FINNED TUBE HEAT EXCHANGER

AIM:

To determine the efficiency of given longitudinal fin and compare it with the theoretical value for the given fin

APPARATUS:

1. Longitudinal finned tube heat exchanger.
2. Bare pipe (pipe without fins).
3. Steam generator to generate steam at constant pressure. The steam generator is also provided with temperature indicator cum controller and a safety valve.

THEORY

In a heat exchanger, the two fluids namely; hot and cold, are separated by a metal wall. Under this condition, the rate of heat transfer will depend on the individual resistance of heat transfer

$$\frac{1}{U_i A_i} = \frac{1}{h_i A_i} + \frac{x}{K A_{lm}} + \frac{1}{h_o A_o}$$

Where

U_i =Overall heat transfer coefficient based on inner area [kcal/h-m^2-^{o}C]

U_o =Overall heat transfer coefficient based on outer area [kcal/h-m^2-^{o}C]

h_i,h_o =Inside and outside film heat transfer coefficient [kcal/h-m^2-^{o}C]

A_i,A_o =inside and outside surface area [m^2]

When viscous liquids are heated in standard tubular heat exchanger by condensing steam or hot fluid of low viscosity, the film heat transfer coefficient of the viscous liquid will be much smaller than that of the hot fluid side. Therefore, it will become controlling resistance for heat transfer. This condition is also present in case of air or gas heaters where the gas side film heat transfer coefficient will be very low (typically of the order of 0.01 to 0.002 times condensing vapor on the other side. Since, the heat transfer coefficients of viscous fluid cannot be improved much, the only alternative is to increase the area available for heat transfer. Subsequently reducing its resistance for the heat transfer. To conserve space and to reduce the cost of equipment in these cases, certain type of heat exchange surfaces has been developed. In these cases, outside area of tube is increased many fold by fins.

Two types of fins, are in common use; longitudinal fins and transverse fins. Longitudinal fins are used when the direction of flow of the fluid is parallel to the axis of tube and transverse fins are used when the direction of the flow of the fluid is across the tube. Spikes, pins, studs or spines are also used for either direction of flow.

The outside area of a finned tube consists of two parts: the area of fins and the area of bare tube not covered by the bases of fins. A unit area of fin surface is not as efficient as a unit area of bare tube surface. It is because of the fact that the added resistance to the heat flow by conduction through the fin. The expression for fin efficiencies can be derived by solving the general differential equation of heat conduction with suitable boundary conditions. *Generally, three boundary conditions are used;*

1. **Fin of infinite length:** so that there is no heat dissipation from its tip, or in other words temperature at the tip of fin is same as that of the surrounding fluid.

2. **Insulated tip:** This condition even though cannot be realized in practice, but considering that the tip area is negligible as compared to the total fin area, heat dissipated from tip can be neglected and hence, [dT/dx] is assumed to be zero at the tip.

3. **Finite heat dissipation from the tip:** Even though the assumption of insulated tip is invalid, most of the fins are treated under this category, and longitudinal fin efficiency for this case is given by the expression:

$$\eta_{fin} = \frac{\tanh(mL)}{mL},$$

Where,

$$m = \sqrt{\frac{hC}{KA}}$$

h = film heat transfer coefficients from the fin surface [kcal/h-m^2-°C]

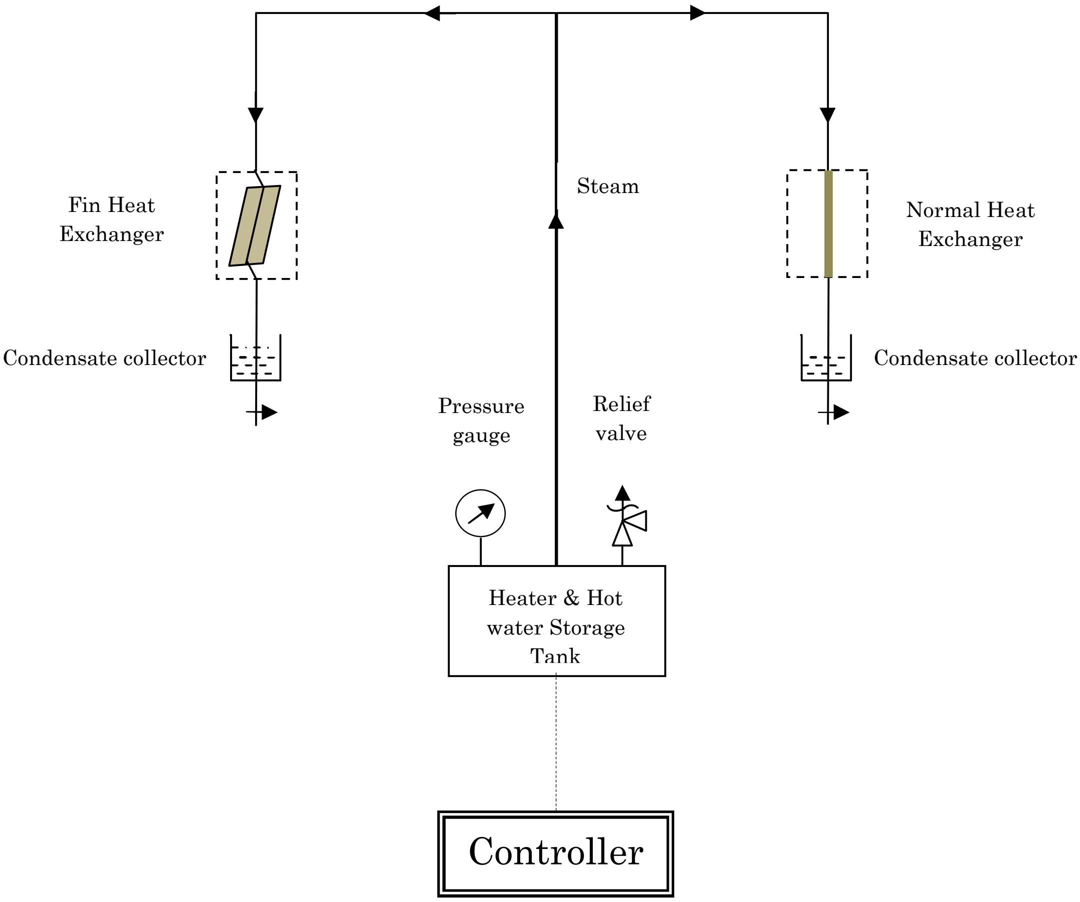
C = Circumference of the fin [m]

K = thermal conductivity of fin material [kcal/h-m^2-°C]

A = cross sectional area of fin [m^2]

From the above equation, it can be seen that the fin efficiency is a function of (mL), and as the value of (mL) increases, the fin efficiency decreases. A reasonable value of fin efficiency will be around 50 to 75% for which (mL) should have a value between 1 and 2. If the fin height L should be sufficient (of the order of 5 to 8 cm), then it can be seen that the value of h should be around 10 to 20 which can be given by air in natural convection. The value of film heat transfer coefficients for any other liquid in natural convection, or any gas in forced convection will be much higher than 20. Thus, the given set-up is used for heat transfer to air in natural convection region.

SCHEMATIC FLOWSHEET



Fin tube heat exchanger

PROCEDURE:

1. Important instructions: Follow instructions 2 and 3 without fail, otherwise electrical heater will burn out.

2. Open the drain valve provided at the bottom of steam generator and drain out the water from

   Steam generator completely.

3. Close the drain valve and charge requisite amount of water through charging valve provided at the top of the steam generator and close it. Ensure that the dead weight safety valve is free.

4. Start the electrical heater of steam generator. Set the desired temperature on the temperature controller and start heating water in the steam generator. Steam will start forming within about 15-20 min of switching on the heater. During this period, keep the condensate collector valve open. Once the steam generation starts, the finned tube heat exchanger as well as the bare pipe will start getting heated up and condensate will start coming out of the needle valve provided at the bottom of condensate collector. When the test section is fully heated up, steam will start coming out of the needle valve. Now regulate the needle valve in such a way

that only condensate comes out of it. The pressure can be regulated between 0-1 atm. as per the requirement.

5. Once the test section (finned tube heat exchanger along with bare pipe without fins) is fully heated, drain out completely the condensate, if any. Close the needle valve on condensate drain line simultaneously starting the stop-watch. Collect the condensate accumulated at an interval of 20 min for both heat exchangers. If the quantity of condensate collected is same for 2 to 3 consecutive readings (with in experimental accuracy), note down the volume of condensate collected and time interval.

OBSERVATIONS:

Finned Tube:

1. Height of fin (L) : 0.05 m
2. Width of fin (W) : 0.5 m
3. Thickness of fin (b) : 0.003 m
4. Number of fins (N) : 4
5. O.D. of fin tube (D) : 0.025 m.
6. Thermal conductivity of fin material (K) : 15.0 kcal/h-m-°C

Bare Tube:

1. Length of tube (l) : 0.6 m
2. O.D. of tube (d) : 0.025 m
3. $T_{ambient}$: °C

OBSERVATION TABLE

Obs. No.	Finned tube heat exchanger		Bare tube heat exchanger		T_{steam}
	Amount of condensate collected, m_1(ml)	Time Interval, t(min)	Amount of condensate collected, m_1(ml)	Interval, t(min)	
1					
2					
3					
4					

5					

CALCULATIONS:

1. Circumference of fin (C):

$$C = 2x(W+b) = \_\_\_\_\_\_\_\_\_\_ \; m$$

2. Cross-sectional area of fin (A):

$$A = Wxb = \_\_\_\_\_\_\_\_\_\_ \; m^2$$

3. Fin area available for heat transfer:

$$A_F = CxLxN = \_\_\_\_\_\_\_\_\_\_ \; m^2$$

4. Tube area available for heat transfer in finned tube heat exchanger:

$$A_b = [(\pi \text{ x } D) - (N \text{ x } b)] \text{ x } W = \_\_\_\_\_\_\_\_\_\_ \; m^2$$

5. Total area of finned tube heat exchanger:

$$A_t = A_F + A_b = \_\_\_\_\_\_\_\_\_\_ \; m^2$$

Sample Calculation for reading no. ____

6. Heat given out by steam through finned tube heat exchanger (Q_1):

$$Q_1 = (m_1/t)\lambda = \_\_\_\_\_\_\_\_\_\_ \; kcal/h$$

7. Heat given out by steam through bare tube (Q_2):

$$Q_2 = (m_2/t)\lambda = \_\_\_\_\_\_\_\_\_\_ \; kcal/h$$

Where, λ = latent heat of vaporization of water at steam pressure = 540 kcal/kg

8. Area available for heat transfer of bare tube

$$A_{\text{bare tube}} = (\pi dl) = \_\_\_\_\_\_\_\_\_\_ \; m^2$$

9. Film heat transfer co-efficient from bare tube (h):

$$h = \frac{Q_2}{A_b \Delta T} = \_\_\_\_\_\_\_\_\_\_ \; kcal/h\text{-}m^2\text{-}°C$$

$$\Delta T = T_{steam} - T_{ambient} = \_\_\_\_\_\_\_\_\_\_ \; °C$$

10. $m = \sqrt{\frac{hC}{kA}} = \_\_\_\_\_\_\_\_\_\_ \; m^{-1}$

11. $mL = \_\_\_\_\_\_\_\_\_\_$

12. η_{Fin}(Theoretical) $= \frac{\tanh(mL)}{mL} =$ ____________

13. Amount of heat actually dissipated by the fin:

$$Q_{Fin} = Q_1 - (A_b h \Delta T) = \_\_\_\_\_\_\_\_\_\_\_\_ \text{ kcal/h}$$

14. Amount of heat that can be dissipated by deal fin:

$$Q_{ideal} = A_F h \Delta T = \_\_\_\_\_\_\_\_\_\_\_\_ \text{ kcal/h}$$

15. Observed value of fin efficiency:

$$\eta_{Fin}(\text{Observed}) = \frac{Q_{\text{Actual fin}}}{Q_{\text{ideal fin}}} = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_$$

RESULT:

Obs. No.	**Amount of heat lost**		**Amount of heat lost**		**Fin efficiency**	
	Through fin tube, Q_1 (kcal/h)	**Through bare tube, Q_2 (kcal/h)**	**Actual fin, Q_{fin} (kcal/h)**	**Ideal fin, Q_{ideal} (kcal/h)**	**Actual**	**Theoretical**
1						
2						
3						
4						
5						

CONCLUSIONS

1. Write down the observations.

2. Try to explain the results from theory studied e arlier.

FURTHER READING

Fundamentals of Heat and Mass Transfer by Frank P. Incropera and David P. Dewitt Chapter 3.

TEACHING ASSISTANT