

Laboratory Manual

For

Computer Aided Process

Synthesis

(3170507)



**LUKHDHIRJI ENGINEERING COLLEGE, MORBI  
MORBI**

***This is to certify that***

**Mr. /Ms. ....  
Enrollment Number: ..... Branch: Chemical,  
Semester: ..... Has satisfactorily completed the term work  
in the subject code.....and Name.....  
from Lukhdhirji engineering college, Morbi.**

**Date of Submission: ..... Staff in charge: .....**

**Head of Department.....**



## LUKHDHIRJI ENGINEERING COLLEGE, MORBI

### VISION

To provide quality engineering education and transforming students into professionally competent and socially responsible human beings.

### MISSION

1. To provide a platform for basic and advanced engineering knowledge to meet global challenges.
2. To impart state-of-art know- how with managerial and technical skills.
3. To create a sustainable society through ethical and accountable engineering practices.



## LUKHDHIRJI ENGINEERING COLLEGE, MORBI CHEMICAL ENGINEERING DEPARTMENT

### VISION

To develop professionally competent & socially responsible chemical engineers by providing quality education.

### MISSION

1. To provide sound basic engineering knowledge to have a successful career in a professional environment.
2. To develop skill sets among the students to make them professionally competent.
3. To cater ethically strong engineers who shall be able to improve the quality of life and to work for sustainable development of society.

### PEO's

- PEO-1 To impart knowledge and skills in students to make them professionally competent in chemical process industries.
- PEO-2 To motivate students for higher studies in technical and management fields.
- PEO-3 To prepare students having soft skills along with leadership quality and management ability to make them successful entrepreneurs.
- PEO-4 To implant the ethical principle and norms of engineering practices in terms of health, safety, and environmental context for the sustainable development of society.

## PROGRAM OUTCOMES (POs)

Engineering Graduates will be able to:

1. **Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
2. **Problem analysis:** Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3. **Design/development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
4. **Conduct investigations of complex problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
5. **Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
6. **The engineer and society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
7. **Environment and sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
8. **Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
9. **Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
10. **Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
11. **Project management and finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
12. **Life-long learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

### PSO

- 1) Apply the knowledge of chemical engineering to accomplish the contemporary need of chemical & Allied Industries.
- 2) To execute the chemical engineering principle and modern engineering tools to design system by considering safety, cost, health, legal, cultural and environmental aspects.

## **Chemical Engineering Department**

### **Laboratory Safety Rules**

- 1 Behave in a responsible manner at all times in the laboratory.
- 2 Ask your teacher before preceding any activity.
- 3 Keep silence.
- 4 Do not touch any equipment, chemicals, or other materials in the laboratory area until you are instructed to do so.
- 5 Perform only those experiments authorized by your teacher.
- 6 Do not eat food, drink beverages, or chew gum in the laboratory.
- 7 Always work in a well-ventilated area.
- 8 Work areas should be kept clean and tidy at all times.
- 9 Wash your hands after performing all experiments.
- 10 Dress properly during a laboratory activity. Long hair, dangling jewelry, and loose or baggy clothing are a hazard in the laboratory.
- 11 Never look into a container that is being heated.
- 12 Obey safety rules.
- 13 After Completion of Experiments turn off equipment properly.
- 14 Drain Water After Compilation of Experiments.
- 15 Before Leaving the Laboratory turns Off Light/Fan.

## **Undertaking of Ethics**

1. I, hereby, promise to abide by the admissible rules and regulations, concerning discipline, attendance, etc. of the L.E.C.MORBI, and also to follow the Code of Conduct prescribed for the Students of the Institute, as in force from time to time and subsequent changes/modifications/amendment made thereto. I acknowledge that, the Institute has the authority for taking punitive actions against me for violation and/or non-compliance of the same.
2. I have performed all the experiments and their calculation done myself.

**Signature of Student**

**Enrollment of Student**



Sr. No.	Experiment No./Assignment No./Project Work.	Title of Experiment/Project	Due Date	Date of Submission	Page No.	Teacher's Sign	Remarks / Marks obtain	Experiment/Project Mapping with CO	Set up
4	Experiment	Use HINT software to find minimum utility requirements for the given stream data by HCC, GCC and Cascade Diagram and also study the effect of varying $\Delta T_{min}$ on the utility requirements.						3170507.2	
5	Experiment	To find the delta T optimum value for a given problem using HINT software						3170507.2	
6	Experiment	Design of heat exchanger network using HINT Software						3170507.2	
7	Experiment	To find the best sequence among of direct and indirect sequence based on $V_{min}$ calculation method and marginal vapour flow rate method						3170507.3	



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8	Experiment	To generate Attainable Region (AR) for Van De Vusse reaction System using MS Excel						3170507.1	
9	Experiment	Explain following question answers						3170507.3	
10	Experiment	Batch Process						3170507.4	

## EXPERIMENT NO 01

**Topic: To determine Minimum utility target and pinch point using temperature interval method**

**Problem: Find the minimum utility requirements (QH and QC) for the given stream data and find the pinch point by using temperature interval (TI) method.  $\Delta T_{\min} = 10^{\circ}\text{C}$ .**

Stream	Tin	Tout	FCp
C1	120	235	0.02
C2	180	240	0.04
H1	260	160	0.03
H2	250	130	0.015

**Procedure:**

- 1) Instead of dealing with hot and the cold streams separately, the Temperature Interval method simplifies the procedure by bringing all the streams to a single common temperature level. This can be done either by raising the temperatures of the cold streams by  $\Delta T_{\min}$  or by lowering the temperatures of the hot stream by  $\Delta T_{\min}$  or by parallelly raising and lowering the temperatures of both cold and hot streams by  $\Delta T_{\min}/2$  respectively.
- 2) Reframe the stream data using any of the above methods. In this instance, the hot stream temperatures have been decrease by  $\Delta T_{\min}$ .
- 3) Arrange the temperatures in the descending order to form the required temperature intervals.
- 4) Add a second column mentioning the temperature difference in different intervals.
- 5) Check for the range of each and every stream in the newly framed stream data and enter the value of  $(\Sigma FC_{\text{ph}} - \Sigma FC_{\text{pc}})$  in the third column which denotes the total summation of the  $FC_p$  values of all the streams present in that particular interval where  $FC_{\text{ph}}$  stands for hot streams and  $FC_{\text{pc}}$  stands for cold streams.
- 6) Construct 4<sup>th</sup> column for the total heat availability/deficiency in a particular interval by multiplying columns 2 and 3. Use formula to drag and complete the entire column.
- 7) Cascade the values of the 4<sup>th</sup> column using relevant formula.

8) Make a final column representing the adjusted cascade values where the most negative value of the cascaded column has been added to every single entry.

9) The top and bottom values represent the  $Q_H$  and  $Q_C$  for the problem with the "0" entry representing the pinch temperature. The exact pinch temperatures can be found by reversing the procedure done in the beginning for reframing the stream data.

Result: 1.  $Q_H =$   
2.  $Q_C =$   
3. Pinch Point:

## EXPERIMENT NO 02

**Topic: Minimum utility target and pinch point using HCC & GCC method in MS Excel**

**Problem: Find the minimum utility requirements for the given stream data and also find the pinch point for a minimum approach temperature difference,  $\Delta T_{\min} = 10^{\circ}\text{C}$ .**

Stream	T <sub>in</sub>	T <sub>out</sub>	FC <sub>p</sub>
C1	120	235	0.02
C2	180	240	0.04
H1	260	160	0.03
H2	250	130	0.015

### **Theory:**

Multiple streams at differing temperatures are to be cooled and heated. For this, reducing the energy consumption by minimizing the capital and operating costs in the heat transfer process becomes a key goal. The process to process heat transfer is to be maximized so that external utility requirements like steam and cooling water are minimum thereby reducing the operating costs. The pinch approach achieves this by separating the entire problem into two parts (above pinch and below pinch) where the minimum utility requirements are found out. Pinch point is obtained as a part of this where the partitioning is done for achieving other targets like minimum number of heat exchangers etc.

### **Procedure:**

- 1) Enter the given stream data table as given in the question
- 2) Form temperature intervals in the descending order keeping a difference of  $\Delta T_{\min} = 10^{\circ}\text{C}$  between the hot and cold side columns
- 3) Mention stream ranges (as given in the data) in the form of their FC<sub>p</sub> values written in between the temperature entries (separate column for each stream). Put the value "0" in the intervals where the particular stream does not exist.
- 4) Calculate available and required heat for hot and cold sides using excel formula for  $Q = FC_p \cdot \Delta T$ . Type "=" and enter the cell reference numbers of temperature and FC<sub>p</sub> entries. Drag the value inserted through formula in the first cell till the end of the column to get all the values of available and required heat.
- 5) Make separate columns for calculating the cascaded heat values on both hot and cold sides. Entries should be in line with temperature values and the first entry in the cascaded heat should be put "0". Use the formula to calculate the second entry and then drag to get the values for the entire column.

- 6) Plot graph between the cascaded heat values of hot and cold versus their respective temperatures (HCC). Goto "Insert" → "Scatter". Name the series as hot or cold composite curve and select the respective values from the table.
- 7) In cases where the hot composite curve lies below the cold composite curve, the hot composite curve must be shifted left side to bring it above the cold composite curve at all places. For this, find out the net heat in another separate column (Available heat – Required Heat). Cascade the net heat values and add the most negative value of this cascaded net heat into the values of cascaded available heat calculated above in step 5. Plot this new cascaded hot side heat values (shifted hot curve) with respect to their hot temperatures to get the shifted hot curve in the same chart.
- 8) The Minimum hot and cold utility requirements can be found by taking the cursor to the starting and terminating points of both cold and shifted hot curves and then finding the difference in their values.
- 9) For plotting Grand Composite curve, make another column named Adjusted Cascaded heat where the most negative value of the Cascaded Net heat column is added to all its entries. The first and the last entries are the Minimum Hot and Cold Utility requirements for the problems and a temperature in front of which "0" is displayed is the pinch temperature for this particular problem. Plot this adjusted cascaded heat with any one of the temperature columns for obtaining the Grand Composite Curve.

Result: 1.  $Q_H =$   
2.  $Q_C =$   
3. Pinch Point:

## EXPERIMENT NO 03

**Topic: To find the pinch point and minimum utility requirement by Linear Programming method (Transshipment Model) using solver in excel**

**Problem: Find the minimum utility requirements ( $Q_H$  and  $Q_C$ ) for the given stream data and find the pinch point.**

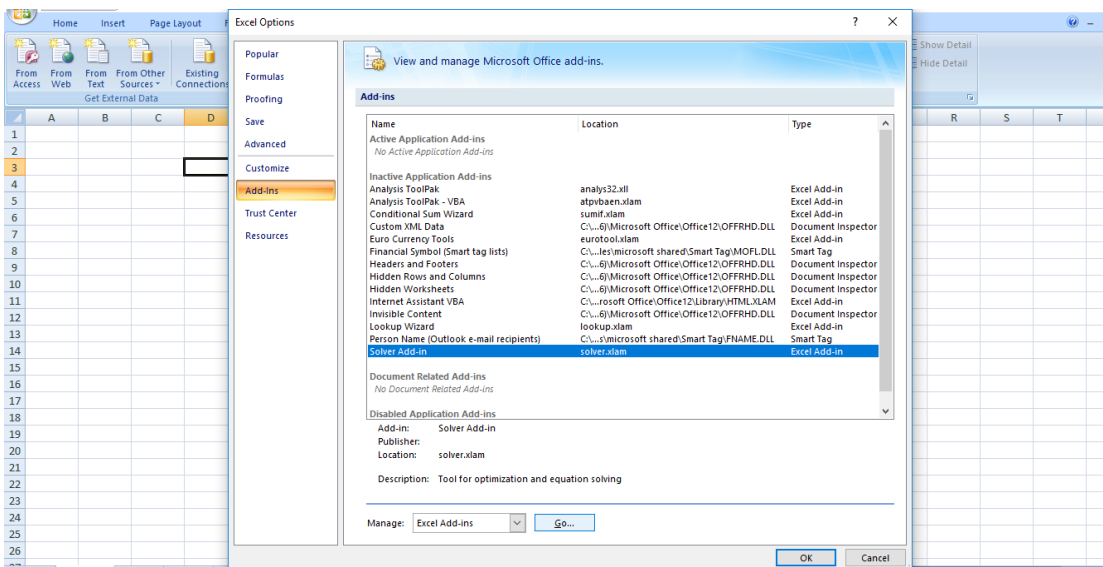
Stream	$T_{in}$	$T_{out}$	$FC_p$
<b>C1</b>	<b>120</b>	<b>235</b>	<b>0.02</b>
<b>C2</b>	<b>180</b>	<b>240</b>	<b>0.04</b>
<b>H1</b>	<b>260</b>	<b>160</b>	<b>0.03</b>
<b>H2</b>	<b>250</b>	<b>130</b>	<b>0.015</b>

### Theory:

Solver is a Microsoft Excel add-in program which can be used for what-if analysis and to find an optimal (maximum or minimum) value for a formula in one cell — called the objective cell — subject to constraints, or limits, on the values of other formula cells on a worksheet. In this practical solver add-in has been used to find the minimum utility requirements (objective cell) subject to the constraints posed by the equations generated in the expanded transshipment model.

### Procedure:

1) Firstly, Add the solver add-in in the excel's "data" tab from the excel options as shown below



- 2) For the given problem statement, prepare the Transshipment model consisting of relevant equations.
- 3) List down all the variables in the model in excel as shown in the figure above. Keep the cells adjacent to the variables blank as they are cell references (marked blue in the figure) to be used while entering the equations.
- 4) List down all the equation names (E1,E2....etc) as shown in the figure. Enter the equations in the cells adjacent to the E1,E2....etc such that all the terms of the equations are one side (marked green in the figure). Use the cell references of the cells adjacent to the variables for entering all the equations using as shown in the figure. Also, enter  $Z = Q_h + Q_c$  in cell adjacent to the objective variable Z.
- 5) After entering all relevant data, open solver dialog box under the data tab. Set Z as the target cell with the objective to minimize the cell adjacent to Z. select the cells adjacent to the variables for “By changing cells” section.
- 6) Enter all the relevant constraints under the constraint section. Cells adjacent to all the variables and equation names should be greater than or equal to zero. Additionally, cells adjacent to the equation names should be equal to zero (denoting the RHS of the equation after all the terms have been taken to the LHS while entering the equations).
- 7) The solver dialog box entry is now complete. Click solve button to get the minimum value of Z in its reference cell.
- 8) In this particular example, there is a pinch point as some residual values are zero. So, the first interval from the top where the residual heat value of hot utility is zero represents the pinch point of the problem.

Result: 1.  $Q_H =$   
2.  $Q_C =$   
3. Pinch Point:

## EXPERIMENT NO 04

**Topic:** Use HINT software to find minimum utility requirements for the given stream data by HCC, GCC and Cascade Diagram and also study the effect of varying  $\Delta T_{min}$  on the utility requirements.

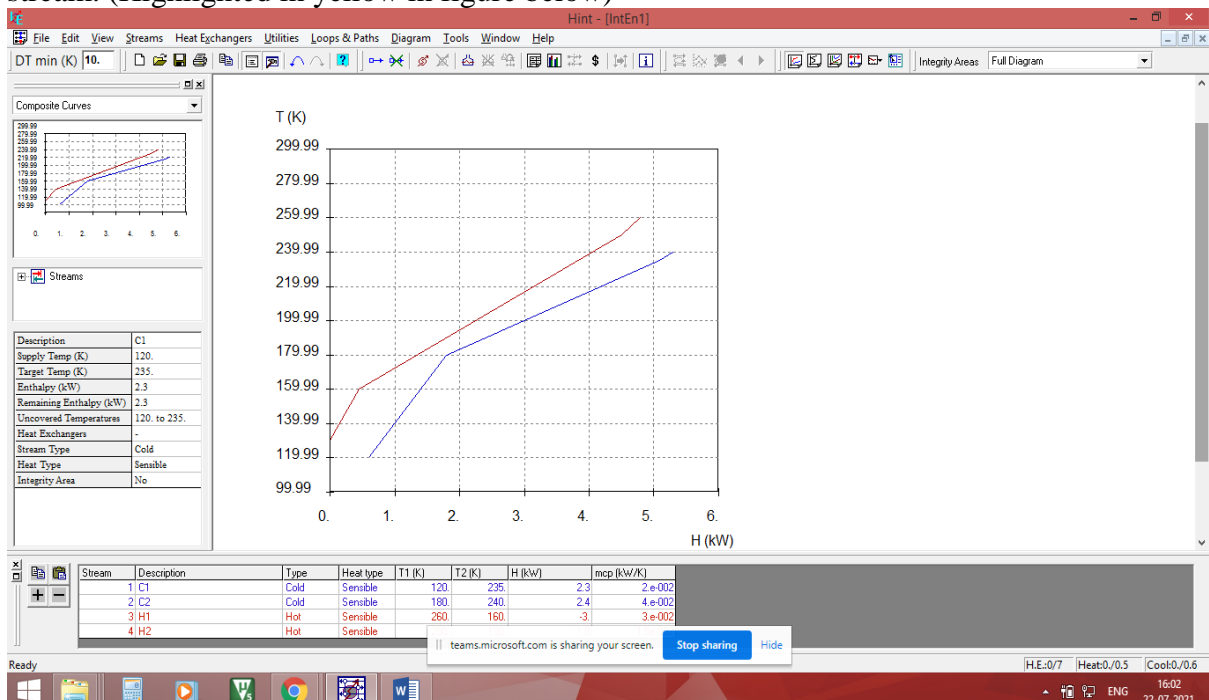
**Problem:** Find the minimum utility requirements (QH and QC) for the given stream data and find the pinch point. Also, study the effect of varying the  $\Delta T_{min}$  on the minimum utility requirement values and pinch point.

Stream	T <sub>in</sub>	T <sub>out</sub>	FC <sub>p</sub>
C1	120	235	0.02
C2	180	240	0.04
H1	260	160	0.03
H2	250	130	0.015

**Procedure:**

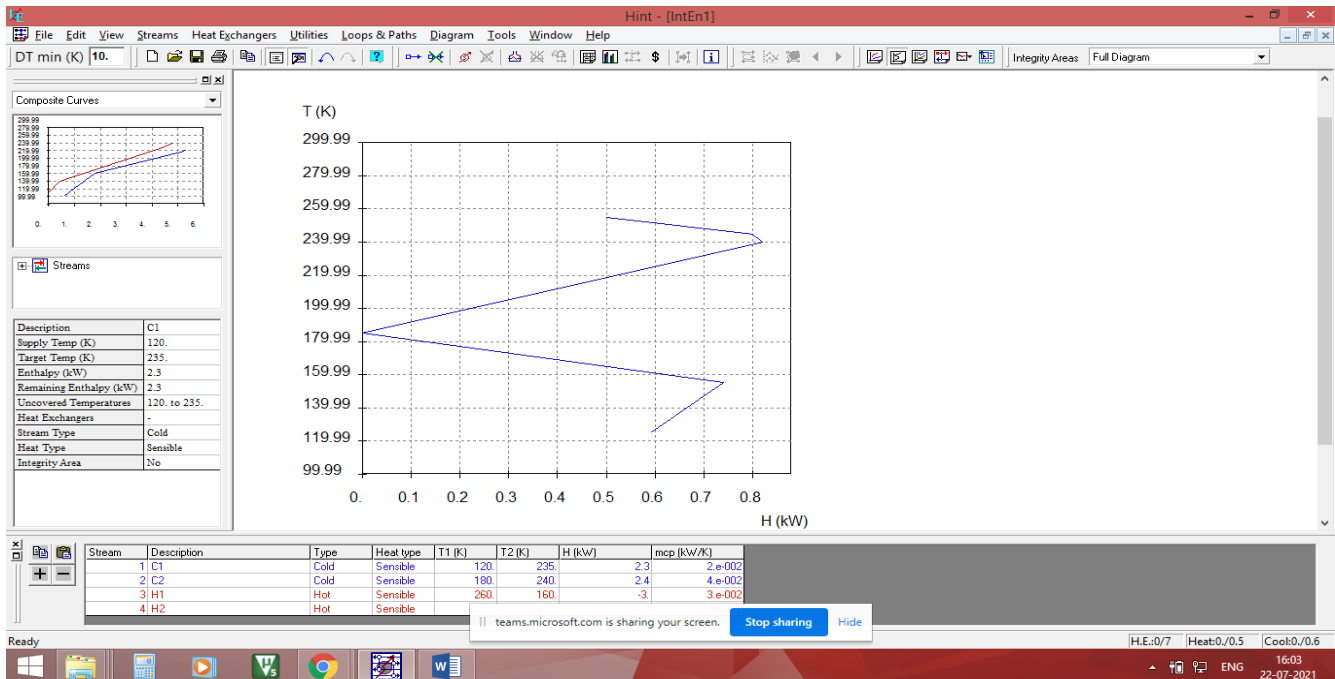
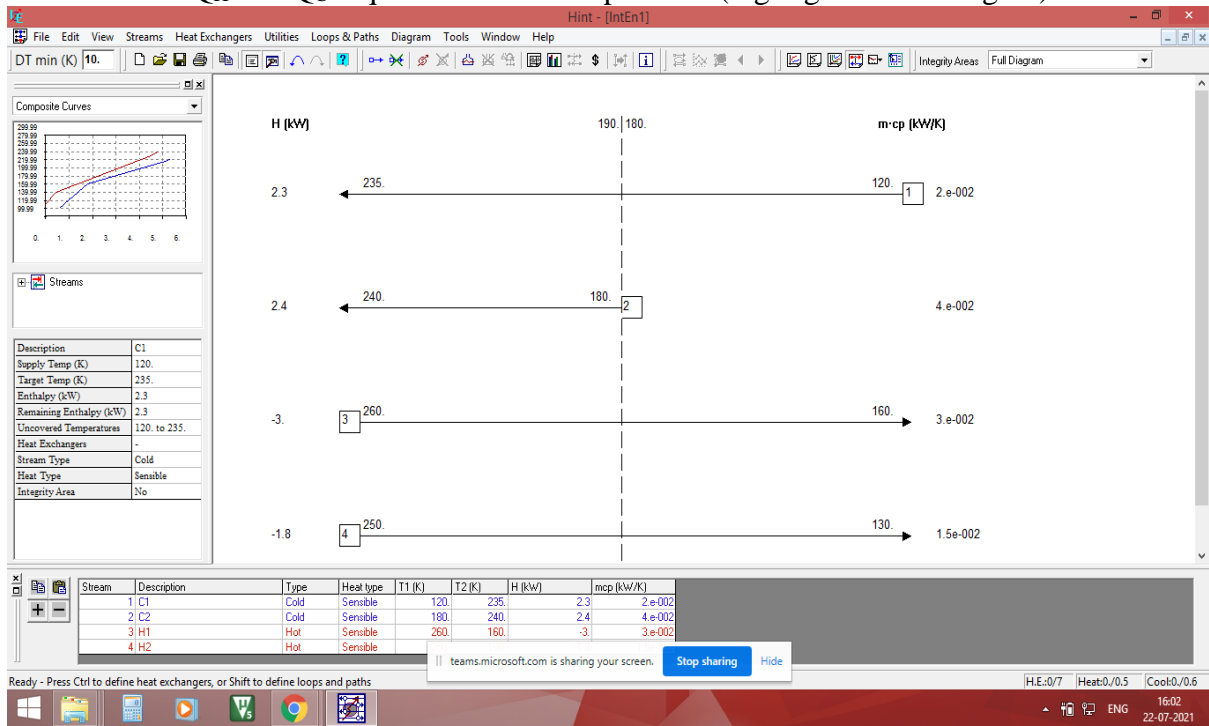
**$\Delta T_{min}$  Analysis using HINT software:**

- 1) Open HINT software, enter the stream data at the bottom by adding the + sign for every single stream. (Highlighted in yellow in figure below)

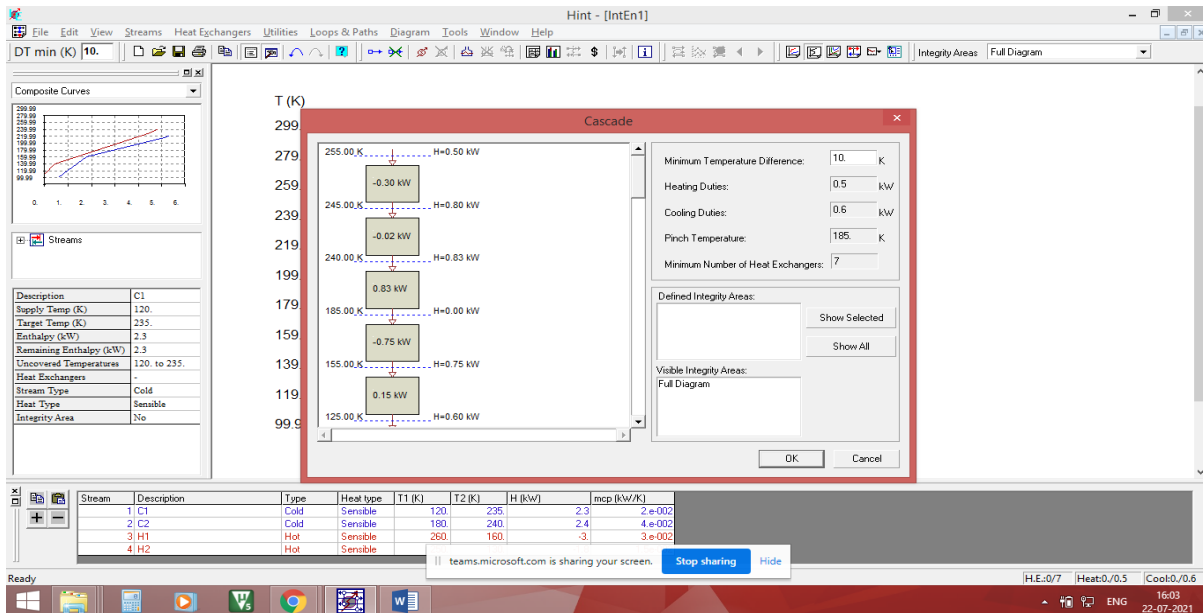




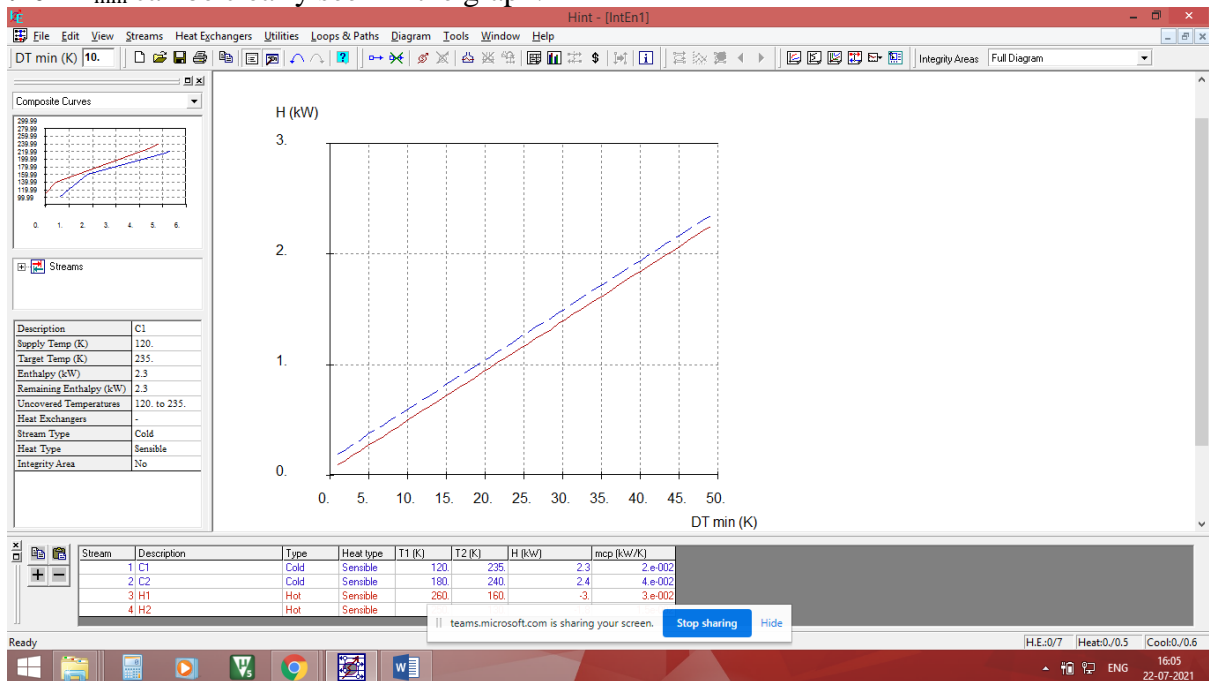
- 2) The HCC and GCC curves can be instantly seen in the “diagrams” tab. The “Grid” diagram shows a pinch temperature of 180/190 °C. And the “cascade” diagram on the left panel shows the Minimum  $Q_H$  and  $Q_C$  requirements for the problem (highlighted in the figure).



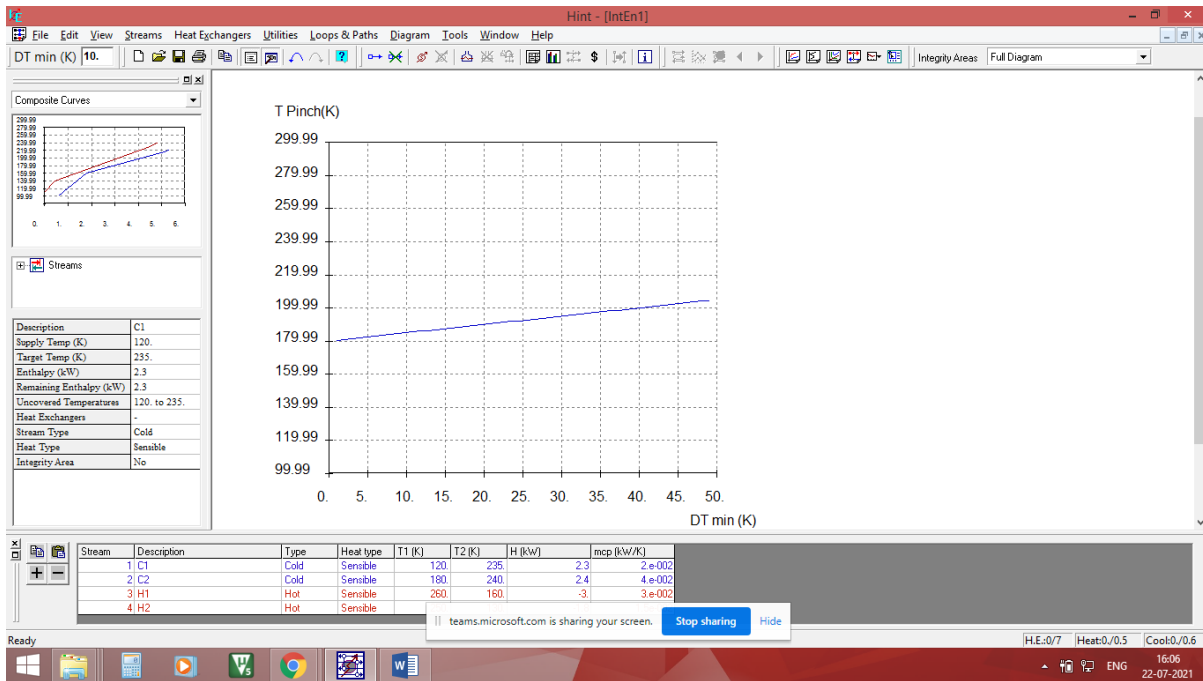
- 3) The default  $\Delta T_{\min}$  minimum in the HINT software is 10 °C. Change the  $\Delta T_{\min}$  value and note the changes in the pinch point temperatures as well as the values of hot and cold utilities.



- 4) The entire analysis for various  $\Delta T_{\min}$  can be directly obtained by going to “diagrams” tab → “DT Analysis” → “energy targets”. A constant rise in the utility requirements with increase in the  $\Delta T_{\min}$  can be clearly seen in the graph.



- 5) Similar analysis can also be obtained for changes in the pinch temperature.



6) It can be clearly seen that the both the utility requirements increase linearly by same amount with increase in  $\Delta T_{\min}$ . Also, the bottom pinch temperature remains constant while the upper pinch temperature varies linearly with  $\Delta T_{\min}$ .

Result: 1.  $Q_H =$

2.  $Q_C =$

3. Pinch Point:

$Q_H, Q_C$  and upper pinch temperature values increase linearly with rise in  $\Delta T_{\min}$  and vice versa.

## EXPERIMENT NO 05

**Topic:** To find the delta T optimum value for a given problem using HINT software.

**Problem:** For the process shown in the table below, pure counter current (1,1) shell and tube heat exchangers are used and  $\Delta T_{\min} = 10\text{K}$ . Use the HINT software to find the  $\Delta T_{\text{optimum}}$  for the given problem.

The cost can be estimated by the following equation:

$$\text{Heat Exchanger Capital Cost (\$)} = 30000 + 400 (A)^{0.9}$$

For total annual cost, the utility costs are as follows:

$$\text{Steam cost} = \$ 120 (\text{kW}^{-1}\text{y}^{-1})$$

$$\text{Cooling water cost} = \$ 10 (\text{kW}^{-1}\text{y}^{-1})$$

$$I=10\%; n=5, \text{Lang Factor} = 1$$

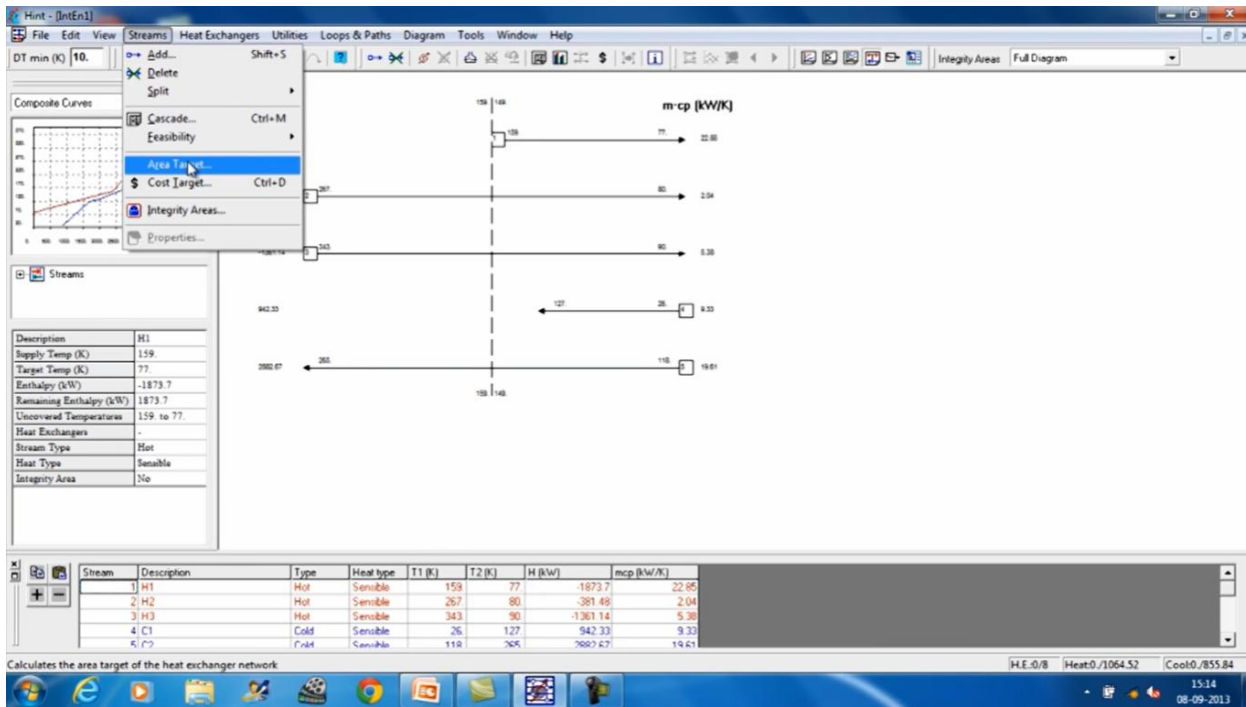
STREAM	T <sub>in</sub> (K)	T <sub>out</sub> (K)	FC <sub>p</sub> (KWK <sup>-1</sup> )	Film Heat Transfer Coefficient (kW M <sup>-2</sup> K <sup>-1</sup> )
H1	159	77	22.85	0.1
H2	267	80	2.04	0.04
H3	343	90	5.38	0.5
C1	26	127	9.33	0.01
C2	118	265	19.61	0.5
Steam	360	359		0.05
Cooling water	20	60		0.2

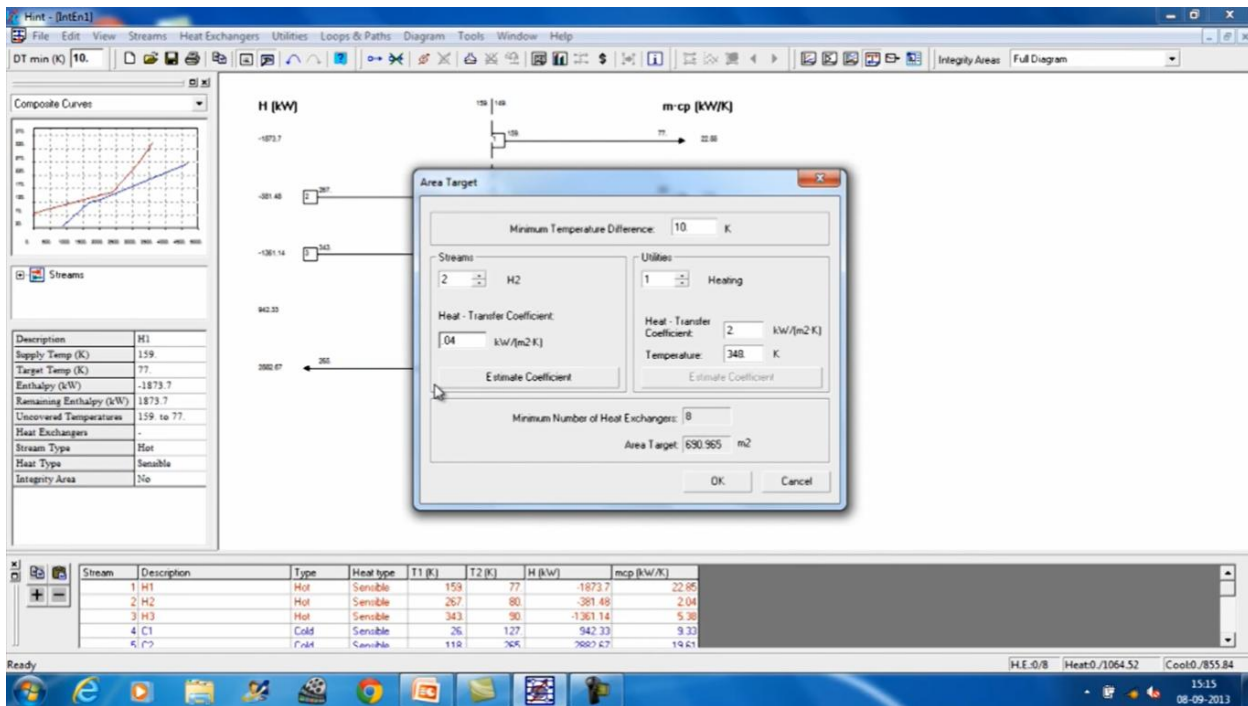
**Procedure:**

**Theory:** HINT software offers a very user friendly interface for carrying out network synthesis problems in heat integration. After adding the details of streams and the utilities, one can easily do area as well as cost targeting to find the  $\Delta T_{\text{optimum}}$  value for the given problem. This is done by selecting the proper diagram option and looking for the  $\Delta T_{\min}$  value where the total cost curve has minima.

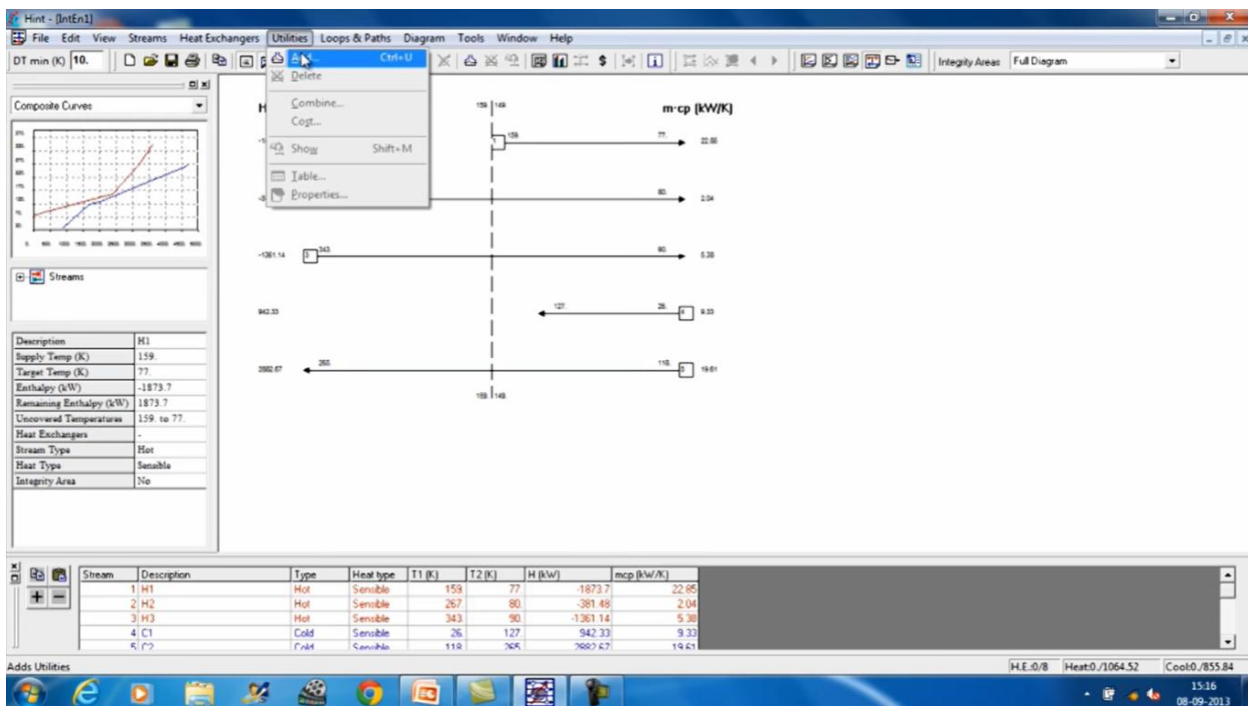
**Procedure:**

- 1) Add all process streams one by one as mentioned in the previous practical's.
- 2) Goto "Streams" tab and click "area target". A new window opens where the heat transfer coefficient values are to be entered one by one for each of the 5 process streams and the 2 utility streams. Ignore the temperatures of the utilities right now as these will be added separately.

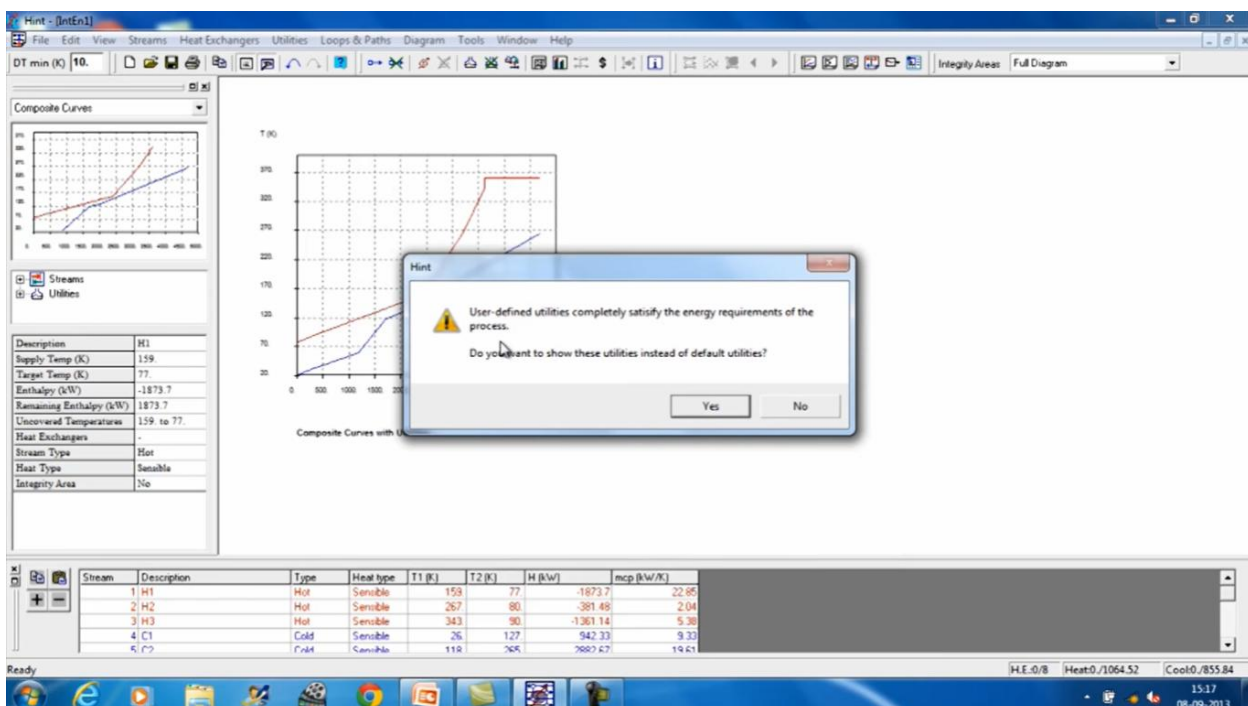
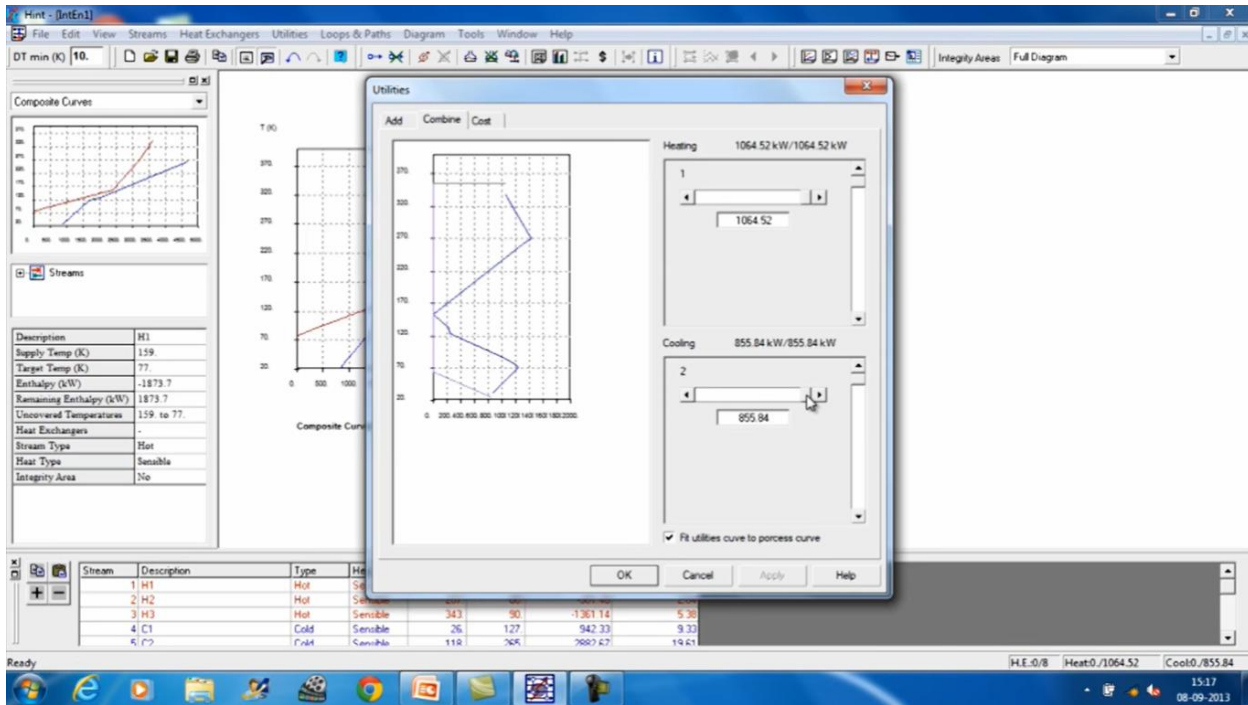




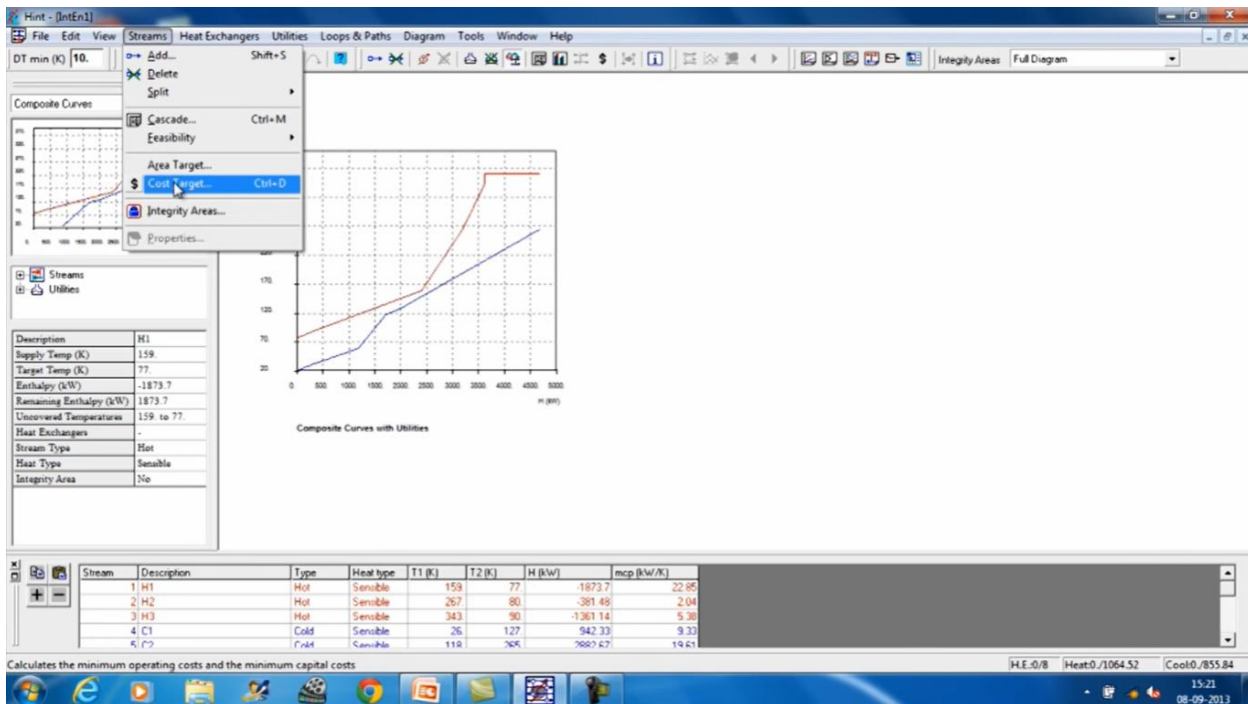
3) Goto “Utilities” tab and add the details of utilities.



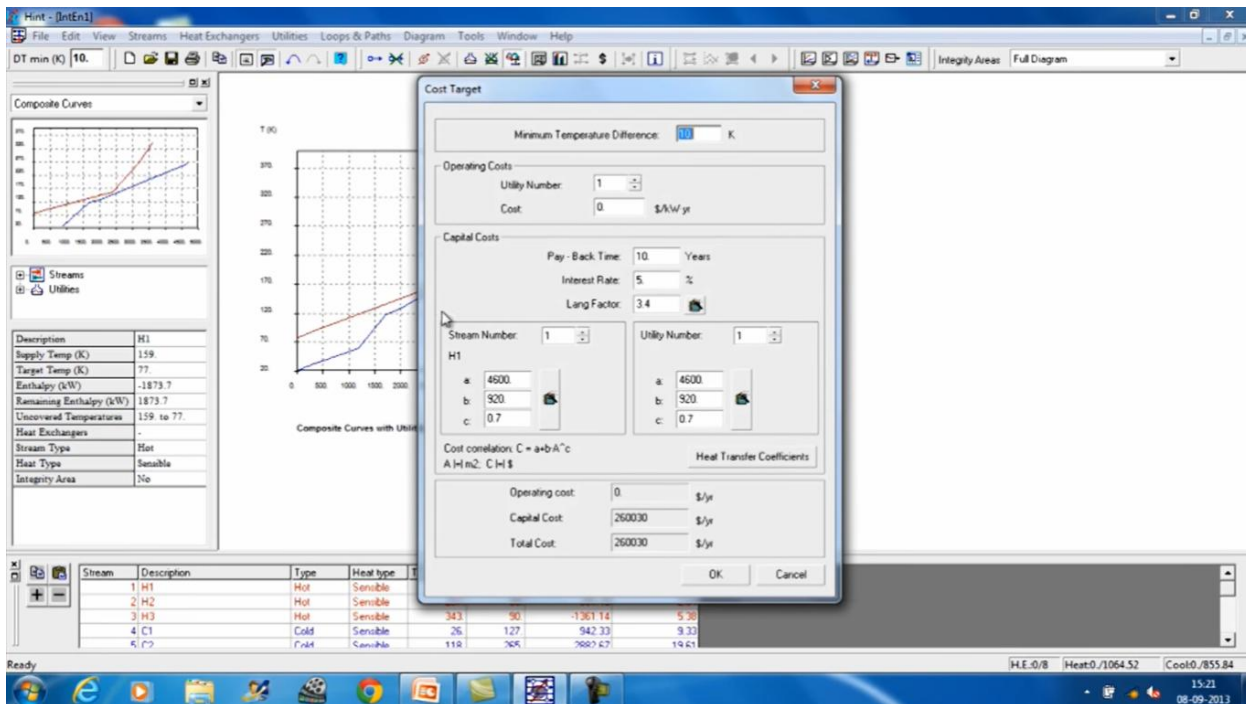
4) After the addition of utilities, click “combine” option in the utilities tab which open a new window. For heating as well as cooling, take the slider all the way to the right signifying that we are using the entire utilities. Click OK and press Yes in the pop up window.



5) Goto “Streams” tab and click “Cost Target”. In the new window, enter all the capital cost and operating cost details given in the question for all the process as well as utility streams one by one. Press OK when done with the entries. The capital and operating costs for the problem can be seen at the bottom of this window.







6) Goto “Diagrams” and in the “Delta T min analysis” option, click the “total cost” in the cost target option. A new graph appears on the window which shows the variation of Total Cost, Capital Cost as well as the Operating Cost with the change in  $\Delta T_{\min}$ . The  $\Delta T_{\min}$  where the total cost curve has minima is the  $\Delta T_{\text{optimum}}$  for the given problem.

**Result:**

The  $\Delta T_{\text{optimum}}$  for the given problem is \_\_\_\_\_K which corresponds to the minimum total cost.

## EXPERIMENT NO 06

**Topic: To design a Heat Exchange Network for the given problem using HINT software**

**Problem: The following problem has a pinch point of 90/80 deg C and the values of minimum hot and cold utility requirements are  $Q_H = 15 \text{ kW}$  and  $Q_C = 45 \text{ kW}$  respectively. Design a heat exchange network using the given stream data in the HINT software.**

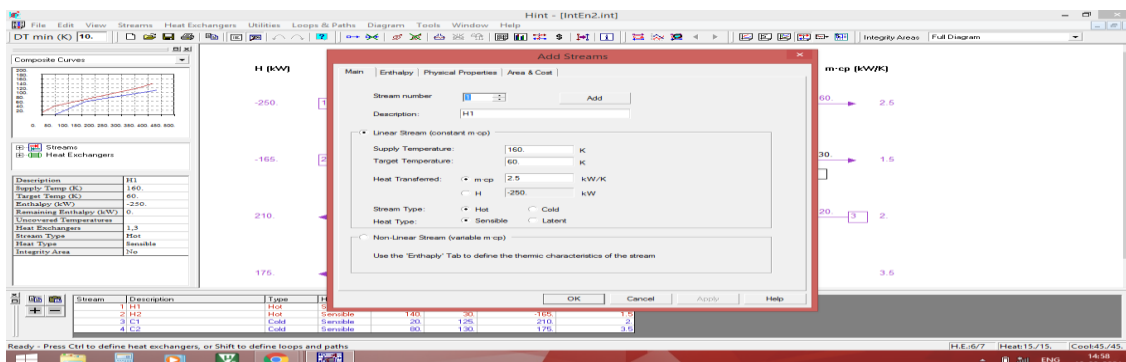
STREAM	T <sub>in</sub> (K)	T <sub>out</sub> (K)	FCp (KWK <sup>-1</sup> )	Film Heat Transfer Coefficient (kW M <sup>-2</sup> K <sup>-1</sup> )
H1	160	60	2.5	2
H2	140	30	1.5	2
C1	20	125	2	2
C2	80	130	3.5	2

**Procedure:**

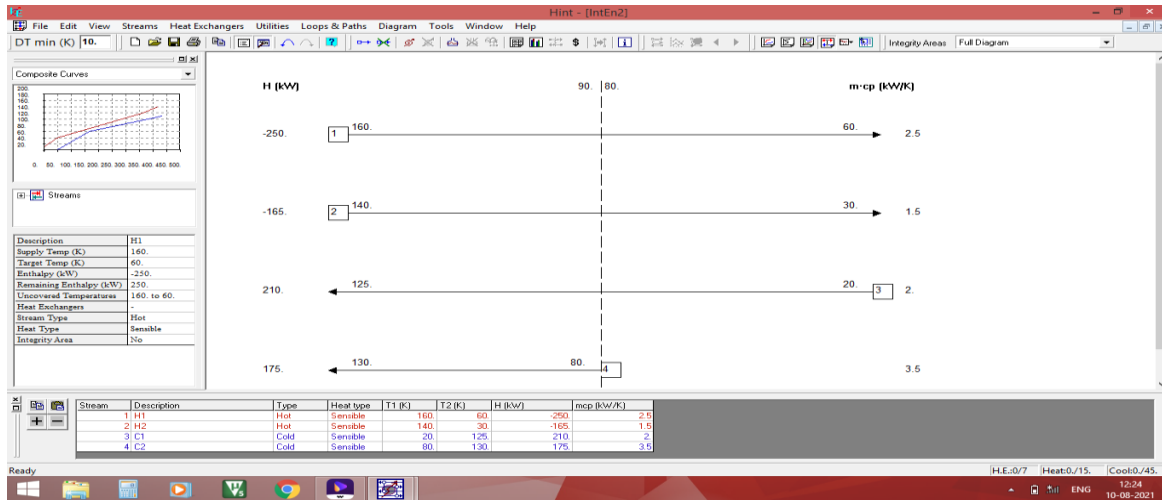
**Theory:** HINT software offers a very user friendly interface for carrying out network synthesis problems in heat integration. With the given stream data, one can easily find the pinch point and the minimum utility requirements and subsequently design a network using the pinch analysis and set of stream matching criteria inbuilt in the software.

**Procedure:**

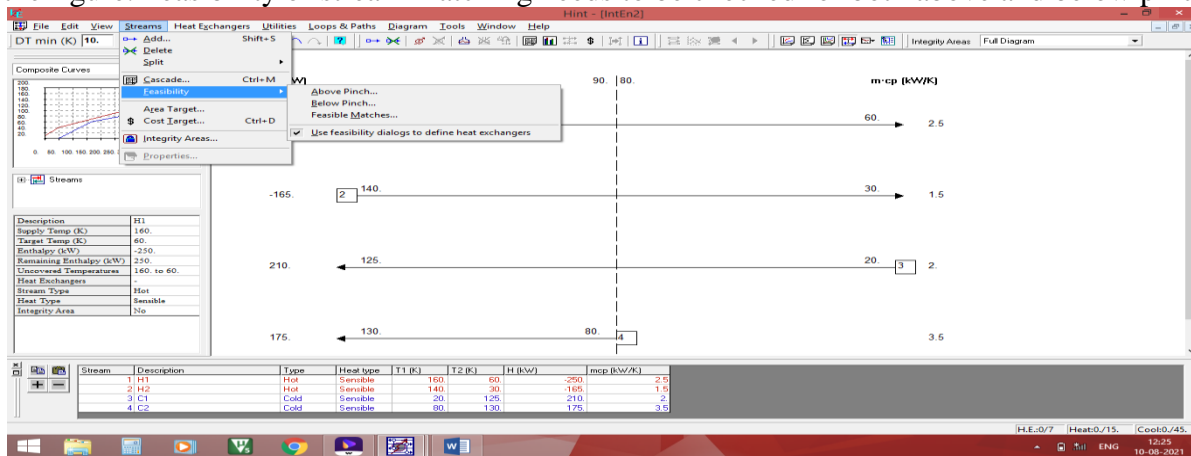
- 1) Add all process streams one by one as mentioned in the previous practicals.



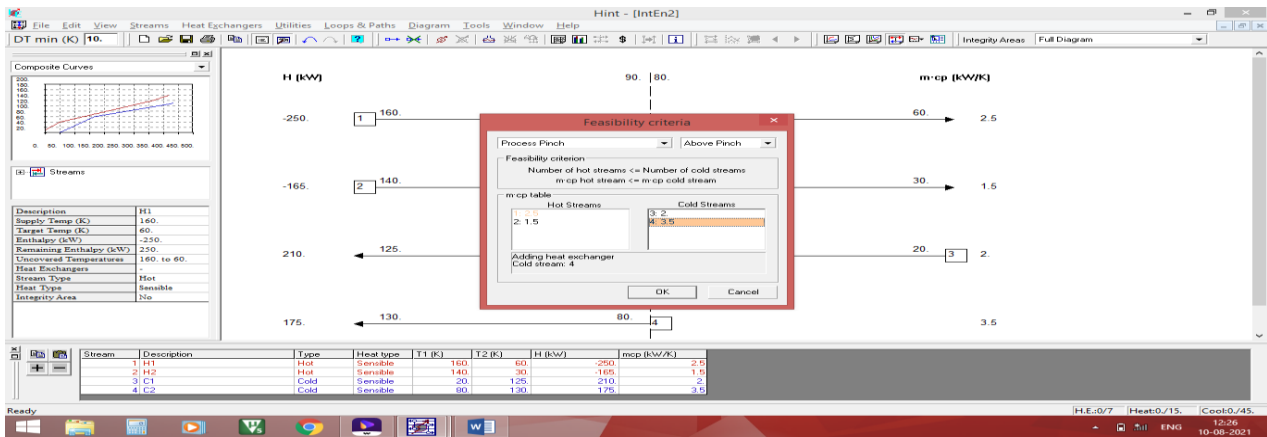
2) In the HINT software, enter the given stream data. Directly check the pinch point and the minimum utility requirements. A grid diagram is shown in the central part which is the basis for network design.



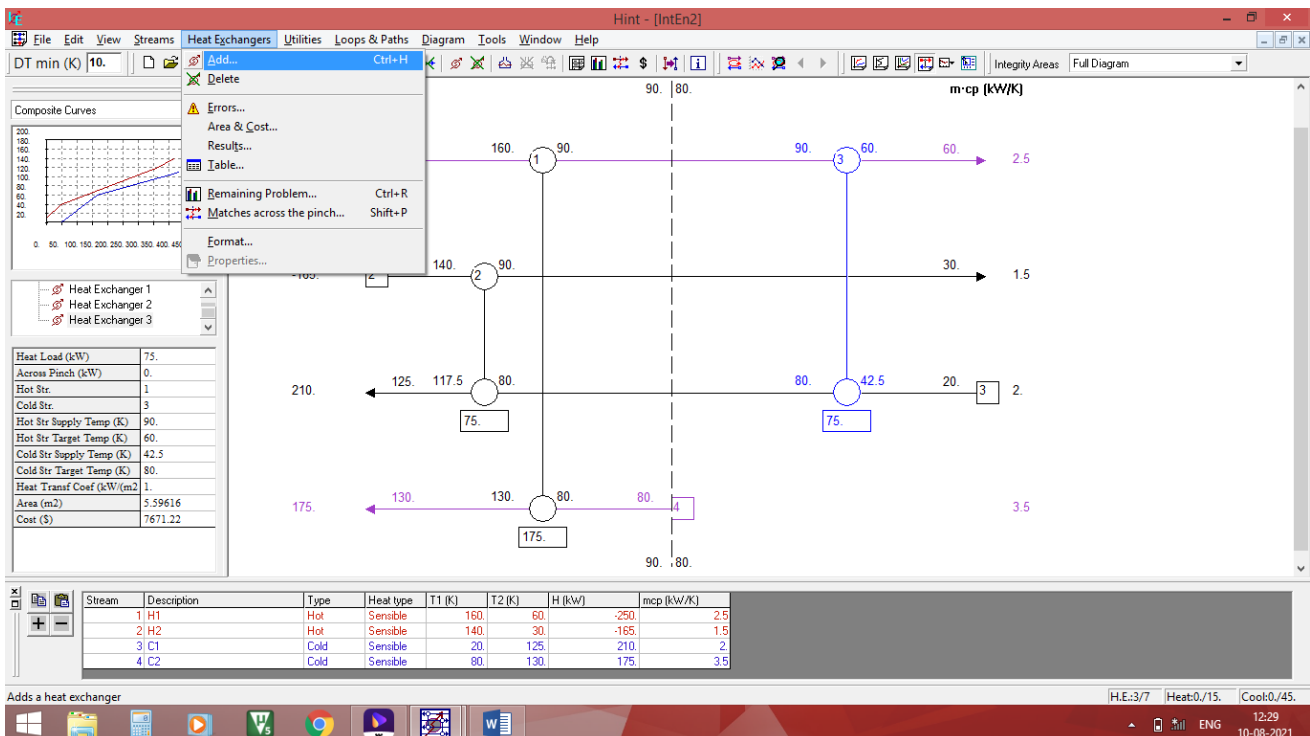
3) To start the network design, goto the “streams” tab and select the “feasibility” option as shown in the figure. Feasibility of stream matching needs to be checked for both above and below pinch areas.



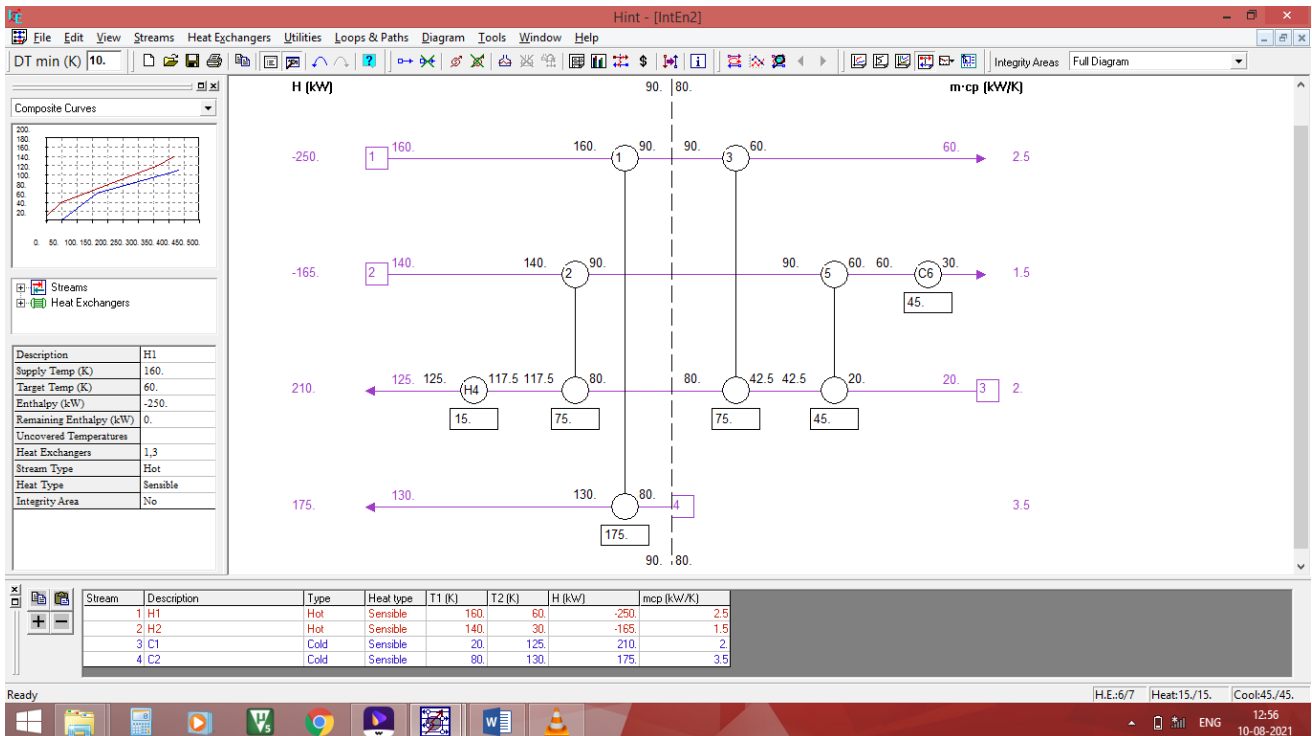
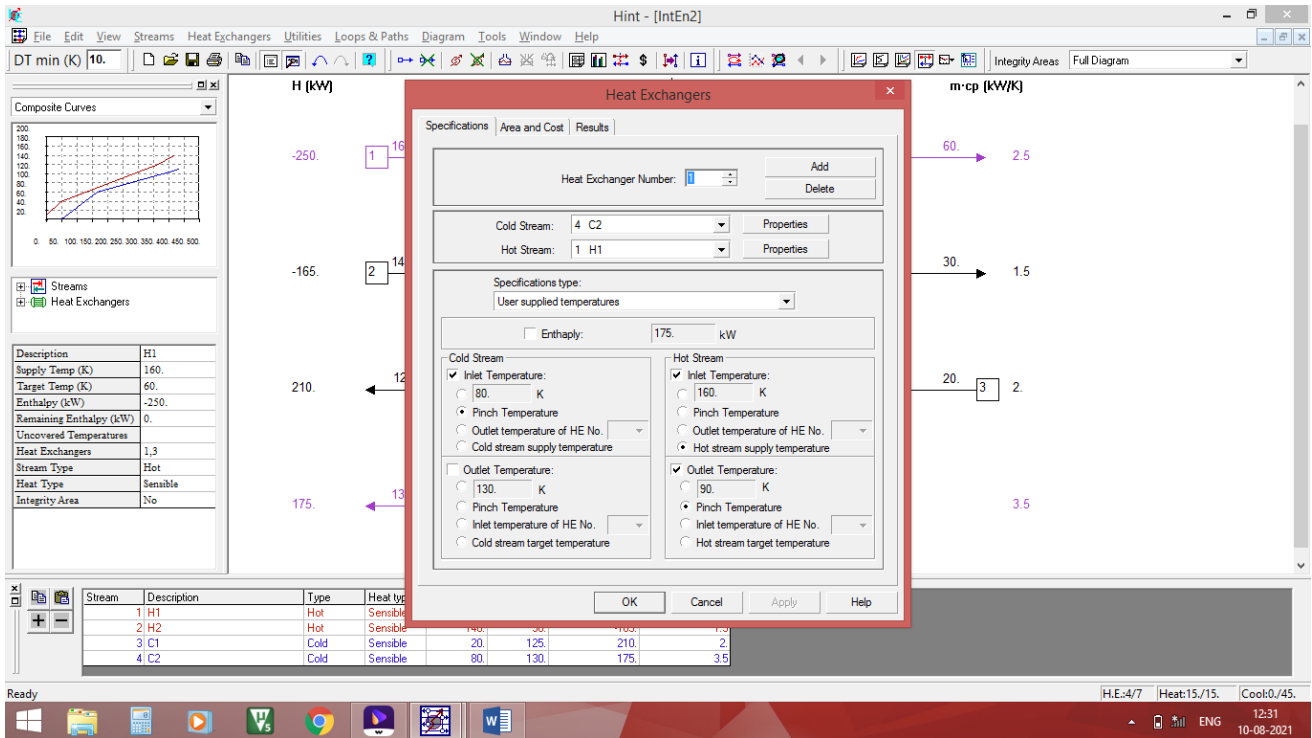
4) Feasibility above the pinch is shown in the figure below. Based on the criteria mentioned in the dialogue box, feasible matches will turn light in colour whereas unfeasible matches will be indicated by an error message as shown in the figure below.



5) After suitable stream matching, heat exchangers for the same will be reflected in the grid diagram as shown in the figure below. The exit temperatures along with the heat duty of the exchanger are indicated.



6) For finishing off remaining part of the above pinch area, manual heat exchangers need to be added manually from the “heat exchangers” tab. Click add button to input a new exchanger for the stream under consideration. Remaining part of the cold stream can be satisfied using hot utilities after entering all the relevant information in the dialog box.



7) Similar procedure below the pinch completes the entire network design where the N-1 rule is satisfied for the total number of heat exchangers above and below the pinch.

**Result:**

The total number of heat exchangers above and below the pinch point is \_\_\_\_\_ and \_\_\_\_\_ respectively and this follows the N-1 rule

## **EXPERIMENT NO 07**

**Topic: To find the best sequence among of direct and indirect sequence based on Vmin calculation method and marginal vapour flow rate method**

### **Problem:**

- Q:1 Separating a mix of n-pentane, n-hexane and n-heptane, assume 99% purity of each stream. The feed contains 20% n-pentane, 30%-hexane and 50% heptane. The relative volatility of n-pentane, n-hexane and n-heptane is given as 5.51, 2.32 and 1 respectively. The feed is entering at bubble point temperature.
- (1) Describe both the sequences for the separation of three component system
  - (2) Evaluate the best sequence based on the Vmin calculation method.
- Q:2 Separating a mix of n-pentane, n-hexane and n-heptane, assume 95% purity of each stream. The feed contains 20% n-pentane, 30%-hexane and 50% heptane. The relative volatility of n-pentane, n-hexane and n-heptane is given as 5.51, 2.32 and 1 respectively. The feed is entering at bubble point temperature.
- (1) Describe both the sequences for the separation of three component system
  - (2) Evaluate the best sequence based on the Vmin calculation method.
- Q:3 Separating a mix of n-pentane, n-hexane and n-heptane, assume 99% purity of each stream. The feed contains 20% n-pentane, 30%-hexane and 50% heptane. The relative volatility of n-pentane, n-hexane and n-heptane is given as 5.51, 2.32 and 1 respectively. The feed is entering at dew point temperature.
- (1) Describe both the sequences for the separation of three component system
  - (2) Evaluate the best sequence based on the Vmin calculation method.
- Q:4 Separating a mix of n-pentane, n-hexane and n-heptane, assume 99% purity of each stream. The feed contains 20% n-pentane, 30%-hexane and 50% heptane. The relative volatility of n-pentane, n-hexane and n-heptane is given as 5.51, 2.32 and 1 respectively. The feed is entering at bubble point temperature.
- (1) Describe both the sequences for the separation of three component system
  - (2) Evaluate the best sequence based on the Marginal vapor flow calculation method.
- Q:5 Separating a mix of n-pentane, n-hexane and n-heptane, assume 99% purity of each stream. The feed contains 10% n-pentane, 10%-hexane and 90% heptane. The relative volatility of n-pentane, n-hexane and n-heptane is given as 5.51, 2.32 and 1 respectively. The feed is entering at bubble point temperature.
- (1) Describe both the sequences for the separation of three component system
  - (2) Evaluate the best sequence based on the Marginal vapor flow calculation method.

- Q:6 Separating a mix of five alcohol A, B, C, D, E. The feed flow rate of alcohol mixtures are 1,0.5,1,7,10 mol/sec respectively. The relative volatility of alcohol A, B, C, D, E are 4.3,4,3,2,1 respectively.
- (1) Describe all the sequences for the separation of five component system
  - (2) Evaluate the best sequence based on the Marginal vapor flow calculation method.
- Q:7 Separating a mix of six alcohol A, B, C, D, E and F. The feed flow rate of alcohol mixtures are 1,2,3,4,5,10 mol/sec respectively. The relative volatility of alcohol A, B, C, D, E and F are 4.3,4,3,2,1, 0.5 respectively.
- (1) Describe all the sequences for the separation of Six component system
  - (2) Evaluate the best sequence based on the Marginal vapor flow calculation method.



## EXPERIMENT NO 08

**Topic To generate Attainable Region (AR) for Van De Vusse reaction System using MS Excel**

**Problem: The following liquid phase, constant density, isothermal reaction network will be used to illustrate the AR approach. It is well known van de Vusse reaction Kinetics.**

Kinetics	PFR model
$  \begin{array}{c}  A \xrightleftharpoons[k_2]{k_1} B \xrightarrow{k_3} C \\  2A \xrightarrow{k_4} D  \end{array}  $	$  \begin{aligned}  \frac{dC_A}{d\tau} &= -k_1 C_A + k_2 C_B - k_4 C_A^2 \\  \frac{dC_B}{d\tau} &= k_1 C_A - k_2 C_B - k_3 C_B  \end{aligned}  $

**Reaction Network Constants and Initial Concentrations**

CA0	CB0	CC0	CD0
1	0	0	0
kmol/ m3	kmol/ m3	kmol/ m3	kmol/ m3
k1	k2	k3	k4
0.01 s-1	5 s-1	10 s-1	100 s-1

The initial characteristics of the reaction network are shown in table. The end goal of this exercise is to determine the reactor configuration that maximizes the production of B for a feed of pure A. These reaction kinetics were used because they represent a reaction network without an intuitively obvious optimal structure. A PFR will maximize the amount of B produced in the first reaction, but a CSTR will minimize the amount of A consumed in the second reaction.

## Procedure:

**Theory:** The concept of an Attainable Region (AR) was first articulated four decades ago by Horn (1964) but, because of a probable inability to understand comprehensively its import, it languished in relative obscurity for another two decades until pioneering work at the University of the Witwatersrand in Johannesburg, South Africa became known. Glasser et al. (1987) investigated a problem of not inconsiderable interest namely, in an isothermal reactor, how could a geometrical area be identified that would contain all the reactants and products associated with a chemical reaction. Attainable Region (ARC) be constructed but that it could be so developed through the use of conventional plug flow reactors (PFRs) and continuously stirred tank reactors (CSTRs) in suitable configurations and with appropriate by-pass arrangements.

Attainable Region can be used to solve the problem of finding an optimum solution for an Objective function which, for example, might be maximum yield, minimum residence time or maximum selectivity, provided these functions could be expressed in terms of the relevant species' concentrations. The geometry of the attainable region was examined again by Hildebrandt et al. (1990). In this paper several reaction systems were studied to identify candidate attainable regions under isothermal and adiabatic conditions and with variable and constant density systems. The effects of direct (cold shot) and indirect (heat exchange) cooling upon the relevant ARC s were analyzed. The reactors considered in the paper were PFRs and CSTRs with suitable by-pass arrangements. The usefulness and practicality of geometric ideas to solve reactor problems were confirmed.

Seodigeng (2006) developed the Recursive Convex Control (RCC) policy as a numerical tool to identify the boundary of an attainable region, AR. The RCC method employs the mathematical features of basic processes, reaction and mixing, to identify the boundary of an AR that satisfies compliance criteria. These compliance criteria for an attainable region, AR, were specified by Glasser et al. (1987) and subsequently were clarified and refined by others including Hildebrandt and Glasser (1990), Nisoli et al. (1997) and Feinberg and Hildebrandt (1997).

The compliance criteria for an attainable region are:

1. The AR includes all defined input and output states.
2. No rate vector on the boundary of the AR points outwards, i.e. all rate vectors must Point inwards or be tangential or be zero.
3. The boundary of the AR is convex.
4. No basic process vectors on the AR boundary can intersect the AR boundary when Extended backwards.
5. No plug flow trajectory exists within the complement of the AR such that a line Linking two points of this trajectory can be extended to intersect the AR.

**Solution:**

Determining the candidate attainable region for this reaction scheme involves the completion of the following simplified steps: selecting the fundamental processes, choosing the state variables, defining and drawing the process vectors, constructing the region, interpreting the boundary as the process flow sheet, and finding the optimum.

## **EXPERIMENT NO 09**

**Topic Explain following question answers.**

Q1: Explain in details Heat Pumping, Vapor Recompression and Rebuilder Flashing,

Q2: Positioning of Heat Engines and Heat Pumps

## **EXPERIMENT NO 10**

### **Topic: Batch Process.**

Q 1: Consider a plant consisting of two stages that mfg. two products A and B the demands are 5 Lac kg/year for A and 3 Lac kg/year for B and production time consider is 6000 hrs. Data for processing time, size factor and cleanup time are as follows.

	Processing time (hrs)		Size factor (m <sup>3</sup> /Production)	
	Stage – 1	Stage – 2	Stage – 1	Stage – 2
A	8	3	0.08	0.05
B	6	3	0.09	0.04
	Cleanup time 4 hrs for A to B and B to A			

The production schedule time is single product campaigns and length of production cycle is 1000hrs. Performed the sizing of vessel from plant.

Q 2: A given batch plant producing 1 single product for which stage 1 required 8 hrs per batch stage 2 for 4 hrs per batch stage 3 7 hrs per batch if zero wait transfer is used what is cycle time and how many parallel units should be placed in each stage to reduce to cycle time for 4 hrs?