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Utilization Waste Heat by Heat Exchanger

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***Abstract* - In present scenario, the energy crisis is the major problem faced by all the industries. Sakthi sugars unit have a Sugar plant and Cogeneration plant. The Cogeneration plant has two multi fuel boiler produces 170 Tonnes per hour of steam at a pressure of 86 kg/sq.cm at a temperature of 510˚C. The steam is used to produce electric power and the exhaust steam is being supplied to sugar plant to boil the sugarcane milk. The return condensate from sugar plant has temperature of 85˚C. It is being cooled by spray pond. In this project, the forced draught air is preheated by flue gas in air preheater. The preheated air is sent to boiler.**

In this project an attempt has been made to utilize the waste heat by a cross flow heat exchanger. By considering these design parameters namely outlet temperature of condensate, Inlet temperature of air, Mass flow rate of water & air. Finally, the potential savings are presented by implement the newly designed cross flow heat exchanger. In cross flow heat exchanger, the hot water flows inside the tube and the air flows over the tube. In turns there is a scope for reduction in fuel consumption.

1.INTRODUCTION

The co-generation boiler at M/s. Sakthi Sugars Ltd. producing 170 Tonnes per hour of steam, at the pressure of 87 kg/sq.cm at the temperature of 510±5°C. The fuel is coal cum bagasse. The boiler is designed for 100% / bagasse and 100% of coal firing. The rated capacity of fuel for the boiler is 130 Tonnes/day. This system is branched into 9atm and 3atm steam line at a temperature of 510±5°C. The 3atm steam is sent to sugar plant for crystal sugar making process. The return condensate from the process is having the temperature of 85°C from the sugar plant and this condensate is cooled by spray pond and the heat is dissipated to atmosphere.

In the existing circuit, forced draught (FD) air is sent through a rectangular duct to air-preheater (APH) unit where FD air is preheated using a fuel gas exhausted. The typical layout of the cogeneration power plant duct system between the air preheater (APH) and forced draught fan. The configuration shows that the inlet and exit of the duct is connected with an elbow. The FD fan inlet duct having rectangular cross section and is made up of galvanized steel. This is connected between the air-preheater and forced draught fan. The power consumption of the fan is 90KW and the mass flow rate through the fan is 41.47 kg/s.

The above two points were considered to design the heat exchanger to utilize the return condensate water temperature to heat the atmospheric air before the APH unit. Thus, the temperature of FD air is increased by 5°C to10°C before the APH. In turns, the outlet condensate temperature is reduced to 5°C to 10°C.

A cross flow heat exchanger is designed to transfer the heat from the condensate water to the air. While designing, the mass flow rate of the air will not be affected, because reduce in mass flow rate of the air will affect the effectiveness of the fuel burning and thus the efficiency may reduce. So, the right design parameters are calculated without affecting the air flow rate. By this design, this cross flow heat exchanger is suitable to heat the FD air from the return condensate effectively. Since, the heat energy acquired by increasing the temperature from 5°C to 10°C, the fuel consumption is reduced in the boiler furnace. So, there is a scope in reduction in fuel consumption and increase the economy of power plant.

2.LITERATURE REVIEW

2.1. Cogeneration power station

A thermal power station is a power plant in which the prime mover is steam driven. Water is heated, turns into steam and spins a steam turbine which either drives an electrical generator or does some other work, like ship propulsion. After it passes through the turbine, the steam is condensed in a condenser and recycled to where it was heated. The greatest variation in the design of thermal power stations is due to the different fuel sources.

Almost all coal, nuclear, geothermal, solar thermal electric, and waste incineration plants, as well as many natural gas power plants are thermal. Natural gas is frequently combusted in gas turbines as well as boilers. The waste heat from a gas turbine can be used to raise steam, in a combined cycle plant that improves overall efficiency. Power plants burning coal, oil, or natural gas are often referred to collectively as fossil-fuel power plants.

In some industrial, large institutional facilities, or other populated areas, there are combined heat and power (CHP) plants, often called cogeneration plants, which produce both power and heat for facility or district heating or industrial applications. AC electrical power can be stepped up to very high voltages for long distance transmission with minimal loss of power. Steam and hot water lose energy when piped over substantial distance, so carrying heat energy by steam or hot water is often only worthwhile within a local area or facility, such as steam distribution for a ship or industrial facility or hot water distribution in a local municipality.

2.2. GENERAL LAYOUT OF MODERN THERMAL POWER PLANT

The general layout of modern thermal power plant consists of four major circuits

2.2.1. Coal and ash circuit

In this circuit, the coal from the storage is fed to the boiler through coal handling equipments for the generation of steam. Ash produced due to the combustion of coal is removed to ash storage through ash handling system.

2.2.2. Air and gas circuit

Air is supplied to the combustion chamber of the boiler either through F.D. Fan or I.D. fan or by using both. The exhaust gas carrying sufficient quantity of heat and ash are passed through the air heater where the exhaust heat of the gasses is given to the air and then the air is passed through the duct collectors where the most of the dust is removed before exhausting to the atmosphere through chimney.

2.2.3. Feed water and steam flow circuit

The steam generation in the boiler is fed to the steam prime mover to develop the power. The steam coming out from the prime mover is condensed in the condenser and then fed to the boiler with the help of pump. The condensate is heated in the feed heater s using the steam tapped from the different point of the turbine. In sugar industry the steam is also tapped for heating the sugar cane juice.

2.2.4. Cooling water circuit

The quantity of cooling water required to condense the steam is considerably large and is taken from the either lake or river (open system). When the adequate water is not available, then the water coming out from the condenser is cooled either in cooling pond or cooling tower (closed system).

2.3. PARTS OF THE THERMAL POWER PLANT

The parts of the thermal power plant are

- Steam turbine
- Steam boiler
- Barring gear
- Super heater
- Deaerator
- Reheater
- Draught system
- Fans
- Condenser
- Feed water heater
- Cooling tower
- Condensate pump
- Transportation of coal
- Exhaust system
- Fly ash collection
- Bottom ash collection

2.3.1. Steam turbine

A steam turbine is a mechanical device that extracts thermal energy from pressurized steam, and converts it into rotary motion. It has almost completely replaced the reciprocating piston steam engine primarily because of its greater thermal efficiency and higher power-to-weight ratio. Because the turbine generates rotary motion, it is particularly suited to be used to drive an electrical generator – about 80% of all electricity generation in the world is by use of steam turbines. The steam turbine is a form of heat engine that derives much of its improvement in thermodynamic efficiency through the use of multiple stages in the expansion of the steam, which results in a closer approach to the ideal reversible process.

2.3.2. Turbine types

When people began to use water power to win mechanical work, they looked first for the best forms of impellers. Three types were established thereby and variations of them are used today in various applications, among other in steam turbines in power stations, as marine propellers, as compressors in gas turbines etc.

The classifications of turbines are

- Pelton turbine
- Francis turbine
- Kaplan turbine

2.3.2.1. Pelt on turbine

The pelton turbine (also free-jet turbine) was invented 1880 by L.A. Pelton. It possesses spoon-shaped shovels, the jet hits the impeller tangentially, gets divided by the two shovels and transfers an impulse.

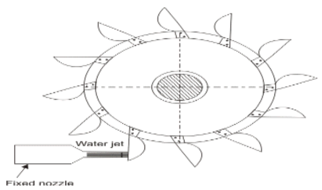

Fig.3.1. Pelton Turbine

The pelton turbine is used in storage power stations with downward gradients up to 2000 meters and can contain up to 6 nozzles.

2.3.2.2. Francis turbine

The reaction turbine invented by J.B. Francis 1849 is hit by the jet almost axially (toward the axle) and radially (away from the center).

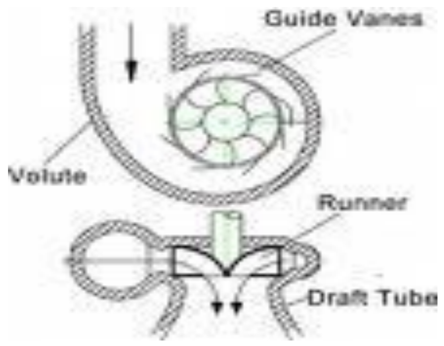

Fig.3.2. Francis Turbine

The rotor blades can be adjusted, in order to ensure an even run. It looks similar to the type shown below as Steam turbine.

2.3.2.3. Kaplan turbine

The Kaplan turbine, developed around 1915 by the Austrian V.Kaplan, looks like a marine propeller. The jet is led thereby axially on the freely adjustable shovel pages.

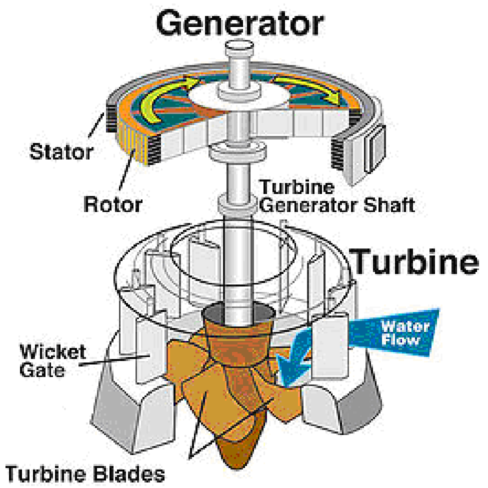

Fig.3.3. Kaplan Turbine

2.3.3. Steam boilers

Steam Generator refers to a furnace that burns the fossil fuel to boil water to generate steam. In the nuclear plant field, steam generator refers to a specific type of large heat exchanger used in a pressurized water reactor (PWR) to thermally connect the primary (reactor plant) and secondary (steam plant) systems, which of course is used to generate steam.

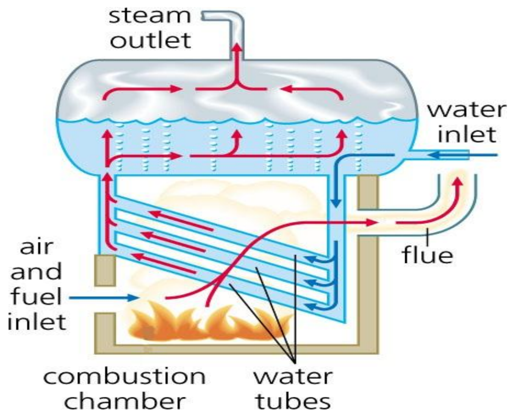

Fig.3.4. Steam Boiler

The steam generating boiler has to produce steam at the high purity, pressure and temperature required for the steam turbine that drives the electrical generator.

2.3.4. Barring gear

Barring gear is the mechanism provided to rotate the turbine generator shaft at a very low speed after unit stoppages. Once the unit is "tripped", the turbine coasts down towards standstill. When it stops completely, there is a tendency for the turbine shaft to deflect or bend if allowed to remain in one position too long. This is because the heat inside the turbine casing tends to concentrate in the top half of the casing, making the top half portion of the shaft hotter than the bottom half. The shaft therefore could wrap or bend by millionths of inches.

2.3.5. Super heater

Fossil fuel power plants can have a superheater and/or reheater section in the steam generating furnace. Nuclear-powered steam plants do not have such sections but produce steam at essentially saturated conditions. In a fossil fuel plant, after the steam is conditioned by the drying equipment inside the steam drum, it is piped from the upper drum area into tubes inside an area of the furnace known as the superheater, which has an elaborate set up of tubing where **the** steam vapor picks up more energy from hot flue gases outside the tubing and its temperature is now superheated above the saturation temperature. The superheated steam is then piped through the main stream lines to the valves before the high pressure turbine.

2.3.6. DE aerator

Power stations use a deaerator to provide for the removal of air and other dissolved gases from the boiler feed water. A deaerator typically includes a vertical, domed deaeration section mounted on top of a horizontal cylindrical vessel which serves as the deaerated boiler feed water storage tank.

There are many different designs for a deaerator and the designs will vary from one manufacturer to another. If operated properly, most deaerator manufacturers will guarantee that oxygen in the deaerated water.

2.3.7. Reheater

Power plant furnaces may have a reheater section containing tubes heated by hot flue gases outside the tubes. Exhaust steam from the high pressure turbine is rerouted to go inside the reheater tubes to pickup more energy to go drive intermediate or lower pressure turbines. This is what is called as thermal power.

2.3.8. Draught system

The draught is one of the most essential systems of the thermal power plant. The purpose of draught is to supply required quantity of air for combustion and removed the burnt products from the system. To move the air through the fuel bed and to produce a flow of hot gasses through the boiler, economizer, preheater and chimney requires a difference of pressure equal to that necessary to accelerate the burnt gasses to their final velocity and to overcome the pressure losses equivalent to pressure head. This different of pressure required to maintain the constant flow of the air bed to discharge the gasses through the chimney to atmosphere is known as draught.

Draught can be obtained by use of a chimney fan, stem or air jet or combination of these. When the draught is produced with the help of chimney only, it is known as natural draught and when the draught is produced by any other means except chimney is known as artificial draught.

2.3.9. Types of draught system

The types of draught systems are

- Forced draught
- Induced draught

2.3.9.1. Forced draught

Forced Draught (FD) fan supplies the air necessary for fuel combustion, and they must be sized to handle the stochiometric air plus the excess air needed for proper burning of the specific fuel for which they are designed. Also they provide air to make up for air heater leakage and of some sealing air required. Centrifugal air foils or variable pitch (axial) fans are preferred for FD service. In a forced draught system, a blower is installed near the base of their boiler and air is forced to pass through the furnace, flues, economizer, and air pre-heater and to the stack.

2.3.9.2. Induced draught

Induced Draught (ID) fan exhaust the combustion products from a boiler. In doing, so, they create sufficient negative pressure to establish a slight suction in the furnace [usually from 0.2 to 0.5 in of water column (50 to 125 Pa)].

This condition gives rise to the name suction firing or balanced draft operation. These fans must have enough capacity to accommodate any infiltration caused by the negative pressure in the equipment of dust work downstream of the furnace and by any seal leakage in air preheater. Since ID fans are typically located downstream of any particulate removal system, they are relatively clean-service fan. Therefore, in most instances, an airfoil centrifugal fan can be selected.

2.3.10. Fan

Fans are widely used in Industrial and commercial applications. From shop ventilation to material handling to boiler applications, fans are critical for the process support.

The two primary types of fans are

- Centrifugal fan
- Axial fan

These types are characterized by the path of the air flow through the fan.

2.3.10.1. Centrifugal fan

Centrifugal fans use a rotating impeller to increase the velocity of an air stream. As the air moves from the impeller hub to the blade tips, it gains kinetic energy. This kinetic energy is then converted to a static pressure increase as the air slows before entering the discharge. Centrifugal fans are capable of generating relatively high pressures. They are frequently used in “dirty” air streams, in material handling applications, and in systems at higher temperatures.

2.3.10.2. Axial fan

Axial fan, as the name implies, move an air stream along the axis of the fan. The air is pressurized by the aerodynamic lift generated by the fan blades, much like a propeller and an air plane wing. Although they can sometimes be used interchangeably with centrifugal fans, axial fans are commonly used in clean air, low pressure, high volume applications. Axial fans have less rotating mass and are more compact than centrifugal fans of comparable capacity. Additionally, axial fans tend to have higher rotational speeds and are somewhat noisier than inline centrifugal fans of the same capacity; however, this noise tends to be dominated by high frequencies, which tend to be easier to attenuate.

2.3.11. Condenser

The surface condenser is a shell and tube heat exchanger in which cooling water is circulated through the tubes. The exhaust steam from the low pressure turbine enters the shell where it is cooled and converted to condensate (water) by flowing over the tubes. Such condensers use steam ejectors or rotary motor-driven exhausters for continuous removal of air and gases from the steam side to maintain vacuum.

2.3.12. Feed water heater

In the case of a conventional steam-electric power plant utilizing a drum boiler, the surface condenser removes the latent heat of vaporization from the steam as it changes states from vapour to liquid. The heat content (joules or Btu) in the steam is referred to as enthalpy. The condensate pump then pumps the condensate water through a feed water heater. The feed water heating equipment then raises the temperature of the water by utilizing extraction steam from various stages of the turbine.

Preheating the feed water reduces the irreversibility involved in steam generation and therefore improves the thermodynamic efficiency of the system. This reduces plant operating costs and also helps to avoid thermal shock to the boiler metal when the feed water is introduced back into the steam cycle.

2.3.13. Cooling tower

Cooling tower are heat removal devices used to transfer process waste heat to the atmosphere. Cooling towers may either use the evaporation of water to remove process heat and cool the working fluid to near the wet-bulb air temperature or rely solely on air to cool the working fluid to near the dry-bulb air temperature.

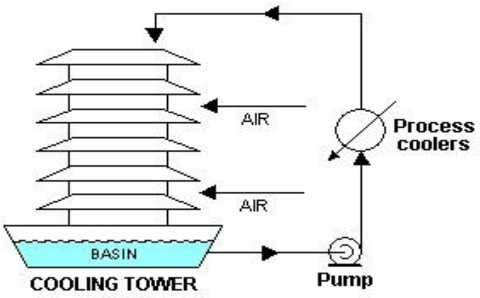

Fig.3.5. Cooling tower

Common applications include cooling the circulating water used in oil refineries, chemical plants, power stations and building cooling. The towers vary in size from small roof-top units to very large hyperboloid structures that can be up to 200 meters tall and 100 meters in diameter, or rectangular structures that can be over 40 meters tall and 80 meters long. Smaller towers are normally factory-built, while larger ones are constructed on site.

2.3.14. Condensate pump

A condensate pump is a specific type of pump used to pump the condensate (water) produced in an HVAC (heating or cooling), refrigeration, condensing boiler furnace or steam system. They may be used to pump the condensate produced from latent water vapor in any of the following gas mixtures

- conditioned (cooled or heated) building air
- refrigerated air in cooling and freezing systems
- steam in heat exchangers and radiators
- the exhaust stream of very-high-efficiency furnaces

2.3.15. Transportation of coal fuel to site and to storage

Most thermal stations use coal as the main fuel. Raw coal is transported from coal mines to a power station site by trucks, barges, bulk cargo ships or railway cars. Generally, when shipped by railways, the coal cars are sent as a full train of cars. The coal received at site may be of different sizes. The railway cars are unloaded at site by rotary dumpers or side tilt dumpers to tip over onto conveyor belts below. The coal is generally conveyed to crushers which crush the coal to about ¾ inch (6 mm) size. The crushed coal is then sent by belt conveyors to a storage pile. Normally, the crushed coal is compacted by bulldozers, as compacting of highly volatile coal avoids spontaneous ignition.

The crushed coal is conveyed from the storage pile to silos or hoppers at the boilers by another belt conveyor system.

2.3.16. Fuel preparation system

In coal-fired power stations, the raw feed coal from the coal storage area is first crushed into small pieces and then conveyed to the coal feed hoppers at the boilers. The coal is next pulverized into a very fine powder. The pulverizes may be ball mills, rotating drum grinders, or other types of grinders. Some power stations burn fuel oil rather than coal. The oil must kept warm (above its pour point) in the fuel oil storage tanks to prevent the oil from congealing and becoming unpumpable. The oil is usually heated to about 100 °C before being pumped through the furnace fuel oil spray nozzles.

Boilers in some power stations use processed natural gas as their main fuel. Other power stations may use processed natural gas as auxiliary fuel in the event that their main fuel supply (coal or oil) is interrupted. In such cases, separate gas burners are provided on the boiler furnaces.

2.3.17. Exhaust system

As the combustion flue gas comes out from the boiler, it is routed through a rotating flat basket of metal mesh which picks up heat and returns it to incoming fresh air as the basket rotates. This is called the pre heater. The gas exiting the boiler is laden with fly ash, which are tiny spherical ash particles. The flue gas contains nitrogen along with combustion products carbon dioxide, sulfur dioxide and nitrogen dioxide. The fly ash is removed by fabric bag filters or electrostatic precipitators. Once removed, the fly ash by product can sometimes be used in the manufacturing of concrete. This cleaning up of flue gases, however, only occurs in the plants that are fitted with the appropriate technology.

2.3.18. Fly ash collection

Fly ash is captured and removed from the flue gas by electrostatic precipitators or fabric bag filters (or sometimes both) located at the outlet of the furnace and before the induced draft fan. The fly ash is periodically removed from the collection hoppers below the precipitators or bag filters. Generally, the fly ash is pneumatically transported to storage silos for subsequent transport by trucks or railroad cars.

2.3.19. Bottom ash collection and disposal

At the bottom of the furnace, there is a hopper for collection of bottom ash. This hopper is always filled with water to quench the ash and clinkers falling down from the furnace. Some arrangement is included to crush the clinkers and for conveying the crushed clinkers and bottom ash to a storage site.

2.4. Heat exchanger

A heat exchanger is a device built for efficient heat transfer from one medium to another. The media may be separated by a solid wall, so that they never mix, or they may be in direct contact. They are widely used in space heating, refrigeration, air conditioning, power plants, chemical plants, petrochemical plants, petroleum refineries, and natural gas processing.]

2.5.CLASSIFICATION OF HEAT EXCHANGER

The Classifications of Heat Exchangers are

- Parallel-flow exchanger
- Counter-flow exchanger
- Cross-flow exchanger
- Condenser or evaporators
- Shell and tube exchangers: used for all applications
- Plate and frame exchangers (plate heat exchangers).
- Plate-fin exchangers.
- Spiral heat exchangers.

2.5.1. Parallel-flow exchanger

The hot fluid and cold fluids flow in the same direction, hence the name parallel-flow. Many devices, such as water heaters, oil heaters and oil coolers, etc., belong to this class. The temperature difference between hot and cold fluid keeps on decreasing from inlet to exit.

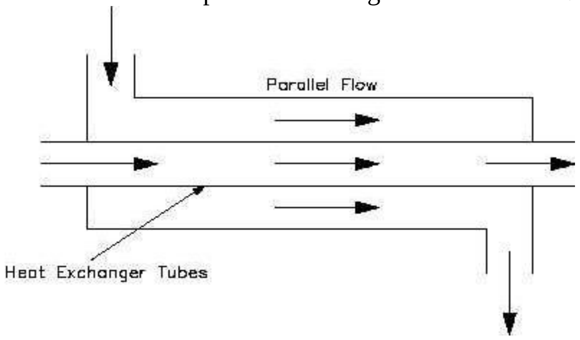

Fig. 3.6. Parallel-Flow Exchanger

2.5.2. Counter-flow exchanger

In this case the fluids flow through exchanger in opposite directions, hence the name counter flow. The temperature difference between the two fluids remains more nearly constant as compared to the parallel-flow type. This arrangement gives maximum heat transfer rate for a given surface area.

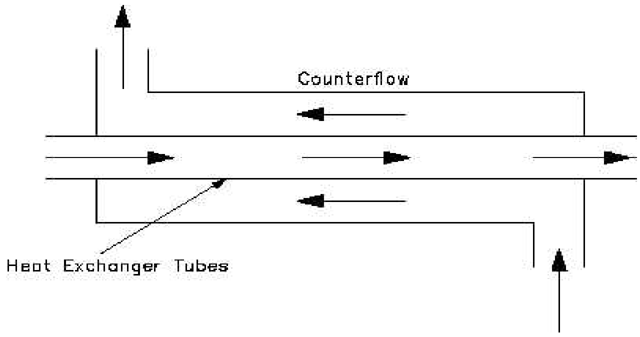

Fig. 3.7. Counter-Flow Exchanger

If the fluid flows through the exchanger only once, it is called a single pass heat exchanger. In many designs, one or both fluids may traverse the exchanger more than once. Such exchangers are called multi-pass exchangers.

2.5.3. Cross-flow exchanger

The two fluids flow at right angles to each other. Two different arrangements of this exchanger are commonly used. In one case, each of the fluids is unmixed as it flows through the exchanger. As a result, the temperatures of the fluids leaving the exchanger are not uniform. An automobile radiator is an example of this type of exchanger. In other case, one fluid is perfectly mixed while the other is unmixed as it flows through the exchanger.

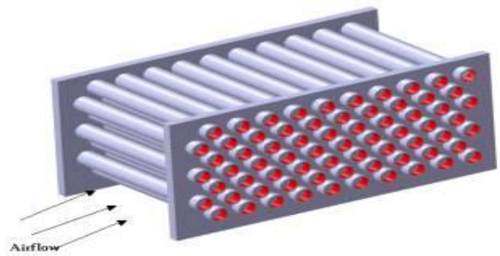

Fig.3.8. Cross -Flow Exchanger

2.5.4. Condenser

In a condenser the condensing fluid (hot fluid) remains at constant temperature throughout the exchanger while the temperature of the colder fluid gradually increases from inlet to outlet.

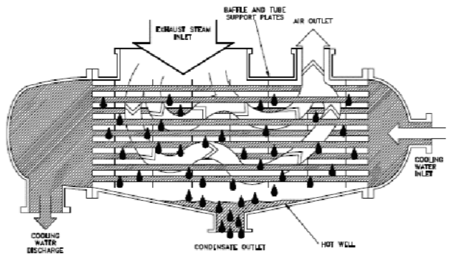

Fig.3.9. Condenser

Similarly in an evaporator the boiling fluid (cold fluid) remains at constant temperature while the hot fluid temperature gradually decreases. The temperature distribution in condenser is shown below. Since the temperature of one of these fluids remains constant, it is immaterial whether the two fluids flow in the same direction of opposite direction.

2.5.5. Shell and tube heat exchanger

Shell and tube heat exchangers consist of a series of tubes. One set of these tubes contains the fluid that must be either heated or cooled. The second fluid runs over the tubes that are being heated or cooled so that it can either provide the heat or absorb the heat required.

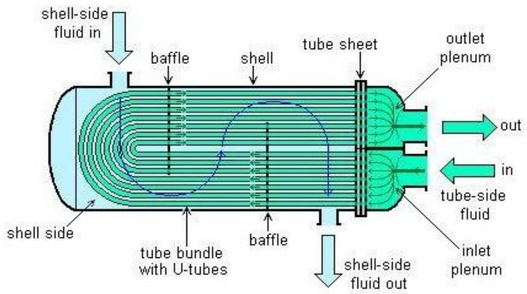

Fig.3.10. Shell and tube heat exchangers

A set of tubes is called the tube bundle and can be made up of several types of tubes: plain, longitudinally finned, etc. Shell and Tube heat exchangers are typically used for high pressure applications (with pressures greater than 30 bar and temperatures greater than 260°C). This is because the shell and tube heat exchangers are robust due to their shape.

2.5.6. Plate heat exchanger

Another type of heat exchanger is the plate heat exchanger. One is composed of multiple, thin, slightly-separated plates that have very large surface areas and fluid flow passages for heat transfer. This stacked-plate arrangement can be more effective, in a given space, than the shell and tube heat exchanger. Advances in gasket and brazing technology have made the plate-type heat exchanger increasingly practical. In HVAC applications, large heat exchangers of this type are called plate-and-frame; when used in open loops, these heat exchangers are normally of the gasketed type to allow periodic disassembly, cleaning, and inspection. There are many types of permanently-bonded plate heat exchangers, such as dip-brazed and vacuum-brazed plate varieties, and they are often specified for closed-loop applications such as refrigeration. Plate heat exchangers also differ in the types of plates that are used, and in the configurations of those plates. Some plates may be stamped with "chevron" or other patterns, where others may have machined fins and/or grooves.

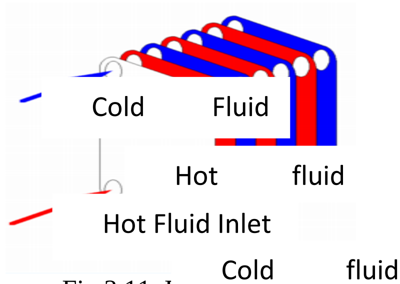

Fig.3.11. Plate Heat Exchanger

2.5.7. Plate fin heat exchanger

This type of heat exchanger uses "sandwiched" passages containing fins to increase the effectivity of the unit. The designs include cross flow and counter flow coupled with various fin configurations such as straight fins, offset fins and wavy fins.

Plate and fin heat exchangers are usually made of aluminium alloys which provide higher heat transfer efficiency. The material enables the system to operate at a lower temperature and reduce the weight of the equipment. Plate and fin heat exchangers are mostly used for low temperature services such as natural gas, helium and oxygen liquefaction plants, air separation plants and transport industries such as motor and aircraft engines.

2.5.8. Spiral heat exchanger

A spiral heat exchanger (SHE), may refer to a helical (coiled) tube configuration, more generally, the term refers to a pair of flat surfaces that are coiled to form the two channels in a counter-flow arrangement. Each of the two channels has one long curved path. A pair of fluid ports is connected tangentially to the outer arms of the spiral, and axial ports are common, but optional.

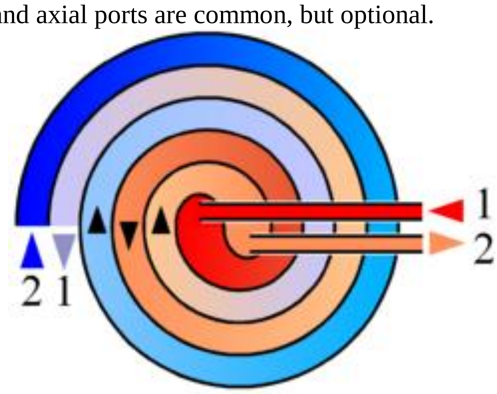

Fig.3.12. Spiral Heat Exchanger

The main advantage of the SHE is its highly efficient use of space. This attribute is often leveraged and partially reallocated to gain other improvements in performance, according to well known tradeoffs in heat exchanger design. (A notable tradeoff is capital cost vs. operating cost.) A compact SHE may be used to have a smaller footprint and thus lower all-around capital costs, or an over-sized SHE may be used to have less pressure drop, less pumping energy, higher thermal efficiency, and lower energy costs

2.6. Fouling

Fouling occurs when a fluid goes through the heat exchanger, and the impurities in the fluid precipitate onto the surface of the tubes. Precipitation of these impurities can be caused by

- Frequent use of the heat exchanger
- Not cleaning the heat exchanger regularly
- Reducing the velocity of the fluids moving through the heat exchanger
- Over-sizing of the heat exchanger

Effects of fouling are more abundant in the cold tubes of the heat exchanger than in the hot tubes. This is because impurities are less likely to be dissolved in a cold fluid. This is because, for most substances, solubility increases as temperature increases. A notable exception is hard water where the opposite is true.

Fouling reduces the cross sectional area for heat to be transferred and causes an increase in the resistance to heat transfer across the heat exchanger. This is because the thermal conductivity of the fouling layer is low. This reduces the overall heat transfer coefficient and efficiency of the heat exchanger. This in turn, can lead to an increase in pumping and maintenance costs.

The conventional approach to fouling control combines the “blind” application of biocides and anti-scale chemicals with periodic lab testing. This often results in the excessive use of chemicals with the inherent side effects of accelerating system corrosion and increasing toxic waste- not to mention the incremental cost of unnecessary treatments. There are however solutions for continuous fouling monitoring In liquid environments, such as the Neosens FS sensor, measuring both fouling thickness and temperature, allowing to optimize the use of chemicals and control the efficiency of cleanings.

2.7. Maintenance

Plate heat exchangers need to be dissembled and cleaned periodically. Tubular heat exchangers can be cleaned by such methods as acid cleaning, sandblasting, high-pressure water jet, bullet cleaning, or drill rods.

In large-scale cooling water systems for heat exchangers, water treatment such as purification, addition of chemicals, and testing, is used to minimize fouling of the heat exchange equipment. Other water treatment is also used in steam systems for power plants, etc. to minimize fouling and corrosion of the heat exchange and other equipment.

A variety of companies have started using water borne oscillations technology to prevent biofouling. Without the use of chemicals, this type of technology has helped in providing a low-pressure drop in heat exchangers.

Problem Identification

In this project, an attempt has been to utilize the waste heat to preheat the air for furnace. In Sakthi Sugars Ltd, a 3 atm. Steam with 510°C is used to boil the sugar cane milk in the process of crystal sugar manufacturing process. After that boiling process, the 3 atm. Steam with 510°C is condensed into water at a temperature of 85°C. The condensed water is pumped out from the sugar plant to the spray pond for cooling process in a 150 diameter pipe line.

In boiler, the atmospheric air is supplied to the boiler for burning of the fuel. The air is pressurized by the forced draught fan in the first stage and it is further pressurized by the secondary forced draught fan in the second stage. Further the air is supplied to the air preheater, where it is preheated by the flue gases. The preheated air is the sent to the boiler for burning process.

The heat of the condensate water is lost to the atmosphere while cooling process. The waste heat can be utilized to preheat the air by cross flow heat exchanger. This improves the efficiency of the system and reduces the fuel consumption.

4.PARTS DESCRIPTION

The parts of the cross flow heat exchanger are

- Tube sheet
- Shell
- Banks of tube
- Gaskets
- Connectors

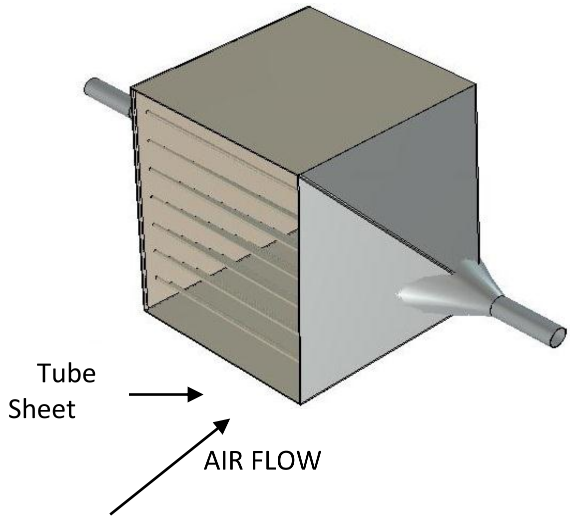

Fig.4.1. Cross flow Heat Exchanger

4.1. Tube sheet

Tube sheet are the holed sheets in which the tube are attached. It made the tube to arrange in order according to holes in it. The tube sheet made the fluid to flow inside the tube.

Fig.4.2.Tube sheet

The tube sheets are used in the manufacture of heat exchangers and pressure Vessels to secure the tube bundle inside the pressure vessel or in heat exchanger. The tube sheets are manufactured in fully machining and drilling operations.

4.2. Shell

Shell is the outer cover of the heat exchanger which guides and supports the outer fluid to move. The fluid moves in between the tube and the sheet. Shell also gives a mechanical support to the baffles. These shells prevent the heat loss from the fluid to the atmosphere and also from the atmosphere to the fluid. Shell materials have a low thermal conductivity or insulated to avoid the heat loss. It also has high corrosion resistance in fluid heat exchangers.

4.3. Tubes

Tubes are the small pipes carrying the hot or cold fluid inside. The heat energy transfer takes through the tubes. Conductive heat transfer takes place at the inside and outside surfaces of the tubes. The conductive heat transfer takes place across the cross section of the tube. The tube material should have high thermal conductivity and high corrosion resistance.

4.4. Gaskets

Gaskets are the leak preventive material. These gaskets are placed in between the tube sheets and the head. These materials also withstand the heat of the fluids.

4.5. Connectors

Connections are the pipe lines connectors, which connects the pipe lines to the shell or the head of the heat exchanger. These connections are welded with the shell and head of the heat exchanger. These connections are made up of temperature resistance material and high corrosive resistance material.

5. SOLUTION

The waste heat dissipated to the atmosphere can be utilized to preheat the forced drought fan air before air preheater. By this method, the waste of energy is saved and

PARAMETER	SPECIFICATION
Mass flow rate	41.47 kg/s
Pressure	170 mmwc at outlet
Operating temperature	45°C
Design temperature	60°C
Speed	980 rpm
Velocity of air	20-22 m/s

it is used to preheat the air, which in turns increases the efficiency of the boiler and reduce the fuel consumption.

To utilize the heat, a cross flow heat exchanger is designed to transfer the heat energy form the condensate water to the boiler feed air.

5.1. Existing circuit

In existing circuit the condensate water is cooled by spray pond. The forced draught air is sent to preheater and the preheated air is passed to boiler.

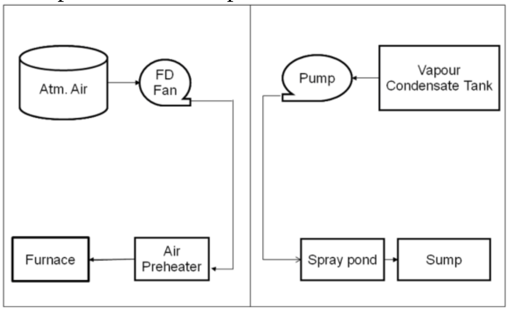

Fig.5.1. Existing Circuit

5.2. Heat exchanger circuit

The heat exchanger which is to be placed in between the air circuit to utilize the heat from condensate water. The temperature of the FD air increases from 5°C to 10°C. Moreover the fuel consumption is also reduced in the boiler furnace.

The atmospheric air is drawn by FD Fan and the air is sent to air preheater through rectangular body of the duct. Before the air is sent to air preheater, the temperature of the FD air is increased by providing heat from the condensate water. These arrangements are placed inside the rectangular box type duct. Hot water flows inside the pipe and the atmospheric air is circulated over the pipe. Therefore, atmospheric air receives the heat around 5-10°C range. But the delivery of the air from the tubular heater should not disturb by velocity.

The pictorial representation of the heat exchanger circuit is shown in figure.

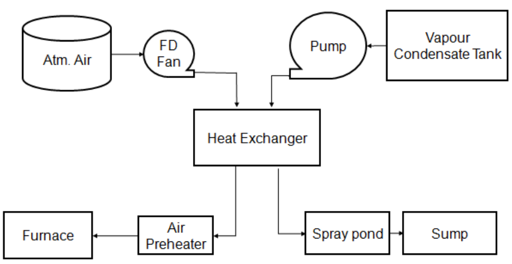

Fig.5.2. Heat Exchanger Circuit

The air is essential for burning of the fuel. The sufficient amount of air is required for the efficient combustion of fuel inside the boiler. The insufficient amount of air will reduce the boiler efficiency. By considering this the heat should be designed without affect the mass flow rate of air.

6. DESIGN CALCULATION

PARAMETER	SPECIFICATION
Mass flow rate	22.22 kg/s
Pressure	0.5 kg/m^2
Temperature	85°C

6.1. Inlet parameters of heat exchanger

The specifications of the condensed water are

Table 5.1. Specification of the Condensed Water

The specifications of the forced draught air are

Table 5.2. Specification of the Forced Draught air

6.2. Properties of condensate water

Inlet temperature T_1 = 85ºC
Density ρ = 970.75 kg/m^3
Kinematics viscosity ϑ = 0.3463 * 10^{-6} m^2/s
Thermal diffusivity α = 0.1647 * 10^{-6} m^2/s
Prandtl number Pr = 2.1
Specific heat capacity C = 4200 J/kg K
Thermal conductivity k = 0.6716 W/mK

6.3. Properties of forced draught air

Inlet Temperature t_1 = 32ºC
Density ρ = 1.156 kg/m^3
Absolute viscosity μ = 18.75 * 10^{-6} Ns/m^2
Kinematic viscosity ϑ = 16.24 * 10^{-6} m^2/s
Thermal diffusivity α = 23.22 * 10^{-6} m^2/s
Prandtl number Pr = 0.693
Specific heat capacity C = 1005 J/kg K
Thermal conductivity k = 0.0269 W/mK

6.4. Velocity calculation

for air
Mass flow rate = 41.47 kg/s
Density = 1.156 kg/m^3
Mass flow rate = Flow Rate * Density
Flow rate = Mass Flow Rate / Density
= 41.47 / 1.156
Flow rate = 35.59 m^3/s
Flow rate = Velocity * Area
Cross Sectional Area of duct = 1900*1600 = 3.04 m^2
Velocity of air = Flow Rate / Area
= 35.59 / 3.04
Velocity of air = 11.7 m/s
FOR WATER
Mass flow rate = 80 Tonnes / hr = 22.22 kg/s
Density = 964.25 kg/m^3
Mass flow rate = Flow Rate * Density

Flow rate = Mass Flow Rate / Density
= 22.22 / 964.25
Flow rate = 0.0230 m^3/s

Flow rate = Velocity * Area
Diameter of pipe = 150 mm
Cross sectional Area of duct = (π / 4) * 0.150^2 = 0.0176 m^2

Velocity of water = Flow Rate / Area
= 0.0230 / 0.0176
Velocity of water = 1.3 m/s

6.5. Selection of material

6.5.1. Tube material

Aluminum alloy (Duralumin) is selected for Tube material

The composition of Aluminum alloy

- Aluminum (over 90%)
- Copper (about 4%)
- Magnesium (0.5%–1%)
- Manganese (less than 1%)

The Physical Properties of Duralumin are

- High thermal conductivity
- High corrosive resistance

6.5.1.1. Properties of duralumin (from heat and mass data book)

Density ρ = 2707 kg / m^3
Specific heat capacity C = 0.883 KJ/kg ºC
Thermal conductivity k = 164 W/m ºC
Thermal diffusivity α = 6.676 * 10^5 m^2/s

6.5.1.2. Duct material

- Galvanized iron is selected for duct material
- Galvanised iron having zinc which react with air and form zinc oxide before iron react with air

The properties of galvanized iron has

- High corrosive resistance against air and moisture

6.6. Specification of pipe

According to Indian standards, the sizes of the pipes available in the markets are at ¼, ½, ¾, 1 inch.

The ½ inch tube is selected for heat exchanger. The diameter for ½ inch tube is

Outer diameter of the tube D_o = 21.336 mm
Inner diameter of the tube D_i = 15.7988 mm

6.7. Tube arrangement

No. of tubes n = 90
No. of tubes in the first column = 7
No. of tubes in the first column = 8
S_p-D_o = 1900/8 = 237.5 mm
S_p = 190 + D_o
S_p = 258.836 mm
For Square Arrangement Sn = Sp/2
S_n = 211.336/2

S_n = 129.48 mm
S_d = $\{S_n^2 + (S_p/2)^2\}^{0.5}$
= $\{129.48^2 + (258.836/2)^2\}^{0.5}$
S_d = 183 mm

6.8. NTU method

Convective Heat Transfer Coefficient for Air

V_{max} = [Sp/ (S_p – D)]
= [258.836/258.836 - 21.336)]
V_{max} = 12.75 m/s

Reynolds no. Re = (U_{max}*Do*ρ)/μ
= (12.75 * 21.336 * 1.156)/18.75 * 10^{-6}
Re = 16.24 * 10^3

For Staggered Arrangement

S_p/D = 9, C= 0.421& n = 0.574

Nusselt No. Nu = 1.33*C*Re^n*$Pr^{0.33}$
= 1.33* 0.421 * (16.24 * 10^3) $^{0.574}$ * $0.693^{0.33}$
Nu = 133.4449

Nusselt No. Nu = h*D_o/k
h = Nu * k/ D_o
h = 168.24 W/m^2 K

For 9 rows, Correction Factor is 0.99

Convention Heat Transfer Coefficient
h = 168.24*0.99

h = 166.56 W/m^2 K

Convective heat transfer coefficient for water

Reynolds no. Re = (U*D_i)/ϑ
= (1.3 * 0.0157988)/(0.3463 * 10^{-6})
Re = 5.93 * 10^4

For L/Di = 101.27 & Re = 5.93 * 10^4

The Colburn Factor J_H = 10

Colburn Factor J_H = ((h*D_i/k)*(C_p*μ)/k)$^{-1/3}$*(μ/μ_w)$^{-0.44}$

h = ((J_H*k/D_i)*(C_p*μ)/k)$^{1/3}$*(μ/μ_w)$^{-0.44}$

the value of (μ/μ_w)$^{-0.44}$ = 1

h= ((100*0.6716/0.0157988)*(4200*970.75)/0.6716) $^{1/3}$

Convective Heat Transfer Coefficient h = 5445.688 W/m^2 K

overall heat transfer coefficient

(1/U_o) = (r_i/r_o)*(1/h_o)+(r_i/r_o)*R_{fo}+(r_i/k)ln(r_o/r_i)+R_{fi}+(1/h_i)

Fouling factors

R_{fo} = 0.0003525 m^2 K/W for air
R_{fi} = 0.0001751 m^2 K/W for water

(1/U_o) = (r_i/r_o)*(1/h_o)+(r_i/r_o)*R_{fo}+(r_i/k)ln(r_o/r_i)+R_{fi}+(1/h_i)

(1/U_o) = ((7.8994 * 10^{-3})/ (10.668 * 10^{-3}))*(1/166.56) + (7.8994 * 10^{-3})/ (10.668 * 10^{-3}) * 0.0003525 + (7.8994 * 10^{-3}/164) ln (7.8994 * 10^{-3})/ (10.668 * 10^{-3}) + 0.0001751 + (1/5445.68)

(1/U_o)= 0.0050

Overall Heat Transfer Coefficient U_o = 196.85 W/m^2 K

Hot fluid (condensate water)

Specific heat capacity C_h = 4200 J/kg K
Mass flow rate m_h = 22.22 kg/s
Capacity rate of hot fluid C_h m_h = 93324 W/K
(C_{max})

Cold fluid (forced draught air)

Specific heat capacity C_c = 1005 J/kg K
Mass flow rate m_c= 41.47 kg/s

Capacity rate of cold fluid C_c m_c = 41677.4
(C_{min})

No. of transfer units = NTU = UA/C_{min}

Where, U_o = 196.85 W/m2 K
A = π*D_i*L*n
= π * 21.336 * 10^{-3} * 1600 * 91
A = 10.08 m^2
NTU = UA/C_{min}
= 10.08 * 196.85/41677.4
NTU = 0.047
C = C_{min}/C_{max}
= 41677.4/93324
C = 0.45

For NTU = 0.5 & C = 0.45, Effectiveness ε = 0.2

Heat Transfer Q = ε* C_{min}*(T_1-t_1)
= 0.2* 41677.4 *(85 - 32)
Q = 441780.4 W

Outlet temperature

Outlet temperature of water T_2 = T_1-(Q/C_h m_h)
= 85 – (441780.4/93324)

Outlet temperature of water T_2 = 80.2°C

Outlet temperature of air t_2 = (Q/C_c m_c) + t_1
= (441780.4/41677.4) + 32

Outlet temperature of air t_2 = 40.6°C

6.9. Energy saved

Energy Saved = Heat Transfer (Q)* Operating Hour

Where, Heat Transfer (Q) = 441780.4 W
Operating Hour = (Hours/Day) * (Days/Year)
= 24 * 365
Operating Hour = 8760 hr/yr

Energy Saved = Heat Transfer (Q)* Operating Hour

= 441780.4 * 8760

Energy Saved = 3869.996 * 10^3 KW hr/ yr

6.10. Fuel saved (in terms of energy)

Fuel saved (In Terms Of Energy) = Energy Saved/ boiler efficiency

Where, The boiler efficiency = 85%

Energy Saved= 3869.996 * 10^3 KW hr/ yr

Fuel Saved (In Terms Of Energy) = Energy Saved/ Boiler Efficiency

= 3869.996 * 10^3 / 0.85

Fuel saved (In Terms Of Energy) = 4552.93724 * 10^3 KW hr/yr

6.11. Fuel saved (in terms of weight)

Fuel saved (In Terms Of Weight) = Fuel Saved (In Terms Of Energy) / colorific value of coal

Where, Colorific value of coal = 6500 Kcal/kg = 7.5596 KW hr/kg

(Coal used is A grade coal)

Fuel saved (In Terms Of Energy)= 4552.93724 * 10^3 KW hr/yr

Fuel saved (In Terms Of Weight) = 4552.93724 * 10^3 / 7.5596

Fuel saved (In Terms Of Weight) = 602272.24 kg/yr = 602.27 Tonnes/yr

money saved

Money Saved = Fuel saved * Prize of the Fuel

Fuel saved (In Terms Of Weight) = 602.27 Tonnes/yr

Prize of the fuel = Rs. 4500 / Ton.

Money Saved = Fuel saved * Prize of the Fuel

= 602.27 * 4500

Money Saved =Rs. 2710215/ yr

Money spent for fuel

Capacity of fuel for boilers = 130 Tonnes/day

Capacity of fuel for boilers = (Tonnes/day) * (days/year)

= 130 * 365

Capacity of fuel for boilers = 47450 Tonnes/yr

Cost of fuel = (Capacity of fuel for boilers/yr) * (prize of the fuel)

= 47450 * 4500

Cost of fuel = Rs.213525000/yr

Reduced fuel = (Capacity of fuel for boilers) – (fuel saved)

= 47450 – 602.27

Reduced fuel = 46847.73 Tonnes/yr

Money reduced = (Cost of fuel/yr) – (Money Saved)

= 213525000 – 2710215

Money reduced = Rs.210814785/yr

7.WORKING PRINCIPLE

In this heat exchanger, the hot water is flow inside the tube and the air is flow outside the banks of the tube.

The water at 85˚C from the sugar plant is flow inside the tubes. The water from the 150 mm diameter pipe is taken into 90 tubes of Outer diameter Do = 21.336 mm & Inner diameter D_i = 15.7988 mm. These tubes are 1600mm long. While flowing through the tubes, a convective heat transfer takes place between the tubes surface and the hot water. The value of convective heat transfer coefficient of water is h = 5445.688 W/m^2 K.

The tube material conducts the heat energy from inside of the tube to the outside surface. The material of the tube is Duralumin. The thermal conductivity of the tube material is k = 164 W/mK.

The air at 32˚C from the forced draught fan is flow over banks of tubes. The velocity of the air is v = 11.7 m/s. The air flows inside the 1900 * 1600 mm^2 duct. The duct material is Galvanized iron. The convective heat transfer takes place between the air and the surface of the tubes. The value of the convective heat transfer coefficient of air is h = 166.56 W/m^2 K.

After the heat transfer, the water flows to the spray pond for the further cooling and the air flows to boiler for the burning of the fuel.

8. ADVANTAGES

1. Energy waste is recovered. Thus the heat lost to the atmosphere is reduced.
2. Inlet temperature of preheated air is increased which increases the efficiency of boiling process
3. The fuel consumption is reduced.
4. Reduced fuel consumption gives the economical benefit to the company.
5. Reduction of the fuel reduces the transportation of coal, preparation of coal and reduces man power.

9. RESULTS AND DISCUSSION

Thus, the heat exchanger is designed to utilize the waste heat from the condensate water to preheat the forced draught air. The heat exchanger recovered some amount of heat energy from the condensate water without wasting it to atmosphere.

Thus, the energy saved from condensate water is used for preheat the forced draught air. The inlet air temperature gets increased and the water temperature is reduced.

The increased air temperature increases the effectiveness of the burning and reduces the fuel consumption. The reduced fuel consumption reduced the money spend for the fuel. Thus, it's an economical benefit of the company.

The amount of fuel used presently in the company is 47450 Tones/yr (A grade coal) and the cost of the fuel is Rs.213525000/yr.

The energy saved from the heat exchanger is 441780.4 W. This energy saved reduces the fuel consumption up to 602.27 Tonnes/yr and reduces Rs. 2710215/ yr.

Thus the fuel consumption is reduced from 47450 Tonnes/yr to 46847.73 Tonnes/yr and the money spend is reduced from Rs.213525000/yr to Rs.210814785/yr.

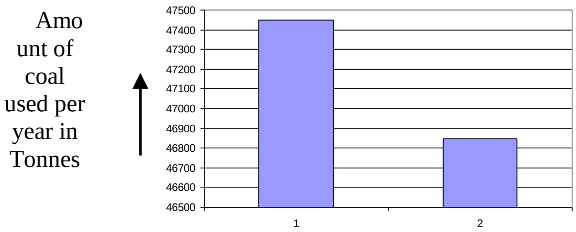

Fig.8.1. Consumption of Coal

1 – Present Amount of coal used per year

2 – Amount of coal per year after the implementation of heat exchanger

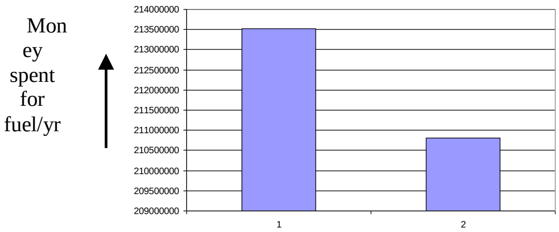

Fig.8.2. Money Spent For Consumption of Coal per Year

1 – Present Money spent for fuel per year

2 – Money spent for fuel per year after the implementation of heat exchanger

10.CONCLUSION AND SCOPE FOR FUTURE WORK

10.1. conclusion

The Cross flow heat exchanger is designed to utilize the waste from the condensate water. The waste heat is used to preheat the air before the air entered into preheater. The water from the sugar plant at 85˚C is taken as the inlet to the heat exchanger. The Duralumin is used as the tube material to transfer heat from water to air, because of its high thermal conductivity and high corrosive resistance.

The air flows over the staggered arrangement tubes and gets the heat energy from the tubes surface. Thus the temperature of the forced draught air is increased and also the effectiveness of the burning is improved. It reduces the fuel consumption up to 602.27 Tonnes/Year and also reduces the money spend for the coal up to Rs. 2710215/ year.

10.2. Scope for future work

- The amount of heat transfer is based on the surface area in which the heat transfer occurs. So, in future the use of the fins on the external surface of the tube will increase the heat transfer area which increases the heat transfer rate.
- Other types of heat exchanger are suggested to utilize the waste heat effectively.

REFERENCE

[1] Domkundwar.Arora and Domkundwar.A, "A Course in Heat & Mass Transfer", Dhanpat Rai & Co (P) Ltd-2003.
[2] Sachdeva,. R.C., "Fundamentals of Engineering Heat and Mass Transfer", New Age International Publishers-2008.
[3] Yunus, A.Cengel., "Heat Transfer, A Practical Approach", Tata McGraw Hill Publishing Company Ltd-2002.
[4] Nag. P.K., "Heat Transfer", Tata McGraw Hill Publishing Company Ltd-2002.
[5] Kothandaraman, C.P. and Subramanyan, S., "Heat and Mass Transfer Data Book", New Age International Publishers-2008.
[6] Kays. M. and London, A., "Compact Heat Exchanger", McGraw Hill Publishing Company Ltd-1984.
[7] www.oddenmfg.com.
[8] www.wlv.com