Experimental Performance Analysis of Air-Cooled Condenser for Low Pressure Steam Condensation

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Abstract: *An experimental set up is made for an air-cooled condenser and observations are obtained at different air velocities. The comparisons are done between various quantities like pressure of steam, mass flow rate, velocity of air , and temperature difference of inlet steam and Outlet steam. It is found that mass flow rate of condensed steam decreases with decrease in pressure of Steam. It also decreases with decrease in Temperature difference. So the capacity of Air cooled condenser is sometimes limited by ambient conditions, but due to other problems concerned with reduced availability of water as the cooling medium for the condensation of exhaust steam, combined with an increased emphasis on environmental considerations. it is still a better alternative than traditional steam surface condenser.*

Keywords**:** *Heat transfer, Condenser, Air cooled condenser, Performance analysis, Low pressure condensation.*

I. Introduction

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.

II. Condensers Used In Power plant

1. **Water Cooled Condenser or Steam Condenser**
2. **Air Cooled Condenser**

2.1 Water Cooled Condenser (Steam 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.

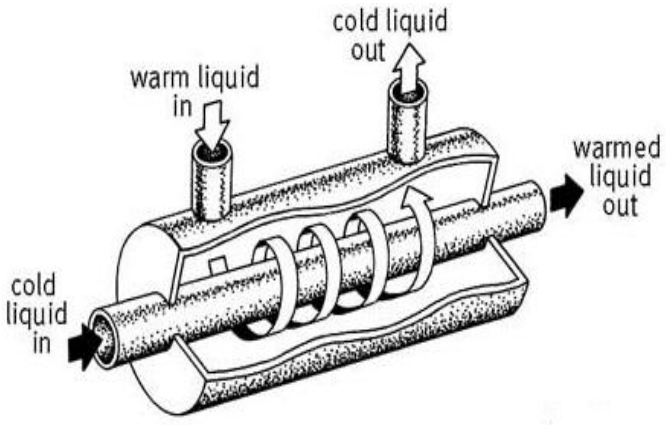

Fig 1.Water Cooled Condenser

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.

2.2 Air Cooled Condenser

Air Cooled condensers are largely in use today due to growing attention being paid to environmental safety. Also, growing demand for water for both domestic and industrial use has brought an increased interest in use of Air Cooled condensers.

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).

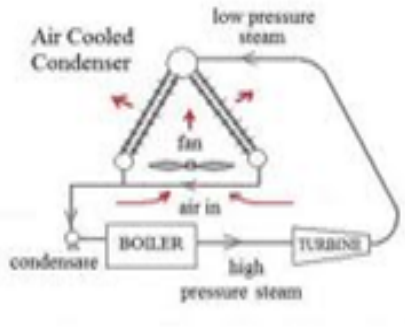

Fig 2.Basic Air Cooled Condenser cycle

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.

III. Literature Survey

[1] A Study was performed on Performance Characteristics of an Air-Cooled Condenser under Ambient Conditions in December 2011. In this study effects of air flow pattern as well as ambient conditions were studied. Unfortunately ACC becomes less effective under high ambient temperature and windy conditions. Fin cleaning plays a vital role in heat rejection. External cleaning improves air side heat transfer coefficient. Ambient conditions affect the steam temperature and heat rejection rate. It is observed that rise in wind velocity decreases thermal effectiveness of ACC up to considerable level. Ambient temperature not only affects performance of ACC at the same time turbine back pressure also increases with rise in ambient temperature. Skirts are effective solution to reduce the effect of wind on volumetric effectiveness. Hot air recirculation increases with wind velocity. Now a day's wind walls are used to reduce this effect. Second option is to increase fan speed. It counter affects on electrical power consumption.

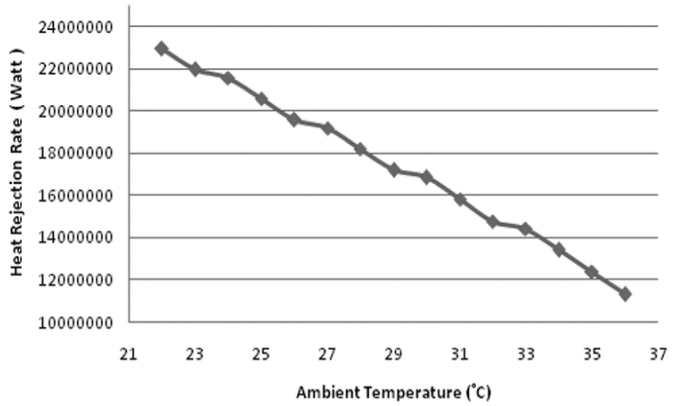

Fig. 3 Heat Rejection for various Ambient Temperatures (Courtesy:Nirma Institute of technology - NUiCONE – 2011)

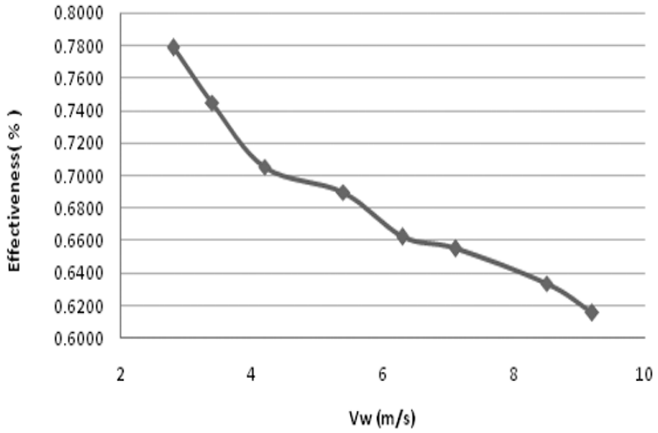

Fig4. Effectiveness at different Wind Velocities (Courtesy: Nirma Institute Of technology - NUiCONE – 2011)

[2] A study was performed to evaluate the performance characteristics of a power plant incorporating a steam turbine and a direct air-cooled dry/wet condenser operating at different ambient temperatures. The proposed cooling system uses existing A-frame air-cooled condenser (ACC) technology and through the introduction of a hybrid (dry/wet) dephlegmator achieves measurable enhancement in cooling performance when ambient temperatures are high. [3] In this study they found that air-conditioning system with air cooled condensers, the condensing unit has to be kept in open for easy access to outdoor air in order to efficiently dissipate heat, During Daytime the solar radiation falling on the surface of the condenser and high ambient temperature can be detrimental for the energy performance. They studied the effectiveness of shading the condensing unit to mitigate the adverse effect of high ambient temperatures due to solar radiation .and analyzed that the theoretical increase in COP due to shading is found to be within 2.5%. [4] Heat transfer by convection in air cooled condensers is studied and improved in this work. In order to enhance the performance of air cooled condensers, it is important to take into consideration both of condensation inside condenser tubes and convection outside, where the enhancement in convection side is the dominant one. Aluminum extruded micro-channel flat tubes improve the performance of condensation more than conventional circular tubes but still has potential for air side improving. So the enhancement of convective heat transfer in air side is achieved in this study by inclination of the flat tubes by a certain angle with respect to horizontal in two cases.

IV. Experimental Analysis

Fig. 5. Experimental set up

4.1 Experimental Setup

Experimental set up consist of –

4.1.1 Fan- Fan is used to provide ambient air to the steam flowing through the finned tube this air cools the steam and thus condenses it.

4.1.2 Steam Generator – Steam Generator is used to produce the steam required for Experimental purpose. A ISI marked pressure cooker is used for this purpose .A funnel & a valve is brazed at the Top of Pressure Cooker to start and stop the supply of water in it.also in another opening pipe is brazed to take out the steam to condenser.

4.1.3 Heater-A Heater is placed below the pressure cooker to heat the water and generate the steam required for experimental purpose.

4.1.4 Pressure Gauge- A Low-Pressure gauge is used to measure the pressure of generated steam in kg/cm2.

4.1.5 Ammeter – Ammeter is used to measure current in amperes.

4.1.6 Voltmeter –Voltmeter is used to measure current in amperes.

4.1.7 Dimmer Switch- A Dimmer Switch is used to regulate voltage and current

4.1.8 Thermocouple- A thermocouple consists of two conductors of different materials (usually metal alloys) that produce a voltage in the vicinity of the point where the two conductors are in contact. The voltage produced is dependent on, but not necessarily proportional to, the difference of temperature of the junction to other parts of those conductors. Thermocouples are a widely used type of temperature sensor for measurement and control and can also be used to convert a temperature gradient into electricity. They are inexpensive, interchangeable, are supplied with standard connectors, and can measure a wide range of temperatures. In contrast to most other methods of temperature measurement, thermocouples are self powered and require no external form of excitation. The main limitation with thermocouples is accuracy; system errors of less than one degree Celsius (C) can be difficult to achieve.

4.1.9 Temperature Indicator- Temperature indicator is a device used to indicate the temperature measured by the thermocouple wire.

4.1.10 Anemometer:-It is a device for measuring wind speed, and is a common weather station instrument. The term is derived from the Greek word anemos, meaning wind, and is used to describe any airspeed measurement instrument used in meteorology or aerodynamics. The first known description of an anemometer was given by Leon Battista Alberti around 1450.

4.1.11 Crimped Fin Tube- Crimped fin made of copper or aluminum. It is brazed over the tube to increase the rate of heat transfer.

The components that are available on the external surface of the bare tube to increase its surface area are called fins. Finned Tubes help better transfer of heat between the outside and inside of tube. With the usage of these tubes having surface area almost eight times of the outer tube, the length of the tube required to heat the viscous oil can be reduced by one sixth. Our Spiral Finned Tubes are popular because of their following advantages:

- High efficiency
- Excellent quality
- Smooth

4.1.12 Experimental Procedure- First of all water is poured in the pressure cooker through funnel brazed above it. The valve for entering water is then closed. Then the heater is switched on and water is allowed to heat. Steam is generated in the pressure cooker which is taken out by opening the valve on other side of cooker .steam is taken out through pipes and its pressure is noted with the help of pressure gauge. This steam enters into finned tube fixed inside the duct and cooled by running the fan at various air-velocities .various temperature readings are taken with the help of thermocouple. The condensed steam coming out of condenser is taken out in a wicker for certain time and mass flow rate is noted.

V. Results

The various quantities like velocities of air, pressure of steam, various temperatures including temperature of inlet steam to condenser and outlet steam from condenser, mass flow rate of condensed steam etc are noted and comparisons between various quantities are plotted.

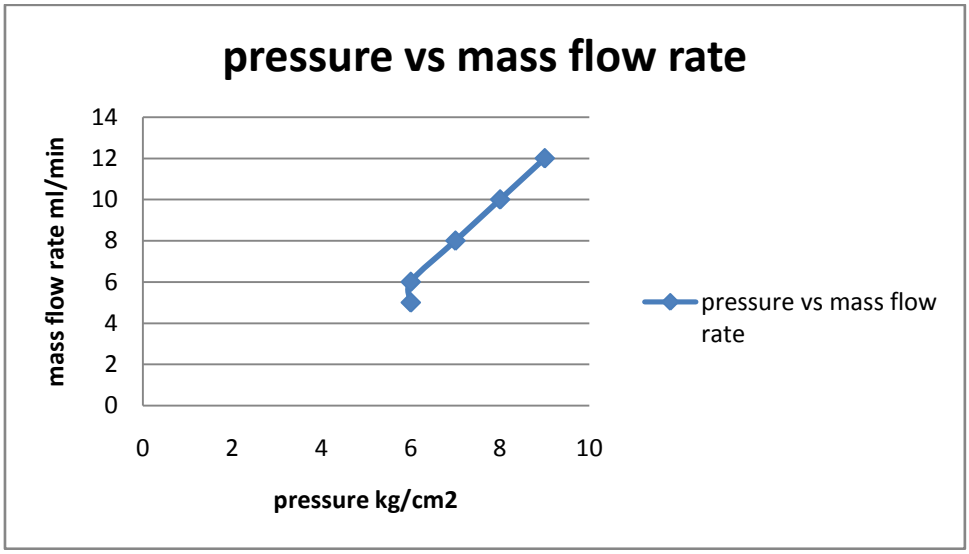

Fig-6 Pressure v/s mass flow rate

This comparison shows that mass flow rate of condensed steam decreases with decrease in pressure of inlet steam

5.1.2 Comparison between Temp Difference and Mass Flow Rate.

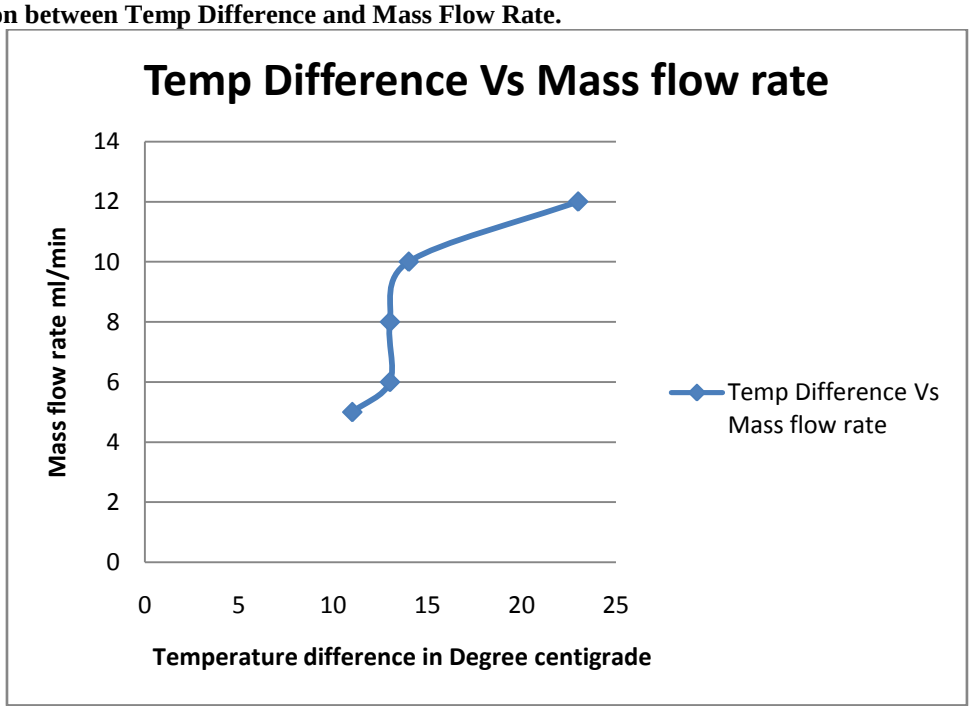

Fig-7 Temp. Difference v/s mass flow rate

This comparison shows that mass flow rate of condensed steam decreases with decrease in Temp. Difference of inlet & outlet steam

5.1.3 Comparison between Velocity and Temperature Difference

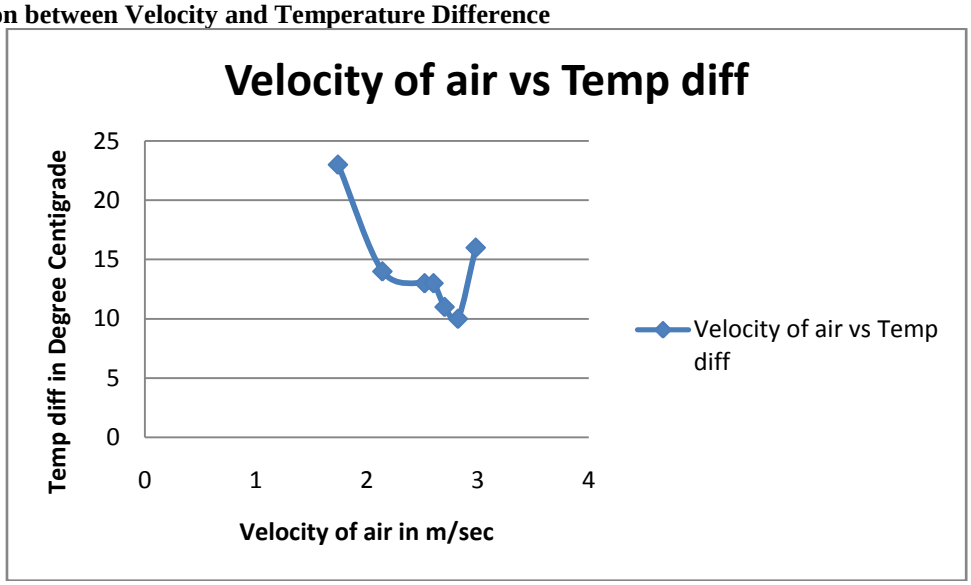

Fig-8 Velocity of air v/sTemp. Difference

5.1.4 Comparison between Pressure and Temperature Difference.

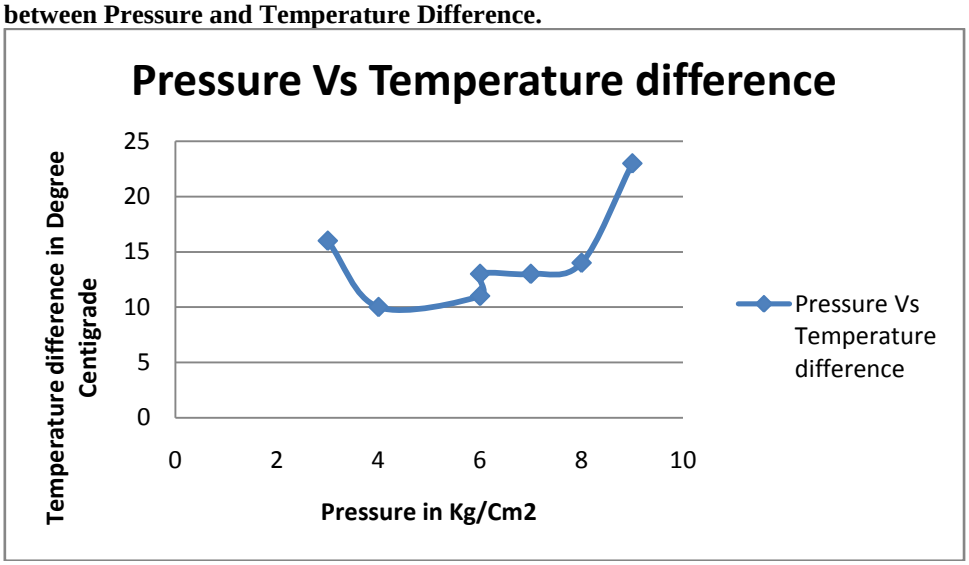

Fig- 9 Pressure V/s Temperature .Difference

VI. Conclusion

It is found that mass flow rate of condensed steam decreases with decrease in pressure of Steam. It also decreases with decrease in Temperature difference of inlet steam and outlet steam of condenser. Although the capacity of Air cooled condenser is sometimes limited by ambient conditions, their selection can avoid a number of other problems concerned with reduced availability of water as the cooling medium for the condensation of exhaust steam, combined with an increased emphasis on environmental considerations. This often makes the selection of an air-cooled condenser a viable alternative to the traditional steam surface condenser.

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