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A study on utilization of discharged hot water for dm/potable water by LTTD method at Ennore thermal station

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Abstract

Thermal stations use coal as combustion material for fuel and the chemical energy stored in coal is converted successively into thermal energy, mechanical energy and finally electrical energy for continuous use and distribution across a wide geographic area. The steam exits the boiler, turbines and passes over cool tubes in the condenser. The condensers capture the used steam and transform it back to water. The cooled water is then pumped back to the boiler to repeat the heating processes. At the same time, water is piped from sea to keep the condensers constantly cool. This cooling water, now warm from the heat exchange in the condensers, is released from the plant. Large quantity of sea water is drawn to the tune of 1760 MLD in the Ennore thermal power station for cooling of condenser tubes. After the cooling purposes the return warm water is cooled and discharged back into the sea through tunnel of 2.50m diameter and subsequently through an open channel near outfall structure of the coast. Discharged hot water at the very first source of exit from the thermal station with a temperature of about 8^0C can be used for heat conversion. The method of LTTD (Low Temperature Thermal Desalination) offers ideal scope for utilization of the already hot water which need not require pre-heating as the method of desalination utilizes 38^0C of temperature in the flash chambers by evaporation and subsequent condensation in the shell and tube condensers of the steam using the sea water with low temperature. Thus an emphasis is made here for avoidance of purchase of raw water for all purposes and avoids tapping of ground water with zero environmental pollution. The brine thus emulated from the process is diluted using the already drawn effluent and discharged into the sea. The study of desalination is to determine and combine available technologies to optimize water production costs and quality. For which a number of factors determine the capital and operating costs for desalination: capacity and type of facility, location, feed water, labour, energy, financing, and concentrate disposal.

Key words: coolant water, desalination, flash chamber, vacuum pump, brine

Introduction

The world's water consumption rate is doubling every 20 years, outpacing two times the rate of population growth. It is projected that by the year of 2025, water demand will exceed supply by 56%, due to persistent regional droughts, shifting of the population to urban coastal cities, and water needed for industrial growth. The demand of fresh water is on the decrease due to climate change. Lack of fresh water reduces economic development and lowers living standards. There is a worldwide need to manage this valuable resource in order to maintain sustainability at all fronts. Oceans make up 97% of the world's supply of water becomes an alternative source to meet the global demand (Yashpal Singh, 2007). Desalination systems can make abundant fresh water both from seawater has become a viable option for the development of new regional water supplies. Ennore thermal power station is a steam driven power plant. The water in the boiler evaporates due to the intense heat, becomes high-pressurized steams that are passing through a conduit, it forces its way through the turbine, thus rotating the turbine at a greater speed and forces the generator and electrical energy is produced. Rest of the steam enters a shell and tube condenser into which the cooling agent (sea water) circulate, the steam will go through the cooling agent. Steam thus changes back to its liquid form and returns to the boiler. The whole process repeats and thus called Rankine Cycle. The returned cooling agent now becomes warm water and is put into a series of heat reduction processes before disposing to the sea (Metcalf and Eddy, 2002).

Study area

Ennore Thermal Plant

Thermal Power stations using pulverized coal as fuel generate large quantities of ash as a by-product and disposal of hot water in a safe manner without affecting the environment is very important. Ennore thermal station located at a distance of around 15 Kms on the northern outskirt of the Chennai city, with an installed capacity of 450 MW has started functioning from 1970. As the subject revolves around the coolant water, the requirement of sea coolant water is drawn from the Ennore creek mouth, which flows, to the Buckingham canal from where water enters the stilling basin in the sea cooling water intake bay (Fig.1).

Materials and methods

Coolant water

The de-mineralized water in the boiler evaporates due to the intense heat produced by combustion of coal, becomes high-pressurized steams forces its way thus rotating the turbine at a greater speed and forces the generator and electrical energy is produced. Rest of the steam enters a shell and tube condenser into which the cooling agent (sea water) circulate, the steam will go through the cooling agent. Steam thus changes back to its liquid form and returns to the boiler.

Requirement of sea water at the time of installation was 80,000 CuM per hour (approx.) i.e., 1920 MLD and the source of cooling water was from the back waters of Ennore creek (once through cooling water system). The Ennore creek mouth usually closes frequently due to northward and southward sand littoral drift because of the natural tidal phenomenon. To tide over the closure of creek mouth which affects flow of sea water into the back waters, a system to pump water from a distance of about 100m from the shore were designed and in operation. However most of the year when the flow in the back waters was continuous another problem of flow of sand drift into and fill up inside the back waters reduced the water depth. To overcome this drift of sand into the backwaters from the mouth, sand dredgers were put into service round the clock during low as well as high tide levels. In the present scenario, the requirement of sea coolant water to an extent of 1760 MLD was mandatory to feed into the stilling basin for condenser cooling at an ambient temperature of 28^0C to 30^0C (Shanthi and Gajendran, 2009). This unit is pumping seawater at the rate of 17, 60,000 kiloliters per day for condenser cooling from Ennore Creek. After condenser cooling, the hot water is discharged into the creek. In order to reduce the thermal pollution and to overcome the difficulty in getting the cooling water due to sand dune formation at the mouth of the creek, the unit has a provision for five cooling towers to recycle the cooling water. The plant also takes sea water as coolant and discharges hot water back to the sea.

Hot Water

The sea water drawn for circulation around the condenser for the purpose of cooling the steam inside the condenser tubes observes the heat inside and in-turn becomes warmer. This return cooling water now as hot water after cooling the condenser tubes is let into the process of reducing the increased temperature of 38^0C of hot water. It is subjected to a series of processes and discharged at a relatively low temperature of 33^0C into the tunnel for a length of 1.2 km and then in the open channel for about a length of 500m as per the pollution control norms for safeguarding aquatic life & coral creatures.

Table 1. Raw water drawn and DM water make up usage

Year	RAW water drawn	DM water used	% of DM water usage
2009-10	86140 MT	83910 MT	97.40%

Raw Water

Raw water is the potable water drawn from various available natural sources in large-scale abundance such as wells, stagnated river/lakes and deep wells to cater continuous needs of the end user such as thermal power station. As such, raw water is drawn from Minjur well fields located at a distance of about 15 km, is pumped by multi stage booster pumping system to be made available in the requisite quantity, and are thus stored in large storage tanks to meet out three days requirement at the Ennore thermal power station. This raw water is subjected to a series of de-mineralization processes in the DM plant for purification from unwanted minerals before feeding into the boilers for steam generation (Table 1). Utmost care is taken in the DM plant to maintain standard quality of the DM water, which is main cause for both consumption of optimum coal combustion as well as requisite steam of high standards. Raw water is purchased at the rate of Rs.70/- per MT from CMWSSB (Chennai metro water). Adjustment of pH and electrical conductivity apart from removal of various unwanted minerals are the main functions at the DM plant. Details of raw water receipt @ the rate of 70/- per MT for 1055924 MT during 2010 and the

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corresponding cost for production of DM water is 95/- per MT (ave.).

Tests and Analysis

Raw water analysis results during 2011

Raw water test analysis reveal that various minerals such as $CaCo_3$, Magnesium, Sulphate, silica were to be removed apart from adjusting the pH to within the range of 7.0 and the processes in the De-mineralization plant reduce the excess concentration (Metcalf and Eddy, 2002), (Fig.2 & Table 2).

Table 2. Raw water quality analysis

RANGE	Max	Min
Conductivity (µs/cm	1040	480
pH	8.2	7.5
PV as $CaCo_3$	NT	NT
MV as CaCo3	170	80
Total hardness ppm	280	120
calcium hardness ppm	180	70
Magnesium hardness ppm	100	50
Carbonate hardness ppm	170	80
Non-Carbonate hardness ppm	110	40
Chloride as Cl ppm	147	56
Sulphate (SO_4) ppm	64	21
Silica as SiO_2	39	10

Cooling water analysis

From the test results of intake cooling water the maximum constituent was chlorides and very high electrical conductivity. The pH value has been within the desired limits (Table 3).

De-mineralized water analysis

Repeated tests revealed concurrent values in maximum and minimum limits thus meeting to the required standards (Fig. 3 & Table 4).

Fig.1. Location showing, Ennore thermal station

Effluent analysis results during 2011

Water sample from the hot water outlet has been tested and the results are furnished in Table 5 and Table

Table 3. Cooling water analysis during 2011

Test	Max	Min	During rainy season	
			Max	Min
Conductivity (µs/cm	66000	30000	2750	790
pH	8.5	7.8	8.0	7.8
Free Chloride as Cl_2 (ppm)	0.3	0.1	0.6	0.2
Dissolved Oxygen as O_2 (ppm)	5.2	NT	5.6	4.7
Ammonia (ppm)	0.2	NT	0.1	NT
Chlorides as Cl (ppm)	19580	11557	681	149

Table 4. De-Mineralized water analysis during 2011

Test	Max	Min
Conductivity (µs/cm	0.6	0.2
pH	6.8	6.7
Silica as SiO_2 (ppm)	10	10

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Table 5. Effluent analysis at various locations

RANGE	Cooling water	Cooling water outlet	Clarifier	NP	LIMIT
Conductivity	32350	38050	21500	5020	10% above the Influent cooling water
pH	8.2	8.2	8.0	9.0	5.5 - 9
TSS (ppm)	420	510	260	90	
TDS (ppm)	18910	22069	12470	2510	--
Chloride as Cl ppm	14889	15243	3900	2659	---
Sulphate (SO_4) ppm	1450	1500	860	250	1000
Oil & grease (ppm)	NT	NT	NT	NT	20

The constituents such as Total Dissolved Solids, Total hardness, Chlorides are in excess over the prescribed Environmental norms and hence these are to be removed in the preliminary phase of filtration.

Thermal desalination

Desalination is the sequence of processes that remove some amount of salt and other minerals from saline water and is rightly termed as desalinization. Sea water is desalinated in order to convert to fresh water so it is suitable for human consumption. This process produces brine, which contains salt and minerals as by-product depending on the feed water. Most of the modern interest in desalination is focused on developing cost-effective ways of providing fresh water for human use in regions where the availability of fresh water is less or becoming, limited. Large-scale desalination typically uses extremely large amounts of energy as well as specialized, expensive infrastructure, making it very costly compared to the use of fresh water from conventional sources such as rivers or groundwater.

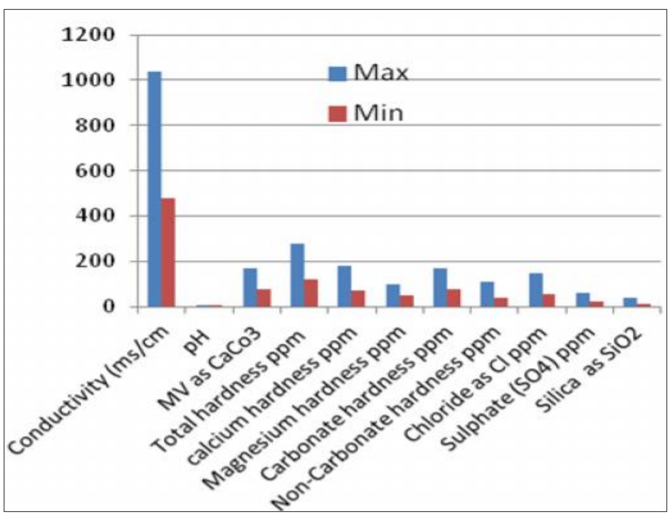

Fig.2. Raw water quality analysis

Methods of desalination includes usage of Membranes in Reverse Osmosis (RO) and Electrodialysis reversal (EDR) systems and utilisation of thermal energy present in the hot water is termed as the Thermal Desalination which diversifies into Multistage flash desalination (MSF) processes, Multiple effect evaporation (MED) and Mechanical vapour compression process (MVC).

The Process

Discharged hot water @ 38^0C was pumped into the

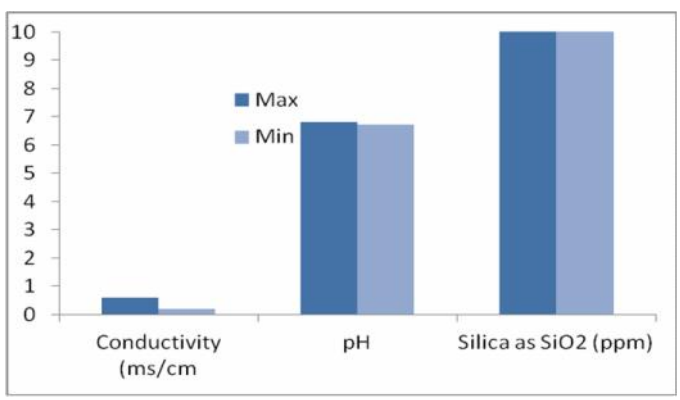

Fig.3. De-Mineralized water analysis during 2011

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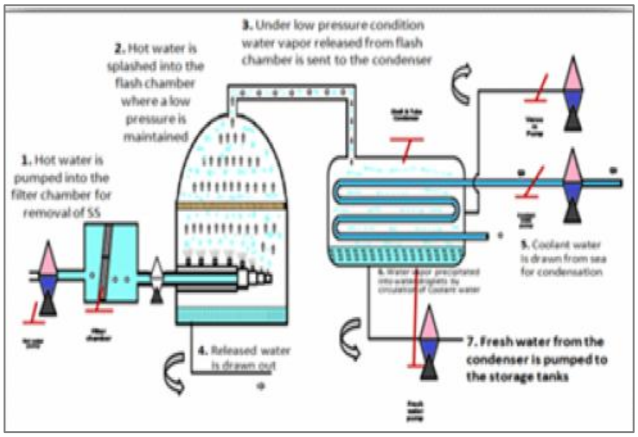

Fig.4. Process flow diagram of the LTTD method

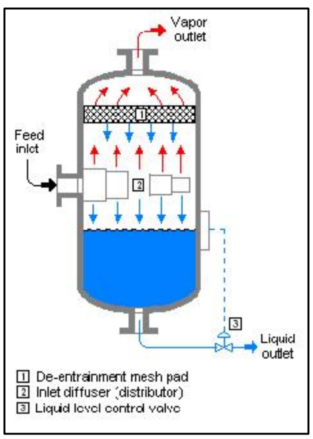

Fig.5. Flash vessel

filter chamber for removal of primary suspended solids. After primary filtration, the filtered hot water was forced into the "FLASH CONTAINER" or "FLASH CHAMBER", where the hot water was splashed in nozzles to spray the hot water. A relatively low pressure (less than the water pressure) of 25 mbar was maintained by the vacuum pump because of this the hot water quickly evaporated taking latent heat of evaporation from the hot water and released as vapor. An absolutely ideal ADIABATIC condition prevailing inside the chamber enhances the evaporation of vapour. The evaporated water vapours move towards the shell and tube condenser and the return water was losing temperature by about 7°C is returned back to the sea. The main condenser was circulated with cold water drawn from sea at a temp of 28^{0}C. Thermodynamically, flash evaporation occurs when a saturated liquid undergoes a sudden reduction in the surrounding pressure. So, that a part of the liquid immediately turns to vapour to regain equilibrium; under adiabatic conditions. The generated vapour receives its latent heat of vaporization at the expenses of the surrounding liquid and both the vapour and the residual liquid are cooled to the saturation temperature at the reduced pressure.

Fresh water was collected from the condensate tank and have been sent to further storage. The NIOT have experimented (Phanikumar *et al*., 2009). This method in the Islands of kavaratti, Lakshadweep is utilizing the surface temperature prevailing at the sea and relatively coolant water, which was drawn from deep sea level for quick condensation with a temperature difference of nearly 8°C (Bhausaheb *et al*. 2010). Thus, the concept of already hot water at thermal stations could well be tapped in this method for conversion (Low Temperature Thermal Desalination Applications for Drinking Water, 2010), (Fig.4 & 5).

Flash Vessel

A vapor-liquid separator drum is a vertical vessel into which a liquid and vapor mixture (or a flashing liquid) is fed and wherein the liquid is separated by gravity, falls to the bottom of the vessel, and is withdrawn. The vapor travels upward at a design velocity which minimizes the entrainment of any liquid droplets in the vapor as it exits the top of the vessel due to relatively very low pressure such that the water droplets are not pulled upward. The size a vapor-liquid separator drum (or knock-out pot, or flash drum, or compressor suction drum) should be dictated by the anticipated flow rate of vapor and liquid from the drum. The following sizing methodology is based on the assumption that those flow rates are known.

Flash Vessel Design

Use a vertical pressure vessel with a length-to-diameter ratio of about 3 to 4, and size the vessel to provide about 5 minutes of liquid inventory between the normal liquid level and the bottom of the vessel (with the normal liquid level being at about the vessel's half-full level). Calculate the vessel diameter by the Souders-Brown equation to determine the maximum allowable vapor velocity:

$$V = (k) [(dL - dV) / dV]^{0.5}$$

Where:

V = maximum allowable vapor velocity, m/sec

dL = liquid density, kg/m^3

dV = vapor density, kg/m^3

k = 0.107 m/s (when the drum includes a de-entraining mesh pad)

Then A, the cross-sectional area of the drum, in m^2 = (vapor flow rate, in m^3/s)/(vapor velocity V, in m/s) and D, the drum diameter, in m = $(4\ A / 3.1416)^{0.5}$

The drum should have a vapor outlet at the top, liquid outlet at the bottom, and feed inlet at somewhat above the half-full level. At the vapor outlet, provide a de-entraining mesh pad within the drum such that the vapor must pass through that mesh before it can leave the drum. Depending upon how much liquid flow you expect, the liquid outlet line should probably have a level control valve. As for the mechanical design of the drum (i.e., materials of construction, wall thickness, corrosion allowance, etc.), use the same methodology as for any pressure vessel.

Mass transfer

Mass transfer was the net movement of mass from one location, usually meaning a stream, phase, fraction or component, to another. Mass transfer occurs in many processes, such as absorption, evaporation, adsorption, drying, precipitation, membrane filtration, and distillation. Mass transfer was used by different scientific disciplines for different processes and mechanisms. The phrase was commonly used in engineering for physical processes that involve diffusive and convective transport of chemical species within physical systems.

Mass transfer coefficient units

$(mol/s)/((m^2)\cdot(mol/m^3)) = m/s$

Transfer of material from one homogenous phase to another was considered as mass transfer, the operations are designed to reduce the concentration of a given component in one stream to increase the concentration on another stream. The driving force for the transfer of material was a pressure or concentration gradient. The separation operations are sometimes identified as equilibrium phase separations or equilibrium contact separations, because the transfer of a component cease when equilibrium conditions prevail. Mass transfer prevails in Liquid to Gas phase as "Desorption", in which a gas was transferred out of the liquid phase to gas phase (Phanikumar *et al.*, 2009).

Outflow 'Brine disposal

Brine disposal was an environmental and economical issue in some areas where the fauna and flora are sensitive to local seawater salinity increase. Brine disposal was studied and engineered case by case. To limit the environmental impact of returning the brine to the ocean, it can be diluted with another stream of water entering the ocean, such as the outfall of a waste water treatment plant or power plant. While seawater power plant cooling water outfalls are not freshwater like waste water treatment plant outfalls, the salinity of the brine, still be reduced. If the power plant was medium to large-sized and the desalination plant was not enormous, the flow of the power plant's cooling water was likely to be at least several times larger than that of the desalination plant. Another method to reduce the increase in salinity was to spread the brine via a diffuser to mix in a mixing zone so that there was only a slight increase in salinity. For example, once the pipeline containing the brine reaches the sea floor, it can split off into many branches, each one releasing the brine gradually along its length through small holes. This method was used in combination with the joining of the brine with power plant or waste water plant outfalls. Because the brine was denser than the surrounding sea water due to the higher solute concentration, discharge into water bodies means that the ecosystems on the bed of the water body are most at risk because the brine sinks and remains there long enough to damage the ecosystems. The brine contains more than double of the normal sea water salt concentration. Usually it was disposed deep in the sea water to avoid as much as possible the fauna and flora damage close to the coasts. The process was much expensive. The option of diluting the brine with the sea water already in the flow and dispose in the surface water close to the sea to reach a similar concentration of the sea water

Material protection

Within desalination installations, there was a course environment when it comes to corrosion of separate parts of the system. Because of this, the material needs to possess a certain resistance to corrosion. This goes for external parts, which are exposed to a salty atmosphere (spillage, leaks), as well as for internal parts. Corrosion of external system parts can usually be prevented by providing them with a surface layer (painting, galvanizing) and by periodic maintenance of the system and closing of leaks. Despite the fact that materials are protected against potential corrosion, they also need to be able to be resistant to pressure, vibrations and changing temperatures. To prevent corrosion and chemical reactions in the part of the system high-pressure parts (10-70 bar), such as pumps, flash chambers, condensers, drains and lids, one needs to use metals to provide them with the same kind of protection. PVC and some metals cannot sufficiently resist corrosion. When corrosion protection was in order, the main material that was used for high-pressure parts was stainless steel. The benefit of stainless steel was resistant to corrosion and erosion. Stainless steel was rarely stricken by galvanic corrosion.

Benefits of desalination

- Reliable fresh water supply
- Affordable cost
- High energy efficiency
- Low environmental impact
- Water for Food, Water for Industry, Water for Life

Conclusions

As the overall concern for the environment and the need for the safe disposal of effluents, a strategic approach evolving potential methodologies for effectively utilize the available energy that would otherwise consume enormous amount of combustion is necessary. Thus the energy which goes as waste is otherwise utilise as another form of resultant product by simple means of vessels which facilitates conversion of state with the use of machineries in this temperature de-salination. The low temperature thermal desalination method offers ideal scope for utilization of the already hot water which need not require pre-heating as the method of desalination utilizes the increased temperature in the flash vessel by mass transfer of liquid to gas and condensation of the steam. An emphasis was made for avoidance of purchase of raw water for all purposes and eliminates tapping of ground water with zero environmental pollution.

References

1. Bhausaheb L. Pangarkar, Sane MG, Saroj B. Parjane, Rajendra M. Abhang and Mahendra Guddad (2010) The Heat and Mass Transfer Phenomena in Vacuum Membrane Distillation for Desalination. International Journal of Chemical and Biological Engineering 3, 1.
2. Low Temperature Thermal Desalination Applications For Drinking Water (2010) National Institute of Ocean Technology, (Ministry of Earth Sciences), Velachery Tambaram Main Road, Narayanapuram, Chennai 600 100.
3. Metcalf and Eddy (2002) Waste water Engineering Treatment and Reuse, 4th edition, McGraw-Hill Science Engineering.
4. Phanikumar VS Sistla, Venkatesan G, Purnima Jalihal and Kathiroli S (2009) Low Temperature Thermal Desalination Plants, National Institute of Ocean Technology, Chennai, India, Proceedings of The Eighth ISOPE Ocean Mining Symposium Chennai, India, September 20-24.
5. Shanthi V and Gajendran N (2009) The impact of water pollution on the socio-economic status of the stakeholders of Ennore Creek, Bay of Bengal (India): Part I. *Indian Journal of Science and Technology*, 2(3), 66-79.
6. Yashpal Singh, Chief Environmental Officer (2007) The Ecology of Thermal Power, U.P. Pollution Control Board, PICUP Building, Vibhuti Khand, Gomti Nagar, Lucknow –INDIA.

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