INSTRUCTION MANUAL
FOR
THERMAL SCIENCE LABORATORY EXPERIMENTS

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GENERAL INSTRUCTIONS

1. The instructions in this manual provide only the outline. Come prepared with the back-up material i.e. go through the theory related to the experiments, know in advance the readings to be taken, the calculations to be performed and the results to be presented

2. The data sheets are to be countersigned by the instructor. The calculations are to be completed and checked by the instructor on the same day. The complete report should be submitted on the day of next lab class.

3. Each student has to submit his/her individual report and his/her individual comments and remarks.

4 The report should include
   - The aim of the experiment
   - A sketch/block diagram of the apparatus
   - A listing of the instruments used with details (type, range, accuracy etc.)
   - Transient/steady state readings in tabular form
   - Results in graphical form where required
   - Comments and natures of the results with standard/reference values.
   - Source of errors and error analysis.

5. The report need not include
   - A description of the Apparatus
   - A description of the experimental procedure

6 The following points should be attended before starting the experiment.
   - Take note of any precaution with regard to the experimental set-up
   - Check electrical connections before starting the experiment.
   - Clarify any doubt with regard to the experiment
   - Do not put on the computer attached to the set-up

DO NOT PUT ON THE SYSTEM UNTIL THE CONNECTION ARE CHECKED BY THE INSTRUCTOR

HEAT EXCHANGER

AIM: To determine the overall heat transfer coefficient 'U' in the parallel flow and counter-flow heat exchanger and to plot the temperature profile on the cold water and hot water circuit.

PRINCIPLE: The process of heat exchange between two fluids that are at different temperatures and separated by a solid wall occurs in many engineering applications. The device used to implement this exchange is termed a heat exchanger, and specific applications may be found in power production, waste heat recovery and chemical processing. Heat exchangers are typically classified according to the flow arrangement. The simplest heat exchanger is one for which the hot and cold fluids move in the same or in opposite directions in a concentric tube. In the parallel flow arrangements of fig.1 shown leaves at the same end. In the counter flow arrangement of fig. 2, the fluids enter at opposite ends, flow in opposite directions, and leave at opposite ends.

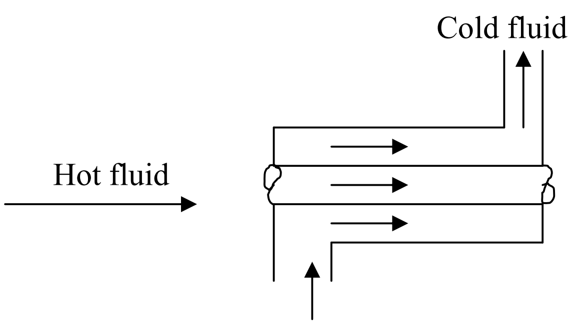

Fig .1 Parallel flow

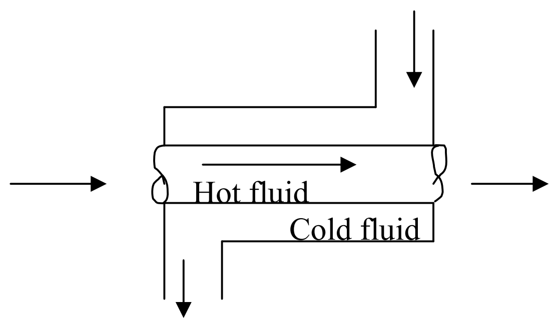

Fig .2 Counter flow

$Q_h = m_h C_{ph} (T_{h,i} - T_{h,o})$; $Q_c = m_c C_{pc} (T_{c,o} - T_{c,i})$
$h \rightarrow$ hot side; $c \rightarrow$ cold side; $i \rightarrow$ inlet; $o \rightarrow$ outlet

With no losses
$Q_h = Q_c$
If $Q_h \neq Q_c$; $Q_m = (Q_h + Q_c)/2$

$Q_m = U A_m \Delta T_{lm}$; where U is the overall heat transfer coefficient.

Logarithmic temperature $\Delta T_{lm} = \dfrac{\Delta T_2 - \Delta T_1}{\ln \dfrac{\Delta T_2}{\Delta T_1}}$

$\Delta T_2 = T_{h,o} - T_{c,o}$; $\Delta T_1 = T_{h,i} - T_{c,i}$ for parallel flow heat exchanger
$\Delta T_2 = T_{h,o} - T_{c,i}$; $\Delta T_1 = T_{h,i} - T_{c,o}$ for counter flow heat exchanger

$A_m = \dfrac{A_h - A_c}{\ln \dfrac{A_h}{A_c}}$, A_h and A_c are the area of the heat exchanger on the hot and cold side

APPRATUS:

Fig3. Shows the various parts of the tubular heat exchanger. A tank with centrifugal pump and electric heater is located beneath the instrument panel. Master switch, emergency stop, pump and heating switches are provided on the apparatus panel. The hot water temperature is set at the heater by means of a thermostat. Tap water is used for the cold water supply and then drained off after the use. The heat exchanger inlet and outlet temperatures are measured at each water circuit by PTC elements. Two more PTC elements are fitted in the heat exchanger. The hot and cold flow rates are measured by two turbine flow meters and set using the valves. The measured values for temperature and flow are digitally displayed on the control panel of the apparatus. The pipes are made of copper and carefully insulated.

Pipe flow can be set for parallel flow or counter heat exchanger as shown in figures 4 & 5.

Parallel flow: open the valves 1 and 3, close the valves 2 and 4.

Counter flow: open the valves 2 & 4, close the valve 1 and 3.

EXPERIMENTAL PROCEDURE:

1) Check the power supply connections and set the heat exchanger either for parallel flow or counter flow.
2) Check the water level in the heater tank. Put on the heaters and wait for half an hour.
3) Start the flow the cold-water circuit by drawing water from tap. Set the flow rate to 40 liters/hour and start the pump so that the water starts flowing the hot water circuit. Set the flow rate to 100 liters /hour.
4) Wait until thermal equilibrium is reached i.e., when the temperatures fluctuates less then 1 ^{0}C per minute. For this purpose, it is sufficient to observe the outlet temperatures i.e.,$T_{c,0}$ and $T_{h,o.}$
5) Once the thermal stability is reached, take the following reading: inlet temperature, outlet temperature and intermediate temperature both in the cold and hot water circuit, flow rate of the cold water and hot water circuit, flow rate of hat water and cold water.
6) Set the heat exchanger for counter flow and repeat all the above steps.
7) Put off the hot water pump and heater. Allow, the cold water to flow for 10 minutes before the cold-water flow is stopped.

WARNING:

1) The turbine flow meter may be operated at a maximum temperature of 70^0 C.
2) Never switch on the heater without water inside the tank.
3) Do not switch on the pump without the tank being full.
4) Do not put the personal computer attached to the heat exchanger device. Any student found putting on the personal computer on his own or who is found the personal computer for the purpose other than running experiment would be immediately disqualified from the laboratory.
5) When the connecting the cooling water, ensure that the intake and outlet are not mixed up. If the flow rate sensor is flowed through in wrong direction, incorrect measurement is obtained.

RESULTS:

Calculate the overall heat transfer coefficient both in parallel flow and counter flow heat exchanger and also plot the temperature profile both on cold water and hot water circuit.

TECHNICAL DATA

Heat Exchanger Area: Hot side = 0.0306 m^2

Cold side = 0.0402 m^2
Mean log = 0.0349 m^2

Different component of Heat Exchanger (figure: 3)
1) Test stand
2) Tank
3) Centrifugal pump
4) Heater
5) Apparatus panel
6) Thermostat
7) Water connections
8) Ball valves

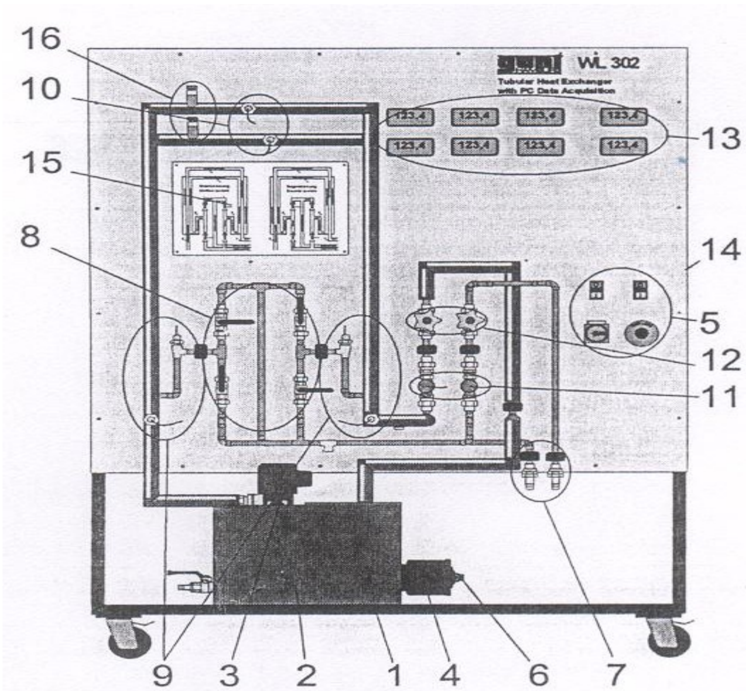

Fig: 3 Different component of Heat Exchanger

9) Temperature detector
10) Turbine flow meters
11) Flow control valves
12) Digital display
13) P.C.interface
14) Indicator panel
15) Bleed valve

Heat Exchanger

Parallel Flow Heat Exchanger

Cold Water Flow Rate (Ltr/hr) :83 L/h
Hot Water Flow Rate (Ltr/hr) :94L/h

S. No	Hot water inlet temperature, (T_1) °C	T_{ci} (T_4)	T_{co}(T_6)	T_{ho}(T_3)	U
1	34.8	29.2	30.8	32.8	
2	43.5	28.2	33.0	37.2	

Hot Water inlet temperature (°C):41.5

S. No	Cold Water Flow Rate (Ltr/hr)	T_{ci}	T_{co}	T_{hi}	T_{ho}	U
1	33	25.6	31.8	41.5	33.7	
2	57	25.4	29.4	41.5	32.6	

Counter Flow Heat Exchanger

Cold Water Flow Rate (Ltr/hr) :33 l/h
Hot Water Flow Rate (Ltr/hr) :27.7 l/h

S. No	**Hot water inlet temperature, °C**	T_{ci}	T_{co}	T_{ho}	**U**
1	30.1	24.5	27.4	27.6	
2	41.2	25.2	32.5	32.7	

Hot Water inlet temperature (°C):41.5

S. No	**Cold Water Flow Rate (Ltr/hr)**	T_{ci}	T_{co}	T_{hi}	T_{ho}	**U**
1	33	25.2	32.7	41.5	32.7	
2	57	24.4	28.5	41.5	31.5	

Conclusion :