2013

Fabrication of Boilers and Pressure Vessels

Zoyeb Batliwala
Sir Padampat Singhania University

Internship Report

on

Fabrication of Boilers and Pressure Vessels

Submitted in partial fulfillment
of the requirement for the award of the degree of

Bachelor of Technology
in
Mechanical Engineering

by

Zoyeb Batliwala

Enrollment No. 10ME001030

Submitted to

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INTERNSHIP CERTIFICATE

TO WHOM IT MAY CONCERN

I hereby confirm that **Zoyeb Kamran Batliwala**, Mechanical Engineering student of the Sir Padampat Singhania University, Udaipur has successfully carried out industrial training/internship of **45 days** at our company from **13th May'13** to **30th June'13** consisting of the following activities:

1) Studied and observed the use of following codes and standards for construction of pressure vessels:

a) ASME SEC II (Materials for fabrication), V (Nondestructive Examination), VIII (Rules for Construction of Pressure Vessels), IX (Welding and Brazing Qualifications)

b) ANSI B 16.5 (flanges and coupling standards)

2) Made basic design calculations as per ASME SECTION VIII Division 1 and made fabrication drawings on CAD of the following equipment:

a) UH-25 scrubber (Satish Dhawan Space Centre, Sriharikota)

b) ECR proton source LCW holding tank (Bhabha Atomic Research Centre, Mumbai)

c) Isrosene storage tank (ISRO Liquid Propulsions Systems Centre, Mahendragiri)

3) Studied and observed the following during pressure vessel fabrication process:

a) Manufacturing of pressure vessel heads (torispherical) by hydraulic press and spinning machine.

b) Rolling of plates by rolling press for pressure vessel shells.

c) Welding by TIG/MMAW and finishing by grinding and buffing / polishing.

d) Heat treatment plant.

e) Non-destructive tests/destructive tests.

And is adept at dispensing the **ASME** BOILER AND PRESSURE VESSEL CODE for construction of pressure vessels and making the fabrication drawings of the same on AutoCAD 2010 (student version).

Date of issue: **30th June'13**

Shariq A. Nizami Sr. Design Engineer Trainee in-charge	**Badruddin K. Halim** Sr. Manager QA/QC	**Bashir T. Nizami** Managing Director

CERTIFICATE

This is to certify that the Internship Report entitled '**Fabrication of Boilers and Pressure Vessels'** being submitted by **Zoyeb Batliwala**, in fulfillment of the requirement for the award of degree of *Bachelor of Technology in Mechanical Engineering*, has been carried out under my supervision and guidance. The matter embodied in this thesis has not been submitted, in part or in full, to any other university or institute for the award of any degree, diploma or certificate.

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ACKNOWLEDGEMENT

I am very thankful to **Allah** Almighty, who has provided me with an amazing opportunity to gain knowledge at PEAPL, GIDC. It was an incredible experience to do internship over here. I learnt many things; some practically, which I have learnt theoretically earlier. I also pay my gratitude to the Almighty for enabling me to complete this Internship Report within due course of time.

For his continuous guidance, enthusiasm and support extended, I take this opportunity — with sheer pleasure — to express my heartfelt gratitude to **Mr. M.Y. Sulemani**, Chairperson, PEAPL. I am grateful to **Mr. Bashir T. Nizami**, Managing Director, PEAPL, for allowing me to take training at their *works* and **Mr. Shariq A. Nizami**, Sr. Design Engineer and Trainee In-charge, PEAPL for giving me all the possible help and necessary guidance during my training period. The acknowledgement remains incomplete without thanking the several factory personnel for their kind cooperation and a special mention, **Mr. Harivardhan Patel** for enhancing my working knowledge about a *company*.

Words are very few to express an enormous gratitude to my affectionate **Parents** for their prayers and strong determination, enabling me to achieve this internship.

I am highly indebted to my Supervisor for the training period, **Mr. Badruddin K. Halim.** Without his kind assistance and expertise my training would not have been possible. The experienced personnel he is, he has been a constant source of inspiration and encouragement and who has had solutions to all my problems, answers to all my questions and who has been full of insight and enthusiasm, right from my day one at training, until the completion of this report.

Lastly, I appreciate the **Mechanical Department** of my University to have given me the opportunity to work and gain knowledge from the professional environment of PEAPL and hence broaden my vision.

ABSTRACT

Within my educational program at the Sir Padampat Singhania University, Udaipur, I had had the opportunity to carry my internship at PEAPL, GIDC and besides practical experience in the area of fabrication, many valuable skills and practical knowledge was gained during the internship duration. Throughout the internship drawing assignments were assigned to me by my Supervisor such as the study and use of codes and standards for construction of pressure vessels, basic design calculations as per the codes and fabrication drawings on CAD. The course of action adopted to complete these activities was to first understand the assignment on hand, then understanding the purpose of the assignment and then learning how to do the required task in an efficient way.

These activities were done according to the course of actions followed at PEAPL *works*. I spent a considerable amount of time *on-field* to observe the fabrication and inspection processes, manufacturing of pressure vessel heads (torispherical) by hydraulic press and spinning machine, rolling of plates by rolling press for pressure vessel shell, welding by TIG/MMAW and finishing by grinding and buffing / polishing, heat treatment plant and non-destructive tests/destructive tests. I mention certain details of the assignments given to me, at the end.

Also, training in this company has increased my knowledge in the technical field. This would much more be beneficial, in view of future prospects.

Keywords: Manufacturing, ASME BPVC, Vessel Fabrication, CAD, Field Study

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1.0 INTRODUCTION

1.1 PEAPL GROUP

Perfect Engineering & Allied Works Pvt. Ltd. belongs to the Perfect Group of Companies. The Nizami Brothers established it in Vadodara in 1940. Their first enterprise, The Nizami Welding and Boiler Repairing Works, was the only approved boiler repairing outfit in the then Bombay State, with the help of British Oxygen Ltd., UK. They developed the difficult Welding Technology of Aluminum & Antimony metals for application in the auto industry in India. By 1967 they were supplying Aluminum and Bronze alloy castings, imported until then for HT Circuit Breakers to Hindustan Brown Boveri (now Asea Brown Boveri Ltd.) and Jyoti Ltd. At the same time vigorous R&D efforts continued to indigenously develop *Hard Anodizing* techniques for the Electric Power Transmission Industries. This included Pressure Vessels supplied to the National Thermal Power Corporation for their entire range of fabricated Air Receivers which met approval from prestigious Third Party Inspection Agencies like Lloyds, Bureau Veritas, Baxcounsel, EIL, PDIL and the Office of the Chief Controller of Explosives etc.

Meanwhile, with the technical assistance of Cooper Heat, UK, the Group installed a huge Heat Treatment Furnace with revolutionary design for the first time in India. In 1991, the Perfect Group diversified into manufacture of Cryogenic Equipment for storage and handling of Liquid Nitrogen & Liquid Oxygen. Along with such large Public Sector Organization like Bharat Heavy Plates and Vessels and I.B.P. Ltd., the Perfect Group is one of the few manufacturers of such equipment in the country. Today, the Perfect Group is one of the few industrial houses in India to have facilities certified as conforming to IS 9000 The Group’s commitment to *Total Quality Management* (TQM) has helped them manufacture top quality equipment at very competitive prices. The Perfect Group is now poised for phenomenal growth in all areas of its activities. The future holds tremendous possibilities.

1.2 ABOUT ASME

The American Society of Mechanical Engineers (ASME) was founded in 1880 in the U.S. by prominent mechanical engineers of the era, namely, Alexander Lyman Holley, Henry Rossiter Worthington, John Edison Sweet and Matthias N. Forney. It was founded to respond effectively and with mutual consensus, to the many boiler and pressure vessel failures, throughout the 19^{th} century.

Today, a worldwide engineering society, ASME is focused on technical, educational, and research issues. It holds technical conferences and professional development courses each year, and sets many industrial and manufacturing standards.

1.2.1 The Codes and Standards

The ASME Boiler and Pressure Vessel Code (BPVC) establishes rules of safety governing the design, fabrication, and inspection of boilers and pressure vessels and nuclear power plant components during construction. The objective of the rules is to provide a margin for deterioration in service. Advancements in design and material, and the evidence of experience, are constantly being added. The BPVC is “An International Historic Mechanical Engineering Landmark,” widely recognized as a model for codes and standards worldwide. Its development process remains open and transparent throughout, yielding “living documents” that have improved public safety and facilitated trade across global markets and jurisdictions for nearly a century. More than 100,000 copies of the BPVC are in use in 100 countries around the world, with translations into a number of languages. The boiler and pressure-vessel sections of the BPVC have long been considered essential within such industries as electric power-generation, petrochemical, and transportation, among others.

The ASME/ANSI B16 - Standards of Pipes and Fittings covers pipes and fittings in cast iron, cast bronze, wrought copper and steel

2.0 PEAPL COMPANY PROFILE

2.1 PEAPL PRODUCTS

(a) High and Low Coded Pressure Vessels
(b) LPG Storage and Mobile Tanks
(c) Heat Exchangers
(d) Columns
(e) Stainless Steel Drums
(f) Reactors
(g) Process Tank & Vessels
(h) Vacuum Chamber Dryers
(i) Fluid Bed Dryers
(j) Rotocone Vacuum Dryers
(k) Paddle Vacuum Dryers
(l) Cryogenic Tanks And Vessels
(m) Nitriding Pots (Furnace)
(p) Non- Ferrous Casting
(o) Stainless Steel Spent Fuel Storage Trays

2.2 CLIENTELE

- Asea Brown Boveri Limited
- Alembic Chemicals Limited

- Bhabha Atomic Research Centre, Mumbai
- Fortune Bio-Tech Ltd.
- Glaxo India Limited
- Torina Pharmaceuticals
- Unichem Ltd.
- Indian Oil Corporation Limited
- Indian Petrochemicals Corporation Limited.
- Gujarat State Fertilizer & Chemicals Limited
- Nuclear Power Corporation Of India Limited, Mumbai
- Torrent Pharma
- Lupin Laboratories Limited
- Larsen & Toubro Limited
- Nicco Corporation Limited (Projects)
- E.R.D.A
- Oil and Natural Gas Commission Ltd.
- Dishman Pharmaceuticals
- Projects & Development India Limited.
- Rashtriya Chemical & Fertilizers Limited
- Ranbaxy Laboratories Limited
- Cipla
- Vikram Sarabhai Space Centre, Trivandrum
- Indian Space Research Organization, Shar Centre, Sriharikota

2.3 INSPECTION & TESTING FACILITIES

Table 2.1 – PEAPL Inspection and Testing Facilities

SURFACE TREATMENT FACILITIES
• Hard Anodising
• Sand Blasting
• Metalising And Painting

FACILITIES FOR DESTRUCTIVE TESTING	
Tensile Impact Nick - Break. Root Bend Face Bend, Macro & Micro IGC Practice A' , C', and E'	Arrangement with 1.Met Heat, Baroda 2.Metallurgical, Mumbai.
Chemical & Metallurgical Examinations	Arrangements With Metheat, Baroda
Pneumatic Testing	100 Kgs/Cm^2 (G)_
Hydraulic Testing	600 Kgs/Cm^2 (G)
Vacuum Testing	Max Vacuum - 755 MM Hg

FACILITIES FOR NONDESTRUCTIVE TESTING	
• Dye Penetrant Test	
• Radiography Test	Arrangements With 1. Baroda Ind X-Ray Services 2. NDT Services , 3. Radiant Industrial Services
• Ultrasonic Test	
• M.P.I	

2.4 FABRICATION FACILITIES

Table 2.2 – PEAPL Fabrication Facilities

Plate bending Cold	
MILD STEEL	2500 x 40 MM THK
STAINLESS STEEL	2500 x 30 MM THK

Lifting Capacity	
20 MT	1 NO.
10 MT	1 NO.
2 MT	1 NO.

Cutting And Grinding Equipment	
Air Plasma Cutting	1 Sets
Manual Gas Cutting Torches	4 Sets
Auto Gas Cutting Equipment	3 Sets
Flexible Shaft Grinder	12 Sets
Portable Grinders	12 Sets

Presses:		
Hydraulic Press	100 MT (1500MM ADMIT	3 NOS.
	150 MT (2500MM ADMIT	
	250 MT (1000MM ADMIT	

Other Forming Machines And Facilities
Manually Operated Tube Bending For 20 Mm Dia To 60 Mm Dia Tubes
Tube Expander With Torque Controller Mechanism

Welding Positioners	
ROTATORS -CAPACITY	5 MT - 1 NO.
	15 MT - 1 NO.

Automatic Welding Machines	
Submerged Arc Welding Machine	1 SET 600 AMP CAP
Tig Machine	5 SET 400 AMP CAP
Semi Automatic Mig/Co2 Welding M/C	1 NO.
Pulse Of Tig Welding M/C	1 NO.

Manual Welding Machines		
Rectifier	600 AMPS	4 NOS.
Rectifier	300 AMPS	4 NOS.
Transformer	300 AMPS	2 NOS.

Facilities For Heat Treatment			
Type	Useful Size	Max Temp	Nos.
Electric Furnaces (for solution annealing	1. 1270 x 600 x 700 MM 2. 1570 x 900 x 570 MM	1200^0 C	
Oil Fired Bogie Type Furnace (with six point integrated temp recording facility)	11000 L X 3000 X 3500 HT.	1000^0 C 1	NO.
	5M x 5M x 15M long	1200^0C 1	NO.
	5M x 2.5M x 5M long	1200^0C 1	NO.

2.5 MACHINE SHOP

Table 2.3 – PEAPL Machine Shop Details

Lathe Machines 6' to 8' Bed Length	
All Geared	3 NOS.
Belt Driven	4 NOS.

Radial Drilling Machine 1 No.	Arm Length	2000 Mm
	Capacity 7	5 Mm
Pillar Drill2 Nos.	Drilling Capacity	25 Mm
		50 Mm

Pillar Drill2 Nos.	Drilling Capacity	25 Mm
		50 Mm

Shaping Machine 24" Stock	1 No.
Milling Machine	1 No
Universal Table Size	1200 X 300
Hack Saw Machine	4 Nos.
Tube Expanders	1-½"
Automatic Torque Control Unit For Tube Expanding	

2.6 WORK FORCE

Table 2.4 – PEAPL Work Force

COMMERCIAL ADMINISTRATIVE PERSONNEL	**15**
TECHNICAL PERSONNEL	**6**
Engineers 2	
Design Engineers	2
Draughtsmen 2	
QUALITY CONTROL PERSONNEL	**6**
Manager 1	
Engineers 2	
Supervisor 3	
WORK SHOP PERSONNEL	**60**
Supervisors Plate Forming Workers	3
Machine Workers	3
Assembly Workers	6
Qualified Workers	6
Labourers	28
Maintenance Workers	3
Store Keepers	3
Turners 5	
GENERAL SERVICE PERSONNEL	4
GRAND TOTAL	**87**

2.7 DESIGN AND MANUFACTURING EXPERIENCE

Table 2.5 – PEAPL Design and Manufacturing Experience

Codes	**ASME SECTION VIII, DIV I & II , TEMA**
	B.S. 1515 & I.S. 2825 CLASS

Manufacturing Experience	Carbon Steel & Alloy Steel
	Stainless Steel 304, 304 L, 316, 316L, 310, 321
	Incoloy, Monel Inconel, Aluminium & Copper.

Statutory & Independent Inspections Normally Carried Out At Our Plant	Lloyd's Register Asia
	B.V.I.S.
	Engineers India Limited.
	Uhde India Limited
	Projects And Development Limited
	Bhabha Atomic Research Centre
	Nuclear Power Corporation
	National Thermal Power Corporation
	ABS Industrial Verification (India) Pvt. Limited.
	Dalal Consultants
	Humphrey & Glasgow
	Bax Counsel
	LINDE

Licenses Held	License From Chief Controller Of Explosives, Nagpur, To Fabricate Unfired Pressure Vessels

SHOP AREA	COVERED	3500 SQ MTR
	PLOT AREA	6000 SQ MTR

3.0 BOILERS

A boiler is an enclosed vessel that provides a means for combustion heat to be transferred to water until it becomes heated water or steam. The hot water or steam under pressure is then usable for transferring the heat to a process. Water is a useful and inexpensive medium for transferring heat to a process.

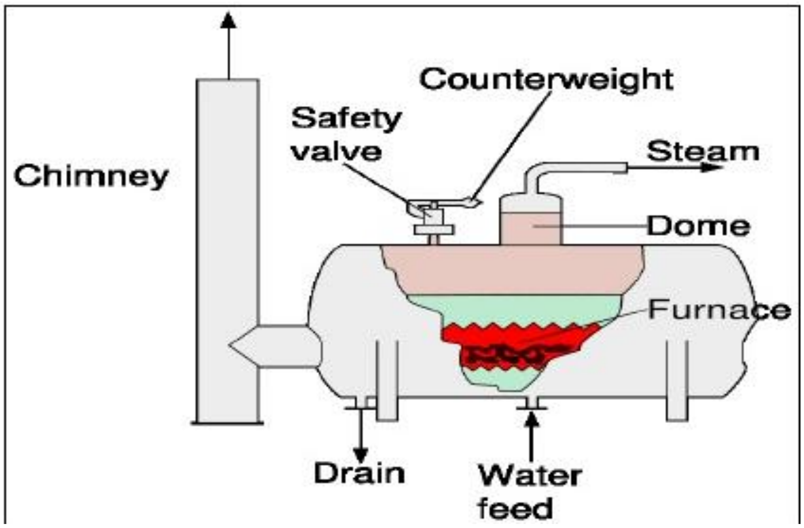


Figure 3.1 – A Boiler: schematic diagram

Boiler designs can be classified into the following major divisions:

1. Fire-tube boilers
2. Water-tube boilers

3.1 FIRE TUBE BOILER

In a fire tube boiler, hot gases pass through the tubes and boiler feed water in the shell side is converted into steam. Fire tube boilers are generally used for relatively small steam capacities and low to medium steam pressures. As a guideline, fire tube boilers are competitive for steam rates up to 12,000 kg/hour and pressures up to 18 kg/cm2. Fire tube boilers are available for operation with oil, gas or solid fuels. The fire, or hot flue gases from the burner, is channeled through tubes that are surrounded by the fluid to be heated. The body of the boiler is the pressure vessel and contains the fluid. In most cases this fluid is water that will be circulated for heating purposes or converted to steam for process use. Every set of tubes that the flue gas travels through, before it makes a turn, is considered a "pass". So a three-pass boiler will have three sets of tubes with the stack outlet located on the rear of the boiler.

Features:

(1) Relatively inexpensive

(2) Easy to clean

(3) Compact in size

(4) Available in sizes from 600,000 btu/hr to 50,000,000 btu/hr

(5) Easy to replace tubes

(6) Well suited for space heating and industrial process applications.

(7) Not suitable for high pressure applications 250 psig and above.

(8) Limitation for high capacity steam generation.

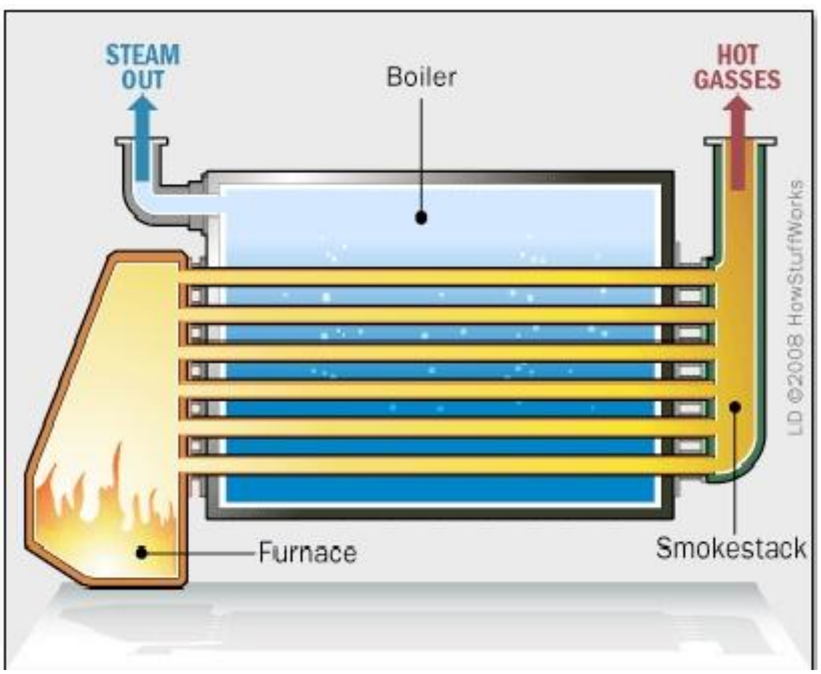


Figure 3.2 – A Fire Tube Boiler: schematic diagram

3.2 WATER TUBE BOILER

In a water tube boiler, boiler feed water flows through the tubes and enters the boiler drum. The circulated water is heated by the combustion gases and converted into steam at the vapor space in the drum. These boilers are selected when the steam demand as well as steam pressure requirements are high as in the case of process cum power boiler / power boilers. Most modern water boiler tube designs are within the capacity range 4,500 – 120,000 kg/hour of steam, at very high pressures. Many water tube boilers are of “packaged” construction if oil and /or gas are to be used as fuel. Solid fuel fired water tube designs are available but packaged designs are less common.

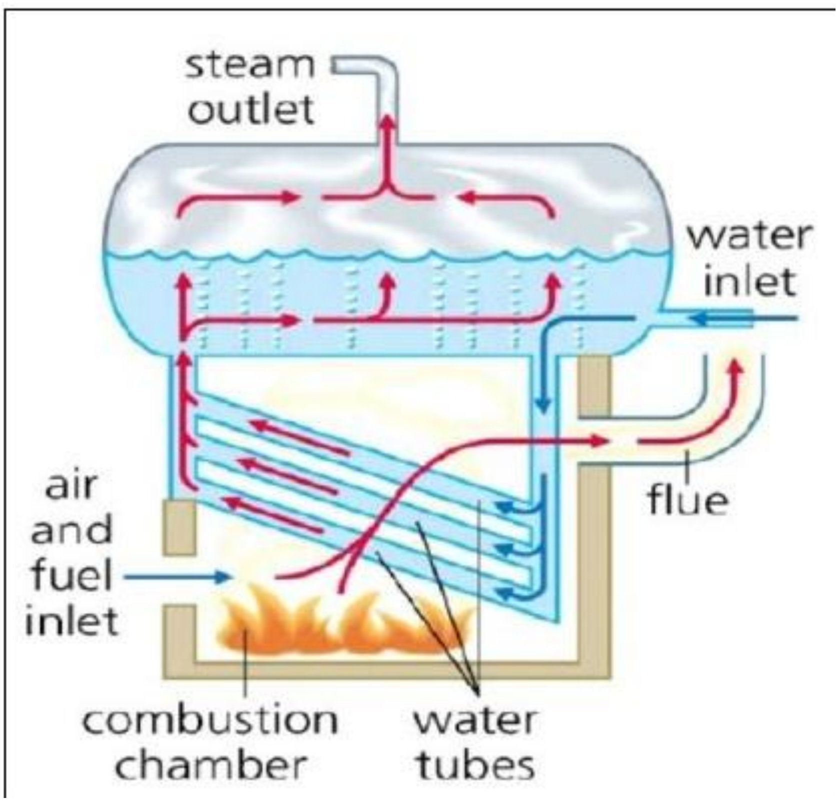


Figure 3.3 – A Water Tube Boiler: schematic diagram

- Features:

(1) Forced, induced and balanced draft provisions help to improve combustion efficiency.

(2) Less tolerance for water quality calls for water treatment plant

(3) Higher thermal efficiency levels are possible

(4) High initial capital cost and large size.

(5) Able to handle higher pressures up to 5,000 psig.

4.0 PRESSURE VESSEL

A pressure vessel is a closed container designed to hold gases or liquids at a pressure substantially different from the ambient pressure. The pressure differential is dangerous and many fatal accidents have occurred in the history of their development and operation. Consequently, their design, manufacture, and operation are regulated by engineering authorities backed by legislation. For these reasons, the definition of a pressure vessel varies from country to country, but involves parameters such as maximum safe operating pressure and temperature.

Figure 4.1 – Pressure Vessels

There are two types of pressure vessels:

1. Spherical pressure vessels
2. Cylindrical pressure vessels

- APPLICATIONS

There are the following major applications of pressure vessels -

(a) Cosmetic industry
(b) Chemical industry
(c) Food and beverage industry
(d) Oil and fire industry
(e) Paper and pulp industry
(f) Pharmaceutical and plastic processing
(g) Power generation
(h) Energy processing

5.0 WELDING

Welding is a process of joining two or more metal pieces as a result of significant diffusion of the atoms of the welded pieces into the joint (weld) region. Welding is carried out by heating the joined pieces to melting point and fusing them together (with or without filler material) or by applying pressure to the pieces in cold or heated state.

Following welding methods I have observed at PEAPL:

1. Gas Tungsten Arc Welding (GTAW, TIG)
2. Manual Metal Arc Welding (MMAW)

5.1 GAS TUNGSTEN ARC WELDING (GTAW, TIG)

Gas Tungsten Arc Welding or Tungsten Inert Gas Arc Welding (GTAW, TIG) is a welding process, in which heat is generated by an electric arc struck between a tungsten non-consumable electrode and the work piece. The weld pool is shielded by an inert gas (Argon, helium, Nitrogen) protecting the molten metal from atmospheric contamination. The heat produced by the arc melts the work pieces edges and joins them. Filler rod may be used, if required. Tungsten Inert Gas Arc Welding produces a high quality weld of most of metals. Flux is not used in the process.

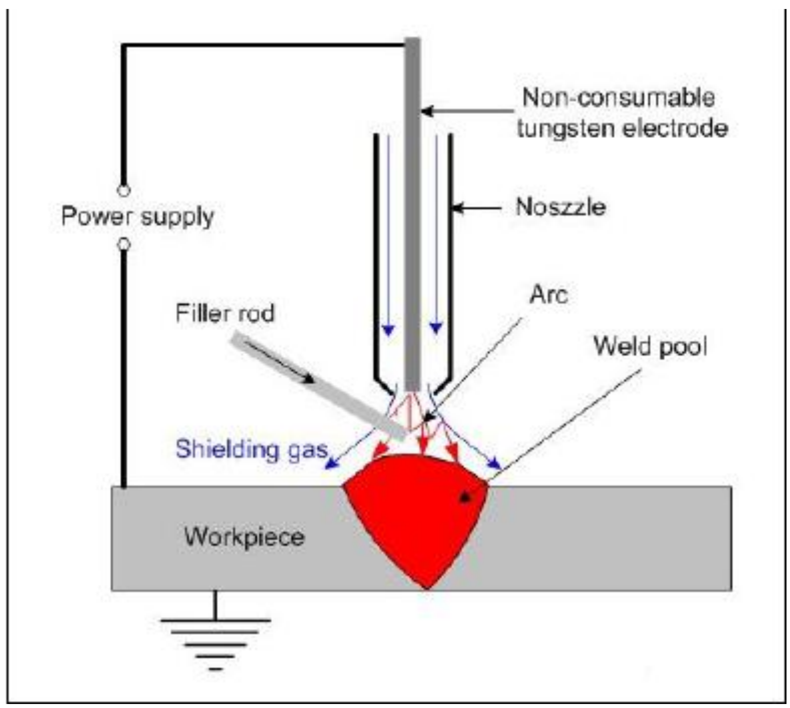


Figure 5.1 – Tungsten inert gas arc welding

5.2 Manual Metal Arc Welding (MMAW)

In this process an arc is drawn between a coated consumable electrode and the work piece. The metallic core-wire is melted by the arc and is transferred to the weld pool as molten drops. The electrode coating also melts to form a gas shield around the arc and the weld pool as well as slag on the surface of the weld pool, thus protecting the cooling weld pool from the atmosphere. The slag must be removed after each layer or once hardened, it should be chipped away to reveal the finished weld. Manual Metal Arc welding is still a widely used hardfacing process.

During welding the current remains constant, even if the arc distance and voltage change. The deposit rate is inferior to 1kg/h and the arc time is about 30%, due to the permanent need to change the consumable electrode.

Metals that can be welded include mild steel in thicknesses from 1/16th up to 2 inches, stainless steel, and cast iron. Arc welding is an excellent method of repair work to cast iron castings. During the arc welding process is that the arc generates enough sustainable high intensity heat to melt the intended metal at any point it is directed to. Combined with the filler / electrode this action effectively fuses two pieces together.

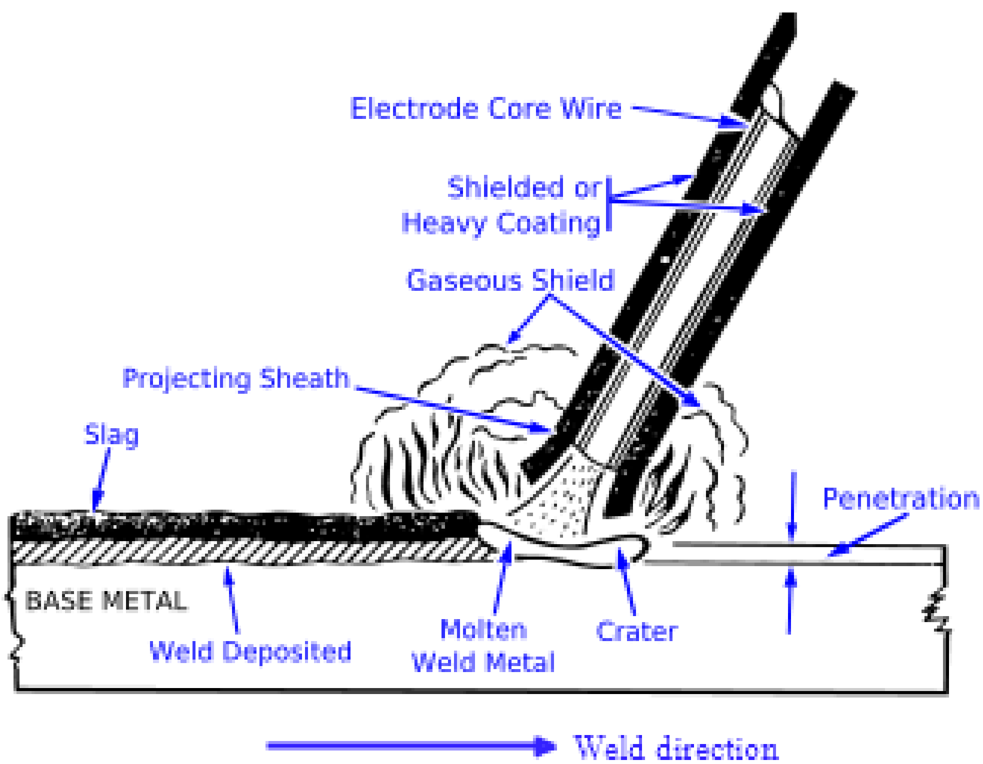


Figure 5.2 – Manual Metal Arc welding Features

- Applications:

(a) Maintenance and repair industries.

(b) Construction of steel structures

(f) Weld carbon steel, low and high alloy steel, stainless steels, cast iron, aluminum, nickel and cooper alloys

6.0 STRESS RELIEVING FURNACE

Also called post welding heat treatment (PWHT) is used for relieving the stress from parts after machining and welding. This is used for C.S and Alloy parts. Machining and Welding induces stresses in parts. These stresses can cause distortions in the part long term. If the parts are clamped in service, then cracking could occur. Also whole locations can change causing them to go out of tolerance. For these reasons, stress relieving is often necessary.

Figure 6.1 – PWHT Furnace

➢ Main parts of Stress Relieving Furnace:

(a) Bed of furnace

(b) Furnace

(c) Burners

(d) Thermocouples

(e) Main stack

(f) Control panel

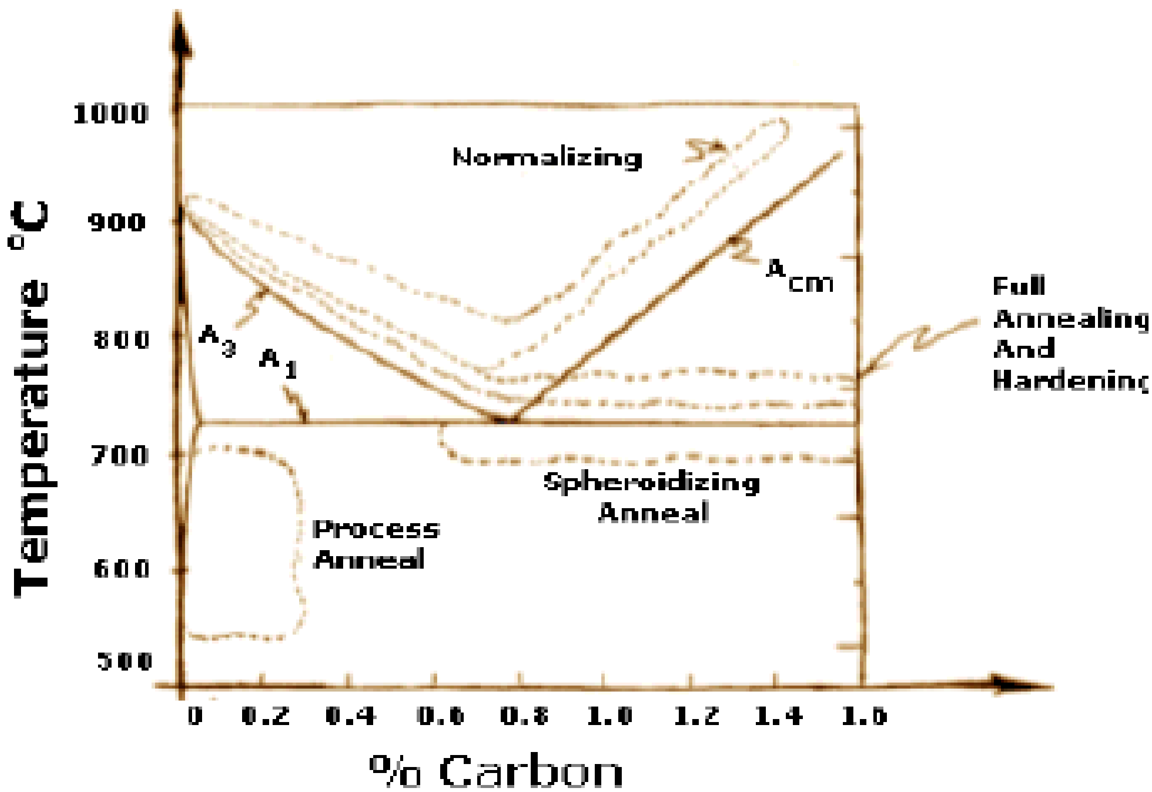


Figure 6.2 – Heat Treatment Process Chart

Stress relieving is done by subjecting the parts to a temperature of about 75 ºC (165 ºF) below the transformation temperature, line A1 on the diagram, which is about 727 ºC (1340 ºF) of steel thus stress relieving is done at about 650 ºC (1202 ºF) for about one hour or till the whole part reaches the temperature. This removes more than 90% of the internal stresses. Alloy steels are stress relieved at higher temperatures. After removing from the furnace, the parts are air cooled in still air.

7.0 DESIGN CODES AND STANDARDS

The following codes have been studied by me to the best of my abilities, during the course of my internship. The various sections of the Codes are in the form of detailed books, each section having a separate book, the main book having Cases and remedial actions, which have to be purchased from ASME by registered and established organizations involved in manufacturing activities or inspection and allied fields.

[A] ASME BOILER AND PRESSURE VESSEL CODE

SECTIONS:

II Materials

Part A — Ferrous Material Specifications

Part B — Nonferrous Material Specifications

Part C — Specifications for Welding Rods, Electrodes, and Filler Metals

Part D — Properties (Customary)

Part D — Properties (Metric)

- The specifications for materials given are identical to the ASTM standards.
- Filler metal procurement guidelines, carbon steel electrodes and of many other materials – Nickel, Tungsten, Aluminum, Zirconium.
- Welding shielding gases have been specified.
- Fluxes for brazing and braze welding and electrodes are given.
- Stress values, yield strengths, thermal expansion values, moduli of elasticity values can be referred.
- Determination of shell thickness from standardized tables.

V Nondestructive Examination

- Procedures have been laid out for NDTs giving their scope, equipments and methods of examination and inspection.

- Detailed view of the radiographic examination, ultrasonic examination method for welds and materials, liquid penetrant examination, magnetic particle examination, eddy current examination, leak tests, acoustic emission exams has been provided.

VIII Rules for Construction of Pressure Vessels

Division 1

Division 2 — Alternative Rules

Division 3 — Alternative Rules for Construction of High Pressure Vessels

- This Code contains mandatory requirements, specific prohibitions and non-mandatory guidance for construction activities.
- The Code is not handbook and cannot replace education, experience and the use of engineering judgments, by design engineers.
- Lays down general requirements for all methods of construction and all materials and provides the scope of the Code.
- Covers materials and design for plates, forgings, castings, bolts, nuts, methods of fabrication, design temperature & pressure, maximum allowable stress values, shell thickness, formed heads, inspection guidelines, pressure relief valves and guidelines for post weld heat treatments, radiography and ultrasonic examination.

IX Welding and Brazing Qualifications

- Relates the qualification of welders, welding operations, brazers and brazing operations and the procedures employed in welding or brazing in accordance with the ASME BPVC and the ASME B31 Code for Pressure Piping.
- Establishes the basic criteria for welding and brazing which are observed in the preparation of welding and brazing requirements that affect procedure and performance – weld orientations, tests and examinations, braze orientations and various tests for the same.

- Generally, a welding operation may be qualified by mechanical, bending tests, radiography of a tests plate or radiography of the initial production weld. Brazers or brazing operation may not be qualified by radiography.

[B] ASME/ANSI B16 – STANDARDS OF PIPES AND FITTINGS

ASME/ANSI B16.5 – Pipe Flanges and Flanged Fittings

The ASME B16.5 - 1996 Pipe Flanges and Flange Fittings standard covers pressure-temperature ratings, materials, dimensions, tolerances, marking, testing, and methods of designating openings for pipe flanges and flanged fittings. The standard includes flanges with rating class designations 150, 300, 400, 600, 900, 1500, and 2500 in sizes NPS 1/2 through NPS 24, with requirements given in both metric and U.S units. The Standard is limited to flanges and flanged fittings made from cast or forged materials, and blind flanges and certain reducing flanges made from cast, forged, or plate materials. Also included in this Standard are requirements and recommendations regarding flange bolting, flange gaskets, and flange joints.

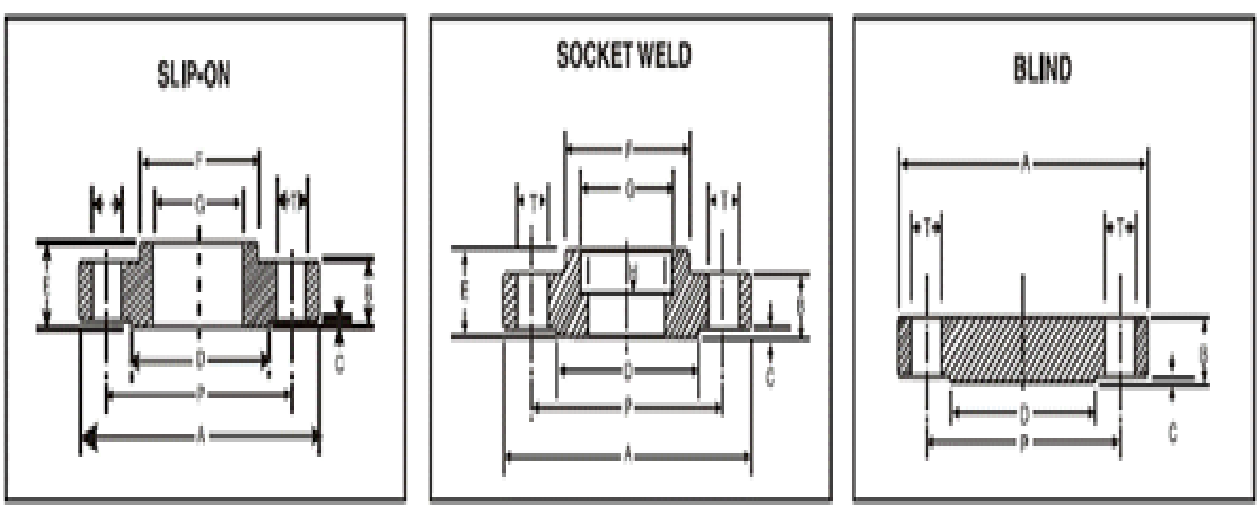


Figure 7.1 – The Various Flanges: Schematic Diagram

Table 7.1 – Flange Dimensions from ANSI B16.5

DIMENSIONS OF CLASS 150 FLANGES AS PER ANSI B 16.5

N.B.	A	B	C	D	E	F	G	H	J	K	L	M	N	O	P	R	T	No.of Holes
15	89	11.1	1.6	35	16	30	22.4	9.5	21.3	-	48	16	16	23.0	60.3	3.0	15.9	4
20	98	12.7	1.6	43	16	38	27.7	11.0	26.7	-	52	16	16	28.0	69.8	3.0	15.9	4
25	108	14.3	1.6	51	17	49	34.5	12.5	33.4	-	56	17	17	35.0	79.4	3.0	15.9	4
32	117	15.9	1.6	64	21	59	43.2	14.5	42.2	-	57	21	21	43.5	88.9	5.0	15.9	4
40	127	17.5	1.6	73	22	65	49.5	16.0	48.3	-	62	22	22	50.0	98.4	6.5	15.9	4
50	152	19.0	1.6	92	25	78	62.0	17.5	60.3	-	64	25	25	62.5	120.6	8.0	19.0	4
65	178	22.2	1.6	105	29	90	74.7	19.0	73.0	-	70	29	29	75.5	139.7	8.0	19.0	4
80	190	23.8	1.6	127	30	108	90.7	20.5	88.9	-	70	30	30	91.5	152.4	9.5	19.0	4
90	216	23.8	1.6	140	32	122	103.4	-	101.6	-	71	32	32	104.0	177.8	9.5	19.0	8
100	229	23.8	1.6	157	33	135	116.1	-	114.3	-	76	33	33	117.0	190.5	11.0	19.0	8
125	254	23.8	1.6	186	37	164	143.8	-	141.3	-	89	37	37	145.0	215.9	11.0	22.2	8
150	279	25.4	1.6	216	40	192	170.7	-	168.3	-	89	40	40	171.0	241.3	12.5	22.2	8
200	343	28.6	1.6	270	44	246	221.5	-	219.1	-	102	44	44	222.0	293.4	12.5	22.2	8
250	406	30.2	1.6	324	49	305	276.4	-	273.0	-	102	49	49	277.0	362.0	12.5	25.4	12
300	483	31.8	1.6	381	56	365	327.2	-	323.9	-	114	56	56	328.0	431.8	12.5	25.4	12
350	533	34.9	1.6	413	57	400	359.2	-	355.6	-	127	57	79	360.0	476.2	12.5	28.6	12
400	597	36.5	1.6	470	64	457	410.5	-	406.4	-	127	64	87	411.0	539.8	12.5	28.6	16
450	635	39.7	1.6	533	68	505	461.8	-	457.2	-	140	68	97	462.0	577.8	12.5	31.8	16
500	698	42.9	1.6	584	73	559	513.1	-	508.0	-	144	73	103	514.0	635.0	12.5	31.8	20
600	813	47.6	1.6	692	83	664	616.0	-	609.6	-	152	83	111	616.0	749.3	12.5	34.9	20

DIMENSIONS OF CLASS 300 FLANGES AS PER ANSI B 16.5

N.B.	A	B	C	D	E	F	G	H	J	K	L	M	N	O	P	R	T	No.of Holes
15	95	14.3	1.6	35	22	38	22.4	9.5	21.3	23.5	52	16	22	23.0	66.7	3.0	15.9	4
20	117	15.9	1.6	43	25	48	27.7	11.0	26.7	29.0	57	16	25	28.0	82.6	3.0	19.0	4
25	124	17.5	1.6	51	27	54	34.5	12.5	33.4	36.0	62	17	27	35.0	88.9	3.0	19.0	4
32	133	19.0	1.6	64	27	64	43.2	14.5	42.2	44.5	65	21	27	43.5	98.4	5.0	19.0	4
40	156	20.6	1.6	73	30	70	49.5	16.0	48.3	50.5	68	22	30	50.0	114.3	6.5	22.2	4
50	165	22.2	1.6	92	33	84	62.0	17.5	60.3	63.5	70	29	33	62.5	127.0	8.0	19.0	8
65	190	25.4	1.6	105	38	100	74.7	19.0	73.0	76.0	76	32	38	75.5	149.2	8.0	22.2	8
80	210	28.6	1.6	127	43	117	90.7	20.5	88.9	92.0	79	32	43	91.5	168.3	9.5	22.2	8
90	229	30.2	1.6	140	44	133	103.4	-	101.6	105.0	81	37	44	104.0	184.2	9.5	22.2	8
100	254	31.8	1.6	157	48	146	116.1	-	114.3	118.0	86	37	48	117.0	200.0	11.0	22.2	8
125	279	34.9	1.6	186	51	178	143.8	-	141.3	145.0	98	43	51	145.0	235.0	11.0	22.2	8
150	318	36.5	1.6	216	52	206	170.7	-	168.3	171.0	98	46	52	171.0	269.9	12.5	22.2	12
200	381	41.3	1.6	270	62	260	221.5	-	219.1	222.0	111	51	62	222.0	330.2	12.5	25.4	12
250	444	47.6	1.6	324	67	321	276.4	-	273.0	276.0	117	56	95	277.0	387.4	12.5	28.6	16
300	521	50.8	1.6	381	73	375	327.2	-	323.9	329.0	130	60	102	328.0	450.8	12.5	31.8	16
350	584	54.0	1.6	413	76	425	359.2	-	355.6	360.0	143	64	111	360.0	514.4	12.5	31.8	20
400	648	57.2	1.6	470	83	483	410.5	-	406.4	411.0	146	68	121	411.0	571.5	12.5	34.9	20
450	711	60.3	1.6	533	89	533	461.8	-	457.2	462.0	159	70	130	462.0	628.6	12.5	34.9	24
500	775	63.5	1.6	584	95	587	513.1	-	508.0	513.0	162	73	140	514.0	685.8	12.5	34.9	24
600	914	69.8	1.6	692	106	702	616.0	-	609.6	614.0	168	83	152	616.0	812.8	12.5	41.3	24

1) All dimensions are in Millimeters

2) Flanges except Lap Joint will be furnished with (1,6) Raised Face, which is included in "Thickness(C)" and "Length through Hub(Y)".

8.0 FINISHING / POLISHING

Polishing and buffing are finishing processes for smoothing a work piece's surface using an abrasive and a work wheel. Technically polishing refers to processes that use an abrasive that is glued to the work wheel, while buffing uses a loose abrasive applied to the work wheel. Polishing is a more aggressive process while buffing is less harsh, which leads to a smoother, brighter finish. Mirror bright finishes are obtained from buffed.

Polishing is often used to enhance the looks of an item, prevent contamination of instruments, remove oxidation, create a reflective surface, or prevent corrosion in pipes. In metallography and metallurgy, polishing is used to create a flat, defect-free surface for examination of a metal's microstructure under a microscope. Silicon-based polishing pads or a diamond solution can be used in the polishing process.

Figure 8.1 – A Buffing Operation In Action

The removal of oxidization (tarnish) from metal objects is accomplished using a metal polish or tarnish remover; this is also called polishing. To prevent further unwanted oxidization, polished metal surfaces may be coated with wax, oil, or lacquer. This is of particular concern for copper alloy products such as brass and bronze.

The term *chem-mechanical* is used to describe action of corrosive slurry on silicon in a polishing process. Multiple rotating heads, each studded with silicon wafers, get forced against a large rotating buffing pad, which is bathed in corrosive slurry. Material removal at elevated temperature progresses first through oxidation, then through oxide removal by abrasion. This cycle repeats with each rotation of a head. Potassium Hydroxide and Silox (white paint-base) can be combined with deionized water to form such slurry.

Polishing may be used to enhance and restore the looks of certain metal parts or objects such as vehicles, handrails, architectural metal and specially pipes are buffed to help prevent corrosion and to eliminate locations where bacteria or mold may reside.

9.0 NONDESTRUCTIVE TESTS (NDTs)

Nondestructive testing (NDT) is a wide group of analysis techniques used in an industry to evaluate the properties of a material, component or system without causing damage. The terms Nondestructive examination (NDE), Nondestructive inspection (NDI), and Nondestructive evaluation (NDE) are also commonly used to describe this technology. Because NDT does not permanently alter the article being inspected, it is a highly-valuable technique that can save both money and time in product evaluation.

- NDT Methods

I witnessed the following methods in action at PEAPL –

1) Surface techniques – Visual / Liquid Penetrant Testing
2) Surface and sub-surface techniques – Magnetic Particle Test/ Eddy Current

(Magnetic method / Electromagnetic method)

3) Volumetric techniques – Radiographic Test, Ultrasonic Test, Acoustic Emission

9.1 VISUAL EXAMINATION

It is the foremost examination normally done for any material / component. It can reveal cracks, corrosion, physical damage, wear and displacement of parts and alignment of mating components, evidence of leak. When direct visual examination is not feasible visual aids like: mirrors, telescopes, boroscopes, fiber optical devices are generally used.

9.2 PENETRANT TEST (PT) OR DIE PENETRANT TEST (DPT)

Dye penetrant inspection (DPI), also called liquid penetrant inspection (LPI) or penetrant testing (PT), is a widely applied and low-cost inspection method used to locate surface breaking defects in all non porous materials (metals, plastics, or ceramics). The penetrant may be applied to all non ferrous materials and ferrous materials; although for ferrous components magnetic-particle inspection is often used instead for its subsurface detection capability. LPI is used to detect casting, forging and welding surface defects such as hairline cracks, surface porosity, leaks in new products, and fatigue cracks on in-service components.

DPI is based upon capillary action, where surface tension fluid low penetrates into clean and dry surface-breaking discontinuities. Penetrant may be applied to the test component by dipping, spraying, or brushing. After adequate penetration time has been allowed, the excess penetrant is removed, a developer is applied. The developer helps to draw penetrant out of the flaw where a visible indication becomes visible to the inspector. Inspection is performed under ultraviolet or white light, depending upon the type of dye used - fluorescent or no fluorescent (visible).

Figure 9.1 – DPT Inspection Steps

- Applications

Used to locate cracks, porosity, and other defects that break the surface of a material and have enough volume to trap and hold the penetrant material. Liquid penetrant testing is used to inspect large areas very efficiently and will work on most nonporous materials.

9.3 MAGNETIC TEST (MT) OR MAGNETIC PARTICLE TEST (MPT)

Magnetic particle inspection (MPI) is a non-destructive testing (NDT) process for detecting surface and subsurface discontinuities in ferroelectric materials such as iron, nickel, cobalt and some of their alloys. The process puts a magnetic field into the part. The piece can be magnetized by direct or indirect magnetization. Direct magnetization occurs when the electric current is passed through the test object and a magnetic field is formed in the material. Indirect magnetization occurs when no electric current is passed through the test object, but a magnetic field is applied from an outside source. The magnetic lines of force are perpendicular to the direction of the electric current which may be either alternating current (AC) or some form of direct current (DC) (rectified AC).

A magnetic field is established in a component made from ferromagnetic material. The magnetic lines of force travel through the material and exit and reenter the material at the poles. Defects such as crack or voids cannot support as much flux, and force some of the flux outside of the part. Magnetic particles distributed over the component will be attracted to areas of flux leakage and produce a visible indication.

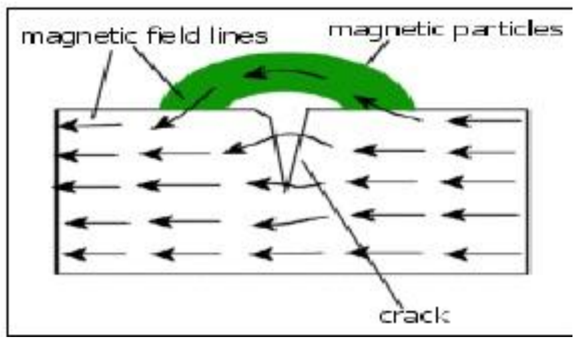


Figure 9.2 – Magnetic Field: MT

- Application

Used for the inspection of ferromagnetic materials (those that can be magnetized) for defects that result in a transition in the magnetic permeability of a material. Magnetic particle inspection can detect surface and near surface defects.

9.4 EDDY CURRENT TESTING

This is based on the principle of electromagnetic induction. When a test coil carrying an alternating current is brought close to a test specimen which is a conductor of electricity. Then the alternating magnetic flux of the coil induces eddy currents in the specimen. The eddy currents induced in the specimen generates a magnetic flux that opposes the test coil magnetic field. The resultant of the test coil flux & flux due to eddy current in the test specimen gives a measure of the changes in test specimens conductivity, dimensions and permeability.

9.5 RADIOGRAPHIC TEST

Radiographic Testing (RT), or industrial radiography, is a nondestructive testing (NDT) method of inspecting materials for hidden flaws by using the ability of short wavelength electromagnetic radiation (high energy photons) to penetrate various materials. Either an X-ray machine or a radioactive source (Ir-192, Co-60, or in rare cases Cs-137) can be used as a source of photons. Neutron radiographic testing (NR) is a variant of radiographic testing which uses neutrons instead of photons to penetrate materials. Very different from X-rays, because neutrons can pass with ease through lead and steel but are stopped by plastics, water and oils.

X-rays are used to produce images of objects using film or other detector that is sensitive to radiation. The test object is placed between the radiation source and detector. The thickness and the density of the material that X-rays must penetrate affect the amount of radiation reaching the detector. This variation in radiation produces an image on the detector that often shows internal features of the test object.

- Applications

Used for the inspection of almost any material for surface and subsurface defects. X-rays can also be used to locates and measures internal features, confirm the location of hidden parts in an assembly, and to measure thickness of materials.

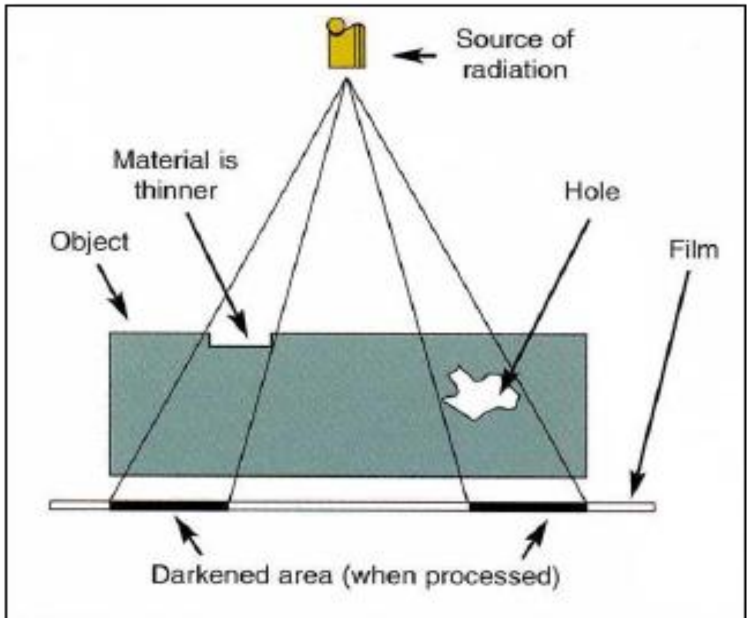


Figure 9.3 – Radiographic Test: Schematic Diagram

9.6 ULTRASONIC TEST

In ultrasonic testing (UT), very short ultrasonic pulse-waves with center frequencies ranging from 0.1-15 MHz and occasionally up to 50 MHz are launched into materials to detect internal flaws or to characterize materials. The technique is also commonly used to determine the thickness of the test object, for example, to monitor pipe work corrosion.

Ultrasonic testing is often performed on steel and other metals and alloys, though it can also be used on concrete, wood and composites, albeit with less resolution. It is a form of non-destructive testing used in many industries including aerospace, automotive and other transportation sectors.

High frequency sound waves are sent into a material by use of a transducer. The sound waves travel through the material and are received by the same transducer or a second transducer. The amount of energy transmitted or received and the time the energy is received are analyzed to determine the presence of flaws. Changes in material thickness and changes in material properties can also be measured. The machine displays these results in the form of a signal with amplitude representing the intensity of the reflection and the distance, representing the arrival time of the reflection.

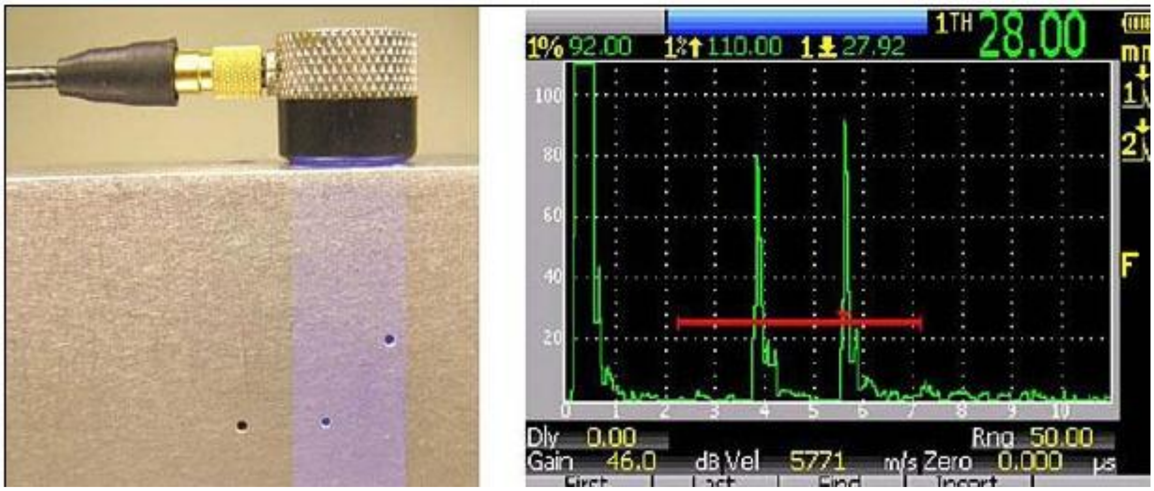


Figure 9.4 – Ultrasonic Test

- Applications

Used for the location of surface and subsurface defects in many materials including metals, plastics, and wood. Ultrasonic inspection is also used to measure the thickness of materials and otherwise characterize properties of material based on sound velocity and attenuation measurements.

9.7 ACOUSTIC EMISSION TESTING

This method is used to assess structural integrity of material and it is possible to detect defects to estimate their rates of growth. It can detect micro cracks in the range of 10-5 to 10-6 inch as they are formed. No extraneous energy is needed for detection of a defect. The defect makes its own signal. Its limitations are that it cannot detect static cracks but can detect crack growth. The method requires skilled operators & interpreters.

10.0 PRESSURE VESSEL HEADS (TORISPHERICAL)

The end caps on a cylindrically shaped Pressure Vessel are commonly known as heads. They are made on hydraulic presses.

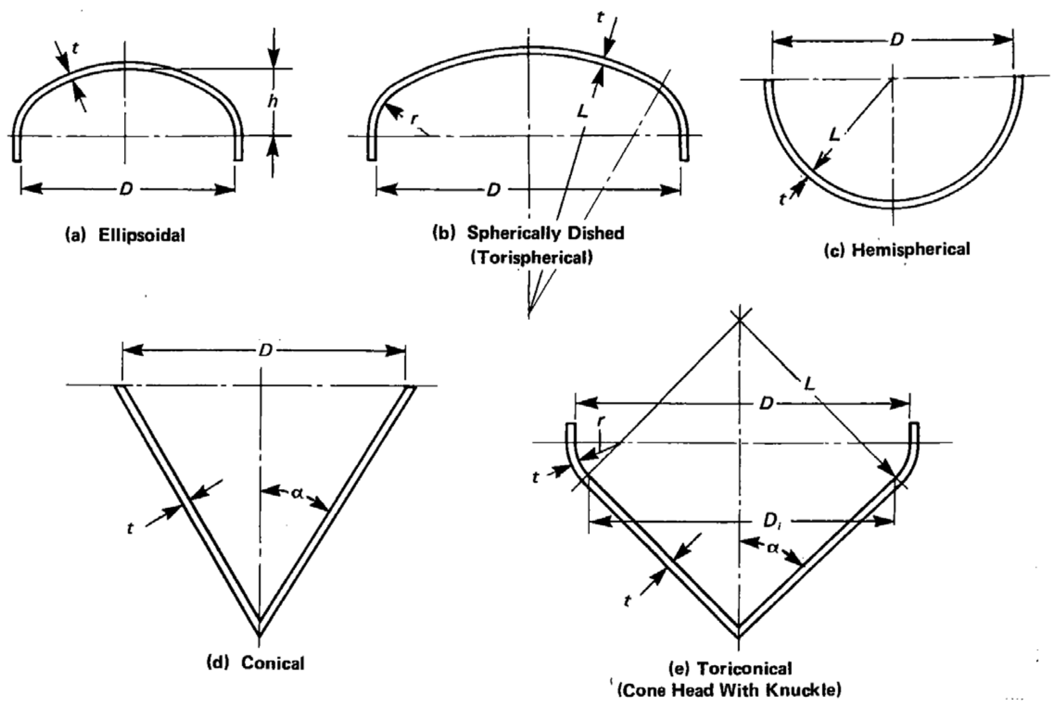


Figure 10.1 – Common Head Shapes

The shape of the heads used can vary. The most common head shapes are:

(a) Ellipsoidal head

This is also called a 2:1 elliptical head. The shape of this head is more economical, because the height of the head is just a quarter of the diameter. Its radius varies between the major and minor axis.

(b) Torispherical head

These heads have a dish with a fixed radius (r1), the size of which depends on the type of torispherical head. The transition between the cylinder and the dish is called the knuckle. The knuckle has a toroidal shape. The most common types of torispherical heads are:

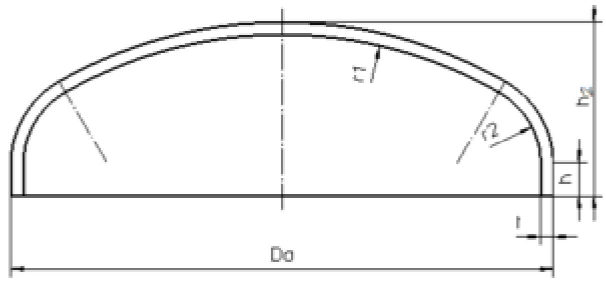


Figure 10.2 – Torispherical Head

Klöpper head

This is a torispherical head. The dish has a radius that equals the diameter of the cylinder it is attached to ($r_1 = Do$). The knuckle has a radius that equals a tenth of the diameter of the cylinder ($r_2 = 0.1 \times Do$), hence its alternative designation "Decimal head".

Also other sizes are: $h \geq 3.5 \times t$, rest of height (let's say h_2) $h_2 = 0.1935 \times Do - 0.455 \times t$.

Korbbogen head

This is a torispherical head also named Semi ellipsoidal head (According to DIN 28013). The radius of the dish is 80% of the diameter of the cylinder ($r_1 = 0.8 \times Do$). The radius of the knuckle is ($r_2 = 0.154 \times Do$).

Also other sizes are: $h \geq 3 \times t$, rest of height (let's say h_2) $h_2 = 0.255 \times Do - 0.635 \times t$. This shape finds its origin in architecture.

(c) Hemispherical head

A sphere is the ideal shape for a head, because the pressure in the vessel is divided equally across the surface of the head. The radius (r) of the head equals the radius of the cylindrical part of the vessel.

(d) Conical head

This is a cone-shaped head.

(e) Flat head

This is a head consisting of a toroidal knuckle connecting to a flat plate. This type of head is typically used for the bottom of cookware.

(f) Diffuser head

This type of head is often found on the bottom of aerosol spray cans. It is an inverted torispherical head.

- Forming the shell sections and heads:

  (a) All plates for shell sections and for heads shall be formed to the required shape by any process that will not unduly impair the physical properties of the material.

  (b) If the plates are to be rolled, the adjoining edges of longitudinal joints of cylindrical vessels shall first be shaped to the proper curvature by preliminary rolling or forming in order to avoid having objectionable flat spots along the complete joints.

  (c) When the vessel shell section, heads or other pressure boundary parts are cold formed by other than the manufacturer of the vessel, the required certification for the part shall indicate whether or not the part has been heat-treated.

- Allowable Forming:

  The code allows two types of forming-

  1) Cold forming – bumping to form the head dish, spinning to form the knuckle portion

  2) Heating to shape

A hydraulic press is a machine using a hydraulic cylinder to generate a compressive force. It uses the hydraulic equivalent of a mechanical lever. The hydraulic press depends on Pascal's principle: the pressure throughout a closed system is constant. Pressure on a confined fluid is transmitted undiminished and acts with equal force on equal areas and at 90 degrees to the container wall.

$$F2 = F1\ (A2/A1)$$

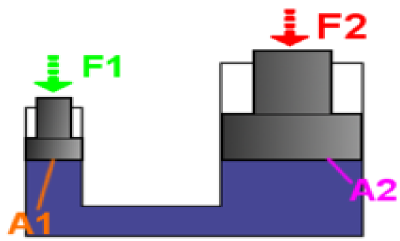


Figure 10.3 Pascal’s Law: Depiction

- Applications

  Hydraulic presses are commonly used for forging, moulding, blanking, punching, deep drawing, and metal forming operations.

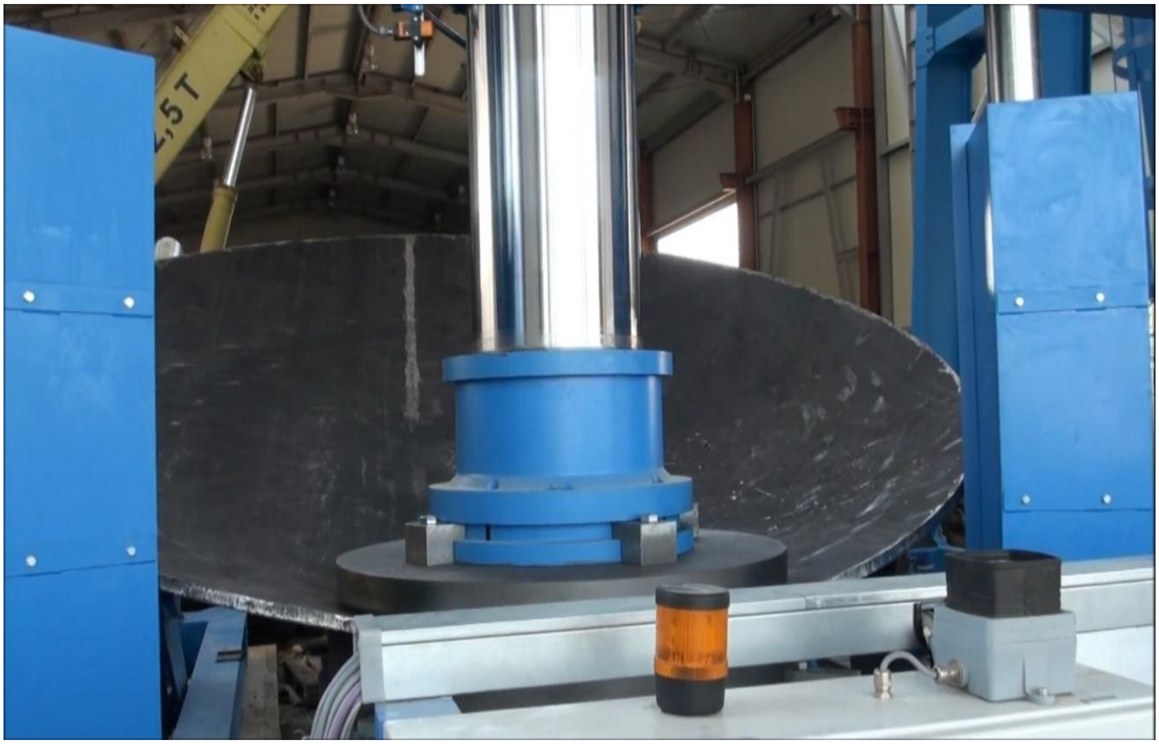


Figure 10.4 – Cold Forming (Dishing)

Figure 10.5 – Head Spinning (Flanging)

Figure 10.6 – Hot Forming

11.0 PRESSURE VESSEL SHELL

Figure 11.1 – Vessel Shell Forming (Rolling)

Figure 11.2 – The Vessel Assembly

12.0 ASSIGNMENTS

PV-Elite is a graphical based, easy-to-use software program that provides engineers, designers, estimators, fabricators and inspectors with complete design capabilities of tall towers, horizontal vessels, individual vessel and heat exchangers. It's a complete solution for analysis and evaluation. Users of PV Elite have designed equipment for the most extreme uses and have done so quickly, accurately and profitably. I did not get to learn the software, but I did handle it and I am aware of its great use in fabrication calculations.

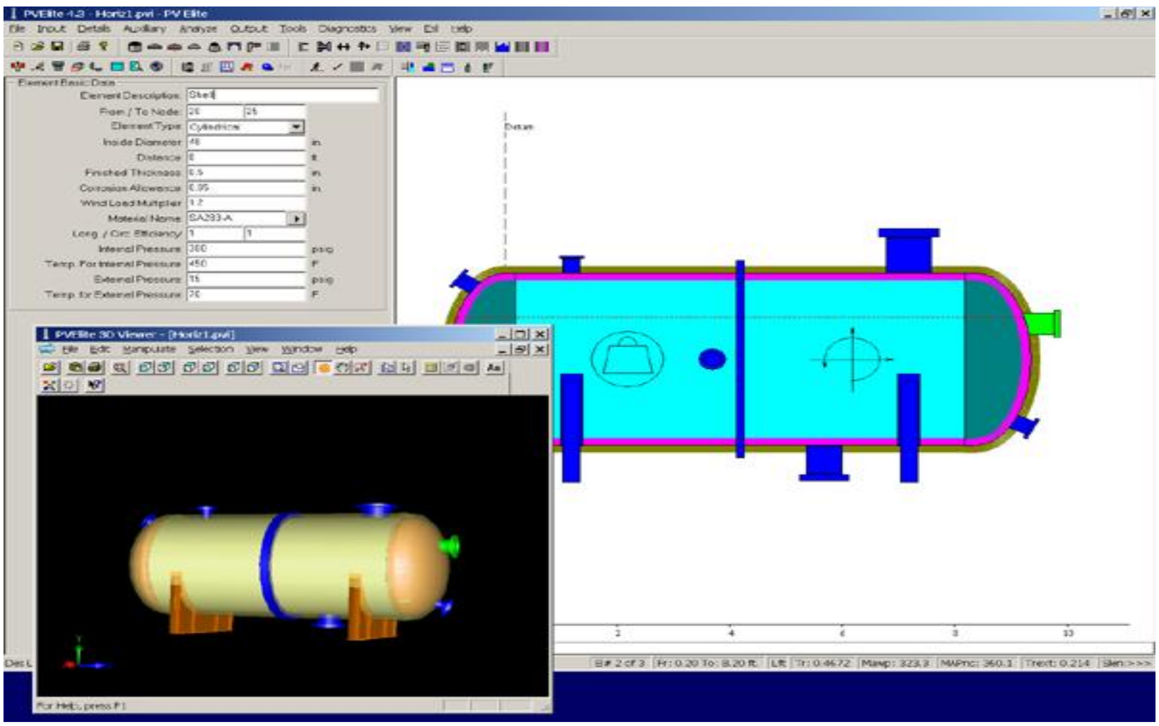


Figure 12.1 – PV Elite Graphic User Interface

Features:

- Vessel Design and Analysis, Rectangular and Non-Circular Vessel Analysis, Individual Component Analysis
- Comprehensive Error Checking, Saddle, Leg and Skirt Design
- Analysis for Horizontal Shipping of Vertical Vessels, Extensive Material Databases, Steel Databases and Modeling

The design reports for the following have been compiled on PV-Elite 2008, by the company and are quite beyond the scope of my internship report. However, the calculations I studied are about internal pressure calculation, external pressure calculation, nozzle, flange calculations, wind load calculation, seismic calculation, detail and element weights and centre of gravity calculations, dished end calculations, shell design, PWHT, Impact test, Hydrostatic test pressure calculations and others, based on the design Codes.

12.1 ISROSENE STORAGE TANK, 150m3

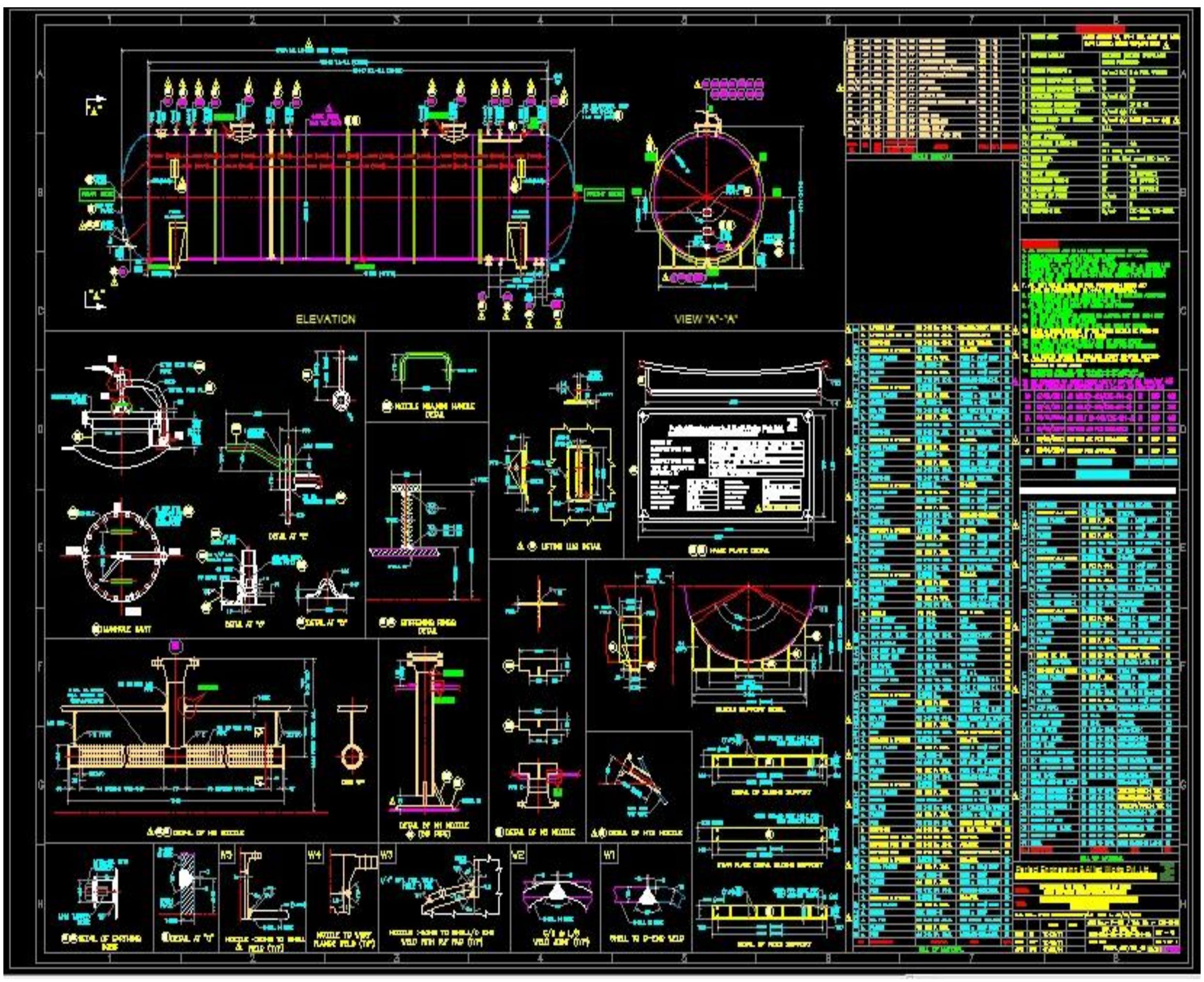


Figure 12.2 – Isrosene Storage Tank, Fabrication Drawing

12.2 UH- 25 SCRUBBER, WITH INTERNALS

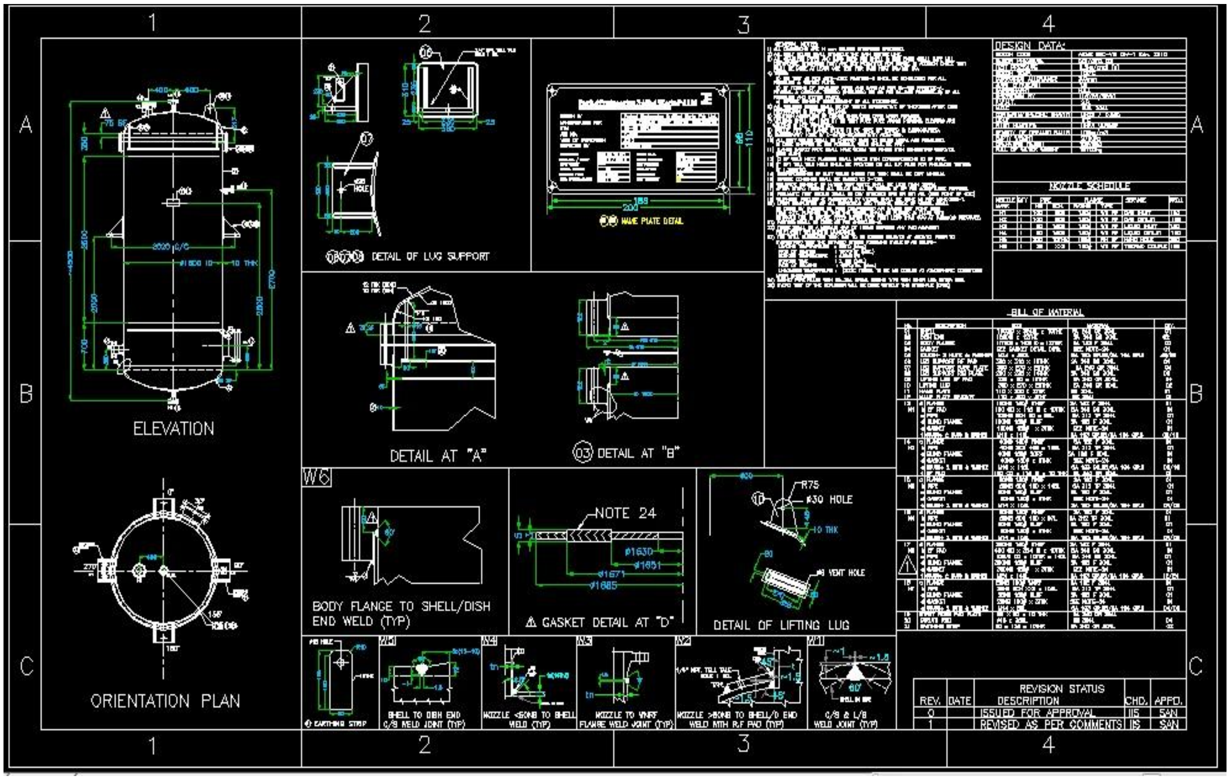


Figure 12.3 – UH-25 Scrubber, Fabrication Drawing

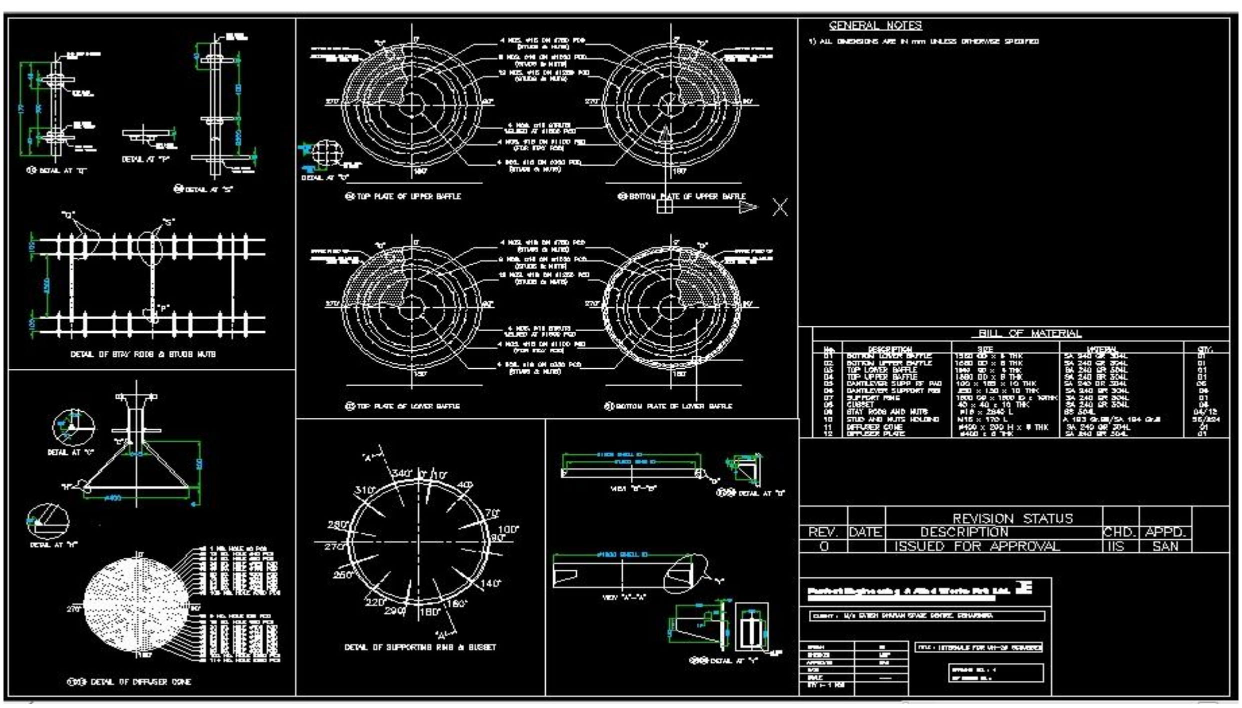


Figure 12.4 – Internals, Fabrication Drawing

12.3 ECR PROTON SOURCE LCW HOLDING TANK

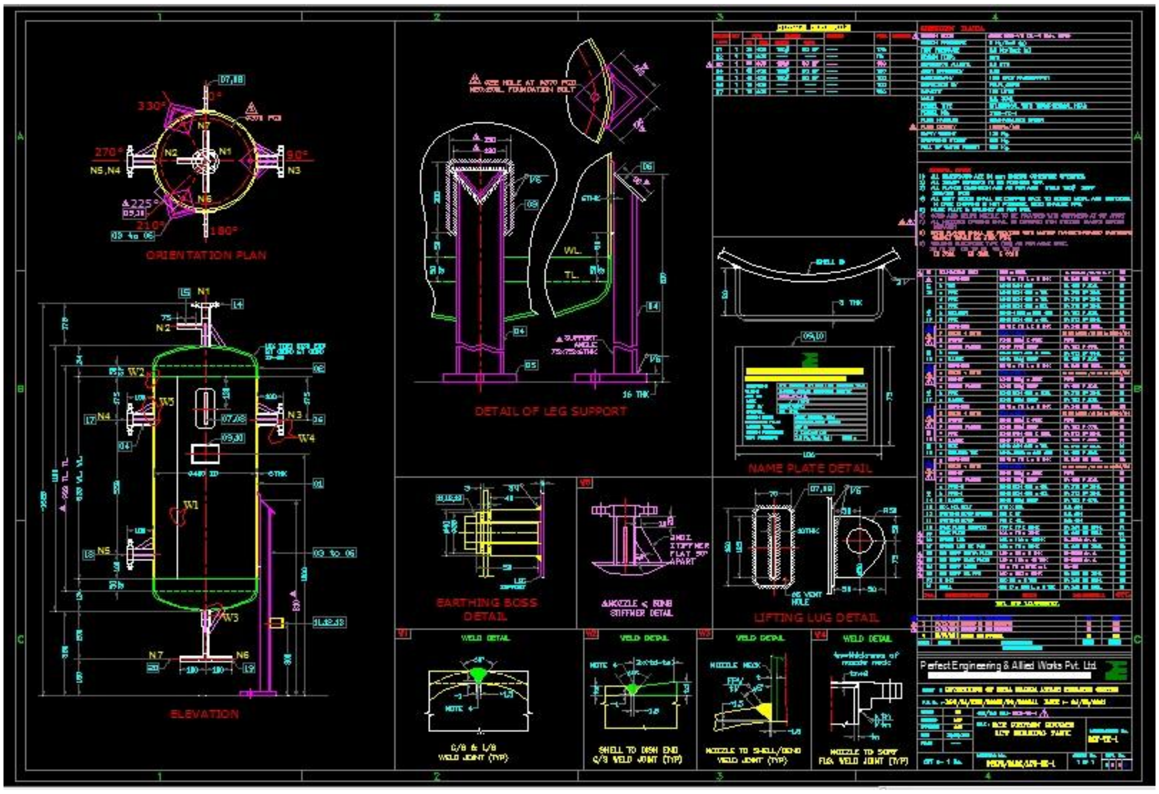
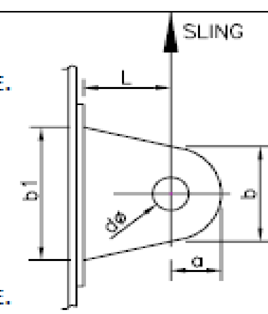


Figure 12.5 – ECR Proton Source LCW Holding Tank, Fabrication Drawing

Table 12.1 – Lifting Lug Design

DESIGN FOR SHEAR
$\sigma_S = F / \{2*\{(b/2-d/2)*t\}$ $=$ 27.78 KG/CM^2 **AS ACTUAL STRESS < ALLOWABLE STRESS, DESIGN IS SAFE.**
DESIGN FOR BEARING
$\sigma_B = F / (d * t)$ $=$ 35.71   **AS ACTUAL STRESS < ALLOWABLE STRESS, DESIGN IS SAFE.**
DESIGN FOR BENDING
SECTION MODULUS 'Z'= $t * b_1^2 / 6$ $=$ 16666.67 MM^3 $\sigma_b = F * L / Z$ $=$ 37.50 KG/CM^2 **AS ACTUAL STRESS < ALLOWABLE STRESS, DESIGN IS SAFE.**
SHEAR STRESS CHECK FOR PAD TO SHELL WELD
$\sigma_{SWP} = F / [2*(W_P + L_P) * 0.707 * F_P]$ $=$ 12.28 KG/CM^2 **AS ACTUAL STRESS < ALLOWBLE STRESS, DESIGN IS SAFE.**
SHEAR STRESS CHECK FOR LIFTING LUG TO SHELL WELD
$\sigma_{SWL} = F / [2*(b_1 + t) * 0.707 * F_L]$ $=$ 11.48 KG/CM^2 **AS ACTUAL STRESS < ALLOWBLE STRESS, DESIGN IS SAFE.**



13.0 CONCLUSION

My training has brought me to realize the engineering problem solving skills that are called for in the fabrication of boilers and pressure vessels. Though I was more involved with studying the Codes and trying to replicate the manufacturing assignments that PEAPL has previously handled—only the design aspects—a considerable amount of time was also spent studying the skills of the workers which are required for fabrication and the thought process of the management in arranging for the required resources. The ASME BPVC is a very comprehensive code and can be understood only through regular practice and execution of it in real life terms. SolidWorks – a mechanical 3D CAD program is utilised. The design aspects if done manually would require superhuman skills, so there are softwares, *exempli gratia* – PV Elite, which have pre-feeded standardized values and entering particular data generates the missing data. Training courses to learn the codes are offered by ASME and several other organizations. A Design Engineer has to attend these conferences and the company should keep updated copies of the ASME BPVC, every three years; the ASME BPVC 2013 would be the latest, offering after the 2010 version, by ASME. Third party inspections are done by companies offering conformity assessment and certification services, namely Lloyd's, Bureau Veritas and others, for Testing, Inspection and Certification (TIC) purpose of the assignments PEAPL receives from their clientele.

A project requires thorough co-operation from all departments to be executed. No single NDT technique serves all the purpose. The choice of a particular technique depends on specimens properties, accessibility & nature of defects expected in the specimen often various techniques are used in conjunction. In the markets – Global, National or Local companies have trusted partners. Besides offering services and products to clients, companies strive to develop innovative solutions to reduce risks, improve performance and promote sustainable development.

14.0 REFERENCES

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APPENDIX A: The 2010 ASME Boiler and Pressure Vessel Code with Addenda – An Overview

<u>Section I- Power Boilers</u> Has rules for construction of power, electric, and miniature boilers; high temperature water boilers for stationary service and power boilers for locomotive, portable and traction service.	**<u>Section II - Materials</u>:** **Section II Part A -** Ferrous Material Specifications; Provides material specifications for ferrous materials adequate for safety for pressure equipment. Includes requirements for mechanical properties, test specimens and methods of testing.
Section II Part B - Nonferrous Material Specifications; Provides material specifications for nonferrous materials adequate for safety for pressure equipment, including requirements for mechanical properties, test specimens & methods of testing.	**Section II Part C -** Specifications for Welding Rods, Electrodes and Filler Metals; Has material specifications for manufacture, acceptability, testing requirements and procedures, operating characteristics and intended uses for welding rods, electrodes and filler metals.
Section II Part D - Properties (Customary) A service Code for reference by boiler and pressure vessel construction Codes having tables of design stress, tensile and yield strength values, and tables and charts of material properties.	**Section II Part D - Properties (Metric)** A service Code for reference by boiler and pressure vessel construction Codes having tables of design stress, tensile and yield strength values, and tables and charts of material properties.
<u>Section III - Rules for Construction of Nuclear Facility Components:</u> **Section III Subsection NCA - General Requirements for Division 1 & Division 2** Contains the glossary and rules pertaining to Duties and Responsibilities, design documentation, quality assurance, Authorized Nuclear Inspection and the use of Code symbol stamps.	**Section III Division 1 Subsection NB - Class 1 Components** Contains requirements for assuring the structural integrity of Class 1 items - materials, design, fabrication, examination, testing and overpressure protection.
Section III Division 1 Subsection NC - Class 2 Components Contains requirements for assuring the structural integrity of Class 2 items - material, design, fabrication, examination, testing and overpressure protection.	**Section III Division 1 Subsection ND - Class 3 Components** Contains requirements for assuring the \structural integrity of Class 3 items - material, design, fabrication, examination, testing and overpressure protection.

Section III Division 1 Subsection NE - Class MC Components Contains requirements for assuring the structural integrity of Class MC items - material, design, fabrication, examination, testing and overpressure protection.	**Section III Division 1 Subsection NF - Supports** Contains requirements for material, design, fabrication, and examination of metal supports designed to transmit loads from the components or piping to the building structure.
Section III Division 1 Subsection NG - Core Support Structures Contains requirements for material, design, fabrication, and examination for structures that directly support or restrain the core within the reactor pressure vessel.	**Section III Division 1 Subsection NH - Class 1 Components in Elevated Temperature Service** Contains requirements for material, design, fabrication, examination, testing and overpressure protection of Class 1 items when temperatures exceed those covered by Subsection NB.
Section III Division 1 – Appendices Contains appendices, both mandatory and Non-mandatory for Section III, Divisions 1 and 2, including a listing of design and design analysis methods, information, and Data Report Forms.	**Section III Division 2 - Code for Concrete Reactor Vessels and Containments** Contains requirements for material, design, construction, fabrication, testing, examination, and overpressure protection of concrete vessels and concrete containment structures.
Section III Division 3 - Containment Systems and Transport Packaging for Spent Nuclear Fuel and High Level Radioactive Waste Requirements for the design and construction of the containment system of a nuclear spent fuel or high level radioactive waste transport packaging.	**Section III Division 5 – High Temperature Reactors** Construction rules for high-temperature reactors, including both gas-cooled reactors and liquid-metal reactors.
Section IV - Heating Boilers Provides rules for design, fabrication, installation and inspection of steam generating boilers, and low pressure hot water boilers that are directly fired by oil, gas, electricity, or coal.	**Section V - Nondestructive Examination** Contains radiographic, ultrasonic and liquid penetrant methods required by other Code Sections, which detect discontinuities in materials, welds, and fabricated parts and components.

<u>Section VI - Recommended Rules for the Care and Operation of Heating Boilers</u> Has guidelines applicable to steel and cast iron boilers within the operating range for Section IV Heating Boilers, including associated controls and automatic fuel burning equipment.	**<u>Section VII - Recommended Guidelines for the Care of Power Boilers</u>** Has guidelines applicable to stationary, portable, and traction type boilers within the operating range for Section I Power Boilers, to assist operators in maintaining plant safety.
<u>Section VIII - Pressure Vessels:</u> **Section VIII Division 1** Provides requirements for design, fabrication, inspection, testing, and certification of fired or unfired pressure vessels operating at pressures exceeding 15 psig.	**Section VIII Division 2 - Alternative Rules** Has requirements for construction and certification of pressure vessels operating at pressures over 15 psig using design by analysis methods, and design stresses higher than Division 1.
Section VIII Division 3 - Alternative Rules for the Construction of High Pressure Vessels Provides requirements applicable to the design, fabrication, inspection, testing, and certification of pressure vessels operating at either internal or external pressures above 10,000 psi.	**<u>Section IX - Welding and Brazing Qualifications</u>** Has rules for qualification of welding and brazing procedures and welders, brazers, and welding and brazing operators for component manufacture. Data cover variables for the process used.
<u>Section X - Fiber-Reinforced Plastic Pressure Vessels</u> Has requirements for construction of an FRP pressure vessel including production, processing, fabrication, inspection and testing methods required for two Classes of vessel design.	**<u>Section XI - Rules for Inservice Inspection of Nuclear Power Plant Components</u>** Provides rules for the examination, inservice testing and inspection and repair and replacement of components and systems in light water and liquid metal cooled nuclear power plants.
<u>Section XII - Rules for Construction and Continued Service of Transport Tanks</u> Covers construction and continued service of pressure vessels for transportation of dangerous goods by highway, rail, air or water at pressures up to 3,000 psig and volumes over 120 gallons.	**<u>Code Cases: Boilers and Pressure Vessels</u>** Provided when the need is urgent, such as: rules for materials or constructions not covered by existing Code rules.

Code Cases: Nuclear Components Provided when the need is urgent, such as: rules for materials or constructions not covered by existing Code rules.	