Design, Fabrication and Testing of a Finned Air Cooled Condenser for Power Plant Applications

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Abstract– In this project the primary goal was to design, construct and test a scale model air cooled condenser (ACC) unit for potential applications in power plants. The density of air is almost 1000 times less than water, therefore to compensate this reduction in the cooling process a significant amount of surface is needed to achieve this process. The scale model ACC was designed by a commercial software. Based on this design the components of the unit were fabricated and assembled. All the fittings were sealed to prevent any leaks of water. Copper was the selected material for the pipes and fittings, this material present excellent thermal conductivity and additionally it does not react with water. Several infrared sensors installed at different locations measure the surface temperature response of the unit. The experimental results show that this unit was able to condense a mass flow rate of 0.00191 kg/s of saturated water vapor at steady state conditions. Natural and forced convection cooling process was applied externally to the unit to release the latent heat of condensation of water vapor. A small temperature difference was observed when the unit was cooled down by natural convection. The mass flow rate of air provided by the fan was 2.98 kg/s, and the temperature increment of air between the outlet and the inlet of the scale model unit was 1.44 degrees Celsius.

Keywords—heat transfer, air cooled condenser, condensation, fins.

I. Introduction

There are three main periods (1930s~1970, 1970s~1990s, and after 2000) in the history of air cooling technologies. The earliest development started in Germany in the late 1930s. From the late 1930s to the 1970s, (primitive) direct air cooling was the dominant technology [1]. Since the late 1950s, several companies began to develop indirect air cooling, which uses closed loop cooling water as a medium for heat transfer. An indirect air cooling system has two heat exchange: first between steam and the cooling water and then between the cooling water and the air. From the 1970s to mid-1990s, indirect air cooling was more popular than direct air cooling. The sizes of air-cooled power generators during this period were mostly 100~300 MW. Because the volume of cooling water is much larger than the volume of exhaust steam, the design of both heat exchangers are easier to construct for a direct air cooling system [1]. Presently, the concept has acquired a new name air cooled condenser (ACC) [2-4]. In this system, exhaust steam from the turbine flow through the tubes bundles of an ACC and is condensed in parallel flow tubes bundles using air flow inducted by properly design axial fans. The two configuration of design (A-frame and V-frame) both of this design have the advantages of low fan power consumption, resistant to corrosion and freezing conditions, required very low maintenance and cost effective solution allowing maximization of the overall costs [5]. This new technology uses the heat transfer from high temperature object to a lower temperature object. Air cooled condenser power plants is helping the thermal industry to become environment friendly by using less water or zero water for the cooling system, thus preserving the environment and not causing emission at all [6].

In the present study a scale model V-shaped air cooled condenser was designed and tested.

II. Design And Construction Of The Air Cooled Condenser

Based on the literature review, a V-shaped ACC was selected for the present study. Figure 1 shows the final design consisting on a V-shaped construction that includes: the main supply line, downpipes tubes, tees, wyes and angular elbows. The design also includes a table to support the ACC. As shown in Figs. (2)- (3) the vapor flows from the main line and then it is evenly distributed through the V-shaped connections of the ACC system; a fan was placed in the bottom side to enhance the cooling process. The air forced convection helps to condense the vapor passing along the ACC. In this design the acceleration of gravity represents and additional driving force that facilitates the fluid flow process in the system. The material selected for the pipe and fittings of the ACC was copper and distilled water was the working fluid. The full representation of the system is presented in Fig. 4. It shows all the components of the system: The V-shaped ACC structure, the steam generator, the fan and the support table of the system.

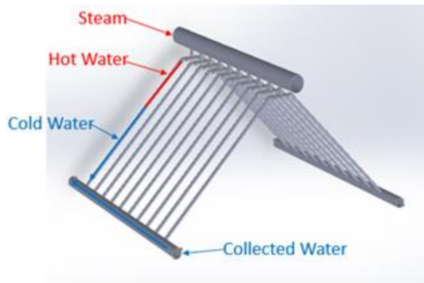


Figure 1: A 3D view of the proposed ACC.

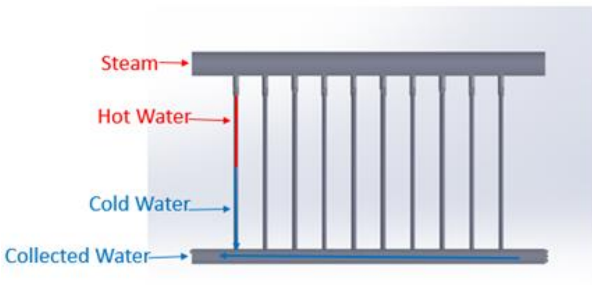


Figure 2: Side view of the proposed ACC.

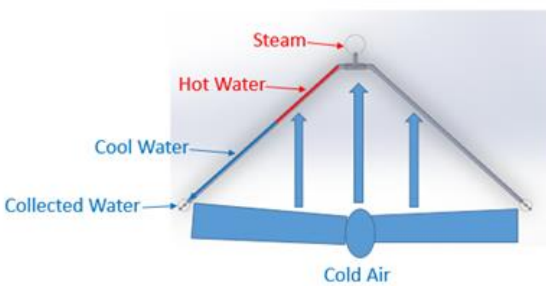


Figure 3: Side view of the proposed ACC.

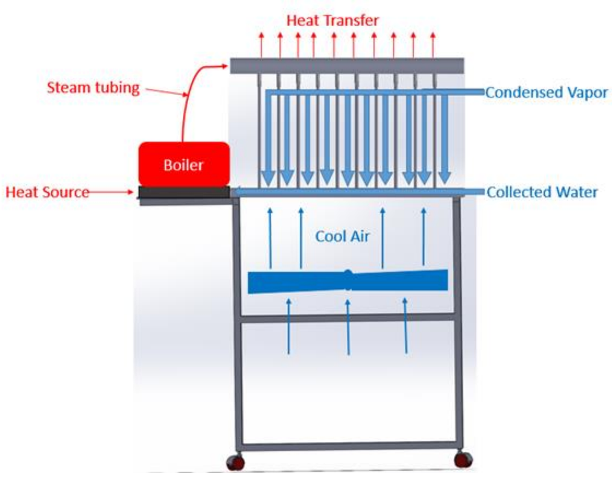
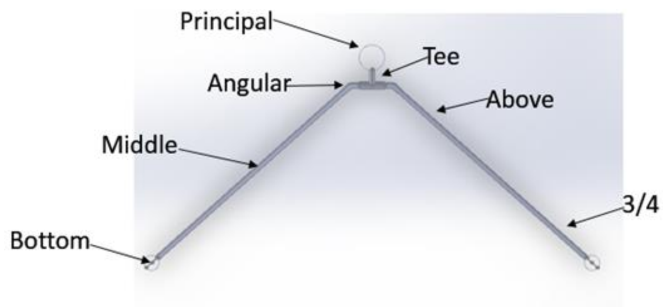


Figure 4: 2D full representation of the ACC system.

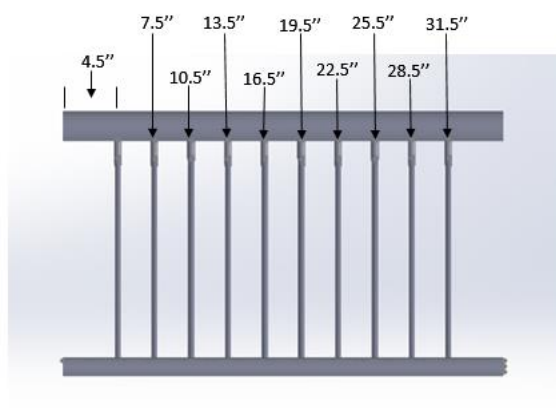
The actual V-shaped ACC is displayed in Fig. 5. This system was placed in the fluid-laboratory for further testings. Several thermocouples type-T were installed at several locations of the system to evaluate the temperature distribution in the system.

Figure 5: Actual configuration of the V-shaped ACC system

The location of the thermocouples that were installed on the air cooled condenser is shown in Figs. (6).



(a)



(b)

Figure 6: Location of thermocouples installed in the system: (a) front view, (b) side view of the ACC.

III. Experimental Results and Discussion

The experimental results of the thermocouples measurements are presented in Figs. (7) and (8).

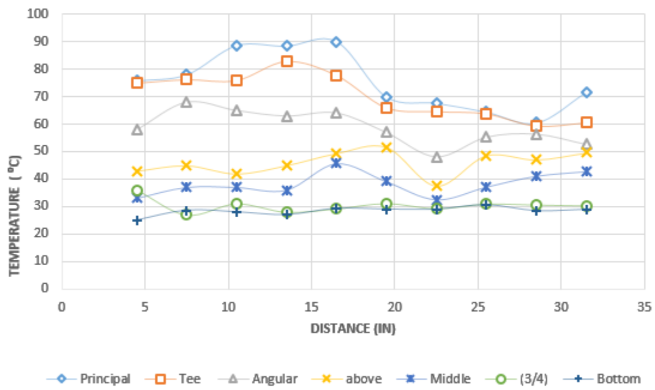


Figure 7: Thermocouples reading without fan.

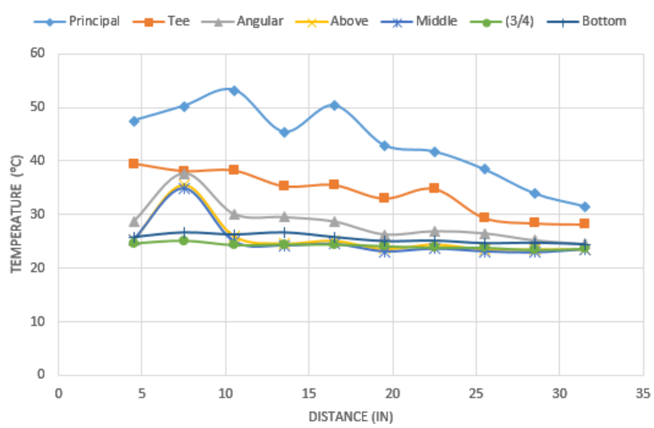


Figure 8: Thermocouples reading with fan.

The results indicate the effects of natural (no fan, Fig. 6) and forced convection (with fan, Fig.7). It is clearly observed that forced convection maintain a more uniform temperature distribution. The effect is more notorious in the principal line (main line). The maximum temperature recorded was 90 degree Celsius with no fan and 52 degrees with the fan activated. The temperature reduction in this line is 42 percent approximately. Forced convection increase the magnitude of the convection coefficient and therefore it improves the cooling process.

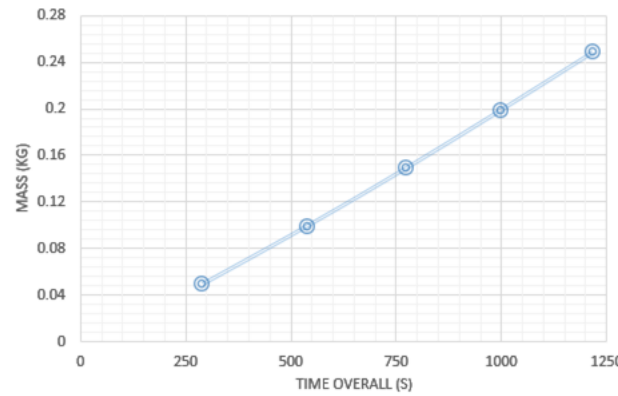


Figure 9: Location of thermocouples installed in the system: (a) front view, (b) side view of the ACC.

Figure 9 shows the mass of water condensed versus time. Based on this result the rate of condensation was 0.0002 kg/s.

II. Conclusions

It was possible to design, built and test successfully a scale V-shaped model air cooled condenser. The system was capable to condense a constant rate of steam during the testing process. The experiment was conducted with the fan on and off. When the fan of the ACC was turned off the maximum temperature on the structures was close up to $90°C$. While when the fan was turned on the surface temperatures were approximately $52°C$. The experimental results show a significant effects of forced convection of air on the temperature distribution of the components of the system.

Acknowledgment

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