Heat Transfer Sessional Manual

Department of Mechanical Engineering

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INDEX

Reference:

1. PROCESS HEAT TRANSFER, by
   Wareh L. McCabe

   Julian C. Smith

   Peter Harioth

   Publication: McGraw Hill (6th edition)

2. Heat and Mass Transfer by Arora & Domkundwar

3. Chemical Engineers' Handbook, by
   Robert H. Perry / Cecil H. Chilton

   Publication: McGraw–Hill Book Company (6th edition)

Special Thanks to: Malla Reddy College of Engineering and Technology

1.HEAT TRANSFER THROUGH COMPOSITE WALL

INTRODUCTION:

In engineering applications, we deal with many problems. Heat Transfer through composite walls is one of them. It is the transport of energy between two or more bodies of different thermal conductivity arranged in series or parallel. For example, a fastener joining two mediums also acts as one of the layers between these mediums. Hence, the thermal conductivity of the fastener is also very much necessary in determining the overall heat transfer through the medium. An attempt has been made to show the concept of heat transfers through composite walls.

DESCRIPTION OF THE APPARATUS:

The apparatus consists of three slabs of Mild Steel, Bakelite and Aluminum materials of thickness 25, 20 & 12mm respectively clamped in the center using screw rod.

At the center of the composite wall a heater is fitted. End losses from the composite wall are minimized by providing thick insulation all round to ensure unidirectional heat flow.

Front **transparent acrylic enclosure** to minimize the disturbances of the surrounding and also for safety of the composite slab when not in use.

Control panel instrumentation consists of:

a. **Mains on indicator**
b. **Console On switch** for activation of the control panel.
c. **Scanner for measurement of**
   i. Temperatures at various locations of the slab.
   ii. Input Voltage.
   iii. Input Current.

d. **Heater regulator** to regulate the input voltage.

With this the whole arrangement is mounted on an aesthetically designed self-sustained Nova pone control panel.

AIM: To determine

1. The overall thermal conductance (C) for a composite wall and to compare with theoretical value.
2. Temperature distribution across the width of the composite wall.

PROCEDURE : MANUAL

1. Symmetrically arrange the plates and ensure perfect contact between the plates.
2. Give necessary electrical connections to the instruments.
3. Switch ON mains and the CONSOLE.
4. Set the heater regulator to the known value.
5. Wait for sufficient time to allow temperature to reach steady values.
6. Note down the Temperatures, voltage and current using the Data logger.
7. Calculate the overall conductance using the formulae given below.
8. Repeat the experiment for different heat input.

OBSERVATIONS:

Sl. No.	Temperatures °C						Heater Input	
	T_1	T_2	T_3	T_4	T_5	T_6	V	I
1								
2								
3								
4								
5								

PROCEDURE: COMPUTERIZED

READINGS – COMPUTERIZED

1. Symmetrically arrange the plates and ensure perfect contact between the plates.
2. Give necessary electrical connections to the instruments.
3. Switch ON mains and the CONSOLE.
4. Set the heater regulator to the known value.
5. Wait for sufficient time to allow temperature to reach steady values.
6. Turn on the computer switch on the panel.
7. Switch on the computer.

8. Open the **" HEAT TRANSFER Software"** from the installed location a welcome screen will be displayed

9. Follow the below steps to operate through software
   a. Login using the given password into the software
   b. Screen will display the concept of the equipment. Now login to the experiment by clicking the **"Click to login"** button on the screen.
   c. Give required username for the experiment to be conducted.
   d. Once the software is opened, the main screen will be displaced
   e. Now, press **"START"** button, and the small screen will opened for any messages and also Specifications to be entered.
   f. Enter the parameters listed for particular test under study.
   g. Now, set the heater regulator to known valve.
   h. Wait for sufficient time to allow temperature to reach steady values.
   i. The software starts displaying the calculated values which can be cross verified based on the formulae give after.

10. Click the **"store"** button to store, the value can be viewed anytime later.
11. After completion of the Experiment, press the **"STOP"** Button.
12. To view the stored data follow the procedure in Annexure.

CALCULATIONS ARE BASED ON THE BELOW FORMULAE:

1. HEAT FLUX ,

$$q = \frac{V \times I}{A} \text{ Watts}$$

Where,

V = voltmeter reading, volts

I = ammeter reading, amps

A = Area of the plate/s = $(\pi d^2/4)$ m^2, d = 0.2m

2. AVERAGE TEMPERATURES:

$T_A = T1$

$T_B = (T2 + T3)/2$

$T_C = (T4 + T5)/2$

$T_D = T6$

Where,

T_A = Average inlet temperature to Aluminium.

T_B = Average outlet temperature from Aluminimum.

Average inlet temperature of MS

T_C = Average outlet temperature to MS.

Average inlet temperature to Bakelite.

T_D = Average outlet temperature to Bakelite.

3. THERMAL CONDUCTANCE:

PRACTICAL:

$$C = \frac{Q}{(T_A - T_D)} \text{ W/m}^0\text{ K}$$

Where,

Q = heat input in watts

(T_A – T_D) = Temperature difference as calculated.

THEORETICAL:

$$C = \frac{1}{1/A\,(L_1 / K_1 + L_2 / K_2 + L_3 / K_3)} \quad \text{W/m °K}$$

K_1 = 205 W/m °K

K_2 = 25 W/m °K

K_3 = 0.08 W/m °K

L_1 = 12 mm L_2 = 25 mm L_3 = 20 mm

4. OVERALL THERMAL CONDUCTIVITY OF THE SLAB, K

$$\frac{Q\ X\ B}{T_{A-}T_D} \text{ W/m}^0\text{K}$$

Where, B = thickness of the plates on one side = 0.057m

TROUBLE SHOOTING: General causes and remedies

CAUSES	REMEDY
Mains on indicator not glowing	Check input electrical connection.
No power to indicators	Switch on the console, still not working call the supplier.
Still unable to start, call the supplier	

Data management system/Unable to acquire data properly

CAUSES	REMEDY
Readings cannot be taken.	Un – install then Re-Install the software.
Low Voltage (minimum should be 220V)	Switch off the system till the voltage is stabilized to proper value.
Variation in the VOLTAGE (should not be more than 10V)	Check and stabilize it
Earthing not properly made.	Check and stabilize it.
Magnetic parts and induction equipments near the Indicators.	Remove it and place 5m away from the equipment.
Unable to take the printout	Check the printer connection. Still unable to so, check the printer software settings and redefine if necessary.
Still unable to acquire, call the supplier	

Indicators not showing proper values – IN CASE USED

CAUSES	REMEDY
Not calibrated properly	Check for any loose connection in the wire and also check for any air gap in the tubes of the pressure tapping points.
Indicator not working properly	Check the sensor wire and connection.
Still unable to find the problem, call the supplier	

DO's	DON'Ts
Check the electrical connections before switching on the panel.	Switch on the panel if the voltage is low as specified.
Ensure water flow to the equipment and continue the flow for 15min before and after the experiment.	Run the equipment without supply of water to the transducer.
Grease the mating parts regularly.	Touch the rotating parts when equipment is running.
Keep the equipment clean and run at least 15min for every week.	Keep the equipment idle for more days as this may clog the moving parts.
Run the equipment in the Temperature limit of 200C.	Over temperature to the equipment, as this may cause damage to the whole system.
Still unable to find the problem, call the supplier	

LIMITATIONS & PRECAUTIONS

1. Maximum Load is limited to 120V.
2. This is a general equipment for study in undergraduate level, for consideration of higher level studies you can add any extra parameter required. For adding the parameters call the supplier.
3. Don’t run the equipment if the voltage is less than 180V.
4. 230V, 1ph with neutral and proper earthing to be provided.
5. Don’t alter the equipment without the supervision of the supplier.

Reference:

1. Heat and Mass transfer by Arora & Domkundwar
2. Chemical Engineers’ Handbook, by
   Robert H. Perry / Cecil H. Chilton

Publication: McGraw – Hill Book Company (6th edition)

EXPT-2

CRITICAL HEAT FLUX APPARATUS

1. INTRODUCTION:

Boiling and Condensation are the specific convection processes which is associated with change of phase. The co – efficient of heat transfer are correspondingly very high when compared to natural conventional process while the accompanying temperature difference are small (quite).

However, the visualization of this mode of heat transfer is more difficult and the actual solutions are still difficult than conventional heat transfer process.

Commonly, this mode of heat transfer with change of phase is seen in Boilers, condensers in power plants and evaporators in refrigeration system.

2. DESCRIPTION OF APPARATUS

1. The apparatus consists of a specially designed **Glass Cylinder**.
2. An arrangement above the Cylinder in the form of **Bakelite plate** is provided to place the main **Heater** and the Nichrome wire heater arrangement.
3. The base is made of MS and is powder coated with Rubber cushion to place the Glass cylinder.
4. **Heater regulator** to supply the regulated power input to the heater.
5. **Digital Voltmeter and Ammeter** to measure poser input ot the heater.
6. **Thermocouples** at suitable position to measure the temperatures of body and the air.
7. **Digital Temperature Indicator** with channel selector to measure the temperatures.
8. The whole arrangement is mounted on an Aesthetically designed sturdy frame made of MS tubes and NOVAPAN Board with all the provisions for holding the tanks and accessories.

AIM:

1. To observe the formation of pool boiling and
2. To draw the graph of heat flux Vs. Bulk Temperature upto Burnout (Critical) condition.

i. PROCEDURE:

1. Fill in the Glass Cylinder with **Distilled Water** above the heater level.
2. Connect the **Nichrome Wire** (Test Wire) of suitable length.
3. Keep the heater regulator to the minimum position.
4. Connect the power cable to 1Ph, 220V, 10 Amps with earth connection.
5. Switch on the Mains On to activate the control panel.
6. By using the Main Heater heat the water to the known temperature and switch off the same.
7. Now, using the Dimmer provided start heating the **Test Wire** by slowly rising the Current till the wire breaks.
8. Meanwhile, record the temperature, voltage and Current till the wire breaks. (also note the above parameters even at the break point.)
9. Repeat the above experiment by replacing the **Test Wire** and for Different Temperatures of Water.

OBSERVATIONS

Sl. No.	Temperatures °C			Heater Input	
	T1	T2	T3	V	I
1					
2					
3					
4					
5					

CALCULATIONS:

1. **Surface Area of the Wire, A**

$$a = \pi DL \quad m^2$$

where d = diameter of Test Wire.

L = Length of Test Wire.

2. **Heat Input, Q**

$$Q = V \times I \text{ Watts.}$$

Where,

V = Voltage in Volts.

I = Current in Amps.

3. **Heat Flux, q**

$$q = \frac{Q}{A} \ W/m^2$$

4. **Heat Transfer Co - efficient, h**

$$h = 1.54q^{0.75} \ W/m^2 K$$

Where,

q = Heat Flux

5. **Temperature Excess, ΔT**

$$\Delta T = \sqrt{\left(\frac{h}{5.58}\right)} \ K$$

TABULAR COLUMN

Sl No	Heat Flux, q	Temperature Excess, ΔT

RESULTS:

- Draw the Graph of **q** vs. **ΔT** and
- Compare **ΔT** with the experimental Values i.e.,

  (Difference of Water Temparatue and the Test Wire/Boiling Temperature)

PRECAUTIONS

1. Clean the tank regularly after every use.
2. Do not run the equipment if the voltage is below 180V.
3. Check all the electrical connections before running.
4. Do not attempt to alter the equipment as this may cause damage to the whole system.

Note: For any further clarifications on how to run the equipment or for up gradation, please write to us at:

3. MEASUREMENT OF SURFACE EMMISSIVITY

INTRODUCTION:

Radiation is one of the modes of heat transfer, which does not require any material medium for its propagation. All bodies can emit radiation & have also the capacity to absorb all or a part of the radiation coming from the surrounding towards it. The mechanism is assumed to be electromagnetic in nature and is a result of temperature difference. Thermodynamic considerations show that an ideal radiator or black body will emit energy at a rate proportional to the fourth power of the absolute temperature of the body. Other types of surfaces such as glossy painted surface or a polished metal plate do

not radiate as much energy as the black body , however the total radiation emitted by these bodies still generally follow the fourth power proportionality. To take account of the gray nature of such surfaces, the factor called emmissivity (ε), which relates the radiation of the gray surface to that of an ideal black surface, is used. The emissivity of the surface is the ratio of the emissive power of the surface to the emissive power of the black surface at the same temperature. Emissivity is the property of the surface and depends upon the nature of the surface and temperature.

DESCRIPTION OF THE APPARATUS:

The setup consists of a **200mm dia two copper plates** one surface blackened to get the effect of the black body and other is platened to give the effect of the gray body. Both the plates with **mica heaters** are mounted on the ceramic base covered with chalk powder for maximum heat transfer. Two Thermocouples are mounted on their surfaces to measure the temperatures of the surface and one more to measure the enclosure/ambient temperature. This complete arrangement is fixed in an **acrylic chamber** for visualization. Temperatures are indicated on the digital temperature indicator with channel selector to select the temperature point. Heater regulators are provided to control and monitor the heat input to the system with voltmeter and ammeter for direct measurement of the heat inputs. The heater controller is made of complete aluminium body having fuse.

With this, the setup is mounted on an aesthetically designed frame with control panel to monitor all the processes. The control panel consists of mains on indicator, Aluminium body heater controllers, change over switches, digital Data logger is used to measure the temperature, voltage and current of the Black body and grey body and other necessary instrumentation. The whole arrangement is on the single bench considering all **safety and aesthetics factors**.

EXPERIMENTATION:

AIM: The experiment is conducted to determine the emmissivity of the non – black surface and compare with the black body.

PROCEDURE:

1. Give necessary electrical connections and switch on the MCB and switch on the console on to activate the control panel.
2. Switch On the heater of the black body and set the voltage (say 30V) using the heater regulator
3. Switch On the heater of the Gray body and set the voltage (say 30V) using the heater regulator.
4. Observe temperatures of the black body and test surface in close time intervals and adjust power input to the test plate heater such that both black body and test surface temperatures are same.

NOTE: This procedure requires trial and error method and one has to wait sufficiently long (say 2hours or longer) to reach a steady state.

5. Wait to attain the steady state.
6. Note down the temperatures at different points and also the voltmeter and ammeter readings.
7. Tabulate the readings and calculate the surface emmissivity of the non – black surface.

PROCEDURE : COMPUTERIZED

TAKING READINGS – COMPUTERIZED

1. Switch on the panel.
2. Switch on the computer.
3. Open the **“ HEAT TRANSFER Software”** from the installed location a welcome screen will be displayed
4. Follow the below steps to operate through software

   Once the software is opened, the main screen will be displaced

   Now, press **“START”** button, and the small screen will opened

   Enter the parameters listed for particular test under study.

   the software starts displaying the calculated values which can be cross verified based on the formulae give after.

5. Switch On the heater of the black body and set the voltage (say 30V) using the heater regulator
6. Switch On the heater of the Gray body and set the voltage (say 30V) using the heater regulator.
7. Observe temperatures of the black body and test surface in close time intervals and adjust power input to the test plate heater such that both black body and test surface temperatures are same.
8. Wait to attain the steady state.
9. Click the **“store”** button to store the value can be viewed anytime later.
10. After completion of the Experiment to press the stop button

OBSERVATIONS:

Sl. No.	Heater input				Temperature, °C				
	Black body		Gray body						
	Voltage, ‘V’ volts	Current ‘I’ amps	Voltage ‘V’ volts	Current ‘I’ amps	T_1	T_2	T_3	T_4	T_5
1									
2									
3									
4									
5									

CALCULATIONS:

1. HEAT INPUT TO THE BLACK BODY, Q_B

_ Q_B = V x I Watts.

2. HEAT INPUT TO THE GRAY BODY, Q_G

_ Q_G = V x I Watts.

3. EMMISSIVITY OF THE GRAY BODY, ε_G

$$\varepsilon_G = 1 - \frac{0.86 \times (Q_B - Q_G)}{\sigma \times A \times (T^4 - T_A^4)}$$

σ = Stefen Boltzmann constant = 5.67×10^{-8} W/ $m^2 k^4$.

Q_G = Heat input to the gray body.

Q_B = Heat input to the black body.

A = Area of plates = $(\pi d^2/4)\ m^2$, d = 0.2m

T = (T1+T2+T3+T4)/4

T_A = enclosure temperature = T5

0.86 = constant , which takes into account various factors such as radiation shape factor, effect of conduction and free convection losses and other factors(such as non uniformities in enclosure temperature) which cause deviations from the typical radiation heat transfer experiment.

RESULT :

The emmissivity of the gray body is ε_G = ________.

NOTE;

IF YOU FIND THE ABOVE METHOD TO BE MORE TEDIOUS, USE **ALTERNATE PROCEDURE AND CALCULATIONS**.

ALTERNATE PROCEDURE:

Give necessary electrical connections and switch on the MCB and switch on the console on to activate the control panel.

1. Switch On the heater of the Gray body and set the voltage (say 45V) using the heater regulator and digital voltmeter.
2. Switch On the heater of the Black body and set the voltage or current (say higher than gray body) using the heater regulator and digital voltmeter.
3. Wait to attain the steady state.
4. Note down the temperatures at different points and also the voltmeter and ammeter readings.
5. Tabulate the readings and calculate the surface emmissivity of the non – black surface.

ALTERNATE OBSERVATIONS:

Sl. No.	Heater input				Temperature, °C				
	Black body		Gray body						
	Voltage, 'V' volts	Current 'I' amps	Voltage 'V' volts	Current 'I' amps	T_1	T_2	T_3	T_4	T_5
1									
2									
3									
4									

ALTERNATE CALCULATIONS:

1. HEAT INPUT TO THE BLACK BODY, Q_B

Q_B = V x I Watts.

2. HEAT INPUT TO THE GRAY BODY, Q_G

________ Q_G = V x I Watts.

3. EMMISSIVITY OF THE GRAY BODY, ε_G

$$\varepsilon_G = \frac{Q_G (T_B^4 - T_A^4)}{Q_B (T_G^4 - T_A^4)}$$

Q_G = Heat input to the gray body.

Q_B = Heat input to the black body.

A = Area of plates = ($\pi d^2/4$) m^2, d = 0.2m

T_B = Temperature of black body = (T1+T2)/2

T_G = T(T3+T4)/2

T_A = Ambient temperature = T5

4. **RESULT** :

The emissivity of the gray body is ε_G = ________.

Reference:

1) Heat and Mass transfer by Arora & Domkundwar
2) Chemical Engineers’ Handbook, by
   Robert H. Perry / Cecil H. Chilton

Publication: McGraw – Hill Book Company (6th edition)

PRECAUTIONS:

1. Check all the electrical connections.
2. Do not run the equipment if the voltage is below 180V.
3. Make sure that heater regulator is at the minimum position before switching on the console.
4. After finishing the experiment open the acrylic door to remove the heat from the chamber.
5. Do not attempt to alter the equipment as this may cause damage to the whole system.

4. HEAT TRANSFER THROUGH FORCED CONVECTION

INTRODUCTION:

Heat transfer can be defined as the transmission of energy from one region to another as a result of temperature difference between them. There are three different modes of heat transfer; namely,

HEAT CONDUCTION	:	The property which allows the passage for heat energy, even though its parts are not in motion relative to one another.
HEAT CONVECTION	:	The capacity of moving matter to carry heat energy by actual movement.
HEAT RADIATION	:	The property of matter to emit or to absorb different kinds of radiation by electromagnetic waves.

Out of these types of heat transfer the convective heat transfer which of our present concern, divides into two catagories, Viz.,

NATURAL CONVECTION: If the motion of fluid is caused only due to difference in density resulting from temperature gradients without the use of pump or fan, then the mechanism of heat transfer is known as "*Natural or Free Convection*".

FORCED CONVECTION:If the motion of fluid is induced by some external means such as a pump or blower, then the heat transfer process is known as "*Forced Convection*".

The newtons law of cooling in convective heat transfer is given by,

$$q = h\,A\,\Delta T$$

Where, **q** = Heat transfer rate, in watts

A = Surface area of heat flow, in m²

ΔT = Overall temperature difference between the wall and fluid, in °C

h = Convection heat transfer co-efficient, in watts/m² °C

This setup has been designed to study heat transfer by forced convection.

DESCRIPTION OF THE APPARATUS:

The apparatus consists of

Heat exchanger tube made of **copper** which is thermally insulated outside to prevent heat transfer losses to the atmosphere.

Band heaters of 500watts capacity.

Heater regulator to supply the regulated power input to the heater.

Data logger is used to measure the Temperature, Voltage ,current and Air flow rat .

Thermocouples at suitable position to measure the temperatures of body and the air.

Blower unit to blow air through the heat exchanger with orifice meter and Differential Pressure Transducer to measure the air flow rate from the blower. A control valve is provided to regulate the air flow.

Control panel to house all the instrumentation.

With this the whole arrangement is mounted on an aesthetically designed self-sustained frame with a separate NOVAPAN Board control panel.

EXPERIMENTATION:

AIM: To determine convective heat transfer coefficient in forced convection.

PROCEDURE : MANUAL

1. Switch on the MCB and then console on switch to activate the control panel.
2. Switch on the blower unit first and adjust the flow of air using wheel valve of blower to a desired difference in manometer.
3. Switch on the heater and set the voltage (say 80V) using the heater regulator.
4. Wait for reasonable time to allow temperatures to reach steady state.
5. Measure the voltage, current and temperatures from T_1 to T_6 at known time interval.
6. Calculate the convective heat transfer co-efficient using the procedure given.
7. Repeat the experiment for different values of power input to the heater and blower air flow rates.

OBSERVATIONS:

SL No.	**Manometer Reading, mm of water**	**HEAT INPUT**		**Air temperature, °C**		**TEMPERATURE, °C**			
	H	**V**	**I**			**SURFACE**			
				T4	**T5**	**T1**	**T2**	*T3*	*T4*
1.									
2.									
3.									
4.									

Where : V = Voltage, volts and I = Current, amps

PROCEDURE : COMPUTERIZED

TAKING READINGS – COMPUTERIZED

1) Switch on the panel.
2) Switch on the computer.
3) Open the **" HEAT TRANSFER Software"** from the installed location a welcome screen will be displayed
4) Follow the below steps to operate through software

   Once the software is opened, the main screen will be displaced

   Now, press **"START"** button, and the small screen will opened

   Enter the parameters listed for particular test under study.

   the software starts displaying the calculated values which can be cross verified based on the formulae give after.
5) Switch on Blower And adjust the air Flow rate By using the Valve See the Air flow rate in Indicator.
6) Switch on the heater and set the voltage (say 40V) using heater regulator.
7) Wait for sufficient time to allow temperature to reach steady values.

8) Repeat the experiment for different heat inputs and also for horizontal position with different heat inputs.
9) Wait to attain the steady state.
10) Click the **"store"** button to store the value can be viewed anytime later.
11) After completion of the Experiment to press the stop button.

CALCULATIONS:

PRACTICAL

1. $h = \dfrac{Q}{A\ (Ti - To)}$

where, Q = heat given to the heater = V x I watts.

A = Area of the tube surface = π d L

d = 0.036m and L = 0.5m

Ti = mean temperature = (T1+T2+T3+T4)/4

To = . (T5+T6)/3

THEORETICAL

$h = (0.023 \times Pr^{0.4} \times Re^{0.8} \times k) / D$

Where,

$Re = \dfrac{\rho VD}{\mu}$

$Pr = \dfrac{\mu\ Cp}{K}$

where ,

D = inner diameter of the tube = 0.036

$V = \dfrac{\text{mass flow rate of air}}{\text{Flow area}}$ m/s

Mass flow rate of air is calculated as follows:

$$= 0.62 \text{ x } a \text{ x } | \sqrt{2gH}$$

where, $a = \frac{\pi d^2}{4}$, $d= 0.015$

$$H = \frac{(h)}{1.293} \text{ m of air column}$$

Flow area is calculated as follows:

$$= \frac{\pi D^2}{4} \quad , \quad D= 0.036$$

All the properties of air should be taken at (Ti + To)/2 from the data hand book.

RESULT:

_Draw the graph of ‘h’ versus ‘Tm’ for theoretical and practical calculations and compare the results.

TROUBLE SHOOTING:General causes and remedie

CAUSES	REMEDY
Mains on indicator not glowing	Check input electrical connection.
No power to indicators	Switch on the console, still not working call the supplier.
Still unable to start, call the supplier	

Data management system/Unable to acquire data properly

CAUSES	REMEDY
Readings cannot be taken.	Un – install then Re-Install the software.
Low Voltage (minimum should be 220V)	Switch off the system till the voltage is stabilized to proper value.

Variation in the VOLTAGE (should not be more than 10V)	Check and stabilize it
Earthing not properly made.	Check and stabilize it.
Magnetic parts and induction equipments near the Indicators.	Remove it and place 5m away from the equipment.
Unable to take the printout	Check the printer connection. Still unable to so, check the printer software settings and redefine if necessary.
Still unable to acquire, call the supplier	

Indicators not showing proper values – IN CASE USED

CAUSES	REMEDY
Not calibrated properly	Check for any loose connection in the wire and also check for any air gap in the tubes of the pressure tapping points.
Indicator not working properly	Check the sensor wire and connection.
Still unable to find the problem, call the supplier	

DO’s & DON’Ts

DO’s	DON’Ts
Check the electrical connections before switching on the panel.	Switch on the panel if the voltage is low as specified.
Ensure water flow to the equipment and continue the flow for 15min before and after the experiment.	Run the equipment without supply of water to the transducer.
Grease the mating parts regularly.	Touch the rotating parts when equipment is running.
Keep the equipment clean & dry and run at least 15min for every week.	Keep the equipment idle for more days as this may clog the moving parts.
Run the equipment in the Temperature limit of 200C.	Over temperature to the equipment, as this may cause damage to the whole system.
Still unable to find the problem, call the supplier	

LIMITATIONS & PRECAUTIONS

1) Maximum Load is limited to 150V.
2) This is a general equipment for study in undergraduate level, for consideration of higher level studies you can add any extra parameter required. For adding the parameters call the supplier.
3) Don't run the equipment if the voltage is less than 180V.
4) 230V, 1ph with neutral and proper earthing to be provided.
5) Don't alter the equipment without the supervision of the supplier.

Reference:

1) Heat and Mass transfer by Arora & Domkundwar
2) Chemical Engineers' Handbook, by
Robert H. Perry / Cecil H. Chilton

Publication: McGraw – Hill Book Company (6th edition)

5. HEAT PIPE DEMONSTRATION

INTRODUCTION:

One of the main objectives of energy conversion systems is to transfer energy from a receiver to some other location where it can be used to heat a working fluid. The heat pipe is a novel device that can transfer large quantities of heat through small surface areas with small temperature differences. Here in this equipment an attempt has been made to show the students, how the heat pipe works with different methods.

DESCRIPTION OF THE APPARATUS:

The apparatus consists of a **Solid Copper Rod** of diameter (d) 25mm and length (L) 500mm with a Source at one end and condenser at other end.

Similarly, **Hollow copper pipe without wick and with wick (SS mesh of 180microns)** with same outer dia and length is provided.

Thermocouples are fixed on the tube surface with a phase angle of 90° on each pipe.

Control panel instrumentation consists of:

e. **Digital Temperature Indicator** with channel selector.
f. **Digital Voltmeter** & **Ammeter** for power measurement.
g. **Heater regulator** to regulate the input power.

With this, the setup is mounted on an aesthetically designed MS Powder coated frame with MOVAPAN Board control panel to monitor all the processes considering all **safety and aesthetics factors**.

EXPERIMENTATION:

AIM:

To determine the axial heat flux in a heat pipe using water as the working fluid with that of a solid copper with different temperatures.

PROCEDURE:

1) Provide the necessary electrical connection and then CONSOLE ON switch.
2) Switch on the heater and set the voltage (say 40V) using heater regulator and the digital voltmeter.
3) Wait for sufficient time to allow temperature to reach steady values.
4) Note down the Temperatures 1 to 6 using the channel selector and digital temperature indicator.
5) Note down the ammeter and voltmeter readings.
6) Calculate the axial heat flux for all the pipes.
7) Repeat the experiment for different heat inputs and compare the results.

OBSERVATIONS:

Sl. No.	Temperatures °C						Heater Input	
	T_1	T_2	T_3	T_4	T_5	T_6	V	I
1								
2								
3								
4								
5								

Where : V = Voltage, volts and I = Current, amps

CALCULATIONS:

1. Calculation of heat flux, q

$$q = \frac{Q}{A} = \frac{k \times \delta T}{\delta X} \quad W/m^2$$

where, k = Thermal conductivity of copper = 375 W/m K

dt = Temperature difference.

dx = Length b/w thermocouples.

RESULT:

_Draw the graph of ‘q’ versus ‘Temperature difference’ for different heat inputs.

Reference:

1) Heat and Mass transfer by Arora & Domkundwar
2) Chemical Engineers’ Handbook, by

Robert H. Perry / Cecil H. Chilton

Publication: McGraw – Hill Book Company (6th edition)

PRECAUTIONS:

1) Check all the electrical connections.
2) Do not run the equipment if the voltage is below 180V.
3) Make sure that heater regulator is at the minimum position before switching on the console.
4) Do not attempt to alter the equipment as this may cause damage to the whole system.

6. HEAT TRANSFER THROUGH LAGGED PIPE

INTRODUCTION:

The costs involved in insulting either heated or refrigerated equipment, air-conditioned rooms, pipes, ducts, tanks, and vessels are of a magnitude to warrant careful consideration of the type and quantity of insulation to be used. Economic thickness is defined as *the minimum annual value* of the sum of the cost of heat loss plus the cost of insulation, or, in more general terms, as the thickness, of a given insulation that will save the greatest cost of energy while paying for itself within an assigned period of time. At low values of thickness, the amortized annual cost of insulation is low, but the annual cost of heat energy is high. Additional thickness adds to the cost of insulation but reduces the loss of heat energy, and therefore, its cost. At some value of insulation thickness, the sum of the cost of insulation and the cost of heat loss will be a minimum, curve C rises because the increased cost insulation is no longer offset by the reduced cost of heat loss.

The calculation of economic thickness for an industrial installation is not easy, owing to the large number of variables and separate calculations involved. This has all been reduced to manual form in "How to determine economic thickness of insulation", published by National Insulation Manufacturers Association, New York.

CRITICAL THICKNESS OF INSULATION:

It must not be taken for granted that insulation only retards the rate of heat flow. The addition of small amount of insulation to small diameter wires or tubes frequently increases the rate of heat flow through the tube to the ambient air. It was shown elsewhere in the standard books with experiment that the rate of heat loss was increased by the addition of the asbestos sheet.

CRITICAL THICKNESS OF INSULATION FOR CYLINDER:

When a solid cylinder of radius R1 is insulated with an insulation of thickness(R2-R1), then the heat flow from the surface of the solid cylinder to the surrounding is given by

$$Q = \frac{2\pi L\,(T_{input} - T_{outlet})}{\frac{1}{K_2}\log_e\frac{R_{outer}}{R_{inner}} + \frac{1}{R_{outer}h_o}} \quad W$$

Where, L is the length of the cylinder,

K_2 is the conductivity of the insulation, and

h_O is the combined(convection and radiation) heat transfer co-efficient on the outer surface of the insulation.

DESCRIPTION:

The experimental set-up consists of a copper pipe of 38mm diameter divided into four zones of 150mm each. The zone 1 is a bare pipe, and zone 2 is wound with asbestos rope to 60mm dia, and that of zone 3 to 90mm dia and zone 4 to 110mm dia. The heater of 500 watts is centred along the length of the pipe (150x4=600mm).

Heater regulator to supply the regulated power input to the heater. **Digital Voltmeter and Ammeter** to measure poser input ot the heater. **Thermocouples** at suitable position to measure the temperatures of body and the air. **Digital Temperature Indicator** with channel selector to measure the temperatures.

Control panel to house all the instrumentation.

With this the whole arrangement is mounted on an aesthetically
designed self-sustained MS powder coated frame with a separate NOVAPAN Board control panel.

EXPERIMENTATION:

AIM:

To determine combined convective and radiation heat transfer coefficient at each zone and compare them to decide the critical thickness of insulation.

PROCEDURE:

1. Switch on the MCB and then console on switch to activate the control panel.
2. Switch on the heater and set the voltage (say 40V) using the heater regulator and digital voltmeter.
3. Wait for reasonable time to allow temperatures to reach steady state.
4. Measure the voltage, current and temperatures from T_1 to T_7 at known time interval.
5. Calculate the heat transfer co-efficient using the procedure given.

6. Repeat the experiment for different values of power input to the heater.

7. OBSERVATIONS:

SL No.	HEAT INPUT		TEMPERATURE, °C SURFACE						
	V	I	T1	T2	T3	T4	*T5*	*T6*	*T7*
1.									
2.									
3.									
4.									

Where : V = Voltage, volts and I = Current, amps

T1 : Bare Point Inner Temperature

T2 : Zone I Inner Temperature

T3 : Zone I Outer Temperature

T4 : Zone II Inner Temperature

T5 : Zone II Outer Temperature

T6 : Zone III Inner Temperature

T7 : Zone III Outer Temperature

CALCULATIONS:

$$Q = \frac{2\,\pi L\,(T_{input} - T_{outlet})}{\frac{1}{K_2}\,log_e \frac{R_{outer}}{R_{inner}} + \frac{1}{R_{outer} h_o}} \quad W$$

where, Q = heat given to the heater = V x I watts.

$R_{outer/inner}$ indicates respective radius of the zones.

$T_{input/outlet}$ indicates respective temp. of the zones.

L = 0.150m

K_2 = Thermal conductivity of insulation.

RESULT:

_Draw the graph of ‘h’ versus ‘Tm’ for theoretical and practical calculations and compare the results.

Reference:

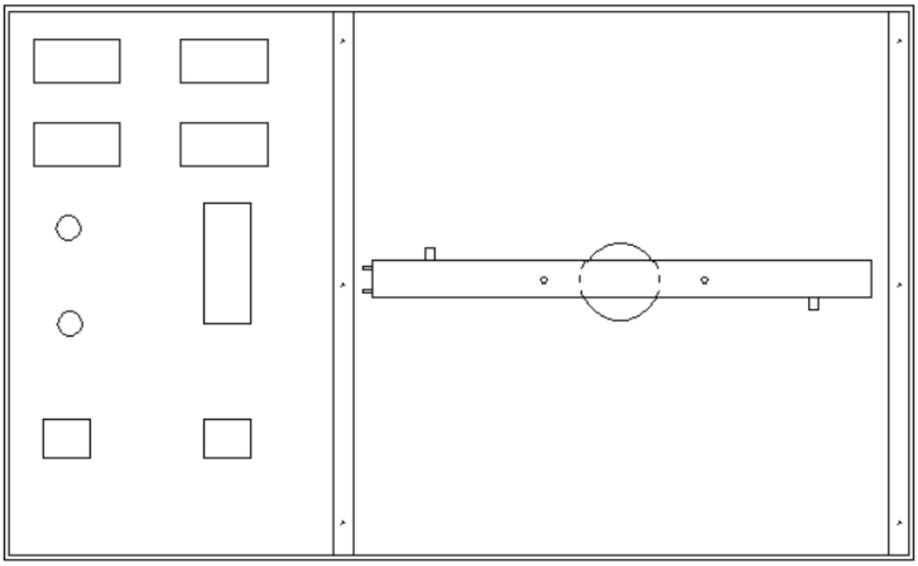
1. Heat and Mass transfer by Arora & Domkundwar
2. Chemical Engineers' Handbook, by

Robert H. Perry / Cecil H. Chilton

Publication: McGraw – Hill Book Company (6th edition)

PRECAUTIONS:

1. Check all the electrical connections.
2. Do not run the equipment if the voltage is below 180V.
3. Make sure that heater regulator is at the minimum position before switching on the console.
4. Do not attempt to alter the equipment as this may cause damage to the whole system.



7. HEAT TRANSFER THROUGH NATURAL CONVECTION

INTRODUCTION:

There are certain situations in which the fluid motion is produced due to change in density resulting from temperature gradients. The mechanism of heat transfer in these situations is called free or natural convection. Free convection is the principal mode of heat transfer from pipes, transmission lines, refrigerating coils, hot radiators etc.

The movement of fluid in free convection is due to the fact that the fluid particles in the immediate vicinity of the hot object become warmer than the surrounding fluid resulting in a local change of density. The colder fluid creating convection currents would replace the warmer fluid. These currents originate when a body force (gravitational, centrifugal, electrostatic etc) acts on a fluid in which there are density gradients. The force, which induces these convection currents, is called a buoyancy force that is due to the presence of a density gradient with in the fluid and a body force. Grashoffs number a dimensionless quantity plays a very important role in natural convection.

DESCRIPTION OF THE APPARATUS:

The apparatus consists of a **Chromium plated Copper tube** of diameter (d) 38mm and length (L) 500mm with a Special electrical heater along the axis of the tube for uniform heating.

Four **thermocouples** are fixed on the tube surface with a phase angle of 90°.

An arrangement to change the position of the tube to vertical or horizontal position is provided.

Front **transparent acrylic enclosure** to minimize the disturbances of the surrounding and also for safety of the tube when not in use.

Contol panel instrumentation consists of:

h. Mains on, console on
i. Data logger is used to measure the Temp, Voltage and current.
j. **Heater regulator** to regulate the input power.

With this, the setup is mounted on an aesthetically designed frame with NOVAPAN Board control panel to monitor all the processes considering all **safety and aesthetics factors**.

EXPERIMENTATION:

AIM:

To determine the natural heat transfer coefficient **‘h’** from the surface of the tube in both vertical and horizontal position.

PROCEDURE : MANUAL

1. Keep the tube in the vertical position.
2. Switch on MCB and then CONSOLE ON switch.
3. Switch on the heater and set the voltage (say 40V) using heater regulator.
4. Wait for sufficient time to allow temperature to reach steady values.
5. Note down the Temperatures 1 to 4 using the Data logger
6. Note down the Voltage and Current.
7. Calculate the convection heat transfer co-efficient using the procedure given below.
8. Repeat the experiment for different heat inputs and also for horizontal position with different heat inputs.

OBSERVATIONS:

Sl. No.	**Position**	**Temperatures °C**				**Heater Input**	
		T_1	**T_2**	**T_3**	**T_4**	**V**	**I**
1							
2							
3							
4							
5							

Where : V = Voltage, volts and I = Current, amps

PROCEDURE : COMPUTERIZED

TAKING READINGS – COMPUTERIZED

1. Switch on the panel.
2. Switch on the computer.
3. Open the **" HEAT TRANSFER Software"** from the installed location a welcome screen will be displayed
4. Follow the below steps to operate through software
5. Once the software is opened, the main screen will be displaced
6. Now, press **"START"** button, and the small screen will opened
7. Enter the parameters listed for particular test under study.
8. the software starts displaying the calculated values which can be cross verified based on the formulae give after.
9. Switch on the heater and set the voltage (say 40V) using heater regulator.
10. Wait for sufficient time to allow temperature to reach steady values.
11. Repeat the experiment for different heat inputs and also for horizontal position with different heat inputs.
12. Wait to attain the steady state.
13. Click the **"store"** button to store the value can be viewed anytime later.
14. After completion of the Experiment to press the stop button

CALCULATIONS ARE BASED ON THE BELOW FORMULAE:

PRACTICAL

1. $$h = \frac{Q}{A\,(T_m - T_a)}$$

where, Q = heat given to the heater = V x I watts.

A = Area of the tube surface = π d L

d = 0.038m and L = 0.5m

Tm = mean temperature = (T1+T2+T3+T4)/4

Ta = Ambient air temperature.

THEORETICAL

1. VERTICAL POSITION: for $10^4 < Gr.Pr < 10^9$

   $h_v = (0.59 \times (Gr.\,Pr)^{0.25} \times k) / L$

2. HORIZONTAL POSITION: for $10^4 < Gr.Pr < 10^9$

   $h_h = (0.53 \times (Gr.\,Pr)^{0.25} \times k) / L$

Where,

$$Pr = \frac{\mu\, Cp}{k} \qquad Gr = \frac{L^3 \rho^2 \beta \; (Tm - Ta)}{\mu^2}$$

$\beta = 1/(273+Tm)$

All the properties of air should be taken at (Tm + Ta)/2 from the data hand book.

Here , L is the characteristic length and is given as:

L = L = 0.5m for vertical position.

L = d = 0.038 for horizontal position.

RESULT:

Draw the graph of 'h' versus 'Tm' for vertical and horizontal positions of the tube actually and theoretically calculated and compare the results.

TROUBLE SHOOTING:

- **General causes and remedies**

CAUSES	REMEDY
Mains on indicator not glowing	Check input electrical connection.
No power to indicators	Switch on the console, still not working call the supplier.
Still unable to start, call the supplier	

Data management system/Unable to acquire data properly

CAUSES	REMEDY
Readings cannot be taken.	Un – install then Re-Install the software.
Low Voltage (minimum should be 220V)	Switch off the system till the voltage is stabilized to proper value.
Variation in the VOLTAGE (should not be more than 10V)	Check and stabilize it
Earthing not properly made.	Check and stabilize it.
Magnetic parts and induction equipments near the Indicators.	Remove it and place 5m away from the equipment.
Unable to take the printout	Check the printer connection. Still unable to so, check the printer software settings and redefine if necessary.
Still unable to acquire, call the supplier	

- **Indicators not showing proper values – IN CASE USED**

CAUSES	REMEDY
Not calibrated properly	Check for any loose connection in the wire and also check for any air gap in the tubes of the pressure tapping points.
Indicator not working properly	Check the sensor wire and connection.
Still unable to find the problem, call the supplier	

- **DO's & DON'Ts**

DO's	DON'Ts
Check the electrical connections before switching on the panel.	Switch on the panel if the voltage is low as specified.
Ensure water flow to the equipment and continue the flow for 15min before and after the experiment.	Run the equipment without supply of water to the transducer.
Grease the mating parts regularly.	Touch the rotating parts when equipment is running.
Keep the equipment clean and run at least 15min for every week.	Keep the equipment idle for more days as this may clog the moving parts.
Run the equipment in the Temperature limit of 200C.	Over temperature to the equipment, as this may cause damage to the whole system.
Still unable to find the problem, call the supplier	

SPECIAL NOTE:

1. The experiment should be carried out in the absence of wind flow through the window as well as in the absence of fan for better results.
2. For better result, the horizontal and vertical experiments should be conducted after the tube is cooled down to almost room temperature.
3. For comparison of results in horizontal and vertical position the temperatures should be considered for equal interval of time, in both cases.

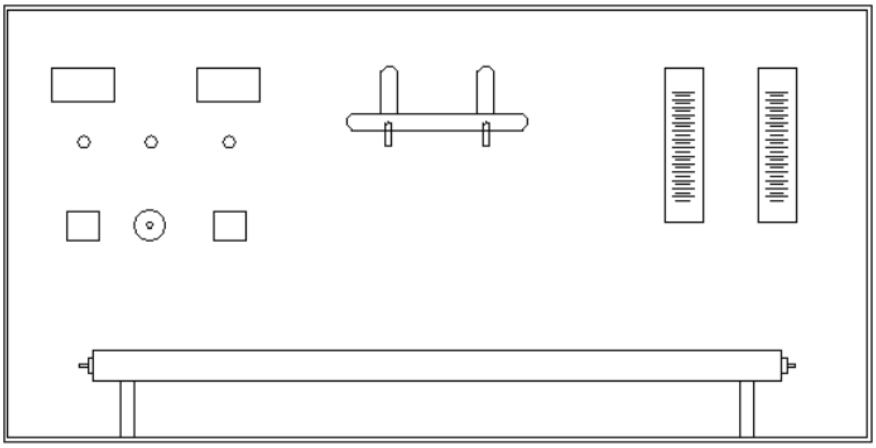
LIMITATIONS & PRECAUTIONS

1. Maximum Load is limited to 120V.
2. This is a general equipment for study in undergraduate level, for consideration of higher level studies you can add any extra parameter required. For adding the parameters call the supplier.
3. Don't run the equipment if the voltage is less than 180V.
4. 230V, 1ph with neutral and proper earthing to be provided.
5. Don't alter the equipment without the supervision of the supplier.

Reference:

1. Heat and Mass transfer by Arora & Domkundwar
2. Chemical Engineers' Handbook, by
Robert H. Perry / Cecil H. Chilton

Publication: McGraw – Hill Book Company (6th edition)



8. PARALLEL & COUNTER FLOWHEAT EXCHANGER

INTRODUCTION:

Heat exchangers are devices in which heat is transferred from one fluid to another. The fluids may be in direct contact with each other or separated by a solid wall. Heat Exchangers can be classified based on its principle of operation and the direction of flow. The temperature of the fluids changes in the direction of flow and consequently there occurs a change in the thermal head causing the flow of heat.

The temperatures profiles at the two fluids in parallel and counter flow are curved and have logarithmic variations. LMTD is less than the arithmetic mean temperature difference. So, it is always safer for the designer to use LMTD so as to provide larger heating surface for a certain amount of heat transfer.

DESCRIPTION OF THE APPARATUS:

The apparatus consists of **concentric tubes**. The inner tube is made of **copper** while the outer tube is made of **Stainless Steel**.
Insulation is provided with **mica sheet** and **asbestos rope** for effective heat transfer.

Provision has been made for **hot water generation** by means of geyser.

Change - Over Mechanism is provided to change the direction of flow of cold water in a single operation.

ACRYLIC Rotameters of specific range is used for direct measurement of water flow rate.

Thermocouples are placed at appropriate positions which carry the signals to the temperature indicator. A **data logger indicator** is provided to measure the temperature.

The whole arrangement is mounted on an **Aesthetically designed self sustained sturdy frame** made of **NOVAPAN board control panel**. The control panel houses all the indicators, accessories and necessary instrumentations.

EXPERIMENTATION:

AIM:

To determine **LMTD & Effectiveness** of the **heat exchanger** under parallel and counter Flow arrangement.

PROCEDURE:

1. Switch ON mains and the CONSOLE.
2. Start the flow on the hot water side.
3. Start the flow through annulus also.
4. Set the exchanger for parallel or counter flow using the
    a. change over mechanism.
5. Switch ON the heater of the geyser.
6. Set the flow rate of the hot water (say 1.5 to 4 Lpm) using
    a. the rotameter of the hot water.
7. Set the flow rate of the cold water (say 3 to 8 Lpm) using the
    a. rotameter of the cold water.
8. Wait for sufficient time to allow temperature to reach steady
    a. values.
9. Note down the Temperatures 1 to 4 using the Scanner.
10. Note down the flow rates of the water and tabulate.
11. Now, change the direction of flow for the same flow rates and
    a. repeat the steps 9 to 11.
12. Repeat the experiment for different flow rates of water.

PROCEDURE : COMPUTERIZED

TAKING READINGS – COMPUTERIZED

1. Switch on the panel.
2. Switch on the computer.
3. Open the **" HEAT TRANSFER Software"** from the installed location a welcome screen will be displayed
4. Follow the below steps to operate through software
5. Once the software is opened, the main screen will be displaced
6. Now, press **"START"** button, and the small screen will opened
7. Enter the parameters listed for particular test under study.

8. Start the flow on the hot water side.
9. Start the flow through annulus also.
10. Set the exchanger for parallel or counter flow using the
    a. change over mechanism.
11. Switch ON the heater of the geyser.
12. Set the flow rate of the hot water (say 1.5 to 4 Lpm) using
    a. the rotameter of the hot water.
13. Set the flow rate of the cold water (say 3 to 8 Lpm) using the
    a. rotameter of the cold water.
14. Wait for sufficient time to allow temperature to reach steady
    a. values.
13. The software starts displaying the calculated values which can be cross verified based on the formulae give after.
14. Click the **"store"** button to store the value can be viewed anytime later.
15. After completion of the Experiment to press the stop button
16. Finally switch of the gyser.

OBSERVATIONS:

Sl. No.	Flow Direction	Temperatures °C				Flow rate, LPM	
		T1	T2	T3	T4	Hot water, H	Cold Water, C
1							
2							
3							
4							
5							

NOTE:

T3 = COLD WATER INLET TEMPERATURE (in case of parallel flow)

COLD WATER OUTLET TEMPERATURE (in case of counter flow)

T4 = COLD WATER OUTLET TEMPERATURE (in case of parallel flow)

COLD WATER INLET TEMPERATURE (in case of counter flow)

T1 = HOT WATER INLET TEMPERATURE.

T2 = HOT WATER OUTLET TEMERATURE.

CALCULATIONS:

1. HEAT TRANSFER RATE ,Q

$$Q = \frac{Q_H \times Q_C}{2}\ WATTS$$

WHERE,

Q_H = heat transfer rate from hot water and is given by:

= $m_H \times C_{PH} \times (T1 - T2)$ W

Where,

m_h = mass flow rate of hot water = H/60 kg/sec.

C_{PH} = Specific heat of hot water from table at temp. (T1+T2)/2

Q_C = heat transfer rate from cold water and is given by:

= $m_C \times C_{PC} \times (T4 - T3)$ W (for parallel flow)

= $m_C \times C_{PC} \times (T3 - T4)$ W (for counter flow)

Where,

m_C = mass flow rate of cold water = C/60 kg/sec.

C_{PC} = Specific heat of cold water from table at temp. (T3+T4)/2

2. LMTD – Logarithmic mean temperature difference:

$$\Delta T_M = \frac{\Delta T_I - \Delta T_O}{\ln(\Delta T_I/\Delta T_O)}$$

Where,

$\Delta T_I = (T_1 - T_3)$ for parallel flow

$\Delta T_I = (T_1 - T_4)$ for counter flow

$\Delta T_O = (T_2 - T_4)$ for parallel flow

$\Delta T_O = (T_2 - T_3)$ for counter flow

NOTE: The suffix H = HOT WATER

C = COLD WATER

I = INLET

O = OUTLET

3. **OVERALL HEAT TRANSFER CO-EFFICIENT:**

$$U = \frac{Q}{A \, X \, \Delta T_M} \quad W/m\,^{\circ}K$$

Where,

Q = heat transfer rate

$A = \pi$ x D_O x L m² where, $D_O = 0.02m$ & L = 1m.

ΔT_M = LMTD.

4. **EFFECTIVENESS OF HEAT EXCHANGER, E**

EXPERIMENTAL:

$$E_{EXP} = \frac{(T_{CO} - T_{CI})}{(T_{HI} - T_{CI})} \quad \text{if } C_{max} > C_{min}$$

$$E_{EXP} = \frac{(T_{HI} - T_{HO})}{(T_{HI} - T_{CI})} \quad \text{IF } C_{max} < C_{min}$$

THEORETICAL:

$$E_{TH} = \frac{1 - e^{-NTU(1+R)}}{(1 + R)} \quad \text{For PARALLEL FLOW}$$

$$E_{TH} = \frac{1 - e^{-NTU(1-R)}}{1 - Re^{-NTU(1-R)}} \quad \text{For COUNTER FLOW}$$

Where,

$C_{MAX} = m_H$ x C_{PH}

$C_{MIN} = m_C \times C_{PC}$

$R = C_{MIN} / C_{MAX}$

NTU = No. of Transfer units is given by

$$= \frac{U \times A}{C_M}$$

C_M = minimum of C_{MIN} & C_{MAX}

Other notations have their usual meaning.

5. PERCENTAGE OF ERROR, %ERROR

$$\%ERROR = \times 100 \ \frac{E_{TH} - E_{EXP}}{E_{TH}}$$

Reference:

1. Heat and Mass transfer by Arora & Domkundwar

2. Chemical Engineers' Handbook, by
Robert H. Perry / Cecil H. Chilton

Publication: McGraw – Hill Book Company (6th edition)

PRECAUTIONS:

1. Check all the electrical connections.
2. Do not run the equipment if the voltage is below 180V.
3. Do not attempt to alter the equipment as this may cause damage to the whole system.

Thank

You