International Journal of ChemTech Research
CODEN (USA): IJCRGG, ISSN: 0974-4290, ISSN(Online):2455-9555
Vol.10 No.14, pp 09-16, 2017

A Study of the Condenser in Nuclear Power Plants

*[1]S.Anandan, [2]R.Rajesh, [3]K. Ganesh

[1]Phd Scholar (NIU), Scientific Officer, Kudankulam Nuclear Power Project,
[2]HOD, Mechanical Engineering Dept. Noorul Islam University, Kumarak oil, India.
[3]Global Business Services-Global Delivery,IBM India Private Limited,IL & FS Financial Center, Bandra East, Mumbai 40051, India.

Abstract : Energy is the master of Every Nation. Either it may be the Electrical Energy or any other means of Energy, the energy makes the nation pride and also increase the nation in global standard.

"Energy neither created nor destroyed; it can be change from one form to another".

The law of conservation of energy is says this. It also seems that energy which a body possesses by virtue of being in motion is said to be the kinetic energy. And in the same time, the energy possessed by a body by virtue of its position relative to others, stresses within itself, electric charge, and other factors are called Potential energy. In Nuclear Power stations the condenser is the machine which will transfer the heat from shell side to tube side. This condenser increases the efficiency of the machine. Here in this article the function of condenser and condenser tubes, the properties which affect the performance of this system and how to increase the efficiency of the machine has been discussed.

Keywords : Energy, Moisture, Condenser.

Introduction:-

In the Nuclear Power station the steam is produced in the steam generator. And the High pressure and high Temperature steam about 60 KG Pressure and 278 degree Temperature is passing to the High Pressure Turbine and rotate the turbine and then it comes out from the last stage Blades of the HP side with loss of its pressure and temperature. This steam again heated up and moisture has been removed by the Moisture separator and re heater system and allows to passes the Low pressure turbine blades. After the LP turbine last stage, the exhaust steam condensate at the condenser by maintaining the vacuum to optimize the efficiency of the system. The water collected in Hot well and from there it pumped to dearator where storage the condensate and there the gases and dissolved oxygen have been removed. From dearator the hot water have been make up to Steam Generator. In this cycle the Condenser is the main equipment which converts the steam to water by cooling media of sea water. Thus the efficiency of the condenser becomes the main important of the system. This article describe the function of the condenser, condenser tubes, tube materials, cleaning of condenser tubes etc.,

Functions:-

The **Condenser** has two major functions:

- Condense and recover the steam that passes through the turbine (Condensers are used in all power plants that use steam as the driving force)
- Maintain a vacuum to optimize the efficiency of the turbine.

The **Condenser Support Systems** have the following functions:

- Clean the condenser tubes
- Maintain the water level in the condenser so that efficiency is not degraded.
- Maintain condenser vacuum

Major Components

Condenser

There is usually one condenser for each low pressure turbine. The condenser has thousands of small tubes that are made out of admiralty metal, copper, stainless steel, or titanium. The condenser is simply a large heat exchanger with tubes usually horizontally mounted. The tubes may be supported (or staked)

The condenser has thousands of small tubes. On-line cleaning systems inject small balls during operation. Periodically, the tubes must be cleaned manually. During outages, the condenser tubes may be non-destructively tested to determine if wear is occurring. Tube leakage cannot be tolerated because the chemicals,

The water from the circulating water system enters the condenser in a water box. The level in the water box must be maintained above the level of the uppermost tubes, otherwise the condenser will not be efficient. Generally the colder the circulating water, the more efficient the plant is. Power plants become less efficient when either the condenser tubes are fouled, e.g. by mud, plugging, or accumulation of other materials that reduce the ability to transfer heat from the steam to the water.

A condenser may heat the circulating water passing through as much as 40 degrees Fahrenheit.

The tubes are generally kept clean by a tube cleaning system that injects small abrasive sponge-like balls. In some cases, the power plant may have to reduce load so that the tubes can be cleaned manually.

Vacuum in the condenser is maintained by either a mechanical vacuum pump or steam driven air ejectors that suck gases (not steam) from the condenser.

The water boxes are kept full using a air ejector or other system that keeps water level in the column from the water box as high as needed - above the tubes.

On the steam side of the condenser, the water collects at the bottom in a hot well that provides the water source for the suction of the condensate pumps.

Steam Cycle

A steam cycle power plant is operated using the Rankine cycle. Water enters a boiler where it is heated to create steam. The steam is then sent through a steam turbine that rotates the shaft of a generator to create electricity. The steam exits the turbine into a condenser, which converts the steam back into saturated water. The saturated water is then pumped back into the boiler to repeat the process.

A Model of Nuclear generating plant turbine.

It seems that in the Rankine cycle, the steam is first cooled down so that it condenses into liquid water and then is heated back up to create steam. This is done because liquid requires much less energy to move than vapor. Because pumps are much more efficient than compressors, the energy consumed by a pump to move the liquid water is negligible compared to the overall amount of energy produced by the system.

There are many extra components that are added to the basic system which are used to improve the cycle's efficiency. Some of these components include: reheaters, moisture separators, and feed water heaters. With reheaters, the steam coming out of the high pressure turbine is rerouted back to the boiler to be heated again before being routed through subsequent lower pressure turbines. This requires a minimal amount of additional heat while providing extra power through the low pressure turbines. Water droplets in the steam can cause damage to the turbine blades. Moisture separators take the wet steam and, as it passes through, filter out the water droplets so that dry steam comes out. Feed water heaters are essentially heat exchangers and it comes in a couple main designs, open and closed. A portion of the steam is taken after the high pressure turbine and routed to the feed water heater where it is used to heat the post-condenser water stream before it is sent to the boiler. This reduces the amount of heat needed from the boiler to produce the required temperature and pressure of the steam going to the turbines

Nuclear Power Plant:-

Nuclear power plants use several different types of reactor designs in order to provide heat input to a Rankine cycle. The two most commonly used reactor designs used are the Pressurized Heavy Water Reactor (PHWR), Boiling Water Reactor (BWR) and the Pressurized Water Reactor (PWR).

PWR uses nuclear fission to create heat that is used to raise the temperature of a water loop. The water loop is kept at a very high pressure so that it can be heated to high temperatures without boiling. The pressurized water is then run through a heat exchanger where it heats a second water loop. This second loop is not pressurized to as high a pressure so that it turns into superheated steam.

Several other types of nuclear reactors, including Gas-Cooled Reactors, Pressurized Heavy Water Reactors, Fast Neutron Reactors, and Light Water Graphite Reactors, are used primarily in other countries or under development and some of its operation.

Feed water System

In Feed water system the water that is circulated through the steam cycle as it comes out of the condenser and collected in Hot well. Then this water sent into the Dearater. In the Dearater the dissolved Oxygen has been removed and sent to Stem Generator. Feed water heaters are used preheat the water in order to decrease the heating time in the boiler and increase the plant's overall efficiency. In large power plants, the water that exits the condenser is sent through a series of feed water heaters. The tanks are heated by steam from the turbine. Each stage of the heating process in the turbine produces steam of a specific temperature that is used to preheat the feed water for that stage. The feed water heater closest to the boiler receives steam from the high-pressure turbine.

Efficiency

The efficiency of the simple steam cycle is generally lower than for other cycles such as the combined cycle. This is mainly due to the fact that not all the heat can be harnessed or completely used after the steam is sent through the steam turbines. This loss is dictated by the laws of thermodynamics and limits the efficiency of the system. The efficiency is set, in part, by the maximum temperature that the steam attains and the minimum temperature that can be used to cool the steam in the condenser.

The main source of the heat rejection occurs in the condenser where the excess thermal energy is discharged to the environment in the form of heat. In order to attain the required amount of power from the system, the turbines and the steam temperatures and pressure must be properly designed in order to work together properly and efficiently. However, there is still extra thermal energy in the liquid-vapor mixture at the exhaust of the low pressure turbines that is not useable due to the moisture content that would damage any more turbines without being reheated significantly. Carnot's theorem also shows that there is some inefficiency in the turbines which is based off of the ratio of cold to hot temperatures in the cycle. This ratio is why there are always inefficiencies in a system. This inefficiency in a steam turbine comes in the form of the extra steam at the turbine exhaust.

The efficiency of the steam turbine power plant depends on the type of fuel used in the boiler. The efficiency of coal-powered plants ranges from 32–42% depending on the pressure and temperature of the steam. The efficiency of advanced coal generation plants, however, can approach 50%. Nuclear generating plants with PWR and BWR reactors usually average 30–35% efficiency. Nuclear generating plants have the capacity to achieve even higher efficiency levels, but are limited by the maximum temperatures allowed in the core, thus limiting efficiency.

Outages

Planned outages are a time where the power plant is shut down in order to check, repair, and replace equipment. During outages at nuclear power plants, for example, operators can replace used fuel assemblies.

They must inspect specific parts of each component in a power plant before restarting the plant operations. Outages are usually scheduled in the spring or fall when electrical demand is the lowest

The casing of a multistage turbine must be removed in order to inspect each turbine blade for possible corrosion, erosion, and cracks. Methods of turbine blade inspection include visual, magnetic particle, and sometimes ultrasonic inspections. To conduct a magnetic particle inspection, engineers magnetize the turbine and spray on a solution to reveal microscopic cracks, metal fatigue, or any other damage to the blades.

The other factors which will affect the condenser efficiencies are the Physical, Mechanical, and Chemical Properties.

To avoid and minimize these effects the materials which selected for condenser and condenser tube is necessary. In the early days the condenser tube material used are like brass, aluminum, copper and its alloys. In recent years the Titanium is the one material which will increase the efficiency of the system. The Titanium is having greater Physical, Mechanical and Chemical Properties to compare with the above said materials. Titanium is less weight, having high corrosion resistance, less friction and wear resistance. In this paper the combination of Friction and Wear resistance has been taken as a sample experiments.

For checking the Friction and Wear Resistance the Pin on Disc Machine has been used. The specification of the Pin on Disc Machine is as follows:-

Specification:-

1. Speed = 480 rpm
2. Normal load = 5-30N
3. Frictional force = 0 to 30N

Least count: 0.1N

Accuracy: (0.1 +/- 2% Measured F.F) in N.

4. Wear = +/- 2 mm

Least count: 1 Micron.

Accuracy (1+/-0.25% Measured Wear) Mic.

Pulley ratio for speed = 1:3.

5. Wear tract diameter = 50-80 mm.
6. Specification size (pin) = 6 mm
7. Wear Disc Size = Dia 100 mm.
8. Thickness = 6-8mm.

TABLES:-

Table: 1. Frictional Forces and Wear Resistance:

Material & Test No	Wear In Microns	Frictional force (N)	Coefficient of friction
BS	1650	3.2	0.32
AL	1220	6.1	0.61
Ti	385	9.2	0.92

Table:2. Load, Specimen and Volume Loss details:

Cof Load	Specimen			Volulme loss in mm3	Scar dia in mm		
	In wt gm	F in wt gm	Wt loss in gm		Maj dia	Min dia	Average scar dia
Bs= 3.2	7.388	7.199	0.189	22.2	6	6	6
Al=6.1	2.378	2.344	0.034	8.5	5.35	5.11	5.23
Ti= 4.51	7.455	7.4350	0.02	4.43	5.1	5.1	5.12

Following calculation made based on the density of the Materials:-

The Density of Brass : 8.7 gm/cm3

The Density of Al : 3.98 gm/cm3

The Density of Ti : 4.51 gm/cm3.

Weight Loss calculations:-

Volume loss = Mass Loss/ Density of Pin.

FIGURES:-

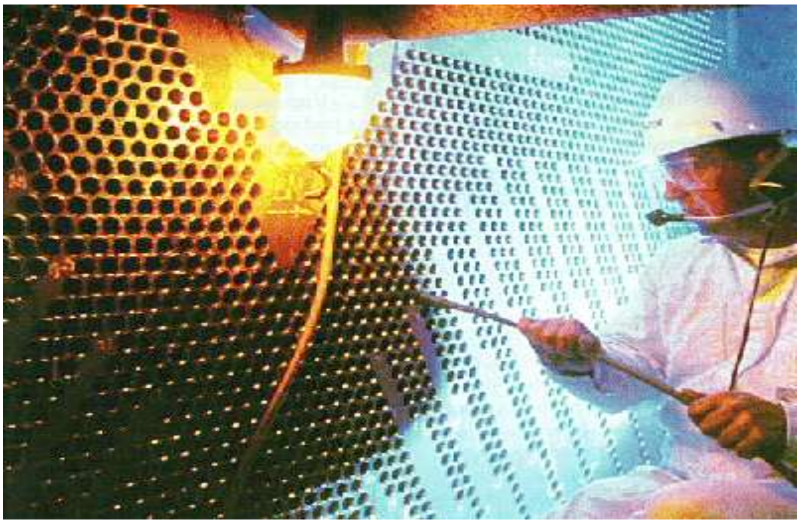

Figure 1. Condenser cleaning work

A probe that might be used to inspect the condenser tubes for defects, thinning, wear, corrosion is illustrated below:

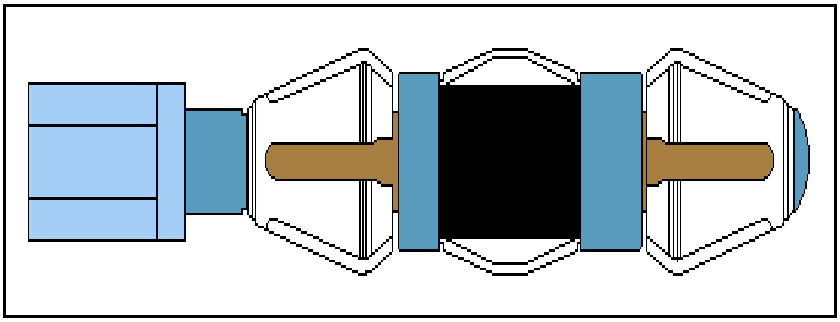

Figure 2. Condenser cleaning (Ball cleaning method) Instrument

Figure 3. A Model of Nuclear generating plant turbine.

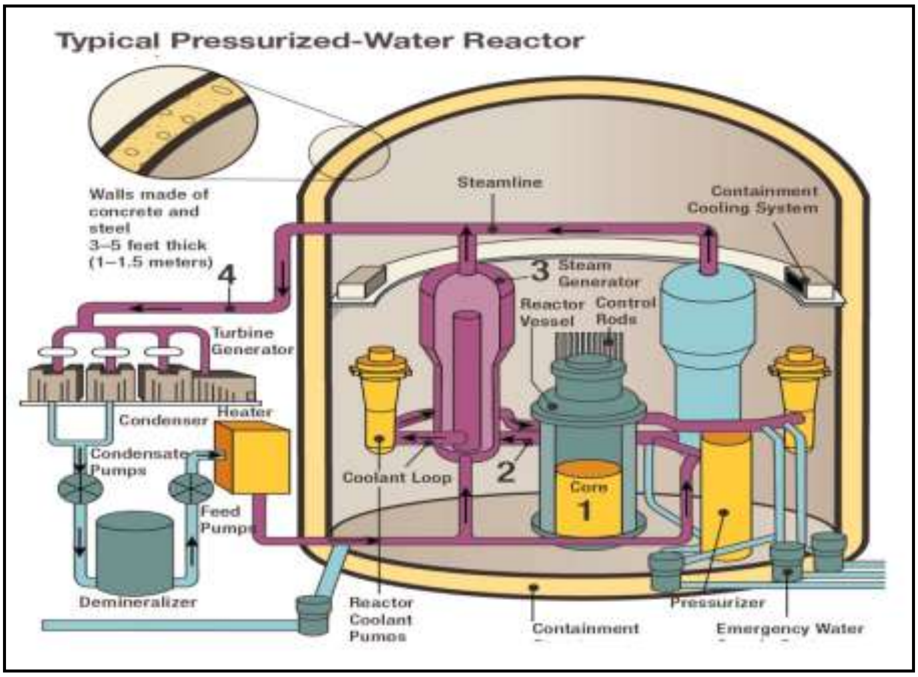

Figure 4. PRW Reactor

Figure 5. Pin on Disc Machine

Figure 6.Erection of Turbine

Conclusion:-

From the above it is easy to understand the function of the Nuclear Power Station, How the condenser and condensate system works, factor affecting the condenser system and also how to increase the efficiency of the system and from the article the final conclusion of this study we observe that the material selection is the main criteria to increase the efficiency of the system.

The following Observation made:-

The Titanium is having minimum Wear and Friction forces,

The Titanium is less weight,

The Titanium is anti corrosion property.

Finally the Titaniuim Grade 2 Material which is being used in Nuclear Power Plants is best suitable material for condenser tubes.

References:-

1. 1.F.M.Kustas, M.S.Misra, Friction and wear of titanium alloys, ASM Handbook. Friction, Lubrication, and wear Technology.18.ASM International, 1992, pp.778-784.
2. 2.G.W.Rowe, Friction, Wear and Lubrication, Terms and definitions, Organization for Economic Cooperation and Development, Birmingham, Gt. Britain, 1966.
3. R.B.Waterhouse, A.Iwabuchi, The effect of ion implantation on the fretting wear of four titanium alloys at temparatures p to 600 degree C, in Proceedings of the International Conference on wear of Materials, ASME, New York, 1985, pp.471-484.
4. Vaishal J. Banker, Jitendra M. Mistry, Wear mode in Inconel Alloys-A literature study. Proceedings of the Advance materials and Product Design 2015. ISSN No. 978-935196-3: 141-147.
5. Chandra Mouli, K.V.V. Srinivas, J & Subbaiah, K.V.Optimisation and Output Forecasting using Ta;guchi0Neural Network Approach IE(I) Journal –PR Vol 86, 2006.
6. Emal Kuram, Babur Ozcelik, Multi-objective optimization using Taguchi based grey relational analysis for micro-milling of A1 7075 material with ball nose and mill. Measurement 2013; 46; 1849-1864.
7. Gerd Lütjering, James C. Williams. Titanium. 2nd edition, Springer, 2007
8. Blau, P.J. (1992). "Friction, Lubrication, and Wear Technology" ASM Handbook 10th edition, ASM International, Materials Park, OH.

*****