Design and Engineering of Pressure Vessels

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Abstract—Pressure vessels find application in the entire chemical and process industries.Manufacturing of huge pressure vessels is one of the main challenges faced by the manufacturing industry.This paper deals with design, manufacture and testing of pressure vessel (Boiler drum in high pressure boiler). Details of Boiler drum, a vital component in high pressure boiler are presented.Input parameters for designing the pressure vessel are detailed.Design, manufacture,testing as per code (ASME) is explained in detail.Pressure vessels are hazardous if they are not properly constructed and mainted.Pressure vessel code governs safety,design,fabrication andinspection.Efforts are made to explain the sequence of various operations carried out in manufacturing the boiler drum.

Index Terms –Pressure vessel, ASME Code, Boiler drum, dished end, welding, hydraulic test, stress relief, Erection

1 INTRODUCTION

The Pressure vessels are subjected to internal pressure.Safety is the top most priority.It is to be ensured that the vessel is safe in the working condition.Economy in design is also to be taken in to consideration

A typical pressure vessel (Boiler drum) manufacturing is discussed in detail in this paper. Design,material selection,fabrication,welding ,heat treatment and testing are discussed.Generally pressure vessels are designed and manufactured as per ASME pressure vesselscode.All aspects of design,fabrication,testing are presented in this paper.

1.1 Input Parameters

For designing any pressure vessel the input parameters arepressure, temperature and capacity.Based on these parameters preliminary design is done.Shape, size is determinedAttachments, if any are to be clearly understood.Material selection is made based on whetherfluid is corrosive or not.

The boiler drum is designed to the following parameters.

Pressure – 170 bar

Temperature – 350 deg C

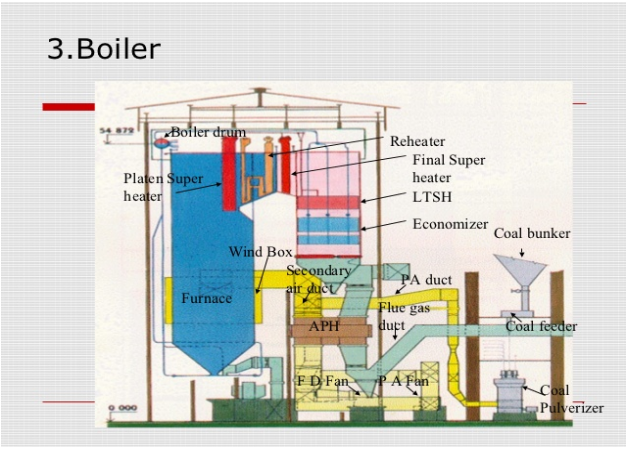

Fig. 1 Boiler

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2 DESCRIPTION

The most important function of boiler drum in a thermal plant is the separation of steam and water.The steam drum is the most impotant part of a boiler.

Boiler drum is a vital component in high pressure boiler.Boiler produces steam at the rated parametersto run the turbine for producing power in any thermal plant.The configuration ofhighpressure boiler is shown in the figure1.The main purpose of the boiler drum isto store water and steam mixure required for steam generation.

Boiler water quality water is produced in water treatment plant.Feed water pumps this treated water to boiler drum via economizer.The water entersthe boilerthrough a section in the convective pass called the economizer.From the economizer it passes through a steam drumand from there it goes through downcomerpipesto inlet headersat the bottom of the water walls.From these headerwater risesthro' the water wallsof the furnacewhere some of it turns in to steamand the mixurewater/steammixurereenters the steam drum.This process is driven by natural circulationbecausethe water in thedown comer pipesis denserthan the water steam mixure in the furnace wallswaste heat is absorbed by the economizer before it enters the boiler drum.From the boiler drum water passes throughdown comer pipesto lower part of the boiler proper as shown in the figure.At the furnace fuel is burntandtheheat is transmitted towater walls.Part of the water is converted to steam and the steam water mixure enters rhe boiler drum.Water and steam mixure is separated in boiler drumThe drum holds water in the lower portion and steam in the upper portion.This is wet steam.The wet steam from the boiler drum is taken to super heaterand finally reaches the turbine

Typical parameters of 500 MW Boiler:

Pressure – 170 bar

Temperaturte – 540 deg C

Generally the size of the boiler drum is 1800 mm for a typical power boiler.Thickness of shell and dished end is calculated as per the code.Length of the pressure vessel is based on the capacity.

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3 DESIGN OF BOILER DRUM

The parameters required for designing the boiler drum are Working pressure, temperature and capacity.Diameter is selected on the basis ofavailability of dished ends which are welded to the cylindrical vessel.The thickness is calculatedas per ASME pressure vessel code and length as per the capacity requirement

Formula for determining thickness as per ASME pressure vessel code

$$t = \frac{PD}{2SE+2yP} + C$$

t =Minimumwall thickness
P=Design pressure
D = Outside diameter
E = Welding factor
Y = Wall thickness welding factor
C = Coorrosion allowance
S = Maximum allowable stress

A typical diagram of boiler drum is shown in the figure 2
A typical diagram

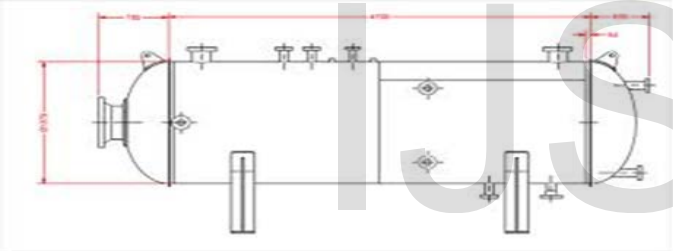

Fig 2. Boiler drum

3.1 Detailed Engineering

Detailed engineering drawings are to be made showing all the details of material reqirement, fabrication details including edge preparation for welding, and details of welding.Heat treatment details are to be indicated.Working pressure, working temperature andtest pressureare indicated in the drawing.

3.2 Materials

The material used for the boiler drum is SA299 as per ASME pressure vessel specification.The physical andchemical properties are as given below.

Table 1.ASME SA299 chemical composition :

Grade	The Element Max (%)					
	C	Si	Mn	P	S	Mo
SA299 GR.A	0.28-0.30	0.13-0.45	0.84 -1.62	0.035	0.035	-
SA299 GR.B	0.28-0.30	0.13-0.45	0.84 -1.62	0.035	0.035	-

Carbon Equivalent: Ceq
=【C+Mn/6+(Cr+Mo+V)/5+(Ni+Cu)/15】%

Table 2. ASME SA299 Mechanical Property :

Grade	Thickness	Yield	Tensile	Elongation
	mm	Min Mpa	Mpa	Min %
SA299 GR.A	t≦50	275-290	515-655	19
	50< t ≦200	275-290	515-655	19
SA299 GR.B	t≦50	310-325	550-690	19
	50 < t ≦200	310-325	550-690	19

Approval of chief Inspector of boilers:
Once the design is frozen,strength calculations are made.They are submitted to Chief Inspector of boilers for their approval along with detailed drawings.After getting the approval only-fabrication of the vessel is started.

Process of Manufacturing:

Once the design drawings are ready, method of manufacturing, stages of inspection are incorporated in the process sheets.Accordingly manufacture of components are taken up.Work will proceed without any loss of time as per schedule.Fabrication work is carried out sequentiallyas per the laid out procedure and completed

Manufacturing:
The required materials as per specification are procured.Quality check of the plate by ultrasonictest is carried out.Test reports from supplier and tests carried out in laboratory are examined.Test pieces are taken from the original material for testing chemical composition andmechanical properties. The boiler drum material is SA299 confirming to ASME standards.First cylindrical shell portion is manufactured.Plates are cut to desired size and heated in a furnace to a temperature of 800 deg C and rolled in a four roller bending machine to form U shapes.The two U shaped components are as shown in the figure.Then they are welded by submerged arc welding and rolled to form cylindrical vessel.Distortion control is very important.Special methods are employed to see that there is no distortion.After wards welds are grinded to remove burrs.The dimensions are checked for its circularity.The acceptable devia tion is +1%of diameter.

Fig.3 Plate bending

The dished ends are manufacturedby cold or hot pressingand in a combination process ofpressing and spinning.Larger size-dished ends are manufactured bycombination process ofboth

pressing and subsequent spinning.For spinning the dished end,a hole of size20 mm to 30 mm diameter is providedat the centre of the blankfor holding during spinning.

The dished ends are manufactured and edges are prepared for welding with cylindrical portion.Root welding (inner side of the vessel) is carried out firstand outer welding iscarried out finally.Both thedished ends are welded to the cylindrical portion to get the final shape of boiler drum as per the drawing.All the welds are X rayed for its quality.All the stubs are welded to the vessel and quality of welds is ensured.Then heat treatment is carried out at 600 deg C to relieve thermal stresses.

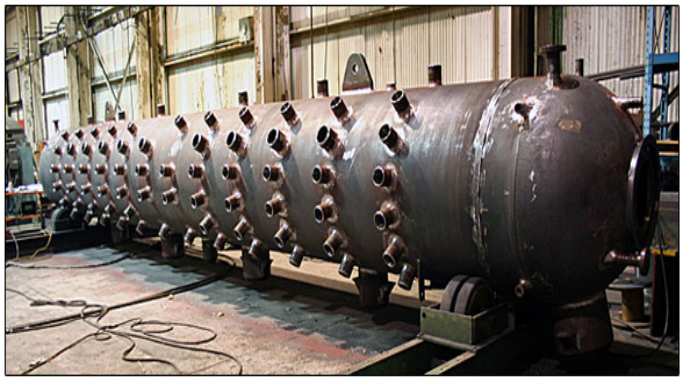

Fig.4 Manufacture of Boiler drum

4 TESTING

Finally the vessel is subjected to hydrostatic test pressure of 1.5 times the design pressure in the presence of boiler Inspectorate.Then it is cleared for sending to the thermal power plant site.

5 TRANSPORTATION

The boiler drum is the single heaviest component and weighs approximately 250 tons for a typical 500 MW boiler.Due care is to be taken for proper transportation.It requires lot of effort for transporting it to site.A specially made vehicle is employed for transportation.Photograph of transport is shown in the figure

Fig 5. Transportation of boiler drum

6 ERECTIONS

The boiler drum is erected at site at a height of 50 M approximately.For this purpose heavy cranes are employed-since this is a massive component.Lifting of drum is shown in the figure.The drum is hung from that level to allow thermal expansion and down comer pipes and riser pipes are welded to the drum.Erection of boiler drum is a daunting task.

Fig 6. Erection of boiler drum

7 CONCLUSION

The design and engineering of boiler drum a vital component in thermal power station is explained in detail.The various processes involved are meticulously followed to fabricate the vessel.Safety is the top most priority.The various precautions taken during the manufacture of boiler drum are explained.Hope this will be of interest to the engineering community.

REFERANCES

[1] ASME Pressure vessel code
[2] Work experience at BHEL,Trichy

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