A PROJECT REPORT

ON

DESIGN AND ANALYSIS OF BOILER

Submitted by

KHAN MOHD. TAHA	**13ME23**
SHAIKH ATAUR REHMAN	**13ME45**
RAMEEZ SHAIKH	**13ME54**
JUNAID SYED	**13ME59**

In partial fulfillment for the award of the Degree

Of

BACHELOR OF ENGINEERING

IN

MECHANICAL ENGINEERING

UNDER THE GUIDANCE

Of

Prof. ALTAMASH GHAZI

DEPARTMENT OF MECHANICAL ENGINEERING

ANJUMAN-I-ISLAM

KALSEKAR TECHNICAL CAMPUS NEW PANVEL,

NAVI MUMBAI – 410206

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ANJUMAN-I-ISLAM

KALSEKAR TECHNICAL CAMPUS NEW PANVEL

(Approved by AICTE, recg. By Maharashtra Govt. DTE,

Affiliated to Mumbai University)

PLOT #2&3, SECTOR 16, NEAR THANA NAKA, KHANDAGAON, NEW PANVEL,NAVI MUMBAI-410206, Tel.: +91 22 27481247/48 * Website: www.aiktc.org

CERTIFICATE

This is to certify that the project entitled

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To the Kalsekar Technical Campus, New Panvel is a record of bonafide work carried out by him under our supervision and guidance, for partial fulfillment of the requirements for the award of the Degree of Bachelor of Engineering in Mechanical Engineering as prescribed by **University Of Mumbai**, is approved.

Project co-guide (Prof. Altamash Ghazi)

Internal Examiner

External Examiner

Head of Department (Prof. Zakir Ansari)

Principal (Dr. Abdul Razak H.)

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APPROVAL OF DISSERTATION

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(Internal Examiner) **(External Examiner)**

___________________ ___________________

Date: ___________

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KHAN MOHD. TAHA 13ME23

SHAIKH ATAUR REHMAN 13ME45

RAMEEZ SHAIKH 13ME54

JUNAID SYED 13ME59

ABSTRACT

This project work deals with a detailed study and design procedure of Boiler. A detailed study of various parts of Boilers like shell, heads, support, nozzles and its reinforcements, etc. are made and designed separately.

The first part deals with study of Boiler i.e. the types of shells used in pressure vessel construction, types of heads & their advantages and disadvantages over each other, nozzles and need for reinforcements and types of stands used with appropriate diagrams. The advantages and disadvantages of each selected part is also done.

The second chapter includes the problem definition, nomenclature, procedure of design which include detailed design of shell based on diameter & tangential stresses constraints, heads based on hemispherical type, nozzles based on flow rates & respective reinforcement and support based on skirt type of selection.

The third and last part deals with the future prospects regarding the improvisation of design & its analysis and optimization using modern tools like ANSYS.

OBJECTIVE OF THE PROJECT

The main subjects covered in these project are Material Technology, Design of Components, Strength of Materials, Engineering Mechanics, Finite Element Analysis, Manufacturing Processes, etc.

In sophisticated Boilers encountered in engineering construction; high Pressure, extremes of temperature and severity of functional performance requirements Pose exciting design problems. The word "DESIGN" does not mean only the Calculation of the detailed dimensions of a member, but rather is an all inclusive Term, incorporating:

1. The reasoning that established the most likely mode of damage or failure;
2. The method of stress analysis employed and significance of results;
3. The selection of materials type and its environmental behavior.

The aim of our project is to abide by these terms and Design a Boiler under such extremes constraints. Further, the analysis will be carried out in ANSYS, which is a modern tool & provides an edge for future engineering , development and computerization. These tools gives an advantage for analysis time reduction and Optimization to ultimately reduce costs.

Last but not the least, knowledge of such designs & modern tools are inevitably important in industries.

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1. INTRODUCTION:

Shell of the Boiler

Types of shell-

The main categories on large, in which the shells are classified, are

- Thin shells
- Thick shells

A cylinder is considered thin when the ratio of its inner diameter (d) to the wall thickness (t) is more than 15 or equal.

When the ratio of inner diameter (d) to the wall thickness (t) is less than 15 it is considered as a thick cylinder. Boiler shells, pipe tubes, storage tanks are the examples of thin walled cylinders while hydraulic cylinders, high pressure pipes, gun barrels, submarines are thick walled cylinders.

In our design, the shell used is a thin cylinder type as the shell thickness required is less as compared to the storage capacity or the inner diameter of the vessel. In thin shells the stresses are assumed to be uniformly distributed over the wall thickness and hence even the analysis becomes simple and convenient.

Material of the Shell for design-

Stainless Steel - Grade 316 (UNS S31600)

Chemical Formula

Fe, <0.03% C, 16-18.5% Cr, 10-14% Ni, 2-3% Mo, <2% Mn, <1% Si, <0.045% P, <0.03% S

Grade 316 is the standard molybdenum-bearing grade, second in importance to 304 amongst the austenitic stainless steels. The molybdenum gives 316 better overall corrosion resistant properties than Grade 304, particularly higher resistance to pitting and crevice corrosion in chloride environments. It has excellent forming and welding characteristics. It is readily brake or roll formed into a variety of parts for applications in the industrial, architectural, and transportation fields. Grade 316 also has outstanding welding characteristics. Post-weld annealing is not required when welding thin sections. Grade 316L, the low carbon version of 316 and is immune from sensitisation (grain boundary carbide precipitation). Thus it is extensively used in heavy gauge welded components (over about 6mm). Grade 316H, with its higher carbon content has application at elevated temperatures, as does stabilised grade 316Ti. The austenitic structure also gives these grades excellent toughness, even down to cryogenic temperatures.

Corrosion Resistance

Excellent in a range of atmospheric environments and many corrosive media - generally more resistant than 304. Subject to pitting and crevice corrosion in warm chloride environments, and to stress corrosion cracking above about 60°C. Considered resistant to potable water with up to about 1000mg/L chlorides at ambient temperatures, reducing to about 500mg/L at 60°C.

316 is usually regarded as the standard “marine grade stainless steel”, but it is not resistant to warm sea water. In many marine environments 316 does exhibit surface corrosion, usually visible as brown staining. This is particularly associated with crevices and rough surface finish.

Heat Treatment

Solution Treatment (Annealing) - Heat to 1010-1120°C and cool rapidly. These grades cannot be hardened by thermal treatment.

Welding

Excellent weld ability by all standard fusion methods, both with and without filler metals. AS 1554.6 pre-qualifies welding of 316 with Grade 316 and 316L with Grade 316L rods or electrodes (or their high silicon equivalents). Heavy welded sections in Grade 316 require post-weld annealing for maximum corrosion resistance. This is not required for 316L. Grade 316Ti may also be used as an alternative to 316 for heavy section welding.

Machining

A “Ugima” improved machinability version of grade 316 is available in round and hollow bar products. This machines significantly better than standard 316 or 316L, giving higher machining rates and lower tool wear in many operations.

Dual Certification

It is common for 316 and 316L to be stocked in "Dual Certified" form - mainly in plate and pipe. These items have chemical and mechanical properties complying with both 316 and 316L specifications. Such dual certified product does not meet 316H specification and may be unacceptable for high temperature applications.

TYPES OF BOILER:

Boilers can be classified as follows:

1. According to the flow of water and hot gases – fire tube (or smoke tube) and water tube boilers.

In fire tube boilers, hot gases pass through tubes which are surrounded with water. Examples: Vertical, Cochran, Lancashire and Locomotive boilers. There may be single tube as in case of Lancashire boiler or there may be a bank of tubes as in a locomotive boiler.

In water tube boilers, water circulates through a large number of tubes and hot gases pass around them. E.g., Babcock & Wilcox boiler.

2. According to the axis of the shell – vertical and horizontal boilers.

3. According to location or position of the furnace. Externally and internally fired boilers.

In internally fired boilers, the furnace forms an integral part of the boilers structure. The vertical tubular, locomotive and the scotch marine boilers are well known examples. Externally fired boilers have a separate furnace built outside the boiler shell and usually below it. The horizontal return tube (HRT) boiler is probably the most widely known example of this type.

4. According to the application – stationery and mobile boilers. A stationary boilers is one of which is installed permanently on a land installation.

A marine boiler is a mobile boiler meant for ocean cargo and passenger ships with an inherent fast steaming capacity.

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Factor of safety in the design-

A higher factor of safety is taken because-

- As the any unknown force which is not been accounted in the design or which cannot be estimated is taken care of.
- After manufacturing of the shell the homogeneity of the material is always a doubt and the material may be weaker at some of the parts.
- Failure in service can cause huge losses in terms of property and lives.
- Stress concentrations at various cross sections may fail the component.
- Higher reliability is achieved.
- Also the vessel is operated in a corrosive environment in the given case.

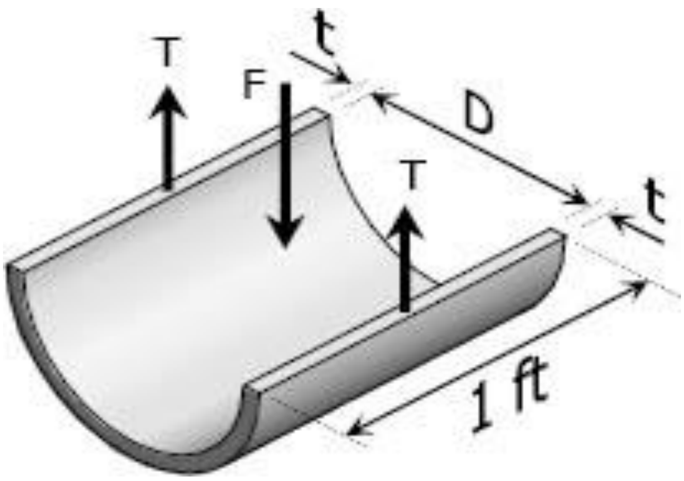
Design failure of shell-

Stresses acting on the shell-

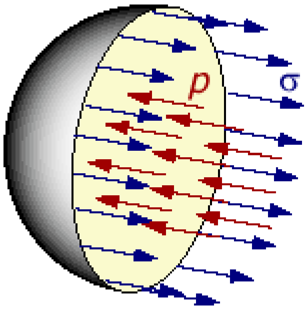
Tangential or circumferential stress σ_t

One such type of stress is the **hoop stress**, which is defined for rotationally-symmetric objects as the average force exerted circumferentially (perpendicular both to the axis and to the radius of the object) in both directions on every particle in the cylinder wall.

$$\sigma_t = P_i * D_i / 2 * t$$



- **Longitudinal Stresses σ_1**



It is defined for rotationally-symmetric objects as the average force exerted lengthwise (parallel to the axis of the object) in both directions on every particle in the cylinder ends.

$\sigma_1 = P_i * D_i / 4 * t$

As the formulas for both the stresses suggest that circumferential stress is twice more than longitudinal and hence, failure of the shell occurs because of this, and the shell is cut lengthwise as shown in fig above. Hence this is taken as the design constraint for the shell. Thickness obtained above is added with a corrosion allowance of 1.5 to 4 mm.

Compound cylinder:

Compound cylinders are used in high pressure applications, as it helps the structure straight down in 2 ways-

- Provides external pressure fitting.
- Acts as insulation when high or low temperature fluid is stored in vessel.

Compound cylinders are advantageous as against simple single layered thickness shell. Such shells are made by a process called Auto-frettage wherein two concentric cylinders with outer cylinder is shrunk in the inner one. This induces compressive stresses in the inner one and reduces the net pressure acting on the cylinder. This is carried out by heating the outer cylinder and expanding its diameter and then put on the inner one under gradual cooling which makes it press fitted.

Hence this is used in the design.

Criteria for jacket and shell thickness:

In the design the maximum tangential or circumferential stresses in both shell and the jacket should be same and are equated. They should also be below the permissible stress values so as to be safe under stressing conditions. The resultant stresses due to internal and external fittings on the shell and the jacket are calculated and then equated. The difference in diameters is calculated by formulas and the jacket inner diameter is found out. At the end of design all stress values are checked that they are under the permissible limits and are to be found safe.

Head:

The end caps on a cylindrically shaped Boiler are commonly known as heads.

Head shapes

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

Hemispherical head

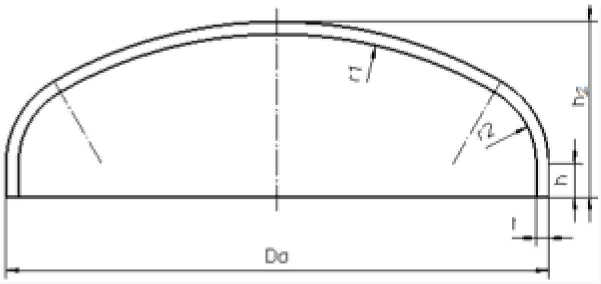
A sphere is the ideal shape for a head, because the pressure in the vessel is divided equally across the surface of the head. The radius (r) of the head equals the radius of the cylindrical part of the vessel.

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.

Tori-spherical head

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



Schematic of a tori-spherical head

Klopper head

This is a tori-spherical 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

(Lets say h_2) $h_2 = 0.1935 \times Do - 0.455 \times t$.

Korbbogen head

This is a tori-spherical head. 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

(lets say h_2) $h_2 = 0.255 \times Do - 0.635 \times t$. This shape finds its origin in architecture.

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.

Diffuser head

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

Conical head

This is a cone-shaped head.

<u>WHY WE HAVE SELECTED HEMISPHERICAL HEAD?</u>

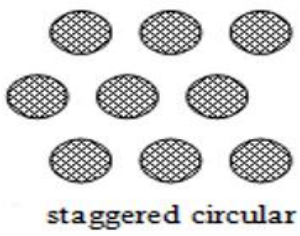
Assume you have made a square cross section for the storage of steam. This is made by welding of 4 plates at the corner. Now you close the open ends with plates. Now you send steam through a pipe and start applying pressure. Now due to pressure inside the walls of the shell assume the shape of a sphere just like a balloon takes its shape. Now the pressure is uniform inside the sphere and the spherical container is more suitable for storing liquids and gases.

Hence we take this advantage in providing hemispherical ends to cylinders.

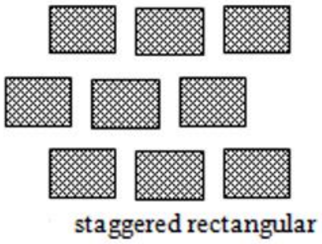
Different types of shape of tubes in boiler

Based on the concept of heat transfer rate from different shapes of fin of same material, We have 3 different shapes namely**,**

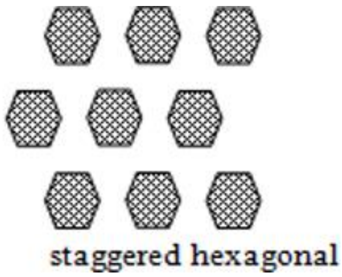
i) St. Circular,



ii) St. Rectangular,



iii) St. Hexagonal.



	Total Heat Transfer Rate					
geometries	Re=37	Re=113	Re=339	Re=565	Re=790	Re=1016.5
Staggered Circular	141.08	149.23	233.07	345.28	370.82	414.71
Staggered Hexagonal	151.36	159.38	251.72	352.27	376.96	434.01
Staggered Rectangle	166.92	156.04	231.74	302.2	368.08	415.79

From the above table, we can clearly conclude that for high Heat Transfer Staggered Hexagonal shape is recommended.

Hence the tube shapes in this boiler is of hexagon shape for high Heat Transfer causing less energy to transfer its heat to water to convert it into steam. Hence less energy is required as compared to other traditional tube shapes.

Heat Treatment

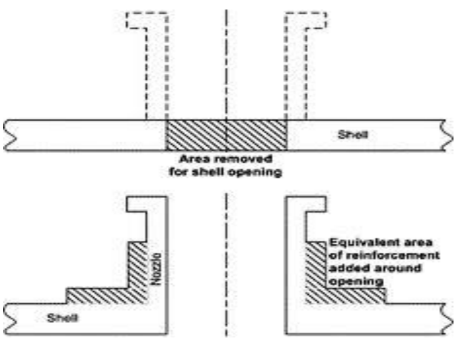
Heat treatment is usually required after cold forming, but not required by heads formed by hot forming.

NOZZLES, OPENINGS AND REINFORCEMENTS:

Nozzles and openings are necessary components of Boilers for the process industries. Openings in a cylindrical shell, conical section or closure may produce stress concentrations, adjacent to the opening and weaken that portion of the vessel. In order to minimize such stress concentrations, it is preferable that the opening be circular in shape. As a second choice the openings may be made elliptical, as a third choice they may be made around. An around opening has two parallel sides and two semicircular ends. Openings of other shapes are permissible if the vessel is tested hydrostatically.

If the opening in a closure of cylindrical vessel exceed one-half the inside diameter of shell, the opening and closure should be fabricated. Others openings require reinforcement. Small sizes of openings which are welded or brazed to a vessel do not require reinforcement.

In the case of shell, opening requiring reinforcement in vessel under internal pressure the metal removed must be replaced by the metal of reinforcement. In addition to providing the area of reinforcement, adequate welds must be provided to attach the metal of reinforcement and the induced stresses must be evaluated.



Materials used for reinforcement shall have an allowable stress value equal to or greater than of the material in this vessel wall except that, when such material is not available, lower strength material may be used; provided, the reinforcement is increased in inversed proportion to the ratio of the allowable stress values of the two materials to the ratio of the two materials to compensate for the lower allowable stress value of any reinforcement having a higher allowable stress value than that of the vessel wall.

SUPPORTS FOR VESSELS:

Cylindrical and other types of vessels have to be supported by different methods. Horizontal vessels are supported by brackets, column, skirt, or stool supports, while saddles support horizontal vessels. The choice of type of support depends on the height and diameter of the vessel, available floor space, convenience of location, operating variables, the size of these vessel, the operating temperature and pressure and the materials of construction.

Brackets of lugs offer many advantages over other types of supports. They are inexpensive, can absorb diametrical expansions by sliding over greased or bronze plates, are easily attached to the vessel by minimum amounts of welding, and easily leveled or shimmed in the field. Lug supports are ideal for thick-walled vessels, but in thin-walled vessels, this type of support is not convenient unless the proper reinforcements are used or many lugs are welded
to the vessel.

It is also necessary to ensure that, the attachment of the support to the vessel, which is usually by fillet welds should be able to transfer the load safely from vessel to support and that, the support should be strong enough to withstand the load of the vessel.

SKIRT:

Horizontal vessels are normally supported by means of suitable structure resting on a reinforced concrete foundation. This support structure between the vessel and the foundation may consist of a cylindrical shell termed as skirt. The skirt is usually welded to the vessel because the skirts are not required to withstand the pressure in the vessel; the selection of material is not limited to codes. The skirt may be welded directly to the bottom dished head, flush with the shell or to the outside of shell. There will be no stress from internal and external pressure for the skirt, unlike for the shell, but the stresses from dead weight and from wind or seismic bending moments will be maximum.

ANCHOR BOLT:

The bottom of skirt of vessel must be securely anchored to the concrete foundations by means of anchor bolts embedded in the concrete to prevent over turning from bending moments induced by seismic and wind loads. The concrete foundation is poured with adequate reinforcing steel to carry tensile loads.

2. PROBLEM DEFINITION:

A storage vessel consisting of compound cylinders. In a tube of inner diameter 750 mm a jacket is truncated of external diameter 900 mm . The vessel is subjected to an internal pressure of 1.5 Mpa . The shrinkage is such that maximum tangential stresses in both inner and outer tubes are same .

Assume,

- All joints are double welded butt joint with full penetration and radiographed.
- Corrosion Allowance = 1.5 mm.

Design for,

a) Contact pressure and dimension of the vessel ,

b) material of the Boiler and permissible stress ,

c) Dimension of hemispherical head ,

d) If length of Boiler is 1.8m determine capacity of Boiler.

3. **<u>Literature Survey</u>**

- *Wei Zhong, Hongcui Feng, Jian Wang, "***Online Hydraulic calculations and operation optimization of industrial steam heating networks considering heat dissipation in pipes***", Energy, Volume 87, July 2015 , Pages 566-577:*

- *Hafiz Muhd. Ali, Mohd. Zishan Qasim, MuzaffarAli,"***Free convection condensation heat transfer of steam on horizontal square wire wrapped tubes", Journal of Heat and Mass Transfer***, Volume 98, July 2014, Pages 350-358:*

- *B.K Hardik, S.V Prabhu,*"**Boiling pressure drop and local heat transfer distribution of water in horizontal straight tubes at low pressure**", *Journal of Thermal Sciences, Volume 110, Dec 2016, Pages 65-83:*

- *Bing Xue, Xiangrui Meng, Jun fukai,"***Dynamic study of steam generation from low grade waste heat in a zeolite-water adsorption heat pump***", Applied Thermal Engineering, Volume 88, Sep 2015, page 451-458:*

4. NOMENCLATURE:

P : design pressure, Mpa

T : design temperature, °C

C : corrosion allowance, mm

D_1 : inside diameter of the shell, mm

D_2 : outside diameter of the shell, mm

R_1 : inside radius of the shell, mm

R_2 : outside radius of the shell, mm

S : maximum allowable stress, Mpa

E : Joint efficiency, %

T : required the thickness, mm

F_r : strength reduction factor

W :weight of the vessel

H : height of center of gravity

N : Number of bolts

A_b : area with in the bolt circles, mm^2

C_b : circumference of bolt circle, mm

Ba : required area of one bolt, mm

As : area within the skirt, mmA2

Cs : circumference on outer diameter of skirt, mm

$D_{So:}$ outer diameter of the skirt, mm

Ds_i: inside diameter of the skirt, mm

F_b : safe bearing load on the concrete, Mpa

I: width of the base plate, mm

B’: shell thickness + corrosion allowance

5. DESIGN:

5.1 Design of Shell:

The shell is designed for the storage of DEA amine solution at high pressure of 100 bar. To maintain the storage capacity, the inner diameter of 1500mm is a constraint. Since a compound cylinder is taken as a shell, the jacket outer diameter is fixed as 1800mm as a constraint to end at. Various stresses acting on the shell discussed in the previous chapter, are worked out and the safe thickness is to be determined. For Autofrettage the diameter difference is important and is required to be found out.

Operating pressure: **1.5 Mpa**

Design pressure: **3 Mpa**

Operating temperature: **200^{0}c**

Design temperature: **220^{0}c**

Inner diameter of shell D_1: **750mm**

Outer diameter of jacket D_3: **900 mm**

Joint efficiency of butt welding $ή_t$: 85**%**

Poisson's ratio μ: **0.275**

Weight density: **7970.4 kg/m^3**

Modulus of Elasticity E: 1**.9 *10^5 N/mm^2**

Material for shell selected: **SS 316**

Material properties:

σ_{ut}**= 580 N/mm^2** σ_{ys}=**290 N/mm^2**

Elongation: **30%**

C_{max}: **0.03** Si_{max}: **0.75** M_n: **2**

P_{max}: **0.04** S_{max}: **0.03**

Cr: **16.5-18** Mo: **2-2.5**

- **To find permissible stresses**:

$[\sigma_t] = \sigma_{ut}$/FOS=413/3.5= **165.7 N/mm^2**

- **Thickness of shell obtained from formulas**:

1. **By circumferential stress criteria**:-

$t = (P_i*D_i)/ (2*[\sigma_t]*ή_t) = (12*1500)/ (2*118*1)$

= 7.98mm

Adding corrosion allowance of 1.5mm

t = 7.98+1.5=9.3mm

Let **t = 10mm (say)**

2. **Based on theory of Thin cylinders with modifications**

$t = (P_i*D_i)/ ([2*[\sigma_t]*ή_t]-P_i) = (3*750)/ ([2*167.5*1]-3)$

= 8.07mm.

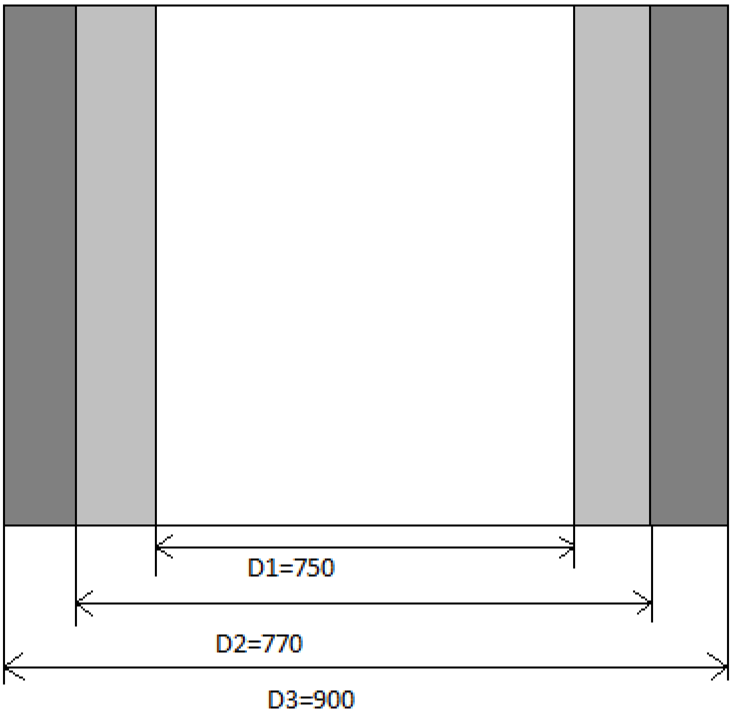
Adding corrosion allowance of 1.5mm

t = 8.07+1.5=**9.57mm**

The values obtained from both the above formulas are approximately equal to 10mm.

Hence final value of thickness **t = 10mm**

Outer diameter of shell will be D_2 = 750+ (2*10) =770mm.



To design based on equal maximum tangential stress in both shell & jacket-

- **Stresses due to internal pressure:**

$\sigma_{tp} = (P_i * D_1^{2/} D_3^{2-} D_1^{2)}) * [(D_3^{2/} 4r^{2)} + 1]$

$= (3*750^2/900^2-750^2)*[(900^2/4r^2) + 1]$

$=75/11*[(900/r)^2 + 1]$

Values of σ_{tp} at various points

Radius (mm)	σ_{tp} (N/mm^2)
375	16.61
385	16.11
450	13.62

- **Stresses due to shrinkage pressure**

a) In jacket-

σ_{ts} = (P*$D_2^{2/}D_3^{2-}D_2^{2)}$*[($D_3^{2/}4r^{2)}$ +1]

= (P*$770^2/900^2-770^2$)*[($900^2/4r^2$) +1]

= 2.73P*[$(900/r)^2$ + 1]

Values of σ_{ts} at various points

Radius (mm)	σ_{tp} (N/mm^2)
385	6.46P
450	5.46P

b) In shell-

σ_{ts} = - (P*$D_2^{2/}D_2^{2-}D_1^{2)}$*[1+ ($D_1^{2/}4r^2$)]

= - (P*$770^2/770^2-750^2$)*[($750^2/4r^2$) +1]

= -19.5P*[$(750/r)^2$ + 1]

Values of σ_{ts} at various points

Radius (mm)	σ_{tp} (N/mm^2)
375	-39P
385	-38P

Since maximum tangential stress in0 both Shell & jacket should be same,

Hence, equating stresses at inner surface of shell & jacket,

16.61-39P=16.11+6.46P

P=0.011Mpa

The resultant stresses are:

	For shell		For jacket	
	R=375	R=385	R=385	R=450
Stresses due to P_i	16.61	16.11	16.11	13.62
Stresses due to P	-0.43	-0.42	0.071	0.06
Resultant stresses	**16.18**	15.69	**16.181**	13.68

For press fitting the outside jacket i.e. for **autofrettage** the difference in inner diameter of jacket and outer diameter of shell should be,

$\delta = (P*D_2/E)*[2*D_2^2*(D_3^2-D_2^2)/ (D_3^2-D_2^2)*(D_2^2-D_1^2)]$

δ = 0.002 mm

Hence, inner diameter of the jacket should be

D_3 = 900-0.02

= **899.998mm**

- **Stresses acting on the compound vessel are:**

$\sigma_r = -P_i =$ **3N/mm²**

$\sigma_t =$ **16.61 N/mm²**

- **Principal stress** in axial direction
  - **in shell**

$\sigma_1 = (P_i*D_1^2)/ (D_2^2-D_1^2)$

$= (3*750^2)/ (770^2-750^2)$

= **55.51 N/mm²**

  - **in jacket**

$\sigma_1 = (P_i*D_2^2)/ (D_3^2-D_2^2)$

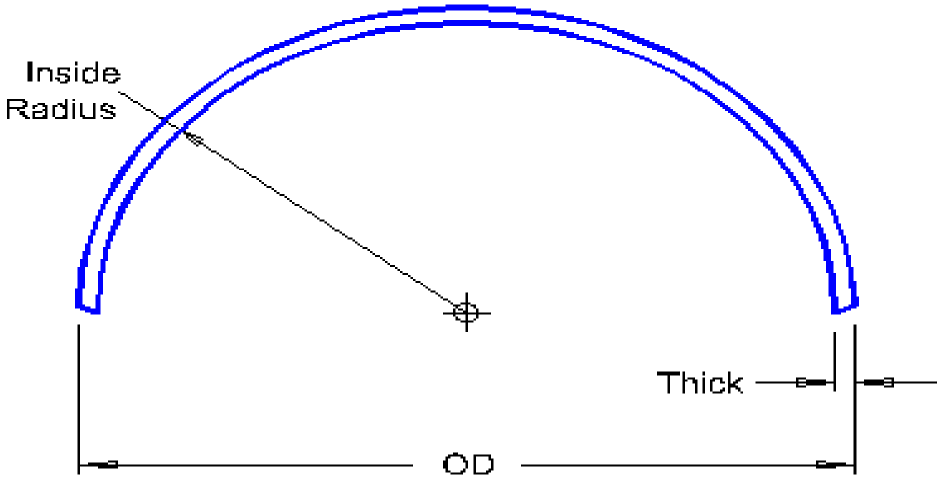
$= (3*770^2)/ (900^2-770^2)$

=**8.19 N/mm²**

The above values of stresses convey they are under the permissible limit of **165.7 N/mm²** and hence the compound shell is safe.

5.2 Design of Heads:

The hemispherical heads are designed with an internal pressure of 12MPa as the operating pressure being 10MPa and the thickness is calculated for the upper shell and lower shell by using the formulas and the constraint being outer diameter of 1800mm.



The **thickness of hemispherical ends** is given by-

For **Upper shell**:- t=(P_i* D_i /4*sigma t)

={(3*(1500)}/(4*165.7)

= 3.39* i.e. approx. 5mm.

For **Lower shell**:- t=(P_i* D_i /4*sigma t)

={(12*(1500)/4*165.7)

= 3.39 i.e. approx. 5mm.

Upper shell:- Internal diameter:-760mm.

External diameter:-770mm.

Lower shell:- Internal diameter:-760mm.

External diameter:-770mm.

For **Autofrettage**:-

For **Upper Shell** and **Lower shell**:-

δ:- $\{(P*D_2/E)(2*(D_2)^2 ((D_3)^2-(D_2)^2)\}$ **/** $\{((D_3)^2-(D_2)^2) ((D_2)^2-(D_1)^2)\}$

= $((0.2596*1660)$ / $2.08*10^5*(2(1660)^2 ((1800)^2-(1660)^2)\}$ **/** $\{((1800)^2-(1660)^2) ((1660)^2-(1580)^2)\}$

δ = 0.4807mm.

5.3 Design of Support:

Reason for selecting skirt as a support:

The reason for selecting the skirt as a support because the force on it is uniformly distributed and it provide a uniform support for the horizontal Boiler.

Reason for selecting structural steel as material:

Selecting structural steel as a material for support because it is good in compressive stress.

Reason for designing a bearing plate:

Skirt support which is welded on the bearing plate is bolted to the ground to fix the Boiler with the help of bearing plate. Also it shares the load acting on the skirt support.

Reason for selecting material of bolt:

Selecting bolt material as ASTM-A307 (medium carbon steel) because it has a good tensile strength. It is available in all sizes and it has a good corrosive property.

1. **Design for bolt:**

Selecting Material for bolt as ASTM – A307 (Medium Carbon Steel)

Tensile Strength = 110,000 psi

= 110,000 * 0.006984

= 768.27 N/mm^2

Taking number of bolts on Bearing plate as **n = 12**.

i) **Calculating force on each bolt:**

$F_{(bolt)}$ = (1638819.5 / 12)

= 136568.29 N

ii) **Calculation of Diameter of Bolt:**

Yield strength = 768.27 / 3.5 (F.O.S = 3.5)

= 219.49 N/mm^2

Area = (Force per bolt) / (yield strength)

= 136568.29 / 219.49

$(\Pi /4) * d^2 = 1440.74$

d= 28.14 mm

d= 30mm (taking next higher value)

Therefore selecting bolt size as **M30.**

6. FUTURE PROSPECTS:

- To design valves for nozzles as per the pressure and diameter constraints according to our project guide directions.

- To use Finite Element Analysis for analysis of the Boiler

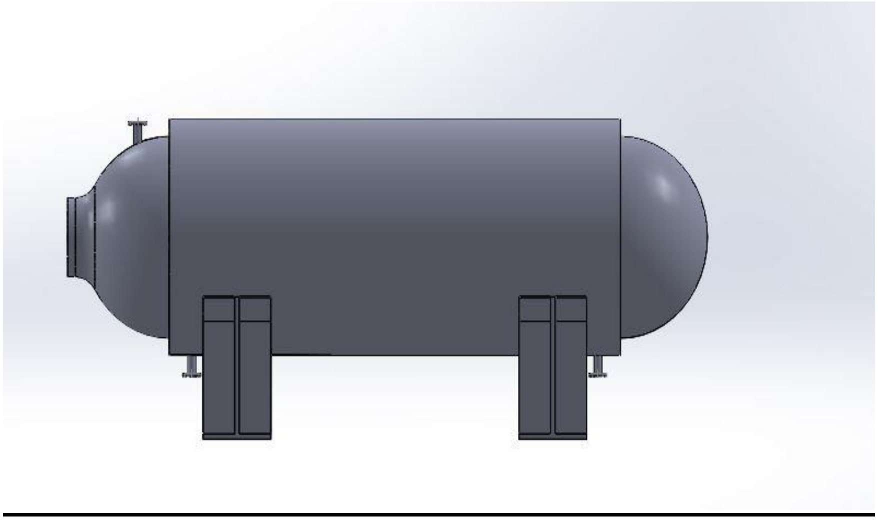
- To use ANSYS & Analyze the design using this software.

- To Optimize the Boiler is also the main criteria of our project like to opt for other types of head, go for column type of support, etc.

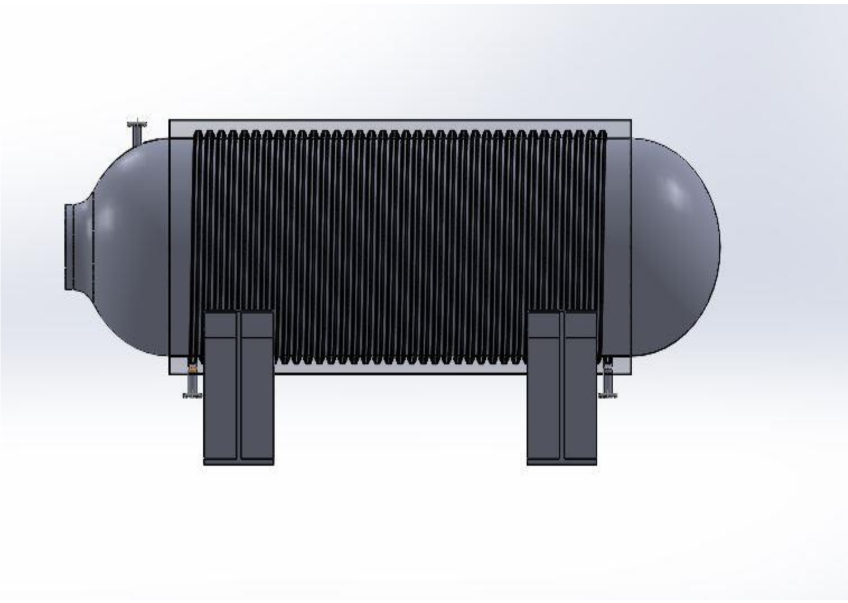
- Improvisation in terms of Head selection, supports, nozzles flow rate and other modern trends in design like opting for cheaper materials of various compositions

7. Assembly View

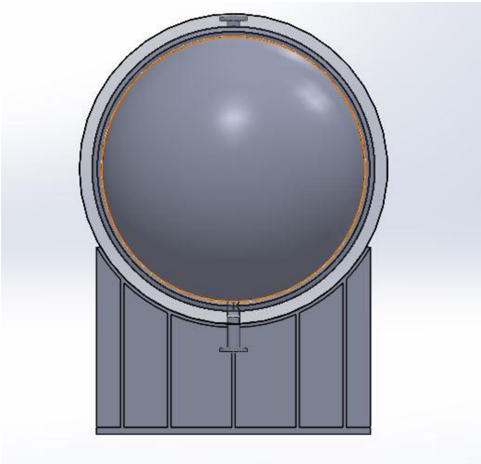
Front view:

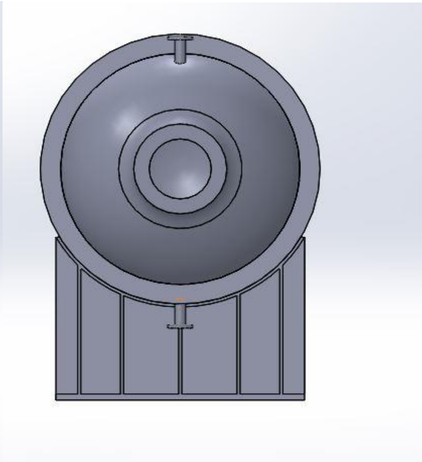


Front view with jacket and tubing:

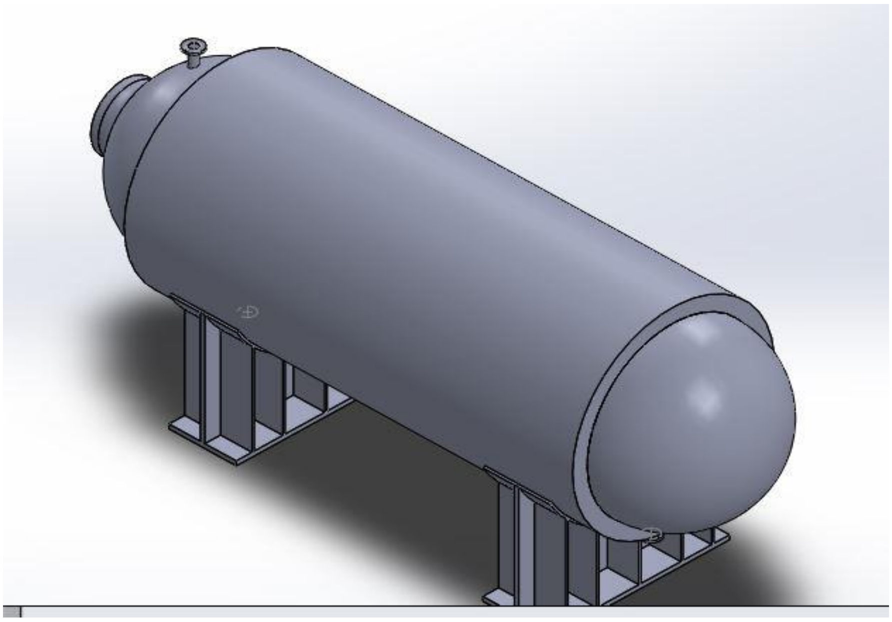


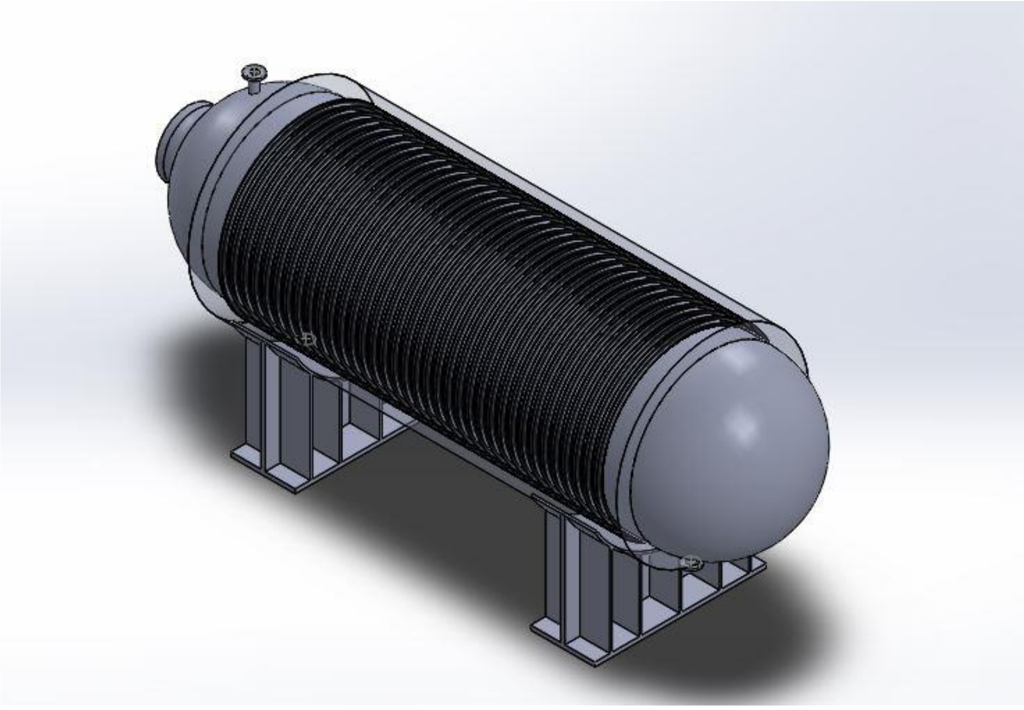
Side views:



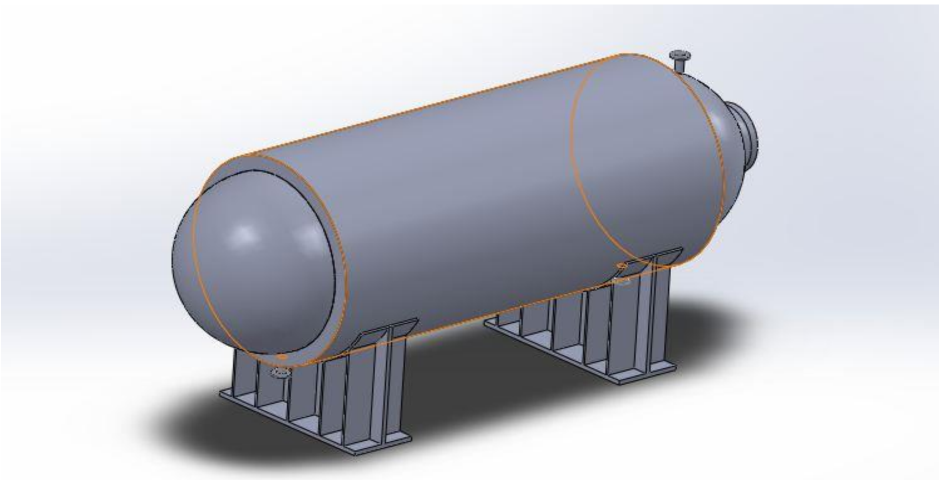


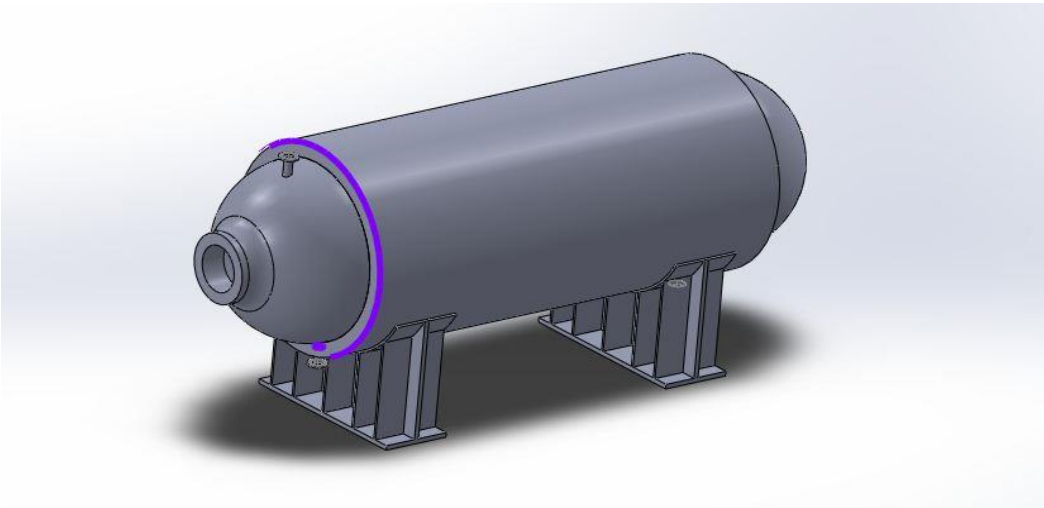
Isometric View:





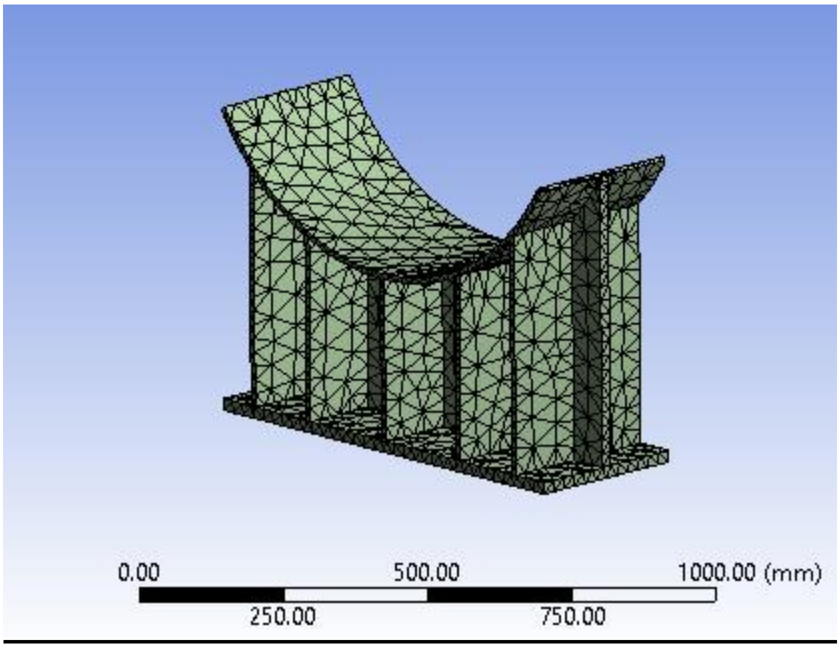
Final Assembly view:



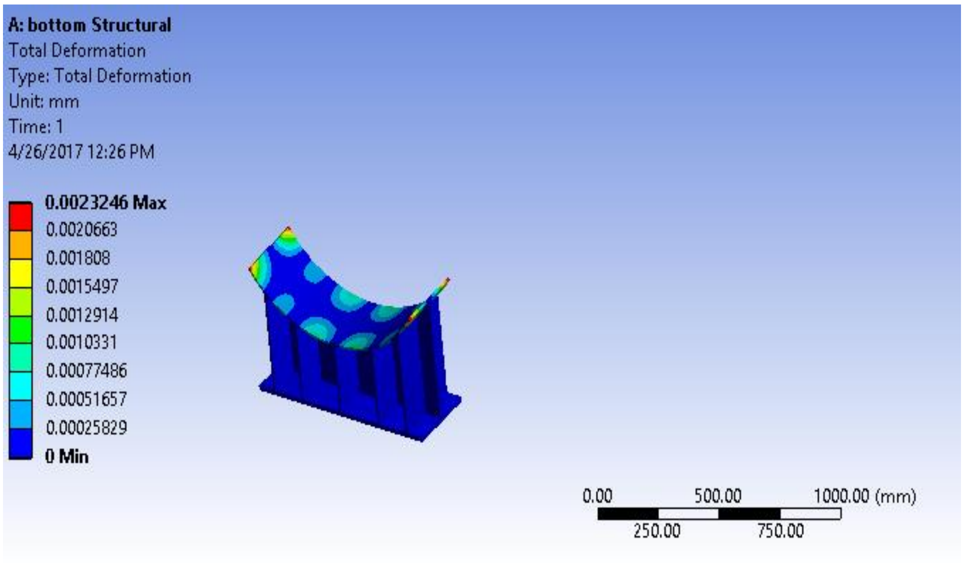


11. Analysis on ANSYS

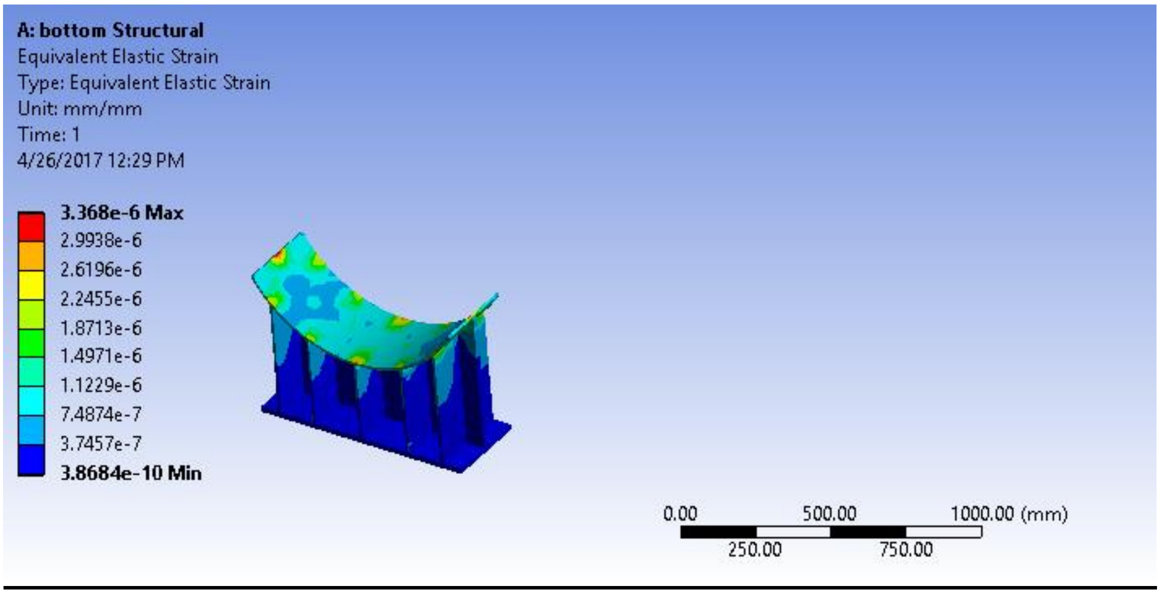
Meshing of bottom



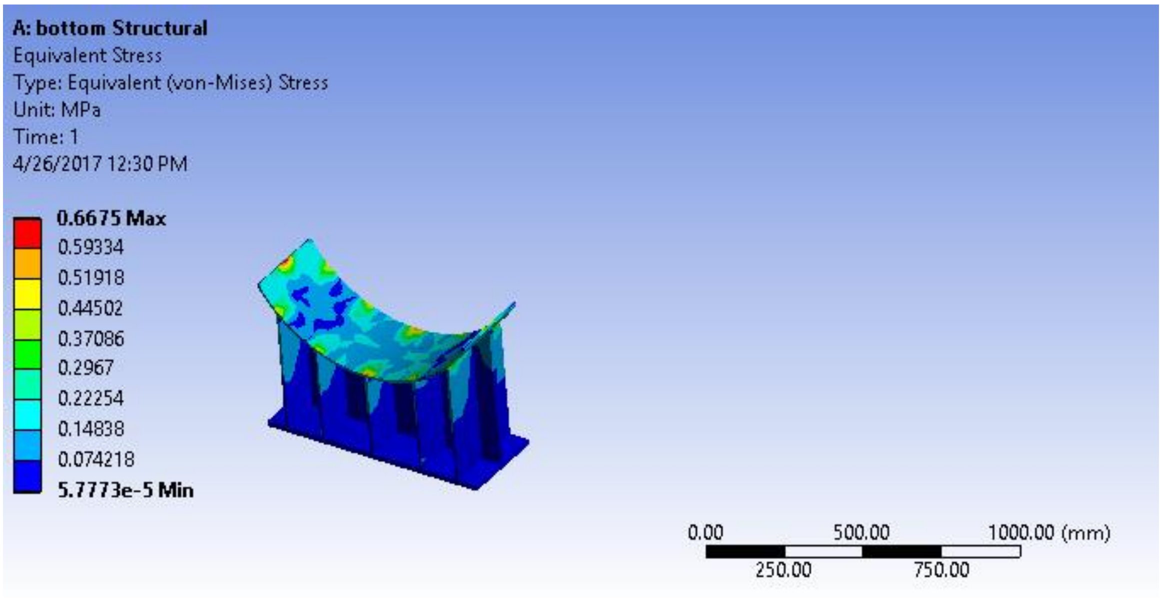
Total deformation analysis of bottom



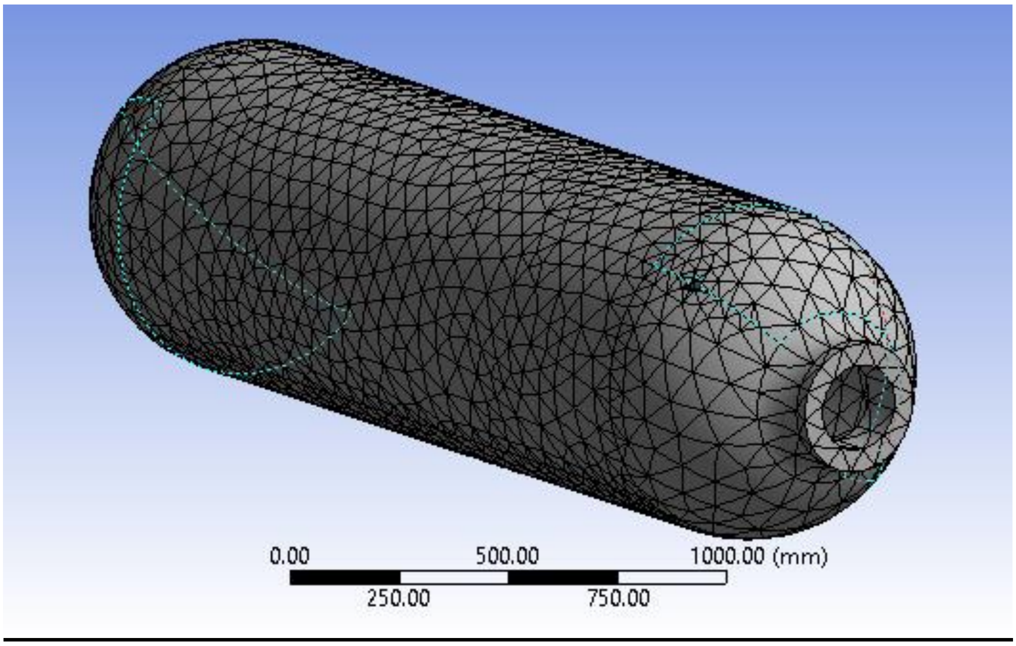
Strain analysis of bottom



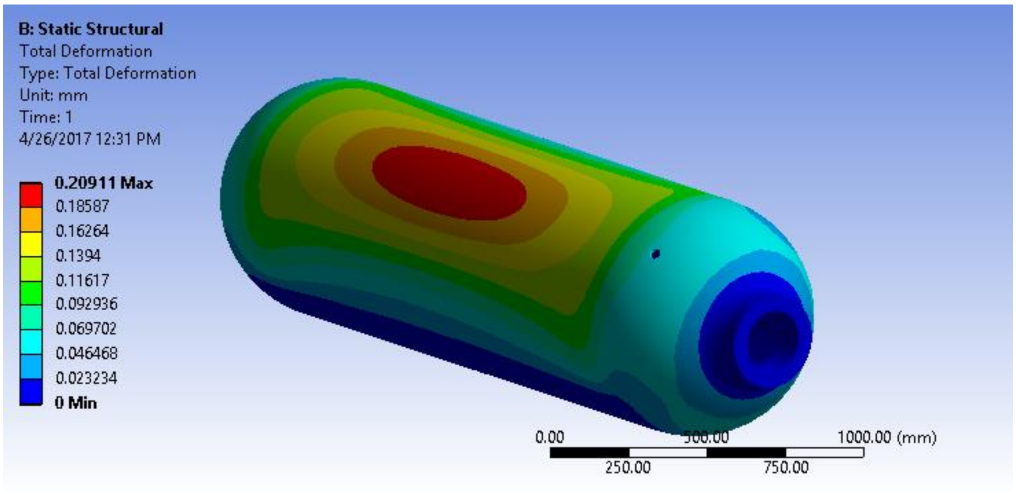
Stress analysis of bottom



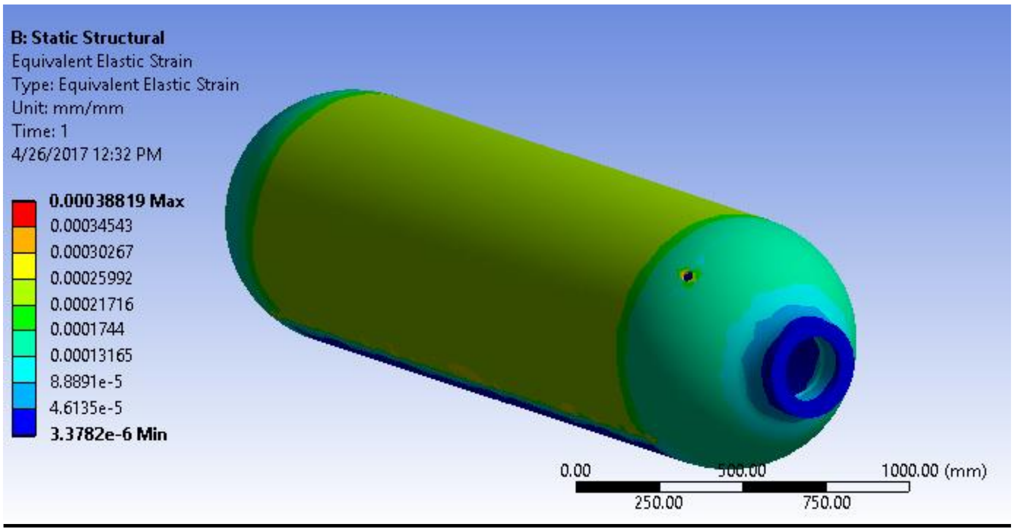
Meshing of shell



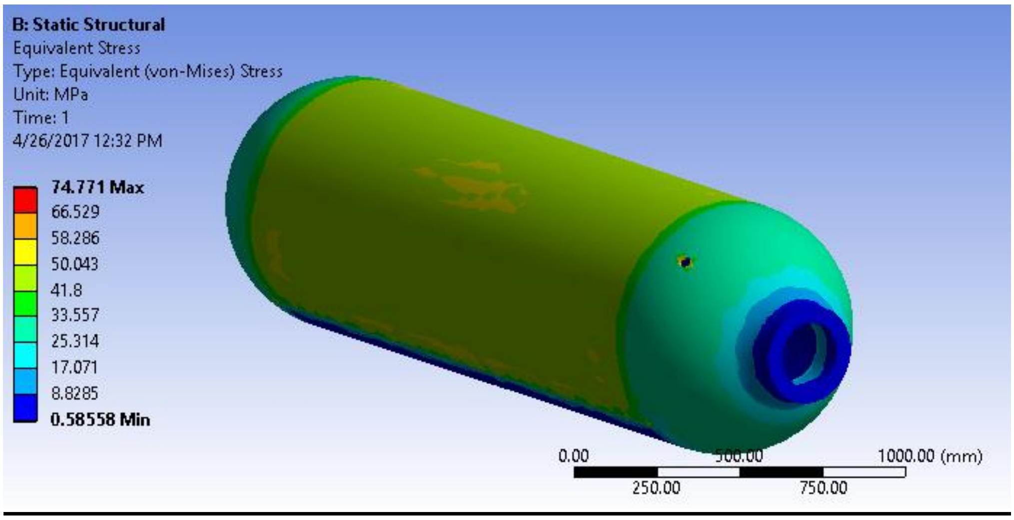
Total deformation of shell



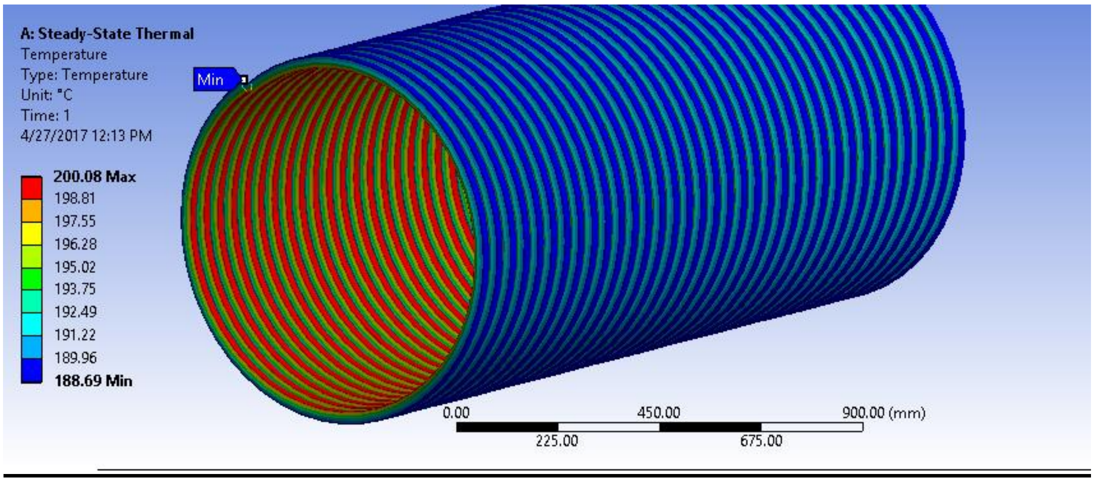
Strain analysis of shell



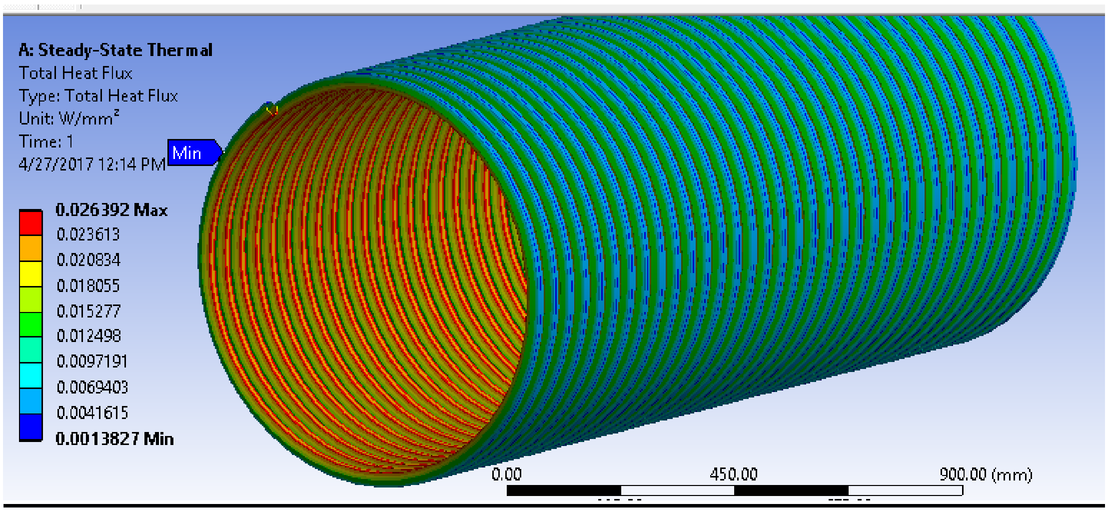
Stress analysis of shell



Thermal analysis of tubes



Total heat flux in tubes



9.CONCLUSION:

In this project, existing designs were studied and analyzed under proper supervision. The shortcomings and limitations of the traditional designs were taken into account while designing the new model.

A detailed literature survey was conducted and all the thesis were compared and analyzed under proper guidance helping us to select the most efficient design. The highlights of the developed design are as follow:

- Heat conduction rate within the tubes is significantly increased due to the new shape of tubes.
- Material selected resists the temperature under which the boiler is to be operated and does not show any visible flaw.
- Opting for a renewable source of energy for input power proves to be sufficient for boiler operation.
- The reformed shape of head of boiler results into better performance.
- The proposed design withstands all the stresses acting on it as observed on ANSYS.

10. REFERENCES:

1. ASME code **2004** section V111 div-2

2. R.S Khurmi; J.K Gupta: Machine Design Handbook (Vol .1),

3. Dennis. R. Moss: Pressure Design Manual,

4. Domkundwar: Thermal Engineering.

5. Mahajan & Joshi: Boiler Equipment,

6. V. B. Bhandhari: Design of Machine Elements,

7. Tool Equipment Design: Joshi and Mahajani.

8. PSG data book

9. International Journal of Science and Research