Design of Air-Cooled Condenser for Steam Condensation

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Abstract-*A heat exchanger is a heat transfer device that exchanges heat between two or more process fluids. A heat exchanger is used for transfer of internal thermal energy between two or more fluids available at different temperatures. In most heat exchanger fluids are separated by a heat-transfer surface, and ideally they do not mix. Heat exchangers have widespread industrial and domestic applications. Today's heat exchangers must meet a variety of highly demanding requirements. In terms of performance, they have to ensure maximum heat transfer while keeping size to a minimum. Furthermore, the durability of heat exchangers must be extremely high, providing trouble-free performance throughout its service life at low manufacturing costs. The obvious advantage of an air cooler is that it does not require water, which means that equipment requiring cooling need not be near a supply of cooling water. In addition, the problems associated with treatment and disposal of water have become more costly with government regulations and environmental concerns. The air-cooled heat exchanger provides a means of transferring the heat from the fluid or gas into ambient air, without environmental concerns, or without great ongoing cost. This is made possible by the large variety of aluminum-based materials and product forms that empower system designers and manufacturers with multiple options for significant design improvement and cost reduction. Aluminum, in its various forms, offers clear possibilities to achieve these goals and is also well positioned to meet the challenges of the increasing market demands for cost effective, energy-efficient products and new customized, innovative applications.*

Keywords-ACHE (Air cooled heat Exchanger), Qair, Qsteam, nusselt no, prandtl no, Hae

I. INTRODUCTION

An air cooled heat exchanger, or ACHE, 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 cooler is a car's radiator. The Air-cooled heat exchanger is a device for rejecting heat from a fluid or gas directly to ambient air. When cooling both fluids and gases, there are two sources readily available, with a relatively low cost, to transfer heat to air and water. 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 where water is not available. A heat exchanger consists of heat-exchanging elements such as a core or matrix containing the heat-transfer surface, and fluid distribution elements such as headers or tanks, inlet and outlet nozzles or pipes, etc. The heat-transfer surface is in direct contact with fluids through which heat is transferred by conduction. The portion of the surface that separates the fluids is referred to as the primary or direct contact surface. To increase heat-transfer area, secondary surfaces known as fins may be attached to the primary surface Air cooled heat exchangers are used for two primary reasons: 1. they increase plant efficiency 2. They are a "green" 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). Uses for air-cooled heat exchangers The applications for air cooled heat exchangers cover a wide range of industries and products, however generally they are used to cooler gases and liquids when the outlet temperature required is greater than the surrounding ambient air temperature. The applications include: Refineries Gas compressor packages Gas transmission facilities Engine cooling Condensing of gases (propane, refrigerants, etc) Steam condensers Principle of Heat Exchanger - Basic Heat Transfer principles The basic heat transfer relationships that exist for shell and tube exchangers also apply to the design of an air-cooled heat exchanger. However, there are more parameters to be considered in the design of an air-cooled exchanger. Since the air-cooled heat exchanger is exposed to changing climatic conditions, problems of control of the air cooler become relevant. A decision must be made as to what the actual ambient air temperature to be used for the design. Some of the governing factors in the design of the air cooler are: Tube diameter, Tube length, Fin height, Number of tube rows, Horse power Plot area. To calculate the sensible heat load Q in KJ/hr, the following equation must be followed:

$$Q = m \times Cp\ (Ti – To)$$

Where, m = the flow of the fluid or gas in Kg/sec. Cp = the average specific heat in KJ/kgK oF of the liquid or gas Ti = inlet temperature of the liquid or gas To = outlet temperature of the liquid or gas.

II. PROBLEM DEFINITION

- 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 litres per day per person.
- The urban area consumption is in upwards of 100-150 litres per day.

III. OBJECTIVES

- Design of Air cooled condenser to avoid the wastage of water
- Calculation of pressure drop of tube side to evaluate the temperature at the outlet
- Validation of the results as per testing

IV. METHODOLOGY

- Literature review regarding concerned topic.
- Study of pressure drop in the tubes
- CAD modelling of Air cooled condenser
- Heat duty in each tube can be calculated

V. DESIGN OF AIR-COOLED CONDENSER FOR STEAM CONDENSATION

1. Q_{steam}

It is calculated by steam flow and latent heat we get in MW

2. Q_{air}

Assume face velocity ranges from 1.5 to 2 m/sec calculate the flux kg/m²·sec to calculate the flow in kg/sec multiply flux by inlet area of tube = no.of tubes*tube pitch*length of tube*module*no. of bundles

To calculate the Qair M*Cpwet *ΔT

To valculate the ΔT calculate the calculate the viscosity (μ) thermal conductivity of air (k) calculate Reynolds number (Re) from that from Reynolds number Nussult no.is calculated

Nu= a*Ry^b

Where a and b are constant and depends on the Tube outside diameter, fin type, Reynolds no. and FPI of tube and Ry is Reynolds no per meter

Calculate prandtl no. from that calculate nusselt no from both calculate Hae which is effective Air side surface area heat transfer coefficient from that the overall heat transfer coefficient is calculated from that NTU is calculated given by UA/C_{min}

From that efficiency of heat exchanger is calculated. Our case is of cross flow so have to choose appropriate flow equation

C_{min} is given by W/mk.

The heat transfer in tube is given by = effectiveness of heat exchanger*C_{min}*($T_{@tubeinlet} – T_{@airinlet}$)*length of tube
We get heat transfer in W/tube this is ideal heat transfer so frictional losses and other losses and temperature factor has to be considered.
=Heat transfer per tube*Ntube_APrim/1000000(MW)

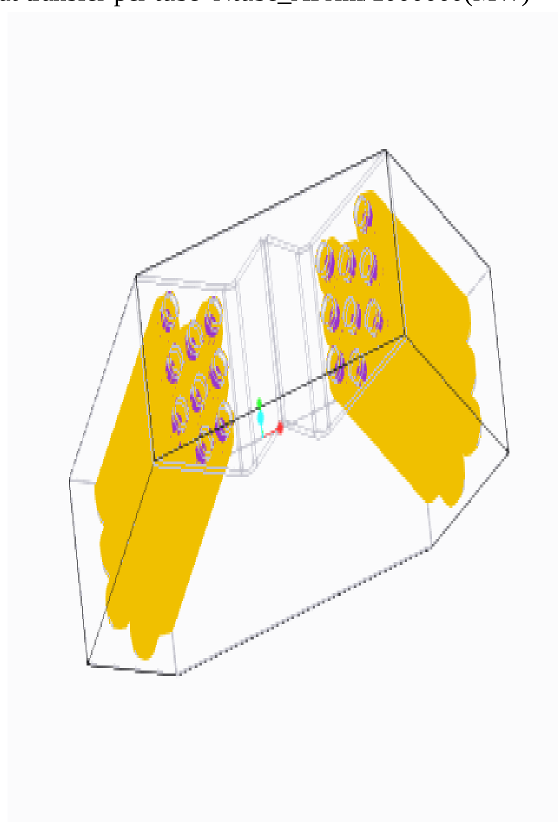

Fig: - Cad model of ‘A’ frame Air cooled condenser

V. GENRAL SELECTION CRITERIA

Some important parameter is given before selecting the Air cooled condenser for different application

Variable	Consideration
Air flow rate	Thumb Rule 3 row :- 240 to 275 m/min 4 row :- 150 to 210 m/min 5 row :- 140 to 180 m/min 6 row :- 100 to 150 m/min
Tube length	Length is establish in conjunction with the bundle width Bundle width normally limited to 3.2 m to 3.5 m API 661 specifies minimum fan coverage of 40%. Therefore, tubes are typically in the range of 8 m to 10 m long (26 ft to 33 ft).
Tube length	Cost of exchanger is lower with smaller diameter tubes Cleaning is more difficult with smaller diameter Minimum recommended (and most common) tube size is 25 mm (1 in) OD Optimize with pressure drop by adjusting the number of passes and tube size
Tube outside diameter	Cost of exchanger is lower with smaller diameter tubes Cleaning is more difficult with smaller diameter Minimum recommended (and most common) tube size is 25 mm (1 in) OD Optimize with pressure drop by adjusting the number of passes and tube size
Fin height	Usual fin heights are 9.5 mm, 12.7 mm, and 15.9 mm (3/8 in., 1/2 in., and 5/8 in.) Selection depends on relative values of air-side and tube-side film coefficients With higher fins, fewer tubes can be accommodated per row Typically, use higher fins for steam condensers and water coolers Typically, use lower fins for gas coolers and viscous liquid hydrocarbon coolers
Fin spacing	Spacing usually varies between 276 to 433 fins/m (7 to 11 fins/in) Typically, use higher density for steam condensers and water coolers Typically, use lower density for gas coolers and viscous liquid hydrocarbon coolers
Number of tubes Rows	Most exchangers have four to six tube rows, but can range from three to ten Air-side film coefficient varies inversely with number of tube rows More rows advantage: more heat transfer area in the same bundle width, reducing number of bundles and sections More rows disadvantage: increases fan horsepower for the same air velocity and lowers the Mean Temperature Difference Typically, four or five tube rows for steam condensers and water coolers Typically, six or seven tube rows for gas coolers and viscous liquid hydrocarbon coolers
Tube pitch	Staggered pattern almost invariably employed Designers tend to use the following combinations of bare-tube OD, finned-tube OD, and tube pitch: 25 mm / 50 mm /60 mm (1 in / 2 in / 2.375 in) 25 mm / 57 mm / 67 mm (1 in / 2.25 in / 2.625 in) **As tube pitch is decreased, air-side pressure drop and power consumption increase more rapidly than the air-side heat transfer coefficient**

VI. CONCLUSION

1. Efficiency of heat exchanger is calculated according to procedure mentioned above is 0.307.
2. Heat transfer across one tube is calculated is 10158 W/tube
3. Heat balancing we can calculate the required area and the face velocity required for ACHE by iteration process which are 57039m2 and 2.03 m/sec respectively.

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REFERENCES

[1] Duvenhage, D. G. Kr6ger*, "The influence of wind on the performance of forced draught air-cooled heat exchangers", Journal of Wind Engineering and Industrial Aerodynamics 62 (1996) 259-277

[2] C.J. Meyer*, D.G. Kr€oger , "Numerical investigation of the effect of fan performance on forced draught air-cooled heat exchanger plenum chamber aerodynamic behavior", Applied Thermal Engineering 24 (2004) 359–371

[3] C.J. Meyer*, D.G. Kroger, "Ai- cooled Heat exchanger inlet flow losses ", Department of Mechanical engineering", Applied Thermal Engineering 21 (2001) 771–786

[4] A. Zapkea, D.G. Kroè Gerb,*, "Countercurrent Gas±Liquid ¯Ow In Inclined And Vertical Ducts Ð I: Flow Patterns, Pressure Drop Characteristics And Flooding" International Journal Of Multiphase Flow 26 (2000) 143-1455

[5] Michael John Kessen, "Optimal Design Of An Air-Cooled Condenser For Flue Gas From A Power Plant", Lehigh University Lehigh Preserve, 2012.

[6] A. E. Conradie And D. G. Kroger," Performance Evaluation Of Dry-Cooling Systems For Power Plant Applications", Department Of Mechanical Engineering, University Of Stellenbosch, Stellenbosch, 7600, South Africa (Received With Revisions 2 May 1995).

[7] D. G. Kroger, "Fan Performance In Air-Cooled Steam Condensers", International Journal Of Adhesion & Adhesives, Vol. 22, 2002, Pp. 311-315, (Received 6 July 1993).

[8] Chiou, J. P., "The thermal performance Deterioration in cross flow heat exchanger due to flow non uniformity", American Society Of Mechanical Engineers Journal Of Heat Transfer, 100:580-587,1978