INTERNATIONAL JOURNAL OF RESEARCH IN AERONAUTICAL AND MECHANICAL ENGINEERING

ISSN (ONLINE): 2321-3051

Vol.3 Issue 10,

October 2015

Pgs: 1-8

A Review of Literature on Air Cooled Steam Condenser (A Heat exchanger used in Steam Power Plant)

[1]Parag Mishra, [2]Dr Manoj Arya

[1]Department of Mechanical Engineering, Radharaman Institute of Research & Technology, Bhopal, MP, India. E mail- parag.mishra05@gmail.com

[2]Department of Mechanical Engineering, MANIT Bhopal, MP, India. E mail: manojarya123@gmail.com

Abstract

Water demand from thermal power plants, mainly for steam condensation (power plant cooling) can place a significant burden on limited local and regional freshwater supplies. An approach to reducing this cooling water demand is the use of direct dry cooling, which requires no consumptive water use and can reduce a power plants water demand by up to95 percent. Direct dry cooling uses air-cooled steam condensers which consist of a series of finned, air-cooled condenser tubes arranged in an A-frame configuration. Steam is routed from the steam turbine to the condenser, where the heat from the condensing steam is rejected to the environment via the finned tubes. Beneath these condenser tubes is an array of fans, which force a stream of air through the condenser. A major limitation to using this cooling technology is that air-cooled steam condensers are unable to maintain their performance during very hot and/or windy periods. This directly affects energy production because a reduction in condenser performance creates backpressure on the steam turbine and reduces electricity generation. Growing demand for water for both domestic and industrial use has brought an increased interest in use of Air Cooled condensers. A steam condenser is a heat exchanger that converts steam from its gaseous state into liquid form by operating at a pressure lower than that of the surrounding atmosphere. Steam condensers are used in various industries, with key sectors including: Power sector, Refineries, Marine and Chemical processing.

In the power sector, steam is used to generate electricity. Oil, coal, gas, nuclear, biomass, and solar thermal power generation methods all use steam to create energy. A steam turbine is used for generating mechanical power in a rotary motion, and is powered by the extraction of thermal energy from pressurized steam, which is produced from water or other liquids. Steam power plants across the globe operate on the standard known as the Rankine Cycle. This cycle consists of four main components: boiler, turbine, steam condenser, and pump. In a simple steam turbine based power plant, water enters a pump, where it is compressed at high pressure – step one in figure three – and then this compressed water passes through the boiler, as can be seen in step two. In the boiler, water is heated by burning fuel, and is converted into steam. This superheated, highly pressurized steam then enters the steam turbine, where it expands to rotate the turbine shaft, thereby generating electricity (step three). Steam from the turbine then enters the steam condenser, where it is condensed back into water (step four). This saturated water then enters the pump to restart the cycle. Steam condensers are also used in Integrated Gasification Combined Cycle (IGCC) and Combined Cycle Gas Turbine (CCGT) power plants that use steam turbines, to reuse the water in the cycle.

1. Introduction

The different types of systems and components used in steam power plant are as follows :

(i) High pressure boiler
(ii) Prime mover
(iii) **Condenser**
(iv) Coal handling system
(v) Ash and dust handling system
(vi) Draught system
(vii) Feed water purification plant
(viii) Pumping system
(ix) Air pre heater, economizer, super heater, feed heaters

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 drives an electrical generator. After it passes through the turbine, the steam is condensed in a condenser and recycled to where it was heated; this is known as a Rankine cycle.Steam is generated in the boiler of the thermal power plant using heat of the fuel burnt in the combustion chamber. The steam generated is passed through steam turbine where part of its thermal energy is converted into mechanical energy which is further used for generating electric power. The steam coming out of the steam turbine is condensed in the condenser and the condensate is supplied back to the boiler with the help of the feed pump and the cycle is repeated. The function of the Boiler is to generate steam. The function of the condenser is to condense the steam coming out of the low pressure turbine. The function of the steam turbine is to convert heat energy into mechanical energy. The function of the condenser is to increase the pressure of the condensate from the condenser pressure to the boiler pressure. The other components like economizer, super heater, air heater and feed water heaters are used in the primary circuit to increase the overall efficiency of the

Condenser: The use of a condenser in a power plant is to improve the efficiency of the power plant by decreasing the exhaust pressure of the steam below atmosphere. Another advantage of the condenser is that the steam condensed may be recovered to provide a source of good pure feed water to the boiler an reduce the water softening capacity to a considerable extent. A condenser is one of the essential components of a power plant. A condenser is a heat transfer device or unit used to condense a substance from its gaseous to its liquid state, typically by cooling it. In doing so, the latent heat is given up by the substance, and will transfer to the condenser coolant. Condensers are typically heat exchangers which have various designs and come in many sizes ranging from rather small (hand-held) to very large industrial-scale units used in plant processes. For example, a refrigerator uses a Condenser to get rid of heat extracted from the interior of the unit to the outside air. Condensers are used in air conditioning, industrial chemical processes .Such as distillation, steam power plants and other heat-exchange systems. Use of cooling water or surrounding air as the coolant is common in many condensers. The main use of a condenser is to receive exhausted steam from a steam engine or turbine and condense the steam. The benefit being that the energy which would be exhausted to the atmosphere is utilized .A steam condenser generally condenses the steam to a pressure significantly below atmospheric. This allows the turbine or engine to do more work. The condenser also converts the discharge steam back to feed water which is returned to the steam generator or boiler. In the condenser the latent heat of condensation is conducted to the cooling medium flowing through the cooling tubes.

CONDENSERS USED IN POWERPLANT:

1. Water Cooled Steam Condenser
2. Air Cooled Condenser

1. STEAM CONDENSER OR WATER COOLED CONDENSER: It is a device or an appliance in which steam condenses and heat released by steam is absorbed by water. A steam condenser is a device which condenses the steam at the exhaust of turbine. It serves two important functions. Firstly, it creates a very low pressure at the exhaust of turbine, thus permitting expansion of the steam in the prime mover to very low pressure. This helps converting heat energy of steam into mechanical energy in the prime mover. Secondly, the condensed steam can be used as feed water to the boiler.

There are two principal types of Steam Condensers

a) Jet condensers

b) Surface condenser

a) Jet condensers: In a jet condenser, cooling water and exhausted steam are together. Therefore, the temperature of cooling water and condensate is the same when leaving the condenser. Advantages of this type of condenser are low initial cost, less flow area required, less cooling water required and low maintenance charges. However its disadvantage is condensate is wasted and high power is required for pumping water.

b) Surface condenser: In a surface condenser, there is no direct contact between cooling water and exhausted steam. It consists of a bank of horizontal tubes enclosed in a cast iron shell. The cooling water flows through the tubes and exhausted steam over the surface of the tubes. The steam gives up its heat to water and is itself condensed. Advantage of this type of condenser are : condensate can be used as feed water, less pumping power required and creation of better vacuum at the turbine exhaust. However, disadvantage of this type of condenser are high initial cost, requires large floor area and high maintenance charges. The surface condenser is used for the majority of steam engine & steam turbine applications.

2. AIR COOLED CONDENSER: An Air cooled condenser, is simply a pressure vessel which cools a circulating fluid within finned tubes by forcing ambient air over the exterior of the tubes. A common example of an Air cooled condenser is car radiator Air cooled heat exchangers are used for two primary reasons. i. They increase plant efficiency ii. They are a good solution as compared to cooling towers and shell and tube heat exchangers because they do not require an auxiliary water supply (water lost due to drift and evaporation, plus no water treatment chemicals are required). An air-cooled heat exchanger can be as small as your car radiator or large enough to cover several acres of land, as is the case on air coolers for large power plants the air-cooled heat exchangers are mostly used when the plant location and the ambient Conditions do not allow an easy and economic use of other cooling systems The most evident advantages of air-cooled Condensers are:

a) No problem arising from thermal and chemical pollution of cooling fluids
b) Flexibility for any plant location and plot plan arrangement because equipment requiring cooling need not be near a supply of cooling water.

c) Reduction of maintenance costs
d) Easy installation

e) Lower environmental impact than water cooled condenser due to the elimination of an auxiliary water supply resulting in water saving

f) No use of water treatment chemicals and no need for fire protection system.

Air-cooled finned-tube condensers are widely used in refrigeration and air-conditioning applications. For the same amount of heat transfer, the operation of air cooled condensers is more economic as compared with water cooled condensers typically air-cooled condensers are of the round tube and fin type. To improve the performance of air-cooled condensers multiple techniques can be achieved such as enhancements on inner pipe surface, changing the tube geometry from round to flat shape and external fins.

Air-cooled steam condensers are increasingly employed to reject heat in modern power plants.Air-cooled condensers (ACCs) use ambient air to cool and condense a process fluid. Mechanical draft ACCs are used extensively in the chemical and process industries and are finding increasing application in the global electric power producing industry due to economic and environmental considerations. The generation of electric power is traditionally a water intensive activity, and with the sustainability of fresh water resources becoming a major concern in many parts of the world, there is increasing pressure on this industry to find ways to reduce their fresh water consumption. Modern thermoelectric power plants with steam turbines are equipped with a cooling system to condense the turbine exhaust steam and maintain a certain turbine exhaust pressure (often referred to as turbine backpressure) in a closed cycle Mechanical draft air-cooled steam condensers (ACSCs) consisting of multiple fan units are used in direct cooled thermoelectric power plants to condense steam in a closed cycle using ambient air as the cooling medium . No water is directly consumed in the cooling process and as such the total fresh water consumption of a power plant with an ACSC is significantly less than one employing wet cooling. There are a number of advantages over and above water consumption reduction, such as increased plant site flexibility and shortened licensing periods, associated with the use of ACSCs.
In a direct cooled steam turbine cycle with an ACSC, low pressure steam is ducted from the turbine exhaust to steam headers that run along the apex of a number of ACSC fan units (also referred to as A-frame units or cells). A typical forced draft ACSC fan unit, consists of an axial flow fan located below a finned tube heat exchanger bundle. The steam condenses inside the finned tubes as a result of heat transfer to ambient air forced through the heat exchanger by the fan. The finned tubes are typically arranged in an A- frame configuration for cooling applications of this magnitude so as to maximize the available heat transfer surface area while keeping the ACSC footprint to a minimum. The inclined tube configuration also aids in the effective drainage of the condensate which is ultimately pumped back to the boiler , or heat recovery steam generator in the case of a combined-cycle plant, to complete the closed cycle. Steam condensers coupled to the exhaust of these turbines return condensate to the power cycle and boiler. Either surface-type or air-cooled condensers can be selected. The former have once-

through or recirculating water as the cooling medium, while the latter are once-through systems employing the atmosphere as the heat sink. Among the advantages of air-cooled steam condensers, compared with wet systems, are elimination of: makeup water supply, blow down disposal, water-freezing problems, water vapor plumes, and concerns over governmental water-pollution restrictions. Because of the dry nature of the equipment, lower system-maintenance costs also result.

Parts of Air Cooled Condenser

An air-cooled steam condenser system starts at the turbine exhaust flange. It includes all of the equipment necessary to condense the steam and return the condensate to the boiler feed water piping.

These items are:

1. Air-cooled steam condenser tower.
2. Air-flow control equipment.
3. Wind and/or cell-partition walls.
4. Steam-bypass heating system.
5. Air removal equipment.
6. Condensate storage tank.
7. Condensate pumps.
8. Steam ducts and expansion joints.
9. Condensate drain and air-removal piping.
10. Instrumentation controls and alarms.
11. Pressure-relief device for protection of steam-turbine exhaust casing.
12. Steam-duct condensate drain system.

The basic air-cooled steam condenser includes the bundles, steam distribution manifold, fans, motors, gear boxes and supporting steel. In large installations, the cost of the tower structure supporting the condenser bundles can be a substantial portion of the total cost. The structure's design specifications for wind load, snow load, live load and seismic requirements should be carefully chosen. Generally, grade-mounted towers cost less than roof-mounted ones.

Limitations on plan dimensions must be made clear in the inquiry specification. Heat sources located close to the proposed tower and discharging into the atmosphere must be identified. The prevailing wind directions define the proper location and orientation of the tower with respect to other large structures and heat sources. Summer winds are important in the consideration of thermal performance, and winter winds in prescribing freeze-protection measures. Noise limitations should also be stated, since lower fan noise generally requires lower tip speed, more fan blades and possibly wider blades.

The purchaser should specify whether the thermal performance guarantees are to be based on steam pressure measured at the turbine exhaust flange, or at the steam manifold inlet at the condenser. Other options are an all-welded system to reduce the potential for air leaks into the condenser, and the use of extruded aluminum fins , which provide longer trouble-free operation than embedded or wrap-on fins (these are prone to galvanic corrosion because of their bimetallic tube-to-fin interface).

Airflow control equipment for freeze protection, though an integral part of the engineered package supplied by the manufacturer, nevertheless reflects the purchaser's preferences and needs. Consideration should be given to variable-pitch fans, air-flow control louvers, steam isolating valves and two-speed motors. The extra price of electric starters needed for two-speed motors should be included.

Wind walls are sometimes necessary to protect the bundles from wind gusts that can upset equilibrium operating conditions and at times cause freezing in some remote parts of the tower. Partition walls between fan cells isolate operating cells from non operating ones. Without partition walls, a non operating fan would induce bypass of air intended for the bundles.

Depending upon the minimum design ambient-air temperature, the type of turbine, and the type of plant operation, it may be economic to provide a steam-bypass heating system for cold-weather startup. This would operate directly off the boiler, requiring both a steam pressure-reducing station and a de-superheating station, with steam flow exhausting directly into the main steam duct. Part of the condenser heating steam during startup would be supplied by the turbine exhaust, and the remainder from this bypass system. Alternatively, large steam-isolating valves can be installed, to supply condenser sections sequentially, with steam flows only from the turbine exhaust.

For the usual full-vacuum steam condenser, a two-stage operating ejector system complete with condensers is normally provided, with or without standby. Its capacity is generally specified by the purchaser in accord with the Heat Exchange Institute Standards for steam surface condensers. Some purchasers add a safety allowance by doubling the venting capacity recommended in the standard. Thc costliest parts of the ejector package arc the inter- and after-condensers, which are shell-and-tube construction. These can be smaller and lower-cost if a separate, colder, cooling-water supply is used instead of the hot condensate.

Motor-operated vacuum pumps can also be chosen; these adapt readily to automated remote operations. The purchaser's inquiry specification should establish, for the air removal package, these points: choice of steam-jet air ejector or motor-driven vacuum pump; motive steam pressure and temperature; hogging-ejector minimum operating time; evacuating capacity of operating ejector package (compared with Standards recommendation); standby requirements for
condensers and ejectors; and condenser cooling-water supply source and temperature.

The condensate storage tank is generally sized for a 5- to 10-min operating storage capacity. Total tank size exceeds this operating storage capacity by an amount representing the total condensate held in the drain pots and drain piping.

The condensate pumps are generally either two 100%-size units or three 50%-size units, to provide standby capability for emergency situations. The system generally has a very low net positive suction head availability so the pumps should be installed close to the condensate storage tank. The pump's total dynamic head must be sufficient to deliver the condensate into the purchaser's boiler feed water system.

The steam duct system (Item 8) connects the condenser inlet-steam manifold to the turbine exhaust flange. It includes expansion joints, anchor points, elbows, turning vanes and duct supports. The purchaser should specify the preferred corrosion allowance for the manifolds and steam ducts since this affects system cost.

The condensate drain piping and manifold system starts at the bottom of the bundles and ends at the condensate storage tank. The air-removal piping and manifold system starts at the top of the bundles and terminates at the steam-jet air ejector package. The instrumentation package includes such devices as temperature indicators and thermocouples; pressure indicators and transducers; vibration-pickup transducers; liquid-level devices; status lights; and recorders. The controls might include storage-tank condensate level; low-flow condensate pump bypass; fan pitch control; air louver control; steam-valve control; and fan-motor control. These controls can be computerized from startup to shutdown, to maximize the turbine's thermal efficiency and power output, minimize the auxiliary-fan power consumption, and protect the condenser from freezing.

In the event of complete electric-power failure to the steam-condenser fans, an atmospheric-relief diaphragm safety device should be installed in the turbine exhaust system, to protect the turbine exhaust hood from excessive steam pressure. This diaphragm generally ruptures and relieves at about 5 psi for turbines designed for full-vacuum service. Some turbine manufacturers provide such a device on the exhaust hood; if not, the purchaser can provide external protection by installing an atmospheric relief valve(s) in the exhaust steam duct close to the turbine.

Air Cooled Steam Condenser Photograph: Original Photograph by Parag

2. Objectives Of Literature Review

The main objective of this master thesis is to evaluate the use of Air Cooled Steam Condenser in Steam Power Plant

3. Conclusion

In Air Cooled Heat Exchanger, the main consumption of Auxiliary power are fans,motor & pumps. The outcome of this literature review is that, we can achieve power saving in Air Cooled Steam Condenser by fans, pumps, motor etc.

Bibliography

1. System and method for use in a combined cycle or rankine cycle power plant using an air-cooled steam condenser. Anil Kumar Sharma,Prakash Narayan,Shinoj Vakkavil June 2010.

2. Mechanism of the air temperature rise at the forced draught fan inlets in an air-cooled steam condenser .Weifeng He, Dong Han, Chen Yue, Wenhao Pu 5 October 2014

3. The effect of screens on air-cooled steam condenser performance under windy conditions M.T.F. Owen' , D.G. Kröger November 2010

4. An Investigation of Air-Cooled Steam Condenser Performance Under Windy Conditions Using Computational Fluid Dynamics M. T. F. Owen and D. G. Kröger 10 January 2013.

5. Air-cooled steam condenser Aleesandro Zanobini 1985

6 GEI Industrial systems limited

7. GEA Air-cooled Systems

8. SPX Cooling technologies

14 Amercool Manufacturing Inc.

15 Air Cooler Governing bodies

16. ASME code, Section VIII, Division 1

17 API661 standard for air-cooled heat exchangers

18.HTRI (Heat Transfer Research Institute)