THE USE OF PROCESS FLOWSHEET SIMULATORS IN SOPH. AND JR. CHEMICAL ENGINEERING COURSES

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ABSTRACT

Process Flowsheet Simulation Software has been used since 1990 in sophomore and junior level chemical engineering courses at Michigan Technological University. MicroCHESS Process Simulation (by COADE) was used in the mass balance course in 1990. Starting in 1991, HYSYS/HYSIM (by Hyprotech Ltd.) has been used in the mass balance, energy balance, stagewise operations and mass transfer/separations courses.

The use of Process Flowsheet Simulation Software is implemented by assigning computer projects. The primary objective of the computer projects is to expose the students to the type of software used for designing chemical processes in industry and in the senior-year design course. Secondary objectives include the experience of working in a student group (initially recommended but now required), the opportunity to undergo the "painful" and frustrating process of learning to use new software, initial exposure to the design of a part of a chemical process, recognition of the value of Process Flowsheet Simulation Software in optimizing a process, an awareness of the role of economics in design, and verification of the concepts studied in class.

The computer projects for the mass balance course always involve a chemical reaction with recycle. The Process Flowsheet Simulation Software uses the Wegstein algorithm to deal with the recycle. The students have already done calculations by hand using Wegstein for simple chemical reaction-recycle problems.

One of the computer projects for the energy balance course involves problems already solved by hand. The students investigate the reliability of the enthalpy estimation techniques used by the physical property package in the software. A second computer project involves the determination of adiabatic flame temperature.

The computer projects for the stagewise operations and mass transfer/separations courses involve one or more columns and usually a recycle stream (absorption or liquid extraction followed by desorption or distillation with solvent recycle and with energy recovery). The students can also compare the enthalpy and equilibrium data used in hand calculations with the values estimated by the software.

All of the above objectives have been achieved. The computer projects must be carefully formulated and be appropriate for the level of the course. Adequate assistance must be provided on use of the software. The students like the design and economic aspects of the computer projects.

INTRODUCTION

In the late 1980’s the Department of Chemical Engineering at Michigan Technological University (MTU) developed a policy of using computers and computer software in all undergraduate courses. The implementation of this policy was left to the individual faculty members. Each faculty member of our department took a slightly different approach. My previous uses of computer projects in undergraduate courses involved the development of FORTRAN programs for tasks such as the determination of the adiabatic flame temperature for an assigned compound. In 1990 I was assigned the responsibility of teaching the sophomore mass balance course. By that time, it was obvious that chemical engineers working in industry
did very little computer programming but, instead, used computer software to solve most of their problems. In particular, most chemical processes are designed using Process Flowsheet Simulation Software such as ASPEN or HYSYS/HYSIM. Furthermore, the MTU chemical engineering students use such software in their senior design courses. Finally, Process Flowsheet Simulation Software can be used to illustrate the principles covered in the course and to demonstrate the advantages of using the computer to solve several design cases. For these reasons, I decided that I would use Process Flowsheet Simulation Software in the mass balance course. I continued to use this approach when I was assigned the sophomore energy balance and stagewise operations courses and the junior mass transfer/separations course.

The selection of the particular Process Flowsheet Simulation Software was based on availability on the department’s computer network and, more importantly, on the appropriateness of the software for sophomore and junior students. The software had to be relatively “user friendly,” especially since my objective was not to teach the software but rather to expose the students to the type of software that they would use later in their careers.

Although ASPEN has been available to the chemical engineering students at MTU for several years, even the seniors have difficulty using it. In 1990, the alternative choice was MicroCHESS Process Simulation (by COADE). MicroCHESS was fairly “user friendly” but required a “key disk” in the floppy drive for copyright protection and involved a two-stage procedure to set up a chemical process. Providing access to the “key disk” for a large class of 50 to 100 students can be very cumbersome. The two-stage procedure required an initial data-entry stage followed by the actual run stage. Corrections to incorrect data or changes in data for a new case generally required redoing the entire data entry. Another disadvantage of MicroCHESS was its limited flexibility. All of the inputs to a process unit must be known before the outputs are calculated.

In 1991, the department purchased HYSIM (by Hyprotech Ltd.). HYSIM was upgraded to HYSIM 386 and then, in 1996, to HYSYS. The main advantages of HYSYS/HYSIM are the interactive nature and the ability to determine either input or output quantities for most process units. Some aspects of HYSYS/HYSIM are relatively “user friendly”; other aspects are very intimidating, especially to sophomores and juniors. HYSYS/HYSIM achieves copyright protection by requiring that an electronic security device called a “dongle” be attached to the mouse port. These dongles occasionally disappear from the computer laboratories or malfunction. Fortunately, MTU has a site license for HYSYS that requires only one dongle on the server for the network. However, each non-networked computer requires its own dongle.
OBJECTIVES OF THE COMPUTER PROJECTS

The use of Process Flowsheet Simulation Software was accomplished by assigning one or more computer projects in each course. The objectives of these projects evolved over time into the following:

1. Expose the students to the type of software used for designing chemical processes in industry.
2. Provide the experience of working in a student group.
3. Give the students the opportunity to undergo the “painful” and frustrating experience of learning to use new software.
4. Expose the students to the design of part of a simplified chemical process.
5. Get the students to recognize the value of Process Flowsheet Simulation Software in optimizing a process.
6. Develop an awareness of the role of economics in the design process.
7. Verify the concepts studied in class.

The first objective is the primary objective of the computer projects. The second objective is intended to prepare the students for group work in the senior Unit Operations Laboratory and Plant Design courses and in industry. Initially, group work on the computer projects was just encouraged, but now the students are required to work in groups of three to five students. The students select their own groups, but I help those having difficulty getting into a group. The third objective was not among my original objectives of the computer projects; however, it became apparent to me when I switched to HYSIM that many of the students were becoming frustrated with learning to use the software. I eventually recognized that the students were undergoing an experience that would happen to them many times in their professional careers. I try to explain this to them and to make their experience as smooth as possible. The fourth through sixth objectives are intended to give the students their initial exposure to various aspects of the design process and to make the computer projects more interesting. Naturally, the process and the economics have to be somewhat simplified, especially for the sophomores. The last objective is intended to show the validity of the concepts presented in class and to develop the students’ confidence in the theory and in the results from the software such that one reinforces the other.

THE MASS BALANCE COURSE

The computer project in the sophomore mass balance course involves a chemical reactor with recycle. The chemical reaction is usually one that has been encountered in homework problems. The process normally involves a mixer, a heater, a reactor, a cooler, a simple separator, a tee, and a “recycle” operation. In some cases, the process may also involve the production of the reactants from basic materials such as air, coke, steam, and natural gas. All of the necessary process information and economic data are provided to the students. Appendix A presents a typical computer project for the mass balance course. The students are also given a two-page handout that provides many hints on using the software (Appendix A). Using the handout and the user’s guide, most students are able to master the use of the software.
The students do a base case and two or more other cases for which one or more process parameters are varied. The students then submit a short report. The first page of the report is a summary table that shows the effect of the varied parameter on other process variables and on the cost of the process. This same type of reporting procedure is used in the courses to be discussed later. The amount of time that each student spends on the project usually varies between 5 and 20+ hours with an average of 10 hours per student. The computer projects in the other courses require about the same amount of time per student.

The computer project is handed out shortly after chemical reaction plus recycle problems and Process Flowsheet Simulation Software have been discussed in class. The class discussion and homework problems emphasize the use of the Wegstein algorithm to deal with recycle problems. This is the same approach that MicroCHESS and HYSYS/HYSIM use. The students have applied Wegstein to recycle situations that involve convergence of a single variable (usually flow rate). In doing the computer project, they have the opportunity to observe the use of Wegstein to converge several variables (flow rate, mole fractions, temperature, and pressure).

THE ENERGY BALANCE COURSE

I have taught the sophomore energy balance course only once in recent years. Two computer projects are assigned. The first computer project (Appendix B) involves six energy balance problems from Felder and Rousseau that were previously solved as homework problems. The second computer project involves the adiabatic flame temperature for a combustion process with the air preheated by the combustion gas (Appendix C).

In the first computer project the students are asked to use HYSIM and the PRSV physical property package to solve the six homework problems and to compare the results from HYSIM with the answers they had obtained by hand calculations. In most cases, the error between the HYSIM and homework values is 1% or less. In one case (Process II, Appendix B) the error is approximately 4%. For the problem with an unknown temperature (Process V, Appendix B) the HYSIM value is within 4 °C of the homework value. One objective of this project is to demonstrate to the students the reliability of the PRSV physical property package in estimating enthalpies.

In the second computer project the students pick the fuel compound and then investigate four cases: the base case, which uses 100% conversion of the fuel with a stoichiometric amount of air at 25 °C, and three values of a selected variable (%-excess air, temperature of the air entering the furnace, %-conversion of the fuel, or oxygen content of the combustion “air”). The students use HYSIM to determine the effect of the variable on the adiabatic flame temperature. The students have already done homework problems that require the use of trial and error to determine adiabatic flame temperature. This project also provides additional exposure to simulation of recycle situations.
THE STAGEWISE OPERATIONS COURSE

Two computer projects are assigned in the sophomore stagewise operations course. The first computer project (Appendix D) involves a basic distillation (feed heater, distillation column, overheads condenser, and reboiler). Occasionally, I have used a flash distillation for the first computer project. The second computer project (Appendix E) involves a liquid extraction process followed by a distillation process for solvent recovery. The recovered solvent is recycled back to the extractor. In the past, an absorber rather than an extractor has been used. Both of the projects use the HYSIM Column Operation. Getting the Column Operation to converge can be very frustrating, even for the experienced user. For this reason, the computer projects must be well specified. The students receive a handout on HYSIM similar to the one for the mass balance course. Also, some hints are given on how to make good initial estimates for starting the column operation.

The first computer project is assigned during the third or fourth week of the quarter. The base case coincides with a distillation homework problem that the students solved using the McCabe-Thiele method and plate-by-plate calculations. The students compare their HYSIM results (PRSV physical property package) to the homework results. The results agree very favorably. The students also look at the effect of varying the reflux ratio on the process variables and on the economics of the process.

The second computer project is assigned near the end of the quarter. The process uses water to extract a solute from an organic phase. The aqueous extract is distilled to recover the solute and any dissolved organic solvent; and the recovered organic solvent is recycled back to the extractor. The students determine the effect of the fresh water flow rate on the process variables and on the economics of the process. This project provides additional experience with not only the Column Operation but also the Recycle Operation.

THE MASS TRANSFER/SEPARATIONS COURSE

Two computer projects are assigned in the junior mass transfer/separations course. The first project (Appendix F) is similar to the first computer project in the stagewise operations course except that the bottoms product is used to partially preheat the feed and the students are required to use the HYSIM tray sizing operation to determine the column diameter and the cost of the column. The second project (Appendix G) involves a gas absorber followed by a stripping column for solvent and solute recovery. This project uses packed columns for the absorber and stripper. Both of these projects require more sophisticated use of the HYSIM Column Operation than was encountered in the stagewise operations course. Because even junior students can have difficulty dealing with the Column Operation, the processes must be very carefully specified and hints provided to minimize difficulties in getting the column to converge. Both projects also reintroduce the students to the HYSIM Recycle Operation.

Prior to the assignment of the first computer project, the class discussion and homework have covered a review of the McCabe-Thiele and plate-by-plate methods and the use of the resulting
vapor and liquid flow rates to size sieve plate columns. The computer project requires the students to compare their computer results for the base case to the homework results and to determine the effect of varying the reflux ratio on the other process variables and on the cost of the process.

An earlier version of the first computer project also required the students to compare the y-x equilibrium data and the enthalpy data used by HYSIM to the values used in the homework for the water-acetic acid system. The y-x data compared favorably. The enthalpies did not; the main discrepancy was due to the HYSIM value for the heat of vaporization of acetic acid. This result was used to demonstrate the need to always question computer generated values.

The second computer project is assigned near the end of the quarter. Absorption, desorption, and the design of packed columns have already been discussed in class and the students have done homework on these topics. In addition to using the HYSIM Column and Recycle Operations, the computer project requires the HYSIM Adjust Operation to establish the solvent flow in the absorber (Appendix G). The combination of the Adjust and Recycle Operations can cause convergence problems in the absorber and in the desorber. For this reason, helpful hints are provided to avoid these problems.

After completion of the second computer project, the students have been exposed to most of the useful features of Process Flowsheet Simulation Software. They should be prepared to use Process Flowsheet Simulation Software in the senior design course and in industry.

PROBLEMS ENCOUNTERED

It is possible for students to completely bypass the computer projects. Under my grading policy for undergraduate courses, the computer project grade is combined with the quiz grade (20% computer projects and 80% quiz grade). This combined grade is equivalent to one exam. There are three regular exams and a final exam. The best four out of the five grades are used to determine the student's course grade. Some students, usually only one to three students per quarter, will not do the computer projects and will use the final exam to replace the computer project/quiz grade. These are usually the poorer students with very low quiz grades. They fail to recognize that they are missing out on an opportunity to become familiar with the Process Flowsheet Simulation Software before they take their senior design courses. The overall grading policy has been highly successful. Because the number of students who bypass the computer project is very small, a change in the grading policy is not necessary at this time.

Some students cope very well with the frustrations of learning how to use Process Flowsheet Simulation Software. They jump right in and work their way around any difficulties with the software. Other students become frustrated very easily and come to me for help as soon as they run into a problem. This can be very time consuming for a class of 100 to 130 students. The careful formulation of the computer projects, especially those involving columns, and the HYSYS/HYSIM handouts are two ways of minimizing this. At the beginning and at the end of each class period, I ask for questions on the computer project and bring up common problems
that the students are encountering. At times, the department has had funds available for student computer consultants who would give seminars on HYSIM and provide some assistance in the computer laboratories. All of these activities make it easier for the students to learn how to use the software.

Computer software is constantly being upgraded. In fact, while this paper was being prepared, HYSYS was upgraded from Version 1.0.6 to Version 1.1. Keeping up with these changes can be time consuming and frustrating. It is necessary to modify any handouts on the software and to make modifications in formulating computer projects. During the fall quarter of 1996, HYSIM was replaced by HYSYS on the MTU computer network. Although HYSYS has the same features as HYSIM, the Windows environment and the way of doing things in HYSYS are completely different. I had only about two weeks to master HYSYS and to modify my computer project and HYSYS handout for the mass balance course. As a result, the computer project was handed out later than usual. Surprisingly, the number of students coming to me with questions was much smaller than normal; probably because HYSYS is a little more “user friendly” than HYSIM.

Many students stop thinking the minute they start using a computer. For example, a few years ago I gave a very open-ended design of a process similar to the one in Appendix G. The students were asked to run a base case and then make modifications to the process to improve it. Several students improved the separation in a distillation column by using a high pressure at the top of the column and a low pressure in the reboiler. They did not stop to think that the vapor would not be able to flow from the reboiler to the top of the column. Other students used the heat from the overheads condenser to heat the reboiler. They did not recognize that this violates the second law of thermodynamics. Unfortunately, HYSIM allowed both of these changes to be made.

RESULTS

The objectives listed at the beginning of this paper have been achieved. The students respond very favorably to the design and economic aspects of the computer projects. Most student groups function very well, probably because the students put together their own groups. Occasionally, I will receive a complaint about a student not contributing to the group effort but the number of these complaints is minimal. Although the students do find some aspects of learning HYSYS/HYSIM to be “painful” and frustrating, they are able to complete the computer projects. The HYSYS/HYSIM handouts, the carefully formulated assignments, and assistance from computer consultants and from me help to ease the pain. Furthermore, working in groups also makes it possible for the students to help each other with problems in learning how to use the software. Finally, the computer projects help to reinforce the material covered in class.

As mentioned earlier, most of the computer projects have an economic aspect to them. Usually one of the final results is the effect of some variable on the total cost of the process and on the cost per unit amount of some product. This makes the projects more interesting to sophomore and junior students.
CONCLUSIONS AND RECOMMENDATIONS

Process Flowsheet Simulation Software can be used effectively in sophomore and junior chemical engineering courses provided that the computer projects based on the software are carefully formulated and are appropriate for the level of the class. Such software can also be used to reinforce the material covered in class and to expose the students to the design of chemical processes. Although the computer projects can be made more open-ended and allow the students to explore the effects of several variables, this must be done very carefully so that the students are not overwhelmed. The problems that the students encounter in learning how to use the software can be minimized by providing handouts on the highlights of using the software and by having someone (faculty or student consultants) available to answer questions.

The approach presented here should work for any Process Flowsheet Simulation Software, not only HYSYS/HYSIM and MicroCHESS.

Sophomore and junior chemical engineering students enjoy computer design problems, especially if there is an economic aspect to them.
OBJECTIVE: To simulate a chemical process using the HYSYS Process Flowsheet Simulation Software.

PROCESS DESCRIPTION: The process involves an ammonia plant. The feed consists of nitrogen, hydrogen, and argon. The nitrogen and hydrogen react to produce ammonia. The ammonia is recovered from the exit gas from the reactor, a portion of the remaining gas is purged to remove the argon, and the rest is recycled. The process flow diagram is shown below:

```
Feed------>Mixer------>Heater------>Reactor------>Cooler
|        |
|--<<--Recycle|--<<--Tee|--<<--Component Splitter
|
|      |        |        | Splitter |
|
| Purge                  |Product |
V                      V
```

Chemical Reaction

\[ \text{N}_2 + 3 \text{H}_2 \rightarrow 2 \text{NH}_3 \]

PROJECT DESCRIPTION: Each group will do the base case and two other cases in order to determine the effect of simultaneously varying the purge rate and the single pass conversion in the reactor on the amount of NH₃ produced (lb/yr), the amount of hydrogen lost in the purge (lb/yr), the %-conversion for the overall process, the flow rate (lbmol/h) of the recycle stream, the mol-% Argon in the purge stream, and the net cost of the process ($/yr and $/lb of NH₃).

From three to five students will work together as a group. GROUP WORK IS REQUIRED!! Each group will submit only one report.

REPORT CONTENTS: COVER PAGE, SAMPLE CALCULATIONS, FLOW DIAGRAM, COMPUTER OUTPUT

COVER PAGE: The cover page should be a summary page containing:

1. Names of those who worked on the project.
2. The parameter that was varied.
3. A table summarizing the results for the three cases (arranged from high to low or low to high). Note that many of these will have to be hand calculated from the HYSYS computer output.
4. An estimate of the total number of hours spent on the project.
SAMPLE CALCULATIONS: A sample calculation of all quantities not calculated by HYSYS must be given.

FLOW DIAGRAM: A labeled flow diagram showing stream names and process unit names is required.

COMPUTER OUTPUT: HYSYS stream data (obtained by printing from WORKBOOK) and Full Stream Specsheets for the Feed, for the Product, and for the streams in and out of the Recycle Operation (obtained by printing from Report Builder).

DEADLINE: For those who want to know their course grade prior to the final exam, the deadline is 5:00 p.m., Wednesday, November 13, 1996. The absolute deadline is 9:00 a.m., Thursday, November 21, 1996.

PROCESS SPECIFICATIONS

Feed: 1000 lbmol/h, 24.75 mol-% N₂, 74.25 mol-% H₂, 1 mol-% Ar, 0 mol-% NH₃, 70 °F, 1500 psia.

Purge Stream: 80 lbmol/h (base case), 50 lbmol/h, and 100 lbmol/h.

Heater: Exit Temperature = 500 °F, Pressure Drop = 0.

Reactor: Use HYSYS Separator. Energy Flow = 0, Vapor Valve = 100% open, Liquid Valve - Set Point = 0%, Liquid Rate = 0, Pressure Drop = 0.

Conversion of N₂ = 25% (base case), 15%, and 30%.

Cooler: Exit Temperature = 70 °F, Pressure Drop = 0.

Component Splitter: Overheads & Bottoms leave at 70 °F, 1500 psia, Fraction to Ovhd: N₂, H₂, Ar = 1, NH₃ = 0.

Recycle: Set the maximum number of iterations to 100, the Wegstein Count to 1, all "tolerances" to 0.001. Assume a temperature, pressure, flow rate, and composition for the stream out of the Recycle Operation.

ECONOMIC DATA

Raw Materials Costs: Feed - $0.02/lb

Energy Costs:
  Heating - $7/1x10⁶ BTU
  Cooling (Reactor and Cooler) - $0.50/1x10⁶ BTU
  Ignore the energy cost for the Component Splitter
Capital Investment: Reactor - $10.00/1000 lb mol feed into the reactor
1. Starting HYSYS:
   a. Use a PC (Rm B006) with WINDOWS NT.
   b. Hit "ctrl-alt-del" to start WINDOWS NT.
   c. Click on the "HYSYS" icon (it may be partially covered by another).

2. Entering PREFERENCES:
   a. Click on "TOOLS" and select "PREFERENCES".
   b. Click on the "UNITS" tab and select "FIELD UNITS".
   c. Click on the "FILES" tab, then click on the "CASES" box, and then enter the Drive:/Directory for storing your HYSYS files.
   d. Click on the "SIMULATION" tab and select either "WORKBOOK" or "PFD" (Process Flow Diagram) for building your process.
   e. Click on "CLOSE".

3. Entering COMPOUNDS and REACTIONS:
   a. Click on "SIMULATION BASIS MANAGER".
   b. Click on the "FLUID PACKAGE" tab, click on "ADD" and then select "PRSV" in the dialog box (use arrows to move up and down).
   c. Click on the "COMPONENTS" tab and select your compounds (can either type them in the dialog box or select from the compound list).
   d. Click on the "REACTIONS" tab, select "ADD REACTIONS", "CONVERSION", "ADD REACTION".
   e. Then click on the "STOICHIOMETRY" tab, click on the dialog box, enter the compounds involved in your reaction, click on the boxes for the "COEFFICIENTS" and type in the stoichiometric coefficient for each compound [POSITIVE(+) for PRODUCTS, NEGATIVE(-) for REACTANTS].
   f. Click on the "BASIS" tab and type in the basis compound for %-Conversion (N₂ or H₂) and type in the %-Conversion.
   g. Close all windows until you see a button for "ENTER MAIN BUILD ENVIRONMENT".

4. Entering STREAM DATA from "WORKBOOK":
   a. To enter data in a particular box, click on that box.
   b. Enter stream name(s) in the top box(es) - the names of all streams can also be entered at the appropriate places when entering OPERATION information.
   c. Enter temperature, pressure, and molar flow rates for the appropriate streams - DO NOT OVER SPECIFY the process, i.e. only enter the values specified in the assignment.
   d. To enter compositions, "DOUBLE CLICK" on the molar flow rate box of the desired stream, enter the mole fractions for each compound, click on "NORMALIZE", and then "OK".

5. Entering OPERATIONS:
a. From "WORKBOOK"-Click on the appropriate operation icon and then the "+" icon; if an operation has already been entered and you want to modify it, click on one of the associated streams and then click on the name of the desired operation (lower left).
b. Click on "FLOWSHEET" and select either "ADD OPERATION" to add a new operation or "FIND OBJECT" to modify an existing OPERATION (or STREAM).

6. The OPERATIONS Windows:
   a. There will be a "CONNECTIONS" tab for entering the names of inlet and outlet streams (including energy streams). Clicking on the dialog boxes will allow you to type in the stream name or select from streams that have already been named.
   b. There will be a "PARAMETERS" tab that can be used to enter other pertinent information.
   c. There may be other tabs for certain OPERATIONS.

   USING HYSYS, p.2

6. The OPERATIONS Windows:
   a. There will be a "CONNECTIONS" tab for entering the names of inlet and outlet streams (including energy streams). Clicking on the dialog boxes will allow you to type in the stream name or select from streams that have already been named.
   b. There will be a "PARAMETERS" tab that can be used to enter other pertinent information.
   c. There may be other tabs for certain OPERATIONS.

   USING HYSYS, p.2

d. There will be "right" and "left" arrows to the lower left that can be used to view all of the tabs.

e. Select "CLOSE" when all of the information has been entered.

7. Comments on Specific HYSYS OPERATIONS:
   a. "MIXER" - "PARAMETERS" tab: select "Set Unknown to Lowest Known".
   b. "HEATER" or "COOLER" - "PARAMETERS" tab: set pressure drop to zero.
   c. "SEPARATOR" (Used as a Reactor):
      I. "CONNECTIONS" tab: give a dummy name to the exit liquid.
      II. "PARAMETERS" tab: set pressure drop and duty to zero.
      III. "REACTIONS" tab: select "Global Reaction Set".
      IV. "VAPOR VALVE" tab: set valve opening to 100%.
      V. "LIQUID VALVE" tab: select "Molar Flow Rate" and set liquid flow rate to zero.
   d. "COMPONENT SPLITTER":
      I. "PARAMETERS" tab: set vapor fraction of Overheads to 1.0 and vapor fraction of Bottoms to 0.0.
      II. "SPLIT" tab: set the fractions to overheads (stream to TEE).
   e. "RECYCLE":
      I. "PARAMETERS" tab: set the Tolerances
      II. "NUMERICAL" tab: set the Maximum Number of Iterations and the Wegstein Count.
      III. "CONVERGENCE" tab: observe the convergence. After convergence the word "Converged" highlighted in Green will appear; prior to this, you will see "Unconverged" highlighted in Red. If you are in WORKBOOK when the RECYCLE Operation is initiated, you can go into the RECYCLE Operation and follow the convergence.

   USING HYSYS, p.3

8. PRINT your Results:
   a. Stream Summary - Click on "FILE" and "PRINT" while in WORKBOOK.
   b. Process Flow Diagram - Click on "FILE" and "PRINT" while in PFD.
   c. To switch between WORKBOOK and PFD - Click on "TOOLS".
   d. To build and print a Report on individual streams and operations:
      I. Click on "TOOLS" and select "REPORTS".
      II. Click on "CREATE", then "INSERT SPECSHEET".
      III. Select "STREAMS", then the desired Stream Name(s), "FULL STREAM SPECSHEET", and then "ADD".

   USING HYSYS, p.3
IV. Select "OPERATIONS", then the desired Operation(s), "FULL SPECSHEET", and then "ADD".

V. Click on "PAGE SETUP", "REMOVE LINE NUMBERS", and "DONE".

VI. Click on "PRINT". NOTE: It may take a while to print your REPORT.

9. MISCELLANEOUS:
   a. To save your file - Click on "FILE" and select "SAVE AS..".
   b. To modify the Reaction Package or modify the Fluid Package - Click on "FLOWSHEET" and select the desired option.
   c. To load an existing HYSYS case - Click on the "Open Folder" button.
   d. To start on a new HYSYS case - Click on the "Manuscript" button.
APPENDIX B
CM205
COMPUTER PROJECT I

OBJECTIVE: To use the HYSIM Process Flowsheet Simulation Software to solve the energy balances for various homework problems and to compare the results from HYSIM to those from hand calculations.

PROCESS DESCRIPTIONS: The flow diagrams for the six processes are shown on the next page.

DEADLINE: The solution must be submitted by 5:00 p.m., Tuesday, April 23, 1996.

PROJECT DESCRIPTION: Have HYSIM determine the quantities indicated by (?) on the flow diagrams and compare these to the values determined in the homework. For temperatures use \((\text{HYSIM-HOMEWORK}) \, ^\circ\text{C}\) to determine the error. For all other quantities, use \((\text{HYSIM-HOMEWORK}) \times 100 / \text{HOMEWORK}\) to determine the %-error.

All students must work in a group (three to five students per group). Each group will submit only one report.

REPORT CONTENTS: COVER PAGE, SAMPLE CALCULATIONS, FLOW DIAGRAM, COMPUTER OUTPUT

COVER PAGE: The cover page should be a summary page containing:
1. Names of those who worked on the project.
2. A tabulation that summarizes the results for the six processes (HYSIM VALUE, HOMEWORK VALUE, and ERROR) for each quantity indicated with a (?) on the flow diagram.
3. An estimate of the total number of hours spent on the project.

SAMPLE CALCULATIONS: A sample calculation for any HYSIM value that had to be calculated from the HYSIM output.

FLOW DIAGRAM: A labeled flow diagram showing HYSIM stream names and process unit names is required.

COMPUTER OUTPUT: HYSIM stream data and unit operation data for all six processes.

PROCESS I (Problem #8.4(d), F&R, p. 391):

\[ Q_1 = ? \]

\[ \begin{align*}
\text{Benzene} & \quad \rightarrow \quad \text{Heater} \\
100 \, ^\circ\text{C}, 101.325 \, \text{kPa} & \quad \rightarrow \quad 300 \, ^\circ\text{C}, 101.325 \, \text{kPa}
\end{align*} \]

PROCESS II (Problem #8.4(f), F&R, p. 391):

\[ Q_2 = ? \]

\[ \begin{align*}
\text{Benzene} & \quad \rightarrow \quad \text{Heater} \\
25 \, ^\circ\text{C}, 101.325 \, \text{kPa} & \quad \rightarrow \quad 75 \, ^\circ\text{C}, 101.325 \, \text{kPa}
\end{align*} \]
PROCESS III (Problem #8.41, F&R, p. 396):

1 kmole/h
Benzene}--------------------->| Cooler |-------------------->
538 ºC, 101.325 kPa | 24 ºC, 101.325 kPa

PROCESS IV (Problem #8.40, F&R, p. 396):

1 kg/h
Water}----------------------->| Heater |-------------------->
25 ºC, Sat'd Liq | 25 ºC, Sat'd Vapor

PROCESS V (Problem #8.34, F&R, p. 395):

520 kg/h
NH₃}---------------------->| Mixer |-------| Heater |---> O₂ -18.9
25 ºC, 101.325 kPa | NH₃-10.0
Mol-% | N₂ -71.1
O₂-21 | 101.325 kPa
N₂-79 | Tₚ=? 600 ºC

PROCESS VI (Problem #8.56, F&R, p. 399):

Ovhds
Benzene-50 | 150 ºC | Toluene-?
Mol-% 1000 kg/h | 420 kPa
Benzene-50 | 60 ºC | Toluene-?
Fractionate Sat'd Vap | Bottoms Toluene-?
(60% of Benzene to Ovhds, 35.055% of Toluene to Ovhds) 150 ºC Sat'd Liq
OBJECTIVE: To use the HYSIM Process Flowsheet Simulation Software to study the adiabatic flame temperature of a combustion process.

PROCESS DESCRIPTIONS: The flow diagrams for the process is shown below:

```
Fuel ------|       |      |         | Hot
|       |      |         | Flue Gas
Cold                Hot    | Mixer |----->| Furnace |---------> |
Mol-% Air ________ Air   |       |      |         |          |
O2-21 ----->2 |         |----->|       |      |         |          |
N2-79          |   Air   |      |_______|      |_________|          |2               |Preheater|                                          |
|         |                                          |
Cold <------[_________]<----------------------------------------- |
Flue Gas
```

DEADLINE: The solution must be submitted by 5:00 p.m., Wednesday, May 15, 1996.

PROJECT DESCRIPTION: Have HYSIM determine the temperature of the hot flue gas leaving the furnace for the base case and for three values of a variable. Each group can select its own fuel.

All students must work in a group (three to five students per group). Each group will submit only one report.

REPORT CONTENTS: COVER PAGE, SAMPLE CALCULATIONS, FLOW DIAGRAM, COMPUTER OUTPUT

COVER PAGE: The cover page should be a summary page containing:

1. Names of those who worked on the project.
2. The fuel used.
3. A tabulation that summarizes the results for the effect of the variable on the temperature of the hot flue gas leaving the furnace.
4. An estimate of the total number of hours spent on the project.

SAMPLE CALCULATIONS: A sample calculation of the amount of air required for each run.

FLOW DIAGRAM: A labeled flow diagram showing HYSIM stream names and process unit names is required.

COMPUTER OUTPUT: HYSIM stream data and unit operation data for each value of the variable.
PROCESS DESCRIPTION:

Fuel: 25 °C, 101.325 kPa, 1000 kmol/h

Cold Air: 25 °C, 101.325 kPa, 0% Excess (base case)

Hot Air: 25 °C (base case), 101.325 kPa

Air Preheater: HYSIM "Heat Exchanger", all pressure drops = 0.

Furnace: HYSIM Reactor (Stoichiometric), 100% Conversion (base case), all carbon goes to CO₂ (base case), Enthalpy of Energy Stream = 0, pressure drop = 0. Note that the stoichiometric coefficients are positive for products and negative for reactants.

VARIABLES: Select one of the following variables:

1. %-Excess Air (10, 20, 30)
2. Hot Air Temperature (100, 200, 300 °C)
3. %-Conversion of Fuel (95, 90, 85)
4. Composition of Air (10 mol-% O₂, 40 mol-% O₂, 100 mol-% O₂)*

* The balance is N₂.
OBJECTIVES: To use the HYSIM Process Flowsheet Simulation Software to simulate a continuous distillation process consisting of a distillation column, a feed preheater, an overheads condenser, and a reboiler.

PROCESS DESCRIPTION:

```
Steam --------> | Cooler | Condensate
 Sat'd Vap. | 90 psia | Sat'd Liq. | 90 psia

Water In | Water Out
T=90°F | T=110°F
14.7 psia | 14.7 psia

Overheads
QF

Cold Feed
F=1000 lbmol/h
v

Preheater

Feed
Hot Feed

x_F=0.6 (H2O)
1-x_F=0.4 (HAc)
T_f=70°F
P=14.7 psia

Overheads Vapor Flow Rate - 0.00
Overheads Liquid Flow Rate - 625 lbmol/h
Reflux Ratio - 2.62 (base case), 2.30, 2.00, 1.60

Bottoms
QR

Steam --------> | Cooler | Condensate
 Sat'd Vap. | 90 psia | Sat'd Liq. | 90 psia
```

NOTE: A liquid at its bubble point (saturated liquid) is indicated in HYSIM by specifying zero (0) for the vapor fraction. A vapor at its dew point (saturated vapor) is indicated in HYSIM by specifying one (1) for the vapor fraction.

PROCESS DATA:
- Distillation column
  - 14 ideal stages (includes overheads condenser and reboiler)
  - Feed plate - 6th stage
  - Overheads vapor flow rate - 0.00
  - Overheads liquid flow rate - 625 lbmol/h
  - Reflux ratio - 2.62 (base case), 2.30, 2.00, 1.60
- Economic Data
  - Cost of Steam - $7/1000 lb (includes cost of reboiler & prehtr)
  - Cost of Cooling Water - $0.25/1000 gal (includes cost of cond’r)
  - Cost of Column - $100,000 (Spread this over three years)
PROJECT DESCRIPTION:
For each reflux ratio determine:
   The composition of the overheads and bottoms products
   The heat duties (BTU/h) for the feed preheater, for the overheads condenser, and for the reboiler
   The steam required (lb/h) for the feed preheater and for the reboiler
   The amount of cooling water (lb/h) required for the overheads condenser
   The liquid and vapor flow rates just above the feed plate and just above the reboiler
   %-Recovery of Acetic Acid in Bottoms Product
   Total Annual Cost of the process ($/yr)
   Total Cost per Pound of Acetic Acid in the Bottoms Product

Compare the HYSIM values for the base case to the values determined in the Homework for Week #2. Calculate a per cent error based on the homework values.

The first page of the submitted solution should contain the names of the group members, a summary table showing the effect of reflux ratio on the above quantities and a comparison of the HYSIM values and the homework values.

The second page should be sample calculations for the %-Recovery, Total Annual Cost, and Cost per pound of HAc.

The next page should be a labeled flowsheet.

Subsequent pages will be properly labeled and identified computer output: stream data, unit operations information, and pertinent output from COLUMN for the distillation (input data, tray data for temperature, liquid and vapor flow rates, and composition - obtained by printing INPUT, STAGES and COMPOSITIONS from the COLUMN Operation).

Students must work together in groups of 2-4 students per group. Submit only one solution per group.

DEADLINE: The solution must be submitted by 5:00 p.m., Wednesday, April 19, 1995.

HYSIM SPECIFICATIONS:
PHYSICAL PROPERTIES PACKAGE: Select PR_Options then PRSV (Peng-Robinson-Stryjek).

HEATERS: HYSIM "COOLER/HEATER" Operation in the Heater Mode.

COOLERS: HYSIM "COOLER/HEATER" Operation in the Cooler Mode.

DISTILLATION: HYSIM "COLUMN" Operation in the Distillation Mode. Condenser acts as a total condenser (no vapor overheads product).
OBJECTIVE: To use the HYSIM Process Flowsheet Simulation Software to simulate transfer of a solute from an organic solvent to liquid water in a liquid-liquid extraction column followed by recovery of the solute and organic solvent in a distillation column.

PROCESS DESCRIPTION: The process will have the basic flowsheet shown below. Solute (Acetic Acid) is removed from an organic liquid solvent (Diethyl Ether) by transfer to liquid water. The exit organic goes to storage. The exit water from the extractor is fed into a distillation column (reboiled absorber) for recovery of solute and organic solvent. The organic solvent is recovered in the overheads product, cooled, mixed with the fresh organic, and fed back to the extractor. The solute is recovered in the bottoms product, cooled, and sent to storage.

PROJECT DESCRIPTION: Each group (2-4 students) will determine the effect of the fresh water flow rate to the extractor on the amount (lbmol/h) and composition (Mol-%) of the exit organic produced; the amount (lbmol/h) and composition (Mol-%) of the solute product; the amount of heat required (BTU/h) for the reboiler; the cooling required (BTU/h) for the organic cooler and for the solute cooler; the cost of the process ($/yr and $/lb of HAc recovered in the solute product).

The first page of the submitted solution must contain a list of the names of the group members and a table summarizing the effect of the variable on the preceding quantities. The following page will be a sample calculation of the quantities not calculated by HYSIM. The next page must be a labeled flowsheet. Subsequent pages will be properly identified computer output: stream data, unit operations information, and pertinent output from COLUMN for the extractor and for the distillation (obtained by printing INPUT, STAGES and COMPOSITIONS from the COLUMN Operation).
DEADLINE: The solution must be submitted by 9:00 a.m., Thursday, May 11, 1995 for those who want to know their course letter grade by Friday, May 12; otherwise, it is due at 5:00 p.m., Wednesday, May 17, 1995.

PROCESS SPECIFICATIONS:
PHYSICAL PROPERTIES PACKAGE: Select Activity_Models, then UNIQUAC, then Peng_Robinson. After selecting your compounds, select "L" (UnifacLLE) for the interaction parameters and then hit "Ins".

PRESSURES: 14.7 psia everywhere.

FRESH ORGANIC: Flow Rate = 143 lbmol/h; 30 mol-% Acetic Acid, 70 mol-% Diethyl Ether; 77 °F.

FRESH WATER TO THE EXTRACTOR: Rate = 833; 555 (Base Case); 278 lbmol/h; pure water; 77 °F.

ORGANIC COOLER and SOLUTE COOLER: Use the HYSIM "COOLER/HEATER" Operation. The exit streams from each of these will be at 77 °F.

RECYCLE: Use the HYSIM "RECYCLE" Operation. Change the number of iterations to 50, the Wegstein Count to 1, and all of the sensitivities to 1. To get the Process started specify the exit stream as diethyl ether at 77 °F, 14.7 psia and a flow rate of 0.

EXTRACTOR: HYSIM "COLUMN" Operation in the Extraction Mode; 5 Stages; Water enters at the top, Organic enters at the bottom. Use the flow rate of fresh organic to estimate the exit organic flow rate.

DISTILLATION: HYSIM "COLUMN" Operation in the Reboiled Absorber Mode; 15 Stages with the feed entering on the 1st Stage.
   Estimated values - Overhead Vapor Flow: Use the flow of ether in feed;
      Top: 77 °F; Bottoms: 212 °F
   Use the CHANGE - SPECIFICATIONS - FRACTIONS commands to specify a diethyl ether mole fraction of 0.00001 in the liquid from Stage 15 (reboiler) to replace the specified overheads vapor rate. Do not specify anything in WORKSHEET for the overheads product nor for the bottoms product.

ECONOMIC DATA - Heating: $7/million BTU (includes cost of Reboiler).
Cooling: $1/million BTU (includes cost of cooler)
Extractor: $150,000 (spread over 3 years)
Reboiled Absorber: $450,000 (spread over 3 years)

RECOMMENDED PROCEDURE FOR BUILDING THE FLOWSHEET:
1. Install the RECYCLE, MIXER and their associated streams. Including the stream out of the RECYCLE (and assumed values).
2. Install the EXTRACTOR and its associated streams.
3. Install the REBOILED ABSORBER, ORGANIC COOLER, and their associated streams. (This should close the loop for the RECYCLE Operation).
4. Install the SOLUTE COOLER.
OBJECTIVE: To simulate an ethanol-water distillation process using the HYSIM Process Flowsheet Simulation Software.

PROCESS DESCRIPTION: The process will have the basic flowsheet shown below. The feed solution is partially heated by the bottoms product in a heat recovery exchanger and then heated in a final feed heater before the feed enters a distillation column equipped with a reboiler and total overheads condenser. The process will operate 24 hours/day, 350 days/year.

PROJECT DESCRIPTION:
1. For the base case (see the process specifications on the next page) use HYSIM to determine: the mol-% ethanol in the overheads product and in the bottoms product, the amount of heat required for the final feed heater (BTU/h), the amount of heat required for the reboiler (BTU/h), the heat removed in the overheads condenser (BTU/h), the amount of heat removed in the overheads cooler, the maximum vapor and liquid flow rates in the rectifying section and in the stripping section of the distillation column, and the required column diameter. Where possible, compare to the results from the homework problems.
2. Do two additional HYSIM runs by varying the reflux ratio in the distillation column (see the process specifications on the next page) and compare the results to the base case.
3. Determine the amount of ethanol that is recovered in the overheads product (lb/yr) and the total cost ($/yr and $/liquid gallon of ethanol in the overheads) for each case.

NOTE: Assume a specific gravity of 0.8 for liquid ethanol.

Up to four students can work together as a group. Each group submits only one solution. The first page of the submitted solution should contain the names of the group members, and a table summarizing Parts 1 through 3 (put the base case in the middle to make it easy for the reader to observe trends). The second page should be a sample calculation for the base case for any quantity not calculated by HYSIM. The fourth page should be a labeled flowsheet. Subsequent pages will be the computer output for each run: stream data, unit operations information, and pertinent output from COLUMN for the distillation column (reflux ratio, tray data for temperature, liquid and vapor flow rates, composition, and a detailed summary of the sieve tray column design - obtained by printing INPUT, STAGES, COMPOSITIONS and SIZE-PRINT-DETAILED_SUMMARY from the COLUMN Operation).

DEADLINE: The solution must be submitted by 5:00 p.m., Wednesday, February 1, 1995.
PROCESS SPECIFICATIONS:

PHYSICAL PROPERTIES PACKAGE: Select PR_Options then PRSV (Peng-Robinson-Stryjek-Vera).

HEAT RECOVERY EXCHANGER: HYSIM "HEAT EXCHANGER" Operation. Specify zero pressure drop for both fluids.

FINAL FEED HEATER: HYSIM "COOLER/HEATER" Operation in the Heater Mode. Specify zero pressure drop.

OVHDS COOLER: HYSIM "COOLER/HEATER" Operation in the Cooler Mode. Specify zero pressure drop.

DISTILLATION: HYSIM "COLUMN" Operation in the Distillation Mode. Use the side liquid stream from the overheads condenser as the overheads product (no vapor overheads product). HYSIM will calculate the temperature, pressure, composition, and flow rate of the overheads and bottoms products.

Number of Ideal Stages = 17*  
Pressure = 14.7 psia  
Feed Stage = 15  
Reflux Ratio =1.84**,1.0,3.0  
Vapor from Stage 1 = 0  
Overheads Product = 570 lbmol/h  
Temperature (Stage 1) = 170 °F  
Temperature (Bottom)= 207 °F  
Type of Trays = Sieve Trays***  
Tray Spacing = 18 in***  
Weir Height = 1.5 in***  
No. of Flow Paths = 1***  
Hole Size = 1/8 in***  
Hole Spacing = 3/8 in***

* Includes overheads condenser and reboiler  
** Base Case Value. Use the "CHANGE" - "SPECIFICATIONS" Commands to change this.  
*** Implemented via the COLUMN Operation after the column has run and converged. Select "SIZE" and then "AUTO_SECTION". Go with the HYSIM default values for all other quantities.

RECYCLE: Set Max Iterations to 50, Wegstein Count to 1, and all of the Sensitivities to 0.001. To get the RECYCLE Operation started use saturated liquid, 14.7 psia, 0 mol-% ethanol and some arbitrary flow rate for the stream leaving the RECYCLE Operation.

COLD FEED: Flow Rate = 5000 lbmol/h, Temperature = 70 °F, Pressure = 14.7 psia, 10 mol-% ethanol

HOT FEED: Saturated liquid (vapor fraction=0.0).

COLD BOTTOMS: Temperature = 90 °F.

COLD OVHDS: Temperature = 90 °F.

COST DATA: Heating (Reboiler and Feed Heater): $7 per million BTU  
(Includes cost of steam plus ht. transfer equipment)  
Cooling (Ovhds Condenser and Ovhds Cooler): $1 per 10⁶ BTU  
(Includes cost of cooling water plus ht. transfer equip.)  
Column: See HYSIM Detailed Design Summary for the Sieve Tray Column (Spread this over three years).  
Bottoms Product: $0.05 per lbmol Ethanol (disposal cost)  
Feed: $2.00 per lbmol Ethanol
OBJECTIVE: To use the HYSIM Process Flowsheet Simulation Software to simulate a natural gas desulfurization process with solvent recovery.

PROCESS DESCRIPTION: The process will have the basic flowsheet shown below. Solute (H₂S) is removed from a contaminated natural gas (CH₄) stream by absorption in a liquid solvent (Monoethanol Amine or MEA). The clean gas is discharged from the process. The spent solvent from the absorber is heated in an energy recovery heat exchanger before being fed into a reboiled absorption column for solute and solvent recovery. The gaseous solute is recovered in the overheads vapor stream, compressed and then liquefied in a cooler. The solvent is recovered in the bottoms product, cooled in the energy recovery unit, cooled further in a solvent cooler, mixed with make-up solvent, and fed back to the absorber.
PROJECT DESCRIPTION: Each student (group) will simulate the base case for the process and will investigate the impact of varying the solute concentration (two additional values) in the exit fuel gas on: amount of solvent circulated, fuel and solvent losses, energy and cooling requirements, required size for the absorber and desorber, and cost of the process.

The first page of the submitted solution must be a table summarizing the comparison of the three cases: solvent rate to the absorber (lbmol/h), make-up solvent required (lb/h), methane lost (lbmol/h), heat required for the reboiler (BTU/h), total cooling required for the solvent cooler and product cooler (BTU/h), total electrical power required for the pump and compressor (kW), diameter and height (ft) of the absorber and of the desorber, cost of the process ($/yr and $/1000 cubic feet of exit fuel gas). The second page should contain any sample calculations required to substantiate the summary information. The next page must be a labeled flowsheet. Subsequent pages will be the computer output required to substantiate the summary information.

Up to four students can work together as a group. Submit the names of the group members along with one solution.

DEADLINE: The solution must be submitted by 9:00 a.m., Thursday, February 16, 1995 for those who wish to know their course grade by Friday; otherwise, it is due at 9:00 a.m., Wednesday, February 22, 1995.

PROCESS SPECIFICATIONS:

COMPONENTS: Methane (CH₄), Hydrogen Sulfide (H₂S) and Monoethanolamine (MEA).

PHYSICAL PROPERTIES PACKAGE: Select PR_Options (Peng-Robinson) and then PRSV (Peng-Robinson-Stryjek-Vera)

TEMPERATURES: Inlet fuel gas, make-up solvent, and cold recycled solvent are at 70 °F; solute product is at 100 °F.

PRESSURES: Inlet fuel gas, make-up solvent and hot recycled solvent are at 30 psia; the final solute product is at 4000 psia. Use zero pressure drop in all heat exchangers.

CONTAMINATED FUEL GAS IN: 99 mol-% methane, 1 mol-% H₂S, 2000 lbmol/h.

EXIT FUEL GAS: Mole Fraction H₂S = 0.0001, 0.0002 (base case), 0.0003 - use the ADJUST operation to obtain these.

MAKE-UP SOLVENT: Pure liquid solvent at 70 °F and 30 psia.

FRESH SOLVENT TO THE ABSORBER: Use the HYSIM "ADJUST" Operation to obtain the flow rate required to achieve the desired H₂S concentration in the exit fuel gas.
ABSORBER: HYSIM "COLUMN" Operation in the Absorber Mode - 20 ideal stages, packed with 1 1/2" plastic Pall Rings), design for 50% of flooding, 30 psia. Use 70 °F for temperature estimates and the methane flow rate in the fuel gas for a vapor flow estimate.

ADJUST: Tolerance: 0.00001; Step Size: 5000 lbmol/h; Minimum: 3000 lbmol/h; Maximum: 200000 lbmol/h. Use a flow rate of 10000 lbmol/h for the flow rate of fresh solvent to get the adjust operation started.

SOLVENT COOLER: HYSIM "COOLER/HEATER".

RECOVERY HEAT EXCHANGER: Cooled solvent leaves at 90 °F; temperature of heated solvent will be determined by HYSIM.

RECYCLE: Use the HYSIM Recycle Operation. Change the number of iterations to 50, the Wegstein Count to 1, and all of the sensitivities to 0.1. To get the Recycle Operation started, assume pure MEA at its bubble point (vapor fraction = 0.0) at 30 psia and use the flow rate of fresh solvent into the absorber.

REBOILED ABSORBER (DESORBER): HYSIM "COLUMN" Operation in the Reboiled Absorber Mode - 20 ideal stages (includes reboiler), packed with 2" metal Raschig Rings, design for 50% of flooding, 15 psia. Use the vapor stream from the top plate as the overheads product. Liquid feed enters on the top plate. Use the feed temperature for temperature estimates, and the methane plus H₂S in the feed for a vapor flow estimate.

Use the CHANGE - SPECIFICATIONS command to specify an H₂S recovery of 0.99 in the vapor from plate 1.

PUMP: Discharge pressure will be 30 psia.

SOLUTE COMPRESSOR: Discharge pressure will be 4000 psia.

PRODUCT COOLER: HYSIM "COOLER/HEATER".

RECOMMENDED PROCEDURE FOR BUILDING THE FLOWSHEET:

1. Install the ABSORBER and its associated streams. Then install the ADJUST operation. Assume pure solvent and a flow rate of 10000 lbmol/h for the fresh solvent stream to get the ADJUST started.
2. Install the RECOVERY HEAT EXCHANGER, the SOLVENT COOLER, and their associated streams including the stream out of the RECYCLE operation.
3. Install the REBOILED ABSORBER and its associated streams.
4. Install the PUMP, RECYCLE Operation and the MIXER. Be sure to remove the composition and temperature specifications on the Fresh Solvent to the ABSORBER.
5. Install the COMPRESSOR and SOLUTE COOLER.
6. Use the "SIZE" command for each column to get the diameter, height, and cost.
COST DATA:

Heating (Reboiler): $7 per million BTU
   (Includes cost of steam plus heat transfer equipment)

Cooling (Solvent and Product Coolers): $1 per million BTU
   (Includes cost of cooling water plus heat transfer equip.)

Electrical Power (Pump and Compressor): $0.08/kwh
   (Includes cost of electricity plus the cost of the pump and compressor)

Column: See HYSIM Detailed Design Summary for the Packed Columns
   (Spread this over three years).

Make-Up Solvent: $0.25/lb MEA

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REFERENCES


BIOGRAPHICAL INFORMATION

ANTON J. PINTAR
Associate Professor of Chemical Engineering, Michigan Technological University (1966-
Present); BS in ChemE from Michigan Tech (1962); PhD in ChemE from Illinois Institute of
Technology (1968). Received the Michigan Tech Distinguished Teacher Award (1981). Major
Interests: Process Safety, Estimation of Fire and Explosion Parameters, Mathematical Modeling
and Applied Math including Numerical Math.