Waste Heat Recovery of Gandhinagar Thermal Power Station

Brijesh Patel[1] Dhaval P Patel[2] N R Sheth[3]
[1]Student, Mechanical Engg. Dept.
[2, 3] Assistant Professor, Mechanical Engg. Dept.,
[1, 3] GEC, Valsad, GTU
[2]GIT, Gandhinagar, GTU

Abstract— The world is facing the challenge of global warming and environment protection. On the other hand, the demand of electricity is growing fast due to economic growth and increase in demand. This thesis presents a literature review and detailed study of waste heat recovery system of the coal fired thermal power station. After studying and analysis more important thing is to optimize the efficiency with implementation of suggestion, which will be suggested by completion of this study, if there any. In this work the efficiency analysis of fuel used, boiler, turbine. Author had analytical calculation of the plant efficiency is found, in stack there is heat loss and heat utilizing in TMC will increase make up water temperature rise. After modification plant efficiency is calculated. The membrane based TMC technology was originally developed, demonstrated and commercialized for industrial steam boiler waste heat and water recovery. A recovery of the exhaust water vapor and an increase such extent in efficiency have been predicted. Several TMC waste heat recovery systems have been in operation in full-scale, industrial applications to document these savings. For applying the TMC technology to power plant use, detailed coal power plant information was collected and analyzed, including flue gas parameters, steam condensate and cooling water parameters, and potential demineralized water usage in a power plant. These method is Eco friendly because reduced flue gas temperature, coal consumption had reduced and potential saving.

I. Introduction

Waste heat is heat, which is generated in a process by way of fuel combustion or chemical reaction, and then "dumped" into the environment even though it could still be reused for some useful and economic purpose. The essential quality of heat is not the amount but rather its "value". The strategy of how to recover this heat depends in part on the temperature of the waste heat gases and the economics involved. Large quantity of hot flue gases is generated from Boilers, Kilns, Ovens and Furnaces. If some of this waste heat could be recovered, a considerable amount of primary fuel could be saved. The energy lost in waste gases cannot be fully recovered. However, much of the heat could be recovered and loss minimized by adopting following measures as outlined in this chapter [6].

A. Benefits of Waste Heat Recovery [10]

Benefits of 'waste heat recovery' can be broadly classified in two categories:

1) Direct Benefits:

Recovery of waste heat has a direct effect on the efficiency of the process. This is reflected by reduction in the utility consumption & costs, and process cost.

2) Indirect Benefits:

1. Reduction in pollution: A number of toxic combustible wastes such as carbon monoxide gas, sour gas, carbon black off gases, oil sludge, Acrylonitrile and other plastic chemicals etc, releasing to atmosphere if/when burnt in the incinerators serves dual purpose i.e. recovers heat and reduces the environmental pollution levels.
2. Reduction in equipment sizes: Waste heat recovery reduces the fuel consumption, which leads to reduction in the flue gas produced. This results in reduction in equipment sizes of all flue gas handling equipments such as fans, stacks, ducts, burners, etc.
3. Reduction in auxiliary energy consumption: Reduction in equipment sizes gives additional benefits in the form of reduction in auxiliary energy consumption like electricity for fans, pumps etc.

B. Development of a Waste Heat Recovery System

Understanding the process

Understanding the process is essential for development of Waste Heat Recovery system. This can be accomplished by reviewing the process flow sheets, layout diagrams, piping isometrics, electrical and instrumentation cable ducting etc. Detail review of these documents will help in identifying:

1. Sources and uses of waste heat
2. Upset conditions occurring in the plant due to heat recovery
3. Availability of space
4. Any other constraint, such as dew point occurring in an equipments etc.

After identifying source of waste heat and the possible use of it, the next step is to select suitable heat recovery system and equipments to recover and utilise the same. Economic Evaluation of Waste Heat Recovery System It is necessary to evaluate the selected waste heat recovery system on the basis of financial analysis such as investment, depreciation, payback period, rate of return etc. In addition the advice of experienced consultants and suppliers must be obtained for rational decision. Next section gives a brief description of common heat recovery devices available commercially and its typical industrial applications.

C. Commercial Waste Heat Recovery Devices Recuperators

In a recuperator, heat exchange takes place between the flue gases and the air through metallic or ceramic walls. Duct or tubes carry the air for combustion to be pre-heated, the other side contains the waste heat stream. A recuperator for recovering waste heat from flue gases is shown in Figure 1.

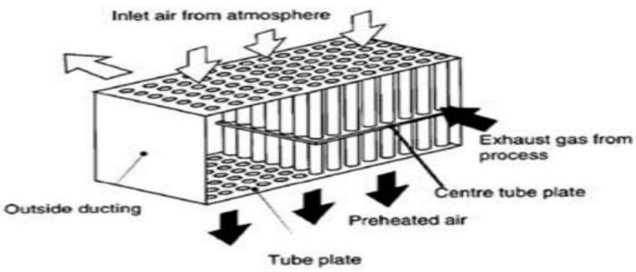

Fig. 1: Waste Heat Recovery using Recuperator

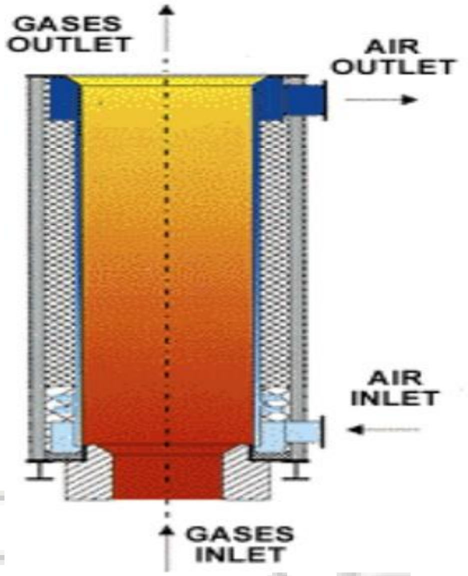

Fig. 2: Metallic Radiation Recuperator

The simplest configuration for a recuperator is the metallic radiation recuperator, which consists of two concentric lengths of metal tubing as shown in Figure 2. The inner tube carries the hot exhaust gases while the external annulus carries the combustion air from the atmosphere to the air inlets of the furnace burners. The hot gases are cooled by the incoming combustion air which now carries additional energy into the combustion chamber. This is energy which does not have to be supplied by the fuel; consequently, less fuel is burned for a given furnace loading. The saving in fuel also means a decrease in combustion air and therefore stack losses are decreased not only by lowering the stack gas temperatures but also by discharging smaller quantities of exhaust gas. The radiation recuperator gets its name from the fact that a substantial portion of the heat transfer from the hot gases to the surface of the inner tube takes place by radiative heat transfer. The cold air in the annuals, however, is almost transparent to infrared radiation so that only convection heat transfer takes place to the incoming air. As shown in the diagram, the two gas flows are usually parallel, although the configuration would be simpler and the heat transfer more efficient if the flows were opposed in direction (or counter flow). The reason for the use of parallel flow is that recuperators frequently serve the additional function of cooling the duct carrying away the exhaust gases and consequently extending its service life.

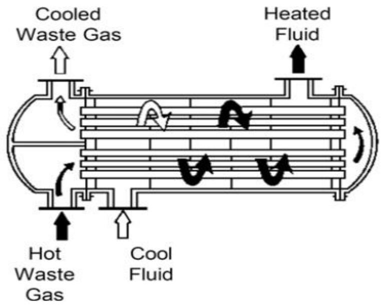

Fig. 3: Convective Recuperator

A second common configuration for recuperators is called the tube type or convective recuperator. As seen in the Figure 3, the hot gases are carried through a number of parallel small diameter tubes, while the incoming air to be heated enters a shell surrounding the tubes and passes over the hot tubes one or more times in a direction normal to their axes. If the tubes are baffled to allow the gas to pass over them twice, the heat exchanger is termed a two-pass recuperator; if two baffles are used, a three-pass recuperator, etc. Although baffling increases both the cost of the exchanger and the pressure drop in the combustion air path, it increases the effectiveness of heat exchange. Shell and tube type recuperators are generally more compact and have a higher effectiveness than radiation recuperators, because of the larger heat transfer area made possible through the use of multiple tubes and multiple passes of the gases.

D. Heat Wheels

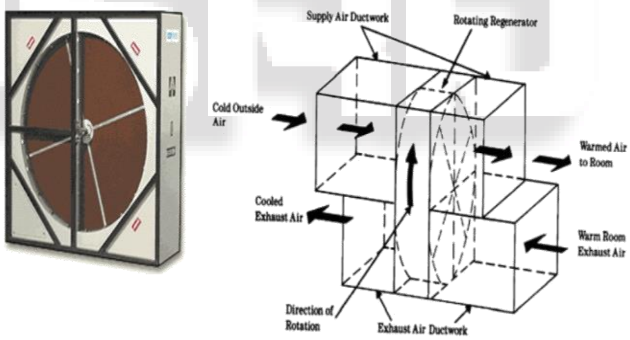

Fig. 4: Heat Wheels

A heat wheel is finding increasing applications in low to medium temperature waste heat recovery systems. Figure 4 is a sketch illustrating the application of a heat wheel. It is a sizable porous disk, fabricated with material having a fairly high heat capacity, which rotates between two side-by-side ducts: one a cold gas duct, the other a hot gas duct. The axis of the disk is located parallel to, and on the partition between, the two ducts. As the disk slowly rotates, sensible heat (moisture that contains latent heat) is transferred to the disk by the hot air and, as the disk rotates, from the disk to the cold air. The overall efficiency of sensible heat transfer for this kind of regenerator can be as high as 85 percent. Heat wheels have been built as large as 21 metres in diameter with air capacities up to 1130 m^3 / min. A variation of the Heat Wheel is the rotary regenerator where the matrix is in a cylinder rotating across the waste gas and air streams. The heat or energy recovery wheel is a rotary gas heat regenerator, which can transfer heat from exhaust to incoming gases.

II. WASTE HEAT RECOVERY IN POWER STATION

A. Low Temperature Waste Heat Recovery System Components [8]

The following chapter describes different approaches to heat recovery and the equipment used to convert the heat energy into a useable form. The system components and the flow of the following section are shown in Figure 5.1 and are further broken down throughout the chapter.

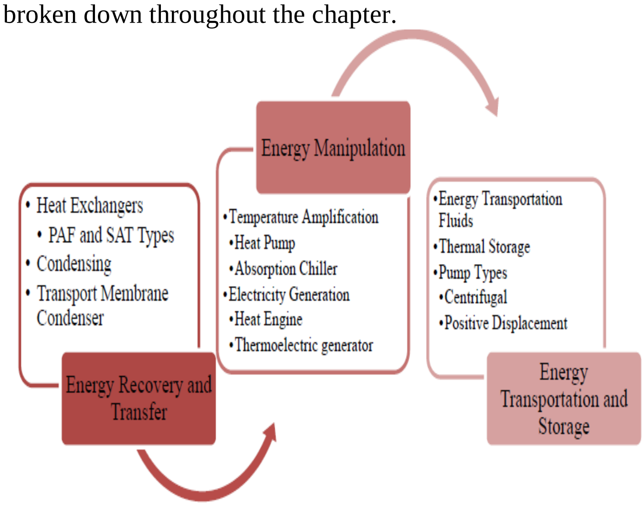

Fig. 5: System Components Flow Chart

There are four types of heat exchange equipment discussed, the first is the shell-and-tube heat exchanger followed by the plate-and-frame heat exchanger. These two heat exchangers are then compared for different applications and their uses along with when a certain type should be chosen over the other are discussed. The next two types are concerned with condensing water vapor from the exhaust and capturing its associated energy. This can be accomplished with either a condensing economizer or with a transport membrane condenser. The two types of technologies are discussed along with the underlying goal behind condensing this water vapor from the exhaust stream.

The second section of this chapter focuses on methods of amplifying the waste heat temperature. This amplification takes in the waste heat and adds additional energy to the system which, in turn, increases the overall temperature of the waste heat stream. This amplification takes in the waste heat and adds additional energy to the system which, in turn, increases the overall temperature of the waste heat stream. This can be accomplished by both a mechanical heat pump and an absorption heat pump. The absorption heat pump can be used for not only this increase in temperature of the waste heat but also to provide a cooling effect which can be used in space conditioning applications. The specific applications for which each of these types are recommended are listed and general performance efficiencies are shown.

The third portion of the chapter discusses different methods of converting the waste heat energy directly into electricity. A large portion of energy consumed today comes from hydrocarbon fuel combustion, and one of the major combustion products is water vapor. For the coal power plants, water vapor exits with the flue gases at a volume percentage 12–16%. Other industrial processes such as drying, wet scrubbers, dry scrubbers, dewatering, and water chilling, produce flue gases with 20–90% moisture content. Typically the water vapor along with its substantial latent heat is exhausted into the atmosphere limiting the thermal efficiency of these processes. If 40–60% of this water vapor and its latent heat could be recovered, thermal efficiency would increase more than 5% for most of these processes. There were several conventional technologies for recovering waste heat from utility boiler flue gases, such as recuperators, regenerators, finned tube economizers, and passive air preheaters.

These technologies are typically used for medium-to high-temperature waste heat, and the challenge is the technologies have material constraints and temperature restrictions. Until now, there has been no practical commercial technology available for recovering water vapor and its substantial latent heat from power plant low temperature flue gases.

B. Introduction to TMC Technology

TMC development work for industrial boilers [7]

Fig. 6 depicts the TMC concept for boiler applications with exhaust gas flowing on one side of a nano porous ceramic membrane tube and cold boiler makeup water flowing counter-current on the opposing side. Water vapor from the flue gas is transported through the membrane structure by first condensing inside the inner separation membrane layer (60–80 Å pore size), then moving through the intermediate layer (500 Å pore size) and finally through the substrate (0.4 lm pore size). Other gas components in the flue gas are blocked from passing through the membrane by the condensed liquid. Condensed water along with its latent heat combines with the cold boiler makeup water, helping to raise its temperature prior to entering the boiler feed water tank or deaerator. A small vacuum is maintained on the water side of the TMC unit to prevent backflow of water due to liquid pressure head and also to provide additional driving force for water to pass through the membrane.

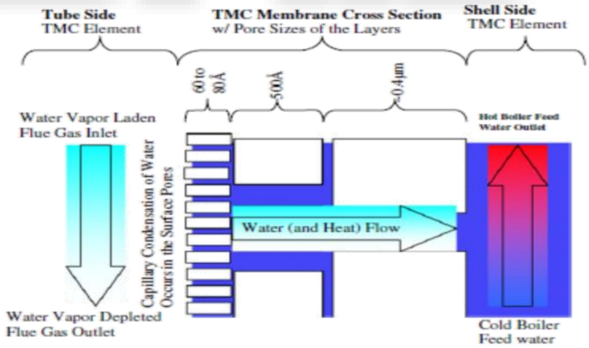

Fig. 6: TMC concept schematic

The first generation TMC design was based on commercially available membrane bundles, incorporated into an arrangement with flue gas flowing downward through the inside of the membrane tubes and boiler makeup water flowing counter currently upward in the TMC shell. The down flow configuration was necessary to attain maximum heat transfer due to natural convective flow of the water on the shell side of the TMC.

However, several improvements were required to reduce the module cost, installation cost, and maintainability to make the product marketable, particularly for the lucrative retrofit boiler market, where a more compact and user-friendly design was required. The following key factors were considered for the 2nd generation TMC design:

– A higher capacity modular design to reduce the number of required modules per unit of flow, thereby allowing for scale up to larger systems.
– Adopt a design that reduces footprint requirements by utilizing an up-flow of exhaust gas and down-flow of water. This design allows for installation of the TMC directly on top of a boiler thereby also reducing ductwork and installation costs.
– Improve the tube bundle design for more effective use of membrane surface thereby reducing the number of tubes required.
– Configure the TMC modules into a housing that allows for pre assembly of the modules, electrical, piping and components. This reduces installation costs and allows for module maintenance without complete disassembly of the TMC vessel.

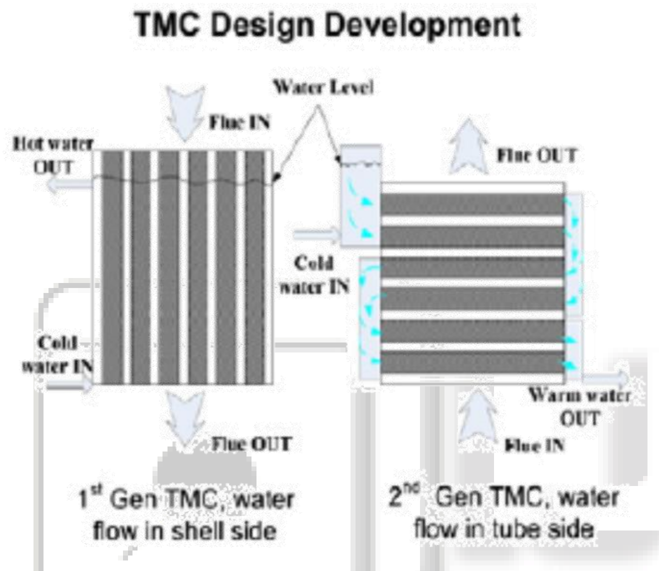

Fig. 7: New membrane module, 1st and 2nd gen TMC

The 2nd generation design was thus developed including the above features. Fig. 7 (left) shows the custom designed membrane module with tube spacing to maximize gas-to-surface contact while minimizing pressure drop. By using compression molded engineering plastic with fast-curing elastomeric potting materials to seal the membrane tubes, the module cost is greatly reduced.

C. Field demonstration for industrial boiler waste heat/water recovery

Three TMC systems have been installed, commissioned and operated in industrial applications including:

– Specification Rubber in Alabama has operated for over 15,000 h with a 94% fuel-to-steam efficiency (HHV), 19% reduction in fuel consumption, 19% reduction in greenhouse gas emissions, and a 20% reduction in boiler feed water. The TMC alone contributes over 40% of the boiler efficiency increase and is responsible for all the water savings.
– Clement Pappas & Company in California has operated for over 10,000 h with a 93% fuel-to-steam efficiency (HHV), 12% reduction in fuel consumption, 12% reduction in greenhouse gas emissions, and a 20% reduction in boiler feed water.
– Baxter Healthcare in California has operated for over 4000 h with a 93% fuel-to-steam efficiency (HHV), 12% reduction in fuel consumption, 12% reduction in greenhouse gas emissions, and a 20% reduction in boiler feed water. This was the first demonstration of the 2nd generation TMC modules.

D. Commercialization [7] [8]

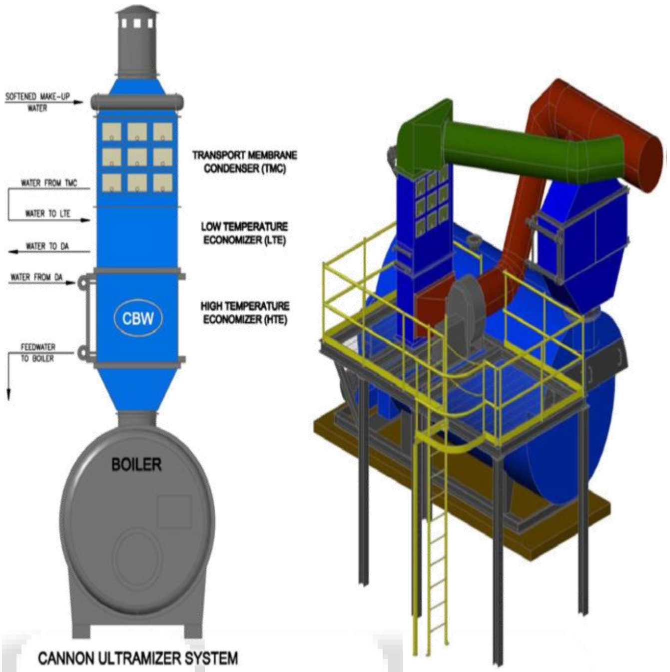

Fig. 8: Stacked installation design (left), and skid installation design (right)

In August 2009 GTI licensed the TMC technology to Cannon Boiler Work (CBW), which is a well-known, trusted supplier of boiler heat recovery devices including economizers, vent condensers, air coolers, after coolers, and other energy efficient devices. They are currently marketing the TMC under the trade name Ultramizer for both new and existing boiler systems. For boiler rooms with sufficient space above the boiler, the Ultramizer is stacked directly on top of the boiler to reduce equipment footprint (Fig.8, left). For boiler rooms without space above the boiler, the Ultramizer is skid mounted and can be located anywhere within 30 m of the boiler (Fig.8, right). Both Ultramizer options are standard packages with the TMC housing, TMC modules, instruments, piping and electrical preassembled for ease of installation. CBW celebrated the first Ultramizer ceremonial start on September 9, 2010 at Latrobe Brewing in Pennsylvania on an existing fire tube boiler system.

E. Pilot-scale TMC investigation for power plant flue gases

Under the support from DOE National Energy Technology Laboratory (NETL) and the Illinois Clean Coal Institute (ICCI), GTI has further developed the TMC technology to a two-stage design tailored to coal power plant flue gas applications. The new two-stage TMC design developed here seeks to achieve maximum heat and water recovery. The recovered high-purity water and heat can be used directly to replace power plant boiler makeup water to improve its efficiency, and any remaining recovered water can be used for FGD water makeup or other plant uses. The TMC technology will be particularly beneficial to coal-fired power plants that use high-moisture coals and/or FGD for flue gas cleanup. The TMC can be used to process high-moisture flue gas from the FGD to recover its water vapor

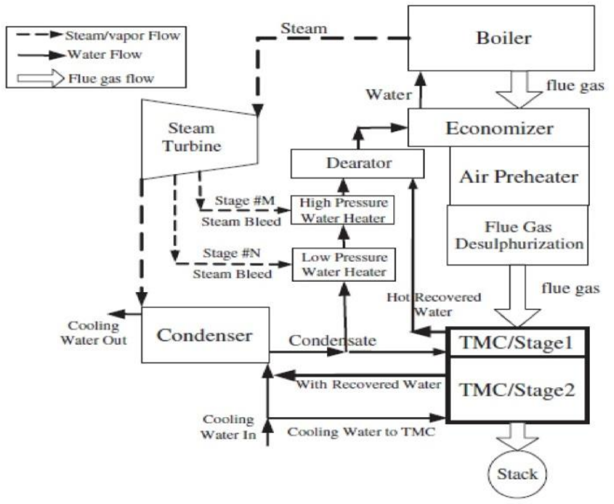

Fig. 9 Two-stage TMC integration with a power plant

and its latent heat to increase boiler efficiency and decrease its water consumption. Fig.9 shows a schematic for integrating the TMC water recovery unit in a typical power generation boiler and steam turbine loop. For the two-stage TMC unit to maximize its function for recovering both water and heat, two separate cooling water streams are used. On the water side, the first-stage TMC inlet water will be obtained from steam condensate from the condenser, and its outlet water with recovered water vapor and associated latent heat from flue gas will go to the deaerator for boiler water makeup. The second stage TMC inlet water will be part of the condenser cooling water stream. The outlet water from this TMC stage will then be routed to go back to the cooling water stream with extra recovered water from the flue gas. On the flue gas side, the TMC is situated between the FGD unit and the stack.

F. *Experimental setup*

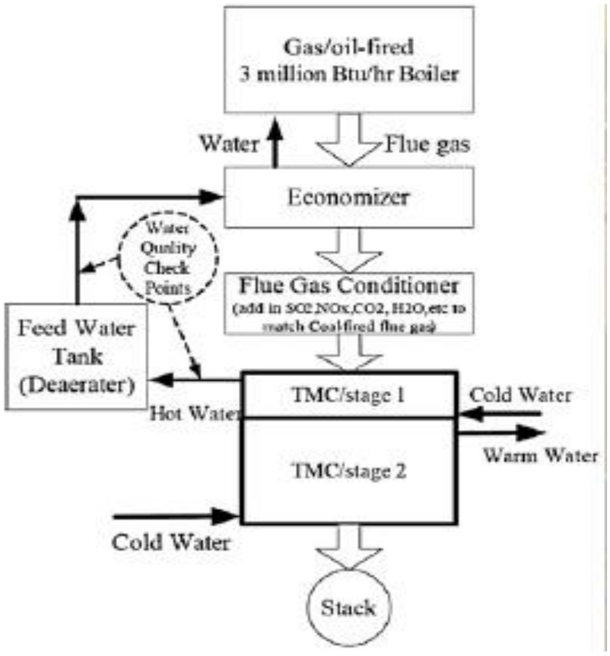

Fig. 10: Pilot-Scale TMC Test Setup Schematic

Figure 10 is schematic of Pilot-Scale TMC Test setup in which flue gas pass from Boiler to Economizer then FGD. In this setup TMC implemented in Stage-1 and Stage-2 for makeup water. Due to putting this two stage in between main component which result increase feed water temperature and reduced flue gas temperature. This hot water was fed in Feed Water Tank through further inlet to economizer then further used in Boiler.

G. *Implement TMC in GTPS*

Various instrumentations are installed throughout the system to measure the water and gas inlet and outlet conditions, and for evaluating the TMC performance. These include temperature, pressure, humidity, water level, and water flow rate sensors. Figure 5.7 shows TMC system P&ID.

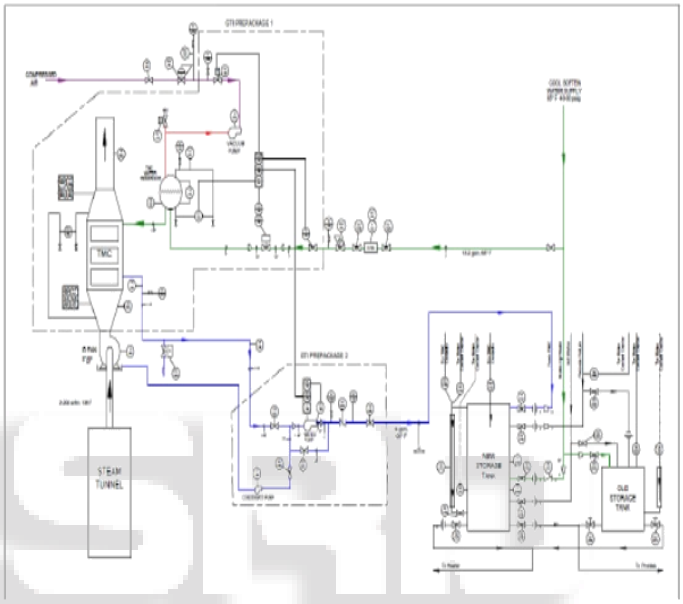

Fig. 11: TMC System P&ID

Form conclusion

In above content we had analysis TMC system for 550MW in USA. They had rise feed water temperature upto 40°C. If we will implement same practical methodology for GTPS. GTPS have also predict same make up water temperature rise upto 40°C.

TMC implement in GTPS

$Q = m\, C_p\, \Delta T$

$= 44.751 \text{ X } 10^3 \text{ X } 4.2 \text{ X } 40$

$Q = 7.5 \text{ X } 10^6$ KJ

Fuel (Coal) saving = 0.438 T/hr

Modified Boiler efficiency with respect to these fuel saving rate

Boiler Efficiency = 76.62%

So, Overall efficiency of Cycle = 33.12%

In overall cycle efficiency had 32.5%, after TMC implementation we got cycle efficiency had 33.12%. It is 2 to 2.5 % rise in efficiency. Due to these result, it had indicate direct affected to fuel consumption rate.

III. CONCLUSION

From the energy analysis made, 210MW of the GTPS – the following conclusion are drawn.

From the analytical calculation of the plant efficiency is found to be 32.5%, in stack there is heat loss upto 147°C these heat utilizing in TMC will increase make up water temperature rise up to 40°C. After modification we get plant efficiency is 33.12%.

The membrane based TMC technology was originally developed, demonstrated and commercialized for industrial steam boiler waste heat and water recovery. A 40% recovery of the exhaust water vapor and an increase of more than 2 to 2.5% in efficiency have been predicted. Several TMC waste heat recovery systems have been in operation in full-scale, industrial applications to document these savings. For applying the TMC technology to power plant use, detailed coal power plant information was collected and analyzed, including flue gas parameters, steam condensate and cooling water parameters, and potential demineralized water usage in a power plant.

These method is Eco friendly because reduced flue gas temperature, coal consumption had reduced and potential saving.

ACKNOWLEDGMENT

It is indeed a great pleasure for me to express my sincere gratitude to those who have always helped me for this dissertation work.

I am extremely thankful to my thesis guide Asst. Prof. N.R.Sheth in Mechanical Engineering Department at Government Engineering College, Valsad is valuable guidance, motivation, cooperation, constant support with encouraging attitude at all stages of my work. I am highly obliged to him for his constructive criticism and valuable suggestions, which helped me to present the scientific results in an efficient and effective manner in this thesis.

I am highly thankful to Asst. Prof. Dhaval Patel in Mechanical Engineering Department at Gandhinagar Institute of Technology, Gandhinagar for his enthusiastic support in planning of experiments, analysis of the experimental data and scientific interpretation of the results. I am also thankful to all the faculty members of Mechanical Engineering Department and my thanks are due to all of the friends who encouraged and supported me during thesis work.

REFERENCES

[1] Maura Vaccarelli[a], Roberto Carapellucci[*a], Lorena Giordano[a],” Energy and economic analysis of the CO_2 capture from flue gas of combined cycle power plants”, Energy Procedia 45 (2014) 1165 – 1174.
[2] Yasser Shawky, Ahmed M. Nada, Fahmy Salah Abdelhaleem, “Environmental and hydraulic design of thermal power plants outfalls ‘‘Case study: Banha Thermal Power Plant, Egypt”, Ain Shams Engineering Journal (2013) 4, 333–342.
[3] Sandhya Hastia, Adisorn Aroonwilasa and Amornvadee Veawaba, “Exergy Analysis of Ultra Super-Critical Power Plant”, Energy Procedia 37(2013) 2544 – 2551.
[4] Ankur Geetea, A.I. Khandwawalab, “Thermodynamic analysis of 120MW thermal power plant with combined effect of constant inlet pressure (124.61bar) and different inlet temperatures”, Case Studies in Thermal Engineering1 (2013)17–25.
[5] Fangtian Sun, Lin Fu a, Shigang Zhang a, Jian Sun a, “New waste heat district heating system with combined heat and power based on absorption heat exchange cycle in China”, Applied Thermal Engineering 37 (2012) 136-144.
[6] Raviprakash kurkiya, Sharad chaudhary, “Energy Analysis of Thermal Power Plant”, International Journal of Scientific & Engineering Research Volume 3, Issue 7, July-2012.
[7] Dexin Wang*, Ainan Bao, Walter Kunc, William Liss, “Coal power plant flue gas waste heat and water recovery”, Applied Energy 91 (2012) 341–348.
[8] Gas Technology Institute, 1700 S Mount Prospect Rd., Des Plaines, IL 60016, USA,” Coal power plant flue gas waste heat and water recovery”, Applied Energy 91 (2012) 341–348.
[9] Seksan Udomsri *, Andrew R. Martin, Viktoria Martin, “Thermally driven cooling coupled with municipal solid waste-fired power plant: Application of combined heat, cooling and power in tropical urban areas”, Applied Energy 88 (2011) 1532–1542.
[10] S.C. Kaushika, V.SivaReddya, S.K.Tyagib,” Energy and exergy analyses of thermal power plants: A review” Renewable and Sustainable Energy Reviews15 (2011)1857–1872.