02%
Div. 2 Cl2	8.19 mm	24.45%

Case Study 1: Flat plate thickness

ASME Section VIII Div 1

Design thickness, (at 250 °C) UG-34(c)(2)

$$t = d*Sqr(C*P / 1000 / (S*E)) + Corrosion$$
$$= 976*Sqr(0.33*2{,}000 / 1000 / (138*1)) + 0$$
$$= 67.5 \text{ mm}$$

ASME Section VIII Div 2 Cl 2

4.6.2.2 Design Thickness	
$t_d = d*\{C*P / (S_{ho}*E)\}^{0.5} + C_i + C_o$	(4.6.1)
Operating Hot & Corroded	
$t_d = 982*\{0.33*(2{,}000 + 0) / 1000 / (144*1)\}^{0.5} + 0 + 0 =$	66.48 mm

ASME Section VIII Div 2 Cl 1

4.6.2.2 Design Thickness	
$t_d = d*\{C*P / (S_{ho}*E)\}^{0.5} + C_i + C_o$	(4.6.1)
Operating Hot & Corroded	
$t_d = 982*\{0.33*(2{,}000 + 0) / 1000 / (143*1)\}^{0.5} + 0 + 0 =$	66.71 mm

Observation:

Code	Thickness	Reduction
Div. 1	67.5 mm	
Div. 2 Cl1	66.71 mm	1.2%
Div. 2 Cl2	66.48 mm	1.5%

Case Study 1: Cylindrical shell thickness (External pressure)

ASME Section VIII Div 1

External Pressure, (Corroded & at 250 °C) UG-28(c)

$L / D_o = 3{,}158.26 / 1{,}500 = 2.1055$

$D_o / t = 1{,}500 / 6.57 = 228.3882$

From table G: $A = 0.000181$

$$P_a = 2*A*E / (3*(D_o / t))$$
$$= 2*0.000181*195294116.13 / (3*(1{,}500 / 6.57))$$
$$= 103 \text{ kPa}$$

Design thickness for external pressure P_a = 103 kPa

t_a = t + Corrosion = 6.57 + 0 = 6.57 mm

ASME Section VIII Div 2 Cl1

$P_a = 2*12{,}314.69*6.27 / 1{,}500 =$	103 kPa
$t_e = 6.27 + 0 = 6.27$ mm	

ASME Section VIII Div 2 Cl1

$P_a = 2*12{,}314.48*6.27 / 1{,}500 =$	103 kPa
$t_e = 6.27 + 0 = 6.27$ mm	

No change as the calculation is yield based

Observation:

Code	Thickness	Reduction
Div. 1	6.57 mm	
Div. 2 Cl1	6.27 mm	4.5%
Div. 2 Cl2	6.27 mm	4.5%

Case Study 1: Formed head thickness (External pressure)

ASME Section VIII Div 1

Equivalent outside spherical radius (R_o)

R_o = K_o*D_o
= 0.8877*1,500
= 1,331.5 mm

A = 0.125 / (R_o / t)
= 0.125 / (1,331.5 / 3.89)
= 0.000365

From Table CS-5 Metric:B = 35.2362 MPa

P_a = B / (R_o / t)
= 35,236.23 / (1,331.5 / 3.89)
= 103 kPa

t = 3.89 mm + Corrosion = 3.89 mm + 0 mm = 3.89 mm

No change as the calculation is yield based

ASME Section VIII Div 2 Cl 1

P_a = 2*19,105.19*3.62 / 1,341.76 =	103 kPa
t_e = 3.62 + 0 = 3.62 mm	

ASME Section VIII Div 2 Cl 2

P_a = 2*19,105.19*3.62 / 1,341.76 =	103 kPa
t_e = 3.62 + 0 = 3.62 mm	

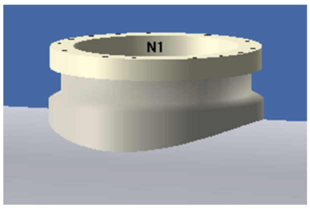
Observation:

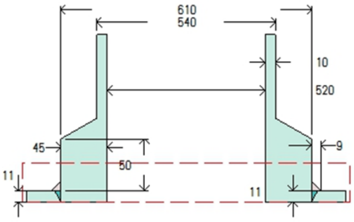
Code	Thickness	Reduction
Div. 1	3.89 mm	
Div. 2 Cl1	3.62 mm	6.9%
Div. 2 Cl2	3.62 mm	6.9%

Case Study 1: Nozzle reinforcement

ASME Section VIII Div 1

UG-37 Area Calculation Summary (cm^2)							UG-45 Summary (mm)	
For P = 2,000 kPa @ 250 °C *The opening is NOT adequately reinforced*							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
49.1404	25.0322	10.5477	13.9348	--	--	0.5497	8.89	10





Area based evaluation: Result failure!!!

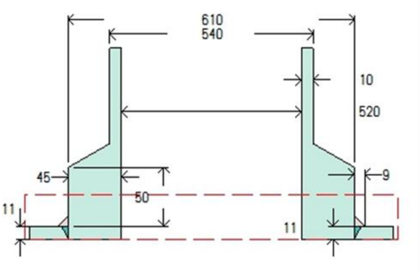
ASME Section VIII Div 2 Cl 1

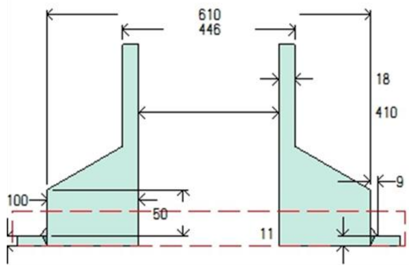
4.5.5 Maximum Local Primary Membrane Stress					
Condition	P (kPa)	P_L (MPa)	S_{allow} (MPa)	Over stressed	P_{max} (kPa)
Design P	2,000	290.779	292.5	No	2,011.84
Design Pe	103	14.975	25.124	No	172.8

ASME Section VIII Div 2 Cl 2

4.5.5 Maximum Local Primary Membrane Stress					
Condition	P (kPa)	P_L (MPa)	S_{allow} (MPa)	Over stressed	P_{max} (kPa)
Design P	2,000	324.36	333	No	2,053.27
Design Pe	103	16.882	17.86	No	108.97

Stress evaluation: Results in decreased reinforcement requirement





UG-37 Area Calculation Summary (cm^2)							UG-45 Summary (mm)	
For P = 2,000 kPa @ 250 °C *The opening is NOT adequately reinforced*							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
49.1404	25.0322	10.5477	13.9348	--	--	0.5497	8.89	10

UG-37 Area Calculation Summary (cm^2)							UG-45 Summary (mm)	
For P = 2,000 kPa @ 250 °C The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
42.5072	42.8522	7.4755	34.827	--	--	0.5497	8.89	18

Case Study 1: Summary

Code Rules	Div1	Div 2 Cl 1	Div 2 Cl2
Pressure (MPa)	2	2	2
Temperature (ºC)	250	250	250
Material (Shell/ dish/ cone)	SA-738 Gr B	SA-738 Gr B	SA-738 Gr B
Allowable stress -Shell/heads/cone (MPa)	168	195	222
Material (Nozzle)	SA-335 P12	SA-335 P12	SA-335 P12
Allowable stress -nozzle (MPa)	114	116	116
Required shell thickness (mm)	10.45	8.98	7.91
Shell weight (kg)	1184	1077.1	862.9
Required dished end thickness (mm)	10.37	6.87	6.04
Dished end weight (kg)	229.5	155.8	134.7
Vessel weight (kg)	2878	2569	2314

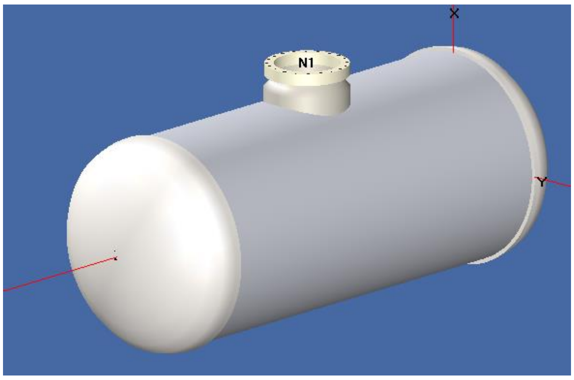
Weight reduction

Code	%
Div 1	-
Div 2 Cl 1	10.6
Div 2 Cl 2	19.4

309kg saving If designed by Cl1

564kg saving If designed by Cl2

Code Rules	Div1	Div 2 Cl 1	Div 2 Cl2
Pressure (MPa)	5	5	5
Temperature (ºC)	250	250	250
Material (Shell/ dish)	SA-516 Gr 70	SA-516 Gr 70	SA-516 Gr 70
Allowable stress (MPa)	138	143	144



Case Study 2: Based on SA-516 Gr 70 1500mm ID @5MPa exposed to 250ºC

Code Rules	**Div1**	**Div 2 Cl 1**	**Div 2 Cl2**
Pressure (MPa)	5	5	5
Temperature (ºC)	250	250	250
Material (Shell/ dish/ cone)	SA-516 70	SA-516 70	SA-516 70
Allowable stress -Shell/ dish/ cone (MPa)	138	143	144
Material (Nozzle)	SA-105	SA-105	SA-105
Allowable stress -nozzle (MPa)	136	136	136
Required shell thickness (mm)	26.79	25.69	25.51
Shell weight (kg)	2979	2770	2770
Required dished end thickness (mm)	27.27	23.81	23.64
Dished end weight (kg)	652	560	560
Vessel weight (kg)	4597	4131	4131

Weight reduction

Code	%
Div 1	-
Div 2 Cl 1	10.1
Div 2 Cl 2	10.1

466 kg saving If designed by Div 2

Section I Code Case for Creep Intolerant CSEF Steels in time dependent service for Section I Construction - Why is it important?

Section I currently, has no rules for CSEF steels that develop the onset of creep cavitation damage which results in very low creep rupture ductility (brittle and unpredictable behavior) in service. This behavior if confirmed renders the CSEF steel damage intolerant.

Code Case 3048 classifies CSEF steel heats based on an initial review or screening of creep rupture ductility (RofA) and to perform subsequent creep testing to generate a lambda parameter to specifically address low creep rupture ductility in design, if confirmed.

This Code Case also provides alternative design rules, where no rules exist, that are conservative for using intolerant CSEF steels.

Creep strength enhanced ferritic (CSEF) steels are a family of ferritic alloys whose high temperature creep strength is enhanced by the creation of a precise condition of microstructure, specifically martensite or bainite, which is stabilized during tempering by controlled precipitation of temper-resistant carbides, carbonitrides, or other stable and/or meta-stable phases.

Creep Intolerant CSEF steels: Creep cavitation susceptibility is indicated by the limited amount of deformation at the time of creep rupture failure. Such materials will exhibit a reduction of area (RoA) value of <70% for specimens which are creep tested at an applied stress that is <60% of the yield stress at the maximum design metal temperature (Section II, Part D, Table Y-1).

Lambda Parameter for Creep Intolerant CSEF steels: Creep intolerant CSEF steels have high susceptibility to creep cavity formation (intolerant behavior), little creep deformation before rupture and high sensitivity to multiaxial stresses (e.g., trending to notch weakening behavior).

The Lambda parameter is calculated using equation below

The lambda parameter shall be calculated from either creep rupture data of the tested heats of material obtained in accordance with ASME Section II Part D Mandatory Appendix 5 or from published creep test data for the applicable CSEF steel.

ε_f = elongation strain at failure

$\dot{\varepsilon}_{min}$ = minimum creep rate. When relevant, the steady state (secondary) creep rate $\dot{\varepsilon}_{ss}$ can be substituted

t_r = time to rupture

$$\lambda = \frac{\varepsilon_f}{\dot{\varepsilon}_{min} t_r}$$

If the value of λ is less than 5, the material shall be classified as creep intolerant material.

If creep rupture testing was not able to be conducted to determine the value of lambda or no published creep rupture data exists for the applicable CSEF steel, the material shall be classified as creep intolerant and shall follow the requirements of this code case for elevated temperature design.

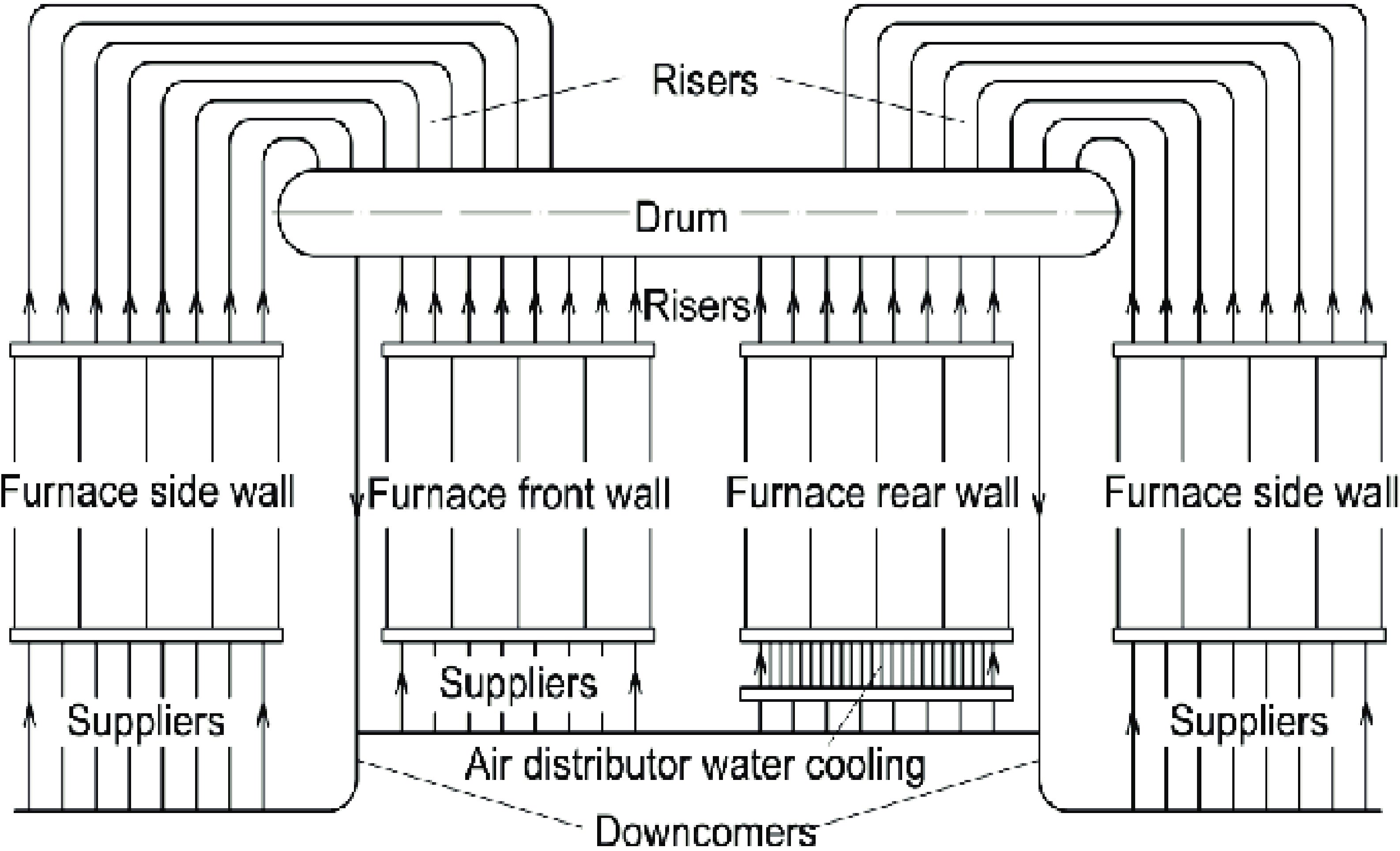
Materials identified as creep intolerant with a component design temperature in the time dependent regime shall use a reduced allowable stress. This reduced allowable stress value is dependent on geometry using a K factor. The allowable stress value provided in ASME B&PV Code Section II, Part D, Table 1A, shall be multiplied by a factor, F, defined by the following Equation.

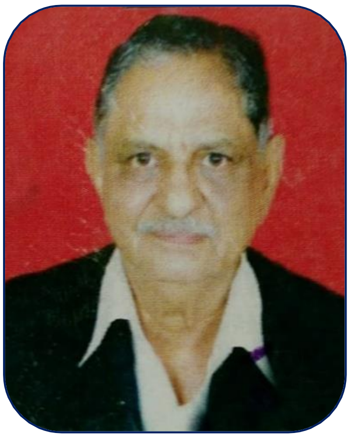
$$F = \frac{1}{1+0.2(K-1)}$$

Geometry/feature	K
Cylindrical welded components under internal pressure	1.0
Longitudinal seam welds	1.5
Dished heads	1.5
Unstayed flat heads and covers	2.5
Openings in shells, headers, heads (with or without compensation)	2.5
Ligaments	2.5
Supports and attachment lugs	2.0

Geometry/feature	F
Cylindrical components under internal pressure	1.000
Longitudinal seam welds	0.909
Dished heads	0.909
Unstayed flat heads and covers	0.769
Openings in shells, headers, heads (with or without compensation)	0.769
Ligaments	0.769
Supports and attachment lugs	0.833

It has been demonstrated by creep testing Grade 91 Type 2 CSEF steel does not exhibit creep intolerant behaviour, and is exempt from this Code Case.


Risers
Drum
Risers
Furnace side wall
Furnace front wall
Furnace rear wall
Furnace side wall
Suppliers
Suppliers
Suppliers
Air distributor water cooling
Downcomers



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INTRODUCTION

Steam Boiler Design is a very, vast & deep subject. Though the steam generation, steam properties, basic fundamentals universally are same but many reputed Steam Boiler manufacturers in world have their own research & development departments where in continuous research is going on for boiler designs. Each manufacturer have own types of steam boilers. Designer has to design steam boilers considering i. type of boiler to be designed, type of fuel to be burned, iii. Calorific value of the fuel to be burnt, iv. Geometrical shapes of the steam pressure parts to be designed, v. the Nationally recognized code under which the pressure parts are to be designed etc.

Generally, types of steam boilers universally

Land steam boilers,

i. Shell -types steam boilers
ii. Shell smoke tubes steam boilers
iii. Shell smoke tubes with water tubes steam boilers
iv. Steam drum, drums, straight tubes staggered corrugated headers, bottom header box types steam boilers, Bi-drum water tubes steam boilers with natural circulation / forced circulation steam boilers.
v. Sub critical, super critical steam boilers
vi. Locomotive type - steam boilers
vii. Marin steam boilers etc.

Steam generation requires heat input in the form of solid, liquid, gaseous, agricultural wastes etc. The heat is generated by burning the fuel in various types of furnaces.

The compliers of this book has tried to concentrate mainly on the various pressure parts, geometrical shapes and sizes, because while designing various pressure parts of steam boiler mostly total pressure acting on the pressure parts' total area is considered. The compliers of this book, while scrutinizing case studies of several accidents of steam boiler pressure parts during past more than 5 decades have finally observed that along with the total steam pressure acting on the areas in contact the resultants resulted because of the geometrical shapes of the pressure parts creates fatal conditions & accident occurs. Though the pressure parts are manufactured with good engineering practices, strictly following code norms. Hence the designer must find the resultants & their directions. Secondly we consider total load on the pressure parts area the load on cylindrical shells, drums, internal, cylindrical furnace drums, smoke tubes both end tube plates having expanding & seal fillet welding, the fillet welds have limitations compared to butt weld. Generally fillet welds are week by about @20 to 30 % compared to the butt welds. In case of steam W.P. above 17.5 kg/sq.cm the shell diameter, having flat tube plates, should be restricted up to 1700 mm for safety point of view, in good olden days the smoke tubes horizontal shell type boilers, such as i. Lancashire, ii. Cornish, iii. marine etc. boilers flat end plates were used up to shell diameters up to @ 6 feet & W.P. restricted to 12 kg/sq.cm. Above W.P. 12 kg/sq.cm & shell diameter 6 ft. the flat end plates used to be partially dished type by forming the edges curved shape. This was to avoid ‘Lap joints’ single/double strap, riveted joint and to use ‘Butt joints’ single/double straps. After the welding techniques were developed & used the pressure parts fabrication, these ‘Lap joint’ were replaced by ‘Filet weld’ & ‘butt joints’ by ‘butt welds. The so called ‘Lap joint’ riveted joint were taken as week compared to the ‘ butt joints’ riveted types, in the same manner the ‘fillet welds’ are also are actually @20 to 30 % less stronger than the ‘butt joints’ of welded types, it is more safe to use ‘butt weld joints’ when the flat portion of the pressure part is more than 6 ft.& W.P. is above 12 kg/sq.cm. Secondly, owner (boiler manufacturer) takes order to supply a boiler, the designer designs it considering economic point of view so that profit of margin is within limits. Owner supplies the unit manufactured, installs at purchasers site. Manufacturer takes every care that while manufacturing all pressure parts good engineering practice is followed along with the inspection authorities also checks, in stages the various parts are as per the code used. Open inspections, hydraulic test & there inspections, after steam test all tests are taken, witnessed and after his full satisfaction he recommends working of the unit after registering as required under saturating systems. All this is always followed but after the unit is registered & certified as required under code the boiler owner is permitted to use the same, under the charge of a competent engineers/ attendant. They strictly see that the boiler is working safely, but the owner may ask the workers to work the boiler with some increased working pressure to save the fuel, or he insists to delay the periodic cleaning intervals to save money. In some cases this practice may be adopted days…months…even years also. Increased working steam pressure, delayed periodic cleanings over stresses the pressure parts & a stage reaches at extreme dangerous point when sudden…fatal accident occurs, boiler explodes with in a fraction of second , various pressure parts, boiler auxiliaries, accessories are blown out few km’s away hitting public property & humans.

The explosion cases are of steam boilers mostly of more than 75 % because of this reasons. Hence we are compelled to elaborate and pen down all these reasons so that designers may think the issue as explained in this write up.

We have drawn few steam boilers designs, its’ so called geometrical shapes, their internal steam pressure acting directions, after striking them how they are reflected back in opposite directions with same force and how the resultant forces are created. For example cylindrical shell having flat end tubes plates, the shell internally when steam pressure is created the pressure strikes shell internal side concentrically, after striking it is reflected back with same force/pressure to the centre. In between the pressure strikes rows of smoke tubes fitted horizontally between both ends flat tube plates, cylindrical horizontally fitted integral furnace (furnaces), attached to the front tube plate of shell & front tube plate of the reversing chamber. After striking the pressure again is reflected back with same force out wards in the direction of shell internal surface but creating a resultant force which always strikes to both ends tube plates. All such resultant forces plus the resultants forces acting horizontally between both parallel end tubes plates having mirror effects multiplying the forces, all such resultant horizontal forces totally creates crushing/shearing effects on all fillet welds weakening them & a stage comes that both ends tubes plates explodes within a fraction of moment. Generally the fillet welds of shell circumferential fillet weld joint with shell end to the flat tube plate edges, all gussets fillet welds with both tubes plates, fillet weld joint of rear flat tube plate throwing furnace drums, reversing chamber's access ring attached to the rear end plat of the reversing chamber. All fillet welds are sheared off & internal all above pressure parts are suddenly thrown out exploding the boiler house/factory building side wall, roof injuring /killing several laborers nearby in the factory, out -side also several public members are injured/killed. The fillet welds are welded with good engineering practices, strict inspections still they shears off! This may be because of resultant forces created by various geometrical shapes of the pressure parts in the pressure vessel.

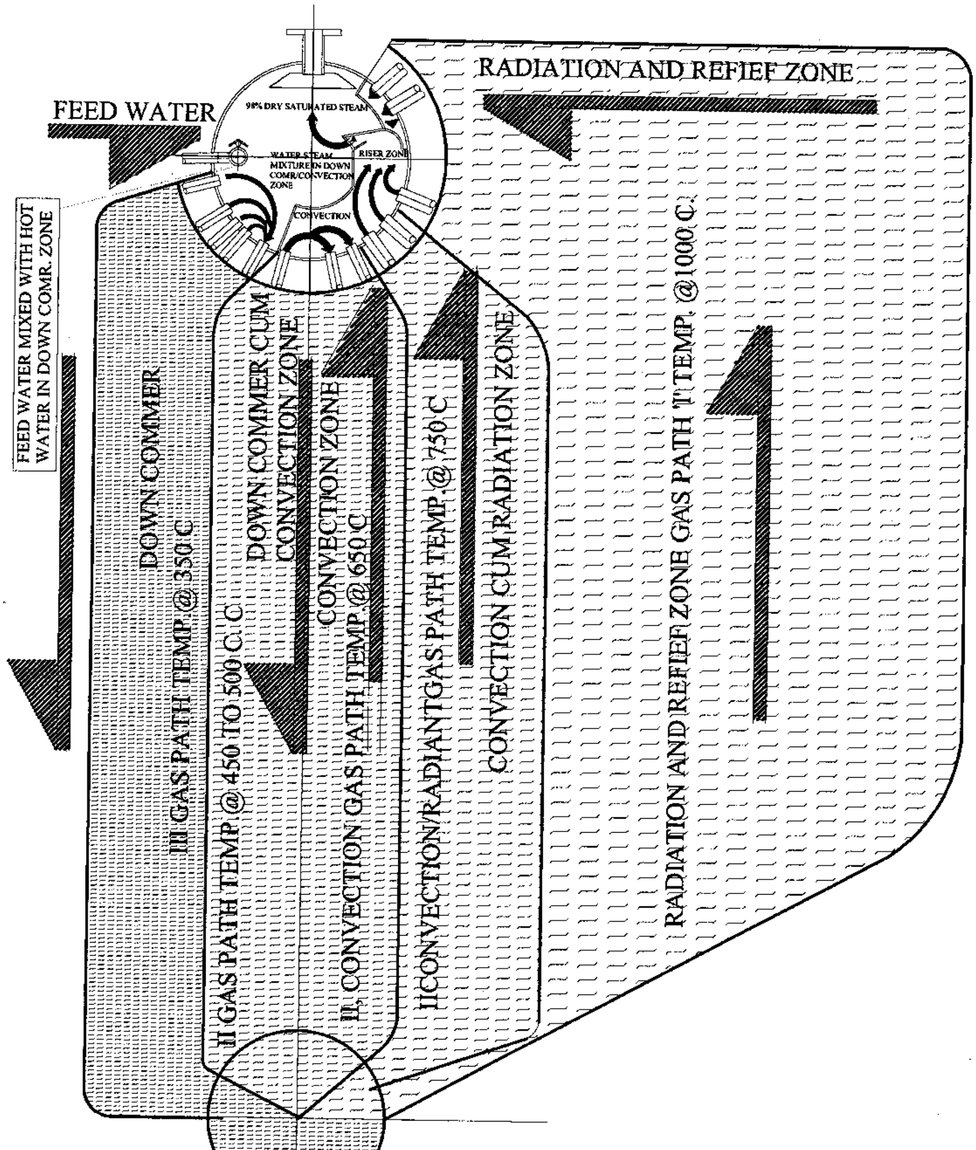
Boiler design is a specialized subject & up till now usually only the engineers working in design departments are studying/utilizing the techniques of boiler design, rather other engineers, in operations, utility, maintenance, mostly kept away from this subject. It is always better/helpful for various industries if the boiler operation/maintenance/utility engineers, boiler repairers' engineers, also have some knowledge of boiler design including the gas & water/steam circulation & their temperatures at various passes are known. Know a days ultra modern steam boilers, high pressure, sub critical/super critical steam boilers are being installed & worked, it has become needed that all engineers must have knowledge of steam boiler designing, along with boiler operation . In the same way the boiler manufacturing firms' all engineers, boiler fabricators, boiler repairing firm's all engineers too must have knowledge of steam boiler designing. This will avoid fatal accidents to the steam boilers & they will be worked more safely in better efficiency in the interest of our Nation. With this main view keeping in mind, we have compiled this book.

We have put efforts to explain the designing by giving several sketches/drawings of pressure vessels' pressure parts. We have also tried to explain step by step how fatal accidents occur due to giving lack of attentions towards the main culprit of the cause of accidents. That is the "total resultants pressure" occurring/resulting in the pressure vessels due the "geometrical shapes" being used in fabricating pressure parts of the pressure vessels. One should try to avoid bigger diameters, flat end, flat end tube plates of cylindrical shell/drums to avoid increased resultants pressure more than its working pressure. The out- side diameters of any flat end/tubes plate must be restricted within six feet (1800 mm) O/D to have safe/accident free pressure vessel. If at all the designer is compelled to use more diameter than 6 feet (1800 mm), he should use all edges of such bigger flat plates of semi-dished/spinned shapes so that all 'fillet welds' are avoided & all' butt weld joints' are used for safety. Unsupported areas of any flat shaped pressure parts must be restricted so that resultants pressure does not increase more than the working pressure of the vessel.

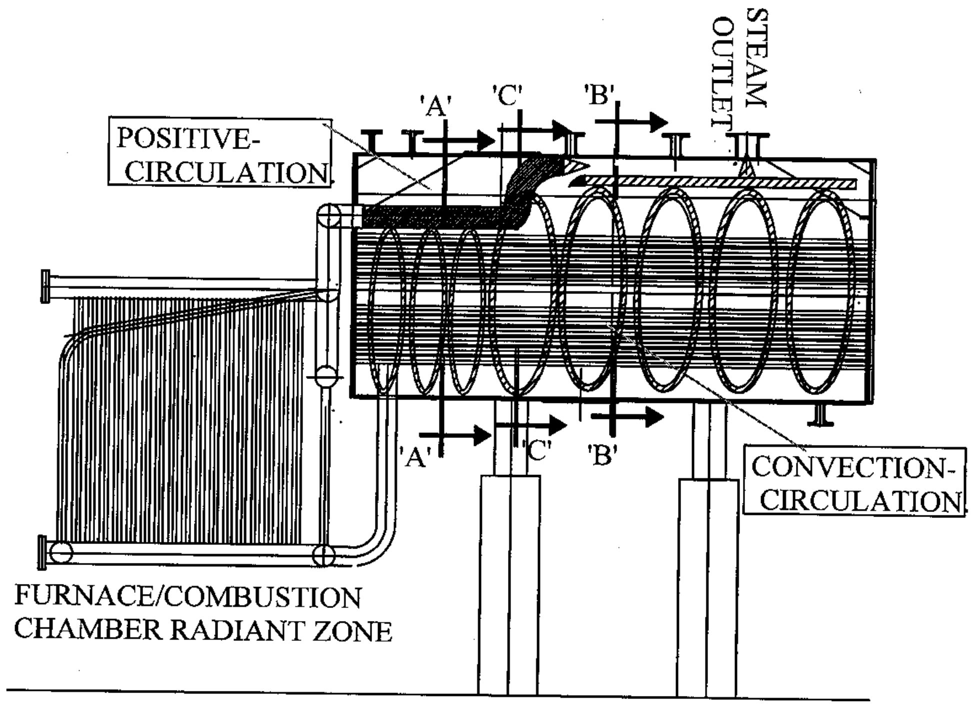
In case of single drum, bi-drums bent water tubes steam- boiler, the steam/water & mud drums are always have end plates of dished shapes. The dish shape always are safe since the resultant pressure is concentrated at the centre of the dish shape thus they are 100 % neutralized keeping pressure parts in same working steam pressure on each surface. Hence there no cases reported of steam drum bursting/explosions. We have explained with help of drawings of steam drums in this write up.

GAS CIRCULATION, WATER,WATER--STEAM,STEAM CIRCULATION TECHNIC IN VARIOUS TYPES OF STEAM BOILERS ARE SHOWN, RATHER EXPLAINED IN THE FOLLOWNG DRAWINGS:

Boiler designer must have the knowledge of i. gas, ii. water, iii. water-steam & iv. steam -circulation in steam generating all types of steam boilers. We have explained the same through various drawings below which will help the designer to under stand the issue.

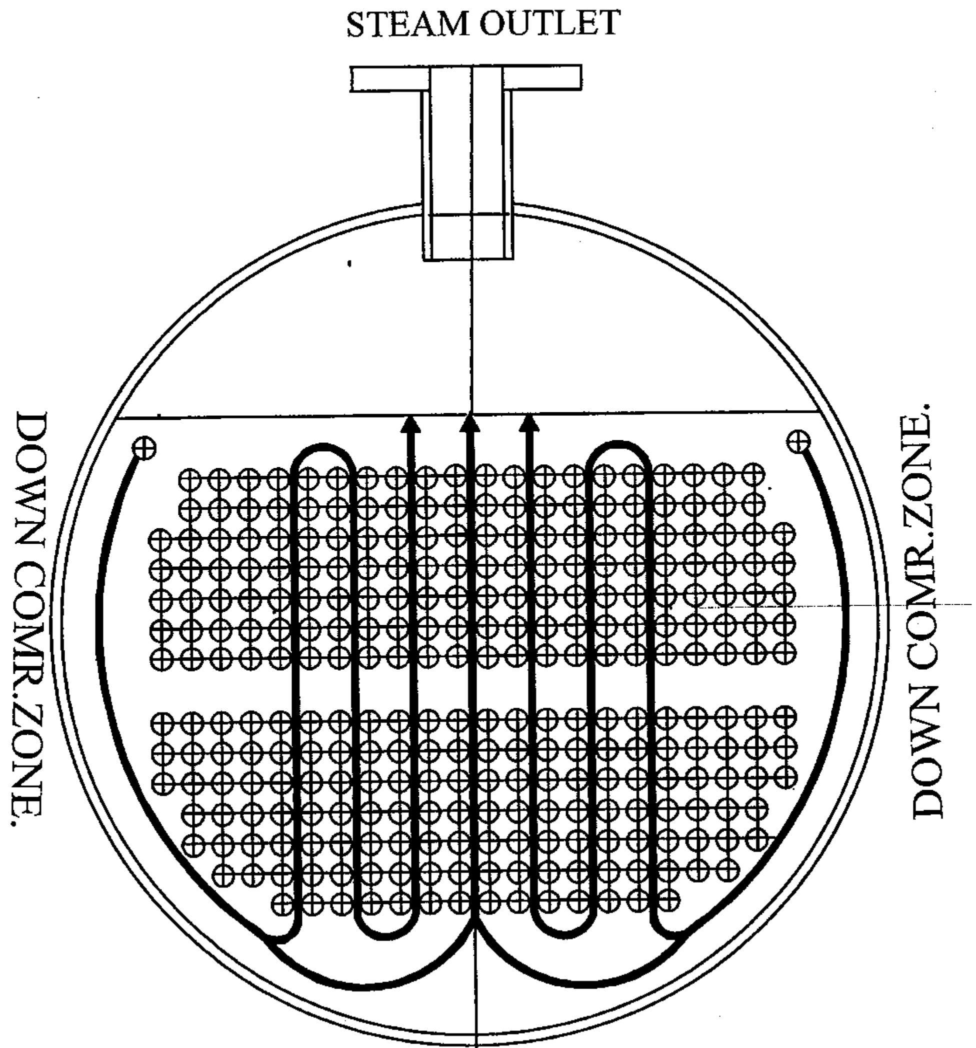


CONVENTIONAL-
WATER TUBE BOILER (GAS,WATER,-
WATER-STEAM CIRCULATION DETAILS)



ELEVATION.

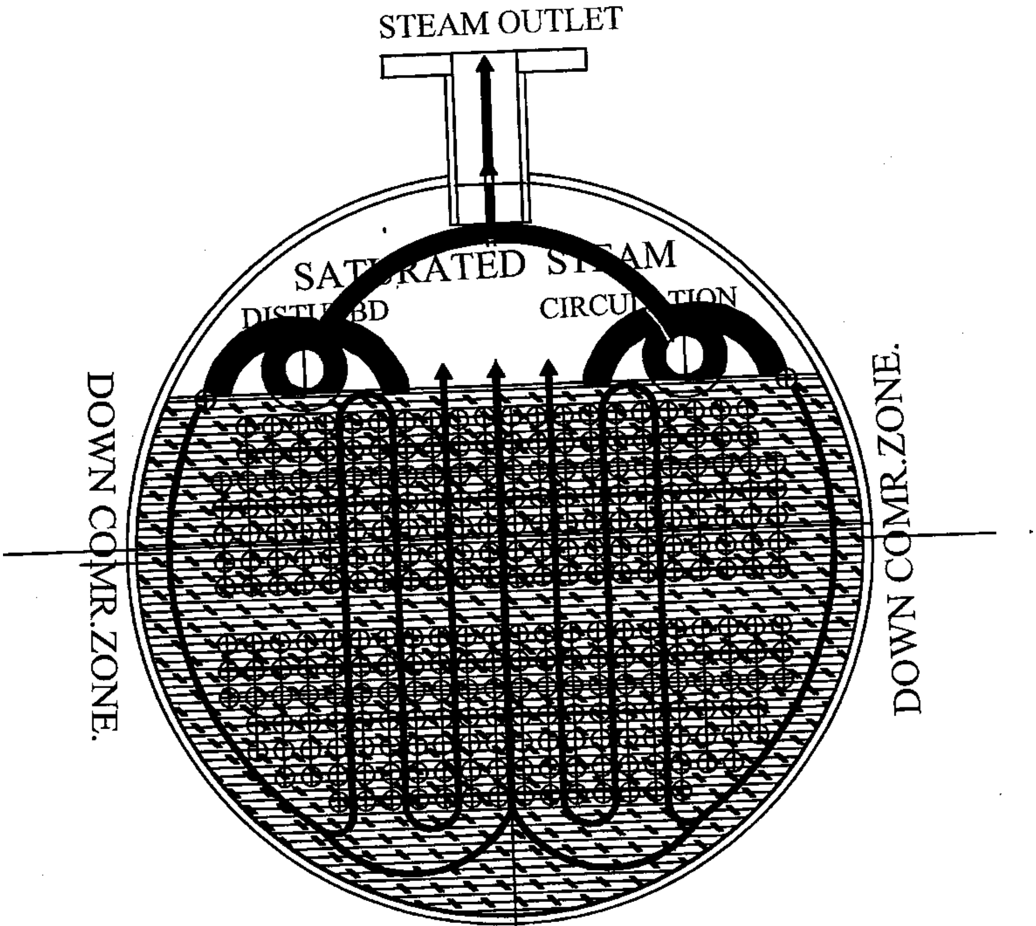
CROSS SECTION OF THE HYBRID SMOKE TUBES/WATER TUBES BOILER SHOWING THE CIRCULATION SYSTEM.



(HYBRID BOILER)

\CONVECTION CUM
POSITIVE CIRCULATION

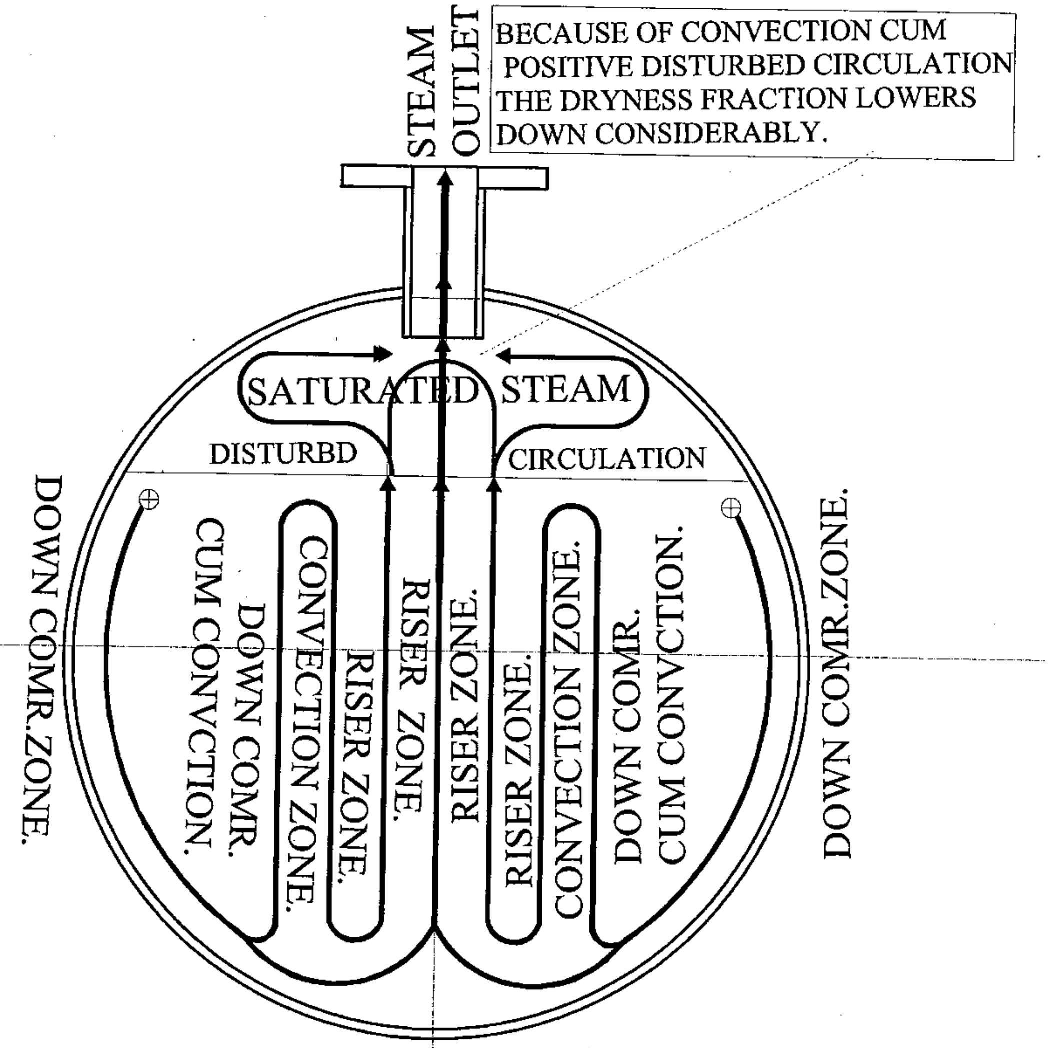
SECTION 'B'-'B'



(HYBRID BOILER)

CONVECTION CUM POSITIVE CIRCULATION

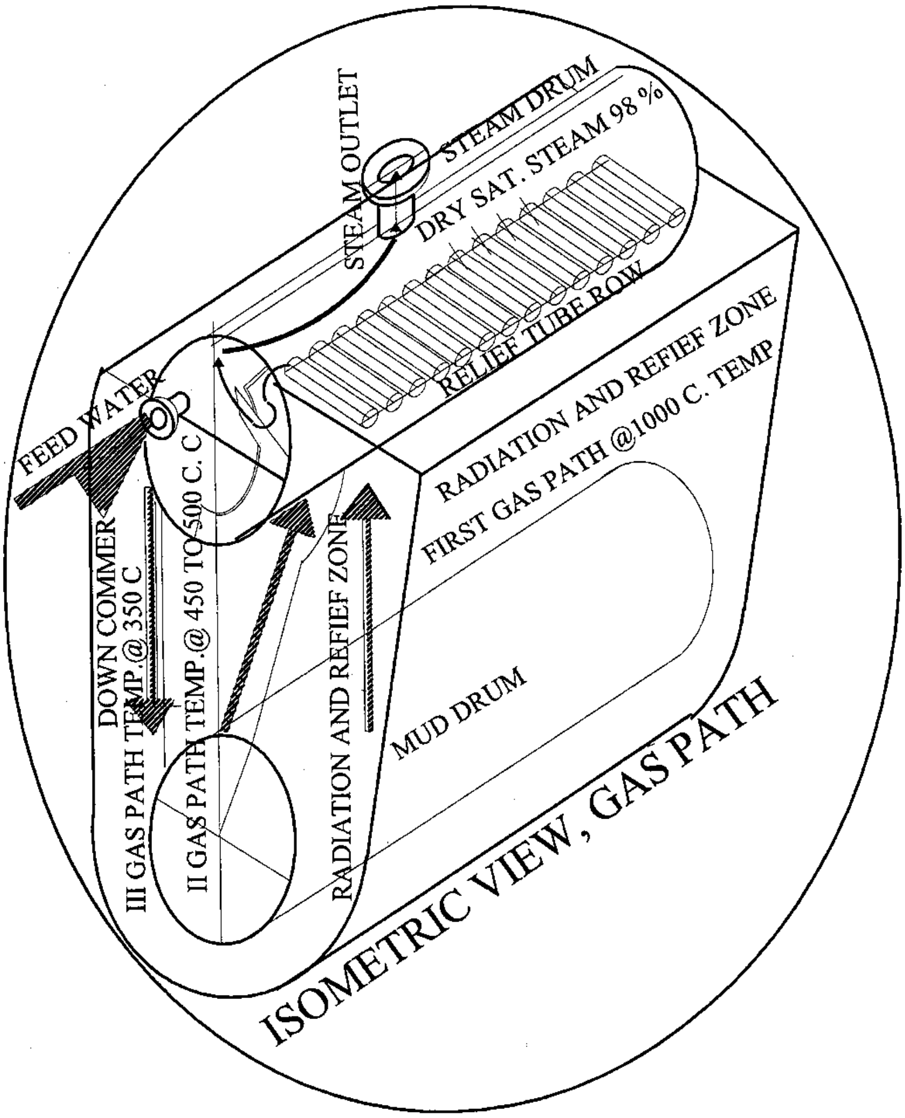
SECTION 'A' -'A'

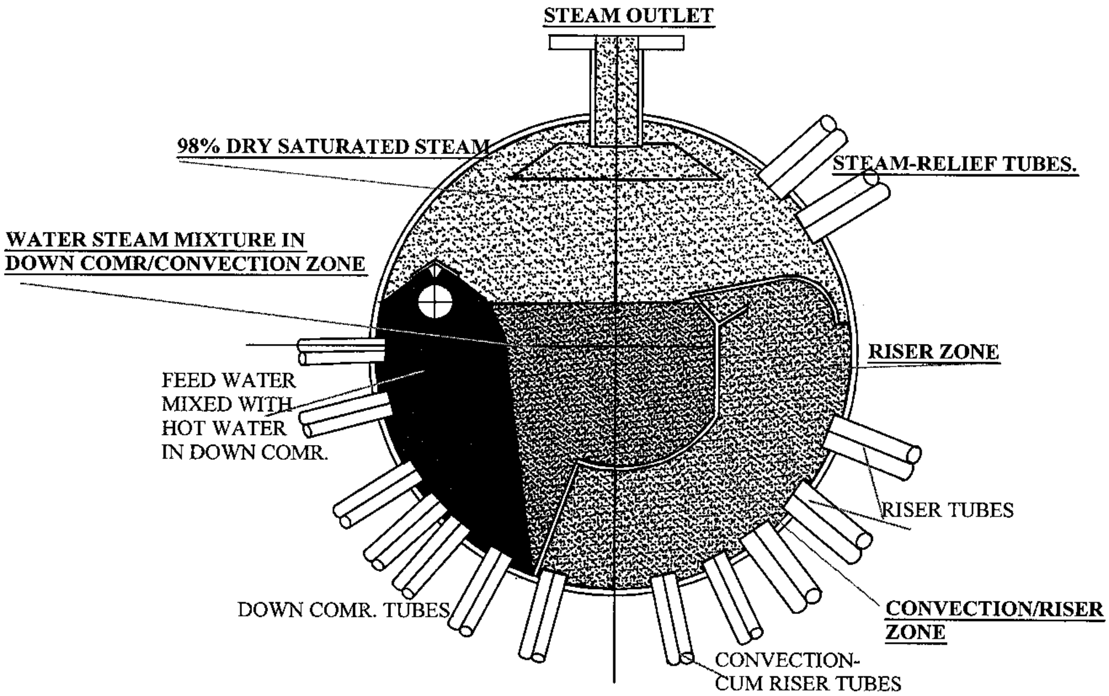


(HYBRID BOILER)

\CONVECTION CUM POSITIVE CIRCULATION

SECTION 'A' -'A'

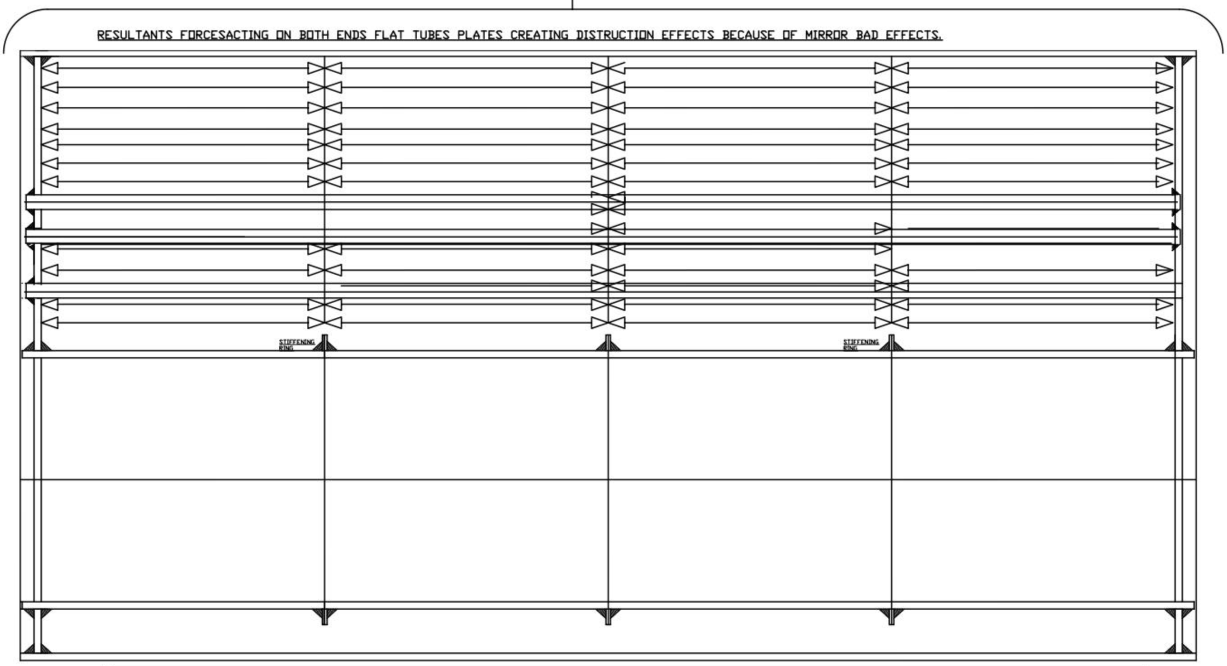

STEAM OUTLET
STEAM DRUM
DRY SAT. STEAM 98 %
RELIEF TUBE ROW
RADIATION AND REFIEF ZONE
FIRST GAS PATH @1000 C. TEMP
FEED WATER
DOWN COMMER
III GAS PATH TEMP.@ 350 C
II GAS PATH TEMP.@ 450 TO 500 C. C
RADIATION AND REFIEF ZONE
MUD DRUM
ISOMETRIC VIEW, GAS PATH



CROSS SECTION OF THE STEAM DRUM OF A WATER TUBE BOILER SHOWING THE CIRCULATION SYSTEM.

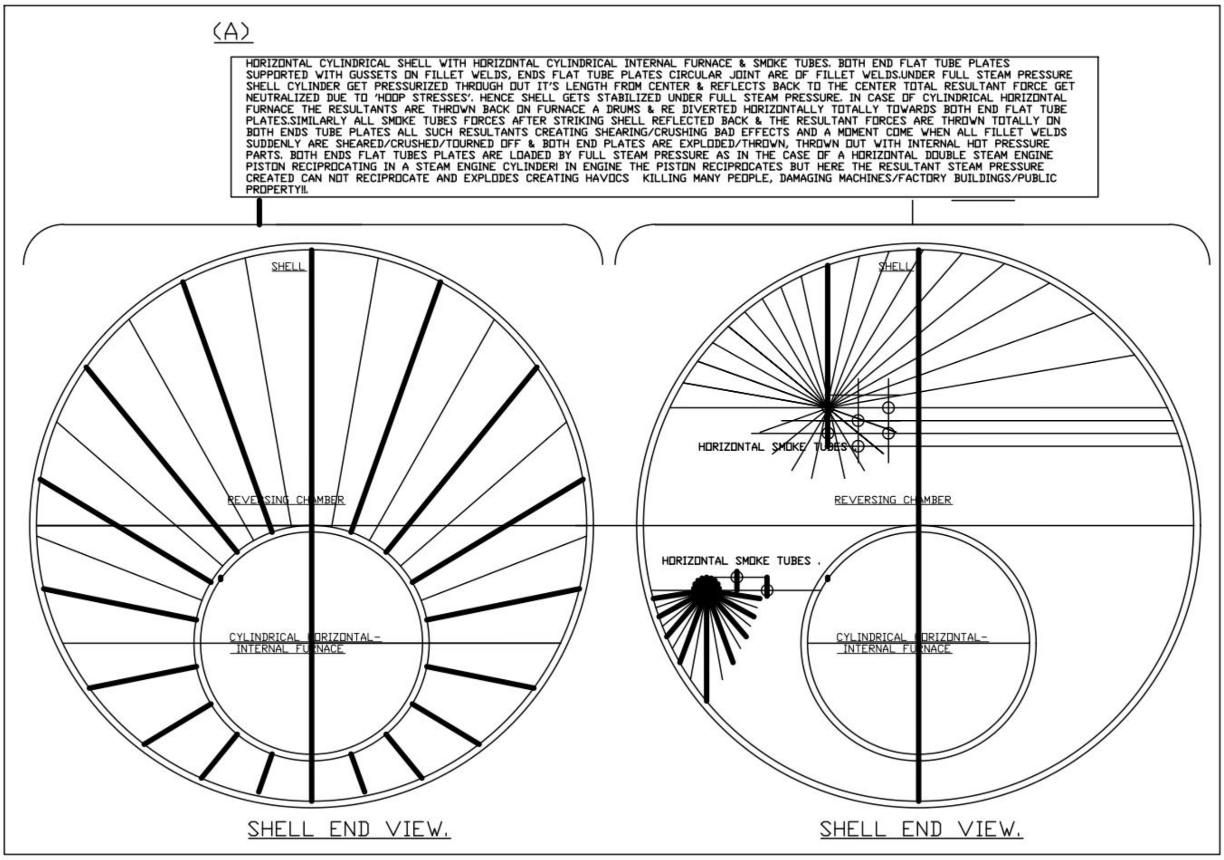
(B)

HORIZONTAL CYLINDRICAL SHELL WITH HORIZONTAL CYLINDRICAL INTERNAL FURNACE & SMOKE TUBES. BOTH END FLAT TUBE PLATES SUPPORTED WITH GUSSETS ON FILLET WELDS, ENDS FLAT TUBE PLATES CIRCULAR JOINT ARE OF FILLET WELDS.UNDER FULL STEAM PRESSURE SHELL CYLINDER GET PRESSURIZED THROUGH OUT IT'S LENGTH FROM CENTER & REFLECTS BACK TO THE CENTER TOTAL RESULTANT FORCE GET NEUTRALIZED DUE TO 'HOOP STRESSES' EFFECTS. .HENCE SHELL GETS STABILIZED UNDER FULL STEAM PRESSURE. IN CASE OF CYLINDRICAL HORIZONTAL FURNACE THE RESULTANTS ARE THROWN BACK ON FURNACE ARE DIVERTED HORIZONTALLY TOTALLY TOWARDS BOTH END FLAT TUBE PLATES.SIMILARLY ALL SMOKE TUBES FORCES AFTER STRIKING SHELL REFLECTED BACK & THE RESULTANT FORCES ARE THROWN TOTALLY ON BOTH ENDS TUBE PLATES ALL SUCH RESULTANTS CREATING SHEARING/CRUSHING BAD EFFECTS AND A MOMENT COME WHEN ALL FILLET WELDS SUDDENLY ARE SHEARED/CRUSHED/TOURNED OFF & BOTH END PLATS ARE EXPLODED/BLOWN,& THROWN OUT WITH INTERNAL HOT PRESSURE PARTS.BOTH ENDS FLAT TUBES PLATES ARE LOADED BY FULL STEAM PRESSURE AS IN THE CASE OF A HORIZONTAL DOUBLE ACTING STEAM ENGINE PISTON RECIPROCATING IN A STEAM ENGINE CYLINDER!, THE PISTON RECIPROCATES BUT HERE THE RESULTANT STEAM PRESSURE CREATED CAN NOT RECIPROCATES AND EXPLODES CREATING HAVOCS, KILLING MANY PEOPLE, DAMAGING MACHINES/FACTORY BUILDINGS,& SURROUNDED LOCALITY!!



(C)

HORIZONTAL CYLINDRICAL SHELL IN SECTION SHOWING INTERNAL HORIZONTAL CYLINDRICAL FURNACE, THE PRESSURE STRESSES ARE ALSO SHOWN TO SHOW THE INTENSITY OF THE RESULTANTS CREATED BECAUSE OF PARALLEL MIRROR BAD EFFECTS DUE TO COMBINED RESULTANAT FORCES TO CREAT EXPLOSIONS/BLOWING OF HOT VARIOUS INTERNAL PRESSURE PARTS.



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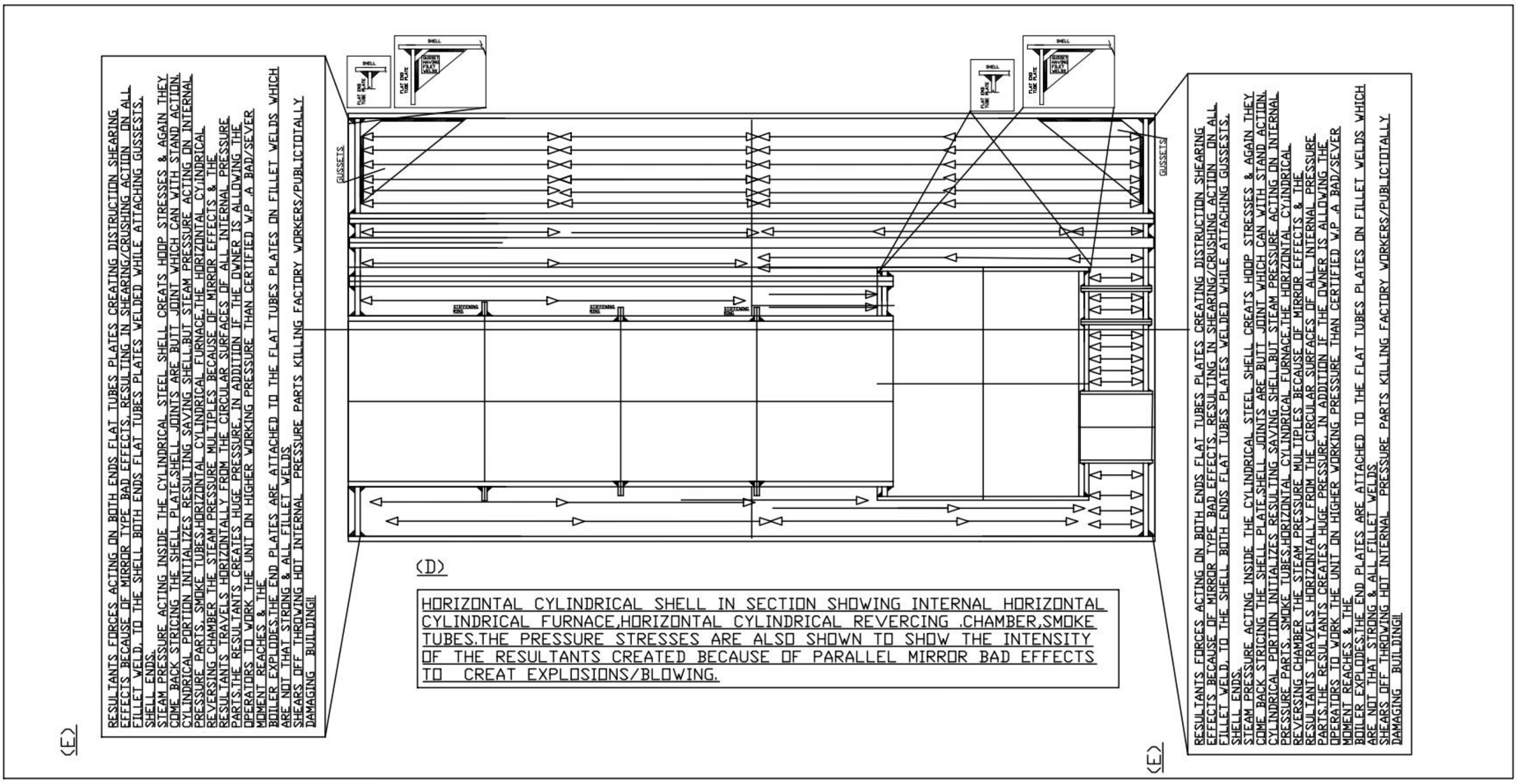
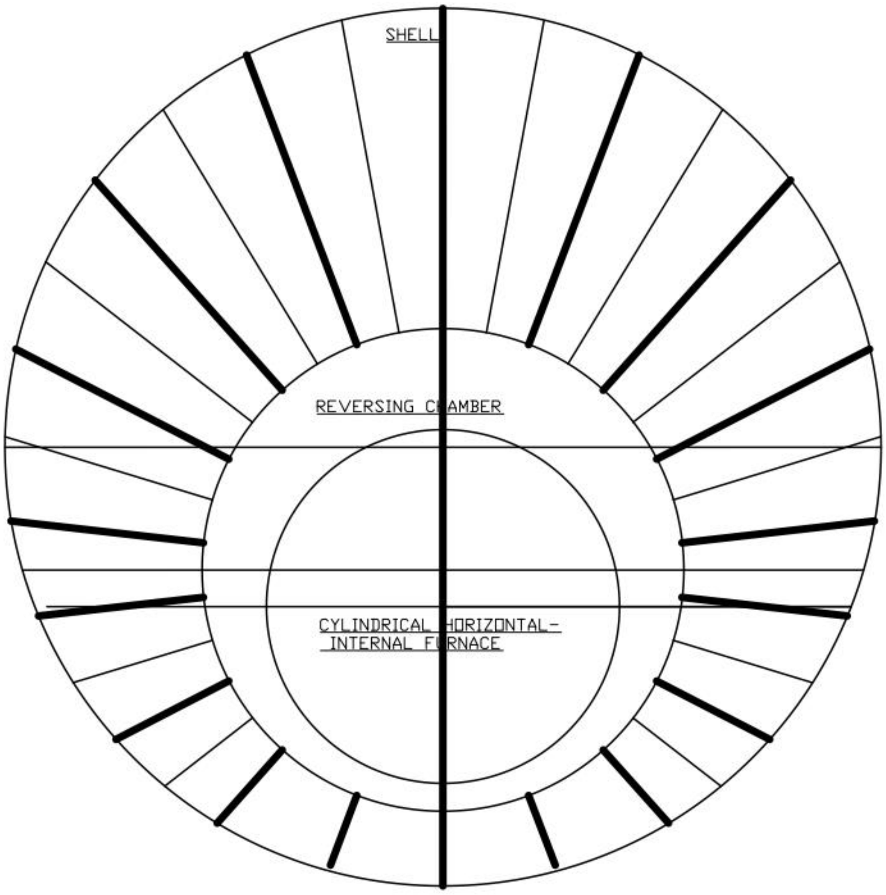

(D)
HORIZONTAL CYLINDRICAL SHELL IN SECTION SHOWING INTERNAL HORIZONTAL CYLINDRICAL FURNACE,HORIZONTAL CYLINDRICAL REVERCING .CHAMBER,SMOKE TUBES.THE PRESSURE STRESSES ARE ALSO SHOWN TO SHOW THE INTENSITY OF THE RESULTANTS CREATED BECAUSE OF PARALLEL MIRROR BAD EFFECTS TO CREAT EXPLOSIONS/BLOWING.
GUSSETS
SHELL

(B)

HORIZONTAL CYLINDRICAL SHELL WITH HORIZONTAL CYLINDRICAL INTERNAL FURNACE & SMOKE TUBES. BOTH END FLAT TUBE PLATES SUPPORTED WITH GUSSETS ON FILLET WELDS, ENDS FLAT TUBE PLATES CIRCULAR JOINT ARE OF FILLET WELDS.UNDER FULL STEAM PRESSURE SHELL CYLINDER GET PRESSURIZED THROUGH OUT IT'S LENGTH FROM CENTER & REFLECTS BACK TO THE CENTER TOTAL RESULTANT FORCE GET NEUTRALIZED DUE TO 'HOOP STRESSES' EFFECTS. .HENCE SHELL GETS STABILIZED UNDER FULL STEAM PRESSURE. IN CASE OF CYLINDRICAL HORIZONTAL FURNACE THE RESULTANTS ARE THROWN BACK ON FURNACE ARE DIVERTED HORIZONTALLY TOTALLY TOWARDS BOTH END FLAT TUBE PLATES.SIMILARLY ALL SMOKE TUBES FORCES AFTER STRIKING SHELL REFLECTED BACK & THE RESULTANT FORCES ARE THROWN TOTALLY ON BOTH ENDS TUBE PLATES ALL SUCH RESULTANTS CREATING SHEARING/CRUSHING BAD EFFECTS AND A MOMENT COME WHEN ALL FILLET WELDS SUDDENLY ARE SHEARED/CRUSHED/TOURNED OFF & BOTH END PLATS ARE EXPLODED/BLOWN,& THROWN OUT WITH INTERNAL HOT PRESSURE PARTS.BOTH ENDS FLAT TUBES PLATES ARE LOADED BY FULL STEAM PRESSURE AS IN THE CASE OF A HORIZONTAL DOUBLE ACTING STEAM ENGINE PISTON RECIPROCATING IN A STEAM ENGINE CYLINDER!, THE PISTON RECIPROCATES BUT HERE THE RESULTANT STEAM PRESSURE CREATED CAN NOT RECIPROCATES AND EXPLODES CREATING HAVOCS, KILLING MANY PEOPLE, DAMAGING MACHINES/FACTORY BUILDINGS,& SURROUNDED LOCALITY!!



(D)

SHELL END VIEW.

HORIZONTAL CYLINDRICAL SHELL IN SECTION SHOWING INTERNAL HORIZONTAL CYLINDRICAL FURNACE,HORIZONTAL CYLINDRICAL REVERCING .CHAMBER,SMOKE TUBES.THE PRESSURE STRESSES ARE ALSO SHOWN TO SHOW THE INTENSITY OF THE RESULTANTS CREATED BECAUSE OF PARALLEL MIRROR BAD EFFECTS TO CREAT EXPLOSIONS/BLOWING.

(E)

RESULTANTS FORCES ACTING ON BOTH ENDS FLAT TUBES PLATES CREATING DISTRUCTION SHEARING EFFECTS BECAUSE OF MIRROR TYPE BAD EFFECTS, RESULTING IN SHEARING/CRUSHING ACTION ON ALL FILLET WELD, TO THE SHELL BOTH ENDS FLAT TUBES PLATES WELDED WHILE ATTACHING GUSSESTS, SHELL ENDS.
STEAM PRESSURE ACTING INSIDE THE CYLINDRICAL STEEL SHELL CREATS HOOP STRESSES & AGAIN THEY COME BACK STRICING THE SHELL PLATE,SHELL JOINTS ARE BUTT JOINT WHICH CAN WITH STAND ACTION. CYLINDRICAL PORTION INITIALIZES RESULTING SAVING SHELL.BUT STEAM PRESSURE ACTING ON INTERNAL PRESSURE PARTS, SMOKE TUBES,HORIZONTAL CYLINDRICAL FURNACE,THE HORIZONTAL CY;INDRICAL REVERSING CHAMBER THE STEAM PRESSURE MULTIPLES BECAUSE OF MIRROR EFFECTS & THE RESULTANTS TRAVELS HORIZONTALLY FROM THE CIRCULAR SURFACES OF ALL INTERNAL PRESSURE PARTS.THE RESULTANTS CREATES HUGE PRESSURE, IN ADDITION IF THE OWNER IS ALLOWING THE OPERATORS TO WORK THE UNIT ON HIGHER WORKING PRESSURE THAN CERTIFIED W.P .A BAD/SEVER MOMENT REACHES & THE
BOILER EXPLODES.THE END PLATES ARE ATTACHED TO THE FLAT TUBES PLATES ON FILLET WELDS WHICH ARE NOT THAT STRONG & ALL FILLET WELDS
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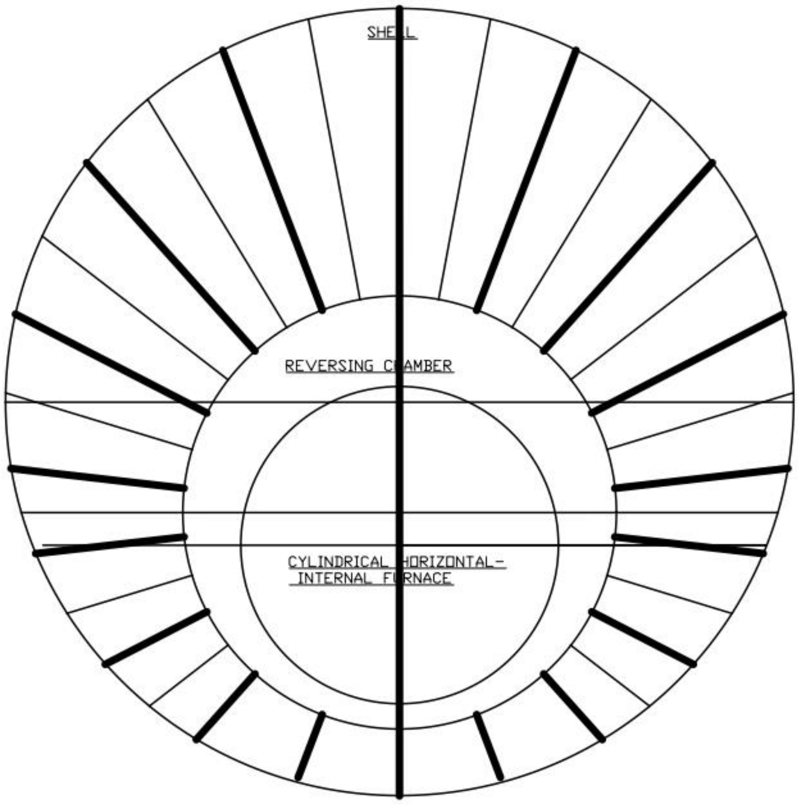

SHELL END VIEW.

(D)

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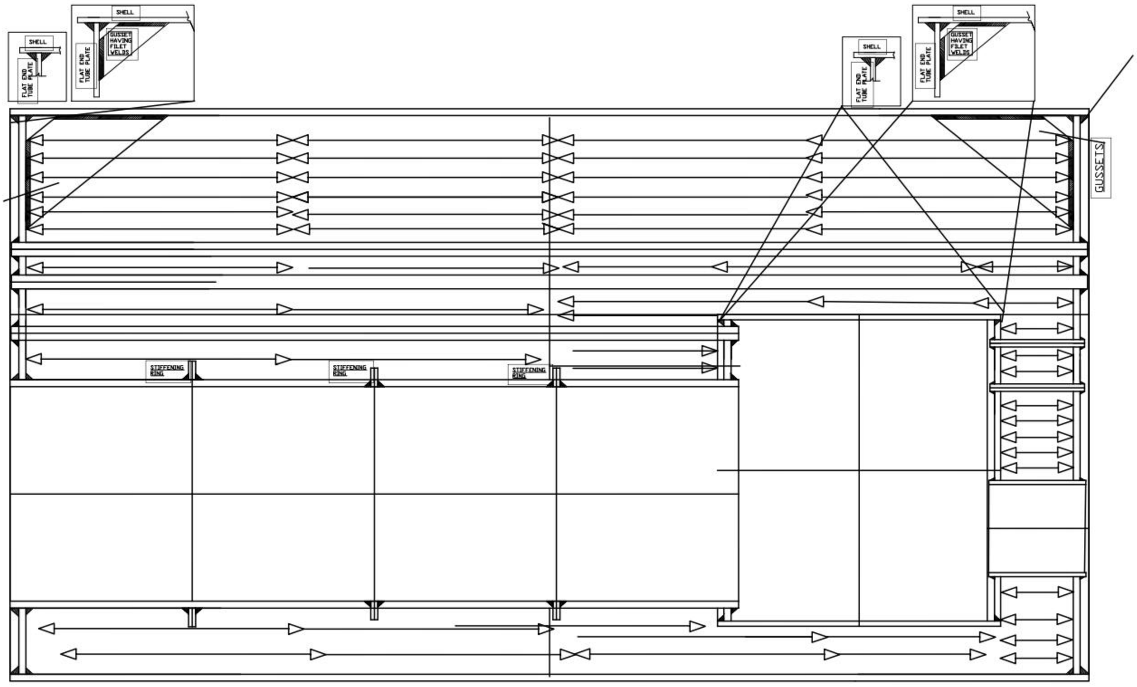

(E)

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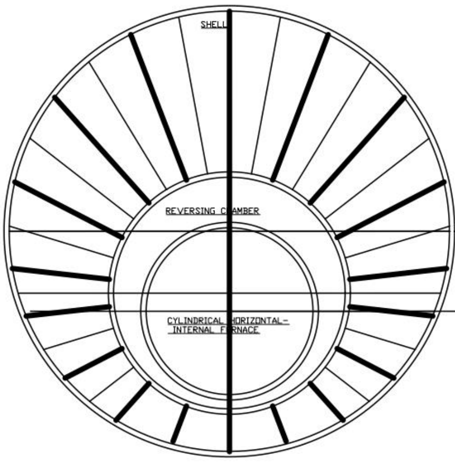
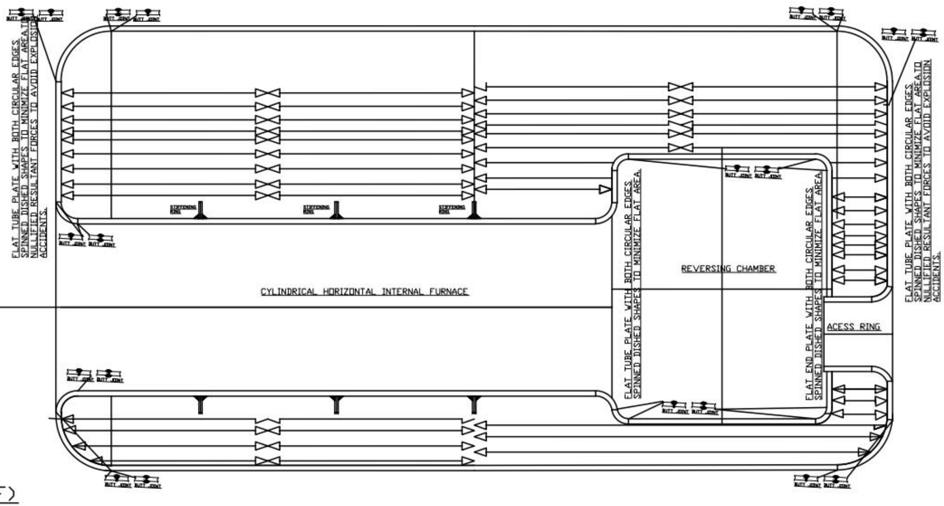
(F)

CYLINDRICAL HORIZONTAL SHELL WITH FLAT TUBE PLATES EDGES SPINED IN SEMI DISHED FORMS WITH ALL BUITT WELDS,TO MINIMIZE FLAT PLATE AREA MINIMIZING RESULTANT STEAM PRESSURE BAD/SHEARING FORCES HAVING INTERNAL HOR.CYLINDRICAL PLANE FURNACE WITH REVERSING CHAMBER, THIS IS TO AVOID EXPLOSIONS/BLOWING OF PRESSURE PARTS TO SAVE WORKERS/PUBLIC & BUILDINGS, (SECTIONAL VIEW).



SECTIONAL FRONT VIEW SHOWING INTERNAL RESULTANT STRESSES



(F)

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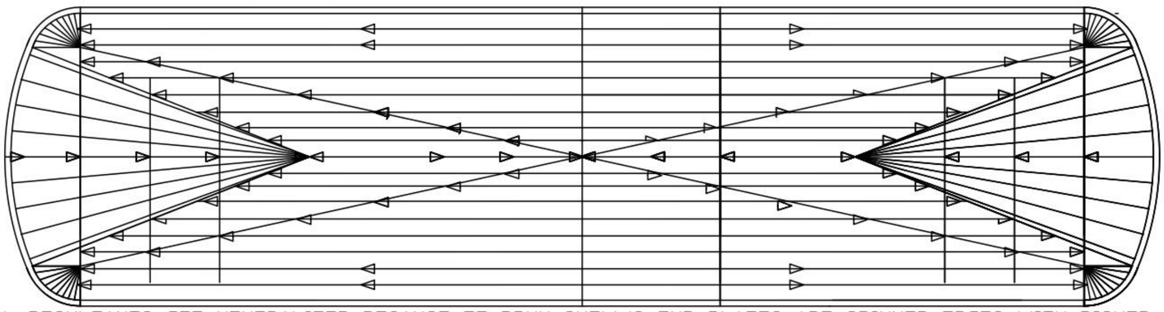
(J)

HORIZONTAL CYLINDRICAL DRUM, BOTH ENDS 'DISHED SHAPED IN PRESCRIBED MANNER' BUTT WELDED EACH OTHER ENDS IN PRESCRIBED MANNER, .UNDER FULL STEAM PRESSURE SHELL,DRUM CYLINDER GETS PRESSURIZED THROUGH OUT IT'S LENGTH FROM CENTER & REFLECTS BACK TO THE CENTER, TOTAL RESULTANT FORCE GETS NEUTRALIZED. INTERNAL STEAM PRESSURE OF THE SHELL DRUM,THE RESULTANT ACTING HORIZONTALLY STRIKES BOTH THE DISHED END PLATES,BUT TO DUE TO GEOMETRICAL SHAPE OF 'DISHED ENDS' ALL RESULTANTS ARE THROWN BACK AT THE EXACT CENTERS RADIUS OF THE DISHED/SPINNED SHAPES AND GET TOTALLY "NULLIFIED." THUS SHEARING/TOURING DISTRICTING FORCES BECOME NIL & VOILES !! THUS THE DRUM REMAINS SAFE THROUGH OUT THE PRESSURIZED CONDITIONS !!
HENCE DESIGNER SHOULD TRY TO AVOID BIGGER DIAMETER FLAT TUBES PLATES,FILLET WELD JOINTS, INSTEAD SHOULD TRY TO ADOPT SPINNED EDGES WITH DISHED/SEMI DISHED GEOMETRICAL SHAPED PRESSURE VESSELS/PARTS OF THE PRESSURE VESSELS.BUTT JOINTS ARE 100 % EFFICIENT & SAFE !!



ALL TOTAL RESULTANTS GET NEUTRALIZED BECAUSE OF DRUM SHELL'S END PLATES ARE SPINNED EDGES WITH DISHED SHAPES. INTERNALS STEAM PRESSURE GETS THROUGH OUT SAME WITHOUT RESULTANTS INCREASED.PRESSURE VESSEL IS SAFE ALL THE TIME

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