# DESIGN AND ANALYSIS OF AIR COOLED CONDENSER BY USING COPPER AND ALUMINIUM TUBES

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**ABSTRACT**

*Heat exchanger is been used even since from 19$^{th}$ century. It is used to transfer heat by mode of Convection. It is been used in a various fields like power plant, steel plants, oil refineries to reduce the temperature of working fluid & to take condensate out from hot steam. In our project we have chosen Aluminum and Copper tubes a forced draft cooling system with a header boxes & tubes .We are about to use two types of tubes for our project. Theoretical calculation of heat transfer co-efficient for Al & Cu tubes will be calculated & compared with experimental values. Cost effectiveness and heat transfer wise the best one will be found. In our project we have chosen a forced convection mode to cool the working fluid. Material selection of tubes plays a vital role in heat transfer rate. Some of the commonly used material for tubes are Copper, Aluminum, Stainless Steel, Duplex. In our project we have selected Copper and Aluminum tubes for study. We have built an experimental set-up with a header box , copper and aluminium tubes , and a fan. All the parameters are needed to calculate heat transfer rate is been analyzed and noted down.*

*Key Words: Heat exchanger, Aluminum and Copper, heat transfer, cooling system, convection*

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## INTRODUCTION

### 1.1 AIR COOLED CONDENSER

The production of electricity requires a reliable, abundant, and predictable source of freshwater. A resource that is limited throughout the world. The process of power generation from fossil fuels such as coal, oil, and natural gas is water intensive. In a country where hardly any city gets 24-hour supply of drinking water .The per capita water availability is shrinking at an incredible pace Water levels of India's dams are falling to record lows Agriculture draws approximately 90% of domestic water .

It is inevitable that India will be water stressed not in the medium term but in the immediate short term. With the present population of over 1,200 million, the per capita water availability is around 1.170 m3/person/year. This translates to 1170 litres/person/per year or less than 3 liters per day per person. The urban area consumption is in upwards of 100-150 liters per day. The water requirement for coal based plant with cooling tower used to be about 7 m3/h per MW without ash water recirculation and 5 m3/h per MW with ash water recirculation.

In recent past, plants have been designed with water consumption requirement in the range 3.5 -4 m3/h per MW. This is important for a country like India, which has about 16% of the world's population as compared to only 4 per cent of its water resources. An installed capacity of 130,370 MW of thermal power plants if assumed running even at 75% PLF would consume over 30 bcm of water.

So an altunate system is apporched for cooling system that is come out of the low pressure turbine. The condensate that can be pumped back in the boiler.

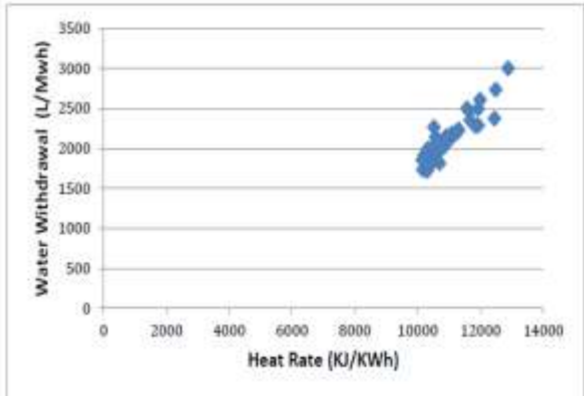


Figure 1.1 Water consumption Vs Power Generation Technology

**1.2ALTERNATIVE COOLING SYSTEMS**
**1.2.1 Direct Dry Cooling Systems.**

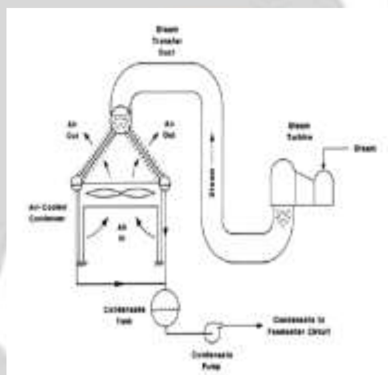

Figure 1.2 Direct dry cooling system

In a steam turbine, ultra-pure water in the form of superheated steam is the main component in driving the turbine and generator to create electricity. Like any significant input to a process, maximizing the efficiency of usage of the primary inputs is key to driving down not only the operational cost of the process but also reducing the environmental footprint of the process. This is particularly applicable in the case of water as it is a scarce commodity.

In the direct cooling system, steam from the final stage turbine blades is channeled directly into radiator-type heat exchangers. The direct cooling system has no cooling towers. The heat is conducted from the steam to the metal of the heat exchanger. Air passing through the exchanger is supplied by a number of electrically driven fans. The air removes the heat, thus condensing the steam back into water which will be used once again to produce steam in the boiler.

**THERMAL RATING OF AIR COOLED CONDENSER BY USING COPPER AND ALUMINIUM FIN TUBES**

**3.1 3D MODEL**

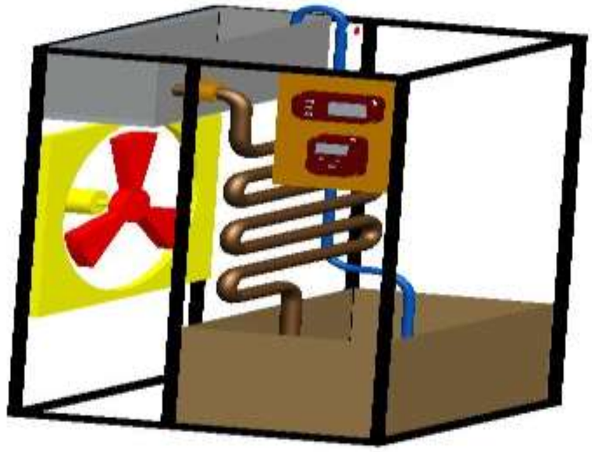

Figure 3.1 3D Diagram

## 3.2 LAYOUT OF AIR COOLED CONDENSER

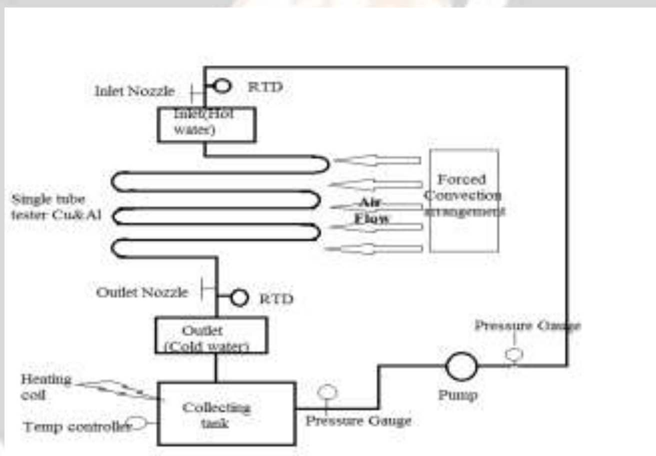


Figure 3.2 Layout diagram

## 3.3 WORKING PRINCIPLE

- Water is stored on collecting tank. It is heated upto $60^0$c with help of a A.C heater and by Virtue of gravity once the valve is opened hot water flow through the tube.
- Water flows through the tube with volumetric flow rate of 0.7 Lit/sec.
- Hot water cools down as it passes through the tubes as we have used forced draft fan in behind the tubes.
- By convection mode of heat transfer Hot water is cooled & cold water is taken out from the Outlet Valve, and stored in cold water collecting tank. Air flow is measured as Lit/sec
- Cold water is again fed into the Collection tank with the help of a pump and process is continued.
- Parameter are varied and heat transfer rate is calculated and a comparison chart is made.

### 3.4 INSTRUMENTS USED

### 3.4.1 RTD ( Resistance Temperature Detector )

Resistance Temperature Detectors operate through the principle of electrical resistance changes in pure metal elements. Platinum is the most widely specified RTD element type although nickel, copper, and Balco (nickel-iron) alloys are also used. Platinum is popular due to its wide temperature range, accuracy, stability, as well as the degree of standardization among manufacturers.RTDs are characterized by a linear positivechange in resistance with respect to temperature. Theyexhibit the most linear signal with respect to temperatureof any electronic sensing device. There are two common constructions for RTD elements. Wire-wound devices are manufactured by winding a small diameter of wire into a coil on a suitable winding bobbin. A number of methods have been used to protect the wire

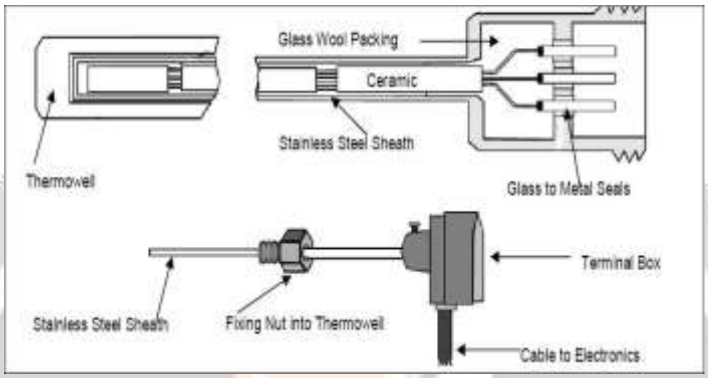


Figure 3.3 RTD

element from shock and vibration. One common technique is to use a ceramic bobbin with a glass or epoxy seal over the coil and welded connections. An alternative to the wire-wound RTD is the thin-film element.

### 3.6OBSERVATION

### 3.6.1Theoretical calculation for Copper tubes

Considering convection loss for fluid flowing inside the channel (or) tube, heat transfer rate is given by,

$Q=hA(T_w - T_\infty)$

$T_w$ –Wall temperature ($50^0$C)

$T_\infty$ - Ambient air temperature (28 $^0$C)

A- Surface area

For volumetric flow rate , $Q = 1.16\times 10^{-5}\ m^3/sec = AC$

$1.16\times 10^{-5} = (\pi/4) \times 0.0254^2 \times C$

$C = (4\times1.165\times10^{-5}) / (\pi \times 0.0254^2)$

$C = 0.023\ m / s$

Reynolds number , $Re = (\rho c d) / \mu$

Properties of water at $60^0$C is taken from steam table

$\rho$= 95 kg / $m^3$Cp = 4.185 KJ / $Kg^0C$

$\mu = 4.71 \times 10^{-4}$ Kg / $m^{-3}$

k = 0.651 W / $m^0C$

Pr = 3.02

$Re = (\rho cd) / \mu$

$Re = (985 \times 0.0254 \times 0.023) / ( 4.71 \times 10^{-4})$

$Re = 1221.735$

$Re < 2000$

Flow is Laminar calculating additional parameter we have

$Re .Pr.( d / L) = ( 1221.735 \times 3.02\times 0.0254) / 1.2$

$= 78.050 > 10$

$Re .Pr.( d / L) > 10$

So we have Nusselt number equation as

$Nu = 1.86 \times ( 1221\times 3.02)^{1/3} \times ( 0.0254 / 1.2)^{1/3}$

$Nu = 8.030$

Heat transfer co efficient = $( K . Nu) / d$

$= ( 0.651 \times 8.030) / 0.0254$

$= 205.808 \text{ W / m}^2\text{c}$

Heat transfer rate of Copper tubes,

$Q=hA(T_w - T_\infty)$

$= 205 \times 3.14 \times 0.0254 \times 1.2\times ( 50-28)$

$Q_{TH}$ = 431. 639 watts.

**Theoretical calculation for Aluminium tubes(AlCr40Mo18)**

$T_W = 40^0C$ & $T_\infty = 28^0C$

Same calculation upto Heat transfer coefficient.

For volumetric flow rate , $Q = 1.16\times 10^{-5} \text{ m}^3\text{/sec} = AC$

$1.16\times 10^{-5} = (\pi/4) \times 0.0254^2 \times C$

$C = (4\times1.165\times10^{-5} ) / ( \pi \times 0.0254^2)$

$C = 0.023 \text{ m / s}$

Reynolds number , $Re = (\rho cd) / \mu$

Properties of water at $60^0C$ is taken from steam table

$\rho= 985 \text{ kg / m}^3$

$Cp = 4.185 \text{ KJ / Kg}^0\text{C}$

$\mu = 4.71 \times 10^{-4} \text{ Kg / m}^{-3}$

$k = 0.651\ W / m^0C$

$Pr = 3.02$

$Re = (\rho c d) / \mu$

$Re = (985 \times 0.0254 \times 0.023) / (4.71 \times 10^{-4})$

$Re = 1221.735$

$Re < 2000$

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$= ( 0.651 \times 8.030) / 0.0254$

$= 205.808\ W / m^2c$

Heat transfer rate of Copper tubes,

$Q=hA(T_w - T_\infty)$

$= 205 \times 3.14 \times 0.0254 \times 1.2\times ( 40-28)$

$Q_{TH} = 235 . 44$ watts

**3.6.2 EXPERIMENTAL CALCULATION**

**FOR COPPER TUBES ( Single tube tester)**

Calculation for 2.5cm pipe and flow rate of 0.5 L/min

For Q=AV

| S.NO | AIR FLOW (m/s) | WATER FLOW($m^3$/s) | INLET TEMP | OUTLET TEMP |
|---|---|---|---|---|
| 1 | 4.1 | $1.16\times10^{-5}$ | 60 | 51 |
| 2 | 4.0 | $1.16\times10^{-5}$ | 60 | 50.5 |
| 3 | 3.9 | $1.16\times10^{-5}$ | 60 | 50 |
| 4 | 3.8 | $1.16\times10^{-5}$ | 60 | 50 |

Table 3.2 Experimental calculation for copper tubes

From Newtons law of cooling considering convection loss for fuel flowing inside the channel or tube we have heat transfer rate equation as

$q=\dot{m}\,C_p\,(Te-T_i)$

$C_p$ of water = 4.18KJ/Kg$^0$C

Volumetric flow rate, Q = A V ( $m^3/s$) = $1.16 \times 10^{-5}\ m^3 / s$

From this calculation velocity of water flow

Mass flow rate , $\dot{m} = \rho AC$

ρ from properties of water at 60$^0$c From pg. no 609 J.p.Holman

$C_p$=4.179 kJ/kg$^0$C

ρ=983.3 kg/$m^3$

μ=4.71 kg/ ms

k=0.654 N/m

Pr=3.01

Simplifying we have, $\dot{m} = \rho Q$

$= 983.3 \times 1.16 \times 10^{-5}$

= 0.011 kg / s

Heat transfer , $q = \dot{m}\,C_p\,(Te-T_i)$

$= 0.011\times 4.179 \times 10^3 \times 10$

= 476.66 watts

**EXPERIMENTAL CALCULATION**

**FOR ALUMINIUM TUBES (AlCr40Mo18) – Single tube tester**

Calculation for 2.5cm pipe and flow rate of 0.5l/min

| S.NO | AIR FLOW (m/s) | WATER FLOW($m^3$/s) | INLET TEMP | OUTLET TEMP |
|---|---|---|---|---|
| 1 | 4.1 | $1.16\times10^{-5}$ | 60 | 51 |
| 2 | 4.0 | $1.16\times10^{-5}$ | 60 | 50.5 |
| 3 | 3.9 | $1.16\times10^{-5}$ | 60 | 50 |
| 4 | 3.8 | $1.16\times10^{-5}$ | 60 | 50 |

Table 3.3 Experimental calculation for aluminium tubes

From Newtons law of cooling considering convection loss for fuel flowing inside the channel or tube we have heat transfer rate equation as

$q=\dot{m}\,C_p\,(Te-T_i)$

$C_p$ of water = 4.18KJ/Kg$^0$C

Volumetric flow rate, Q = A V ( $m^3/s$) = $1.16 \times 10^{-5}$ $m^3$ / s

From this calculation velocity of water flow

Mass flow rate , $\dot{m}$ = ρAC

ρ from properties of water at $60^0C$ From pg. no 609 J.p.Holman

$C_p$=4.179 kJ/$kg^0C$

ρ=983.3 kg/$m^3$

μ=4.71 kg/ ms

k=0.654 N/m

Pr=3.01

Simplifying we have, $\dot{m}$ =ρQ

$= 983.3 \times 1.16 \times 10^{-5}$

= 0.011 kg / s

Heat transfer , $q = \dot{m} C_p (Te-T_i)$

$= 0.011\times 4.179 \times 10^3 \times 5$

= 229 . 845 watt

**Comparison of Heat transfer rate for Cu & Al tubes**

| S.No | Tube material | Heat transfer rate ( water) | | Cost |
|---|---|---|---|---|
| | | Theoritical | Exprimental | |
| 1 | Copper | 431.639 | 476.66 | 1500 |
| 2 | Aluminium | 235.44 | 229.845 | 1000 |

Table 3.4 Comparison of Heat transfer rate for Cu & Al tubes

**3.7GRAPH**

**Comparison of Experimental and Theoretical heat transfer value for Copper tube**

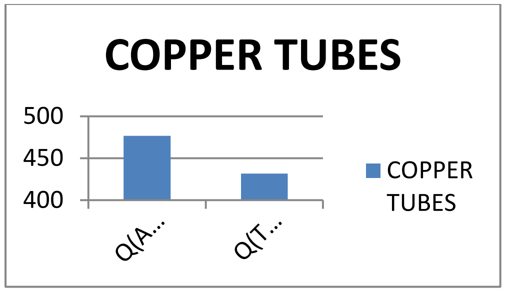


Figure 3.7 Copper tube

**Comparison of Experimental and Theoretical heat transfer value for Copper tube**

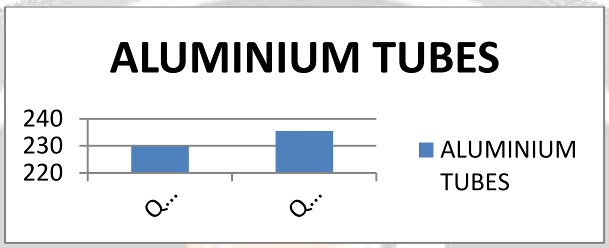


Figure 3.8 Aluminium tube

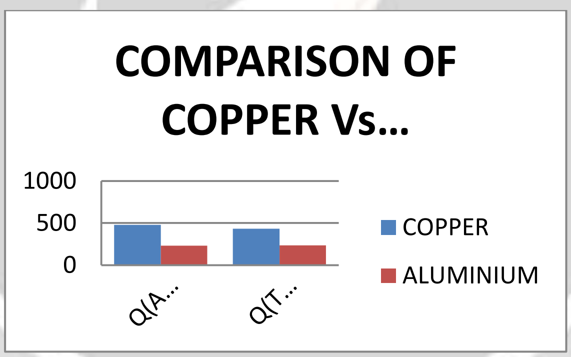


Figure 3.9 Comparison of Copper Vs Aluminium

**CONCLUSION**

In this project we have analyzed two different single tube tester of Copper and Aluminium materials. For same experimental set-up conditions (Water flow rate and Air flow rate being the same), we have calculated theoretical and experimental heat transfer value for Copper and Aluminium tubes. A comparison chart is made between Copper and Aluminium tubes along with a graph. From this observations if is found that for the same experimental set-up copper tubes have higher heat transfer rate comparing to aluminium tubes. So for application in Diesel unit (or) Thermal power plants where high rate of heat transfer is required, Copper tubes are preferred for and applications which require low rate of heat transfer aluminium is used.

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