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Improvement of Thermal Efficiency in Superheater tubes by changing Fin Design

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ABSTRACT:

A small unit of improvement in the design of the fins in the super heater gives a large value of positive impact on the performance of super heater in the steam generation system.The core concept of the project is to increase the heat transfer (Q) and the flue gas flow rate through the fins by redesigning the circular plate type of fin existing in the former super heater tubes to spiral design, thereby increasing the total surface area of the conducting material used as fins. Such redesign is aimed at minimal change in weight and the cost of the super heater, with maximum positive impact on the overall efficiency of the steam power generation. That means to increase the heat transfer from the gases to the finned tubes in the lower temperature zones are- Increase the temperature difference (T_s-T_∞) between the surface and the fluid, Increase the convection coefficient h and Increase the fluid flow over the surface since h is a function of the flow velocity. The greater the velocity, the higher the increase in h and increase the contact surface area like heat sink with fins. When temperature and convective heat transfer coefficient are up to the mark to empower efficiency of super heater, we are left with the only alternative of increasing the effective surface area by using fins or extended surfaces. By increasing the area using spiral fins, the efficiency and heat transfer is increasing considerably. There is 2.14% of efficiency increasing in super heaters and 109 KW of heat is additionally transferred because of redesigning of fins.

1.INTRODUCTION:

Today, most of the electricity produced throughout the world is from steam power plants. However,electricity is being produced by some other powergeneration sources such as hydropower, gas power,bio-gas power, solar cells,etc.

The environmental impact of electricity generation is significant because modern society uses large amounts of electrical power. This power is normally generated at power that converts some other kind of energy into electrical power. Each system has advantages and disadvantages, but many of them pose environmental concerns. It is necessary to reduce energy consumption at a global level in order to solve the problems concerning environment and energy, such as global warming, and most of all, it is required for the developing countries to take energy saving measures, where economic and population present a considerable growth.Therefore, finding the means of improving the existing system of power generation has become very important project and research for many industries consuming and distributing larger scale of electricity for production processes and to operate modern appliances both at work and at domestic levels.

Recently, many industries using their own in-house power generation units, have come up or implemented initiatives or several projects, to increase the power generation within their in-house power generation system, especially from biomass fuels, by installing back -pressure or condensing /extraction steam turbine generators, that take advantage of generating steam at higher pressure and temperature than needed for the process usage. Such projects have increased both the biomass fuel firing capacity and raised the operating steam pressure and temperature of existing boilers to make power generation more economical.

2.OVERVIEW OF BHPV:

BHARAT HEAVY PLATE AND VESSELS LIMITED is established in 1966 by the government of India in Andhra Pradesh, Vishakhapatnam.

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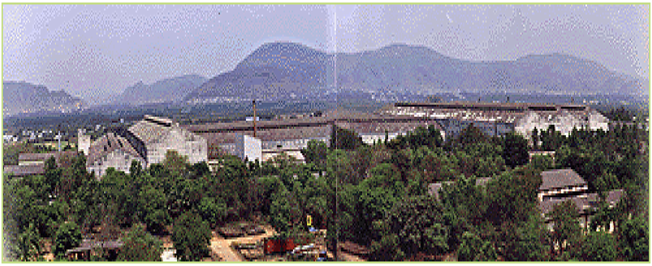

It is the largest fabrication industry of process equipment in India for the fertilizers, petroleum, chemical, petro-chemical and alloyed industries. It is fully owned by the government of India and managed by the autonomous board of directors.BHPV Ltd means Bharat heavy plate &vessels Ltd is a fabrication industry. BHPV is located at Vishakhapatnam which is 20km away from the city on the highway NH5 towards Anakhapalli. BHPV is constructed in 378 acres of land with man power of 1500 employees out of which 300 are executives and 150 are supervisors, balance are technical and non- technical. The turnover of this company is 350 Cores per annum. At the moment the government is thinking of merging with BHEL which produces industrial and power boilers.

2.1PRODUCTS MANUFACTURED BY BHPV:

In BHPV variety of products like vessels, heat exchangers, storage tanks, cryogenic vessels, and titanium air bottles etc are manufactured.

•PRESSURE VESSELS:

BHPV has extended their activities to cover the design, manufacture, erection, testing and commissioning of pressure vessels (industrial boilers) with horizontal transfer to supply boilers of capacities 100 ton /hr. The fuel can be coal, gas, oil or biogas with pressure and temperature to suit the requirement of customer.

•HEAT EXCHANGERS:

Almost all types of tabular exchangers for practical requirement of every process industry are fabricated and supplied. Heat exchangers from low pressure atmospheric tinned collars to high-pressure heat exchangers with test pressure as high as 450 kg/sq.cm. are also fabricated in this industry.

•STORAGE TANKS:

Storage tanks are used to store fluid under low pressure (below 5kg/sq.cm) are designed and fabricated in BHPV.

•CRYOGENIC VESSELS:

Cryogenic vessels are double walled vessels with stainless inner shell and carbon steel outer shell. Perlite insulated and evacuated to 0.01 Torr with guaranteed low evaporation rates and filled with completed instrumentation.

•TITANIUM AIR BOTTLES:

Titanium air bottles are used in spacecraft, missiles in which air is filled under pressure. This bottle consists of two dished ends, which should be welded carefully in vacuum. So these air bottles are fabricated and welded in this industry.

•QUALITY POLICY:

“ To maintain a commanding position as a supplier of quality products systems and services by continuous updating of technologies to meet international standards and to build a high level of customer confidence and satisfaction by providing cost effective quality products”.

2.2 REQUIREMENT OF CRYOGENIC MATERIALS:

While plain carbon and alloy steels show marked change from ductile to brittle state as temperatures are lowering and no marked change occurs in the case of nickel steel, stainless steel, copper, aluminum etc. A metallurgical generalization is possible by saying that metals other than iron which posses a body centered cubic metals such as aluminum,

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copper and nickel show only a slightly increase in yield strength and retain the room temperature ductility as low as -196°C and in addition, face centered lattice structure can distort to a greater extent than a body centered lattice structure.

2.3.PROPERTIES OF CRYOGENIC MATERIALS:

Some of the properties of the cryogenic material are as follows:

•Toughness at low temperature especially in the presence of notches frames and cracks.
•The metals and alloys should have face centered cubic structure such that this will remain elastic and deformable at sub zero conditions.
•The tensile stress should be lower than yield stress.
•The materials having well weld ability, workability and ease in fabrication of equipment.
•Corrosion resistance is important for air separation equipment as well as cryogenic storage tanks especially while handling Oxygen storage tanks.
•Fracture toughness i.e., ability to resist rapid crack propagation should be high.

2.4 DIFFERENT CRYOENIC MATERIALS

Austenitic steels, stainless steels, fine grain double normalized and tempered nickel steels, copper and aluminum are excellent materials, which can be withstand cryogenic temperature.

•STAINLESS STEELS:

Austenitic stainless steels are suited for cryogenic applications as they remain tough and ductile even at -269°C. alloys have lesser yield strength when compared to steel and are unaffected by temperature changes.

•COMPOSITION OF AIR:

The main components of air by volume as follows

NITROGEN	: 78.11%
OXYGEN	: 20.93%
ARGON	: 0.93%
HELIUM	: 0.0015%
WATER VAPOUR	: DEPENDS ON ATMOSPHERE
CARBON DI OXIDE	: 0.03%

2.5 BASICS OF CRYOGENIC LIQUIDS:

Oxygen and Nitrogen condense to form a mixture of two liquids which are mixable in all proportions. This liquid mixture can be separated into oxygen and Nitrogen by using the difference in relative volatilities of these two substances by the process of distillation at atmospheric pressure. Nitrogen has a boiling point of -196°C as compared to -183°C for oxygen and is more volatile than oxygen.

Besides at given temperature, the vapor phase that is in equilibrium with a given liquid mixture of nitrogen and oxygen is more volatile. Inversely, in case of a gaseous mixture of O2 and N2 condensing partially the resulting liquid phase is richer. For instance, a gaseous mixture having roughly the same comparison as air that is containing 21% of oxygen will be in equilibrium with a liquid containing 40% of oxygen.

Argon with a boiling point of -186°C at atmospheric pressure occupies an intermediate position between nitrogen and oxygen and will behave accordingly in a mixture with the either component. Dew point of air as well as boiling point of nitrogen, oxygen and argon rise with increase in pressure. Therefore it might be expected that rising the pressure high enough to make them boil at ordinary temperatures can liquefy these gases.

However, in principle it is not possible and temperatures of the gas must be reduced to a minimum characteristic value called as CRITICAL TEMPERATURE and before that each of these gases should be condensed by application of higher pressure. The pressure required to condense a gas at critical temperature called CRITICAL PRESSURE. Values of critical constants of some components of air are given in the following table:

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Gas	Boiling Point centigrade	Boiling point Kelvin	Volume expansion to gas	Flammable	toxic	Odour
Helium-3	-269.9	3.2	757to 1	No	No	No
Helium-4	-268.9	4.2	757to1	No	No	No
Hydrogen	-252.7	20.4	851to1	Yes	No	No
Deuterium	-249.5	23.6	....	Yes	Radioactive	No
Tritium	-248.0	25.1	....	Yes	Radioactive	No
Neon	-245.9	27.2	1438to1	No	No	No
Nitrogen	-195.8	77.3	696to1	No	No	No
Carbon mono oxide	-192.0	81.1	....	No	No	No
Fluorine	-187.0	86.0	888to1	No	Yes	Sharp
Argon	-185.7	87.4	847to 1	No	No	No
Oxygen	-183.0	90.1	860to1	No	No	No
Methane	-161.4	111.7	578to1	Yes	No	No
Krypton	-151.8	121.3	700to1	No	No	No
Tetraflouromet hane	-128	145.0	....	No	Yes	No
Ozone	-111.9	161.3	....	Yes	Yes	Yes
Xenon	-109.1	164.0	573to1	No	No	No
Ethylene	-103.8	169.3	....	Yes	No	Sweet
Boron tri fluoride	-100.3	172.7	....	No	Yes	Pungen t
Nitrous oxide	-89.5	183.6	666to1	No	No	Sweet
Ethane	-88.3	184.8	....	Yes	No	No
Hydrogen chloride	-85.0	188.0	....	No	Yes	Pungen t
Acetylene	-84.0	189.1	....	Yes	Yes	Garlic
Flouroform	-84.0	189.1	....	No	No	No
Chloro tri-fluoromethane	-81.4	191.6	....	No	Yes	Mild
Carbondioxide	-78.5	194.6	553to1	No	Yes	Pungen t

Table 1: Cryogenic materials and their properties

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2.6 BHPV WORKSHOP LAY OUT AND DEPARTMENTS:

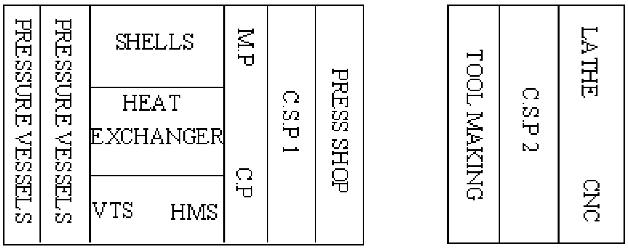

Fig 1 layout of BHPV workshop

In between these shops Quality Control Departments are allocated for maintain Quality. Each ans every section having the Quality control department to check the comphonents producing in the shop. The Quality policy followed here is

•QUALIYY ASSURANCE:

Here Third party will come for inspection. Actually the Q.C Department had been completed the tests so the QC Department will assure the Quality to the Third party. this is the procedure they are following in Quality control.

3.SUPERHEATER:

A super heater is a device found in steam boilers that is used to convert wet, saturated steam into dry steam. Super heaters are a very beneficial part of the steam cycle, because dry steam contains more thermal energy and increases the overall efficiency of the cycle. Dry steam also is less likely to condense within the cylinders of a reciprocating engine or the casing of a steam turbine. Boiler super heaters can be found in three varieties: radiant super heaters, convection super heaters and separately fired super heaters.

•A radiant super heater is placed directly in the combustion chamber.

•A convection super heater is located in the path of the hot gases.

•A separately fired super heater, as its name implies, is totally separated from the boiler.

Fig2: Super heater

Radiant super heaters are located directly within the combustion chamber of the boiler itself. This arrangement allows for the burner from the boiler to heat both the boiler tubing and the super heater tubes, making radiant super heaters highly effective devices. These are most commonly found in steam power plants and also were widely used in steam automobiles. In steam automobiles and power plant boilers alike, the super heater tubes — sometimes known as vaporizer coils — were located directly on top of the burner. Steam usually is run through the superheater after it has been admitted through the throttle.

Convection super heaters are most commonly found on locomotives. Much like a convection oven, this type of super heater utilizes the hot gases from the burner to reheat the steam. A convection super heater can be extremely efficient, because most of the thermal energy is given only to the boiler tubing, and what would normally be exhaust instead heats the super heater tubes. These are also found in power plants, but they were mostly implemented in steam locomotives.

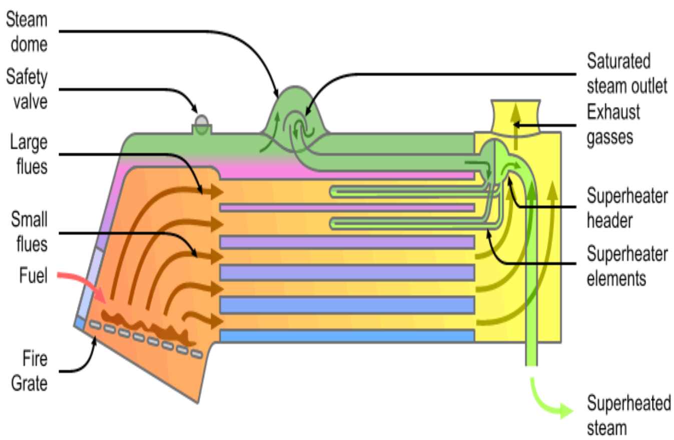

Fig 3: Super heater location in steam power plant

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Super heaters have many advantages, the most notable being reduced fuel consumption and increased efficiency. The only disadvantage is increased maintenance costs, but super heaters still generally are considered to be worth any extra costs. Another disadvantage of super heaters is found almost exclusively on locomotives using fire-tube boilers. Without proper and regular maintenance, the tubing within the super heater is prone to rupture. If the tubing was to rupture, high pressure steam could escape through the opening and into the firebox of the locomotive, and such an event would put any personnel in the engine cab in serious danger.

3.1.ADVANTAGES OF USING SUPER-HEATED STEAM:

Superheated steam has higher heat content and therefore more work/ sec can be obtained. Superheated steam has higher temperature, therefore thermal efficiency is increased. (The performance of any thermal system is improved by increasing its maximum temperature and reducing its minimum temperature - usually atmosphere -Superheating does both).The problem of condensation of steam in the boiler itself is greatly avoided. This increases the ambient usage of coal for boiler steam production.Superheating is done using the heat in the waste flue gases (normally). Had we not gone for superheating, the heat would have been wasted as the fuel wastage would have been still higher. Also the high temperature of flue gases, when let into the atmosphere, it would have caused "more" pollution and more the temperature, more the diffusivity.Superheated steam's greatest value lies in its tremendous internal energy that can be used for kinetic reaction through mechanical expansion against turbine blades and reciprocating pistons, that produces rotary motion of a shaft.

The value of superheated steam in these applications is its ability to release tremendous quantities of internal energy yet remain above the condensation temperature of water vapor; at the pressures at which reaction turbines and reciprocating piston engines operate. Of prime importance in these applications is the fact that water vapor containing entrained liquid droplets is incompressible. If steam doing work in a reciprocating engine or turbine, cools to a temperature at which liquid droplets form; the water droplets entrained in the fluid flow will strike the mechanical parts of engines or turbines, with enough force to bend, crack or fracture them.

Superheating and pressure reduction through expansion, ensures that the steam flow throughout its passage through a turbine or an engine, always remains as a comprisable gas, which will not damage the internal moving parts of the turbine or engine through which the steam passes.

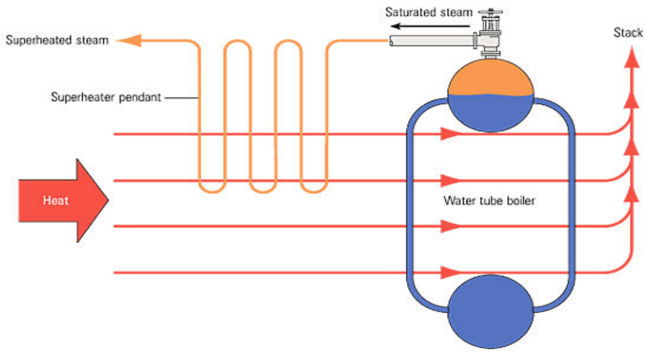

Fig4: Steam flow process

Table 2: A given set of inlet and outlet temperatures of the fluids:

SL .NO	GAS TEMPARATURE (^{0}C)	STEAM TEMPARATURE (^{0}C)
1	Platen Superheater Inlet temperature :1236.4 Outlet temperature:1077	Platen Superheater Inlet temperature :404 Outlet temperature:475
2	Final Superheater Inlet temperature :1077 Outlet temperature:962.4	Final Superheater Inlet temperature :475 Outlet temperature:540
3	Re-heater Inlet temperature :962.4 Outlet temperature:724.3	Re-heater Inlet temperature :345 Outlet temperature:540
4	Low temperature Superheater Inlet temperature :724.3 Outlet temperature:481.3	Low temperature Superheater Inlet temperature :359 Outlet temperature:404.2

This above table is mentioning the operating temperatures of the different power plants at different locations. Here the flue gasses and steam entering in the super heater tubes, outlet temperatures are given in this table.

4. THERMAL POWER PLANTS:

In a coal based power plant coal is transported from coal mines to the power plant by railway in wagons or in a merry-go-round system. Coal is unloaded from the wagons to a moving underground conveyor belt. This coal from the mines is of no uniform size. So it is taken to the Crusher house and crushed to a size of 20mm.

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From the crusher house the coal is either stored in dead storage(generally 40 days coal supply) which serves as coal supply in case of coal supply bottleneck or to the live storage(8 hours coal supply) in the raw coal bunker in the boiler house. Raw coal from the raw coal bunker is supplied to the Coal Mills by a Raw Coal Feeder. The Coal Mills or pulverizer pulverizes the coal to 200 mesh size.

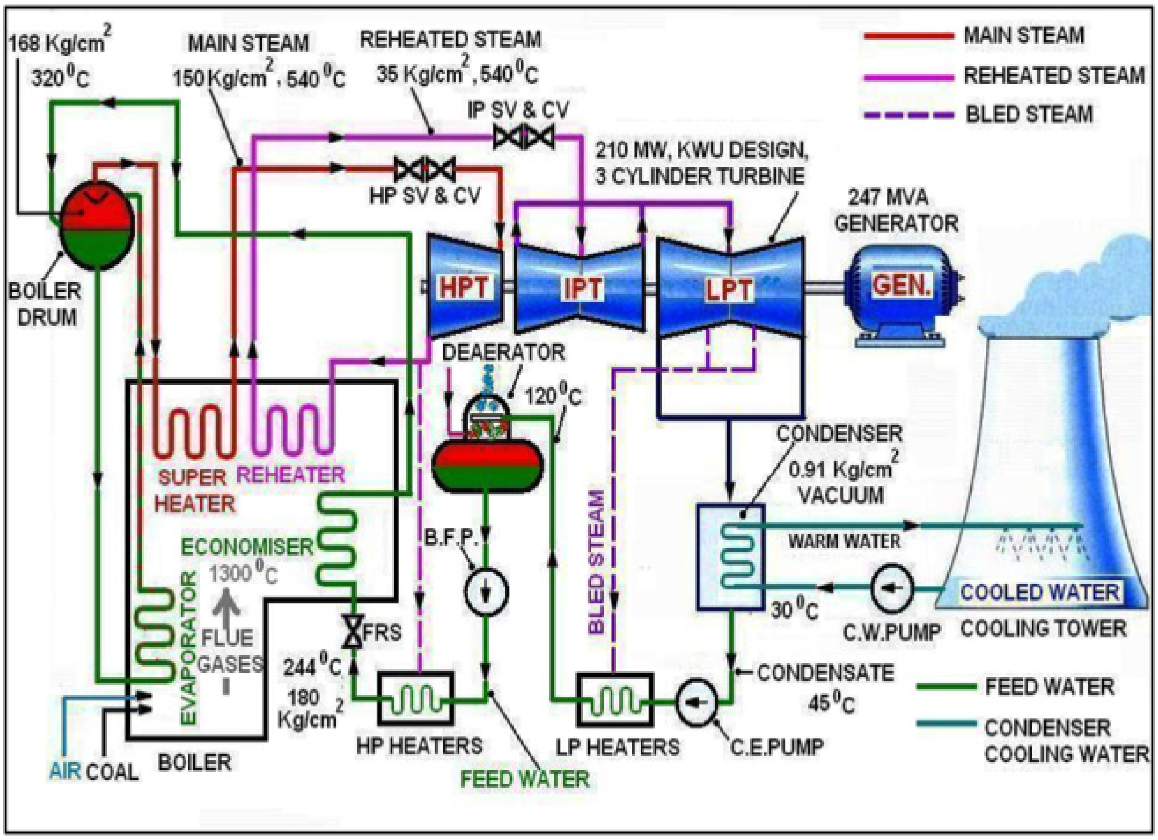

Fig.5 Diagram of a typical coal-fired thermal power station

PRINCIPLE:

Coal based thermal power plant works on the principal of Modified Rankine Cycle.

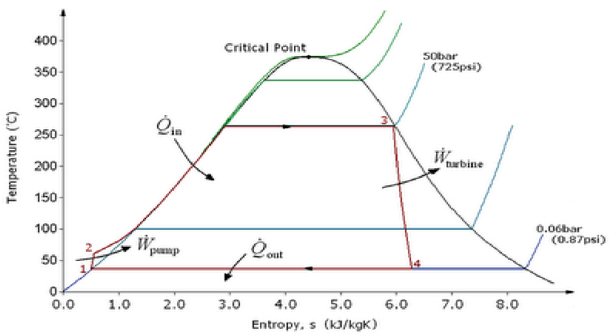

Fig6: Rankine-Cycle

There are four processes in the Rankine Cycle. These states by numbers.

Process 1-2
The working fluid is pumped from low to high pressure,as the fluid is a liquid at this stage the pump requires little input energy.

Process 2-3
The high pressure liquid enters a boiler where its heated at constant pressure by an external heat source to become a dr saturated vapour. The input energy can easily calculated by moiler diagram or h-s chart or steam tables.

Process 3-4
The dry saturated air expands through a turbine, generating power. this decreases the temperature and pressure of the vapour,and some condensation may occur. The output will be calculated by using steam tables.

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Process 4-1

The wet vapour then enters a condenserwhere condensed at constant temperature to become saturated liquid.

4.1 AIR PRE-HEATER:

The heat carried out with the flue gases coming out of economizer are further utilized for preheating the air before supplying to the combustion chamber. It is a necessary equipment for supply of hot air for drying the coal in pulverized fuel systems to facilitate grinding and satisfactory combustion of fuel in the furnace.

Fig7: Air Preheated

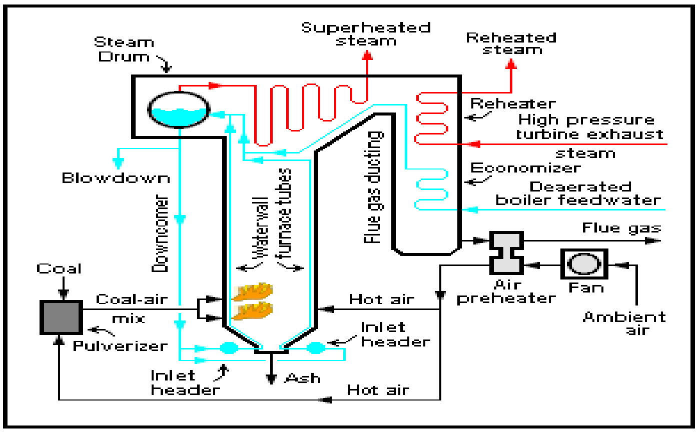

Fig8: Preheater and Reheater location

4.2RE-HEATER:

Power plant furnaces may have a re-heater section containing tubes heated by hot flue gases outside the tubes. Exhaust steam from the high pressure turbine is rerouted to go inside the re-heater tubes to pickup more energy to go drive intermediate or lower pressure turbines.

4.3.STEAM TURBINES:

Steam turbines have been used predominantly as prime mover in all thermal power stations. The steam turbines are mainly divided into two groups: -

» Impulse turbine
» Impulse-reaction turbine

The turbine generator consists of a series of steam turbines interconnected to each other and a generator on a common shaft. There is a high pressure turbine at one end, followed by an intermediate pressure turbine, two low pressure turbines, and the generator. The steam at high temperature (536 ‘c to 540 ‘c) and pressure (140 to 170 kg/cm2) is expanded in the turbine.

4.4 CONDENSER:

The condenser condenses the steam from the exhaust of the turbine into liquid to allow it to be. If the condenser can be made cooler, the pressure of the exhaust steam is reduced and efficiency of the cycle increases. The functions of a condenser are:

1) To provide lowest economic heat rejection temperature for steam.
2) To convert exhaust steam to water for reserve thus saving on feed water requirement.
3) To introduce make up water.

4.5 BOILER FEED PUMP:

Boiler feed pump is a multi stage pump provided for pumping feed water to economiser. BFP is the biggest auxiliary equipment after Boiler and Turbine. It consumes about 4 to 5 % of total electricity generation.

4.6.COOLING TOWER:

The cooling tower is a semi-enclosed device for evaporative cooling of water by contact with air. The hot water coming out from the condenser is fed to the tower on the top and allowed to tickle in form of thin sheets or drops. The air flows from bottom of the tower or perpendicular to the direction of water flow and then exhausts to the atmosphere after effective cooling.

The cooling towers are of four types:

1. Natural Draft cooling tower
2. Forced Draft cooling tower
3. Induced Draft cooling tower
4. Balanced Draft cooling tower

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Fig9: Cooling tower

4.7 ADVANTAGES OF COAL BASED THERMAL POWER PLANT:

•They can respond to rapidly changing loads without difficulty
•A portion of the steam generated can be used as a process steam in different industries
•Steam engines and turbines can work under 25 % of overload continuously
•Fuel used is cheaper
•Cheaper in production cost in comparison with that of diesel power stations

4.8.DISADVANTAGES OF COAL BASED THERMAL POWER PLANT:

•Maintenance and operating costs are high
•Long time required for erection and putting into action
•A large quantity of water is required
•Great difficulty experienced in coal handling
•Presence of troubles due to smoke and heat in the plant
•Unavailability of good quality coal
•Maximum of heat energy lost
•Problem of ash removing

5.BASICS OF HEAT TRANSFER:

In the simplest of terms, the discipline of heat transfer is concerned with only two things:temperature, and the flow of heat. Temperature represents the amount of thermal energy available, whereas heat flow represents the movement of thermal energy from place to place.

On a microscopic scale, thermal energy is related to the kinetic energy of molecules. The greater a material's temperature, the greater the thermal agitation of its constituent molecules (manifested both in linear motion and vibrational modes). It is natural for regions containing greater molecular kinetic energy to pass this energy to regions with less kinetic energy.Several material properties serve to modulate the heat transferred between two regions at differing temperatures. Examples include thermal conductivities, specific heats, material densities, fluid velocities, fluid viscosities, surface emissivities, and more. Taken together, these properties serve to make the solution of many heat transfer problems an involved process.

5.1 RADIATION:

All materials radiate thermal energy in amounts determined by their temperature, where the energy is carried by photons of light in the infrared and visible portions of the electromagnetic spectrum. When temperatures are uniform, the radiative flux between objects is in equilibrium and no net thermal energy is exchanged. The balance is upset when temperatures are not uniform, and thermal energy is transported from surfaces of higher to surfaces of lower temperature.

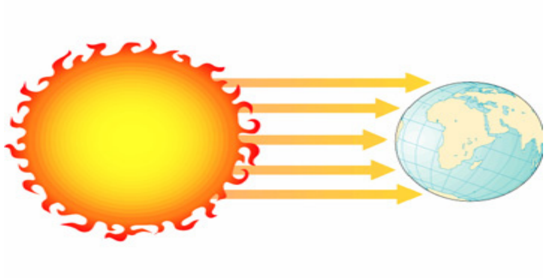

Fig.10 Radiation (Sun's heat falling on earth)

6.ANALYSIS:

Heat transfer between a solid surface and a moving fluid is governed by the Newton's cooling law:

$$Q = hA(T_s - T_\infty)$$

where T_s is the surface temperature and T_∞ is the fluid temperature.

The means to increase the heat transfer from the gases to the element in the lower temperature zones are;

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1)Increase the temperature difference (Ts-T∞) between the surface and the fluid.
2) Increase the convection coefficient h. This can be accomplished by increasing the fluid flow over the surface since h is a function of the flow velocity and the higher the velocity, the higher the h. Example: a cooling fan.
3) Increase the contact surface area A. Example: a heat sink with fins.

Many times, when the first option is not in our control and the second option (i.e. increasing h) is already stretched to its limit, we are left with the only alternative of increasing the effective surface area by using fins or extended surfaces. Therefore, the following theoretical analysis is being studied to improve the fin efficiency on the superheater tubes manufactured at BHPV by our project group as detailed here after.

6.1.EXISTING FIN DESIGN AT BHPV (CIRCULAR FINS):

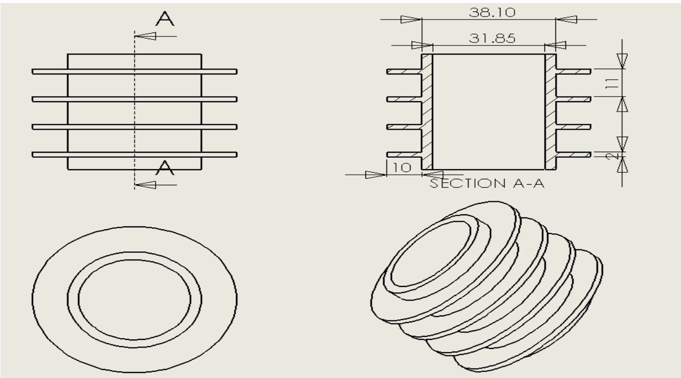

Fig. 11Existing fin (circular plate)

6.1.1 SPECIFICATIONS:

Outer Diameter of the Pipe (DO) =38.100 mm
Inner Diameter of the Pipe (DI) =31.850 mm
Thickness of the Pipe (t) =03.125 mm
Thickness of the Fin (t) =02.000 mm
Width of the Fin (w) = 10.000 mm
Pitch of the Fin (p) =11.000 mm
Specimen = SA106GrA

6.1.2 PROPERTIES OF SA106GrA

Thermal conductivity (k) =51W/m.K
Density (ρ) =7815 kg/m^3
Thermal Diffusivity (α) =14.80×10^{-6}m ^{2} /s
Specific heat(c) =445 J/kg K

6.1.3 WORKING CONDITIONS

Temperature of flue gasses at inlet T (i) flue)=10770 C
Temperature of steam at inlet of super heater T (I) Steam=4750 C
Temperature of steam at outlet of super heaterT(o) Steam=5400 C
Temperature of flue gasses at outlet T (o) Flue=932.40 C
Flow velocity of Flue gassesv f =10-18 m/s
Flow velocity of steam v s=10-25 m/s
Average velocity of flue gasses v f (avg)=14 m/s
Average velocity of steam v s (avg)=17.5 m/s

6.1.4 PROPERTIES OF FLUE GASSES AT 10770 C TEMPERATURES

Density (ρ) =0.261 kg/m3
Thermal Diffusivity (α) =335.85×10^{-6}m ^{2} /s
Specific heat(c) =1319.09 J/kg K
Thermal conductivity (k) =0.1155073 W/m.K
Absolute viscosity (μ) =50.1518×10-6 Ns/m ^{2}
Kinematic viscosity (ϑ) =191.856 ×10^{-6}m ^{2} /s
Prandlt number Pr=0.5723

6.1.5 PROPERTIES OF STEAM AT SUPERHEATER TEMPERATURE AND PRESSURE:

Density (ρ) =92.80 kg/m^3
Thermal Diffusivity (α) =0.081×10^{-6}m ^{2} /s
Specific heat(c) =12351 J/kg K
Thermal conductivity (k) =0.09304 W/m.K
Absolute viscosity (μ) =25.06×10^{-6} Ns/m ^{2}
Kinematic viscosity (ϑ) =0.272×10^{-6}m ^{2} /s
Prandlt number Pr =3.35
In forced convection formulae

Reynold"s number Re $_D$= $\frac{\rho \times D_0 \times v}{\mu}$

Nussult number Nu$_D$= **0.25×(Re $_D$)$^{0.6}$×(Pr)$^{0.38}$** $(\frac{\Pr f}{\Pr w})^{0.25}$

6.2. CIRCULAR FINS:

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Calculate

$$L_c^{1.5}\sqrt{\frac{h}{k.A_m}} = 0.0845$$

$$(A = \text{area of fin} + \text{area of un finned surface})$$

$$A = \pi \times r^2 + \pi(r_{2c}{}^2 - r^2)$$

$$= 1079.706 + 3385.548 = 4465.25 \times 10^{-6}\ m^2$$

From the efficiency comparison chart for circular fins η_f=96.52 %

$Q_{fin}=Q_{MA}\times\eta f = 0.9652 \times 127.33 = 122.89$ W

Heat transfer in total module Q =122.89×1000×40=4915600W

6.3 SPIRAL FINS

$$L_c^{1.5}\sqrt{\frac{h}{k.A_m}} = 0.0562$$

$$\text{spiral fin area } A = 4516 \times 10^{-6}\ m^2$$

From the efficiency comparison chart for spiral fins = 98.66 %

$Q_{fin}=Q_{MA}\times\eta f = 0.9866 \times 127.33 = 125.62$ W

Heat transfer through spiral finned tubes of a module =125.62×1000×40

=5024800W

6.4 ECONOMIC CALCULATIONS:

Amount of extra heat transfer per unit area is =2.72W

Total heat transfer in a module =1000×40×2.72=108800W

=108.8kw

Cost of production to generate 1KW heat (Rs) =1.28

Amount of money we are saving per unit time for one module

=1.28×108.8

=139.26/-

6.5 RESULT:

Table 3: Comparison of fin

Description	Existing Fin	Proposed Fin
Fin Type	Circular Plate	Spiral fin
Heat Transfer Surface area	0.004465 m^2	0.004516 m^2
Heat flow	Continuous up to one pitch	Continuous to full length
Heat Transfer	122.89 W	125.62 W
Fin Efficiency	96.52 %	98.66%

It can also be shown that higher the fin to tube surface, the tube wall and fin tip temperatures will be higher as also the gas pressure drop. Higher the fin density, lower the heat transfer coefficient and vice versa as seen by the chart below for heat transfer in finned tubes.

7.CONCLUSIONS:

It is desirable to have a lower pinch point for maximum steam generation rate and effective flue gas energy utilization. Spiral fins offer compact heat recoveries because of high gas turbulence and improved exposed contact surface. Fin spiraling improves gas penetration, which improves flow velocity resulting in higher heat transfer. In the redesigned fin from circular plate to spiral plate fin, the increase in fin efficiency is found as 2.14% in a unit pitch of fin, with an increase in heat transfer rate as 125.62w from 122.89w Higher fin density for any surface does not make any difference in heat transfer analysis as it acts as solid fin design. At definite tube diameter the pressure drop is Minimum and offers best heat recovery under all design conditions.

In the present case it is obtained at 38.1m. As waste heat recovery systems are widely used in power, petrochemical and refinery operations as the steam generators therefore there is demand of the finned tube as it offers high volume to surface ratios and high heat transfer coefficients. It fetches nearly Rs140 per unit time in each module.While using flue gases for heating the super heater requires periodical cleaning of super heater fins with the proper cleaning technology as the flue gases contain carbon dioxide as the main constituent. Other than this, the fin designs can be further improved for obtaining higher thermal efficiency of steam power plants. One of the recommendations can be designing the plain spiral fin further to serrated spiral fin, which may yield higher and smoother gas flow rate.

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The serrated spiral fin design also helps in reducing the overall weight of the system, thereby reducing the cost of fin material too, making the system more economical.

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