Group C1a

CHEMICAL ENGINEERING LAB II PROJECT FINAL REPORT

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Fouling in Finned Tube Heat Exchanger

OBJECTIVE:-

- To determine the efficiency of the longitudinal fin with fouling and compare it with the efficiency of a normal fin.
- To determine the fouling factor(fouling resistance) .

Concept

Fouling is the formation of unwanted material deposits on heat transfer surfaces during process heating and cooling

TYPES OF FOULING

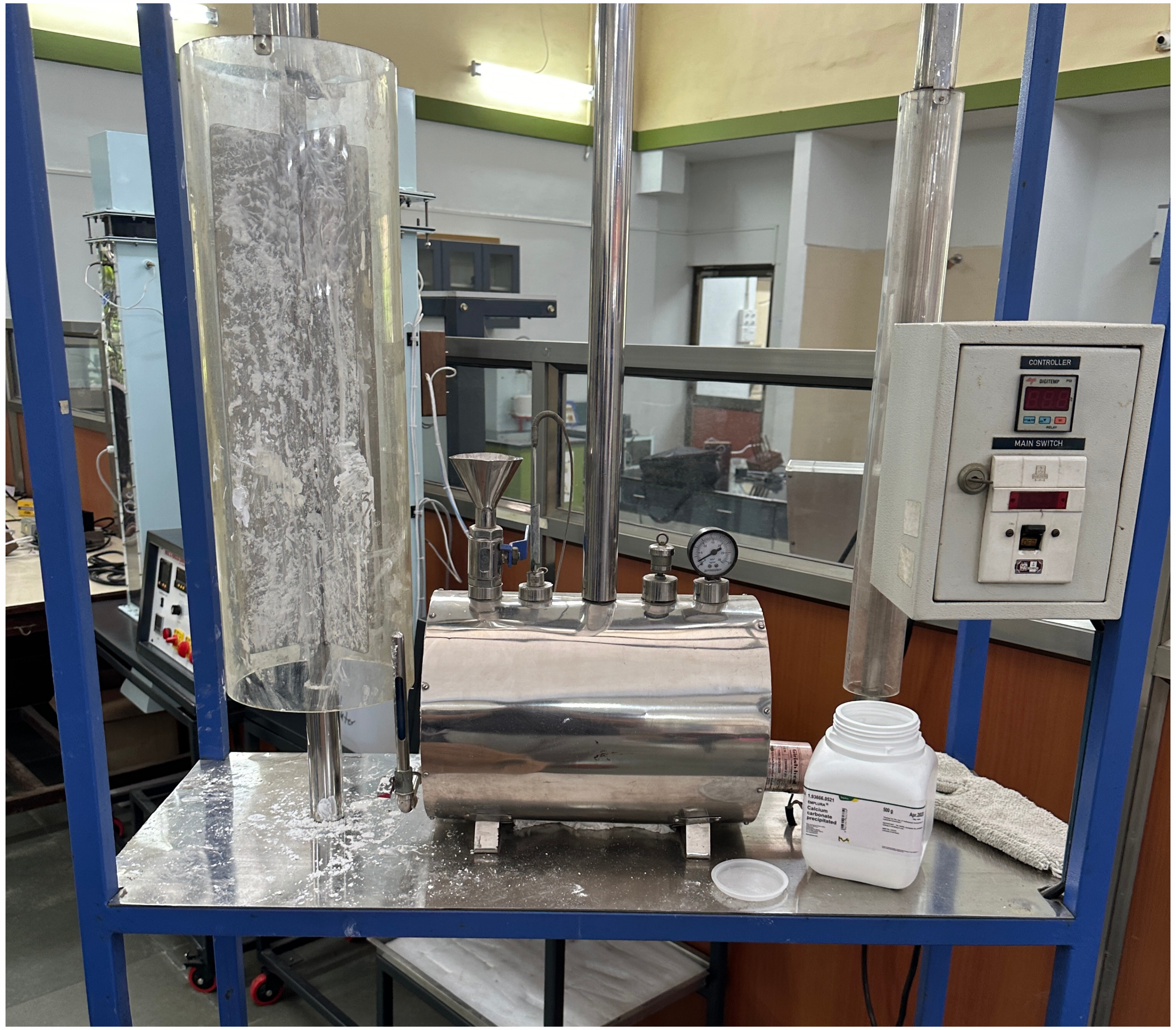
- **Incrustation**: the accumulation of a crust or coating of processed fluids, minerals, or cleaning agents on the surface of heat exchanger parts.

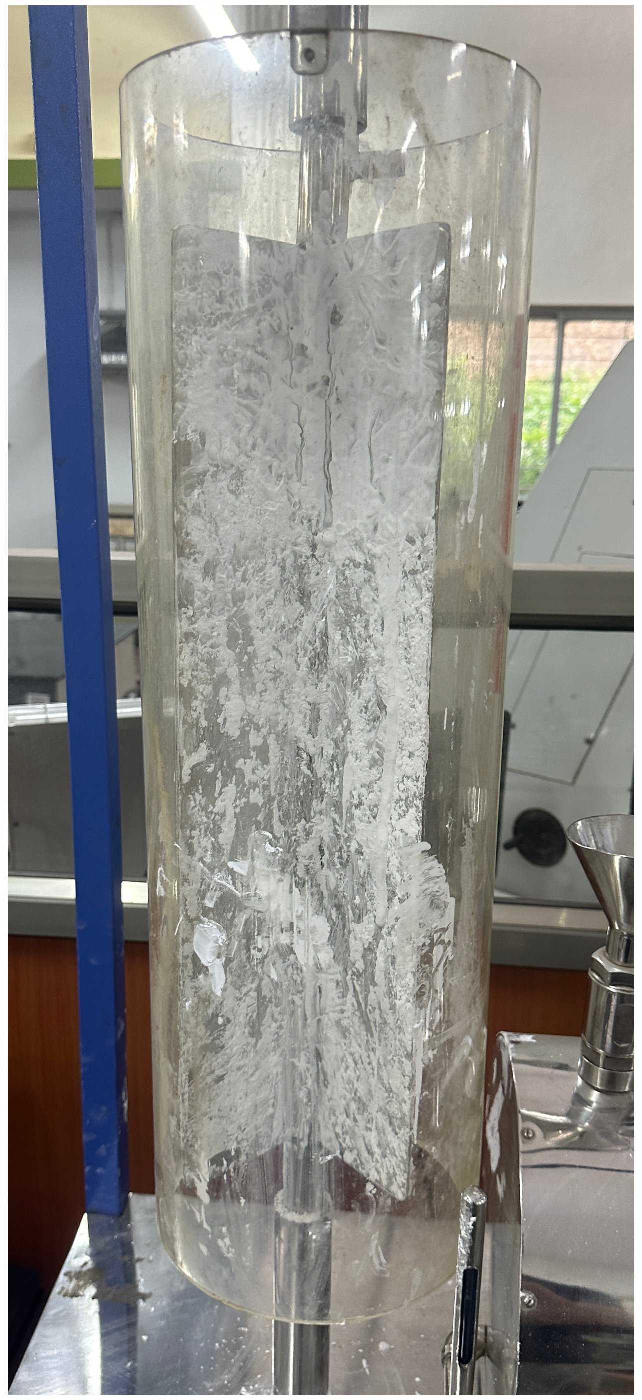
- **Scaling**: a type of incrustation caused by calcium carbonate, calcium sulfate, and silicates.

- **Sediment**: comes from corrosion products, metal oxides, silt, alumina, and diatomic organisms (microalgae) and their excrement.

- **Biological growth**: Sources of biofouling include bacteria, nematodes, and protozoa.

EXPERIMENTAL SETUP





DISADVANTAGES OF FOULING

- **Reduced Heat Transfer Efficiency**: Fouling deposits act as insulating layers, reducing the thermal conductivitv of the heat exchanger surfaces. This diminishes the efficiency of heat transfer and necessitates a higher temperature difference between the hot and cold fluids to maintain the desired heat transfer rate.

- **Increased Energy Consumption:** To compensate for the reduced heat transfer efficiency, more energy is required to maintain the desired heat exchange rate. This leads to increased energy consumption and higher operational costs.

- **Reduced System Performance**: Fouling can lead to a decrease in the overall performance of the heat exchanger. It may result in a lower heat transfer coefficient, causing the heat exchanger to operate below its design specifications.

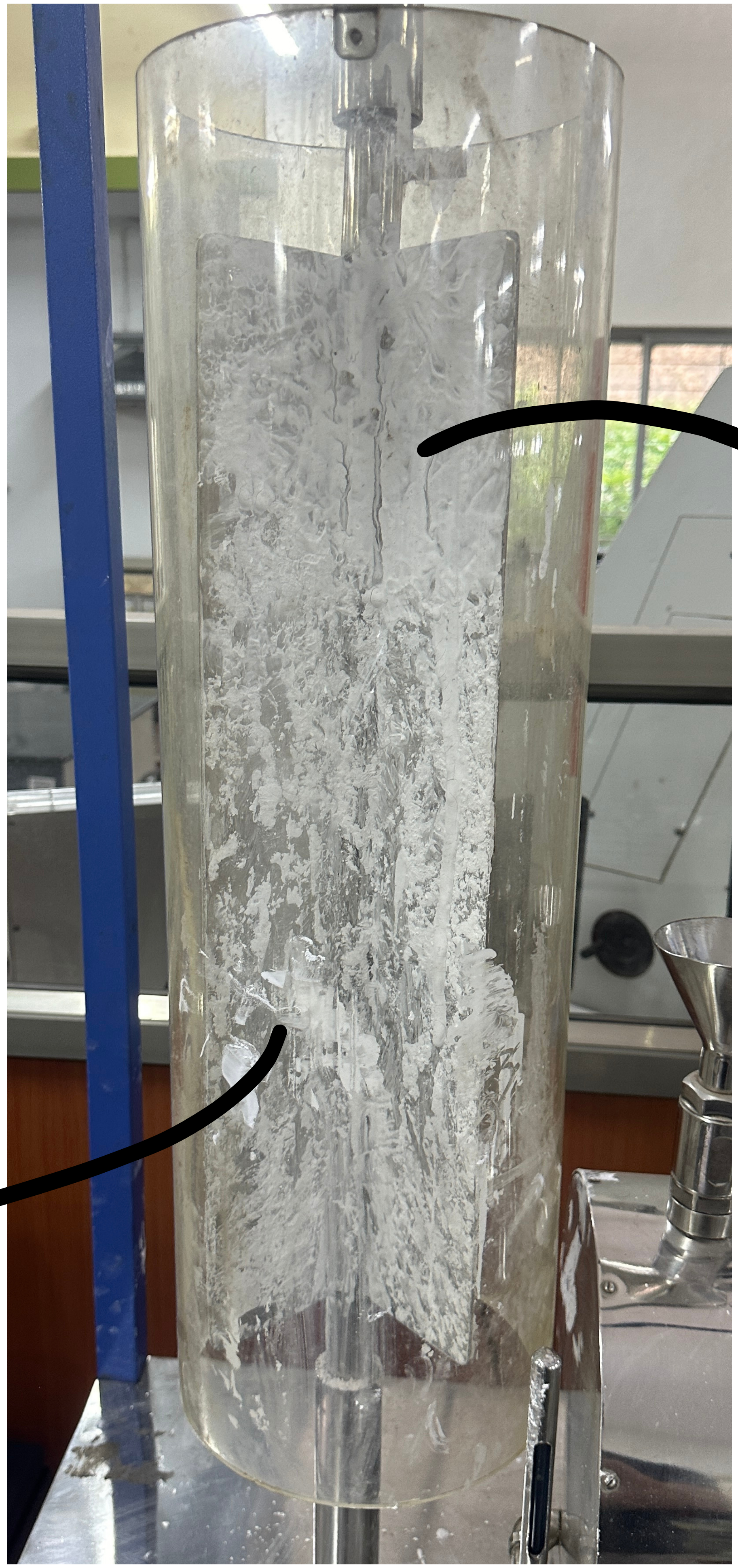
- **Shorter Equipment Lifespan**: The accumulation of fouling materials can lead to corrosion, erosion, and other forms of material degradation on the heat exchanger surfaces. This can shorten the equipment's lifespan and increase maintenance and replacement costs.

- **Increased Maintenance Requirements**: Frequent cleaning and maintenance are necessary to remove fouling deposits. Maintenance not only requires time and labor but also results in downtime, reducing the availability of the heat exchanger.

- **Risk of Microbiological Growth**: In some cases, fouling can create an environment conducive to the growth of microbiological organisms, such as bacteria or algae. This can further exacerbate fouling problems and lead to microbiologically induced corrosion (MIC).

- **Pressure Drop**: Fouling deposits can obstruct flow paths, causing an increase in pressure drop. This can result in a higher energy requirement for fluid circulation and may necessitate more powerful pumps

Finned Tube Heat Exchanger with Fouling



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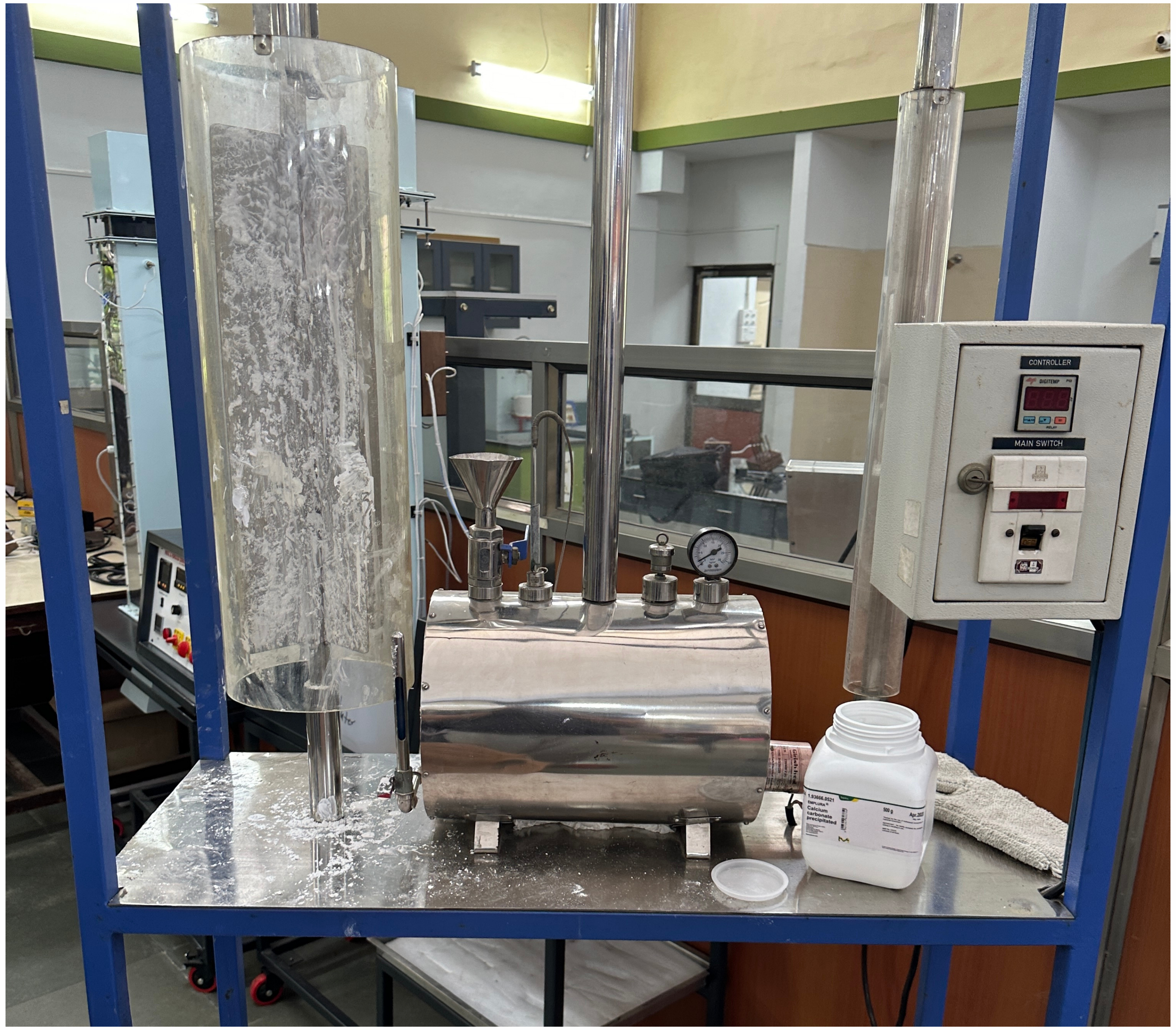

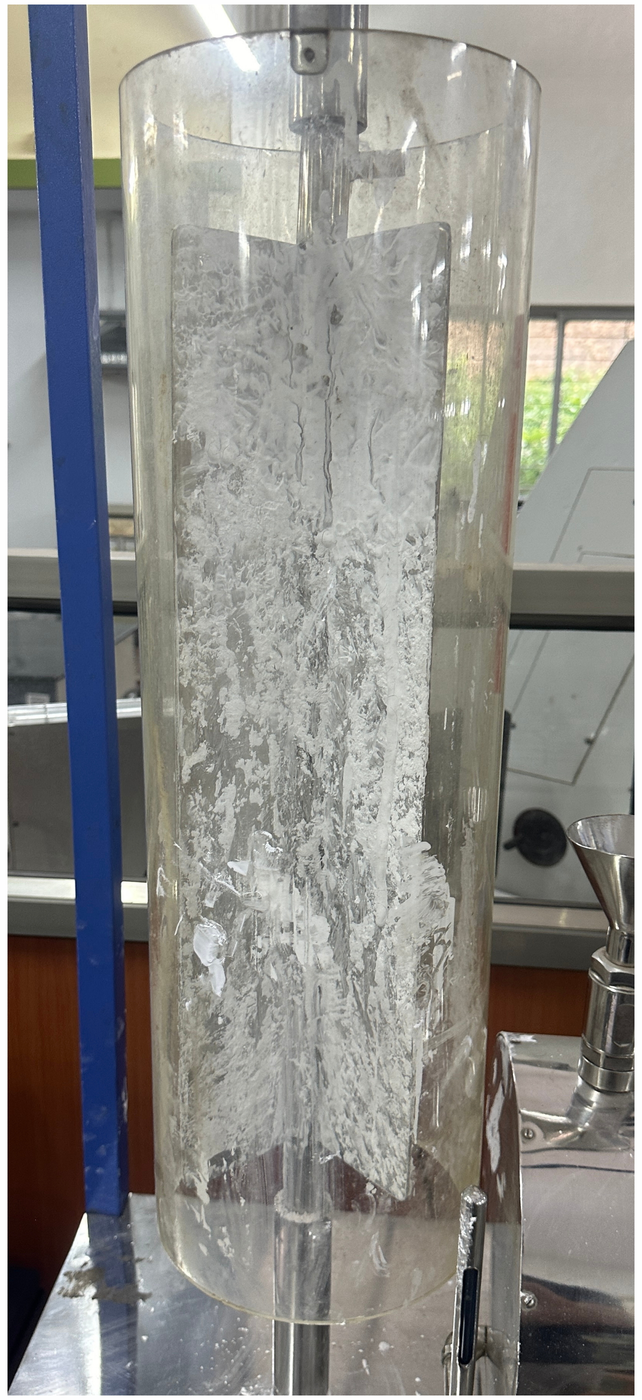

THEORY

Heat transfer from a hot solid surface to a flowing fluid is governed by the Newton's law of cooling shown by Eq. (1).

$$Q = hA_S\left(T_S - T_\infty\right) \tag{1}$$

where T_S is the surface temperature and T_∞ is the temperature of the fluid far from the surface. Therefore, heat transfer rates may be enhanced by:

i. Increasing the temperature difference $\left(T_S - T_\infty\right)$ between the surface and the fluid.

ii. Increasing the heat transfer coefficient h.

iii. Increasing the contact surface area A_S.

The overall heat transfer coefficient is given by Eq. (2) shown below:

$$\frac{1}{U_i A_i} = \frac{1}{h_i A_i} + \frac{x}{k_m \bar{A}_l} + \frac{1}{h_o A_o} \tag{2}$$

where

U_i is the overall heat transfer coefficient based on inside surface area in units of Kcal/hr m^2 °C

h_i and h_o represent the inside and outside heat transfer coefficients in units of Kcal/hr m^2 °C

A_o is the outside surface area in m^2 and A_i is the inside surface area in m^2

k_m is the thermal conductivity of the wall in Kcal/hr m°C

$\bar{A}_l$ is the logarithmic mean of inside and outside area of the tube in m^2

FIN EFFICIENCY

The fin efficiency is defined as ratio of actual heat transfer rate through fin to the maximum possible heat transfer rate that could occur through fin. It is denoted by η.

For longitudinal fin with insulated tip, the theoretical fin efficiency is given by Eq. (3) below

$$\eta_{fin} = \frac{\tanh\left(mL_{fin}\right)}{mL_{fin}} \tag{3}$$

Where L_{fin} is length along the only direction where temperature is assumed to vary in the fin.

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

h = heat transfer coefficient from the fin surface in Kcal /hr m^2 °C

C = circumference of the fin in m

k = thermal conductivity of fin material in Kcal /hr m°C

A = cross-sectional area of fin in m^2

FOULING FACTOR

The fouling factor represents the theoretical resistance to heat flow due to a build-up of a layer of dirt or other fouling substance on the tube surfaces of the heat exchanger

$$R_f = \frac{1}{U_{fouling}} - \frac{1}{U_{clean}}$$

PROCEDURE

1. Start-up procedure
    a. Plug in coil from heater to power supply.
    b. Open drain valve provided at the bottom of steam generator and drain out the water
    c. from Steam Generator completely.
    d. Close the drain valve.
2. Add 4 litres of distilled water through feed valve at the top of steam generator and close it. *Ensure dead weight safety valve is free.*
3. Check water level in the steam generator and *make sure that water level is such that the heating coil remains completely immersed in water throughout the experiment.*
4. *Start the electrical heater of steam generator. Initially supply full voltage to the electrical heater. Set the operating temperature to 105°C. Temperature should not exceed 110° C during the experiment.*
5. Steam will start forming at approximately 20 min. after switching on the heater.
6. Once steam starts forming, Finned Tube Heat Exchanger (FTHX) and Bare Tube Heat Exchanger (BTHX) will start getting heated up and condensate will begin forming inside
7. the tube.
8. Drain valve is opened at 15 min. intervals for Finned Tube Heat Exchanger to collect
9. condensate in plastic containers and at intervals of 30 min. collect the condensate for the Bare Tube Heat Exchanger.
10. *Condensate should be completely drained out, but steam should not escape during the collection of the condensate. Hence, do not open drain valve completely.*
11. If the quantity of condensate collected is same for 2-3 consecutive readings, note down the volume of condensate collected and time interval.
12. Note the observations in the table format given below and note readings till the experiment is completed.
13. On completion of experiment, the shutdown procedure is:
    a. a) Reset temperature values to room temperature, i.e., 25°C-27°C.
    b. b) Remove the plug from power supply after switching off.
    c. c) Discard all water collected during the experiment in a distilled water can.
    d. d) Any water that may have spilled or leaked should be cleaned up.

EXPERIMENTAL DATA

	Volume (ml)	
Time (min)	Finned Tube	Bare Tube
15	80	
30	65	65
45	65	
60	65	55
75		
90		60
105		
120		60

GIVEN DATA

Finned Tube		
Height of fin (L)	0.5	m
Width of fin (W)	0.07	m
Thickness of fin (b)	0.003	m
Number of Fins (N)	4	
O.D. of fin tube	0.025	m
Height of Tube	0.58	m
Thermal conductivity	13.97	KCal/hr m °C
Density of water	1	g/cm^3
lambda	557.97	KCal/Kg

Bare Tube		
O.D. of tube	0.025	m
Height of tube	0.58	m

CALCULATIONS

Calculations		
Circumference of fin (C) = 2 (L+b)	1.006	m
Cross sectional area of fin (A’) = L x b	0.0015	m^2
Fin area available for heat transfer (AF)	0.28168	m^2
(AB) = π x D x Lt – N x b x L	0.0395530934	m^2
(At) = (AF) + (AB)	0.3212330935	m^2
(Q1) = m1 x λ	145.0722	KCal/hr
(Q2) = m2 x λ	66.9564	KCal/hr
Area of bare heat tube exchanger	0.0455530934	m^2
h from bare heat tube exchanger	19.59805431	KCal/hr m^2°C
m	30.67338009	1/m
m*Lfin	2.147136606	
n theoretical	45.3196347	%
QFin = Q1 – (AB X h X ΔT)	86.93492444	KCal/hr
Qideal = AF x h x ΔT	414.0284954	KCal/hr
n Observed	20.99732879	%
error	53.66836268	%

Calculations were done using excel

For Standard Experiment

https://docs.google.com/spreadsheets/d/13qOrx_vClxEwxTpLCs6XF1VRpAdWa-OK-GHv-6-ypFo/edit#gid=0

For Fouling Experiment

https://docs.google.com/spreadsheets/d/1THxj21JMdzXFP80WiCKD_itsJP4fxjAnlTTNfdEt6XY/edit#gid=0

Fouling Factor Calculation

$$\boxed{R_f = \frac{1}{U_{fouling}} - \frac{1}{U_{clean}}}$$

$$U_{fouling} = 6.02 \ W/m^2K$$

$$U_{clean} = 6.95 \ W/m^2K$$

$$R_f = \frac{1}{6.02} - \frac{1}{6.95}$$

$$R_f = 2.22 \times 10^{-2} \ m^2K/W$$

RESULTS

	Normal Finned Tube	Finned tube with Fouling
Condensation	75ML	65ML
Heat given out by steam	167.4 Kcal/hr	145 Kcal/hr
Theoretical Efficiency	47.45%	45.30%
Observed Efficiency	30.88%	20.99%
Error	34.90%	53.30%
Heat Transfer Coeff	6.95 W/m^2K	6.02 W/m^2K

CONCLUSIONS

1

Fouling decreases the efficiency of heat transfer process

2

Finned tube with fouling had a lower heat transfer coefficient than the normal finned tube

3

The observed efficiency of finned tube with fouling is 32% lower than the efficiency of the normal finned tube

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Thank you!