I

Name ____________________

Roll No. ____________ Year 20____ 20____

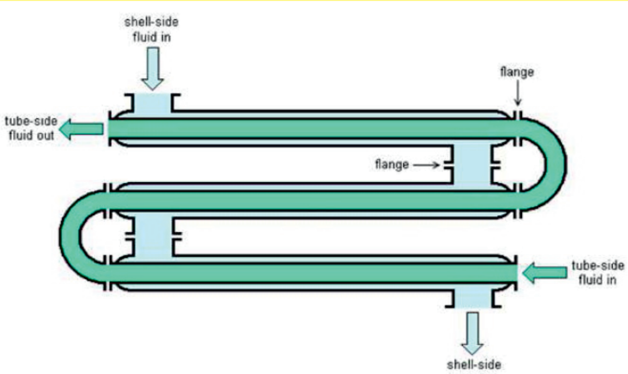
Exam Seat No. ____________________

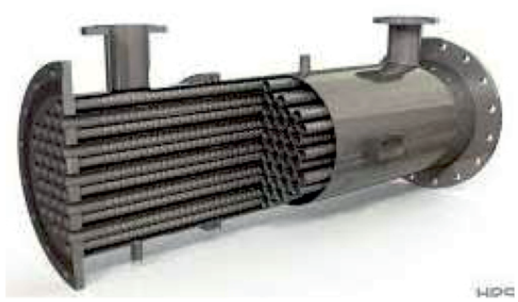
CHEMICAL GROUP | SEMESTER - V | DIPLOMA IN ENGINEERING AND TECHNOLOGY

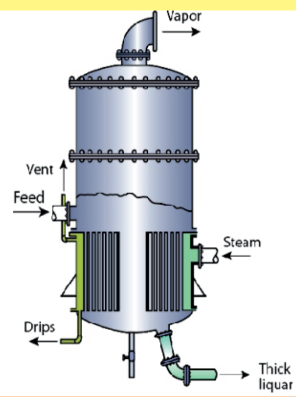
A LABORATORY MANUAL

FOR

HEAT TRANSFER OPERATION (22510)







MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION, MUMBAI

(Autonomous) (ISO 9001 : 2015) (ISO / IEC 27001 : 2013)

VISION

To ensure that the Diploma level Technical Education constantly matches the latest requirements of technology and industry and includes the all-round personal development of students including social concerns and to become globally competitive, technology led organization.

MISSION

To provide high quality technical and managerial manpower, information and consultancy services to the industry and community to enable the industry and community to face the changing technological and environmental challenges.

QUALITY POLICY

We, at MSBTE are committed to offer the best in class academic services to the students and institutes to enhance the delight of industry and society. This will be achieved through continual improvement in management practices adopted in the process of curriculum design, development, implementation, evaluation and monitoring system along with adequate faculty development programmes.

CORE VALUES

MSBTE believes in the followings:

- Education industry produces live products.
- Market requirements do not wait for curriculum changes.
- Question paper is the reflector of academic standards of educational organization.
- Well designed curriculum needs effective implementation too.
- Competency based curriculum is the backbone of need based program.
- Technical skills do need support of life skills.
- Best teachers are the national assets.
- Effective teaching learning process is impossible without learning resources.

A Laboratory Manual

for

Heat Transfer Operation

(22510)

Semester – V

(CH)

Maharashtra State

Board of Technical Education, Mumbai

(Autonomous) (ISO:9001:2015) (ISO/IEC 27001:2013)

Maharashtra State Board of Technical Education,
(Autonomous) (ISO:9001: 2015) (ISO/IEC 27001 : 2013)
4th Floor, Government Polytechnic Building, 49, Kherwadi,
Bandra (East), Mumbai - 400051.
(Printed on May,2019)

Maharashtra State
Board of Technical Education

Certificate

This is to certify that Mr. / Ms ………………………………….
Roll No………………………of Fifth Semester of Diploma in Chemical Engineering of Institute ………………………………..
(Code………………..) has completed the term work satisfactorily in course **Heat Transfer Operation(22510)** for the academic year 20…….to 20…..... as prescribed in the curriculum.

Place ………………. Enrollment No……………………

Date:…................... Exam Seat No. …………………......

Course Teacher **Head of the Department** **Principal**

Seal of the Institute

Preface

The primary focus of any engineering laboratory/ field work in the technical education system is to develop the much needed industry relevant competencies and skills. With this in view, MSBTE embarked on this innovative 'I' Scheme curricula for engineering diploma programs with outcome-based education as the focus and accordingly, relatively large amount of time is allotted for the practical work. This displays the great importance of laboratory work making each teacher; instructor and student to realize that every minute of the laboratory time need to be effectively utilized to develop these outcomes, rather than doing other mundane activities. Therefore, for the successful implementation of this outcome-based curriculum, every practical has been designed to serve as a ***'vehicle'*** to develop this industry identified competency in every student. The practical skills are difficult to develop through 'chalk and duster' activity in the classroom situation. Accordingly, the 'I' scheme laboratory manual development team designed the practicals to ***focus*** on the ***outcomes***, rather than the traditional age old practice of conducting practicals to 'verify the theory' (which may become a byproduct along the way).

This laboratory manual is designed to help all stakeholders, especially the students, teachers and instructors to develop in the student the pre-determined outcomes. It is expected from each student that at least a day in advance, they have to thoroughly read through the concerned practical procedure that they will do the next day and understand the minimum theoretical background associated with the practical. Every practical in this manual begins by identifying the competency, industry relevant skills, course outcomes and practical outcomes which serve as a key focal point for doing the practical. The students will then become aware about the skills they will achieve through procedure shown there and necessary precautions to be taken, which will help them to apply in solving real-world problems in their professional life.

This manual also provides guidelines to teachers and instructors to effectively facilitate student-centered lab activities through each practical exercise by arranging and managing necessary resources in order that the students follow the procedures and precautions systematically ensuring the achievement of outcomes in the students.

Chemical Engineers work as plant operators/ process engineer in various process industries. The processes and operations involve the exchange of heat and need to calculate the amount of heat transferred. To operate a plant efficiently and economically, knowledge of heat transfer is essential. Moreover the handling and operation of heat transfer equipment also play an important role in energy saving. Proper selection of heat exchange equipment improves efficiency of the plant.

Although all care has been taken to check for mistakes in this laboratory manual, yet it is impossible to claim perfection especially as this is the first edition. Any such errors and suggestions for improvement can be brought to our notice and are highly welcome.

Programme Outcomes (POs) to be achieved through Practical of this Course

Following POs and PSO are expected to be achieved through the practical of the chemical engineering.

PO1. Basic knowledge: Apply knowledge of basic mathematics, sciences and basic engineering to solve the **Chemical Engineering** problems

PO2. Discipline knowledge: Apply **Chemical Engineering** knowledge to solve industry based Chemical Engineering problems.

PO3. Experiments and practice: Plan to perform experiments and practices to use the results to solve Technical problems related to **Chemical Engineering**.

PO4. Engineering tools: Apply relevant technologies and Chemical engineering tools with an understanding of the limitations

PO6. Environment and sustainability: Apply Chemical engineering solutions also for sustainable development practices in societal and environmental context.

PO7. **Ethics:** Apply ethical principles for commitment to professional ethics, responsibilities and norms of the practice also in the field of Chemical engineering.

PO8. Individual and team work: Function effectively as a leader and team member in diverse/ multidisciplinary teams.

PO9. Communication: Communicate effectively in oral and written form.

PSO1. Chemical Engineering Equipment: Operate equipment and materials effectively and efficiently used in chemical reactions.

PSO2. Material management and quality control: Manage chemicals and equipment to produce quality chemical products

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List of Industry Relevant Skills

The following industry relevant skills of the competency '***Use heat transfer principles to increase efficiency and to save energy in chemical process plants.'***

are expected to be developed in you by undertaking the practical of this practical manual.

1. Operate heat exchangers.
2. Operate plant after training in simulator
3. Practice energy saving.
4. Do maintenance of heat exchangers.

Practical- Course Outcome matrix

Course Outcomes (COs)

a. Calculate rate of heat transfer by conduction.
b. Apply the concept of convection to operate heat exchanger.
c. Calculate amount of heat transfer by radiation.
d. Choose proper heat transfer equipment for given application.
e. Calculate energy associated with an evaporator.

S. No.	Practical Outcome	CO a.	CO b.	CO c.	CO d.	CO e.
1.	Use thermal conductivity equipment consisting of solid metallic rod to calculate thermal conductivity.	√	-	-	-	-
2.	Use composite wall equipment to calculate total resistance offered by composite wall.	√	-	-	-	-
3.	Use composite wall equipment to calculate rate of heat loss through composite wall	√	-	-	-	-
4.	Use natural heat convection equipment to calculate heat transfer coefficient	-	√	-	-	-
5.	Use forced heat convection equipment to calculate heat transfer coefficient.	-	√	-	-	-
6.	Measure various parameter controlled in a heat exchanger using process simulator.	√	√	√	√	-
7.	Calculate emissivity of the given material.	-	-	√	-	-
8.	Using Stefan- Boltzman law apparatus determine Stefan-Boltzmann constant.	-	-	√	-	-
9.	Using emissivity measurement apparatus compare the outside surface temperatures of black body and test plate	-	-	√	-	-
10.	Using double pipe heat exchanger calculate overall heat transfer coefficient for co-current flow.	-	√	-	√	-
11.	Using double pipe heat exchanger calculate overall heat transfer coefficient for counter-current flow.	-	√	-	√	-
12.	Using shell and tube heat exchanger calculate overall heat transfer coefficient.	-	√	-	√	-
13.	Using finned tube heat exchanger calculate overall heat transfer coefficient.	-	√	-	√	-
14.	Compare the values of Overall heat transfer coefficients for co current and counter current in any heat exchanger	-	√	-	√	-

15.	Using an open pan evaporator determine capacity of evaporator.	-	-	-	-	√
16.	Using an evaporator calculate overall heat transfer coefficient.	-	-	-	-	√

Guidelines to Teachers

1. ***Teacher need to ensure that a dated log book*** for the whole semester, apart from the laboratory manual is maintained by every student which s/he has to ***submit for assessment to the teacher*** in the next practical session.
2. There will be two sheets of blank pages after every practical for the student to report other matters(if any), which is not mentioned in the printed practicals.
3. For difficult practical if required, teacher could provide the demonstration of the practical emphasizing of the skills which the student should achieve.
4. Teachers should give opportunity to students for hands-on after the demonstration.
5. Assess the skill achievement of the students and COs of each unit.
6. One or two questions ought to be added in each practical for different batches. For this teachers can maintain various practical related question banks for each course.
7. If some repetitive information like data sheet, use of software tools etc. has to be provided for effective attainment of practical outcomes, they can be incorporated in Appendix.
8. For effective implementation and attainment of practical outcomes, teacher ought to ensure that in the beginning itself of each practical, students must read through the complete write-up of that practical sheet.
9. During practical, ensure that each student gets chance and takes active part in taking observations/ readings and performing practical.
10. Teacher ought to assess the performance of students continuously according to the MSBTE guidelines

Instructions for Students

1. For incidental writing on the day of each practical session every student should maintain a ***dated log book*** for the whole semester, apart from this laboratory manual which s/he has to ***submit for assessment to the teacher*** in the next practical session.
2. For effective implementation and attainment of practical outcomes, in the beginning itself of each practical, students need to read through the complete write-up including the practical related questions and assessment scheme of that practical sheet.
3. Student ought to refer the data books, IS codes, Safety norms, Electricity act/rules, technical manuals, etc.
4. Student should not hesitate to ask any difficulties they face during the conduct of practical.

Content Page

List of Practicals and Progressive Assessment Sheet

14.	Compare the values of Overall heat transfer coefficients for co current and counter current in any heat exchanger	103					
15.	Using an open pan evaporator determine capacity of evaporator.	114					
16.	Using an evaporator calculate overall heat transfer coefficient.	120					
Total							

Note: To be transferred to Proforma of CIAAN-2017.

Practical No. 1: Measure the thermal conductivity of solid metallic rod

I. Practical Significance :

Thermal conductivity "k" is a characteristic property of a material through which heat is flowing. It is a measure of ability of a substance to conduct heat. Larger the value of k, higher will be the amount of heat conducted. Thermal conductivity is the quantity of heat passing through a material of unit thickness with unit heat flow area in unit time when unit temperature difference is maintained across the opposite faces of material.

II. Relevant Program Outcomes (POs)

PO 1.Basic knowledge: Apply knowledge of basic mathematics, sciences and basic engineering to solve the Chemical engineering problems.

PO2. Discipline knowledge: Apply **Chemical Engineering** knowledge to solve industry based Chemical Engineering problems.

PO3. Experiments and practice: Plan to perform experiments and practices to use the results to solve technical problems related to **Chemical Engineering**.

III. Competency and Practical Skills

'Use heat transfer principles to increase efficiency and to save energy in chemical process plants.'

1. Use thermocouple to measure temperature.
2. Use voltmeter and ammeter to measure voltage and current.

IV. Relevant Course Outcomes

Calculate rate of heat transfer by conduction.

V. Practical Outcome

Use thermal conductivity equipment consisting of solid metallic rod to calculate thermal conductivity.

VI. Relevant Affective Domain Related Outcomes.

1. Follow safe practices

2. Maintain tools and equipment.

VII. Minimum Theoretical Background

The physical law governing the transfer of heat through a uniform material by conduction mode is Fourier's law. It states that the rate of heat flow by conduction through a uniform material is directly proportional to the area normal to the direction of the heat flow and the temperature gradient in the direction of the heat flow.

Mathematically Fourier's law is given by

$Q = -kA[dT/dx]$

The proportionality constant 'k' is called thermal conductivity. Thermal conductivity depends upon the nature of material and its temperature. Thermal conductivities of solids are higher than that of liquids and liquids are having higher thermal conductivities than for gases. Materials having higher values of thermal conductivity are referred to as good conductors of heat. The best conductor of heat is silver followed by red copper, gold and aluminium. The materials having low values of thermal conductivity are called as and used as heat insulators to minimize the rate of heat flow.

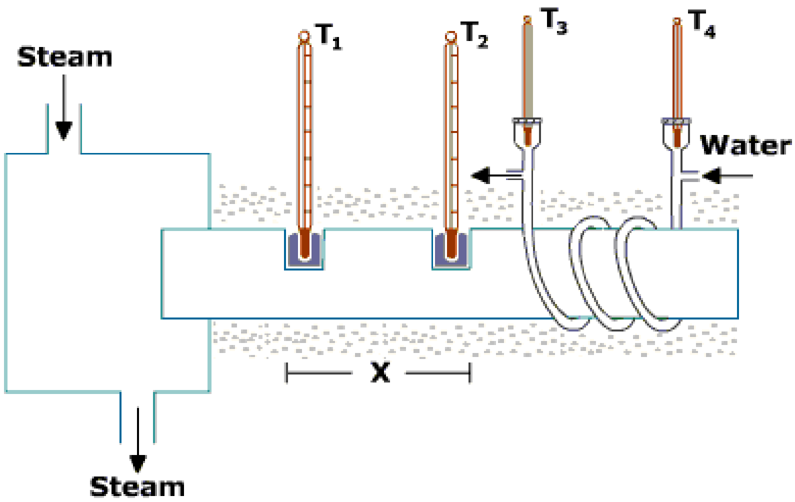

Figure 1 thermal conductivity of metal rod

VIII. Experimental set up:

Figure 2

IX. Resources required

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1.	Thermal conductivity of metal rod set up	As per standard specification	1
2.	Metal rod	Diameter = 28 mm Length = 20 cm	1
3.	Thermocouple		4

X. Precautions to be followed.

1. Readings should be taken at steady state only.
2. The power should not exceed the maximum limit.

XI Procedure

1. Start water supply to the system.
2. Start heater and set dimmer such a way that it will give approx.100V of reading.
3. Note down V and A reading.
4. After attaining steady state, note down temperatures of thermocouples.
5. Gradually increase power by increasing values of V and A.
6. Take 8 sets of reading.
7. Heat losses through apparatus are negligible since the surface is well insulated.

XII. Resources used

Sr. No.	Name of Resource	Suggested Broad Specification		Quantity	Remarks (If any)
		Make	Details		
1					
2					
3					

XIII. Actual procedure followed

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XIV. Precautions followed

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XV. Observations and Calculations:

1. Diameter of rod (D) = …………. cm
2. Length of rod (L) = …………. cm

Sr. No.	Voltage V	Current I	Q=V.I	temperatures		T_1-T_4	K= QL/A.ΔT
				T_1	T_4		
1							
2							
3							
4							
5							
6							
7							
8							

Sample calculation for set no.

1. Area of rod A = $\pi D^2/4$ =

2. Q= V*I =

3. Temperature drop (ΔT) = (T_1-T_4) =

4. k =QL/AΔT

XVI. Results

Thermal conductivity of metal rod =

XVII. Interpretation of results

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XVIII. Conclusions

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XIX Practical related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

a) Give the unit of thermal conductivity in SI
b) Identify the MOC of metal rod.
c) Obtain the value of thermal conductivity of five metals from literature.
d) Define steady state and unsteady state conduction

[Space for Answers]

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XX References / Suggestions for further Reading

- https://nptel.ac.in/courses/112106138/37
- https://www.youtube.com/watch?v=8WTRDbtQQMg
- http://tpm.fsv.cvut.cz/student/documents/files/BUM1/Chapter16.pdf
- http://htv-au.vlabs.ac.in/Heat_Transfer_by_Conduction/

XXI. Assessment Scheme

Performance Indicators		Weightage
Process related (15 Marks)		**60%**
1	Preparation of the experimental set up	20%
2	Setting and operation	20%
3	Safety measures, observation and recording	20%
Product related (10 Marks)		**40%**
4	Calculation and Interpretation of result	20%
5	Practical related question and submission of report	20%
Total (25 marks)		**100 %**

Names of Student Team Members

1. …………………………
2. …………………………
3. …………………………
4. …………………………

Marks Obtained			**Dated signature of Teacher**
Process Related(15)	**Product Related(10)**	**Total (25)**	

Practical No. 2: Calculate total resistance offered by composite wall of three layers and compare with the theoretical value.

I. Practical Significance

Thermal conductivity 'k' is a characteristic property of a material through which heat is flowing. It is a measure of ability of a substance to conduct heat. Larger the value of k, higher will be the amount of heat conducted. Thermal conductivity is the quantity of heat passing through a material of unit thickness with unit heat flow area in unit time when unit temperature difference is maintained across the opposite faces of material.

II. Relevant Program Outcomes (POs)

PO1. Basic knowledge: Apply knowledge of basic mathematics, sciences and basic engineering to solve the Chemical engineering problems.

PO2. Discipline knowledge: Apply **Chemical Engineering** knowledge to solve industry based Chemical Engineering problems.

PO 3. Experiments and practice: Plan to perform experiments and practices to use the results to solve technical problems related to Chemical engineering.

III. Competency and Practical Skills

'Use heat transfer principles to increase efficiency and to save energy in chemical process plants.'

1. Use thermocouple to measure temperature.
2. Use voltmeter and meter to measure voltage and current.

IV. Relevant Course Outcomes

Calculate rate of heat transfer by conduction.

V. Practical Outcome

Use composite wall equipment to calculate total resistance offered by composite wall.

VI. Relevant Affective domain related Outcome(s)

1. Follow safe practices.
2. Maintain tools and equipment.
3. Practice good housekeeping

VII. Minimum Theoretical Background

The physical law governing the transfer of heat through a uniform material by conduction mode is Fourier's law. It states that the rate of heat flow by conduction through a uniform material is directly proportional to the area normal to the direction of the heat flow and the temperature gradient in the direction of the heat flow.

Mathematically Fourier's law is given by

$Q= -kA[dT/dx]$

The proportionality constant 'k' is called thermal conductivity. Thermal conductivity depends upon the nature of material and its temperature. Thermal conductivities of solids are higher than that of liquids and liquids are having higher thermal conductivities than for gases. Materials having higher values of thermal conductivity are referred to as good conductors of heat. The best conductor of heat is silver followed by red copper, gold and aluminium. The materials having low values of thermal conductivity are called as and used as heat insulators to minimize the rate of heat flow.

When a wall is formed out of a series of layers of different materials, it is called as composite wall. For a composite wall, rate of heat flow can be calculated as

$Q= \Delta T/R$

Where, ΔT is the overall temperature drop and R is the total resistance.

Total resistance $R= R_1 + R_2 + R_3$

R_1 , R_2 , R_3 are individual resistances offered by the layers.

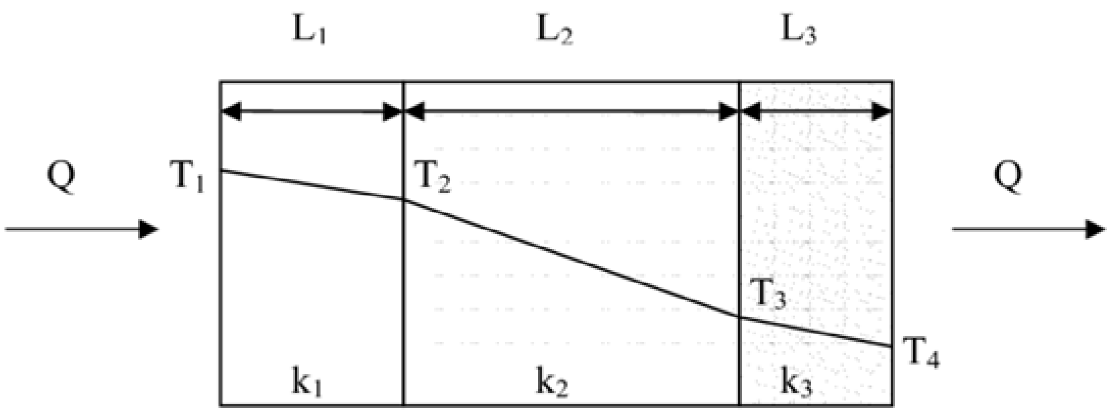

Fig. 1 Heat flow through composite wall

VIII. Experimental set up :

Fig 2

IX. Resources required

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Composite wall assembly	As per ASTM specification	1
2	Disc	Diameter = 180 cm	
2a	Steel disc	Thickness = 19 mm	1
2b	Bakelite disc	Thickness = 10 mm	1
2c	Wood disc	Thickness = 8 mm	1
3	Thermocouples		8

X. Precautions to be followed

1. Keep dimmer stat at zero before start
2. Readings should be taken at steady state only.
3. The power input should not exceed the maximum allowable limit.

XI. Procedure

1. See that plates are symmetrically arranged on both sides of the heater plate.
2. Operate the hand press properly to ensure perfect contact between the plates.
3. Start the supply of heater by varying the dimmer stat; adjust the input as the desired value.
4. Wait till steady state is reached.
5. Note down temperatures indicated by all 8 thermocouples.

6. Note down V and I values.
7. Repeat steps 3 to 6 for varying values of V and I.

XII. Resources used

Sr. No.	Name of Resource	Suggested Broad Specification		Quantity	Remarks (If any)
		Make	Details		
1					
2					
3					
4					
5					
6					

XIII. Actual procedure followed

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XIV. Precautions followed

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XV. Observations and Calculations:

Thermal conductivity of material 1 (k_1) =

Thermal conductivity of material 2 (k_2) =

Thermal conductivity of material 3 (k_3) =

Thickness of material 1 (X_1) =

Thickness of material 2 (X_2) =

Thickness of material 3 (X_3) =

Slab diameter (D) =

SrNo.	Voltage(V)	Current(I)	Temperatures							
			T1	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**T8**
1										
2										
3										
4										

Sample calculation for set no.

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1. Heat transfer area (A) = $\pi D^2/4$ =
2. Resistance of disk 1 (R_1) = X_1/k_1 A
3. Resistance of disk 2 (R_2) = X_2/k_2 A
4. Resistance of disk 3 (R_3) = X_3/k_3 A
5. Total resistance R(theoretical) = $R_1 + R_2 + R_3$
6. Heat input Q = V*I =
7. $T_A = (T_1 + T_2) / 2$ =
8. $T_D = (T_7 + T_8) / 2$ =
9. $(T_A - T_D)$ =
10. $Q = \Delta T/R$ or $R = \Delta T/Q$
    R (practical) =

XVI. Results

1. Total resistance (theoretical) = ………
2. Total resistance (practical) = ………

XVII. Interpretation of results

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XVIII. Conclusions

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XIX. Practical related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

a) Give the unit of thermal resistance.
b) Give any two industrial applications of composite wall.
c) List out five thermal insulators.

[Space for Answers]

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XX. References / Suggestions for further Reading

- http://www.rpsinstitutions.org/downloads/question%20bank/ht.pdf
- https://www.sanfoundry.com/heat-transfer-questions-answers-conduction-composite wall/
- https://www.youtube.com/watch?v=HbzUeBCmjNQ
- https://www.youtube.com/watch?v=S8bXc8YhtXU

XXI. Assessment Scheme

Performance Indicators		Weightage
Process related (15 Marks)		**60%**
1	Preparation of the experimental set up	20%
2	Setting and operation	20%
3	Safety measures, observation and recording	20%
Product related (10 Marks)		**40%**
4	Calculation and Interpretation of result	20%
5	Practical related question and submission of report	20%
Total (25 Marks)		**100 %**

Names of Student Team Members

1. …………………………
2. …………………………
3. …………………………
4. …………………………

Marks Obtained			**Dated signature of Teacher**
Process Related(15)	**Product Related(10)**	**Total (25)**	

Practical No. 3: Calculate rate of heat loss through composite wall.

I. Practical Significance

Thermal conductivity "k" is a characteristic property of a material through which heat is flowing. It is a measure of ability of a substance to conduct heat. Larger the value of k, higher will be the amount of heat conducted. Thermal conductivity is the quantity of heat passing through a material of unit thickness with unit heat flow area in unit time when unit temperature difference is maintained across the opposite faces of material.

II. Relevant Program Outcomes (POs)

PO 1. Basic knowledge : Apply knowledge of basic mathematics, sciences and basic engineering to solve the Chemical engineering problems.

PO 3.Experiments and practice: Plan to perform experiments and practices to use the results to solve technical problems related to Chemical engineering.

PO 4. Engineering tools: Apply relevant technologies and Chemical engineering tools with an understanding of the limitations.

III. Competency and Practical Skills

Use heat transfer principles to increase efficiency and to save energy in chemical process plants.'

1. Use thermocouple to measure temperature.
2. Calculate resistance offered by a material.

IV. Relevant Course Outcomes

1. Calculate rate of heat transfer by conduction.

V. Practical Outcome

Use composite wall equipment to calculate rate of heat loss through composite wall.

VI. Relevant Affective domain related Outcome(s)

1. Follow safe practices
2. Maintain tools and equipment.

VII. Minimum Theoretical Background

The physical law governing the transfer of heat through a uniform material by conduction mode is Fourier's law. It states that the rate of heat flow by conduction through a uniform material is directly proportional to the area normal to the direction of the heat flow and the temperature gradient in the direction of the heat flow.

Mathematically Fourier's law is given by

$$Q = -kA[dT/dx]$$

The proportionality constant ‘k’ is called thermal conductivity. Thermal conductivity depends upon the nature of material and its temperature. Thermal conductivities of solids are higher than that of liquids and liquids are having higher thermal conductivities than for gases. Materials having higher values of thermal conductivity are referred to as good conductors of heat. The best conductor of heat is silver followed by red copper, gold and aluminium. The materials having low values of thermal conductivity are called as and used as heat insulators to minimize the rate of heat flow.

When a wall is formed out of a series of layers of different materials, it is called as composite wall. For a composite wall, rate of heat flow can be calculated as

$Q = \Delta T/R$

Where, ΔT is the overall temperature drop and R is the total resistance.

Total resistance $R = R_1 + R_2 + R_3$

R_1 , R_2 , R_3 are individual resistances offered by the layers.

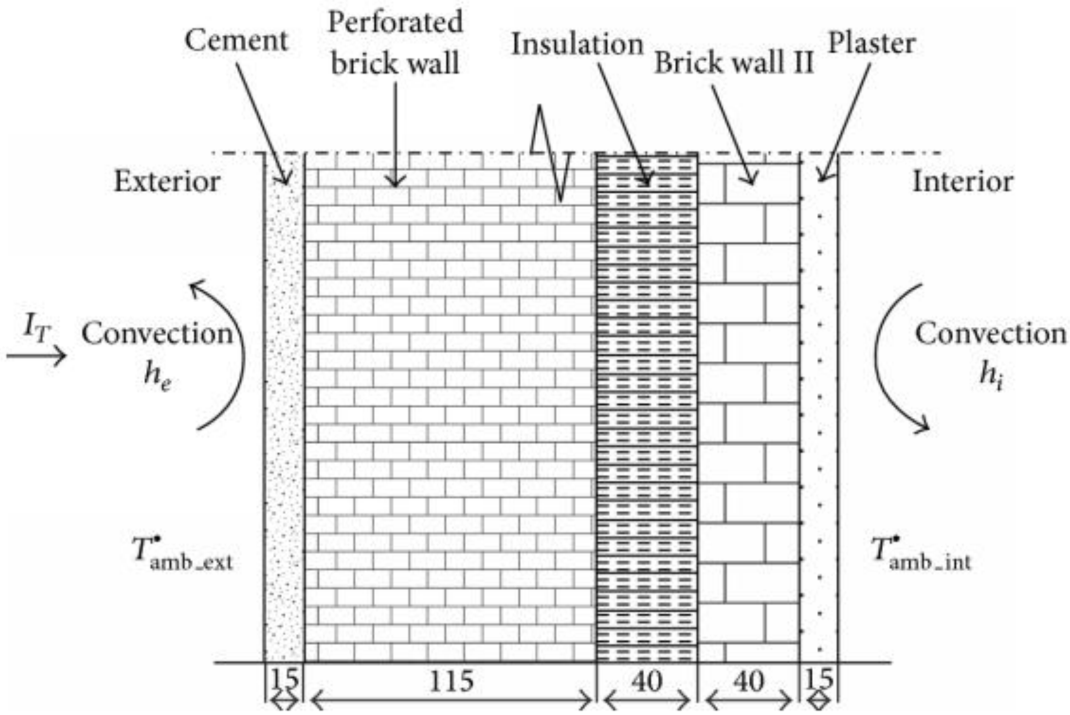

Fig.1- Composite wall

VIII. Experimental set up:

Figure 2

IX. Resources required

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Composite wall assembly	As per ASTM specification	1
2	Disc	Diameter = 180 cm	
2a	Steel disc	Thickness = 19 mm	1
2b	Bakelite disc	Thickness = 10 mm	1
2c	Wood disc	Thickness = 8 mm	1
3	thermocouples		8

X. Precautions to be followed

1. Keep dimmer stat at zero before start
2. Readings should be takes at steady state only.
3. The power input should not exceed the maximum allowable limit

XI. Procedure

1. See that plates are symmetrically arranged on both sides of the heater plate.
2. Operate the hand press properly to ensure perfect contact between the plates.
3. Start the supply of heater by varying the dimmer stat; adjust the input as the desired value.
4. Wait till steady state is reached.
5. Note down temperatures indicated by all 8 thermocouples.
6. Note down V and I values.
7. Repeat steps 3 to 6 for varying values of V and I.

XII. Resources used

Sr. No.	Name of Resource	Suggested Broad Specification		Quantity
		Make	Details	
1				
2				
3				
4				
5				
6				

XIII. Actual procedure followed

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XIV. Precautions followed

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XV. Observations and Calculations:

Thermal conductivity of material 1 (k_1) =

Thermal conductivity of material 2 (k_2) =

Thermal conductivity of material 3 (k_3) =

Thickness of material 1 (X_1) =

Thickness of material 2 (X_2) =

Thickness of material 3 (X_3) =

Slab diameter (D) =

Sr. No.	Voltage(V)	Current(I)	Temperatures							
			T1	T2	T3	T4	T5	T6	T7	T8
1										
2										
3										
4										

Sample calculation

1. Heat transfer area (A) = $\pi D^2/4$ =

2. Resistance of disk 1 (R_1) = X_1/k_1 A

3. Resistance of disk 2 (R_2) = X_2/k_2 A

4. Resistance of disk 3 (R_3) = X_3/k_3 A

5. Total resistance R = $R_1 + R_2 + R_3$

6. Heat input Q = V*I =

7. $T_A = (T_1 + T_2) / 2$ =

8. $T_D = (T_7 + T_8) / 2$ =

9. $\Delta T = (T_A - T_D) =$

10. $Q = \Delta T/R$

$Q =$

Sr. No.	Q=V*I	T_A	T_D	$\Delta T = T_A - T_D$	R	$Q = \Delta T/R$

XVI. Results

Total heat loss through composite wall is -------

XVII. Interpretation of results

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XVIII. Conclusions

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XIX. Practical related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

a) Define Kichoff's law .

b) Differentiate between thermal conductors and insulators.

c) Identify the materials out of which the different layers of composite wall are made.

d) What is the driving force for heat transfer?

e) How various factors affect the thermal resistance of a substance?

[Space for Answers]

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XX. References / Suggestions for further Reading

- http://www.rpsinstitutions.org/downloads/question%20bank/ht.pdf
- https://www.sanfoundry.com/heat-transfer-questions-answers-conduction-composite-wall/
- https://www.youtube.com/watch?v=HbzUeBCmjNQ
- https://www.youtube.com/watch?v=S8bXc8YhtXU

XXI. Assessment Scheme

Performance Indicators		Weightage
Process related (15 Marks)		**60%**
1	Preparation of the experimental set up	20%
2	Setting and operation	20%
3	Safety measures, observation and recording	20%
Product related (10 Marks)		**40%**
4	Calculation and Interpretation of result	20%
5	Practical related question and submission of report	20%
Total (25 Marks)		**100 %**

Names of Student Team Members

1…………………………

2…………………………

3…………………………

4…………………………

Marks Obtained			**Dated signature of Teacher**
Process Related(15)	**Product Related(10)**	**Total (25)**	

Practical No. 4: Calculate heat transfer coefficient in natural convection.

I. Practical Significance

Heat transfer by convection is due to fluid motion. Cold fluid adjacent to a hot surface receives heat which it imparts to the bulk of the cold fluid by mixing with it. Free or natural convection occurs when the fluid motion is not implemented by mechanical agitation. The main objective of this experiment is to calculate the heat transfer coefficient under natural convection..

II. Relevant Program Outcomes (POs)

PO 1. Basic knowledge: Apply knowledge of basic mathematics, sciences and basic engineering to solve the Chemical engineering problems.

PO 3. Experiments and practice: Plan to perform experiments and practices to use the results to solve technical problems related to Chemical engineering.

PO 4. Engineering tools: Apply relevant technologies and Chemical engineering tools with an understanding of the limitations.

PO 7. Ethics: Apply ethical principles for commitment to professional ethics, responsibilities and norms of the practice also in the field of Chemical engineering.

PO 9. Communication: Communicate effectively in oral and written form.

III. Competency and Practical Skills

Use heat transfer principles to increase efficiency and to save energy in chemical process plants.'

1. Use thermocouple to measure temperature.
2. Use voltmeter and ammeter to measure voltage and current.

IV. Relevant Course Outcomes

Apply the concept of convection to operate heat exchanger.

V. Practical Outcome

Use natural heat convection equipment to calculate heat transfer coefficient.

VI. Relevant Affective domain related Outcome(s)

1. Follow safe practices
2. Practice good housekeeping.
3. Maintain tools and equipment.

VII. Minimum Theoretical Background

The heat flow mechanism in fluid is due to convection. Convection is the transfer of heat from one point to another point within a fluid by mixing of hot and cold portions of fluid. Convection is classified as free or natural convection and forced convection.

When the circulating currents arise from the heat transfer process itself, i.e. from the density difference arising in turn due to temperature difference/ gradient within the fluid mass, the mode of heat transfer is called free or natural convection.

When the circulating currents are produced by an external agency such as an agitator in a reaction vessel, pump, fan or blower, the mode of heat transfer is called forced convection. Here fluid motion is independent of density gradients. The mechanical agitation may be supplied by stirring, although in most process applications it is induced by circulating the hot and cold fluids at rapid rates on the opposite sides of pipes or tubes. Forced convection is more rapid and is more common.

In case of convective heat transfer taking place from a surface to a fluid, the circulating currents die out in the immediate viscinity of the surface and a film of the fluid free of turbulence covers the surface. Heat transfer through this film takes by thermal conduction. Since the thermal conductivity of most fluids is low, the main resistance to heat transfer lies in the film. Therefore an increase in the velocity of the fluid over the surface results in improved heat transfer mainly because of reduction in the thickness of the film. If the resistance to heat transfer is considered as lying within the film covering the surface, the rate of heat transfer Q is given by

$$Q = kA\Delta T/ x$$

The effective thickness x is not generally known and therefore this equation is rewritte in the form:

$$Q = hA\Delta T$$

Where, h is called film heat transfer coefficient. The value of ‘h’ depends upon the various properties of the fluid, linear dimension of the surface and fluid velocity.

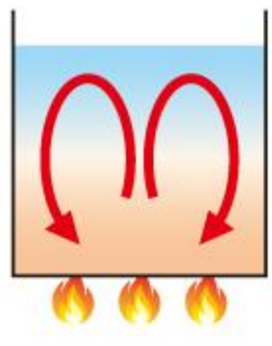

Fig 1 Natural convection- flow is driven only by temperature difference

VIII. Experimental set up:

Figure 2

IX. Resources required

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Natural convection apparatus		1
2	Tube	Diameter = 38 mm, length= 500 mm	1
3	Duct	20mm*20mm*0.75m	1
4	Thermocouples		8
5	Dimmer stat	2 Amp, 260 V	1

X. Precautions to be followed

1. Keep dimmer stat at zero position before switching on the heater.
2. Operate the changeover switch of temperature indicator gently from one position to other.

XI. Procedure

1. Switch on the supply.
2. Adjust the dimmer stat to obtain the required heat input.
3. Wait till steady state is reached.

4. Measure surface temperatures at various points T_1 to T_7.
5. Note the ambient temperature T_8.
6. Repeat steps 2 to 5 for different heat inputs.

XII. Resources used

SI No.	Name of Resource	Suggested Broad Specification		Quantity	Remarks(If any)
		Make	Details		
1					
2					
3					
4					
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XIII. Actual procedure followed

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XIV. Precautions followed

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XV. Observations and Calculations:

1. Diameter of cylinder (D) = -------------cm
2. Length of cylinder (L) = -------------cm

Sr. No.	V	I	Temperatures							$T_{8=}$ T_a
			T_1	T_2	T_3	T_4	T_5	T_6	T_7	
1										
2										
3										

Sample calculation for set no.

1. Area of cylinder (As)= πDL=------------------cm^2
2. Ts = $(T_1 + T_2 + T_3 + T_4 + T_5 + T_6 + T_7) / 7$

   =
3. Ts - Ta =
4. Q= V*I =
5. Heat loss due to due to radiation $Q_R = \varepsilon.As.\sigma.(Ts^4 - Ta^4)$; $\sigma = 5.67*10^{-8}$

   =
6. Heat loss due to convection = $Q - Q_R$
7. Heat transfer coefficient h = $(Q-Q_R)$ / As. (Ts-Ta)

   = W/m^2K

Sr. No.	**Q=V*I**	**Q_R**	**$Q-Q_R$**	**Ts**	**Ta**	**Ts-Ta**	**h**

XVI. Results

Heat transfer coefficient h = ………………

XVII. Interpretation of results

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XVIII. Conclusions

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XIX. Practical related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

a) Differentiate between forced and natural convection.
b) Define film heat transfer coefficient 'h'.
c) Give the unit of film heat transfer coefficient.
d) Give two examples for natural convection.
e) Give the equation relating overall and individual film heat transfer coefficient

[Space for Answers]

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XX. References / Suggestions for further Reading

- https://nptel.ac.in/courses/112101097/22
- https://nptel.ac.in/courses/103103032/21
- https://nptel.ac.in/courses/103103032/22
- https://nptel.ac.in/courses/103103032/23
- http://vlab.amrita.edu/?sub=1&brch=194&sim=791&cnt=3

XXI. Assessment Scheme

Performance Indicators		Weightage
Process related (15 Marks)		**60%**
1	Preparation of the experimental set up	20%
2	Setting and operation	20%
3	Safety measures, observation and recording	20%
Product related (10 Marks)		**40%**
4	Calculation and Interpretation of result	20%
5	Practical related question and submission of report	20%
Total (25 Marks)		**100 %**

Names of Student Team Members

1…………………………

2…………………………

3…………………………

4…………………………

Marks Obtained			Dated signature of Teacher
Process Related(15)	**Product Related(10)**	**Total (25)**	

Practical No. 5: Calculate heat transfer coefficient in forced convection.

I. Practical Significance

Heat transfer by convection is due to fluid motion. Cold fluid adjacent to a hot surface receives heat which it imparts to the bulk of the cold fluid by mixing with it. Free or natural convection occurs when the fluid motion is not implemented by mechanical agitation. But when the fluid is mechanically agitated, the heat is transferred by forced convection. Forced convection is more rapid and therefore very common. Heat flow to a fluid pumped through a heated pipe is an example of forced convection.

II. Relevant Program Outcomes (POs)

PO 1. Basic knowledge: Apply knowledge of basic mathematics, sciences and basic engineering to solve the Chemical engineering problems.

PO 3. Experiments and practice: Plan to perform experiments and practices to use the results to solve technical problems related to Chemical engineering.

PO 4. Engineering tools: Apply relevant technologies and Chemical engineering tools with an understanding of the limitations.

III. Competency and Practical Skills

'Use heat transfer principles to increase efficiency and to save energy in chemical process plants.'

1. Use thermocouple to measure temperature.
2. Use U tube manometer to measure differential pressure

IV. Relevant Course Outcomes

Apply the concept of convection to operate heat exchanger.

V. Practical Outcome

Use forced heat convection equipment to calculate heat transfer coefficient.

VI. Relevant Affective domain related Outcome(s)

1. Follow safe practices
2. Maintain tools and equipment.

VII. Minimum Theoretical Background

The heat flow mechanism in fluid is due to convection. Convection is the transfer of heat from one point to another point within a fluid by mixing of hot and cold portions of fluid. Convection is classified as free or natural convection and forced convection. When the circulating currents arise from the heat transfer process itself, i.e. from the density difference arising in turn due to temperature difference/ gradient within the fluid mass, the mode of heat transfer is called free or natural convection.

When the circulating currents are produced by an external agency such as an agitator in a reaction vessel, pump, fan or blower, the mode of heat transfer is called forced convection. Here fluid motion is independent of density gradients. The mechanical agitation may be supplied by stirring, although in most process applications it is induced by circulating the hot and cold fluids at rapid rates on the opposite sides of pipes or tubes. Forced convection is more rapid and is more common.

In case of convective heat transfer taking place from a surface to a fluid, the circulating currents die out in the immediate viscinity of the surface and a film of the fluid free of turbulence covers the surface. Heat transfer through this film takes by thermal conduction. Since the thermal conductivity of most fluids is low, the main resistance to heat transfer lies in the film. Therefore an increase in the velocity of the fluid over the surface results in improved heat transfer mainly because of reduction in the thickness of the film. If the resistance to heat transfer is considered as lying within the film covering the surface, the rate of heat transfer Q is given by

$$Q = kA\Delta T / x$$

The effective thickness x is not generally known and therefore this equation is rewritte in the form:

$$Q = hA\Delta T$$

Where, h is called film heat transfer coefficient. The value of 'h' depends upon the various properties of the fluid, linear dimension of the surface and fluid velocity.

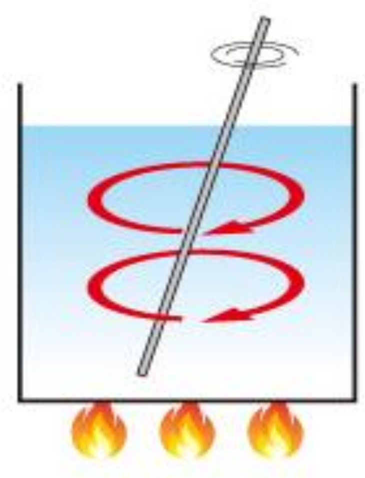

Fig 1 Forced convection where Flow is driven by an external factor

VIII. Experimental set up:

Figure 2

IX. Resources required

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Forced convection apparatus		1
2	Pipe	ID= 26 mm OD= 33 mm Length of test section = 400 mm	1
3	Orificemeter	Diameter = 16 mm	1
4	Thermocouples		6
5	Dimmerstat	2 Amp, 260 V	1

X. Precautions to be followed.

1. Keep dimmer stat at zero position before switching on the heater.
2. Operate the changeover switch of temperature indicator gently from one position to other.

XI. Procedure

1. Put on main supply.
2. Adjust the heater input with the help of dimmerstat.
3. Start the blower and adjust the air flow with valve.
4. Wait till steady state is reached.
5. Note down voltage, current and temperatures T_1 to T_7.
6. Note down manometer difference.
7. Repeat steps 2 to 6 for different heat inputs.

XII. Resources used (with major specifications)

SI No.	Name of Resource	Suggested Broad Specification		Quantity	Remarks (If any)
		Make	Details		
1					
2					
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4					
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XIII. Actual procedure followed

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XIV. Precautions followed

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XV. Observations and Calculations:

Sr. No	Voltage V	Current I	Temperatures							Manometer difference
			T_1	T_2	T_3	T_4	T_5	T_6	T_7	

Sample Calculation for set no.

1. Air inlet temperature T_1= Ta = ^oC

2. Air outlet temperature T_7= ^oC

3. Density of air (ρ_a)= 1.293* 273/ (273+T_1) = ________________ Kg/m^3

4. Diameter of orifice (do)= mm

5. Cross section area of orifice $A_o = \pi do^2 / 4$ = ____________ m^2

6. Manometer difference ΔHm = _____________ m of water

$$\Delta H_f = \Delta Hm(\rho_w / \rho_a) =$$

Where ρ_w = density of water = 1000kg/m^3

7. Volumetric flow rate of air (q) = Co Ao$\sqrt{(2g \Delta H_f)}$ =

Co =0.64

8. Mass flow rate of air (m_a) = q* ρ_a =

9. Heat gained by air Q = m_a * Cp * (T_7-T_1) =

Specific heat of air Cp = 1 kJ/kg K

10. Average inside surface temperature Ts = (T_2+T_3 +T_4+T_5 +T_6) / 5 =

11. Bulk mean temperature of air Tm = (T_1+T_7) / 2 =

12. Heat loss due to due to radiation $Q_R = \varepsilon.A.\sigma.(Ts^4 – Ta^4)$

=

13. Heat loss due to forced convection = Q - Q_R

14. Heat transfer coefficient $h = (Q-Q_R) / A.(Ts-Tm)$

$= \quad\quad W/m^2K$

Sr. No	Q	Q_R	$Q-Q_R$	Ts	Tm	h

XVI. Results

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XVII. Interpretation of results

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XVIII. Conclusions

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XIX. Practical related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

a. Write down Dittus- Boelter equation for turbulent flow for heating.
b. State the effect of turbulence on heat transfer coefficient.
c. Give the expression for Prandtl number (N_{PR}) and Nusselt number (N_{NU}).
d. State any two properties of fluid on which the value of surface heat transfer coefficient depends.

[Space for Answers]

XX. References / Suggestions for further Reading

- https://nptel.ac.in/courses/Webcourse-contents/IISc- BANG/Heat%20 and%20Mass% 20Transfer/pdf/M6/M6TeacherSlides.pdf
- https://nptel.ac.in/courses/103103032/15
- https://nptel.ac.in/courses/112101097/21

XXI. Assessment Scheme

Performance Indicators		Weightage
Process related (15 Marks)		**60%**
1	Preparation of the experimental set up	20%
2	Setting and operation	20%
3	Safety measures, observation and recording	20%
Product related (10 Marks)		**40%**
4	Calculation and Interpretation of result	20%
5	Practical related question and submission of report	20%
Total (25 Marks)		**100 %**

Names of Student Team Members

1…………………………

2…………………………

3…………………………

4…………………………

Marks Obtained			Dated signature of Teacher
Process Related(15)	**Product Related(10)**	**Total (25)**	

Practical No. 6: Use process simulator to measure various parameters.

I. Practical significance:

Simulation software is used to study the effect on various process variables such as pressure, temperature, flow, level by introducing / activating malfunctions in the normal operation.

II. Relevant Program Outcomes *(POs)*

PO 3.Experiments and practice: Plan to perform experiments and practices to use the results to solve technical problems related to Chemical engineering.

PO 4. Engineering tools: Apply relevant technologies and Chemical engineering tools with an understanding of the limitations.

III. Competency and Skills

'Use heat transfer principles to increase efficiency and to save energy in chemical process plants.'

1. Change parameter susing simulator.
2. Take appropriate action based on trends.

1V. Relevant Course Outcome(s)

1. Calculate rate of heat transfer by conduction.
2. Apply the concept of convection to operate heat exchanger.
3. Choose proper heat transfer equipment for given application.

V. Practical Outcome

Measure various parameters controlled in a heat exchanger using process simulator.

VI. Relevant Affective Domain Related Outcomes.

a. Load the exercise and run the simulation.
b. Record the change in values of process variable with introduction of malfunction.

VII. Minimum Theoretical Background

The objective in training a student on this system is to explore the control system tied up to non- linear process behavior. In the temperature and pressure control module, temperature controller regulates the pressure of steam entering the heat exchanger.

The steam pressure on shell side is non – linear function of temperature on shell side into the heat exchanger.

The non – linearity in the relation between steam pressure on shell side and shell side temperature comes into the existence because the temperature of the liquid out rises. It sends a remote signal to the pressure controller who in turn shall reduce the steam flow to the exchanger and gradually the temperature of cold liquid out will decrease.

There are two controllers acting as a master and slave and controlling two significant operating variables viz. temperature of cold liquid outlet and pressure of the steam.

The temperature controller regulates the pressure of the steam entering the heat exchanger.

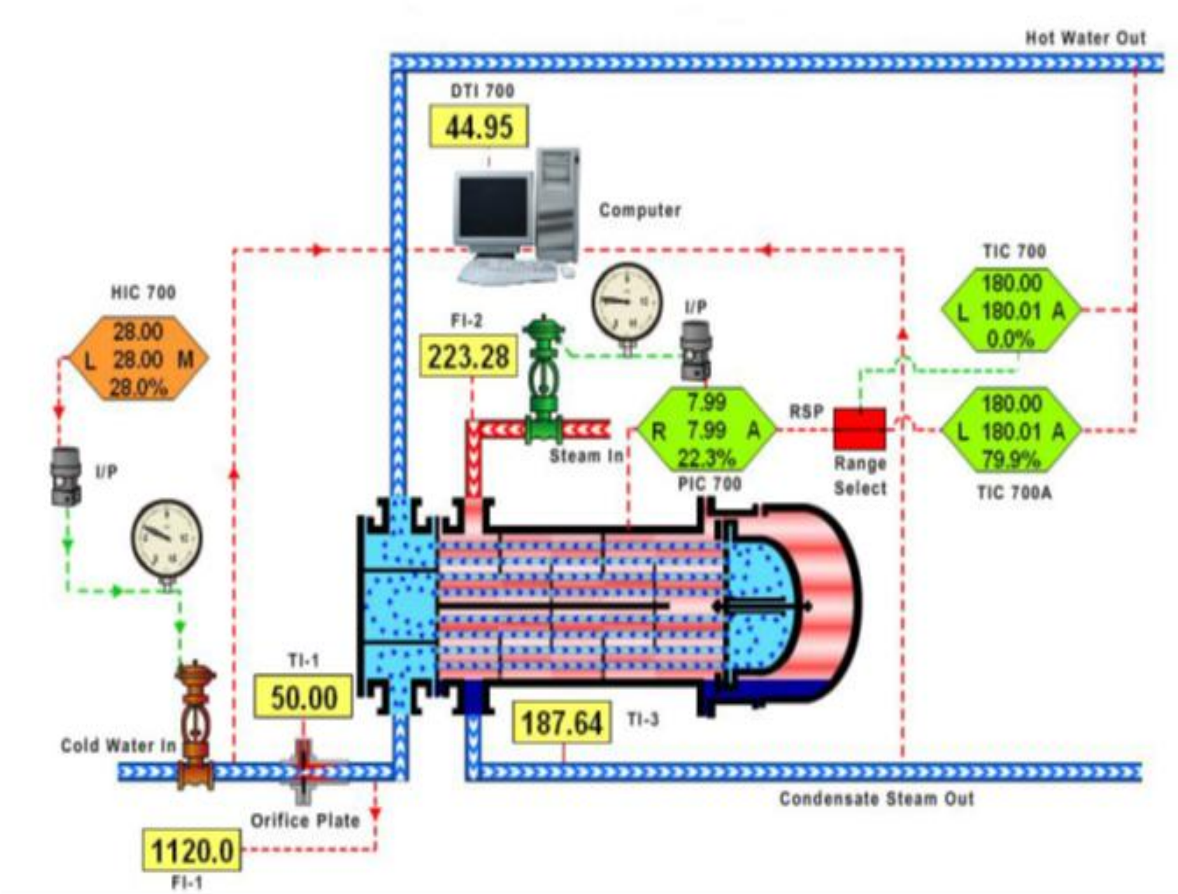

Fig 1 process simulator

VIII. Experimental setup

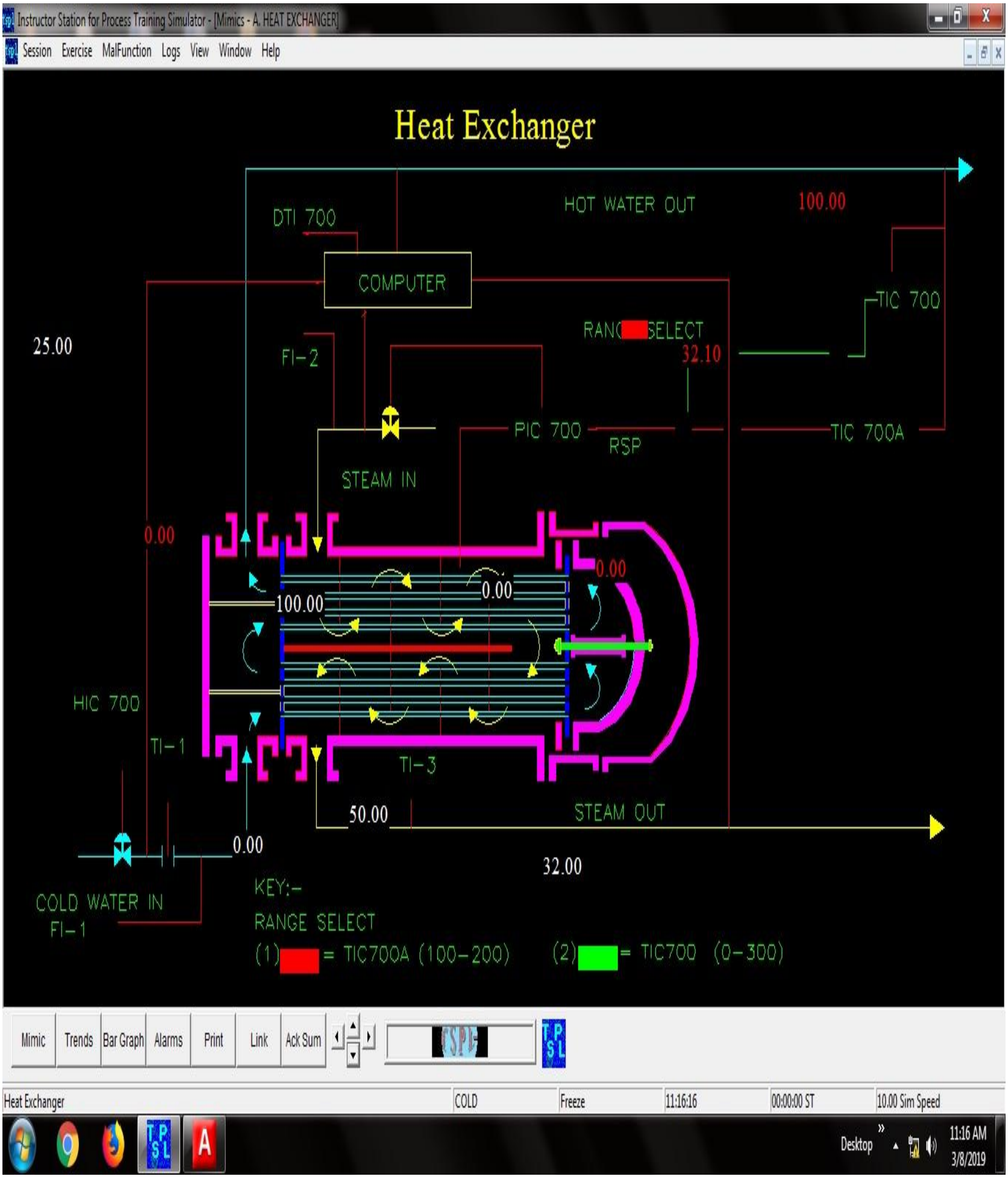

Figure 2

IX. Resources Required.

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Simulation software	Tri-angle simulation	1

X. Precautions to be followed.

1. After starting the software, ensure that the name of heat exchanger is showing in the dialogue box.

XI. Procedure

1. Load design (9999 N 220) exercise from old database to run the simulation.
2. Decrease the set point of final temperature (TIC-01) of hot liquid and note down the changes in
   a. Hot big inlet flow rate (FIC-02).
   b. Cold water outlet temperature(TI-03)
   c. Bypass hot liquid flow rate (FI-03)
3. Increase the set point of final temperature (TIC-01) of hot liquid and note down the changes in
   a. Hot big inlet flow rate (FIC-02).
   b. Cold water outlet temperature (TI-03)
   c. Bypass hot liquid flow rate (FI-03)
4. Decrease the set point of water flow rate (FIC-01) and note down the changes in
   a. Cold water outlet temperature (TI-03).
   b. Hot liquid outlet temperature (TI-04)
   c. Hot liquid outlet flow rate (FI-04)
   d. By pass stream of hot liquid flow rate (FI-03)
5. Increase the set point of cold water flow rate (FIC-01) and note down the the changes in
   a. Cold water outlet temperature (TI-03).
   b. Hot liquid outlet temperature (TI-04)
   c. Hot liquid outlet flow rate (FI-04)
   d. By pass stream of hot liquid flow rate (FI-03)

XII. Resources used.

Sr No.	Name of Resource	Suggested Broad Specification		Quantity	Remarks (If any)
		Make	Details		
1					
2					

XIII. Actual Procedure Followed.

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XIV. Precaution followed.

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XV. Observation and Calculation

1. Set point of final temperature in (TIC-01) of hot liquid is decreased from ………^{0}C to ………….^{0}C
   a. Hot liquid inlet flow rate (FIC-02) changes from …….kg/h to ……kg/h
   b. Cold water outlet temperature (TI-03) changes from ………^{0}C to ……..^{0}C.
   c. Bypass hot liquid flow rate (FI-03) changes from ………kg/h to ……..kg/h.

2. Set point of final temperature in (TIC-01)of hot liquid is increased from ……..^{0}C to …….^{0}C
   a. Hot liquid inlet flow rate (FIC-02) changes from …….kg/h to ……kg/h
   b. Cold water outlet temperature (TI-03) changes from ………^{0}C to ……..^{0}C
   c. Bypass hot liquid flow rate (FI-03) changes from ………kg/h to ……..kg/h.

3. Set point of cold water flow rate (FIC-01)is decreased from ……kg/h to ……..kg/h
   a. Cold water outlet temperature (TI-03) changes from ………^{0}C to ……..^{0}C
   b. Hot liquid outlet temperature (TI-04) changes from ………^{0}C to ……..^{0}C.
   c. Hot liquid outlet flow rate (FI-04) changes from ………kg/h to ……..kg/h
   d. Bypass stream of hot liquid flow rate (FI-03) changes from ………kg/h to ….. kg/h.

4. Set point of cold water flow rate (FIC-01)is increased from …….kg/h to ……kg/h
   a. Cold water outlet temperature (TI-03) changes from ………^{0}C to ……..^{0}C
   b. Hot liquid outlet temperature (TI-04) changes from ………^{0}C to ……..^{0}C
   c. Hot liquid outlet flow rate (FI-04) changes from ………kg/h to ……..kg/h
   d. Bypass stream of hot liquid flow rate (FI-03) changes from ………kg/h to ……..kg/h

XVI Results

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XVII. Interpretation of Results

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XVIII. Conclusions

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XIX. Practical Related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

a) What is the effect on cold water flow rate with the outlet temperature of hot liquid?
b) What is the effect on cold water outlet temperature when flow rate of hot liquid increases?
c) What is the effect on cold water outlet temperature when cold water flow rate is increased?
d) What is the effect on hot liquid outlet flow rate when cold water flow rate decreases?

[Space for Answers]

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XX. References/ Suggestions for Further Reading

- https://controlguru.com/pid-control-of-the-heat-exchanger/
- https://www.oilandgaseng.com/articles/applying-heat-exchanger-control-strategies/
- https://controlguru.com/step-test-data-from-the-heat-exchanger-process/

XXI. Assessment Scheme.

Performance Indicators		Weightage
Process related (15 Marks)		**60%**
1	Preparation of the experimental set up	20%
2	Setting and operation	20%
3	Safety measures, observation and recording	20%
Product related (10 Marks)		**40%**
4	Calculation and Interpretation of result	20%
5	Practical related question and submission of report	20%
Total (25 Marks)		**100 %**

Names of Student Team Members

1…………………………

2…………………………

3…………………………

4…………………………

Marks Obtained			Dated signature of Teacher
Process Related(15)	**Product Related(10)**	**Total (25)**	

Practical No. 7: Calculate emissivity of a plate.

I. Practical Significance

Radiation is regarded as a phenomenon to hot and luminous bodies. The substances having nearly complete or unit absorptivities are called black body. A black body absorbs all radiation falling on it. Lampblack, platinum black and bismuth black are examples of black body. The ratio of the total emissive power (E) of a body to that of a black body (E_b) at the same temperature is known as emissivity (e) of that body.

II. Relevant Program Outcomes (POs)

PO 1. Basic knowledge: Apply knowledge of basic mathematics, sciences and basic engineering to solve the Chemical engineering problems.

PO 2. Discipline knowledge: Apply Chemical engineering knowledge to solve industry based Chemical Engineering problems.

PO 7. Ethics: Apply ethical principles for commitment to professional ethics, responsibilities and norms of the practice also in the field of Chemical engineering.

PO 8. Individual and team work: Function effectively as a leader and team member in diverse/ multidisciplinary teams.

PO 9. Communication: Communicate effectively in oral and written form.

III. Competency and Practical Skills

'Use heat transfer principles to increase efficiency and to save energy in chemical process plants.'

1. Use thermocouple to measure temperature.
2. Use voltmeter and ammeter to measure voltage and current.

IV. Relevant Course Outcomes

Calculate amount of heat transfer by radiation.

V. Practical Outcome

Calculate emissivity of the given material.

VI. Relevant Affective domain related Outcome(s)

1. Follow safe practices
2. Practice energy conservation.
3. Maintain tools and equipment.
4. Follow ethical practices.

VII. Minimum Theoretical Background

Radiation refers to the transport of energy through space by electromagnetic waves. It depends upon the electromagnetic waves as a means for transfer of energy from a source to a receiver. Heat transfer by radiation is of much more importance at higher temperature levels as compared to conduction and convection. Radiant energy is believed to originate within the molecules of the radiating body, the atoms of such molecules vibrating in a simple harmonic motion as linear oscillators. A body at a given temperature will emit radiation of a whole range of wavelength and not a single wavelength. The total quantity of radiant energy of all wavelengths emitted by a body per unit area and time is the total emissive power.

When radiant energy falls upon a body, it may be all or partially absorbed, reflected or transmitted. The fraction of radiant energy absorbed is called absorptivity (α), fraction reflected is called reflectivity (ρ) and the fraction transmitted is called transmissivity (τ)

$$\alpha + \rho + \tau = 1$$

The substances having nearly complete or unit absorptivities are called black body. A black body absorbs all radiation falling on it.

The ratio of the total emissive power (E) of a body to that of a black body (E_b) at the same temperature is known as emissivity (e) of that body.

$$e = E/E_b$$

Emissivity depends on the temperature of the body only. The emissivity of a body is the measure of how it emits radiant energy in comparison with a black body at the same temperature.

As per Kirchhoff's law, when any body is in thermal equilibrium with its surroundings, its emissivity and absorptivities are equal.

Fig 1 Emissivity apparatus

VIII. Experimental set up:

Figure 2

IX. Resources required

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Emissivity measurement apparatus		1
2	Black plate	Diameter = 0.15 m	1
3	Test plate	Diameter = 0.15 m	1
4	Thermocouples		4

X. Precautions to be followed

1. Keep the dimmer stat at zero position before switching on and switching off the heaters.
2. Keep the assembly undisturbed while testing.
3. Do not disturb the thermocouple setting.
4. Do not touch your finger to or scratch on the plate and test plate.

XI. Procedure

1. Check that the dimmer stats are at zero position and the duct is closed.
2. Switch on the main switch and give some power to both the plates by adjusting the dimmer stat. The power supplied to black plate heater should be equal to that of test plate heater.
3. Go on checking the temperatures of each of the plate surface. These temperatures are required to be equal. To get them equal, test and adjust the dimmer stat so as to get uniform temperature. Take an individual test for each plate, but the parameters of temperatures should be equal.
4. After getting equal temperatures on both the surfaces, individually note temperatures of each plate as well as duct temperatures.

XII. Resources used

SI No.	Name of Resource	Suggested Broad Specification		Quantity	Remarks (If any)
		Make	Details		
1					
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XIII. Actual procedure followed

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XIV. Precautions followed

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XV. Observations and Calculations:

Plate	Input		Surface temperature
	V	I	
Test plate			
Black plate			

1. Diameter of the plate D =
2. Effective area of the plate A= -------------------m^2

Sample calculation for set no.

1. Enclosure temperature $T_E = T_3 =$ $^0C =$ K
2. Plate surface temperature (Ts) = $T_1 = T_2 =$ $^0C =$ K
3. Heat input to black plate Wb = V*I = W
4. Heat input to test plate W_T = V*I = W
5. Surface area of test plate (A) =
6. $Wb - W_T = \sigma.A[Ts^4 - T_E^4] (1 - \varepsilon)$

   σ = Stefan Boltzman constant = $5.67*10^{-8}$

   or ε =

XVI. Results

Emissivity of the material ε = ………………

XVII. Interpretation of results

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XVIII. Conclusions

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XIX. Practical related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

a. Define radiation.
b. Write any two examples for radiation.
c. Define the terms absorptivity, reflectivity and transmissivity.
d. Define emissivity and emissive power.

[Space for Answers]

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XX. References / Suggestions for further Reading

- https://vlab.amrita.edu/?sub=1&brch=194&sim=802&cnt=1
- https://nptel.ac.in/courses/112106139/pdf/4_2.pdf
- https://nptel.ac.in/courses/103103032/module7/lec30/1.html

XXI. Assessment Scheme

Performance Indicators		Weightage
Process related (15 Marks)		**60%**
1	Preparation of the experimental set up	20%
2	Setting and operation	20%
3	Safety measures, observation and recording	20%
Product related (10 Marks)		**40%**
4	Calculation and Interpretation of result	20%
5	Practical related question and submission of report	20%
Total (25 marks)		**100 %**

Names of Student Team Members

1…………………………

2…………………………

3…………………………

4…………………………

Marks Obtained			**Dated signature of Teacher**
Process Related(15)	**Product Related(10)**	**Total (25)**	

Practical No. 8: Determine Stefan Boltzman constant

I. Practical Significance

By knowing the value of Stefan Boltzman constant, we can calculate the total emissive power of surface. Stefan Boltzman law states that total emissive power of a surface is proportional to fourth power of absolute surface temperature.

II. Relevant Program Outcomes (POs)

PO 1. Basic knowledge: Apply knowledge of basic mathematics, sciences and basic engineering to solve the Chemical engineering problems

PO 2. Discipline knowledge: Apply Chemical engineering knowledge to solve industry based Chemical Engineering problems.

PO 3. Experiments and practice: Plan to perform experiments and practices to use the results to solve technical problems related to Chemical engineering.

PSO 2. **Material management and quality control:** Manage chemicals and equipment to produce quality chemical products.

III. Competency and Practical Skills

'Use heat transfer principles to increase efficiency and to save energy in chemical process plants.'

1. Use orifice meter for accurate measurement of flow rate.
2. Measure the differential pressure using manometer.

IV. Relevant Course Outcomes

1. Calculate amount of heat transfer by radiation.

V. Practical Outcome

Using Stefan Boltzman law apparatus determine Stefan Boltzman constant.

VI. Relevant Affective domain related Outcome(s)

1. Follow safe practices
2. Maintain tools and equipment.
3. Practice good housekeeping.
4. Follow ethical practices.

VII. Minimum Theoretical Background

All substances emit thermal radiation. When heat radiation is incident over a body, part of radiation is absorbed, transmitted through and reflected by the body. A surface which absorbs all thermal radiation incidents over it is called black surface (body). For black surface, transmissivity and reflectivity are zero and absorptivity is unity. Stefan Boltzman law states that total radiation from a perfect black body is proportional to the fourth power of the absolute temperature of the body.

$$W_b \ \alpha \ T^4$$

$$W_b = \sigma T^4$$

For non black body $W/W_b = \varepsilon$

Therefore $W = \varepsilon \sigma T^4$

Where σ is Stefan Boltzman constant = $5.67*10^{-8}$ W/ m^2 K^4

ε is emissivity of the surface

T is absolute temperature

Fig 1 Stefan Boltzman apparatus

VIII. Experimental set up:

Figure 2

IX. Resources Required

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Stefan Boltzman apparatus		1

X. Precautions

1. Never put ON the heater before putting water in the tank.
2. Put off the heater before draining the water from heater tank.
3. Drain the water after completion of experiment.
4. Operate all the switches and controls gently.

XI. Procedure

1. See that water inlet cock of water jacket is closed and fill up sufficient water in the heater tank.
2. Put ON the heater.
3. Blacken the test disc with the help of lamp black and let it cool.
4. Put the thermometer and check water temperature.
5. Boil the water and switch off the heater.

6. See that drain cock of water jacket is closed and open water inlet cock.
7. See that there is sufficient water above the top of hemisphere(a piezometer tube is fitted to indicate water level).
8. Note down the hemisphere temperature (up to channel 1 to 4).
9. Note down the disc temperature (i.e. channel 5).
10. Start the timer, buzzer will start ringing. At the start of timer cycle, insert test disc into the hole at the bottom of hemisphere.
11. Note down the temperatures of disc, every five times of the buzzer rings.
12. Take at least 8-10 readings

XII. Resources used

Sr No.	Name of Resource	Suggested Broad Specification		Quantity	Remarks (If any)
		Make	Details		
1					
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XIII. Actual procedure followed

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XIV. Precautions followed

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XV. Observations and Calculations:

Sr. No	Hemisphere temperature ^oC
1	$T_1 =$
2	$T_2 =$
3	$T_3 =$
4	$T_4 =$

Sr. No	Time interval	Test disc temperature ^oC
1	0	
2	25	
3	50	
4	75	
5	100	
6	125	
7	150	
8	175	
9	200	
10	225	

Sample calculation for set no.

1. Area of test disc $A = \pi d^2 /4 =$

2. Mass of test disc m = ………………kg

3. Plot a graph of temperature rise of test disc with time as base and find out its slope (dT/ dt)

4. Hemisphere temperature $T_H = (T_1 + T_2 + T_3 + T_4)/4 =$…………..$^0C$

   = …………..K

5. Initial test disc temperature $T_D = T_5 + 273$

6. $\sigma = m.Cp.(dT/dt) / A.(T_H^4 - T_D^4)$

   = …………………

XVI. Results

Stefan Boltzman constant $\sigma =$ ……………………W / m^2 K

XVII. Interpretation of results

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XVIII. Conclusions

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XIX Practical related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

a. Name laws of black body radiation
b. Explain Stefan Boltzman law with mathematical expression.
c. Explain Plank's law

[Space for Answers]

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XX References / Suggestions for further Reading

- https://www.youtube.com/watch?v=onGuJZS8-Sc
- http://vlab.amrita.edu/index.php?brch=194&cnt=1&sim=548&sub=1
- http://elartu.tntu.edu.ua/bitstream/123456789/1793/1/lab_O3.pdf

XXI. Assessment Scheme

Performance Indicators		Weightage
Process related (15 Marks)		**60%**
1	Preparation of the experimental set up	20%
2	Setting and operation	20%
3	Safety measures, observation and recording	20%
Product related (10 Marks)		**40%**
4	Calculation and Interpretation of result	20%
5	Practical related question and submission of report	20%
Total (25 Marks)		**100 %**

Names of Student Team Members

1. …………………………

2.…………………………

3.…………………………

4.…………………………

Marks Obtained			**Dated signature of Teacher**
Process Related(15)	**Product Related(10)**	**Total (25)**	

Practical No: 9: Compare the outside temperatures of black body and test plate.

I. Practical Significance:

Radiation is regarded as a phenomenon to hot and luminous bodies. The substances having nearly complete or unit absorptivities are called black body. A black body absorbs all radiation falling on it. Lampblack, platinum black and bismuth black are examples of black body.

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II. Relevant Program Outcomes (POs)

PO1. Basic knowledge: Apply knowledge of basic mathematics, sciences and basic engineering to solve the Chemical Engineering problems

PO2. Discipline knowledge: Apply Chemical Engineering knowledge to solve industry based Chemical Engineering problems.

PO3. Experiments and practice: Plan to perform experiments and practices to use the results to solve technical problems related to Chemical Engineering.

PO 8. Individual and team work: Function effectively as a leader and team member in diverse/ multidisciplinary teams.

PO 9. Communication: Communicate effectively in oral and written form.

PSO 2. Material management and quality control: Manage chemicals and equipment to produce quality chemical products.

III. Competency and Practical Skills

'Use heat transfer principles to increase efficiency and to save energy in chemical process plants.'

1. Use thermocouple to measure temperature.

IV. Relevant Course Outcomes

1. Calculate amount of heat transfer by radiation.

V. Practical Outcome–

Using emissivity measurement apparatus compare the outside surface temperatures of black body and test plate.

VI. Relevant Affective domain related Outcome(s)

1. Follow safe practices
2. Maintain tools and equipment.
3. Follow ethical practices.
4. Demonstrate working as a leader/a team member

VII. Minimum Theoretical Background

Radiation refers to the transport of energy through space by electromagnetic waves. It depends upon the electromagnetic waves as a means for transfer of energy from a source to a receiver. Heat transfer by radiation is of much more importance at higher temperature levels as compared to conduction and convection. Radiant energy is believed to originate within the molecules of the radiating body, the atoms of such molecules vibrating in a simple harmonic motion as linear oscillators. A body at a given temperature will emit radiation of a whole range of wavelength s and not a single wavelength. The total quantity of radiant energy of all wavelengths emitted by a body per unit area and time is the total emissive power.

When radiant energy falls upon a body, it may be all or partially absorbed, reflected or transmitted. The fraction of radiant energy absorbed is called absorptivity (α), fraction reflected is called reflectivity (ρ) and the fraction transmitted is called transmissivity (τ)

$$\alpha + \rho + \tau = 1$$

The substances having nearly complete or unit absorptivities are called black body. A black body absorbs all radiation falling on it.

The ratio of the total emissive power (E) of a body to that of a black body (E_b) at the same temperature is known as emissivity (e) of that body.

$$e = E/E_b$$

Emissivity depends on the temperature of the body only. The emissivity of a body is the measure of how it emits radiant energy in comparison with a black body at the same temperature.

As per Kirchhoff's law, when any body is in thermal equilibrium with its surroundings, its emissivity and absorptivities are equal.

Fig 1 Emissivity apparatus

VIII. Experimental set up :

Figure 2

IX. Resources required

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Emissivity measurement apparatus		1
2	Black plate	Diameter = 0.15 m	1
3	Test plate	Diameter = 0.15 m	1
4	Thermocouples		4

X. Precaution

1. Keep the dimmer stat at zero position before switching on and switching off the heaters.
2. Keep the assembly undisturbed while testing.
3. Do not disturb the thermocouple setting.
4. Do not touch your finger to or scratch on the plate and test plate.

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XI. Procedure

1. Check that the dimmer stats are at zero position and the duct is closed.
2. Switch on the main switch and give some power to both the plates by adjusting the dimmer stat. The power supplied to black plate heater should be equal to that of test plate heater.
3. Note down the temperatures of each of the plate surface.
4. Note down the temperatures of outside the test plate and black plate.
5. Repeat the procedure for different values of power input.

XII. Resources used (with major specifications)

Sr. No.	Name of Resource	Suggested Broad Specification		Quantity	Remarks (If any)
		Make	Details		
1					
2					
3					
4					

XIII. Actual procedure followed

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XIV. Precautions followed

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XV. Observations and Calculations:

Sr. No	Test plate				Black plate			
	V	I	Surface temperature	Outside temperature	V	I	Surface temperature	Outside temperature
1								
2								
3								
4								
5								

Sample calculation for set no.

1. Power input to test plate W_T=V*I =
2. Power input to black plate W_b =V*I =
3. Surface temperature of test plate =
4. Outside temperature of test plate =
5. Surface temperature of black plate =
6. Outside temperature of black plate =

XVI. Results

When the power input is …………..W,

Outside temperature of black plate = ………….

Outside temperature of test plate = ………..

XVII. Interpretation of results

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XVIII. Conclusions

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XIX. Practical related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

1. Define black body
2. Define gray body
3. Define monochromatic emissivity
4. Explain Kirchhoff's law of radiation

[Space for Answers]

XX. References / Suggestions for further Reading

- http://www.svcetedu.org/cms/images/mech/uploads/htlab.pdf
- https://www.youtube.com/watch?v=pbCf4507QvM
- https://www.youtube.com/watch?v=YQTB50AaKsc
- https://www.youtube.com/watch?v=H3TcLoapJBo

XXI Assessment Scheme

Performance Indicators		Weightage
Process related (15 Marks)		**60%**
1	Preparation of experimental set up	20%
2	Setting and operation	20%
3	Safety measures, observation and recording	20%
Product related (10 Marks)		**40%**
4	Calculation and Interpretation of result	20%
5	Practical related question and submission of report	20%
Total (25 Marks)		**100 %**

Names of Student Team Members

1. …………………………
2. …………………………
3. …………………………
4. …………………………

Marks Obtained			Dated signature of Teacher
Process Related(15)	Product Related(10)	Total (25)	

Practical No: 10. Operate double pipe heat exchanger and calculate overall heat transfer coefficient for co current flow

I. Practical Significance:

The heat transfer coefficient is an important parameter during thermal application in Chemical Process industry. Double pipe heat exchangers are used in industries for heating or cooling of process fluids. Flow pattern affects the overall heat transfer coefficient.

II. Relevant Program Outcomes (POs)

PO1. Basic knowledge: Apply knowledge of basic mathematics, sciences and basic engineering to solve the Chemical **Engineering** problems

PO2. Discipline knowledge: Apply **Chemical Engineering** knowledge to solve industry based Chemical Engineering problems.

PO3. Experiments and practice: Plan to perform experiments and practices to use the results to solve technical problems related to Chemical **Engineering**.

PO 9. Communication: Communicate effectively in oral and written form.

PSO 2.Material management and quality control: Manage chemicals and equipment to produce quality chemical products.

III. Competency and Practical Skills

'Use heat transfer principles to increase efficiency and to save energy in chemical process plants.'

1. Use thermocouple to measure temperature.
2. Use rotameter to measure volumetric flow rate.

IV. Relevant Course Outcomes

1. Apply the concept of convection to operate heat exchanger.
2. Choose proper heat transfer equipment for given application.

V. Practical Outcome

Using double pipe heat exchanger calculate overall heat transfer coefficient for co current flow.

VI. Relevant Affective domain related Outcome(s)

1. Follow safe practices
2. Maintain tools and equipment.

VII. Minimum Theoretical Background

In its simplest form, the double pipe heat exchanger, (also known as a concentric pipe, hairpin, jacked pipe and jacketed U-tube heat exchangers), consists of a single tube mounted inside another. One fluid flows in the inner pipe, while a second fluid flows annular space created between two concentric pipes. The Overall heat transfer coefficient takes in to account the individual heat transfer coefficient of each stream and resistance of the pipe material. The heat transfer coefficient is the heat transferred per unit area per kelvin. When both fluids (hot and cold) flow in the same direction from one end of heat exchanger to the other end of heat exchanger then the flow is called co-current flow or parallel flow.

Double pipe heat exchangers are used when the heat transfer area required is relatively small.

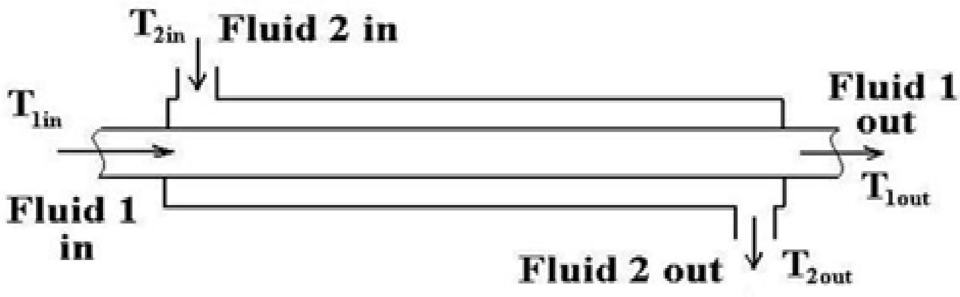

Fig. 1 Double pipe heat exchanger for co current flow

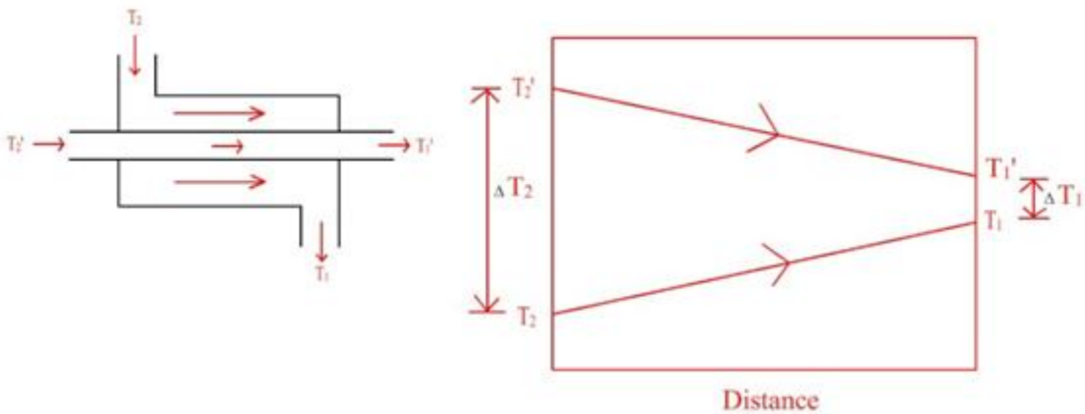

Fig. 2 Temperature profile for co current flow

VIII. Experimental set up:

Figure 3

IX. Resources required

SI No.	Name of Resource	Suggested Broad Specification	Quantity
1	Inner pipe	ID = 26mm OD= 43 mm length = 1.2 m	1
2	Outer pipe	ID = 68mm OD= 76 mm	1
3	Rotameter	1-10 LPM	2

X. Precautions

1. Adjust flow rate properly and, consider the reading corresponding to reading edge of the float.
2. Wait for the float to be stable before taking the reading.
3. Wait for steady state condition to reach before taking inlet and outlet temperatures of hot and cold fluid.

XI. Procedure

1. Make the hot and cold water to flow through double pipe heat exchanger by opening the valves.
2. Adjust the flow rates of both fluids by adjusting the valves.
3. Switch ON the heater and wait for steady state condition to be attained.
4. Measure the flow rate of hot and cold water with the help of rotameter.
5. Note down the readings of inlet and outlet temperatures of hot and cold water.
6. Repeat the procedure for different flow rates of cold water.

XII. Resources used (with major specifications)

Sr No.	Name of Resource	Suggested Broad Specification		Quantity	Remarks (If any)
		Make	Details		
1					
2					
3					

XIII. Actual procedure followed

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XIV. Precautions followed

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XV. Observations and Calculations:

1. Inner Diameter of inner pipe (di) =
2. Outer Diameter of inner pipe (do) =
3. Length of pipe (L) =

Sr. No.	Cold Water			Hot Water		
	Flow Rate (lit/Sec)	T_{ci} (K)	T_{co} (K)	Flow Rate (lit/Sec)	T_{hi} (K)	T_{ho} (K)
1						
2						
3						
4						

Sample calculation for set no

Properties of water at mean temperature

Cp_h = ……………. KJ/kgK

Cp_c = …………….. KJ/kgK

ρ_h = ………… kg/m^3

ρ_c = ……….. kg/m^3

Q = rate of heat transfer

1. $Q_h = m_h \times Cp_h \times (T_{hi} - T_{ho})$

   = ……………………..

   = …………….W.

Where

T_{hi} = Inlet temperature of Hot fluid in K

T_{ho} = Outlet temperature of Hot fluid in K

m_h = Mass flow rate of hot water in kg/sec

Cp_h = Specific heat capacity of hot water in KJ/kg.K

2. $Qc = m_c \times Cp_c \times (T_{co} - T_{ci})$

   = ……………………..

   = …………….W.

Where

T_{ci} = Inlet temperature of cold fluid in K

T_{co} = Outlet temperature of cold fluid in K

m_c = Mass flow rate of cold water in kg/sec

Cp_c = Specific heat capacity of cold water in KJ/kg.K

3. Q = (Qh+Qc)/2

   Q = ……………….

4. Overall Heat Transfer coefficient

   $Q = U \times A \times \Delta T_{lm}$

   Where $\Delta T_{lm} = \Delta T_2 - \Delta T_1 / \ln(\Delta T_2/\Delta T_1)$

   $\Delta T_1 = (\Delta T_{hi} - \Delta T_{ci})$ = ……….. ………………… =……….. K

   $\Delta T_2 = (\Delta T_{ho} - \Delta T_{co})$ = ……….. ……………….. =………. .K

ΔT_{lm} = ………………………………………… . = ……….K

Inside heat transfer area (A_i) = π x D_i x L

= ……………………………………

= ……………..m^2

Outside heat transfer area (A_o) = π x Do x L

= ……………………………………

= ……………..m^2

Overall heat transfer based on outside area (U_o)

5. Q = U_o x A_o x ΔT_{lm}

U_o = Q/(A_o x ΔT_{lm})

= ……………………………………………

= …………….W/m^2K

6. Overall heat transfer based on inside area (U_i)

Q = Ui x A_i x ΔT_{lm}

U_i = Q/(A_i x ΔT_{lm})

= ……………………………………………

= …………….W/m^2K

Sr. No.	**Qh**	**Qc**	**Q**	**ΔT_{lm}**	**U_o**	**U_i**
1						
2						
3						
4						

XVI. Results

1. Overall heat transfer based on inside area (U_i) =

2. Overall heat transfer based on outside area (U_o)

XVII. Interpretation of results

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XVIII. Conclusions

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XIX. Practical related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

a. Give the range of rotameter used to find flow rates of hot and cold water.
b. Draw the temperature length curve for co current flow in double pipe heat exchanger.
c. Give any two advantages of double pipe heat exchanger.
d. Give any two disadvantages of double pipe heat exchanger.
e. Give any industrial application of co current flow double pipe heat exchanger.

[Space for Answers]

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XX. References / Suggestions for further Reading

- http://vlabs.iitb.ac.in/vlab/chemical/exp8/index.html
- https://www.che.utah.edu/site-specific-resources/chemical- https://nptel.ac.in /courses/103103032/11

XXI. Assessment Scheme

Performance Indicators		Weightage
Process related (15 Marks)		**60%**
1	Preparation of experimental set up	20%
2	Setting and operation	20%
3	Safety measures, observation and recording	20%
Product related (10 Marks)		**40%**
4	Calculation and Interpretation of result	20%
5	Practical related question and submission of report	20%
Total (25 Marks)		**100 %**

Names of Student Team Members

1. …………………………

2.…………………………

3.…………………………

4.…………………………

Marks Obtained			**Dated signature of Teacher**
Process Related(15)	**Product Related(10)**	**Total (25)**	

Practical No. 11: Operate double pipe heat exchanger and calculate overall heat transfer coefficient for counter current flow

1. Practical Significance

The heat transfer coefficient is a very important parameter during thermal application in Chemical Process industry. Double pipe heat exchangers are used in industries for heating or cooling of process fluids. Flow pattern affects the overall heat transfer coefficient. Heat transfer rate is more in counter current flow.

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II. Relevant Program Outcomes (POs)

PO1. Basic knowledge: Apply knowledge of basic mathematics, sciences and basic engineering to solve the Chemical Engineering problems

PO2. Discipline knowledge: Apply Chemical Engineering knowledge to solve industry based Chemical Engineering problems.

PO3. Experiments and practice: Plan to perform experiments and practices to use the results to solve technical problems related to Chemical Engineering.

PO6. Environment and sustainability: Apply Chemical engineering solutions also for sustainable development practices in societal and environmental contexts.

PO 8. Individual and team work: Function effectively as a leader and team member in diverse/ multidisciplinary teams.

III. Competency and Practical Skills

'Use heat transfer principles to increase efficiency and to save energy in chemical process plants.'

1. Use thermocouple to measure temperature.
2. Use rotameter to measure volumetric flow rate

IV. Relevant Course Outcomes

1. Apply the concept of convection to operate heat exchanger.
2. Choose proper heat transfer equipment for given application

V. Practical Outcome

Using double pipe heat exchanger calculate overall heat transfer coefficient for counter current flow

VI. Relevant Affective domain related Outcome(s)

1. Follow safe practices
2. Maintain tools and equipment.
3. Practice energy conservation.

VII. Minimum Theoretical Background

In its simplest form, the double pipe heat exchanger, (also known as a concentric pipe, hairpin, jacked pipe and jacketed U-tube heat exchangers), consists of a single tube mounted inside another. One fluid flows in the inner pipe, while a second fluid flows in the outer pipe annuals. The Overall heat transfer coefficient takes in to account the individual heat transfer coefficient of each stream and resistance of the pipe material.

The heat transfer coefficient is the heat transferred per unit area per kelvin. When both fluids (hot and cold) flow in the opposite direction from one end of heat exchanger to the other end of heat exchanger then the flow is called co-current flow or parallel flow.

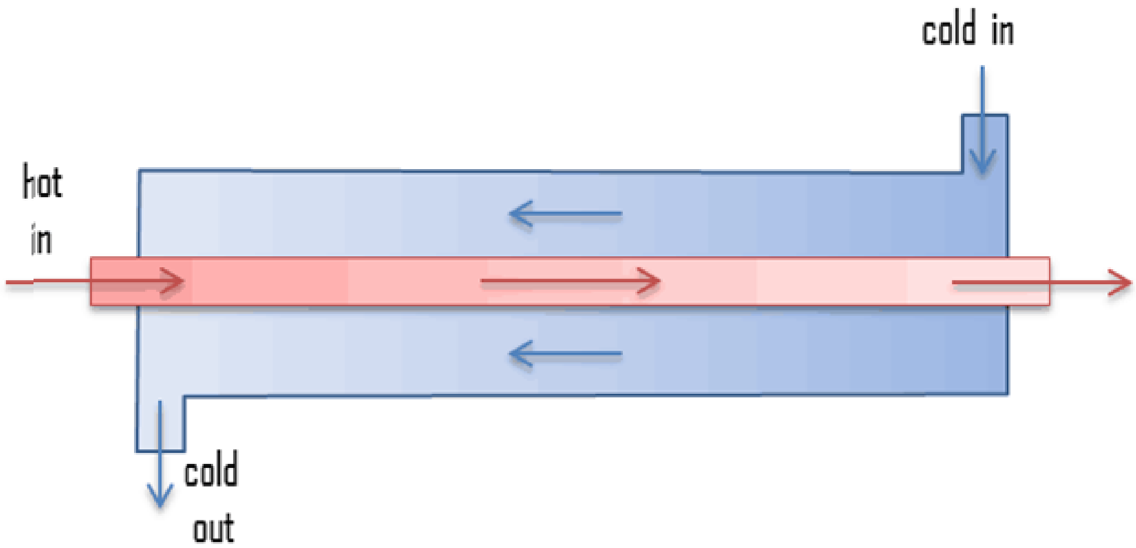

Fig 1 Double pipe heat exchanger-Counter current flow

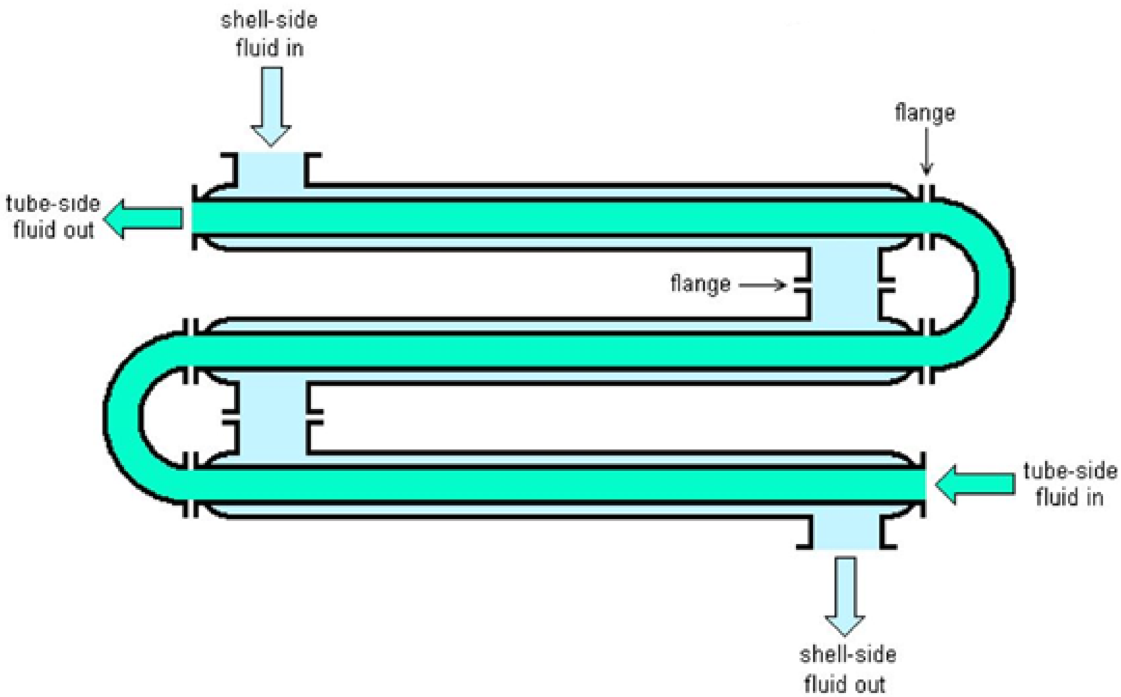

Fig 2 double pipe heat exchanger

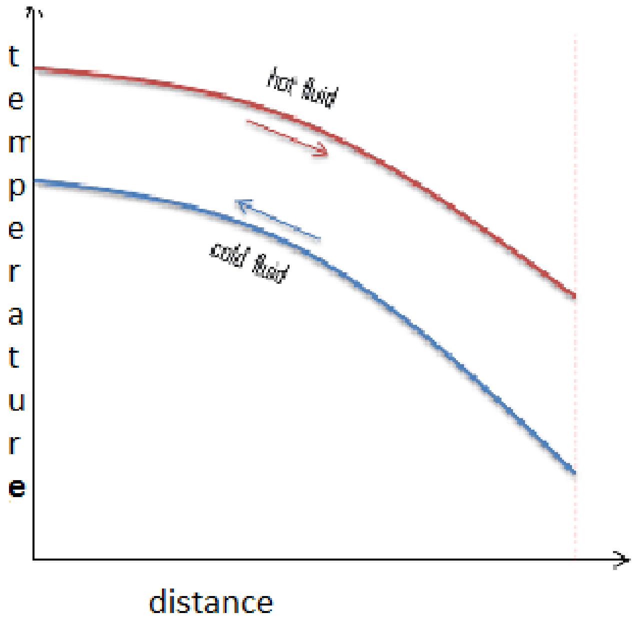

Fig 3 temperature profile for counter current flow

VIII.   Experimental set up:

Fig4

IX. Resources required

SI No.	Name of Resource	Suggested Broad Specification	Quantity
1	Inner pipe	ID = 26mm OD= 43 mm, length = 1.2 m	1
2	Inner pipe	ID = 68mm OD= 76 mm	1
3	Rotameter	1-10 LPM	2

X. Precautions to be followed

1. Adjust flow rate properly and, consider the reading corresponding to reading edge of the float.
2. Wait for the float to be stable before taking the reading.
3. Wait for steady state condition to reach before taking inlet and outlet temperatures of hot and cold fluid.

XI. Procedure

1. Make the hot and cold water to flow through double pipe heat exchanger by opening the valves.
2. Adjust the flow rates of both fluids by adjusting the valves.
3. Switch ON the heater and wait for steady state condition to be attained.
4. Measure the flow rate of hot and cold water with the help of rotameter.
5. Note down the readings of inlet and outlet temperatures of hot and cold water.
6. Repeat the procedure for different flow rates of cold water.

XII. Resources used

Sr. No.	Name of Resource	Suggested Broad Specification		Quantity	Remarks (If any)
		Make	Details		
1					
2					
3					

XIII. Actual procedure followed

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XIV. Precautions followed

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XV. Observations and Calculations:

1. Inner Diameter of inner pipe (di) =
2. Outer Diameter of inner pipe (do) =
3. Length of pipe (L) =

Sr. No.	Cold Water			Hot Water		
	Flow Rate (lit/Sec)	T_{ci} (K)	T_{co} (K)	Flow Rate (lit/Sec)	T_{hi} (K)	T_{ho} (K)
1						
2						
3						
4						

Calculations:

Sample calculation for set no:

1. Properties of water at mean temperature

Cp_h = _...................... KJ/kgK

Cp_c = …………….. KJ/kgK

ρ_h = ………… kg/m^3

ρ_c = ……….. kg/m^3

2. $Q_h = m_h \times Cp_h \times (T_{hi} - T_{ho})$

= ……………………..

= …………….W.

Where

T_{hi} = Inlet temperature of Hot fluid in K

T_{ho} = Outlet temperature of Hot fluid in K

m_h = Mass flow rate of hot water in kg/sec

Cp_h = Specific heat capacity of hot water in KJ/kg.K

3. $Q_c = m_c \times Cp_c \times (T_{co} - T_{ci})$

= ……………………..

= …………….W.

Where

T_{ci} = Inlet temperature of cold fluid in K

T_{co} = Outlet temperature of cold fluid in K

m_c = Mass flow rate of cold water in kg/sec

Cp_c = Specific heat capacity of cold water in KJ/kg.K

4. $Q = (Q_h + Q_c)/2$

Q = ……………….

5. Overall Heat Transfer coefficient

$Q = U \times A \times \Delta T_{lm}$

Where $\Delta T_{lm} = \Delta T_2 - \Delta T_1 / \ln(\Delta T_2/\Delta T_1)$

$\Delta T_1 = (T_{hi} - T_{co})$ = ……….. ……………… =……….. K

$\Delta T_2 = (T_{ho} - T_{ci})$ = ……….. ……………….. =………. .K

ΔT_{lm} = ……………………………………… = ……….K

6. Inside heat transfer area $(A_i) = \pi \times D_i \times L$

= ……………………………………

= ………………m^2

7. Outside heat transfer area $(A_o) = \pi \times Do \times L$

= ……………………………………

= ………………m^2

8. Overall heat transfer based on outside area (U_o)

$Q = U_o \times A_o \times \Delta T_{lm}$

$U_o = Q/(A_o \times \Delta T_{lm})$

= …………………………………………….

= …………….W/m^2K

9. Overall heat transfer based on inside area (U_i)

$Q = Ui \times A_i \times \Delta T_{lm}$

$U_i = Q/(A_i \times \Delta T_{lm})$
= ……………………………………………

= ……………W/m^2K

Sr. No.	Qh	Qc	Q	ΔT_{lm}	U_o	U_i
1						
2						
3						
4						

XVI. Results

The Overall heat transfer coefficient for counter current double pipe heat exchanger is found to be

U_o = ……………W/m^2K

U_i = ……………W/m^2K

XVII. Interpretation of results

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XVIII. Conclusions

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XIX. Practical related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

a. Give the range of rotameter used to find flow rates of hot and cold water.
b. Draw the temperature length curve for Counter current flow in double pipe heat exchanger.
c. Give any two advantages of double pipe heat exchanger.
d. Give any two disadvantages of double pipe heat exchanger.
e. Give any industrial application of Counter current flow double pipe heat exchanger

[Space for Answers]

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XX. References / Suggestions for further Reading

- https://nptel.ac.in/courses/112105248/12
- https://www.youtube.com/watch?v=Z8yHW0KIhYA
- https://www.youtube.com/watch?v=ICwBmCbV2pI

XXI. Assessment Scheme

Performance Indicator		Weightage
Process related (15 Marks)		**60%**
1	Preparation of experimental set up	20%
2	Setting and operation	20%
3	Safety measures, observation and recording	20%
Product related (10 Marks)		**40%**
4	Calculation and Interpretation of result	20%
5	Practical related question and submission of report	20%
Total (25 Marks)		**100 %**

Names of Student Team Members

1. …………………………

2.……………………………

3.……………………………

4.…………………………..…

Marks Obtained			Dated signature of Teacher
Process Related(15)	**Product Related(10)**	**Total (25)**	

Practical No. 12: Operate shell and tube heat exchanger and calculate overall heat transfer coefficient

I. Practical Significance

The heat transfer coefficient is a very important parameter during thermal application in Chemical Process industry. Shell and tube heat exchangers comprise of a shell which allows one fluid to make its way through the tubes while another fluid flows through the shell in order to transfer the heat between the two different fluids. These heat exchangers are used in industries for heating or cooling of process fluids.

II. Relevant Program Outcomes (POs)

PO1. Basic knowledge: Apply knowledge of basic mathematics, sciences and basic engineering to solve the Chemical Engineering problems

PO2. Discipline knowledge: Apply Chemical Engineering knowledge to solve industry based Chemical Engineering problems.

PO3. Experiments and practice: Plan to perform experiments and practices to use the results to solve technical problems related to Chemical Engineering.

PO4 Engineering tools: Apply relevant technologies and Chemical engineering tools with an understanding of the limitations

PO 8. Individual and team work: Function effectively as a leader and team member in diverse/ multidisciplinary teams.

III. Competency and Practical Skills

'Use heat transfer principles to increase efficiency and to save energy in chemical process plants.'

1. Use thermocouple to measure temperature.
2. Use rotameter to measure volumetric flow rate.

IV. Relevant Course Outcomes

1 Apply the concept of convection to operate heat exchanger.

2 Choose proper heat transfer equipment for given application.

V Practical Outcome

Using shell and tube heat exchanger calculate overall heat transfer coefficient.

VI Relevant Affective domain related Outcome(s)

1. Follow safe practices
2. Maintain tools and equipment.
3. Practice energy conservation
4. Demonstrate working as a leader/ a team member.

VII Minimum Theoretical Background

A shell and tube heat exchanger is a class of heat exchanger designs. It is the most common type of heat exchanger in oil refineries and other large chemical processes, and is suited for higher-pressure applications. As its name implies, this type of heat exchanger consists of a shell (a large pressure vessel) with a bundle of tubes inside it. One fluid runs through the tubes, and another fluid flows over the tubes (through the shell) to transfer heat between the two fluids. The set of tubes is called a tube bundle, and may be composed of several types of tubes: plain, longitudinally finned, etc. Two fluids, of different starting temperatures, flow through the heat exchanger. One flows through the tubes (the tube side) and the other flows outside the tubes but inside the shell (the shell side). Heat is transferred from one fluid to the other through the tube walls, either from tube side to shell side or vice versa. Heat exchangers with only one phase (liquid or gas) on each side can be called one-phase or single-phase heat exchangers. Two-phase heat exchangers can be used to heat a liquid to boil it into a gas (vapor), sometimes called boilers, or cool a vapor to condense it into a liquid (called condensers), with the phase change usually occurring on the shell side. Counter current heat exchangers are most efficient because they allow the highest log mean temperature difference between the hot and cold streams.

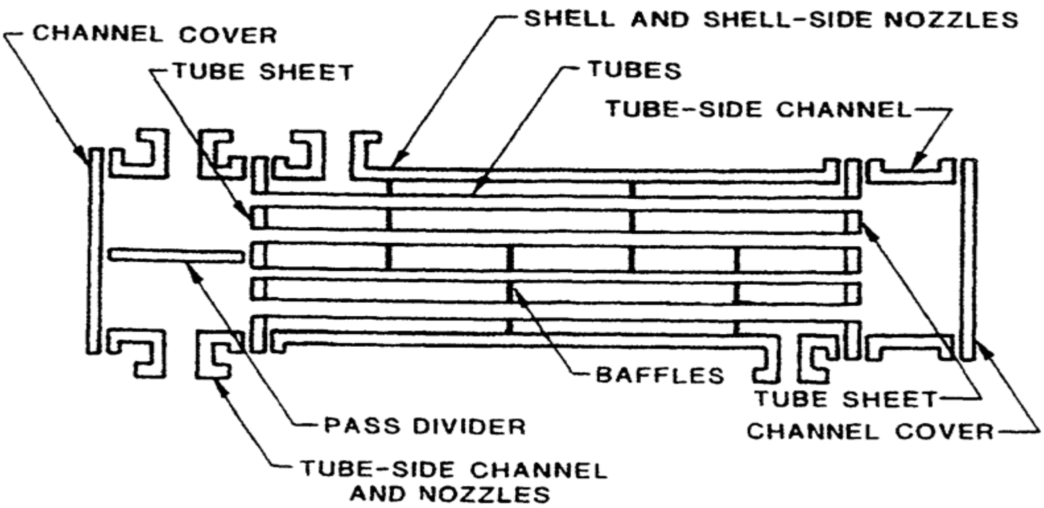

Fig 1 shell and tube heat exchanger

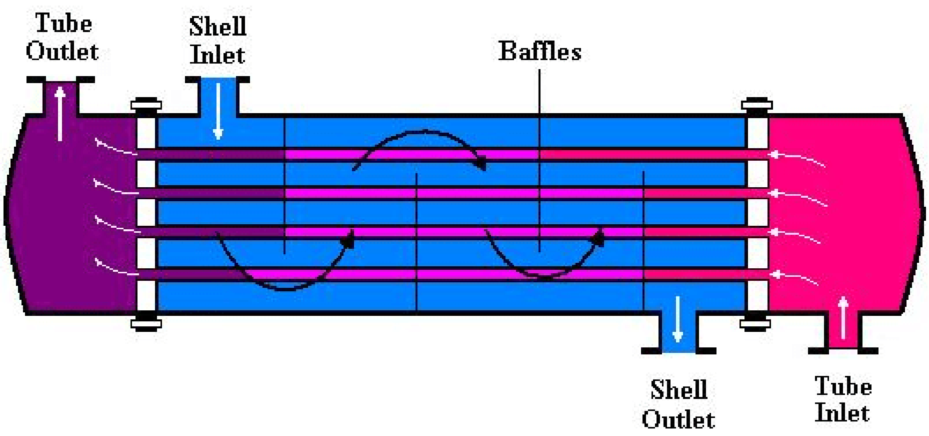

Fig 2 shell and tube heat exchanger

VIII. Experimental set up:

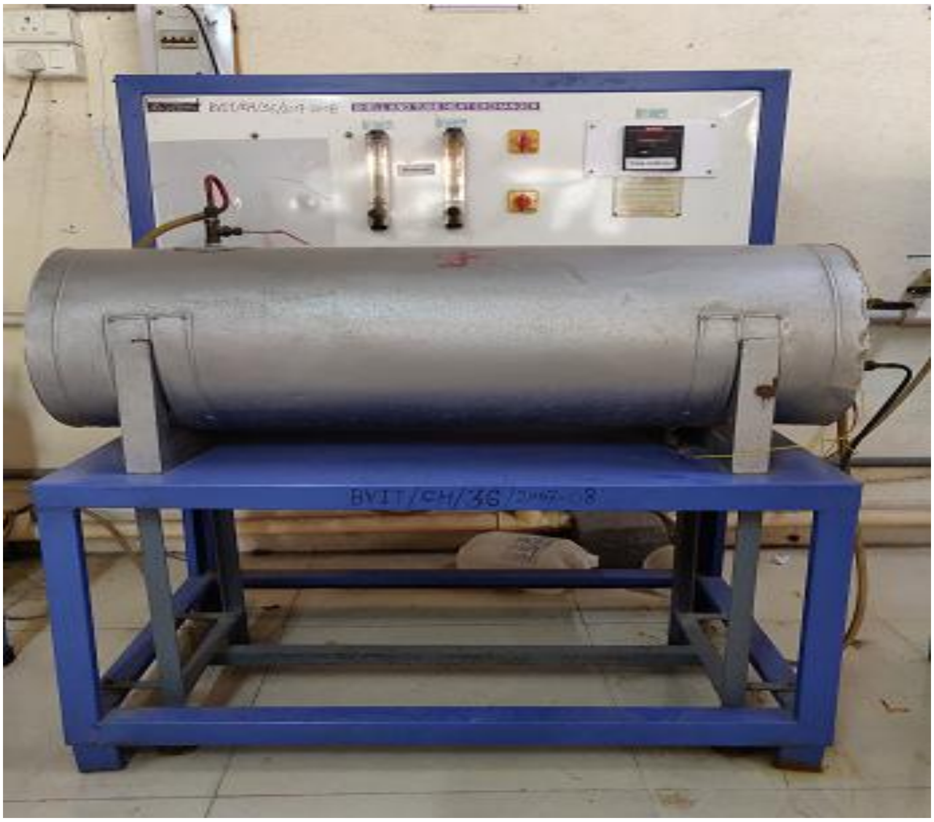

Fig 3

IX. Resources required

SI No.	Name of Resource	Suggested Broad Specification	Quantity
1	Tube	ID = 26mm OD= 32mm Length = 800 mm	14
2	Shell	ID = 250 mm length= 800 mm	1
3	Baffles		2
4	Rotameter	1-11 LPM	1

X. Precautions

1. Adjust flow rate properly and, consider the reading corresponding to reading edge of the float.
2. Wait for the float to be stable before taking the reading.
3. Wait for steady state condition to reach before taking inlet and outlet temperatures of hot and cold fluid.

XI. Procedure

1. Make the cold water to flow through shell side first and then allow hot water to flow through tube side of the shell and tube heat exchanger by opening the valves.
2. Adjust the flow rates of both fluids by adjusting the valves.
3. Switch ON the heater and wait for steady state condition to be attained.
4. Measure the flow rate of hot and cold water with the help of rotameter.
5. Note down the readings of inlet and outlet temperatures of hot and cold water.
6. Repeat the procedure for different flow rates of cold water.

XII. Resources used

Sl No.	Name of Resource	Suggested Broad Specification		Quantity	Remarks (If any)
		Make	**Details**		
1					
2					
3					
4					

XIII. Actual procedure followed

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XIV. Precautions followed

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XV Observations and Calculations:

1. Inner Diameter of inner pipe (di) = ……………..mm
2. Outer Diameter of inner pipe (do) = ……………..mm
3. Length of pipe (L) = ……………..mm
4. Number of Tubes (n) = ……………..mm

Sr. No.	Cold Water			Hot Water		
	Flow Rate (lit/Sec)	T_{ci} (K)	T_{co} (K)	Flow Rate (lit/Sec)	T_{hi} (K)	T_{ho} (K)
1						
2						
3						
4						

Sample calculation for set no

1.Properties of water at mean temperature

Cp_h = ……………. KJ/kgK

Cp_c = …………….. KJ/kgK

ρ_h = ………… kg/m^3

ρ_c = ……….. kg/m^3

2. $Q_h = m_h \times Cp_h \times (T_{hi} - T_{ho})$

= ……………………..

= …………….W.

Where

T_{hi} = Inlet temperature of Hot fluid in K

T_{ho} = Outlet temperature of Hot fluid in K

m_h = Mass flow rate of hot water in kg/sec

Cp_h = Specific heat capacity of hot water in KJ/kg.K

3. $Q_c = m_c \times Cp_c \times (T_{co} - T_{ci})$

= ……………………..

= …………….W.

Where

T_{ci} = Inlet temperature of cold fluid in K

T_{co} = Outlet temperature of cold fluid in K

m_c = Mass flow rate of cold water in kg/sec

Cp_c = Specific heat capacity of cold water in KJ/kg.K

4. $Q = (Q_h+Q_c)/2$

Q = ……………….

5. Overall Heat Transfer coefficient

$Q = U \times A \times \Delta T_{lm}$

Where $\Delta T_{lm} = \Delta T_2 - \Delta T_1 / \ln(\Delta T_2/\Delta T_1)$

$\Delta T_1 = (T_{hi} - T_{co})$ = ……….. ………………… =……….. K

$\Delta T_2 = (T_{ho} - T_{ci})$ = ……….. ……………….. =………. .K

ΔT_{lm} = …………………………………… = ……….K

6. Inside heat transfer area (A_i) = $\pi \times D_i \times L \times n$

= ………………………

= ………………m^2

7. Outside heat transfer area (A_o) = $\pi \times Do \times L \times n$

= …………………………

= ………………m^2

8. Overall heat transfer based on outside area (U_o)

$Q = U_o \times A_o \times \Delta T_{lm}$

$U_o = Q/(A_o \times \Delta T_{lm})$

= …………………………………………….

= …………….W/m^2K

9. Overall heat transfer based on inside area (U_i)

$Q = Ui \times A_i \times \Delta T_{lm}$

$U_i = Q/(A_i \times \Delta T_{lm})$

= …………………………………………….

= …………….W/m^2K

Sr. No	Q_h (W)	Q_c (W)	Q= $(Q_h+Q_c)/2$	U_i ($W/m^2.K$)	U_o ($W/m^2.K$)

XVI Results

The Overall heat transfer coefficient for 1, 2 counter current Shell and Tube heat exchanger is found to be

U_o = ……………W/m^2K

U_i = ……………W/m^2K

XVII. Interpretation of results

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XVIII. Conclusions

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XIX. Practical related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

a. Give advantages of shell and tube heat exchangers.
b. Define tube pitch and baffle pitch
c. Through which side of shell and tube heat exchangers the following liquids are directed? Give reasons also.
   1. Corrosive liquid
   2. Viscous liquid
   3. High pressure liquid
d. Give the uses of baffles in shell and tube heat exchangers

[Space for Answers]

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XX. References / Suggestions for further Reading

- http://textofvideo.nptel.ac.in/103101137/lec59.pdf
- https://www.youtube.com/watch?v=jc_hL_tSFzo
- https://www.youtube.com/watch?v=mw7J8zyLsvg
- https://www.youtube.com/watch?v=zUjTa5BajxQ

XXI. Assessment Scheme

Performance Indicators		Weightage
Process related (15 Marks)		**60%**
1	Preparation of experimental set up	20%
2	Setting and operation	20%
3	Safety measures, observation and recording	20%
Product related (10 Marks)		**40%**
4	Calculation and Interpretation of result	20%
5	Practical related question and submission of report	20%
Total (25 Marks)		**100 %**

Names of Student Team Members

1. …………………………

2.…………………………

3.…………………………

4.…………………………

Marks Obtained			Dated signature of Teacher
Process Related(15)	Product Related(10)	Total (25)	

Practical No. 13: Operate finned tube heat exchanger and calculate overall heat transfer coefficient

I. Practical Significance

The heat transfer coefficient is a very important parameter during thermal application in Chemical Process industry. Finned tube heat exchangers are specifically used when one or both of the fluids exchanging heat have low values of individual heat transfer coefficient. By attaching fins or metal pieces to heat transfer surface the area of heat transfer is increased which increases heat transfer rate and heat transfer coefficient.

II. Relevant Program Outcomes (POs)

PO1. Basic knowledge: Apply knowledge of basic mathematics, sciences and basic engineering to solve the Chemical Engineering problems.

PO2. Discipline knowledge: Apply Chemical Engineering knowledge to solve industry based Chemical Engineering problems.

PO3. Experiments and practice: Plan to perform experiments and practices to use the results to solve technical problems related to Chemical Engineering.

PO4.Engineering tools: Apply relevant technologies and Chemical engineering tools with an understanding of the limitations.

PO 8.Individual and team work: Function effectively as a leader and team member in diverse/ multidisciplinary teams.

PO 9.Communication: Communicate effectively in oral and written form.

PSO 2.Material management and quality control: Manage chemicals and equipment to produce quality chemical products.

III. Competency and Practical Skills

'Use heat transfer principles to increase efficiency and to save energy in chemical process plants.'

1 Use thermocouple to measure temperature.

2 Use rotameter to measure volumetric flow rate.

IV. Relevant Course Outcomes

1 Apply the concept of convection to operate heat exchanger.

2 Choose proper heat transfer equipment for given application.

V. Practical Outcome

Using finned tube heat exchanger calculate overall heat transfer coefficient.

VI. Relevant Affective domain unrelated Outcome(s)

1. Follow safe practices
2. Maintain tools and equipment.
3. Practice energy conservation.

VII. Minimum Theoretical Background

A heat exchanger is a device used to transfer heat between two or more fluids. It is used in both heating and cooling of process fluids. The fluids may be separated by solid wall to prevent mixing of fluids. They are widely used in space heating, refrigeration, air conditioning, power stations etc. The classic example of finned tube heat exchanger found in an internal combustion engine in which a circulating fluid known as coolant flows through radiator coils and air flows past the coils, which cools the coolant and heats the incoming air. Finned tube heat exchangers have tubes with extended outer surface area or fins to enhance the heat transfer rate from the additional area of fins. Finned tubes or tubes with extended outer surface area enhance the heat transfer rate by increasing the effective heat transfer area between the tubes and surrounding fluid. The fluid surrounding finned tubes maybe process fluid or air.

Types of Finned Tubes

Longitudinal Fins

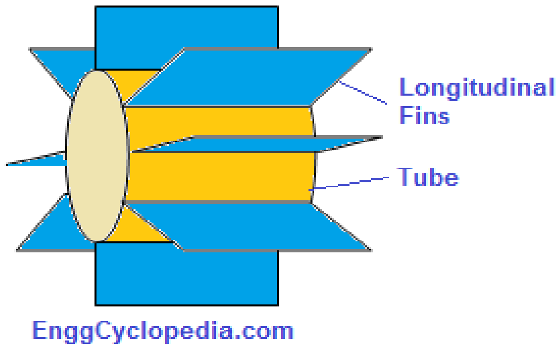

Fig.1 - Longitudinally finned tube in heat exchanger

Longitudinal fins on a tube are best suited for applications where the flow outside the tubes is expected to be streamlined along the tube length, for example double pipe heat exchangers with highly viscous fluid outside the finned tube. Longitudinal fins on a tube run along the length of tubes. The cross sectional shapes of this fin can be either flat or tapered. For different cross sectional geometries, various correlations are available in the literature to evaluate the heat transfer coefficients on outer side of the tubes.

Transverse Fins

Transverse fins are normally used for gas flows or turbulent flows and for cross flow type exchangers or shell and tube heat exchangers. For air coolers, tubes with transverse fins are best suited.

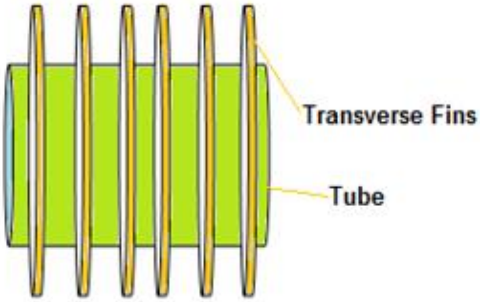

Fig.2 Transverse fins

VIII. Experimental set up:

Fig3

IX. Resources required

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Finned tube heat exchanger set up	Length = 1m	1
2	Outer tube	OD =75 mm, ID = 70 mm	1
3	Inner tube	OD = 22.5 mm ID = 20.5 mm	1

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
4	Fins	Length = 1m, height = 12mm, thickness= 1mm	6
5	Orificemeter	Diameter = 30mm	1
6	Rotameter	2.5 – 25 LPM	1

X. Precautions

1. Adjust flow rate properly and, consider the reading corresponding to reading edge of the float.
2. Wait for the float to be stable before taking the reading.
3. Wait for steady U tube manometer fluid before taking the readings.
4. Wait for steady state condition to reach before taking inlet and outlet temperatures of hot and cold fluid.

XI. Procedure

1. Start the blower and adjust the required air flow rate with help of control valve and U tube manometer.
2. Start water flow on tube side and adjust the water flow rate with control valve and rotameter.
3. Switch ON the heater and keep constant flow rates of both fluids.
4. Wait for steady state condition by maintaining constant temperatures of both fluid inlet and outlet.
5. When steady state reaches, enter the observations in observation table.
6. Note down the readings of inlet and outlet temperatures of hot and cold water.
7. Repeat the procedure for different flow rates of hot water.

XII. Resources used

Sr No.	Name of Resource	Suggested Broad Specification		Quantity	Remarks(If any)
		Make	Details		
1					
2					
3					
4					
5					
6					

XIII. Actual procedure followed

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XIV. Precautions followed

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XV. Observations and Calculations:

1. Outer Diameter of tube (do) =
2. Length of tube (l) =
3. Length of fin (L) =
4. Height of fin (H) =
5. Thickness of fin (b) =
6. Area of fin (A) = L (2H+b) mm^2 =
7. Number of Fin (N) =
8. Fin area available for heat transfer (A_f) = A x N =
9. Tube area available for heat transfer (A_b) = (π x do x L – N x b) =
10. Total area of finned tube heat exchanger (At) = $A_f + A_b$ =
11. Outside diameter of pipe (Do) =
12. C/S Area of pipe (A_o) =
13. C/S Area of Orifice (A_2) =

Sr. No.	Air			Water		
	Manometer difference (Δh)	T_{ci} (K)	T_{co} (K)	Flow Rate (lit/Sec)	T_{hi} (K)	T_{ho} (K)
1						
2						
3						
4						

Sample calculation for set no

1. Air flow rate (Q)

$$Q = \frac{S_B * C_o}{\sqrt{1-\beta^4}} \cdot \frac{\sqrt{2\Delta P}}{\sqrt{\rho_a}} =$$

Q = -------------------------------

Where,

$S_B = \pi/4 * D_o{}^2$ = ---------------------------------m^2

Do = diameter of Orifice = ---------------m

β = do/dp = ------------------------.

Dp = diameter of pipe = ------------------m

$\Delta P = \Delta h\ (\rho_b - \rho_a) * g$ = ------------------

ρ_b = density of manometric fluid = -------------kg/m^3

ρ_a = density of air = ………… kg/m^3

Δh = Manometric difference =------------------m

2. Mass flow rate of air (m)

   $m = Q * \rho_a$ = =---------------- kg/m^3

3. Heat gained by air (Q_a) air

   $Qa = m * Cpa * (T_{co} - T_{ci})$

   =……………W

   m = mass flow rate of air (kg/s)

   Cpa = Sp. heat of air at mean bulk temperature (J/kg.K)

   T_{ci} (inlet air temperature) = ---------K

   T_{co} (outlet air temperature) = ----------K

4. Heat transfer from hot water (Q_h)

   $Qh = m_h * Cph * (T_{ho} - T_{hi})$ =------------------

=……………W

m_h = mass flow rate of hot water (kg/s)

Cph= Sp. Heat of hot water (J/kg.K)

T_{hi} (inlet water temperature) = ---------K

T_{ho} (outlet water temperature) = ----------K

5. $Q = (Q_a + Q_h) / 2$

= ------------------W

6. Overall heat transfer coefficient

$Q = U_i * A_i * \Delta T_{lm}$

=

$U_i = Q / A_i * \Delta T_{lm}$ = ------------------- W/m^2K

= ------------------- W/m^2K

Where,

A_i = inside heat transfer area of pipe = π * di * L

= _____________ m^2

$$\Delta T_{lm} = \frac{\Delta T_1 - \Delta T_2}{\ln (\Delta T_1/\Delta T_2)} = \text{------------------}$$

ΔT_1 =

ΔT_2 =

Sr. No	Q_h (W)	Q_a (W)	Q (W)	ΔT_{lm}	U_i $W/m^2.K)$

XVI. Results

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XVII. Interpretation of results

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XVIII. Conclusions & Recommendation

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XIX. Practical related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

a. Give the range of rotameter used to find flow rates of air and hot water.
b. Draw neat sketches of transverse fins and horizontal fins.
c. Give any two advantages of finned tube heat exchanger.
d. Give any two industrial applications of finned tube heat exchanger.
e. state the reasons why you would prefer finned heat exchanger for certain heat transfer process.

[Space for Answers]

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XX. References / Suggestions for further Reading

- http://volfram.in/finned-tube-type-heat-exchanger.html
- https://nptel.ac.in/courses/112105248/22
- https://nptel.ac.in/courses/103103027/pdf/mod1.pdf
- https://www.youtube.com/watch?v=_orVHvX0syw

XXI. Assessment Scheme

Performance Indicators		Weightage
Process related (15 Marks)		**60%**
1	Preparation of experimental set up	20%
2	Setting and operation	20%
3	Safety measures, observation and recording	20%
Product related (10 Marks)		**40%**
4	Calculation and Interpretation of result	20%
5	Practical related question and submission of report	20%
Total (25 Marks)		**100 %**

Names of Student Team Members

1. …………………………

2…………………………

3…………………………

4…………………………

Marks Obtained			**Dated signature of Teacher**
Process Related(15)	**Product Related(10)**	**Total (25)**	

Practical No. 14: Operate a heat exchanger for co current and counter current flows

I. Practical Significance

A heat exchanger is a device used to effect the process of heat exchange between two fluids that are at different temperatures. The three basic flow arrangements in a heat exchanger are co current or parallel, counter current and cross flow. The rate of heat transfer in counter current flow heat exchangers is more than that in co current flow exchangers. The parallel flow arrangement is used whenever it is necessary to limit the maximum temperature of the cooler fluid.

II. Relevant Program Outcomes (POs)

PO1. Basic knowledge: Apply knowledge of basic mathematics, sciences and basic engineering to solve the Chemical Engineering problems

PO2. Discipline knowledge: Apply Chemical Engineering knowledge to solve industry based Chemical Engineering problems.

PO3. Experiments and practice: Plan to perform experiments and practices to use the results to solve technical problems related to Chemical Engineering.

PO4.Engineering tools: Apply relevant technologies and Chemical engineering tools with an understanding of the limitations

PO6. Environment and sustainability: Apply Chemical engineering solutions also for sustainable development practices in societal and environmental contexts.

PSO 2.Material management and quality control: Manage chemicals and equipment to produce quality chemical products

III Competency and Practical Skills

'Use heat transfer principles to increase efficiency and to save energy in chemical process plants.'

1. Use thermocouple to measure temperature.
2. Use rotameter to measure volumetric flow rate.

IV. Relevant Course Outcomes

1. Apply the concept of convection to operate heat exchanger.
2. Choose proper heat transfer equipment for given application.

V. Practical Outcome

Compare the values of overall heat transfer coefficients for co current and counter current in any heat exchanger

VI. Relevant Affective domain unrelated Outcome(s)

1. Follow safe practices
2. Maintain tools and equipment.

VII. Minimum Theoretical Background

Heat exchangers according to the flow arrangement are parallel or co current flow heat exchanger, counter current flow heat exchanger and cross flow heat exchanger. Parallel flow heat exchanger is the one in which two fluid streams enter at one end, flow through it in the same direction and leaves at the other end. Double pipe heat exchangers and shell and tube heat exchangers can be operated in parallel flow fashion. Counter current flow heat exchanger is the one in which two fluid streams flow in opposite direction. Double pipe heat exchangers and shell and tube heat exchangers can be operated this way. Cross flow heat exchanger is the one in which one fluid moves through the exchanger at right angles to the flow path of the other fluid. Plate type heat exchangers employ cross flow.

The temperature gradient in case of parallel flow is maximum at the entrance and continuously decreases towards the exit, whereas the temperature gradient is fairly constant over the length of heat exchanger in case of counter current flow. Hence, with a counter current flow arrangement, the heating surface has nearly constant capacity through the exchanger and with parallel flow arrangement, the capacity at exit is much less as compared to that at the entrance. In parallel flow arrangement, it is not possible to bring the hot fluid temperature below the outlet temperature of the cold fluid and thus has a considerable effect on the ability of heat exchanger to recover heat. The parallel flow arrangement is used whenever it is necessary to limit the maximum temperature of the cooler fluid.

In counter current flow, it is possible for the cooling liquid to leave at a higher temperature than the heating fluid, and one of the greatest advantages of counter current flow is that it is possible to extract a higher proportion of the heat content of the heating fluid. The rate of heat transfer in counter current flow is more than that in co current.

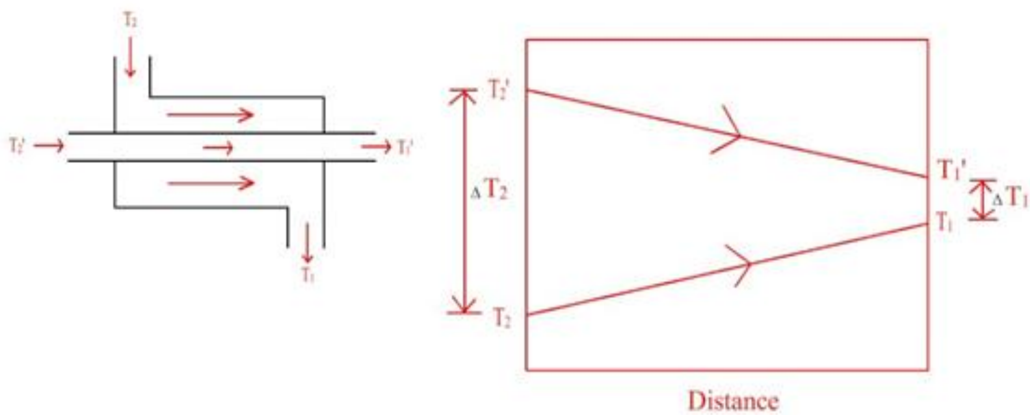

Fig.1 parallel flow heat exchanger with temperature profile

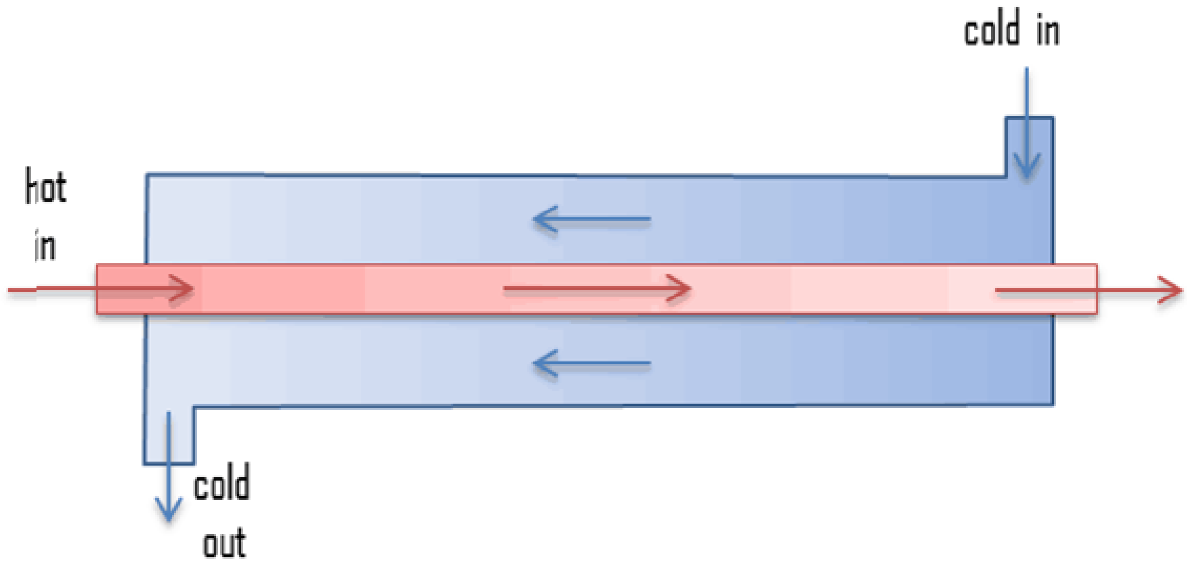

Figure 2 counter current flow heat exchanger

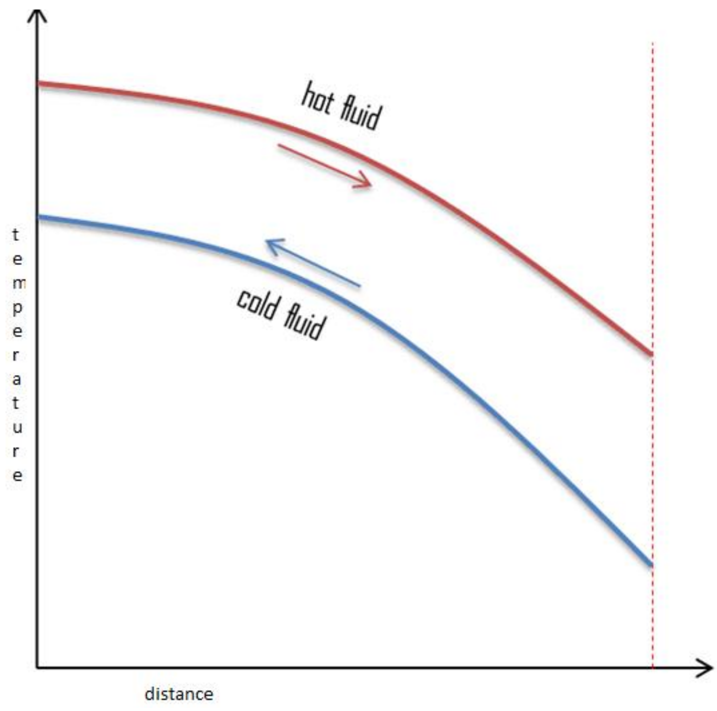

Fig.3 temperature profile in counter current flow

VIII. Experimental set up :

Fig 4

IX. Resources required

SI No.	Name of Resource	Suggested Broad Specification	Quantity
1	Inner pipe	ID = 26mm OD= 43 mm, length = 1.2 m	1
2	Inner pipe	ID = 68mm OD= 76 mm	1
3	Rotameter	1-10 LPM	2

X. Precautions

1. Adjust flow rate properly and, consider the reading corresponding to reading edge of the float.

2. Wait for the float to be stable before taking the reading.

3. Wait for steady state condition to reach before taking inlet and outlet temperatures hot and cold fluid.

XI. Procedure

a. Co current flow

1. Adjust the valves for co current flow.
2. Make the hot and cold water to flow through double pipe heat exchanger by opening the valves.
3. Adjust the flow rates of both fluids by adjusting the valves.
4. Switch ON the heater and wait for steady state condition to be attained.
5. Measure the flow rate of hot and cold water with the help of rotameter.
6. Note down the readings of inlet and outlet temperatures of hot and cold water after steady state is attained.
7. Repeat the procedure for a different flow rate of cold water.

b. Counter current flow

8. Adjust the valves for counter current flow.
9. Make the hot and cold water to flow through double pipe heat exchanger by opening the valves.
10. Adjust the flow rates of both fluids for values done for co current flow by adjusting the valves.
11. Switch ON the heater and wait for steady state condition to be attained.
12. Measure the flow rate of hot and cold water with the help of rotameter.
13. Note down the readings of inlet and outlet temperatures of hot and cold water after steady state is attained.
14. Repeat the procedure for a different flow rate of cold water.

XII. Resources used

SI No.	Name of Resource	Suggested Broad Specification		Quantity	Remarks (If any)
		Make	Details		
1					
2					
3					

XIII Actual procedure followed

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XIV. Precautions followed

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XV. Observations and Calculations:

a. Co current flow

Sr. No.	Cold Water			Hot Water		
	Flow Rate (lit/Sec)	T_{ci} (K)	T_{co} (K)	Flow Rate (lit/Sec)	T_{hi} (K)	T_{ho} (K)
1						
2						

b. Counter current flow

Sr. No.	Cold Water			Hot Water		
	Flow Rate (lit/Sec)	T_{ci} (K)	T_{co} (K)	Flow Rate (lit/Sec)	T_{hi} (K)	T_{ho} (K)
1						
2						

Calculations

a. co current : Sample calculation for set no:

1. Properties of water at mean temperature

Cp_h = ……………. KJ/kgK

Cp_c = ……………... KJ/kgK

ρ_h = ………… kg/m^3

ρ_c = ……….. kg/m^3

2. $Q_h = m_h \times Cp_h \times (T_{hi} - T_{ho})$

   = ……………………..

   = …………….W.

3. $Qc = mc \times Cp_c \times (T_{co} – T_{ci})$

   = ……………………..

   = …………….W.

4. Q = (Qh+Qc)/2

   Q = ……………….

   Overall Heat Transfer coefficient

5. $Q = U \times A \times \Delta T_{lm}$

   Where $\Delta T_{lm} = \Delta T_2 - \Delta T_1 / \ln(\Delta T_2/\Delta T_1)$

   $\Delta T_1 = (\Delta T_{hi} - \Delta T_{ci})$ = ……….. ………………… =……….... K

   $\Delta T_2 = (\Delta T_{ho} - \Delta T_{co})$ = ……….. ……………….. =………. .K

   ΔT_{lm} = ………………………………………… . = ……….K

6. Inside heat transfer area $(A_i) = \pi \times D_i \times L$

   = ……………………………………

   = ……………… m^2

7. Overall heat transfer coefficient based on inside area (U_i)

   $Q = Ui \times A_i \times \Delta T_{lm}$

   $U_i = Q/(A_i \times \Delta T_{lm})$

   = …………………………………………….

   = …………….W/m^2K

b. Counter current : Sample calculation for set no:

1. Properties of water at mean temperature

Cp_h = ……………. KJ/kgK

Cp_c = …………….. KJ/kgK

ρ_h = ………… kg/m^3

ρ_c = ……….. kg/m^3

2. Q = rate of heat transfer
   $Q_h = m_h \times Cp_h \times (T_{hi} - T_{ho})$

   = ……………………..

   = …………….W.

3. $Qc = mc \times Cp_c \times (T_{co} - T_{ci})$

   = ……………………..

   = …………….W.

4. Q = (Qh+Qc)/2
   Q = ……………….

   Overall Heat Transfer coefficient

5. $Q = U \times A \times \Delta T_{lm}$

   Where $\Delta T_{lm} = (\Delta T_2 - \Delta T_1) / \ln(\Delta T_2/\Delta T_1)$

   $\Delta T_1 = (T_{hi} - T_{co})$ = ……….. ………………… =……….. K

   $\Delta T_2 = (T_{ho} - T_{ci})$ = ……….. ……………….. =………. .K

   ΔT_{lm} = ………………………………………. . = ……….K

6. Inside heat transfer area $(A_i) = \pi \times D_i \times L$
   = ……………………………………

   = ………………m^2

7. Overall heat transfer coefficient based on inside area (U_i)

   $Q = Ui \times A_i \times \Delta T_{lm}$

   $U_i = Q/(A_i \times \Delta T_{lm})$

= …………………………………………….

= ……………W/m^2K

Sr. No.	Co current flow			Counter current flow		
	Q	ΔT_{lm}	**Ui**	**Q**	ΔT_{lm}	**Ui**
1						
2						

XVI. Results

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XVII. Interpretation of results

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XVIII. Conclusions

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XIX. Practical related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

a. Differentiate between co current and counter current flow heat exchangers on the basis of rate of heat transfer and area required.
b. Give the expression to calculate LMTD for co current flow.
c. Give the expression to calculate LMTD for counter current flow.
d. Which type of flow will give higher value of heat transfer coefficient?

[Space for Answers]

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XX. References / Suggestions for further Reading

- https://nptel.ac.in/courses/112105248/12
- https://www.youtube.com/watch?v=Z8yHW0KIhYA
- https://www.youtube.com/watch?v=ICwBmCbV2pI

XXI. Assessment Scheme

Performance Indicators		Weightage
Process related (15 Marks)		**60%**
1	Preparation of experimental set up	20%
2	Setting and operation	20%
3	Safety measures, observation and recording	20%
Product related (10 Marks)		**40%**
4	Calculation and Interpretation of result	20%
5	Practical related question and submission of report	20%
Total (25 Marks)		**100 %**

Names of Student Team Members

1. …………………………
2. …………………………
3. …………………………
4. …………………………

Marks Obtained			**Dated signature of Teacher**
Process Related(15)	**Product Related(10)**	**Total (25)**	

Practical No. 15: Determine capacity of an open pan evaporator.

I. Practical Significance

In chemical industry, the manufacture of heavy chemicals such as caustic soda, table salt and sugar starts with dilute aqueous solutions from which large quantities of water must be removed before crystallization can take place in suitable equipment. The purpose of the majority of power plant evaporators is the separation of pure water from raw or treated water. The impurities are continuously withdrawn from the system as blow down. In the power plant evaporator the unevaporated portion of the feed is the residue, whereas in the chemical evaporator it is the product.

II. Relevant Program Outcomes (POs)

PO1. Basic knowledge: Apply knowledge of basic mathematics, sciences and basic engineering to solve the Chemical Engineering problems

PO2. Discipline knowledge: Apply Chemical Engineering knowledge to solve industry based Chemical Engineering problems.

PO3. Experiments and practice: Plan to perform experiments and practices to use the results to solve technical problems related to Chemical Engineering.

PO 8.Individual and team work: Function effectively as a leader and team member in diverse/ multidisciplinary teams.

PO 9.Communication: Communicate effectively in oral and written form.

III. Competency and Practical Skills

'Use heat transfer principles to increase efficiency and to save energy in chemical process plants.'

Operate open pan evaporator.

IV. Relevant Course Outcomes

Calculate the energy associated with an evaporator

V. Practical Outcome

Using an open pan evaporator determine capacity of evaporator

VI. Relevant Affective domain related Outcome(s)

1. Follow safe practices
2. Maintain tools and equipment.
3. Demonstrate working as a leader / a team member.

VII. Minimum Theoretical Background

In an evaporation operation, the concentration of a solute in a solution is increased by boiling off the solvent. This operation is generally performed prior to crystallization. The heat required for evaporation is generally provided by the condensation of steam. The steam is on one side of a metal surface and the evaporating solution on the other side of the metal surface. In an evaporation operation, heat is utilized to 1) increase the temperature of the solution to its boiling point (sensible heat) and 2) supply the latent heat of vaporization of the solvent.

Performance of a steam heated tubular evaporator is evaluated in terms of capacity and economy. Capacity of an evaporator is defined as the number of kilograms of water vaporized/ evaporated per hour. If the feed solution is at the boiling temperature corresponding to the pressure in the vapour space of an evaporator, then all the heat that is transferred through the heating surface is available for evaporation and the capacity is proportional to the heat transfer rate. If cold feed solution is fed the evaporator, heat is required to increase its temperature to the boiling point and thus the capacity for a given rate of heat transfer will be reduced accordingly as heat used to increase the temperature to the boiling point is not available for evaporation. When the feed solution to the evaporator is at a temperature higher than the boiling point corresponding to the pressure in the vapour space, a portion of the feed evaporates adiabatically and the capacity is greater than that corresponding to the heat transfer rate.

Economy of an evaporator is defined as the number of kilograms of water evaporated per kilogram of steam fed to the evaporator.

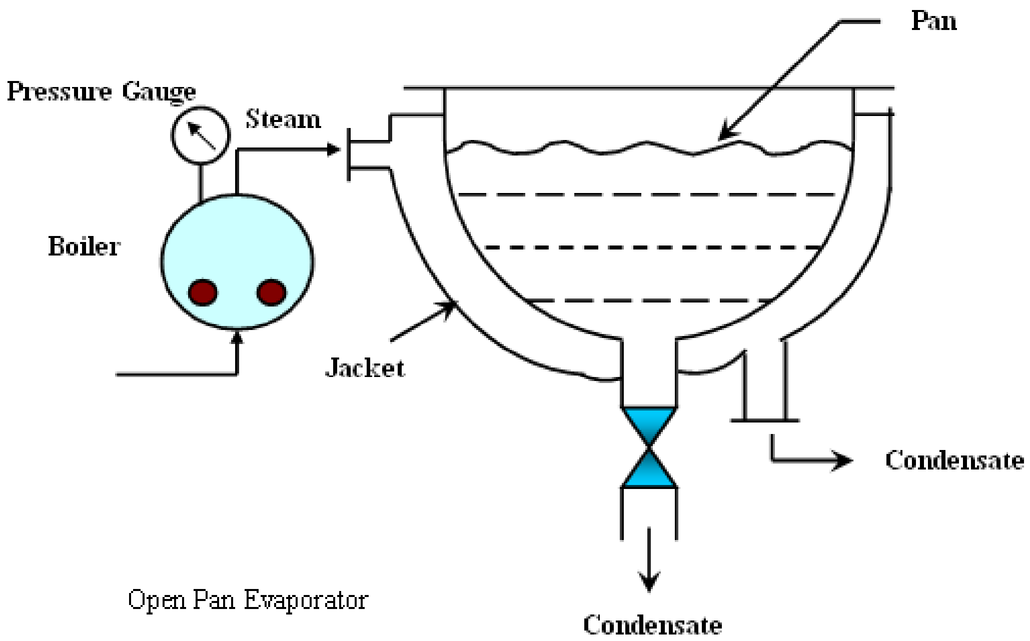

Fig 1 open pan evaporator

VIII. Experimental set up : -

Figure 2

IX. Resources required

SI No.	Name of Resource	Suggested Broad Specification	Quantity
1	Open pan	Diameter = 30 cm Height = 10 cm	1
2	Weighing machine	5 kg	1

X. Precautions

1. Pan should be cleaned before use.
2. Accurate weight should be taken.

XI. Procedure

1. Clean the pan and find its weight W_1 gm.
2. Prepare a 10-20 % NaCl solution.
3. Transfer the solution to the pan.
4. Take the weight of solution with pan W_2 gm.
5. Heat the solution using electric heater or flame for one hour.

6. Switch off the heater.
7. Allow the solution to cool.
8. Note down the weight of solution W_3.

XII. Resources used

Sr. No.	Name of Resource	Suggested Broad Specification		Quantity	Remarks (If any)
		Make	Details		
1					
2					

XIII. Actual procedure followed

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XIV. Precautions followed

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XV. Observations and Calculations:

1. Initial weight of pan W_1 = …………kg
2. Weight of pan and dilute solution W_2 = …………kg
3. Weight of pan and concentrated solution W_3 = ………kg
4. Weight of water evaporated = W_2-W_3 = …………kg
5. Capacity of evaporator =………………kg/h

XVI. Results

Capacity of evaporator =

XVII. Interpretation of results

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XVIII. Conclusions

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XIX. Practical related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

a. Define evaporation
b. List the properties of solution which affect evaporation operation.
c. Define capacity and economy of evaporator.
d. How evaporation is different from drying?

[Space for Answers]

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XX References / Suggestions for further Reading

- https://www.youtube.com/watch?v=6FSdoqbk6QA
- https://www.youtube.com/watch?v=v3iBHPAPA4M
- https://www.youtube.com/watch?v=ZbeRFEC6DHc

XXI. Assessment Scheme

Performance Indicators		Weightage
Process related (15 Marks)		**60%**
1	Preparation of experimental set up	20%
2	Setting and operation	20%
3	Safety measures, observation and recording	20%
Product related (10 Marks)		**40%**
4	Calculation and Interpretation of result	20%
5	Practical related question and submission of report	20%
Total (25 Marks)		**100 %**

Names of Student Team Members

1…………………………

2…………………………

3…………………………

4…………………………

Marks Obtained			Dated signature of Teacher
Process Related(15)	**Product Related(10)**	**Total (25)**	

Practical No. 16: Calculate overall heat transfer coefficient for an evaporator.

I. Practical Significance

In chemical industry, the manufacture of heavy chemicals such as caustic soda, table salt and sugar starts with dilute aqueous solutions from which large quantities of water must be removed before crystallization can take place in suitable equipment. The purpose of the majority of power plant evaporators is the separation of pure water from raw or treated water. The impurities are continuously withdrawn from the system as blow down. In the power plant evaporator the unevaporated portion of the feed is the residue, whereas in the chemical evaporator it is the product.

II. Relevant Program Outcomes (POs)

PO1. Basic knowledge: Apply knowledge of basic mathematics, sciences and basic engineering to solve the Chemical Engineering problems

PO2. Discipline knowledge: Apply Chemical Engineering knowledge to solve industry based Chemical Engineering problems.

PO3. Experiments and practice: Plan to perform experiments and practices to use the results to solve technical problems related to Chemical Engineering.

PO4.Engineering tools: Apply relevant technologies and Chemical engineering tools with an understanding of the limitations

PO8. Individual and team work: Function effectively as a leader and team member in diverse/ multidisciplinary teams.

PO9. Communication: Communicate effectively in oral and written form.

III. Competency and Practical Skills

'Use heat transfer principles to increase efficiency and to save energy in chemical process plants.'

Operate an evaporator.
Use weighing balance for accurate weighing.

IV. Relevant Course Outcomes

Calculate energy associated with an evaporator.

V. Practical Outcome

Using an evaporator calculate overall heat transfer coefficient

VI. Relevant Affective domain related Outcome(s)-

1. Follow safe practices
2. Maintain tools and equipment.
3. Practice energy conservation

VII. Minimum Theoretical Background

In an evaporation operation, the concentration of a solute in a solution is increased by boiling off the solvent. This operation is generally performed prior to crystallization. The heat required for evaporation is generally provided by the condensation of steam. The steam is on one side of a metal surface and the evaporating solution on the other side of the metal surface. In an evaporation operation, heat is utilized to 1) increase the temperature of the solution to its boiling point (sensible heat) and 2) supply the latent heat of vaporization of the solvent.

Performance of a steam heated tubular evaporator is evaluated in terms of capacity and economy. Capacity of an evaporator is defined as the number of kilograms of water vaporized/ evaporated per hour. If the feed solution is at the boiling temperature corresponding to the pressure in the vapour space of an evaporator, then all the heat that is transferred through the heating surface is available for evaporation and the capacity is proportional to the heat transfer rate. If cold feed solution is fed the evaporator, heat is required to increase its temperature to the boiling point and thus the capacity for a given rate of heat transfer will be reduced accordingly as heat used to increase the temperature to the boiling point is not available for evaporation. When the feed solution to the evaporator is at a temperature higher than the boiling point corresponding to the pressure in the vapour space, a portion of the feed evaporates adiabatically and the capacity is greater than that corresponding to the heat transfer rate.

Economy of an evaporator is defined as the number of kilograms of water evaporated per kilogram of steam fed to the evaporator. In a single effect evaporator the amount of water evaporated per kg steam fed is always less than one and hence economy is less than one. The economy of an evaporator can be increased by 1. Use of multiple effect evaporation system and 2. vapour recompression.

VIII. Experimental set up :

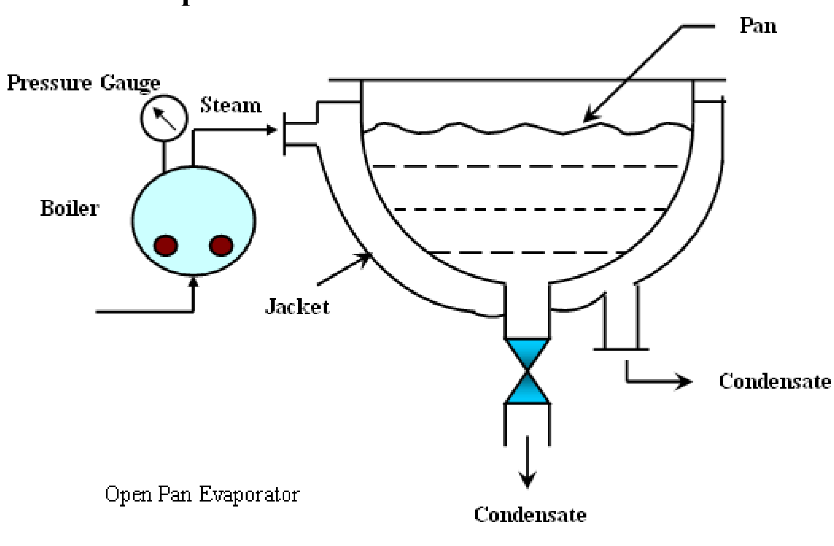

Fig. 1

IX. Resources required

SI No.	Name of Resource	Suggested Broad Specification	Quantity
1	Steam source	boiler	1
2	Open pan evaporator	2 lit Capacity	1
3	Temperature indicators	0-100^{0}C	2

X. Precautions

Steam pressure should not exceed the permissible limit.

XI. Procedure

1. The diameter of the vessel is measured.
2. The steam boiler is started and pressure is developed.
3. 0.5 liters of milk (or any other aqueous solution) is measured and poured into the pan.
4. Steam is allowed by opening the valve and steam pressure is adjusted to 0.5 to 1 kg/cm^2 and stop clock is started.
5. The evaporation is continued until 80% of the liquid is evaporated and milk/ solution gets concentrated.
6. The boiling temperature of milk/ solution is noted down.
7. Steam supply is stopped and the boiler is switched off.
8. The concentrated milk/ solution is collected and weighed.

XII. Resources used

SI No.	Name of Resource	Suggested Broad Specification		Quantity	Remarks (If any)
		Make	Details		
1					
2					
3					

XIII. Actual procedure followed

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XIV. Precautions followed

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XV. Observations and Calculations:

1 Diameter of pan = ………… cm

2. Height from center =…………..cm

3. Initial weight of milk/water (W_1) =…………Kg

4. Final weight of milk/water (W_2) =…………..Kg

5. Pressure gauge reading = …………..Kg/cm^2

6. Surface temperature (T_S) =……..……. ^0C

7. Initial temperature of milk (Tm_1) = ………….. ^0C

8. Final temperature of milk (Tm_2) =…………... ^0C

9. Time of evaporation (t) =…………... min

Sample calculation

1. Amount of water evaporated $V = W_1 - W_2$

2. Rate of evaporation $V_1 = V/t$ Kg/min

3. The rate of heat transfer = $V_1 * l$ J/min, where l = Latent heat of vaporization at atm pressure

4. Diameter of pan = d = cm

5. Heat transfer area =

6. Average milk boiling temperature = $(Tm_1+Tm_2)/2 = Tm$

7. $Q = UA\Delta T$

8. $U = Q/(A* Ts-Tm)$ $W/m^2\,^oC$

XVI. Results

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XVII. Interpretation of results

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XVIII. Conclusions & Recommendation

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XIX. Practical related Questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

a. Economy of a single pan evaporator is less than one. Give reason.

b. Explain the methods to increase economy of evaporator.

c. Give the different feeding arrangements for multiple effect evaporator.

[Space for Answers]

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XX. References / Suggestions for further Reading

- https://www.swep.net/refrigerant-handbook/6.-evaporators/asas1/
- https://nptel.ac.in/courses/103103032/39
- https://nptel.ac.in/courses/112105129/pdf/R&AC%20Lecture%2023.pdf

XXI. Assessment Scheme

Performance Indicators		Weightage
Process related (15 Marks)		**60%**
1	Preparation of experimental set up	20%
2	Setting and operation	20%
3	Safety measures, observation and recording	20%
Product related (10 Marks)		**40%**
4	Calculation and Interpretation of result	20%
5	Practical related question and submission of report	20%
Total (25 Marks)		**100 %**

Names of Student Team Members

1…………………………

2…………………………

3…………………………

4…………………………

Marks Obtained			Dated signature of Teacher
Process Related(15)	**Product Related(10)**	**Total (25)**	

List Of Laboratory Manuals Developed by MSBTE

First Semester:

1	Fundamentals of ICT	22001
2	English	22101
3	English Work Book	22101
4	Basic Science (Chemistry)	22102
5	Basic Science (Physics)	22102

Second Semester:

1	Bussiness Communication Using Computers	22009
2	Computer Peripherals & Hardware Maintenace	22013
3	Web Page Design with HTML	22014
4	Applied Science (Chemistry)	22202
5	Applied Science (Physics)	22202
6	Applied Machines	22203
7	Basic Surveying	22205
8	Applied Science (Chemistry)	22211
9	Applied Science (Physics)	22211
10	Fundamental of Electrical Engineering	22212
11	Elements of Electronics	22213
12	Elements of Electrical Engineering	22215
13	Basic Electronics	22216
14	'C' programming Language	22218
15	Basic Electronics	22225
16	Programming in "C"	22226
17	Fundamentals of Chemical Engineering	22231

Third Semester:

1	Applied Multimedia Techniques	22024
2	Advanced Serveying	22301
3	Highway Engineering	22302
4	Mechanics of Structures	22303
5	Building Construction	22304
6	Concrete Technology	22305
7	Strength Of Materials	22306
8	Automobile Engines	22308
9	Automobile Transmission System	22309
10	Mechanical Operations	22313
11	Technology Of Inorganic Chemicals	22314
12	Object Oriented Programming Using C++	22316
13	Data Structure Using 'C'	22317
14	Computer Graphics	22318
15	Database Management System	22319
16	Digital Techniques	22320
17	Principles Of Database	22321
18	Digital Techniques & Microprocessor	22323
19	Electrical Circuits	22324
20	Electrical & Electronic Measurment	22325
21	Fundamental Of Power Electronics	22326
22	Electrical Materials & Wiring Practice	22328
23	Applied Electronics	22329
24	Electrical Circuits & Networks	22330
25	Electronic Measurments & Instrumentation	22333
26	Principles Of Electronics Communication	22334
27	Thermal Engineering	22337
28	Engineering Matrology	22342
29	Mechanical Engineering Materials	22343
30	Theory Of Machines	22344

Fourth Semester:

1	Hydraulics	22401
2	Geo Technical Engineering	22404
3	Chemical Process Instrumentation & Control	22407
4	Fluid Flow Operation	22409
5	Technology Of Organic Chemicals	22410
6	Java Programming	22412
7	GUI Application Development Using VB.net	22034
8	Microprocessor	22415
9	Database Managment	22416
10	Electric Motors And Transformers	22418
11	Industrial Measurements	22420
12	Digital Electronics And Microcontroller Applications	22421
13	Linear Integrated Circuits	22423
14	Microcontroller & Applications	22426
15	Basic Power Electronics	22427
16	Digital Communication Systems	22428
17	Mechanical Engineering Measurments	22443
18	Fluid Mechanics and Machinery	22445
19	Fundamentals Of Mechatronics	22048

Fifth Semester:

1	Design of Steel and RCC Structures	22502
2	Public Health Engineering	22504
3	Heat Transfer Operation	22510
4	Environmental Technology	22511
5	Operating Systems	22516
6	Advanced Java Programming	22517
7	Software Testing	22518
8	Control Systems and PLC's	22531
9	Embedded Systems	22532
10	Mobile and Wireless Communication	22533
11	Industrial Machines	22523
12	Switchgear and Protection	22524
13	Energy Conservation and Audit	22525
14	Power Engineering and Refrigeration	22562
15	Solid Modeling and Additive Manufacturing	22053
16	Guidelines & Assessment Manual for Micro Projects & Industrial Training	22057

Sixth Semester:

1	Solid Modeling	17063
2	Highway Engineering	17602
3	Contracts & Accounts	17603
4	Design of R.C.C. Structures	17604
5	Industrial Fluid Power	17608
6	Design of Machine Elements	17610
7	Automotive Electrical and Electronic Systems	17617
8	Vehicle Systems Maintenance	17618
9	Software Testing	17624
10	Advanced Java Programming	17625
11	Mobile Computing	17632
12	System Programing	17634
13	Testing & Maintenance of Electrical Equipments	17637
14	Power Electronics	17638
15	Illumination Engineering	17639
16	Power System Operation & Control	17643
17	Environmental Technology	17646
18	Mass Transfer Operation	17648
19	Advanced Communication System	17656
20	Mobile Communication	17657
21	Embedded System	17658
22	Process Control System	17663
23	Industrial Automation	17664
24	Industrial Drives	17667
25	Video Engineering	17668
26	Optical Fiber & Mobile Communication	17669
27	Therapeutic Equipment	17671
28	Intensive Care Equipment	17672
29	Medical Imaging Equipment	17673

Pharmacy Lab Manual

First Year:

1	Pharmaceutics - I	0805
2	Pharmaceutical Chemistry - I	0806
3	Pharmacognosy	0807
4	Biochemistry and Clinical Pathology	0808
5	Human Anatomy and Physiology	0809

Second Year:

1	Pharmaceutics - II	0811
2	Pharmaceutical Chemistry - II	0812
3	Pharmacology & Toxicology	0813
4	Hospital and Clinical Pharmacy	0816

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