Experiment. No. 1 Date

FINNED TUBE HEAT EXCHANGER

Objective

To study the performance of a Finned Tube Heat Exchanger

Aim

To calculate the LMTD, heat transfer rate and overall heat transfer coefficient.

Introduction

The heat which is conducted through a body must frequently be removed by some convection process. For example, the heat lost by conduction through a furnace wall must be dissipated to the surroundings through convection. In heat exchanger, finned tube arrangement is used to remove heat from a hot fluid.

Theory

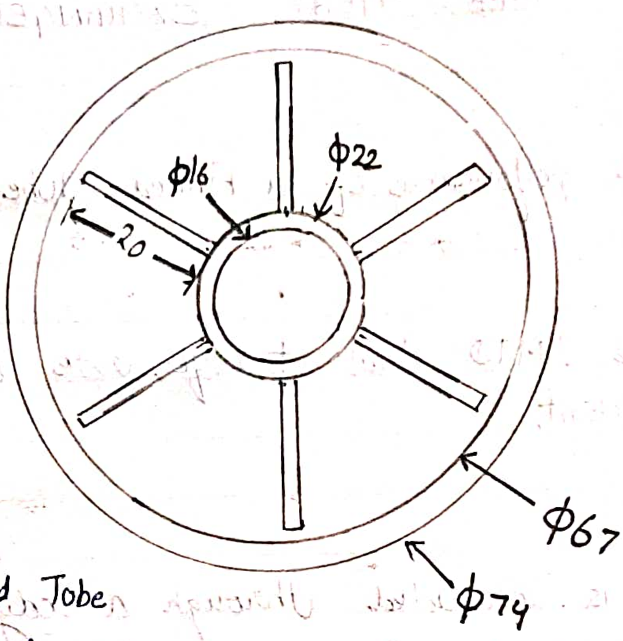
Finned tube heat exchangers are also known as extended surface heat exchangers in which outside area of tube is extended by fins, and the outside area in contact with fluid thereby made much larger than the inside area.

Overall heat transfer coefficient can be calculated by the formulae

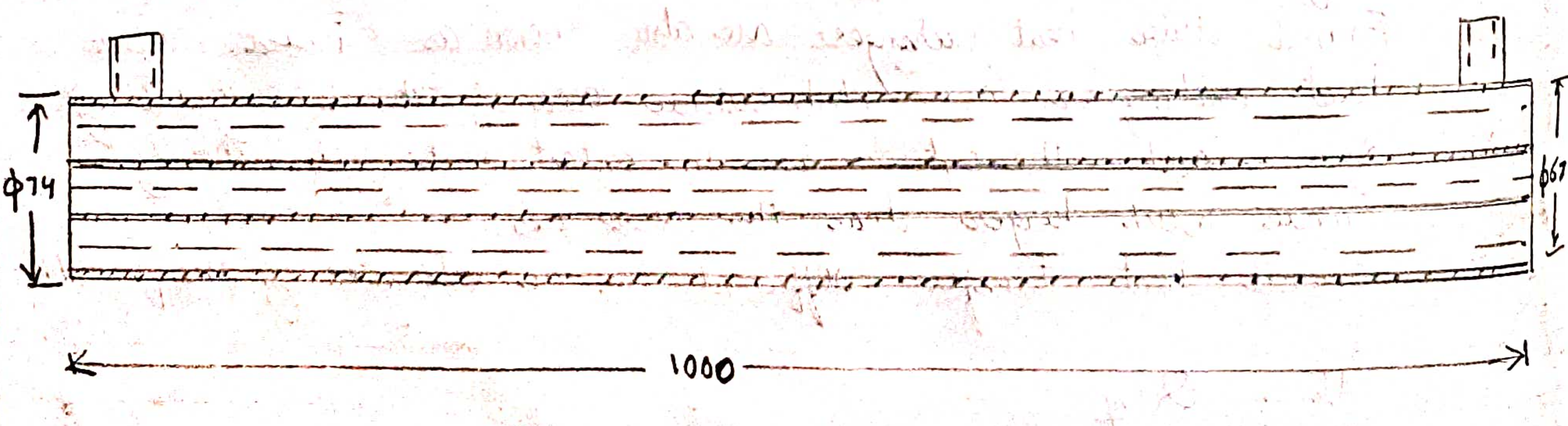
$$U_o = \frac{Q_{avg}}{A_o \Delta T_m}$$

$$U_i = \frac{Q_{avg}}{A_i \Delta T_m}$$

Teacher's Signature



Side View of Finned Tobe Heat Exchanger



Front View of Finned Tube Heat Exchanger

Experiment. No. .... Date.............

Utilities Required

i) Electricity Supply: Single Phase, 220V AC, 50Hz, 4 kW with earth connection
ii) Water Supply : continuous @ 5 LPM at 1 Bar
iii) Drain required
iv) Floor Area required : 1.75 m X 1m

Experimental Procedure

- Set the desired water temperature in the DTC
- Switch on the pump & heater and wait till desired temperature achieves
- Set the valves in opening / closing mode as required per parallel / counter flow.
- Adjust the flow rate by Rotameter, control valve and bypass valve.
- At steady state (constant temperature) record the temperatures and flow rate of hot and cold water for both parallel & counter flow.

Precautions

- Note the readings only if steady state has been achieved.
- Check the valves (on/off) for parallel & counter flow

OBSERVATION

DATA

D_o = Outer diameter of tube = 0.022 m

D_i = Inner diameter of tube = 0.016 m

L = Fin length = 1m

Y = Fin height = 0.020 m

N_f = No. of fins per tube = 6

Observation Table

S. No.	Mode (Parallel / Counter)	F_h (LPH)	T_1 °C	T_2 °C	F_c (LPH)	T_3 °C	T_4/T_5 °C
1	Parallel	205	59.35	56.3	130	32.6	37.3 = T_4
2	Counter	205	59.4	56.2	130	32.3	37.8 = T_5

Calculations

For parallel flow

Properties of water (C_{ph}, ρ_h) at

$$T_h = \frac{T_1 + T_2}{2} = \frac{59.35 + 56.3}{2} = 57.825\ °C$$

$$T_c = \frac{T_3 + T_4}{2} = \frac{32.6 + 37.3}{2} = 34.8\ °C$$

$C_{ph} = 4.184$ KJ/Kg-K

$C_{pc} = 4.178$ KJ/Kg K

$\rho_h = 984.3196$ kg/m^3

$\rho_c = 994.132$ kg/m^3

$$M_h = \frac{F_h \times \rho_h}{3600 \times 1000}\ kg/s = \frac{205 \times 984.3196}{3600 \times 1000} = 0.05605\ kg/s$$

$$Q_h = M_h C_{ph} (T_1 - T_2) = 0.056 \times 4.184 (59.35 - 56.3) = 0.7152\ kW$$
$$= 7152.848\ W$$

$$M_c = \frac{F_c \times \rho_c}{3600 \times 1000} = \frac{130 \times 994.132}{3600 \times 1000} = 0.035899\ kg/s$$

$$Q_c = M_c C_{pc} (T_4 - T_3) = 0.035 \times 4178 (37.3 - 32.6) = 704.938\ W$$

$$Q = \frac{Q_h + Q_c}{2} = 710.1114$$

$\Delta T_1 = T_1 - T_3 = 59.35 - 32.6 = 26.75\,°C$

$\Delta T_2 = T_2 - T_4 = 56.3 - 37.3 = 19\,°C$

$$\Delta T_m = \frac{\Delta T_1 - \Delta T_2}{\ln \frac{\Delta T_1}{\Delta T_2}} = \frac{26.75 - 19}{\ln\left(\frac{26.75}{19}\right)} = 22.654492\,°C$$

$$A_o = \cancel{2}L(\pi D_o \cancel{+} + 2N_F Y) \doteq 1(\pi \times 0.022 + 2 \times 6 \times 0.02) = 0.30908\ m^2$$

$$A_i = \pi D_i \times L = \pi \times 0.016 \doteq 0.05024\ m^2$$

$$U_o = \frac{Q}{A_o \Delta T_m} = \frac{710.1114}{0.30908 \times 22.654492} = \cancel{84.928\ W/m^2\,°C}$$

$101.41\ W/m^2\,°C$

$$U_i = \frac{Q}{A_i \Delta T_m} = \frac{710.1114}{0.05024 \times 22.654492} = 623.910\ W/m^2\,°C$$

For Counter Flow

Calculations

Properties of water (C_{ph}, ρ_h) at

$$T_h = \frac{T_1 + T_2}{2} = \frac{59.4 + 56.2}{2} = 57.8\,°C$$

Experiment. No. .... Date..............

$\Delta\ (C_{pc}, \rho_c)$ at

$$T_c = \frac{T_3 + T_5}{2} = \frac{32.3 + 37.8}{2} = 35.05^\circ C$$

$C_{ph} = 4.184\ KJ/kg K$
$C_{pc} = 4.178\ KJ/kg-K$
$\rho_h = 984.3322\ Kg/m^3$
$\rho_c = 994.04627\ Kg/m^3$

$$M_h = \frac{F_h \times \rho_h}{3600 \times 1000} = \frac{205 \times 984.3322}{3600 \times 1000} = 0.056\ kg/s$$

$$Q_h = M_h C_{ph} (T_1 - T_2)$$
$$= 0.056 \times 4184 (59.4 - 56.2) = 749.7728\ W$$

$$M_c = \frac{F_c \times \rho_c}{3600 \times 1000} = \frac{130 \times 994.04627}{3600 \times 1000} = 0.035\ Kg/s$$

$$Q_c = M_c C_{pc} (T_5 - T_3) = 0.035 \times 4178 (37.8 - 32.3) = \cancel{3728.865\ W}\ 804.265\ W$$

$$Q = \frac{Q_h + Q_c}{2} = \frac{749.7728 + \cancel{8028.86}\ 804.265}{2} = \cancel{2239.3164\ W}\ 777.0189\ W$$

$\Delta T_1 = T_1 - T_5 = 59.4 - 37.8 = 21.6^\circ C$
$\Delta T_2 = T_2 - T_3 = 56.2 - 32.3 = 23.9^\circ C$

$$\Delta T_m = \frac{\Delta T_1 - \Delta T_2}{\ln \frac{\Delta T_1}{\Delta T_2}} = \frac{2.3}{0.10118} = 22.731^\circ C$$

Teacher's Signature ....

$$U_i = \frac{Q}{A_i \, \Delta T_m} = \frac{2239.3164}{0.05024 \times 22.731} = 1960.863 \ W/m^2 \, ^\circ C$$

$$U_o = \frac{Q}{A_o \, \Delta T_m} = \frac{2239.3164}{0.30908 \times 22.731} = 318.732 \ W/m^2 \, ^\circ C$$

$$U_i = \frac{Q}{A_i \, \Delta T_m} = \frac{777.0189}{0.05024 \times 22.731} = 680.398 \ W/m^2 \, ^\circ C$$

$$U_o = \frac{Q}{A_o \, \Delta T_m} = \frac{777.0189}{0.30908 \times 22.731} = 110.596 \ W/m^2 \, ^\circ C$$

Conclusion

We calculated LMTD as $\dfrac{\Delta T_1 - \Delta T_2}{\ln\left(\frac{\Delta T_1}{\Delta T_2}\right)}$

For parallel flow

$Q_h = 715.284\,W$

$Q_c = 704.938\,W$

For counter flow

$Q_h = 749.772\,W$

$Q_c = 804.265$

Generally Q_h should be greater than Q_c. But in counter flow, there may be some apparatus inaccuracy due to which we are getting $Q_c > Q_h$

For Parallel Flow

LMTD = 22.654°C

U_o = 101.41 W/m²°C

U_i = 623.91 W/m²°C

For counter flow

LMTD = 22.731°C

U_o = ~~680~~.110.596 W/m²°C

U_i = 680.398 W/m²°C

Experiment. No. .... Date.............

Pool Boiling Apparatus

Objective
To study about the critical flux in a pool boiling apparatus.

Aim
To determine the critical heat flux of a given wire.

Introduction
When heat is added to a liquid from a submerged solid surface which is at a temperature higher than the saturated temperature of the liquid, it is used for the part of the liquid to change phase. The change in phase is called 'Boiling'.

Theory
The experimental set-up is designed to study the pool-boiling phenomenon up to critical heat flux. The pool boiling over the heater wire can be visualised in the different regions up to the critical heat flux point at which the wire melts. The heat flux from the wire is slowly increased by gradually increasing the applied convection to nucleate boiling can be seen. The formation of bubbles and their growth in size and number can be visualised followed by vigorous bubble formation & their immediate carrying over to surface and ending this in the breaking of wire indicating the occurence of critical heat flux point.

The heat flux supplied to the surface is plotted against $(T_w - T_1)$ (The difference between the temperature of the surface & the boiling temperature of the liquid)

Teacher's Signature ....

It is seen that the boiling curve can be divided into 3 regions:

i) Natural Convection Region
ii) Nucleate Boiling Region
iii) Film Boiling Region

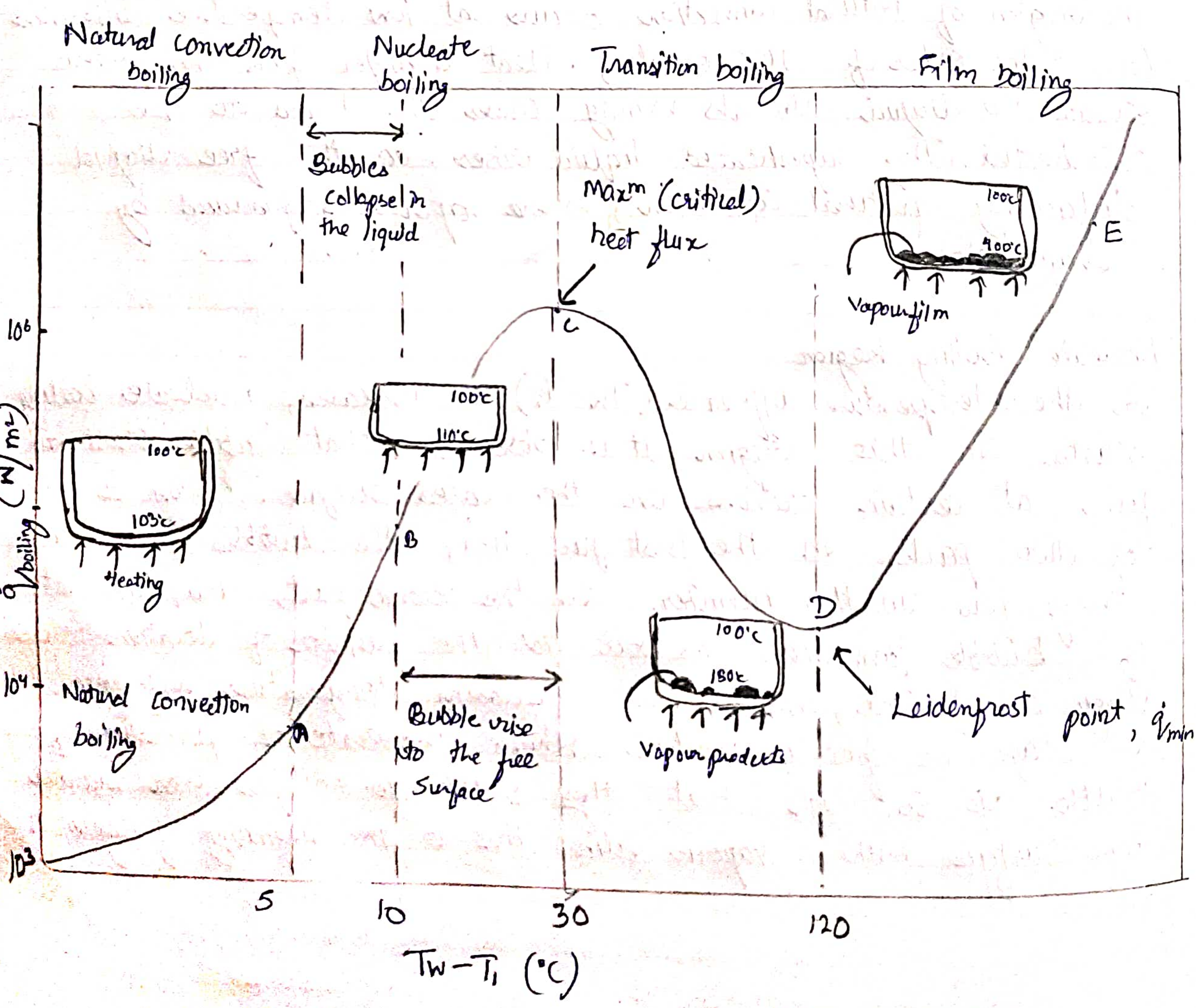
Natural Convection Region

The region of natural convection occurs at low temperature differences (of the order of 10°C or less). Heat transfer from the heated surface to liquid in its vicinity causes the liquid to be superheated. This superheated liquid rises to the free liquid surface by natural convection, where vapour is produced by evaporation

Nucleate Boiling Region

As the temperature difference $(T_w - T_1)$ is increased, nucleate boiling starts. In this region, it is observed that bubble start to form at certain locations on the heated surface. Region II consists of two parts. In the first part, II-a, the bubbles formed are very few in the number. In the Second part, II-b, the rate of bubble formation as well as the number of locations where they are formed, increase. With increasing temperature difference, a stage is finally reached when the rate of formation of bubble is so high, that they start to collapse and blanked the surface with a vapour film. This is the beginning of region III

Pool Boiling Curve



Experiment. No. .... Date.............

Film Boiling Region

In the first part of region III, the vapour film is unstable, so that film boiling may be occuring on a portion of the heated surface area, while nucleate boiling may be occuring on the remaining area. In the second part of region III, a stable film covers the entire surface. The temperature difference is the order of 100°deg C and consequently radiative heat transfer across the vapour film is also signifiant.

Utilities Required

→ Electricity Supply : Single Phase, 220V AC, 50Hz, 5-15 Amp. combined socket with earth connection

→ Water Supply (Initial Full)

→ Floor drain required

→ Floor area required (1m X 1.5m)

Procedure

- Connect the test heater wire. But ensure switches given on the panel are at OFF position
- Set the desired bath temperature with the help of DTC (70-80°C)
- Switch ON the heater and wait till desired temperature achieved.
- Very gradually increase the voltage across test heater by changing the varlac from one position to the other
- Go on increasing the voltage till wire breaks and carefully note down the voltage and current at this point.
- Repeat the experiment for different water bath temperature

Observation & Calculation

Data

Diameter of test heater = 0.132 mm

Length of the wire, L = 0.08m

Observation Table

Sr. No.	Bulk Temperature (°C)	V (Volt)	I (Amp)	$W = VI$	q_c (W/m^2)
1	70°C	24.5	5.1	124.95W	3.76827×10^6 W/m²
2	80°C	30.1	6.1	183.61	5.53736×10^6

Calculations

$$A = \pi \times d \times L = \pi \times 0.132 \times 0.08 = 33.1584 \times 10^{-6} m^2$$

Experiment. No. ....

Date.............

Precautions

- Slowly increase the voltage of the heater
- Ensure the apparatus to be powered off while changing the test heater
- The water may be extremely hot, so be careful while changing the test heater

Conclusion

The test heater wire has very less surface area due to which very small bubbles get generated.

The critical heat flux (q_c) is determined for both 70C & 80°c.

$$(q_c)_{70°c} = 3.76 \times 10^6 \; W/m^2$$

$$(q_c)_{80°c} = 553 \times 10^6 \; W/m^2$$

Teacher's Signature ....