CFD ANALYSIS OF STEAM BOILER TUBE USED IN POWER PLANT

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ABSTRACT

A steam boiler is a closed vessel in which water or other liquids are heated under pressure and the steam released from the boiler is used for various heating applications. The main things in the design of a boiler for a application are thermal design and analysis. Design for manufacture, physical size and cost. In this thesis the steam flow in steam boiler without baffles is modeled using AUTO CAD design software. The thesis will focus on CFD analysis of steam boiler without baffles. The aim of this study is to determine the temperature, velocity, and pressure drop for the steam boiler with and without baffles through CFD analysis.

KEYWORDS. - *Steam boiler – CFD Analysis – Evaluation – Simulation – Resulting.*

1. INTRODUCTION

The steam boiler is modeled using the given specifications and design formula from data book. The isometric view of steam boiler is shown in below figure. The steam boiler outer casing body profile is sketched in sketcher and then it is revolved up to 3600 angle using revolve option and tubes are designed and assemble to in steam boiler using extrude option[1].
The efficiency of oil fired fire tube boiler was calculated by evaluating the heat losses. Investigation on the performance of the boiler was conducted by examining the heat losses, identifying the reasons for losses, measuring the individual loss and developing a strategy for loss reduction. This study was carried out in Texmaco package horizontal fire tube boiler at Travancore Titanium Products Ltd (TTPL), Trivandrum, Kerala. The boiler efficiency was measured by indirect method. Heat losses in dry flue gas and due to unburned fuel were found to be the major problems. Since they were interrelated, installation of Zirconium oxygen sensor was recommended as a common remedy[2].
In this paper the shell tube heat exchanger is analyzed with ANSYS, where the shell contains of tubes inside it and hot water flows through it and cold water flows through the outer path way of the tube on the shell. The heat transfer, velocity and stream line flow of the fluid is analyzed in this paper. The analysis is under taken for two various shell tube heat exchangers, the various shell tube heat exchangers are (a) Shell tube heat exchanger without baffler (b) Shell tube heat exchangers with baffler. Shell tube heat exchanger without baffler is the heat exchanger where a normal shell will be proceeded to the analysis and the result is extracted. Shelltube heat exchanger with baffler isthe heat exchanger where a baffler will be presented on the shellwhere it provided a lot of time for the cold fluid to be in contact with hot tube so that the heat transfer will get more efficient[3].
High Pressure Boilers provides a comprehensive overview of the safe and efficient operation of high pressure boilers and related equipment. The latest combustion control technology, as well as EPA regulations and their implications, are included in this edition. This edition has been reorganized to provide a systems view of boiler operation. All aspects of high pressure boilers are discussed and illustrated, and a comprehensive glossary and appendix provide helpful reference material. This textbook is designed for both learners preparing to obtain a boiler operator's license and for boiler operators intending to upgrade their skills[4].

A boiler or steam generator is a closed vessel used to generate steam by applying heat energy to water. During the process of generating steam, the steam boiler is subjected to huge thermal and structural loads. To obtain efficient operation of the power plant, it is necessary to design a structure to withstand these thermal and structural loads. Using CAD and CAE software's is the advanced methodology of designing these structures before constructing a prototype. In this project finite element analysis of the steam boiler was carried out to validate the design for actual working conditions. The main tasks involved in the project are performing the 3D modeling of the boiler and finite element analysis. In this project, design optimization of the boiler is also done based on the results obtained from the thermal and structural analysis. NX-CAD software is used for design and 3D modeling. ANSYS software is used for doing finite element analysis[5].

Steam generators are widely used in industries for several purposes like power production, processing, heating etc. In industry steam generators are the major fuel consumers. In a normal steam generator about 4% of hot water is wasted as blow down. Due to this, a large amount of heat energy is wasted. This project aims to bring a heat recovery system to prevent heat losses, so that a large savings can be made. So in this a heat recovery system was designed to minimize the losses[6].

A boiler or steam generator is a closed component in which fluid is converted into steam by heating under pressure. Thus steam produced from a boiler has many practical applications. The design considerations such as physical size, materials, cost and Thermal specifications of a boiler vary with applications. The aim of this thesis work is to develop optimized boiler to preserve temperature & pressure more efficiently; generally boiler are made with Mild Steel (MS) / Stainless steel with coatings according to the conditions; in this project MS with reaper and dual shell will be analyzed. Coupled field and fatigue analysis will be conducted on plain reaper (empty), & with filler materials to work as insulation layer; in coupled field analysis thermal and structural loads will be analyzed at a time to fine stress, strain, and flux in dual load conditions[7].

Steam boiler is a closed vessel in which water or other fluid is heated under pressure and the steam released out by the boiler is used for various heating applications. The main considerations in the design of a boiler for a particular application are Thermal design and analysis, Design for manufacture, physical size and cost. In the present work a fire tube boiler is analyzed for static and Thermal loading. The geometric model of boiler is created in CATIA V5 software as per the drawing. This model is imported to HYPERMESH through IGES format and FEA model with converged mesh is developed using shell elements. To this FEA model various loading conditions like design pressure, thermal loads and operating conditions are applied. One of the supporting legs is arrested in all the directions and the other one is arrested only in X, Z directions and all rotations[8].

Different reasons of failure can be in appropriate transportation problem and loose application of refractory, excessive temperature developed in shell, sigma phase embrittlement, failure of anchors, improper storage of material etc. The materials and its properties used for refractory are studied here with its different types. This report is related to thermal and structural analysis of refractory which is 75 mm thick and temperature distribution at certain distance by using ANSYS software.3D Model is drawn in solid works and then imported to ANSYS for next analysis. By applying thermal and structural conditions we get the results[9].

Alkali recovery aiming at recovering NaOH is the best available technology in China's pulp and paper indus-try; an alkali recovery boiler is a popular one among all alkali recovery units. For the purpose of designing the most reasonable tube-panel of an evaporator in a 1500 t/d alkali recovery boiler, a total of 8 kinds of cases are put forward for finite element analysis. The modeling, meshing and calculation are carried out for each case. The stress values and their distribution rules are revealed in this paper. The slotting size for the water tubes panel is analyzed by using the optimum design module of ANSYS. After all cases are compared with each other, the optimal one is developed and exemplified in conclusion[10].

2. MODELING

2.1 AUTO CAD 2018

- The part modeling environment in which the extrude command is used for the modeling of the boiler and the stiffeners are made using the glide command.

- The parameters required for the modelling of boiler are contour dimensions height, length, fillet radius, hole diameter.

- Holes were made using surface trim command. The 3D SOLID is prepared by thickness in the third dimension provided after selecting the 2-D shell element.

Table 1 Steam Boiler Parameter

Sl. No.	Parameter		Forms
1	Shell	Inner diameter	69 mm
		Outer diameter	75 mm
		Length	1000 mm
2	Tube	Inner diameter	6 mm
		Outer diameter	12 mm
		Length	600 mm
3	Number of tubes		6

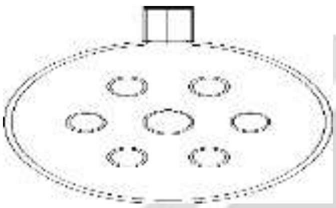

Fig 1. Front View of Steam Boiler

Fig 2 3D model of Steam Boiler

2.2 ANALYSIS MODAL OF STEAM BOILER

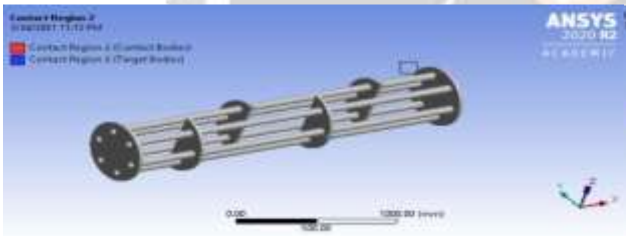

Fig 3 Steam Boiler tube

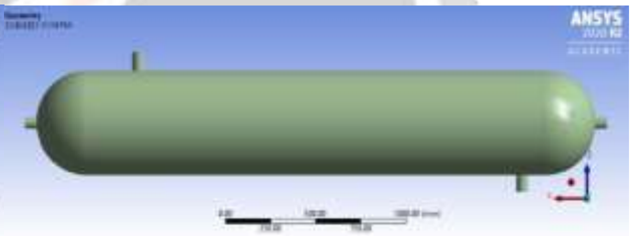

Fig 4 steam boiler after insertion of tube

- ANSYS 19 used to Analysis the steam boiler. In design simulation Quadra paver element is used for meshing of steam boiler.
- Equivalence of the nodes is executed for this element. ANSYS has quadratic displacement behavior and is well suited to modeling irregular meshes.
- For the meshing of the steam boiler stiffeners the above described nodal Quadra element is used with steam boiler meshing.
- The materials are assigned from the fluent database to the steam boiler in materials list in ANSYS.
- The analysis was carried out for the temperature calculated. At first the steam boiler is analyzed by considering the temperature calculated.
- The pressur, veloxity and maximum and minimum temperature are obtained which will give comparative results for modifications in the steam boiler.

3. CFD ANALYSIS

Computational fluid dynamics (CFD) study of the system starts with the construction of desired geometry and mesh for modelling the dominion. Generally, geometry is simplified for the CFD studies. Meshing is the discretization of the domain into small volumes where the equations are solved by the help of iterative methods. Modelling starts with the describing of the boundary and initial conditions for the dominion and leads to modelling of the entire system. Finally, it is followed by the analysis of the results, discussions andconclusions.

3.1 Geometry

Table 2 Naming of various parts of the body with state type

ART UMBER	ART OF THE ODEL	TATE TYPE
	nner Fluid	luid
	nner_Pipe	olid
	uter_Fluid	luid
	uter_Pipe	olid

Steam boiler is built in the ANSYS workbench design module. It is a parallel -flow heat exchanger. First, the fluid flow (fluent) module from the workbench is selected. The design modeler opens as a new window as the geometry is double clicked.

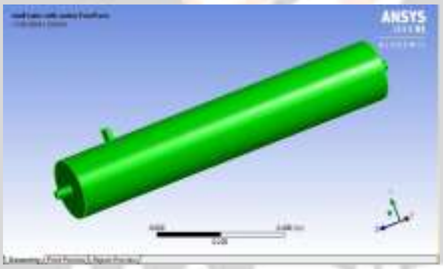

Fig 5 Geometry

Save the project at this point and close the window. Refresh and update the project on the workbench.

3.2 Mesh

Initially a relatively coarser mesh is generated. This mesh contains mixed cells (Tetra and Hexahedral cells) having both triangular and quadrilateral faces at the boundaries. Care is taken to use structured hexahedral cells as much as possible. It is meant to reduce numerical diffusion as much as possible by structuring the mesh in a well manner, particularly near the wall region. Later on,a fine mesh is generated. For this fine mesh, the edges and regions of high temperature and pressure gradients are finely meshed.

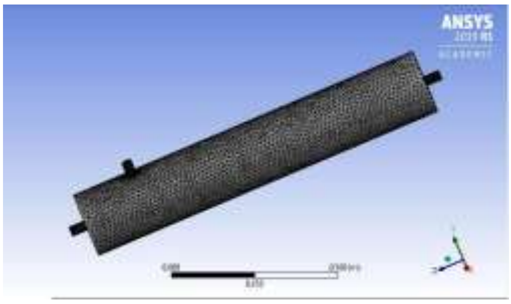

Figure 6 Steam Boiler Mesh Module

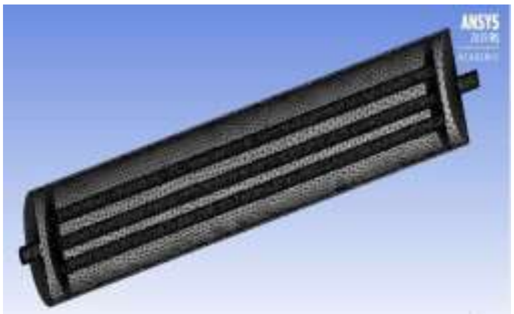

Figure 7 Cut Section View of Mesh Model 1

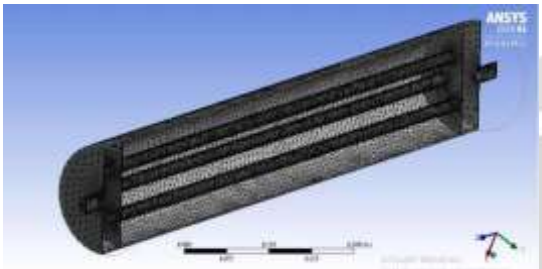

Figure 8 Cut Section View of Mesh Model 2

3.3 Named Selection

The different surfaces of the solid are named as per required inlets andoutlets for inner and outer fluids. The outer wall is named as insulation surface.

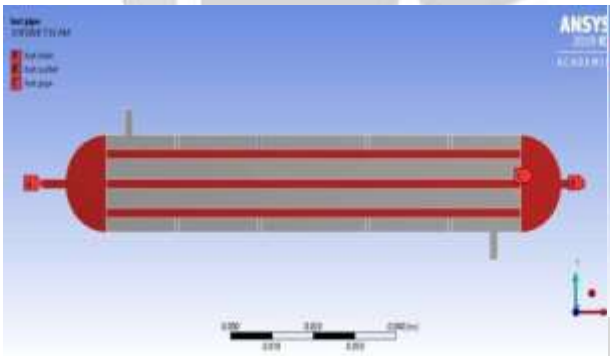

Figure 9 Steam Boiler Named Section hot pipe

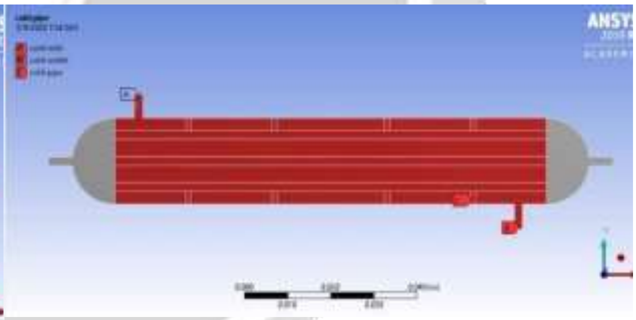

Figure 10 Steam Boiler Named Section for cold pipe

Save project again at this point and close the window. Refresh and update project on the workbench. Now open the setup. The ANSYS Fluent Launcher will open in a window. Set dimension as 3D, option as Double Precision,processing as Serial type and hit OK. The Fluent window will open.

4. SOLUTION

4.1 Problem Setup

The mesh is checked and quality is obtained. The analysis type is changedto Pressure Based type. The velocity formulation is changed to absolute and timeto steady state. Gravity is defined as y = -9.81 m/s2

4.2 Models

Energy is set to ON position. Viscous model is selected as "k-ε model (2 equations). Radiation model is changed to Discrete Ordinates.

4.3 Materials

The create/edit option is clicked to add water-liquid and copper, steel to thelist of fluid and solid respectively from the fluent database.

4.3.1 Cell zone conditions

The parts are assigned as water and copper, steel as per fluid/solid parts.

4.3.2 Boundary Conditions

Boundary conditions are used according to the need of the model. The inletand outlet conditions are defined as mass flow rate inlet and pressure outlet. As this is parallel -flow with two tubes so there are two inlets and two outlets. The walls are separately specified with respective boundary conditions. No slip condition is considered for each wall.

Except the tube walls each wall is set to zero heat flux condition. The details about all boundary conditions can be seen in the table 3 as given below.

Table 3 Shows the Boundary Conditions

Quantities	Boundary condition
Working fluid	Water, Steam
Water	Mass flow rate = 0.025 kg/s Temperature = 300 k
Steam	Mass flow rate = 0.125 kg/s Temperature = 900 k

4.3.3 Materials properties

The inner_inlet is selected from the drop down list of "compute from". Thevalues are:

4.3.3.1 Area = 1 m2

4.3.3.2 Density = 998.2 kg/m3

4.3.3.3 Length = 39.37008 inch

4.3.3.4 Temperature = 348 K

4.3.3.5 Velocity = 0.9942 m/s

4.3.3.6 Viscosity = 0.001003 kg/m-s

4.3.3.7 Ratio of specific heats = 1.4

4.3.4 Solution Methods

The solution methods are specified as follows:

4.3.4.1 Scheme = Simple

4.3.4.2 Gradient = Least Square Cell Based

4.3.4.3 Pressure = Standard

4.3.4.4 Momentum = Second Order Upwind

4.3.4.5 Turbulent Kinetic Energy = Second Order Upwind

4.3.4.6 Turbulent Dissipation Rate = Second Order Upwind

4.3.5 Solution Control and Initialization

Under relaxation factors the parameters are

4.3.5.1 Pressure = 0.3 Pascal

4.3.5.2 Density = 1 kg/m3

4.3.5.3 Body forces = 1 kg/m2s2

4.3.5.4 Momentum = 0.7 kg-m/s

4.3.5.5 Turbulent kinetic energy = 0.8 m2/s2

Then the solution initialization method is set to Standard Initialization whereas the reference frame is set to Relative cell zone. The inner inlet is selected from the compute from drop down list and the solution is initialized.

4.3.6 Measure of Convergence

It is tried to have a nice convergence throughout the simulation and hence criteria is made strict so as to get an accurate result. For this reason residuals aregiven as per the table 4 that follows.

Table 4 Residuals

Variable	Residual
x-velocity	10^{-6}
y-velocity	10^{-6}
z-velocity	10^{-6}
Continuity	10^{-6}
Specific dissipation energy/dissipation energy	10^{-5}
Turbulent kinetic energy	10^{-5}
Energy	10^{-9}

4.3.7 Run Calculation

The number of iteration is set and the solution is calculated and variouscontours, vectors and plots are obtained

5. RESULTS AND DISCUSSION

5.1 Counters

The temperature, pressure and velocity distribution along the heat exchanger can be seen through the contours.

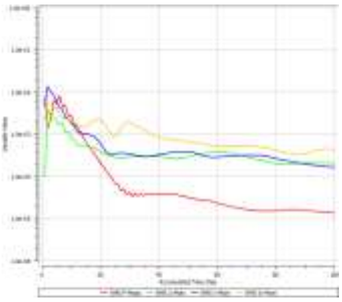

Figure 11 Iterations of steam boiler

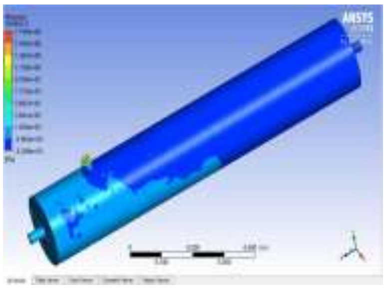

Figure 12 Steam Boiler Pressure Distribution 1

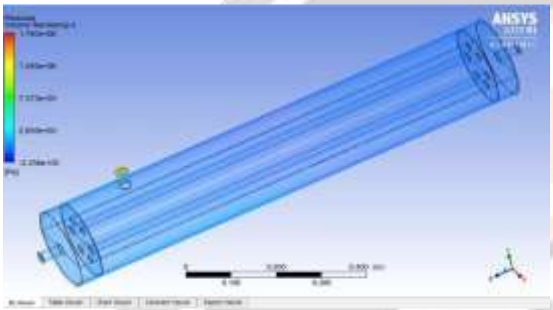

Figure 13 Steam Boiler Presser Distribution 2

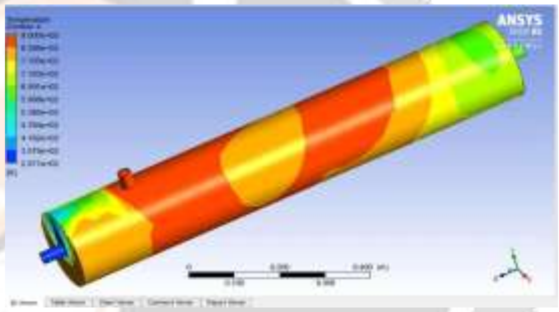

Figure 14 Steam Boiler Temperature Distribution 1

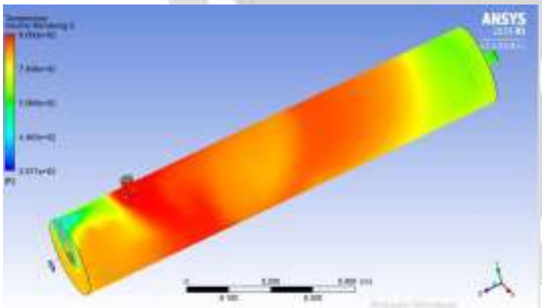

Figure 15 Steam Boiler Temperature Distribution 2

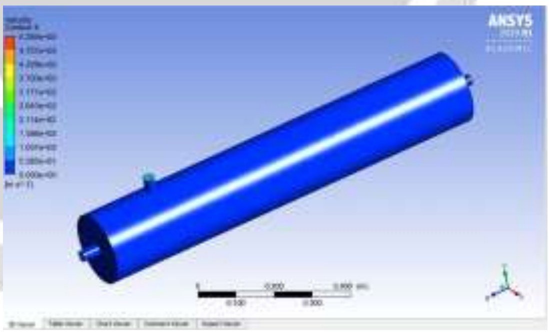

Figure 16 Steam Boiler Velocity Distribution 1

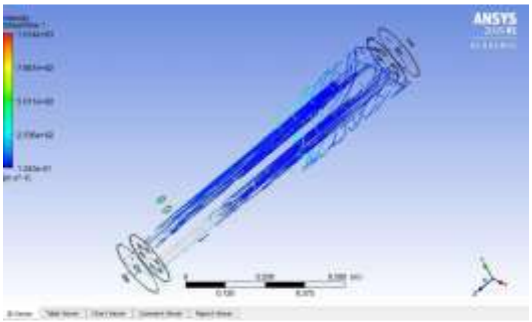

Figure 17 Steam Boiler Velocity Distribution 2

5.2 Contours of steam boiler with baffles

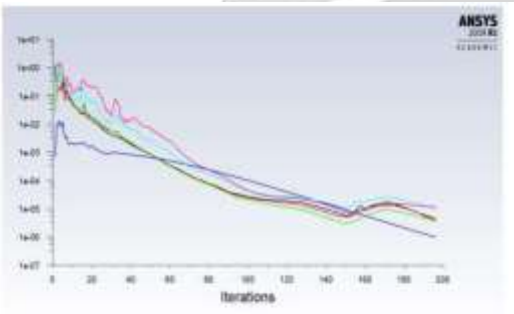

Figure 18 Iterations of steam boiler

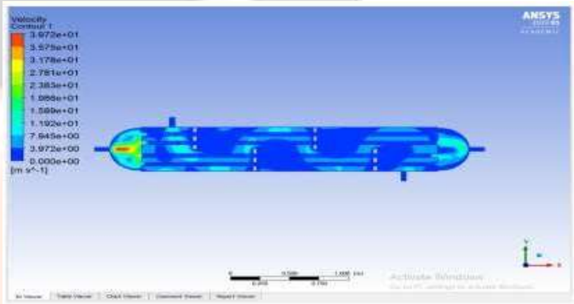

Figure 19 Velocity distribution of steam boiler with baffles

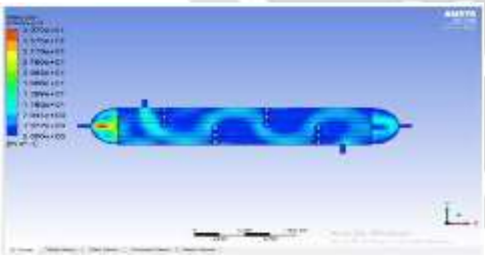

Figure 20 Steam Boiler with baffles Velocity Distribution 1

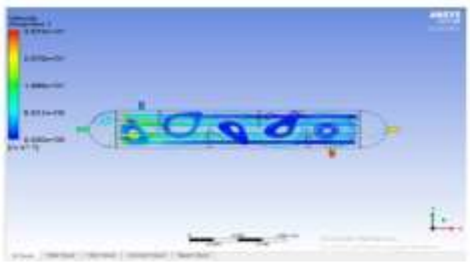

Figure 21 Steam Boiler with baffles Velocity Distribution 2

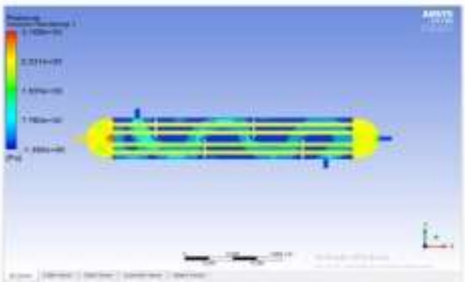

Figure 22 Pressure Distribution of Steam Boiler

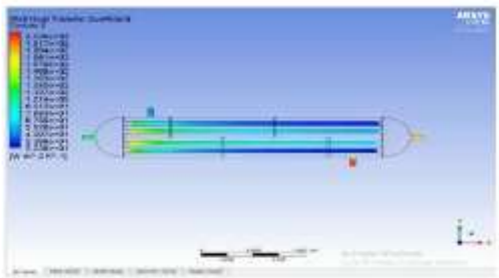

Figure 23 Steam Boiler with baffles

with baffles Temperature Distribution 2

5 CONCLUSION

In this project the steam flow in steam boiler tubes is modeled using AUTO CAD design software. The thesis will focus on CFD analysis of steam boiler without baffles. CFD analysis to determine the temperature, velocity, pressure drop. From the above analysis the temperature is increases from 300k to 600k. In future steam boiler is analyzed with baffles. CFD analysis to determine the temperature steam boiler with baffles..

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