CACHE NEWS

NEWS ABOUT COMPUTERS IN CHEMICAL ENGINEERING EDUCATION

No. 37 Fall 1993

The CACHE CORPORATION

WHAT IS CACHE?

CACHE is a not-for-profit organization whose purpose is to promote cooperation among universities, industry and government in the development and distribution of computer-related and/or technology-based educational aids for the chemical engineering profession.

CREATION OF THE CACHE CORPORATION

During the 1960s the rapid growth of computer technology challenged educators to develop new methods of meshing the computer with the teaching of chemical engineering. In spite of many significant contributions to program development, the transferability of computer codes, even those written in FORTRAN, was minimal. Because of the disorganized state of university-developed codes for chemical engineering, fourteen chemical engineering educators met in 1969 to form the CACHE (Computer Aids for Chemical Engineering) Committee. The CACHE Committee was initially sponsored by the Commission on Education of the National Academy of Engineering and funded by the National Science Foundation. In 1975, after several successful projects had been completed, CACHE was incorporated as a not-for-profit corporation in Massachusetts to serve as the administrative umbrella for the consortium activities.

CACHE ACTIVITIES

All CACHE activities are staffed by volunteers including both educators and industrial members and coordinated by the Board of Trustees through various Task Forces. CACHE actively solicits the participation of interested individuals in the work of its ongoing projects. Information on CACHE activities is regularly disseminated through CACHE News, published twice yearly. Individual inquiries should be addressed to:

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CACHE NEWS

The CACHE News is published twice a year and reports news of CACHE activities and other noteworthy developments of interest to chemical engineering educators. Persons who wish to be placed on the mailing list should notify CACHE at the aforementioned address. Contributions from CACHE representatives are welcome. This issue was editied by D. M. Himmelblau with contributions from a number of CACHE members and representatives.

CACHE NEWS

No. 37 Fall 1993

Interactive Computer Modules for Chemical Engineering Instruction
By H. Scott Fogler and Susan M. Montgomery, University of Michigan 1

PICLES: The Process Identification and Control Laboratory Experiment Simulator
By Douglas J. Cooper, University of Connecticut 6

CD-ROM Technology and CACHE
By Peter Rony, Virginia Polytechnic Institute 13

Announcements 24

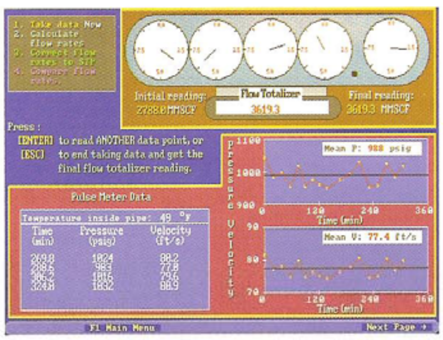
Standard Order Form 25

Interactive Computer Modules for Chemical Engineering Instruction

By H. Scott Fogler and Susan M. Montgomery, University of Michigan

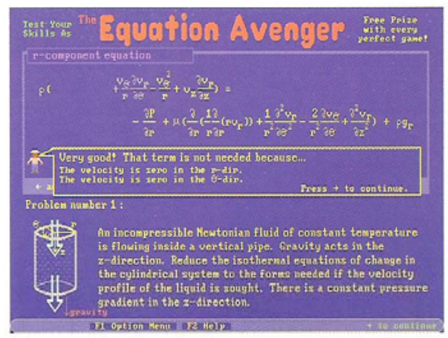
Over the past five years twenty four interactive computer modules have been developed to enhance the teaching of chemical engineering courses in material and energy balances, fluids and transport, separations, and reactor design. This article describes the history of the project, module features and educational benefits of using the modules, and also provides some suggestions for implementation into existing courses.

Material and Energy Balances



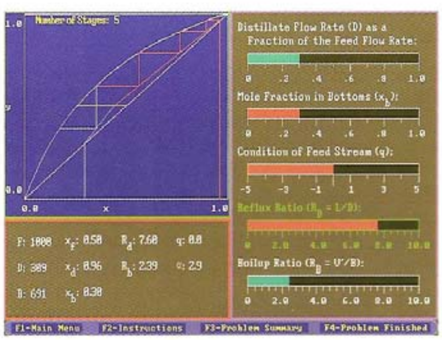
Gas - Taking ultrasonic flow meter data to diagnose a flow meter.

Fluids and Transport



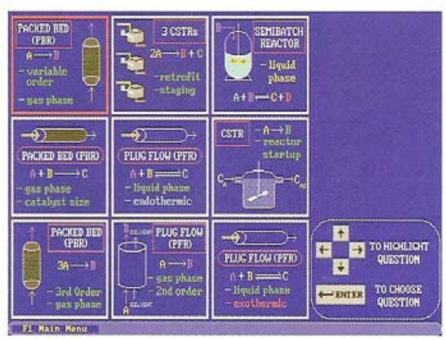
Simp - Simplifying the equations of motion and energy.

Separations



McCabe - Designing a distillation tower.

Reaction Kinetics



Tictac - Determining the effect of changes in process parameters.

Introduction

In his travels to engineering colleges around the world, the principal author [HSF] has observed the global community that is emerging in engineering. Foreign students, particularly in developing countries, are using the same textbooks as American students, have the same computers available (though not as many), and have made a quantum jump in their facility in writing and speaking english. What is particularly impressive, however, is that they appear to have an increased awareness of the importance of their role as future problem solvers in the increased development of their country. This sense appears to be lacking among American students. In order for our students to compete globally, it is necessary that we instill in them the problem solving foundations necessary to change their current perception of engineering as an amalgamation of facts and concepts supplemented by ever more complex calculations. The use of interactive computing has a role in enhancing not only the delivery of fundamentals but also increasing problem solving skills.

Project History

In the early 1970s, a number of interactive computer modules on reaction engineering were developed for use on the University of Michigan's mainframe time-sharing computer. These modules focused on problem solving, freeing the student from the hassle of computation and mere formula plugging, so that the focus could remain on process exploration and analysis. These simulations were enthusiastically received at a national meeting. Unfortunately, the programs were not easily transportable to computing environments at other universities.

Today, undergraduate chemical engineering students have access to a large number of IBM (or IBM-compatible) computers. In the early 1980s, many of the original reaction engineering modules were translated to an IBM format, using BASICA. Starting in 1988, after receipt of a National Science Foundation grant "A Focus on Developing Innovative Engineers", work began on a new generation of interactive computer modules for chemical engineering. A large number of modules were developed and tested both at the University of Michigan and at over 50 universities around the world. The resulting 24 interactive computer modules for the material and energy balance, fluids and transport, separations, and kinetics courses, were distributed by the CACHE Corporation in August 1993 to all the chemical engineering departments in the United States and Canada.

Educational benefits

The current generation of interactive computer modules, take advantage of three of the unique features of computers - computation, interactivity, and graphical animations - to address a variety of learning modes. The modules allow students to "review and demonstrate mastery of the material at their own pace, provides them with immediate feedback to their responses, and allows them to explore the effects of parameter variations on a system, perform simulations to optimize its performance, and carry out simulated experiments from which they can obtain the data needed to model the system,.as well as allowing a randomness to individual problems."[1]. It is becoming well established that students learn best when they experiment with subject matter themselves, and are actively involved in the subject matter [2].

During the 5-year development process, we have incorporated the pedagogical expertise we have gained through extensive testing both at the University of Michigan and many other universities. This testing has allowed us to ensure that the modules best address the issues that ensure success in interactive computer learning:

- Ease of use
- Maintaining focus on the concepts
- Minimal tediousness
- Promoting learning
- Individual guidance.

Additional features of some modules include introduction to new technologies using graphical animations, and entertaining motivators, which have been shown to increase the students' interest and motivation for the module content [3].

Module Components and examples

Interactive computer modules typically include:

- *Menu*
- *Interactive review of fundamentals*
- *Demonstration*
- *Interactive exercise*
- *A solution to the exercise*
- *Evaluation*

The features of the modules are best described using examples from some of the modules.

Gas, developed for the mass and energy balances course, is designed to provide the student with an important example of non-ideal behavior of gases. The module starts with a brief *review* of three frequently-used equations of state: The ideal gas equation, compressibility factor, and the Redlich-Kwong equation:

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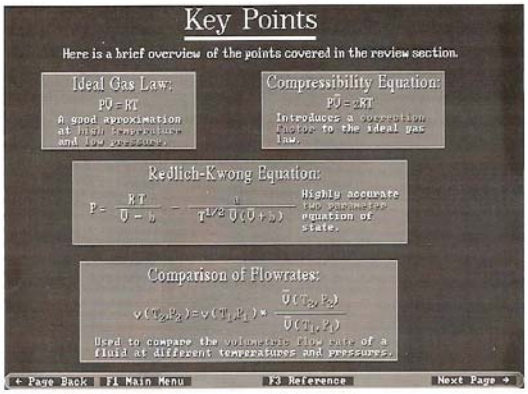
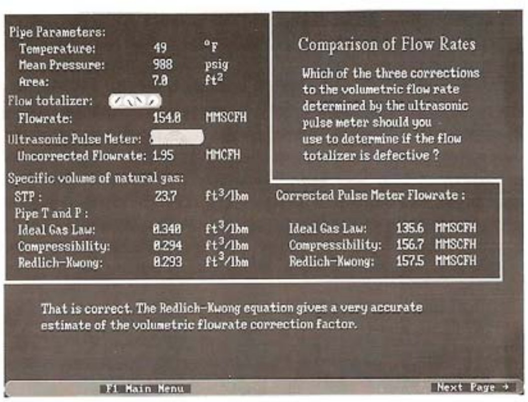
[1] Fogler, Montgomery and Zipp, *Comp. Appl. in Eng. Educ., Vol 1(1)* 11-12, September/October 1992.

[2] Felder, R.M., *Engineering Education*, April 1988, pp. 674-681.

[3] R. Snow and M. Farr, Aptitude, Learning, and Instruction. Vol 3: Conative and Affective Process Analysis. Hillsdale, NJ, Erlbaum, 1987.

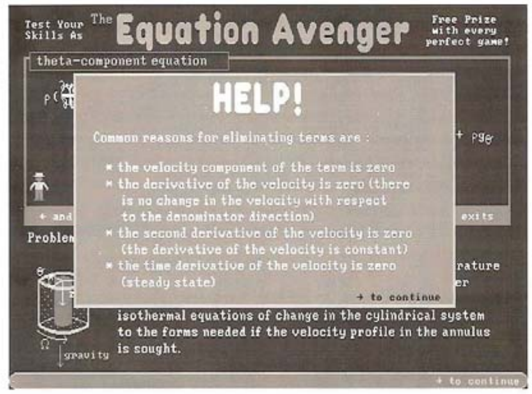


In the *interactive exercise*, the student must evaluate the performance of a possibly-defective flowmeter with the help of an ultrasonic flow meter. The student first takes the necessary data, using an interactive screen shown in the first page of this article, then must convert the pulse meter data to STP conditions, to compare them with flow meter data. After this conversion, the student must determine which gas law should be used for the comparison:

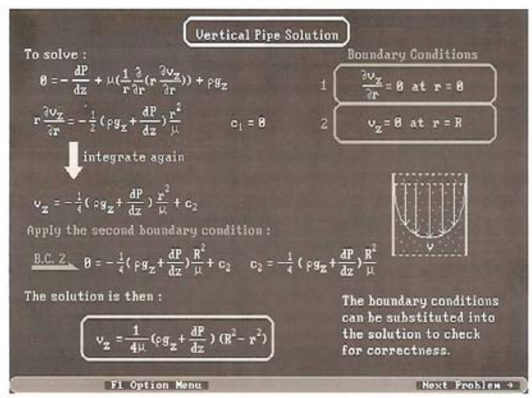


The student is evaluated at every step, and shown the correct solution when necessary. Following the scenario interaction, the student must answer some follow-up questions to ensure that the concepts have been mastered.

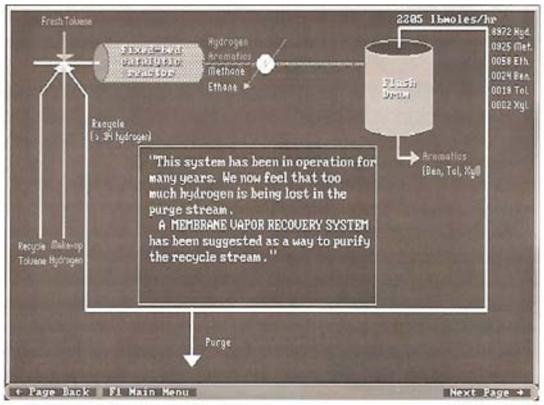
A popular module for the fluids and transport courses is Simp, that provides practice in the simplification of the differential equations of motion and energy. The student first chooses between solving momentum or heat balance problems, or a combination of the two. Three problems are selected randomly from a pool of four momentum and four heat balance problems, according to the student's choice. In the interaction portion of the module the student must simplify the appropriate equations of motion or energy. The scenario is a "shooting gallery", where the student must "shoot down" those terms that are equal to zero, as shown in the second color graphic. Guidance is available to students in the form of criteria used to eliminate terms:



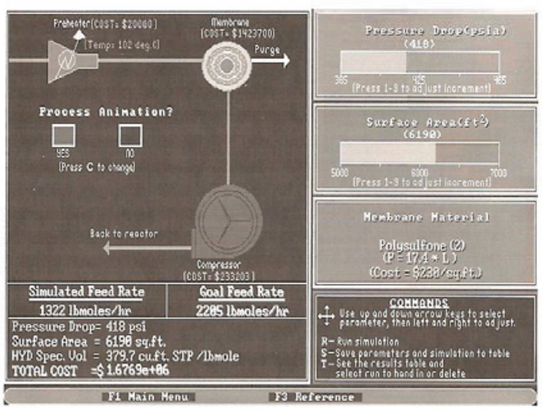
Every decision as to whether or not a term should be dropped is instantly evaluated, as shown in the color graphic. After the equations are correctly simplified, the student must choose the boundary conditions to solve the problem, after which the solution of the equations is shown:



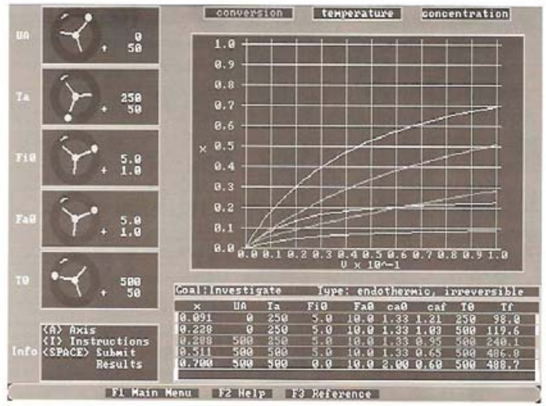
A module that introduces students to *new technology* is **Membranes**, for the Separations course, with focus on gas permeability and Fick's first law. In this module the student is introduced to the emerging field of membrane technology. The *review* section derives the equations for gas permeability that will be used in the design of the spiral-wound membrane system. Information on membrane materials, types of membranes (hollow fiber vs. spiral wound), economic factors, and components of a membrane separation system are also provided. The *interactive exercise* starts with a description of an operation that would benefit from a membrane vapor recovery system:



After determining the optimum location of the recovery system, the student uses a design *simulator* to optimize the pressure drop, surface area, and membrane material of the most cost-effective system that will perform the required separation. The final membrane system chosen is then *evaluated*. The simulator can be accessed directly from the main menu if desired.



Heatfx2, one of the modules for the chemical reaction kinetics course, focuses on the effect of parameter variations on the operation of a nonisothermal plug flow reactor. This *simulation* allows the student to explore the effect of various parameters on the performance of a non-isothermal plug flow reactor. The student may choose from eight simulations that span all combinations of exothermic/endothermic, reversible/irreversible conditions, as well as one simulation that includes the effect of pressure drop. The parameters that may be varied include heat transfer coefficient, inlet reactant and diluent flow rate, inlet temperature, and ambient temperature:



The results of the simulator may be analyzed in the form of plots of concentration, conversion or temperature as a function of reactor volume. The module may also be run in the *interaction* mode, in which the student must achieve specific goals (e.g. achieve a given conversion without exceeding a given temperature within the reactor) within each simulation.

Module Implementation

The modules typically replace homework assignments. A performance number that encodes the student's performance is generated by most modules. Other innovative uses of the modules have also been tried successfully:

1) The modules that consist mainly of simulations have been **used in class**, with an LCD overhead panel and projector, to illustrate important concepts. They can also be used to test students' predictions as to the effect of a parameter variation on a system.

2) These simulation-intensive modules, such as Heatfx2, described earlier, are generally made available to the students for **general exploration**, with instructions to use the modules to become familiar with parameter variation effects, and to be able to explain these effects in terms of process variables.

3) The review sections of some of the modules provide a supplemental **self-paced interactive review** to the concepts covered in class. In some instances, the review sections can replace the tedious portions of some lectures, particularly equation derivations. These reviews are also useful to the students to provide a quick review before exams.

4) The modules that introduce students to real world applications of chemical engineering principles can be used as

background preparation for a more extensive **open-ended project**. Students could work on the module first to familiarize themselves with the general application to be explored by the open-ended problem.

5) Students can work the modules in **groups of two**, rather than individually. Working in groups encourages discussion of the concepts being covered and their implementation, providing a more enriching learning experience. In addition, this allows students practice at communicating their ideas to somebody else so that they are understood, and defending their opinions when they conflict with those of others. It is important to ensure that one of the students does not become a passive observer, however, leaving it up to the other student to do all the interaction.

Available Modules

A complete set of 24 modules was mailed in August 1993 to the chairs of every chemical engineering department in the United States. They are available for license-free use until 30 June 1994. After that time, please contact the CACHE Corporation (P.O. Box 7939, Austin, TX 78713 (512) 471-4933) to obtain a license at a mininal fee that will cover maintenance updates and mailing costs. The modules included in the mailing are:

MATERIAL AND ENERGY BALANCES

UNITS	*Units conversion program*
GAS	*Equations of state - Natural gas pipeline*
VLE	*Vapor-liquid equilibrium - Soda pop production*
BIOWASTE	*Material balances - Biowaste facility*
BALANCES	*Material and energy balances - Production of low alcohol beer*

FLUIDS AND TRANSPORT

SHELL	*Shell momentum and energy balances*
SIMP	*Simplification of the equations of motion and energy transfer*
VISC	*Rheology - Identification of liquids*
PATCH	*Diffusion - Drug patch design*
THERMOWELL	*Conduction, convection and radiation*

SEPARATIONS

BASIS	*Introduction to Separation Processes*
CASCADES	*Liquid-liquid extraction.*
MCCABE	*Binary distillation.*
ABSORP	*Absorption tower design*
MEMBRANES	*Spiral membrane optimization*

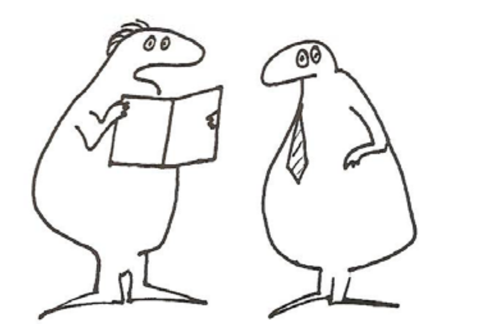
CHEMICAL REACTION KINETICS:

KINCHAL1	*Kinetics Challenge 1 - Introduction to kinetics*
STAGING	*Reactor staging and optimization*
KINCHAL2	*Kinetics Challenge 2 - Stoichiometry and rate laws*
COLUMBO	*CSTR-Volume Algorithm - A murder mystery.*
TICTAC	*Ergun, Arrhenius, and Van't Hoff equations in isothermal reactor design.*
ECOLOGY	*Collection and analysis of rate data - Ecological engineering*
HETCAT	*Heterogeneous catalysis.*
HEATFX-1	*Simulation - Mole and energy balances in a CSTR.*
HEATFX-2	*Simulation - Mole and energy balances in a PFR.*

Acknowledgements

The authors gratefully acknowledge funding from the National Science Foundation grant USE-8953534, as well as the assistance in distribution and support of the CACHE Corporation. The work of Dr. Robert P. Zipp, original Project Manager, in setting the standards for this project, was invaluable. In addition, the assistance of the numerous undergraduate software developers associated with this project, as well as that of the faculty of the Chemical Engineering Department at the University of Michigan and at other schools, who provided technical assistance and tested these modules with their undergraduate students, was instrumental to the success of this project.

IF A SYSTEM IS OF SUFFICIENT COMPLEXITY, IT WILL BE BUILT BEFORE IT IS DESIGNED, IMPLEMENTED BEFORE IT IS TESTED, AND OUTDATED BEFORE IT IS DEBUGGED.



PICLES: The Process Identification and Control Laboratory Experiment Simulator

By Douglas J. Cooper, Associate Professor, University of Connecticut

A Training Simulator for the Real World

A well designed simulator can provide students many experiences that have the realistic flavor of the real world. More important, however, is that such a simulator provides these experiences quickly and at minimal cost. PICLES, the Process Identification and Control Laboratory Experiment Simulator, is such a training simulator for exposing students to many important real world aspects of process dynamics and control.

Traditional control classes devote significant portions of the class to the manipulation and analysis of processes described by transfer functions. A couple of experiences in the laboratory during the term are then used to illustrate how this theory works in the real world. Unfortunately, lab studies can take several hours to perform, thus making it difficult for the students to explore more than the most significant issues in the lab. Also, if the equipment is behaving in the typical "real world" fashion (that is to say, not working quite properly) the important control lessons in these few studies can become obscured as students learn the important lesson that real equipment can be cantankerous.

One extremely important lesson that students should experience first hand is how limiting a transfer function can be in describing the dynamic behavior of a process. Given that a transfer function is a linear, ordinary differential equation with constant coefficients, it {s no surprise that they even fail to describe the dynamics of a trivial process such as liquid draining through a hole in the bottom of a vessel.

In fact, real processes are nonlinear, have measurement noise and other nonideal behaviors. We tell students that for a narrow range of operation, a simple transfer function model is sufficient for describing the local dynamic behavior of the process and that controller design can proceed based on such a model. We also show them sophisticated analysis and controller design methods for obtaining specified controller performance if only the process did behave like the transfer function.

The PICLES training simulator enables students to explore the implications of a great many analysis and design methods throughout the term by providing them access to several simulated processes with real world behaviors. To reinforce this real world concept, the processes are all represented by colorful dynamic graphics. After selecting a process, students must use engineering judgment to decide what identification studies they should perform to best represent the local process character around the point of expected operation.

After collecting the data using say, step or pulse tests, they then use methods learned in class to model the process. They will see that a different model can result from steps or pulses up versus steps or pulses down. They will learn that measurement noise forces them to make judgment calls about the data and that constraints on the manipulated variable can corrupt the true process character. In fact, they will learn that these and other decisions must be carefully considered for every application before they have the process understanding required to perform a controller design.

With a design in hand, they then go back into PICLES to learn how well the design methods work in the real world. They will literally see that their controller design is only an initial approximation that must be fine-tuned by trial and error. They must use engineering judgment to decide how to proceed. Decisions include balancing controller performance over a range of nonlinear operation and considering both set point tracking and disturbance rejection.

The Real World of PICLES

Students say that PICLES is very easy, and even fun, to use. The commands can be executed with just a few key-strokes. Colorful graphics let students follow the dynamics on the screen as the results of their actions unfold.

The processes in PICLES exhibit different nonlinear behaviors so students can see how process character can change with operating regime. This also lets them explore the implications of nonlinearity on controller design and implementation. The processes range from low to high order and have different process gains, time constants and apparent dead times so students can investigate the implications of these process characters.

The processes have noise in the sampled data so students can experience that in practice, performance criteria such as overshoot and damping often cannot be speci~ied with great accuracy. Disturbances in each process let the students realize that designing only for set point response performance is often insufficient in the real world.

In the current release (version 2.1), available controllers are all PID, and with PICLES, it is easy to explore P-Only, PI and full PID control. There is a PID Velocity algorithm and PID Position algorithm so students can study reset windup. They can select Derivative on Measurement or Derivative on Error so they can learn what derivative kick" is all about. Some controllers require the student to enter the bias or null value, while others have a bumpless feature where the bias is automatically set in a fashion similar to some commercial controllers.

There are also model based controllers in PICLES. A Smith predictor enables students to study how dead time compensation can improve controller performance. A Feed Forward element permits them to see how disturbance rejection works using both static and dynamic compensators. Decouplers enable them to explore methods for minimizing loop interaction in multivariable applications.

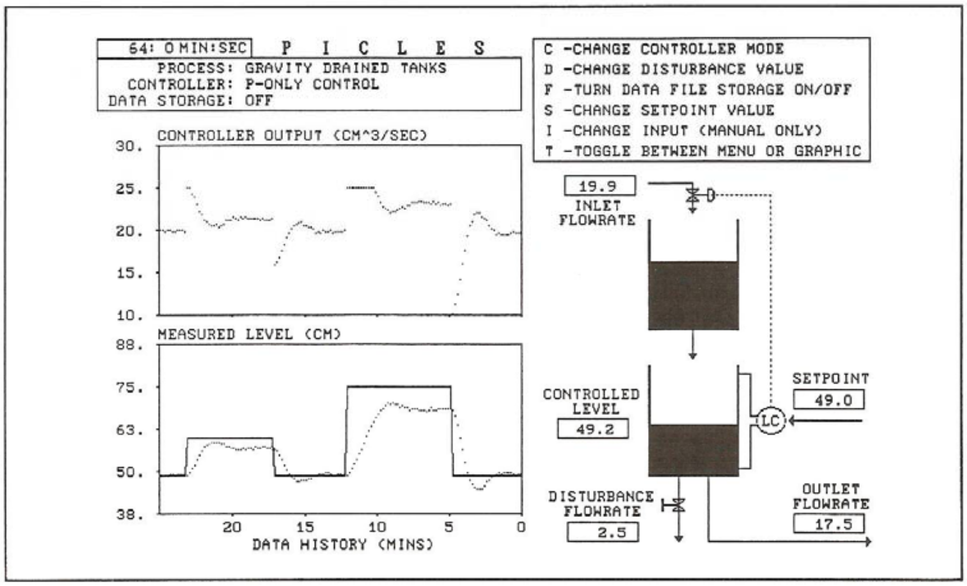


Figure 1 - Gravity Drained Tanks under P-Only control shows increasing offset as set point moves further from design value.

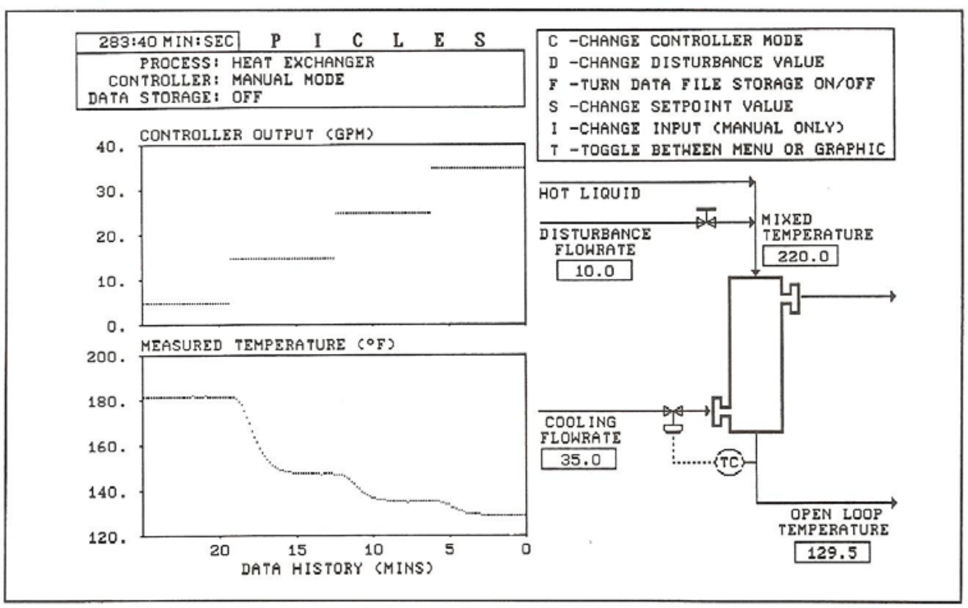


Figure 2 - Heat Exchanger shows negative process gain and nonlinear behavior.

Computer System Requirements

PICLES is designed to run on IBM compatible personal computers. The computer must have at least EGA graphics, although VGA graphics provides better resolution. For rapid execution, a computer with a '386 or '486 processor should be used. A math coprocessor is not required but adds additional speed to program execution.

The PICLES Processes

Gravity Drained Tanks

This process, shown in Figure 1, is two non-interacting gravity drained tanks in series (see assignment 3d later in this article for more about this figure). The manipulated variable is the flow rate of liquid entering the first tank. The measured/controlled variable is liquid level in the second tank. The disturbance variable is a flow out of the second tank due to a positive displacement pump. Thus, the disturbance is independent of level except that it loses suction at extremely low liquid levels in the second tank. The nonlinear behavior arises because drain rate from each tank is proportional to the square root of the hydrostatic head (liquid level in the tank).

Heat Exchanger

As shown in Figure 2, this process is a counter-current lube oil cooler (see assignment la for more about this figure). The manipulated variable is the flow rate of cooling water on the shell side. The measured/controlled variable is lube oil temperature exiting the exchanger on the tube side. Thus, this process has a negative steady state gain. An interesting characteristic of this nonlinear process is that disturbances, generated by changing the flow rate of warm oil that mixes with the hot oil entering the exchanger, display an inverse or nonminimum phase behavior.

Design a Process

Design a Process has a display, shown in Figure 3, that is similar to that found on commercial controllers (see assignment 6a for more about this figure). Design a Process permits students to input a transfer function and obtain a visual appreciation when studying problems found in textbooks. The student can specify a steady state process gain, an apparent dead time, up to three process time constants and a valve time constant. A "Linearity Factor" can also be specified if nonlinear behavior is to be modeled.

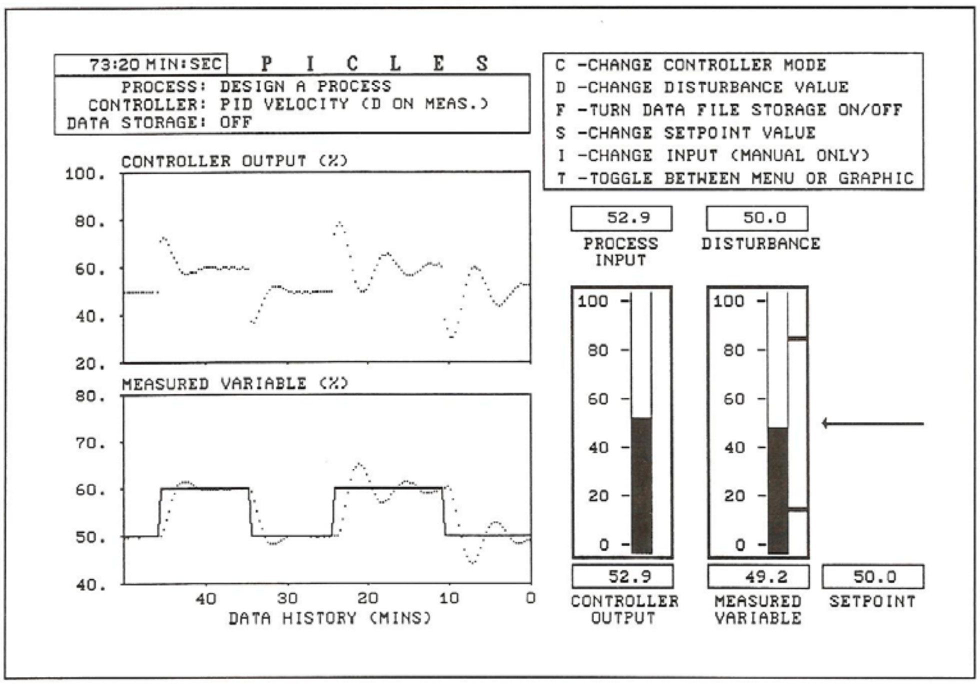


Figure 3 - Design a Process under PI control shows that increasing dead time degrades controller performance.

Mystery Processes

These processes are not, if fact, mysterious. Rather, these simulations are really just "Design a Process" that have been assigned fanciful names and have had all parameters prespecified and hidden from the student. Thus, each Mystery Process displays a behavior that ranges from first to fourth order and with different overall process gains, time constants, apparent dead times and degrees of nonlinearity. Because there is no *a priori* knowledge of expected process behavior, the student must rely on "real world" process identification studies for controller design. Mystery Processes simulate the disassociation that is typically felt when tuning controllers from a remote control room, thus making these simulations ideal for project work later in the semester. All of the mystery processes use the same graphic as shown in Figure 3.

Pumped Tank

This process is a liquid brine surge tank. The manipulated variable is brine flow rate out of the bottom of the tank and is adjusted with a throttling valve at the discharge of a constant pressure pump. This approximates the behavior of a centrifugal pump operating at relatively low throughput. The measured/controlled variable is liquid brine level and the disturbance variable is the flow rate into the tank. This process presents an interesting control challenge because of the integrating nature of the process.

Distillation Column

The Distillation Column, shown in Figure 4, is a binary distillation column that separates water and methanol (see assignment 8c for more about this figure). The column dynamics are simulated using a model published by Wood and Berry (1973). There are two measured/controlled variables and two manipulated variables. The reflux rate controls the distillate composition and the rate of steam to the reboiler controls the bottoms composition. The feed rate to the column is the disturbance variable. This process illustrates interaction between two controllers.

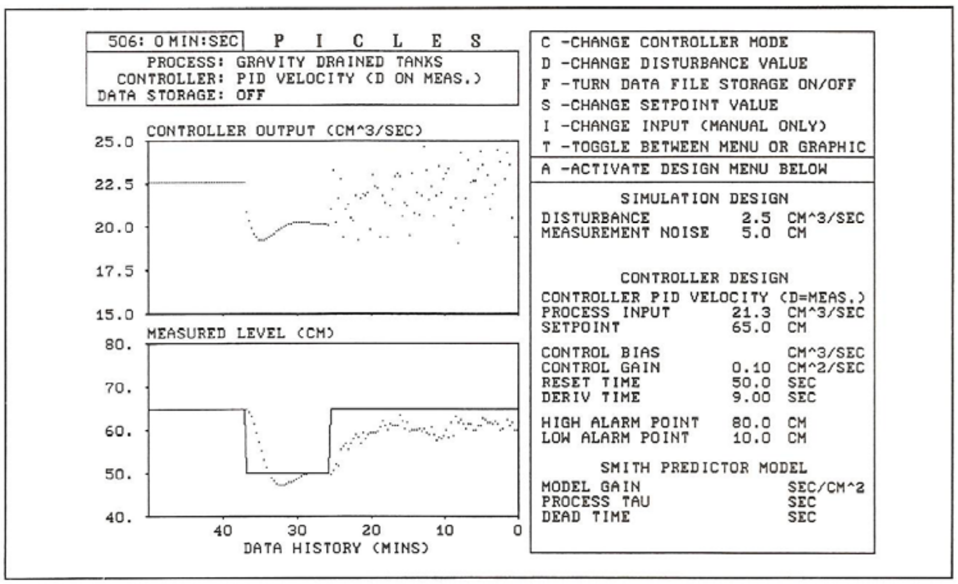


Figure 4 - Distillation Column with both top and bottom concentration under PI control shows performance is affected by loop interaction.

Available Controllers

The control algorithms in the current version of PICLES are all PID and include:

- Manual Control
- P-Only Control (Manual Bias)
- Velocity PID Control (Derivative on Measurement)
- Velocity PID Control (Derivative on Error)
- Position PID Control (Bumpless)
- Velocity PID with Smith Predictor
- Velocity PID with Feed Forward
- Velocity PID with Decoupler (Distillation Column Only)

To implement a PI controller, simply choose one of the PID algorithms and set the Derivative Time to zero.

Figure 5 shows the Design Menu used to specify controllerparameters. The process being simulated in this figure is the Gravity Drained Tanks process (see assignment 5a for more about this figure). Note that the simulation noise level can be changed if it is appropriate for an assignment. Also, in the spirit of the "real world," high and low alarms can be set to provide additional challenge in process identification and controller validation studies.

Although the limitation to PID algorithms is viewed as a serious limitation by some, I try to exploit this fact during classroom lectures. For example, I establish that the PID controller is a special case of the Internal Model Control and Direct Synthesis design methods. Also, I show how the Smith Predictor is a limiting case of some predictive controller design methods. Thus, PICLES can be used to explore certain aspects of these newer design standards.

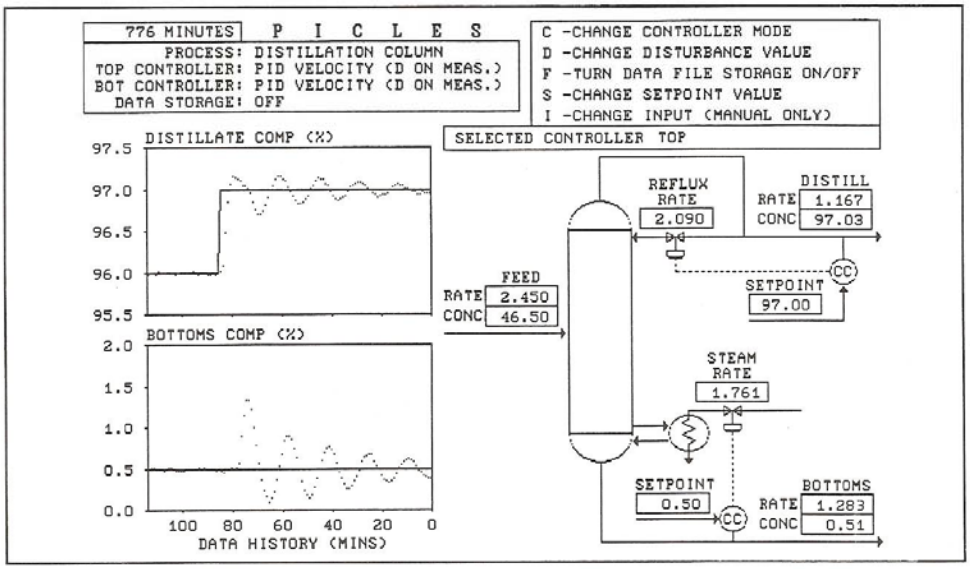


Figure 5 - Design Menu of Gravity Drained Tanks under PID control shows that derivative action becomes inappropriate when measurement noise is added.

How I Use PICLES in My Course

I start the class with the Gravity Drained Tanks process. The model can be easily derived, the process behaves intuitively and the nonlinear character is modest. Since I believe that some practice in programming is important, I also have the students program their own Gravity Drained Tanks process based on the equations derived in class. I then have them determine the process parameters which cause their simulation to approximate the dynamics of the PICLES simulation.

After several assignments in process dynamics and process identification, I move on to the Heat Exchanger. It is a slightly more complicated process but it still behaves intuitively. The process has a higher degree of nonlinearity and also has a negative steady state gain, which reinforces that process gains not only have magnitude and units, but also a sign. The nonminimum phase or inverse dynamics of the disturbance response provides another new twist.

After they have explored several investigations of process dynamics, some identification methods and explore a few controllers and design techniques using Gravity Drained Tanks and Heat Exchanger, I use the Mystery Processes for project work I assign a different Mystery Process to each group of students and let them tie things together by doing an identification, preliminary controller design, and finally determining a single "best" tuning for both set point tracking and disturbance rejection all as one assignment. Because the processes are nonlinear, each student can have their own project by specifying different ranges of operation for each problem (e.g. Adam must design for an the output range of 30-40%)

I use Design a Process intermittently to isolate specific process behaviors. For example, I ask them to implement a true first order process under P-Only control and let them demonstrate that such a process is unconditionally stable for all values of controller gain. They then show that a second order process under P-Only control can approach the limit of stability, and finally, that higher order processes under P-Only control can go unstable. When combined with a class discussion on system stability using root-locus, the students benefit from relating theory to practice while the subject is being taught.

As another example of using Design a Process later in the course, I assign them a set of time constants and a process gain and have them design and validate a controller. Then, keeping those process variables and tuning parameters fixed, they add dead time to the process and discuss their observations on the effect dead time has on closed loop performance. Finally, they design and implement a Smith predictor to relate our in-class derivations and discussions with actual application to assist them in understanding the benefits of dead time compensation.

When the students start becoming confident, I give them the Pumped Tank process. The integrating nature of the process really surprises them and requires me to do a lot of explaining ("Why is there no offset with a P-Only controller?" "How come with a PI controller, this process goes unstable when the controller gain is too high and too low").

Finally, the Distillation Column lets the students see what can happen when more than one controller is operating on the same process. The interactions show them that optimizing controllers individually does not necessarily produce an optimum solution when the controllers begin to interact. Also, the students can investigate how model based decouplers can work to minimize this interaction.

Example Homework Assignments

To illustrate how PICLES can be integrated into an existing course in process control, this section lists sample homework assignments. These assignments follow the order of development used in the popular textbooks and let students visually appreciate these important concepts. The five figures previously discussed also serve as partial answers to selected problems.

Assignment on Process Dynamics

1. Using Heat Exchanger in Manual mode:
   a. Starting from three different steady states, plot how the outlet temperature responds to manipulated cooling water flow rate steps of fixed size. Based on these plots, discuss the nonlinear nature of the process. (Answer: Figure 2 shows the nonlinear nature of the process because the outlet temperature responds differently for three step changes of equal size in the manipulated cooling water flow rate).
   b. Explain why this process has a negative steady state process gain.

Assignment on Process Identification

2. Using Design a Process:
   a. Generate an open loop input/output step response curve for an ideal first, second and third order process. Specify the same steady state process gain and zero dead time for each experiment. Now fit a First Order Plus Dead Time (FOPDT) model to each response. Compare on a plot each model response to the actual process response.
   b. Compare the dominant time constant and apparent dead time of each FOPDT model to the process parameters input into Design a Process. Discuss the strengths and weaknesses of using such a model to approximate the character of higher order processes.

Assignment on P-Only control

3) Using the Gravity Drained Tanks in P-Only mode:
   a. For a design liquid level, determine the value and units of the controller bias.
   b. Obtain a FOPDT model describing process dynamics around this design liquid level and use it to design a P-Only controller using ITAE, direct synthesis, IMC, etc.
   c. Starting with your controller gain and bias value, use trial and error to find the "best" gain, where for this assignment "best" is defined as a 25% decay ratio for set point steps of a specified size. Now show the ability of this "best" controller to reject step disturbances.
   d. Starting from the design operating level and using your "best" tuning, make set point step changes of various sizes in both directions. Discuss your observations. (Answer: Figure 1 shows two set point steps of different size while using the same controller design, and that offset increases as the set point moves further from the design point of operation).
   e. Pick a specific set point change and plot the response of the process when using your "best" controller gain, half of that gain and twice that gain. Discuss your observations on the relationship between controller gain and offset

Assignment on PI Control

4) Using Gravity Drained Tanks or Heat Exchanger in PI velocity mode:
   a. Starting with the position (or continuous) PI algorithm, derive the PI- velocity mode. Explain why no bias is needed for this controller form.
   b. Using an assigned method, design and implement a PI controller. With these parameters as a starting point, use trial and error to find the controller gain and reset time which provides a "best" performance. Here best performance is defined as a 10~o overshoot and 10 a 25% decay ratio to a set point step of specified size. Why can we design for two performance criteria with a PI controller but only for one with a P-Only controller?
   c. Plot a matrix of process responses for the same set point step where this matrix includes all combinations of your "best" tuning, a gain that is double and half of your best, and a reset time that is double and half of your best. Use your observations to explain the role of controller gain and reset time on controller performance.

Assignment on PID Control

5) Using the Gravity Drained Tanks in PID velocity mode:
   a. Design and implement a PID controller and compare its performance to PI control. For this comparison, test a number of set point and disturbance scenarios and show where the derivative action really pays off. Plot the distinctive scenarios and use them to explain why or why not any performance benefit occurred (Answer Figure 5 shows

two set point steps with measurement noise been added just before the second step. As shown, derivative action can produce poor performance when employed on a noisy measured variable).

Assignment on Dead Time and the Smith Predictor

6) Using Design a Process:
   a. For the assigned process gain and set of time constants, design and validate a PI velocity mode controller to achieve desired performance. Keeping the process variables and tuning parameters constant, add dead time to the process and discuss your observations on the effect dead time has on closed loop performance for this same set point step. (Answer Figure 3 shows two sets of set point steps. PI controller tuning is fixed throughout. Controller performance has degraded significantly from the first set point steps where the process possesses no dead time compared to the second set of steps, where the process possesses 30 seconds of dead time).
   b. Keeping the same process gain, set of time constants and including the dead time, tune your controller to produce the desired performance used in a). Compare this plot and tunings to the case where no dead time was present. Discuss your observations.
   c. Now design and implement a Smith predictor and again tune the controller to produce desired performance. Compare this plot and tunings with the previous two cases and discuss the pros and cons of dead time compensation.

Assignment on Disturbance Rejection and Feed Forward

7) Using Gravity Drained Tanks or Heat Exchanger process:
   a. For the design point of operation, develop a FOPDT model of the disturbance-to-output dynamic relationship. Using this model, compare a static and dynamic feed forward compensator for step changes in the disturbance variable.
   b. For the Gravity Drained Tanks, the disturbance immediately impacts the measured variable while there is a lag before input variable manipulations can compensate. Explain how this influences your comparison of the static and dynamic compensators.
   c. For the Heat Exchanger, there is a reasonable lag before a disturbance impacts the measured variable. Discuss how this influences your comparison of the static and dynamic compensators.

Assignment on Multivariable Control and Decoupling

8) Consider controller design for the Distillation Column given specified design operating concentrations for the distillate and bottoms.
   a. While the bottom controller remains in Manual mode, design and implement a PI controller for the top controller. Plot the performance of the controller for distillate concentration set point steps both up and down.
   b. While the top controller remains in Manual mode, design and implement a PI controller for the bottoms controller. Plot the performance of the controller for bottom concentration set point steps both up and down.
   c. Using the controller tuning parameters from a) and b), implement PI controllers on both loops. Make set point changes for both controllers and discuss loop interaction (Answer: Figure 4 shows that neither controller performs well when both are online, although both performed well when commissioned individually).
   d. Now design and implement PI controllers with both static and dynamic decoupling. Perform the same set point changes as in c) and discuss the impact of model based decoupling.

Final Notes

For more information about PICLES and available teaching materials, contact:

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CD-ROM Technology and CACHE

By Peter Rony, Virginia Polytechnic Institute

Part I: Standards, Hardware, and Drives

Introduction

"CD-ROMs are coming!" The 1990s version of Paul Revere arguably is William Gates, CEO of Microsoft Corporation, which has already made a substantial corporate commitment to CD-ROM technology with several published CD-ROM titles including "Word for Windows & Bookshelf," which contains on a single CD-ROM The Concise Columbia Encyclopedia, The American Heritage Dictionary, Roget's II Electronic Thesaurus, Bartlett's Familiar Quotations, World Almanac and Book of Facts 1992, The Concise Columbia Dictionary of Quotations, Hammond's Atlas, and the Microsoft Word for Windows User Guide. In the author's opinion, Mr. Gates and his corporation have correctly seen the future, and are responding.

CD-ROM (an acronym for Compact-Disk Read-Only Memory) technology will explode in the marketplace within the next two to three years. By 1995, it will become "obvious" to most PC users that they must have a CD-ROM drive—portable, internal or external. Although "multimedia" is the buzzword that one hears most often today, it is the CD-ROM disk that, in the author's opinion, is the driving force for multimedia software. CD-ROMs can be manufactured at the rate of one disk every 6 seconds. The bottom line is that the CD-ROM disk represents a 10X to 100X factor improvement in the quantity of digital memory conveniently and inexpensively accessible to computer users. File sizes encountered, generated, communicated, and employed by engineers will increase by a factor of 10 to 100, from approximately 1 Mb per file—sufficient to fit on a high-density floppy diskette—to 10 Mb, 30 Mb, and even 100+ Mb per file, sufficient to fit on a 128-Mb magneto-optical diskette or a 640-Mb CD-ROM disk. Given a choice of using either "disk" or "disk," in this article we shall use the latter term.

In this two-part contribution, which includes excerpts from a draft article on CD-ROMs being prepared for the journal, "Computer Application sin Engineering Education," we shall summarize some key aspects of CD-ROM technology, identify selected ChE educational opportunities for CD-ROMs, and describe current CACHE ad hoc task force activities.

CD-ROM Media

A CD-ROM disk is a 12-cm diameter, polycarbonate wafer one side of which contains a thin, reflective aluminum coating on a surface that has a continuous spiral of data pits encoding up to 640 Mb of data. The total length of the spiral, from hub to rim, is approximately 3 miles. An infrared laser within a CD-ROM drive shines on the disk; reflected light from the aluminized surface is read continuously by a light-sensitive diode. Pits and lands reflect the laser light differentially, leading to a radio- frequency signal that is sampled for transitions between the logic 0 and 1 states. Data is delivered at rates of between 150 kbyte/sec (low-end drives) and 300 kbyte/sec (high-end, double-speed drives), substantially slower than hard-disk-drive data- transfer rates. Error-detection and correction algorithms in the CD-ROM drive software reduce error rates to approximately one byte in 2000 disks. [1]

Pits are 1 to 3 microns long by 0.5 microns wide and 0.1 microns deep. The basic digital logic unit of data storage is the sector, which corresponds to an audio playing time of 1/75 second and a pit spiral length of 1.5 cm. CD-ROM disk sector addresses have the same format as CD disk sectors. A CD-ROM sector contains 2352 bytes, of which 2048 are user data and 304 are positioning, error detection/correction, and speed information. The total playing time of a CD or a CD-ROM disk is 72 minutes. This corresponds to a total CD-ROM disk capacity of 72 minutes x 60 sec/min x 75 sectors/sec x 2048 bytes/sector = 663.6 Mb. [1]

The process of manufacturing quantities of a CD-ROM disk consist of preparing a glass disk master; using a laser lathe and electroforming to encode the data on the glass; creating stampers (dies); molding the disk's polycarbonate wafer; aluminizing one surface of each wafer; adding a protective coating to the aluminized surface; printing and packaging [1]. Manufacturing costs are subdivided into four categories:

(a) Pre-mastering, the creation of 640 Mb of ISO-9660 formatted sequential data to be transferred to the CD-ROM disks: approximate cost, $250.00.
(b) Mastering, the production of the glass disk master and stampers for the polycarbonate disks: approximate cost, $1000.00.
(c) Replication, the production of quantities of finished CD-ROM disks: approximate cost, $2.00 per disk up to 500 copies, $1.40 per disk between 1000 and 5000 copies.
(d) 2-Color disk printing: no extra charge.
(e) Packaging: $0.35 for a jewel box, $0.05 for shrink-wrap, and $0.05 for tea bag [2].

An alternate CD-ROM medium is the blank CD-R (for CD Recordable) disk. Finished CD-ROM disks (called "one-offs") are produced one at a time with the aid of a CD-R drive, which contains a high-powered laser that burns pits into a pre-grooved, 12-cm disk consisting of a polycarbonate wafer, an organic dye coating, and a gold reflective layer. Approximately 30 minutes is required to prepare a one-off, and another 30 minutes to verify the 640 Mb of burned-in data. Blank diskettes, at the time that the first draft of this manuscript was written (February 1993) cost between $40 and $50. As of July 1993, blanks can be obtained for only $19 each. Optimists, basing their predictions on past learning curves for computer media, suggest that blanks will cost less than $5 each within several years. The author has a feeling of deja vu. The first Intel 256-byte, 1702A EPROM integrated circuit cost, in the early 1970s, as much as $70 in quantities of one. Today, 131,072-byte, 27C010-20 EPROMS can be obtained from Jameco for as low as $8.95 each [3].

CD-ROM Standards

CD audio disks have been successful because both the disks and the CD players are completely standardized. The compact disk (CD) was a technological product of a cooperation between Sony and Philips, who produced a "Red Book" standard in 1980. This standard described the size of the disk, the size of the pits and lands that digitize audio signals, and their arrangement in a spiral from hub to rim. CDs are sequential access media.

The CD-ROM specification, known as the "Yellow Book," extended the technology to different types of data, not just audio signals, on a physical CD disk. A question of formatting standards came up, and led by 1985 to the "High Sierra" data formatting standard, which was adopted with a few modifications as the current International Standards Organization "ISO 9660 standard" (1988). The objective was to permit the reading of any CD-ROM disk in any CD-ROM drive, independent of computer platform (Windows, Macintosh, DOS, UNIX, OS/2, and so forth).

Details of the ISO-9660 file system format are described by Jolitz and Jolitz [4]. ISO-9660 is an operating-system-independent file system. A key gimmick of the ISO 9660 format is its ability to store data either in Intel 80x86 microprocessor format ("little endian") or Motorola 680x0 microprocessor format ("big endian") in data bytes that are twice as big as normal [4,5]. The least significant 16 bits in the 32-bit word hold the little endian value, and the most significant 16 bits hold the big endian value. The result is that a single ISO-9660-formatted CD-ROM disk can be read from a CD-ROM drive connected, for example, to either a Macintosh, a Sun workstation, or an IBM- class personal computer. "ISO 9660 is a least-common-denominator file system: It sacrifices features of the Mac (e.g., icons and resource forks) and UNIX (e.g., symbolic links and permissions) and it doesn't permit updates" [6].

One might conclude that the CD-ROM drive world is as well standardized as the CD audio drive world, and that any CD-ROM drive—even the $299 specials—can be purchased with confidence to play all types of CD-ROM disks. Unfortunately, such is not the case as of early 1993. A purchaser is confronted with new issues and jargon—CD-ROM XA, Kodak Photo CD, Philips CD-I, dual-speed, and multisession—that frustrate the identification of an acceptable drive. These points were made in an issue of PC Week received in late February 1993:

> "...users of CD ROM drives are facing at least one large headache: a plethora of incompatible hardware standards and software formats, which make adoption of the technology difficult."
>
> "'One of the biggest problems now is platform fragmentation,' said Julie Schwerin, president of Infotech. 'If a user wants to get a CD ROM and doesn't have a PC or Mac already, there's at least 12 different ways he can go. You'd be hard-pressed to make a decision.'"
>
> "The list of formats includes High Sierra and ISO 9660; Apple Computer Inc.'s CD-plus-G and CD-plus-MIDI; Tandy Corp.'s VIS; Philips Consumer Electronics Co.'s CD-Interactive; the CD Extended Architecture from Philips, Sony Corp. of America and Microsoft Corp.; Commodore Business Machines Inc.'s CD-TV; Sony's Data Diskman and MMCD; Kodak's Photo CD; Nintendo of America Inc.; Sega of America Inc. and forthcoming products from 3DO Inc." [7]

CD-ROM Extended Architecture (CD-ROM XA) formatted disks are covered under the Yellow Book's free-form, mode-2 sectors. Philips has added the "Green Book" standard for Compact Disk Interactive (CD-I) CD-ROMs. In progress is an "Orange Book" standard for magneto-optical (MO) and CD-recordable (CD-R) disks. Part 2 of the Orange Book defines single-session versus multisession CD-R, and is "the subject of much current confusion." [6]

The importance of "multisession" compact disk technology can be observed with the Kodak Photo CD optical disk system. Photographers can bring the same Photo CD disk to a Kodak dealer repeatedly, adding new photographs each time. "In order to take full advantage of the multiple-write capabilities of the Photo CD system most CD-ROM users will have to upgrade to new multisession CD-ROM XA Mode 2 drives. Without a multisession CD-ROM player your CD-ROM will only see the first session on the Photo CD. If you fill the Photo CD with 100 images in the first session, you will see the entire contents of the disk. But if you have added images to the disk over multiple sessions, you would see only the first images unless you get a multisession CD-ROM player." [8]

Tom Halfill summarized the important issues in selecting a CD-ROM drive in the recent Byte article, "Start the Presses." [6]

> "Here's the bottom line. If you need a CD-ROM drive to access static information—encyclopedias, technical manuals, reference books, and so on—you can get by with an inexpensive single-speed drive without XA or multisession support. For multimedia CD-ROM applications involving sound and animation, consider a dual-speed drive for best throughput. If you anticipate using Photo CD at all, you'll need at least an XA-ready single-session drive. For serious Photo CD work, settle for nothing less than a dual-speed drive with full XA and multisession capability."

The author was tempted in February 1993 to suggest that if you do not absolutely need a CD-ROM drive, wait until the technological dust settles by the end of 1993. But as early as March 1993 it is possible to purchase a satisfactory CD-ROM drive. The Engineering Fundamentals Department at Virginia Tech recently placed on bid an order for twelve CD-ROM drives that have the following specifications: "External CD-ROM Drive and adapter card for Microchannel IBM PS/2 model 55SX with the following specifications: (1) Dual speed, (2) Photo CD compatible (XA ready), (3) Multisession capable, (4) 280 ms or less average seek time, (5) Sustained data transfer rate of 300 kilobytes/sec, (6) CD audio play software, (7) Microchannel adapter card and cable, and (8) 1-year warranty, parts and labor." A SCSI adapter card for an ISA backplane can be substituted for the Microchannel (MCA) SCSI card.

Five months later, the technological dust has already settled. Without question, if you, as a professional, desire to purchase a CD-ROM drive, you must use the adjectives stated above, namely, double-speed, XA-ready, multisession, PhotoCD capable. The author purchased, in June 1993, a Toshiba XM-3401 CD-ROM drive, an Adaptec SCSI interface card, and compatible Adaptec SCSI software drivers. The Engineering Fundamentals department purchased, over a Chinon drive [9], one of the NEC MultiSpin models [10]. By August 1993, almost all entering Virginia Tech engineering freshmen (1000+ students) will purchase an IBM ValuePoint, 486DX, 33-MHz, 120-Mb hard-disk drive, 8-MB RAM, local-bus personal computer equipped with a Panasonic 563 double-speed, Kodak PhotoCD-multisession, XA-capable CD-ROM drive, a Sound Blaster 16 card, Labtec stereo headphones, and SVGA graphics. Not only CD-ROM drives, but multimedia techniques are coming to engineering education at the author's university.

Other CD-ROM Technology Hardware

With the ability to store 640 Mb of digital information with files that exceed 100 Mb in size, new opportunities exist to create such files. While beyond the scope of this brief article, it is useful to mention the new types of hardware that provide the new opportunities associated with CD-ROM technology. Theauthor cannot go into much detail here because this hardware technology is changing rapidly—in price, performance, and standards—and because he has yet to have experience with it.

(a) *Image Digitization Hardware*
Images present on black-and-white or color paper, slides, and photographs can now be subjected to high-density digitization, yielding files as large 5 to 10 Mb. Kodak Photo CD provides five versions of the same image, but at different resolutions: 2048 x 3072 pixels, 1024 x 1536 pixels, 512 x 768 pixels, and two smaller preview images. The author has used the Microtek ScanMaker 1650S slide digitizer hardware in conjunction with a Macintosh Quadra to produce high-resolution *.PCX files of 4.5 Mb size. For images on paper, the Microtek ScanMaker 600S digitizer hardware provides equally large file sizes because of the 8.5" x 11" size of black-and-white or color pages.

(b) *Audio Digitization Hardware and Software*

(c) *SuperVHS Video Digitization Hardware and Software*

(d) *Audio Playback Hardware and Software*
Jim Louderback, in the February 22, 1993 issue of PC Week, pointed out that "most sound cards on the market have limited functionality...functions are hard-wired into the board. For example, a Creative Labs Sound Blaster owner would have to purchase a Pro Audio Spectrum to get real sound or equalization."What to do? He points out that, "a new model of audio technology is emerging in the 80x86 world—one based on open reprogrammable digital signal processors (DSPs)—which lets users substitute flexible software for rigid hardware." "Intel, along with other companies, is doing its best to turn the PC into a total communications command center. With this line of thought, the PC is envisioned as a hub connected to the telephone, the PBX, the fax machine, and other users. According to Pat Gelsinger of Intel, this functionality will render the current crop of audio devices obsolete." "The DSP model also allows all types of analog data to be digitized and processed. Theoretically, a single DSP could handle stereo high-fidelity playback, a 19.2 kilobytes/sec modem-based file transfer, a wireless phone conversation, and a fax transmission. Analog Devices' latest DSP, the ADSP-2115, for instance, is being used for all of these types of applications." [11]

(e) *Video Playback Hardware and Software*
An ActionMedia II board and associated software contained in an IBM M57 Ultimedia PC was used to demonstrate CACHE CD-ROM #1 at the November 1992 National AIChE Meeting in Miami Beach. The demonstrated video has now been digitized using QuickTime for playback on a Macintosh Quadra. The key message to readers is to focus on hardware solutions to digitized video playback, not software solutions, which may be short lived.

(f) *Magneto-Optical Drives*

(g) *High-Capacity Hard Disk Drives*

Personal CD-ROM Publishing Hardware: CD-R Drives

Udell and Eglowstein summarized, in a February 1993 sidebar in Byte magazine, the currently available CD-R drives [12]. Available drives and manufacturers at the time they wrote their article (probably late spring or summer 1992) included, respectively:

(a) CD-Studio, by Young Minds, Inc. [13]
(b) Personal RomMaker, by JVC Information Products Co. [14]
(c) CD Record, by Dataware Technologies, Inc. [15]
(d) Multimedia ISO Formatter, by Sony Corp. of America [16]

CD-Studio was an $18,250 solution for UNIX-based CD-ROM publishers that contains a double-speed Philips CDD 521 recorder, a 1-Gb hard disk, and two SCSI adapters. The Personal RomMaker, for $12,799, required a Mac IIci or better, a high-speed Maxtor 8760 SCSI drive, operating System 7.x, 4 Mb of RAM, and HyperCard 2.1 or higher. Users could choose from several CD-ROM disk formats: ISO 9600, Apple HFS, High Sierra, or a hybrid HFS and ISO 9660 format. CD Record is directed toward the IBM PC market, at a cost of $8995. It contained a Philips CDD 521 recorder. Sony's CDW-900E Multimedia ISO Formatter, approximately $11,500 in cost, ran at single or double speed but did not have multisession support. At present, it appear to the author, as of February 1993,that with all of these CD-R drives you needed to have all of your CD-ROM files available to be recorded in a single session of 640 Mb maximum.

The rapid change in CD-R hardware technology has been breathtaking. Royce White, presented an extremely provacative talk as chairman of the "CD-ROM Recordable" session at a May 1993 SIGCAT meeting. Mr. White spoke knowledgeably as a member of dataDisc Corporation [17]. He noted the following:

- Two years ago, the cost of a CD-R machine was $30,000 to $50,000 with media costs (blank disks) greater than $100.
- Today, costs range between $4000 and $19,000, with media less than $20 per blank disk.
- By 1994, it is predicated that a CD-R machine will cost less than $2000, with media approximately $10 per blank disk.
- By 1995, it is predicated that a CD-R machine will cost less than $1000, with media in the range of $5 to $7 per blank disk.
- Uses for CD-Rs include test disks, archives, program testing, backup, data transfer, master disks, music, and multimedia, among other applications.
- Less than two years ago, the key players in CD-R technology were Sony, Yamaha, and Meridian Data. Today, the key players are Sony, JVC (Victor Corporation of Japan), Philips, Kodak, Pinnacle Micro, Ricoh, Yamaha, Dennon, and others (music).
- As far as the future is concerned, there will be smaller units, lower prices, more/compressed data, complete audio/video capabilities, and "a CD-Recorder in every garage."

Royce White then proceeded to summarize the characteristics of current CD-R machines:

- Prospector (Visitel),$1495, no PhotoCD, no multisession, no XA
- CD Maker (Tempra), $2495, no PhotoCD, yes multisession, yes XA
- Rom Maker (JVC), $8995, no PhotoCD, yes multisession, yes XA
- Pinnacle Micro, $3995, no PhotoCD, yes multisession, yes XA
- TOPIX (Optical Media), to $2495, no PhotoCD, yes multisession, yes XA
- PPS (KAware), $1995, no PhotoCD, yes multisession, no XA Personal
- Scribe (Meridian), $1995, no PhotoCD, no multisession, no XA
- CD Prepare (Dataware), $1995, no PhotoCD, no multisession, yes XA
- CD-GEN (CD-ROM Strategies), $1995, no PhotoCD, yes multisession, yes XA
- Gear (Elektroson BV), to $3995, maybe PhotoCD, yes multisession, yes XA
- Yamaha CDR, $3495, yes XA
- Ricoh RS-9200CD, $3495, yes XA
- Pinnacle RCD-202, $3995, yes XA, yes PhotoCD, maybe yes multisession
- JCV XR-W1001, $8995, yes XA
- Kodak PCD 200, $5995, yes XA, yes PhotoCD, maybe yes multisession
- Philips CDD521, $5995, yes XA, yes PhotoCD, maybe yes multisession
- Sony CDW900E, $9995, yes XA

The Multimedia Lab (Virginia Tech)

A key reason, beyond his basic enthusiasm for CD-ROM technology, for the author being willing to assume responsibility for the ad hoc task force was his knowledge of the development of "The MultiMedia Lab," co-sponsored by the College of Engineering, College of Architecture, and Office of the Provost at Virginia Tech. This lab is located down the hall from the ChE undergraduate labs and its director, Gordon Miller (a recently graduated architect with extensive computer experience, specially in computer graphics) has his office within the ChE complex of labs in a new engineering building, Hancock Hall. It is useful here to describe the characteristics of The MultiMedia Lab for two reasons: (1) it can serve as a model for other universities that may wish to also create multimedia labs, and (2) its facilities will support some of the activities, in chemical engineering education, of the CACHE ad hoc task force.

Opened on September 18, 1992, The MultiMedia Lab is, "an interdisciplinary facility used to develop computer-based educational programs and computer-based presentations. The lab provides support for two primary groups, (a) projects wherein courseware is being developed, and (b) advanced research projects involving learning research as well as other projects of a more general nature that may take advantage of the highly advanced development environment provided by the lab. In addition, the lab supports the multimedia development needs of the SUCCEED coalition and its Technology and Communication Center based at Virginia Tech."

"The MultiMedia Lab has a highly integrated environment for multimedia development on both the Apple Macintosh (R) and IBM Ultimedia (R) platforms. The Macintosh Quadra computers run System 7.0.1, and the Ultimedia machines run MS-DOS version 5.0, Microsoft Windows 3.1, and OS/2 2.0. The Macintosh computers also read and write MS-DOS formatted disks, so files can be moved freely from one platform to another. All computers have digital audio boards and CD-ROM players. The Apple Macintosh computers display 16 7 million colors, and the IBM Model 95s can use 65,000-color XGA."

"Every single machine in the lab is on the campus network backbone. For those users taking advantage of the Lab for Scientific Visual Analysis next door, the two labs are on the same Ethernet network and any MAC, IBM, or UNIX volume can be mounted on any machine in either lab."

"The lab is set up to accommodate several of the most popular formats of removable media. We have chosen the SONY 128 Mb (ISO) removable optical drive as a standard for all machines on both platforms."

"The lab has a Microtek flatbed scanner that can scan up to 600 dots per inch in full 24-bit color. A Microtek slide scanner can scan slides at almost 2000 dots per inch in full 24-bit color. Almost every computer in the lab can capture a single frame of video. Full motion digital is also available. Video can be captured from VHS, SVHS, 8-mm, and Hi8 video tape formats. Videos can also be edited."

"The most common output will most likely be a computer-based interactive multimedia project. This may be distributed in a number of ways. The lab will be able to author its own CD-ROM disks for primarily computer-based systems that use or do not use digital video support. The video-based systems that require the development of a video laser disk will also be able to premaster a full working prototype of the video laser disk in the lab. The lab will have digital film records for output to 35-mm slide and 4" x 5" transparencies for the purposes of presentation and publication, respectively. Also, any computer interaction can be output to video tape for presentations."

As an authorized user of The MultiMedia Lab facilities since September 1992, the author can verify the existence of most of the above-stated capabilities. He has made the assumption that analog video tape work (capture, edit, output, digitization) should be performed using SuperVHS video tape, not VHS video tape.

Both Gordon Miller and the author will be speakers on the topics of multimedia technology and on CD-ROM technology, respectively, at the "Visualization in Chemical Engineering Systems" session, chaired by Sangtae Kim and Alan Coon, at the November St. Louis National AIChE meeting. The call for papers for this session stated: "This session will address issues arising from the use of computer imaging technology to visualize scientific and engineering data and information. As the quantities of such data (typically obtained via direct measurement and/or computer simulation) continue to increase, visualization techniques become vital to the comprehension and interpretation of these data." [18]

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17. Royce White, dataDisc, Route 2, P.O. Box 1108, Gainesville, VA 22065. Phone: (703) 347-211. FAX: (703) 347-9085.
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Part II: CACHE Activities With Respect to CD-ROM Technology

CACHE Ad Hoc Task Force on CD-ROM Technology

The CACHE Corporation ad hoc task force on CD-ROM Technology was formed on August 13, 1992 with the appointment of CACHE trustee Peter R. Rony as the task force chairman. A second member of the task force is Professor Michael Cutlip, the current president of CACHE who, in his inaugural address (New Orleans CACHE board of trustees meeting, spring 1992), made a compelling case for CD-ROM technology.

The ad hoc task force mission statement is based closely on the CACHE Corporation mission statement:

> To distribute computer-related and/or technology-based educational aids for the chemical engineering profession using CD-ROM technology.

Initial ad hoc task force goals included:

1. To enhance the quality of ChE education using CD-ROM technology.
2. To enhance the quality and accessibility of ChE information using CD-ROM technology.
3. To collect and organize ChE information resources, specially electronic information resources.
4. To test software and hardware techniques suitable for producing CD-ROMs that serve ChE faculty and students.
5. To produce and distribute CD-ROM disks.
6. To serve as a ChE educational focus and to communicate information on CD-ROM technology to ChE colleagues.

The first objectives of the task force were (1) to produce at least one demonstration chemical engineering CD-ROM and (2) to both demonstrate it and make several presentations about anticipated task force activities at the 1992 Miami Beach National AIChE meeting. On October 23, 1992, Larry Boden and colleagues at Nimbus Information Systems [Ruckersville, which is north of Charlottesville, Virginia] provided the blank disk, the equipment, and the labor to produce CACHE CD-ROM #1, a single, "one-off" (CD-R) disk. CACHE publicly thanks them for their kind assistance. The CD-ROM was demonstrated on an IBM M57 Ultimedia personal computer equipped with OS/2 and an ActionMedia II digital video adapter board. CACHE CD-ROM #1 may have historical significance as the first ChE CD-ROM, or at least the first ChE educational CD-ROM. Hundreds, if not thousands, will follow in chemical engineering by the end of this decade.

CD-ROM Publishing in Chemical Engineering[1]

Being a technology leader, CACHE would be commercializing its first CD- ROM (late in 1994, perhaps in conjunction with its 25th anniversary) in an environment where there are few high-speed, multisession, XA-ready CD-ROM drives available in either academia or industry. This situation will change significantly within several years. CACHE might have 200 CD-ROM disks to distribute, but an audience that could not see how they work.

Since most ChE professionals do not have a CD-ROM drive in their PCs, there is some question concerning why CACHE or any organization would desire to develop CD-ROMs for ChEs. We have the proverbial "chicken-and-egg-situation." What to do? These arguments were presented to Mark Rosenzweig, Editor-in-Chief of Chemical Engineering Progress (CEP) during the Miami Beach National Meeting. Mark wrote an editorial for the December 1992 issue of CEP. Of special interest was his description of the fact that the preprints for the first Separations Division Topical Conference weighed nearly six pounds, and came to almost 1200 pages. Further, "these preprints represented less than 15% of all the presentations at the Miami Beach meeting. Preprints of all the presentations would have meant at least a sixfold increase in the number of pages and heft."

A similar story, with a sadder conclusion, came recently in an October 15, 1992 letter from the co-chairmen of the Annual Pittsburgh Modeling and Simulation Conference:

> "...Costs of the Conference have steadily risen, but in the last several years, cost of publishing the Proceedings have skyrocketed. Although we have done our best to contain all of these costs in ways that we have previously communicated with you, we have not been successful."
>
> "Since the Conference has always been a break-even event on the basis of registration fees alone, we are now looking at registration fees in the $300.00 range for a 2-day conference. This would be almost a 50% increase in the registration fee to continue the Conference. Therefore, we are informing you by this letter that no additional Modeling and Simulation Conferences will be held unless you explicitly hear from us to the contrary."

Perhaps the professional world needs fewer conferences, and perhaps some readers will shed few tears over the demise of this one. But the broader message is that rising publication costs increasingly threaten the ability of any professional organization to provide substantial printed information to its meeting attendees. This is a global problem that transcends engineering.

CD-ROMs to the rescue? Who knows? What form might they take? The author's initial guess was that the common denominator for the electronic display of text, equations, and figures was some version of the Adobe Systems Postscript (TM) standard. On November 12, 1992 he posed the question of Postscript-based document display software to two colleagues.

John Hassler, a faculty member at the University of Maine (HASSLER@MAINE) "ran a search on SIMIDX and only found (a) in TXTUTL - GETPSTXT.ARC (Convert Postscript to ASCII), and (b) in VENTURA - PSUTILS.ARC (Postscript utilities — no further description). I am sure such utilities must exist, perhaps as part of a word processor or Desktop Publishing package, but I don't know of any."

Dr. P. Kip Mercure (76067.432@CompuServe.COM), a colleague in the Camile Products group at The Dow Chemical Company, conveyed thefollowing information:

> "I note that Adobe Systems has introduced a family of products to read documents in a mixed environment of Macintosh, Microsoft Windows, DOS and Unix platforms. The products will be called 'Acrobat,' and are supposed to work with documents, photographic images, illustrations, graphs and charts in a 'Portable Document Format.'"

Adobe Acrobat? If you have been reading the trade journals starting in November 1992, you likely read the pre-release publicity about this product scheduled for release during 1993. In the February 1993 issue of Byte magazine, Rich Malloy's article, "COMDEX: Bigger Than Ever" selects the "best of show" as:

> "And finally, we had to choose the Best of the Best, our Best of [COMDEX] Show Award. This honor was won easily by Adobe's Acrobat technology. We see this technology as having a far-reaching impact on the world of personal computing. If Acrobat delivers what Adobe says it will, it should touch the lives of every PC user. By helping to cut the wasteful use of paper, it should also help preserve resources, thereby touching the lives of everyone on the planet." [2]

During the week prior to the CACHE trustees meeting in Colorado [July 23-24, 1993], the author tested Adobe Acrobat technology on Word 2.0 for Windows, Lotus Freelance, and Interleaf Publisher version 3.5 files. Acrobat technology worked perfectly, even better than expected. A manuscript, "The Portable Document Format (PDF) in Chemical Engineering," was written and distributed to all trustees at the CACHE meeting.

The Economics of CD-ROM File Distribution

CACHE planned, late in 1992, to test the CD-ROM waters with both CD-R disks and by piggybacking on Nimbus Information Systems' ROMWARE demos. Within about a year, late in 1994, CACHE plans to enter the business of creating custom CD-ROM disks for the chemical engineering educational community. Even today, the economics are attractive: after paying $1000 in "mastering" costs and $250 in "pre-mastering" costs, an organization can replicate its own CD-ROM disks for only $2.00 each in minimum quantities of 200-500, and $1.40 each for quantities of 1000-5000. For 200 CD- ROMs, the per-CD-ROM cost is $8.25; for 1000 CD-ROMs, the cost is only $2.65.

Consider the November 1993 AIChE National meeting in St. Louis. Assume 200 sessions with 6 papers/session. Assume an attendance of 2500, each of whom is the recipient of a single, CD-ROM disk containing 640 Mb of meeting information. What would be the cost to produce each CD-ROM and how much information could each author place on the meeting CD-ROM? With 1200 papers and 640 Mb, each author would be provided with approximately 0.5 Mb space on the CD-ROM. Mastering is $1000, pre-mastering is $250, replicates are $1.40 each, and "tea bag" containers (to save money) are $0.05 each. Therefore, the cost to produce each meeting CD-ROM would be $1.95.

Consider a FOCAP-X conference that has 25 speakers and 10 discussion sections (assume 240 Mb for the discussions). With 400 Mb left to be divided among 25 authors, each author would be provided with 16 Mb space on the conference CD-ROM. With attendance of 200 participants, replicate costs of $2.00 each, and tea bag containers, each conference CD-ROM would cost $8.30.

Some Lessons in CD-ROM Technology

The author would now like to describe some of the problems encountered and lessons learned in producing CACHE CD-ROM #1, with the hope that these observations will guide the initial efforts of other academic colleagues who desire to create their own CD-ROMs. It should be kept in mind that the cost of a CD-R machine is dropping rapidly (see Part I).

Initial Objectives

The initial objectives, in mid August 1992, were to produce and demonstrate a CD-ROM disk containing chemical engineering files for the November 1992 Miami Beach National AIChE meeting. The four anticipated sub-tasks included: (1) the production and collection of files for the demo CD-ROM; (2) the conversion of files to ISO-9660 format; (3) the creation of a CD-ROM disk that could be transported to Miami Beach; and (4) the demonstration of this disk on a suitable personal computer.

What Information Should CACHE CD-ROM #1 Contain?

Most academic organizations are not yet prepared to take advantage of the full 640 Mb capacity of a single CD-ROM disk. This was certainly the task force's situation in August 1992. What digital information could be stored on the proposed CACHE CD-ROM in time for the Miami Beach meeting? Before this question was answered, we considered the storage characteristics of a CD-ROM disk. According to the CD-ROM, Inc. spring 1992 catalog [3], a 12-cm plastic CD-ROM disk based upon the Philips/Sony patent could "store up to 685 Mb of data, text, images, audio signals, or video. This capacity equals approximately 300,000 pages of text or data, or 6000 EGA images, or 72 minutes of audio, or 60 minutes of full motion video (30 frames per second synchronized with sound) or any combination of the above." Another way of estimating CD-ROM storage capacity is as follows [4]:

AM-quality audio: 11 kbytes per second
VGA graphics 640 x 480 x 256 colors = 300 kbytes/screen
VGA graphics 640 x 480 x 16 colors = 22 kbytes/screen

Files for the CACHE CD-ROM #1

Concerning files to be demonstrated, the task force initially identified the following chemical engineering and non-ChE software for possible inclusion in the CACHE CD-ROM #1:

(a) POLYMATH (Mike Cutlip, Connecticut, and Mordechai Shacham, Ben Gurion)
(b) GAMS Optimization Software (Ignacio Grossmann, Carnegie-Mellon)
(c) CACHE Model Predictive Control Toolbox (CACHE-Tools) (Manfred Morari, Caltech and Larry Ricker, Washington)
(d) U. Michigan/CACHE NSF Curriculum Improvement Project (Scott Fogler and Susan Montgomery, Michigan)
(e) Purdue/CACHE NSF Curriculum Improvement Project Video Presentations by Mobil and Tennessee Eastman (Robert Squires and S. Jayakumar, Purdue)
(f) Safety images information (Dan Crowl, Wayne State; Joe Louvar, BASF Corporation; and Vincent Van Brunt, South Carolina)
(g) DIPPR, Student Version (Ronald Danner, Penn State; Theodore Selover, DIPPR Technical Director; and National Institute of Standards and Technology)
(h) Chemical Engineering databases (Martyn Ray, Curtin University of Technogy)
(i) MicroMentor (Brice Carnahan, Michigan)
(j) UC Signal/UC Online (Alan Foss, Berkeley)
(k) PICLES (Douglas Cooper, Connecticut)
(l) Computer Tools for Chemical Engineering Courses (Samuel Davis, Rice)
(m) Tennessee Eastman Plant-wide Process Control Problem (James Downs and Ernest Vogel, Tennessee Eastman, Kingsport, Tennessee)
(n) Electronic presentations created using Lotus Freelance and Showpartner F/X (Peter Rony, Virginia Tech).
(o) Siemens' Application Productivity Tool (Siemens Industrial Automation, Johnson City, Tennessee)
(p) APT Applications Programs (Siemens Industrial Automation and also Peter Rony, Virginia Tech)
(q) Tutsim (Tutsim Products, Palo Alto, California)
(r) Tutsim Applications Programs (Peter Rony, Virginia Tech)
(s) Virginia Tech promotional video, "A Window to the World" (Virginia Tech)
(t) Commercial packages from vendors of chemical engineering software?
(u) CACHE Corporation promotional material: What is CACHE?

It proved more difficult than initially anticipated to obtain some of the above software in digital form for inclusion in CACHE CD-ROM #1.

BFDF—Big, Fat, Dumb File

An appropriate acronym was suggested to the author by Larry Boden at Nimbus Information Systems: BFDF, or "Big, Fat, Dumb File." The concept of BFDF applied only to items (e), (f), (o), and (s) in the above listing. Item (s), 13 minutes of digitized video, required approximately 120 to 130 Mb. Item (o), APT software, required a total of 13 Mb. Item (f) required as much as 4.5 Mb per slide for a total 36 slides each digitized in the high-resolution mode. The remaining files in the list were typical, small DOS files that could be handled with one or several 1.44 Mb diskettes, with or without digital compression.

Software Drivers Are in a State of Flux

A key demonstration desired for the Miami Beach AIChE meeting was an example of digitized video. Robert Squires kindly provided a SuperVHS copy of the 20-minute, Mobil videotape, but for political reasons in Blacksburg it was decided to first digitize a 13-minute, Virginia Tech promotional video, "A Window to the World." During September-October 1992, the software drivers for the IBM Ultimedia machines were not yet available to The MultiMedia Lab. Consequently, neither video tape could be digitized in Blacksburg.

As of the date of writing of this manuscript, February 1993, there was a proliferation of video digitization and playback software: Microsoft Video for Windows, QuickTime for Windows, and so forth. The author had no personal experience with any of these video digitizing standards. Readers are encouraged to attend the "Visualization" session at the St. Louis AIChE meeting for further information about these topics from Gordon Miller, Director of the Virginia Tech MultiMedia Lab [5].

Digitizing "A Window to the World"

Having decided to digitize the Virginia Tech promotional video, "A Window to the World," as our first BFDF to be placed on a CD-R disk, the next step was to utilize the anticipated MultiMedia lab capability to digitize this video. Unfortunately, the Sony CDW-900E Multimedia ISO Formatter and the 1.6 Gb hard disk had not arrived in Blacksburg by October 1992.

The Kindness of Colleagues

The IBM Institute for Academic Technology (IAT) in North Carolina came to our rescue [6]. Drew Robinson at IAT kindly digitized the promotional video to produce a single, 117-Mb file, VATECH.AVS, stored on a 128-Mb magneto-optical diskette. Since he had business with Nimbus Information Systems, he physically transported VATECH.AVS to Ruckersville, Virginia along with a variety of other IBM test *.AVS audio and video files. All these files were ultimately placed on CACHE CD-ROM #1 through the kindness of Larry Boden at Nimbus Information Systems. All *.AVS files were successfully played back using an ActionMedia II playback card on an IBM M57 Ultimedia computer located in The MultiMedia Lab.

Data Storage Media in CD-ROM Technology

We encountered a significant data storage problem. How would we transfer megabytes of files physically from Virginia Tech in Blacksburg to Nimbus Information Systems in Ruckersville, north of Charlottesville, Virginia? Nimbus listed the following possibilities in a September 1992 brochure:

- One-half-inch, 9-track tape (variety of formats)
- 1.4-Gb, 4 mm DAT tape (ANSI-labeled and TAR formats)
- 2.4-Gb, 8 mm tape (ANSI-labeled or CD-ROM premastered formats)
- 3.5-inch floppy diskette
- 5.25-inch floppy diskette
- CD-ROM drive
- Archive 150 (Fastape backup)
- Syquest 44 Mb removable cartridge
- SONY magneto optical disk (MDI format, any Sony 501 compatible)
- WORM cartridge (LaserStor PC-800 or Maxtor OC-800)
- Archive 250 streaming tape

Unfortunately, our capabilities in Blacksburg consisted only of:

- 128-Mb magneto-optical diskettes
- Syquest 88 Mb removable cartridge
- 3.5-inch floppy diskette
- 5.25-inch floppy diskette
- complete personal computer

There was a mismatch in storage media. Ultimately, we brought twenty, 3.5-inch, 1.44-Mb floppy diskettes by automobile to Nimbus. We had a group of 4.5-Mb *.PCX high-resolution safety images on a 128-Mb magneto optical diskette, but could not transfer them for lack of equipment at Nimbus as of October 1992. In early 1993, Nimbus purchased a 128-Mb magneto-optical drive. In the future, the preferred data transfer medium in Blacksburg will likely be a CD-R disk.

Large Hard Disk Drives Required

In order to use blank CD-R disks, it is necessary to have a large hard disk drive—perhaps 1.6 Gb—to store (a) the 640 Mb of files to be stored on a CD-ROM, and (b) the ISO-9660 formatted files that are actually transferred to a blank CD-R disk. Two Maxtor drives were purchased for The MultiMedia Lab, one for the IBM and the other for the Mac platforms.

The MultiMedia Lab Physical Barrier

The MultiMedia Lab at Virginia Tech was organized and managed in a way such that users were not allowed to bring in their own computers and use cabling to link to Lab PCs via serial or parallel ports. If you did not have your own 128-Mb magneto-optical drive or 44-Mb Syquest removable drive, as of October 1992 you could not transfer BFDF either in or out of the lab. A physical barrier existed. An alternative was the use of the Ethernet network that linked all of MultiMedia Lab computers to the campus backbone. We purchased for $129 a 3Com EtherLink III [7], installed it in an IBM PS/2 Model 30/286 in our undergraduate lab, but did not yet test it because of the limited size of the hard disk drive (20 Mb) in the PS/2. A test of Ethernet using a 212 Mb hard drive is scheduled for sometime in 1993.

Get Written Approval for the Use of Intellectual Property

CD-ROM technology will be a boon to owners of intellectual property stored in electronic form, including as books, reference texts, databases, programs, digitized audio libraries, digitized image libraries, digitized video libraries, and so forth. Check your legal rights to use all such information if you plan to produce replicate CD-ROM disks, for example, 100 disks sent to 100 different ChE departments. With the natural urge to completely fill all 640 Mb of a CD-ROM disk, the chances that you may run afoul of somebody's copyright are high.

Creating CACHE CD-ROM #1

The author observed the process at the Nimbus Information Systems site. A key item of hardware was a very large (Gb) hard disk drive that could store several 640-Mb images including the original group of files (in DOS or Macintosh format) and the corresponding ISO-9660 formatted files. The first task consisted of loading the DOS partition on this drive with the files to be burned into the CD-R disk. To the IBM *.AVS files already present at Nimbus (from the week before) the author added 20 floppy diskettes worth of CACHE and chemical engineering files. One subdirectory was chosen to be a "hidden subdirectory" by changing a single byte in the file allocation table for the subdirectory. A hexadecimal editor did the job.

The second task consisted of creating an ISO-9660 partition containing all the files. This task consumed approximately 20 minutes. The ISO-9660 files were transferred to 8-mm tape, which was physically moved to the CD-ROM recorder, where the data was electronically transferred to the recorder's own hard disk.

The third task consisted of burning in the ISO-9660 files into a single CD-R disk. The process took 30 minutes. An additional 30 minutes were consumed verifying the accuracy of the produced CD-R disk. Clearly, a CD-ROM recorder is designed only for small production runs: one or several duplicate CD-ROMs.

The Hidden Subdirectory

The author learned about an interesting gimmick while observing the creation of CACHE CD-ROM #1: the "hidden subdirectory." By changing a single byte in the file allocation table (FAT) for the subdirectory, it can be rendered invisible to normal directory commands found in DOS, Windows 3.1, and OS/2 operating systems. If you know the name of the subdirectory, you can access it under DOS using the CD command. Once CD and the subdirectory name are executed, all the files within the "hidden subdirectory" can be viewed on the monitor.

The era when software is distributed as a bunch of 1.44-Mb floppy diskettes—for example, 20 diskettes for OS/2 version 2.0—will draw to a close within a few years. Simple economics dictate that CD-ROM disks will ultimately replace floppy diskettes as the preferred distribution medium by most software vendors. The "hidden subdirectory" approach is a mild form of copy protection: if you do not know that a subdirectory exists on a CD-ROM, you will not access it. Unfortunately, software to defeat this technique will quickly appear as shareware (if it does not already exist), so the utility of this approach is limited.

File Compression and Encryption

Encryption may become a critical technology for sharing the large memory storage capacity of a CD-ROM among different file distributors. It is worth repeating a quote from the spring 1992 catalog of CD-ROM, Inc.: "Password access for your authorized users is provided to your encrypted infobase. Software search engines must have a password protection scheme." [3] It is not clear whether or not the CD-ROM, Inc. password protection technique is limited to the database search software ("encrypted infobase") or whether the entire set of database information is thoroughly encrypted.

As a future distributor of software on CD-ROM, CACHE faces a challenge in economics. The 640 Mb capacity of a single CD-ROM disk may be sufficient to distribute, for example, 30 different CACHE software titles and associated manuals. Substantial economic incentive exists to combine all 30 titles on a single CD-ROM, which could be updated once a year as sales permit. ChE student, faculty, and departmental customers may wish to purchase only a few of these titles.

One answer is the encryption of individual subdirectories associated with specific titles. For examples, the Polymath subdirectory of files could be encrypted, the GAMS subdirectory of files could be encrypted, and so forth. Is this possible? Easily. Pkware, Inc. markets software, PKZIP for DOS, that simultaneously performs encryption and compression of subdirectories.[8]

"PKZIP creates .ZIP archive files. PKZIP has many options to allow you to control the way in which you compress the files. All attributes of a file can be stored, such as hidden and system attributes, as well as directory tree structures. Inclusion of the directory tree structure allows you to retain the subdirectory hierarchy and include more than one file with the same name...PKZIP has optional keyword encryption, providing secure protection for sensitive data."

"PKUNZIP extracts files from .ZIP archive files. PKUNZIP has many options, allowing you to control which files are extracted and where to place them. PKUNZIP allows you to restore directory structures stored within a .ZIP file."

It should be noted that two versions of PKWARE's PKZIP/PKUNZIP software exists, the original version and the recently marketed version 2.0. Unfortunately, the *.ZIP dot extension is used for both versions despite the fact that the algorithm for version 2.0 compression is changed. The author has yet to develop experience with version 2.0 and to determine whether or not any impediment exists.

Internet file servers routinely supply their files as compressed files; *.ZIP files are very popular today. Most files are available in the original PKZIP/PKUNZIP version. Also available are shareware decompression programs, for example, UNZIP.EXE, that can be distributed to students in not-for-profit situations. Multiple copies of Pkware, Inc. PKZIP for DOS software is available at $16 per copy in amounts between 50-99 copies, and $12 per copy in amounts between 100-199 copies.

Professor John Hassler (University of Maine), who has always been a good source of what is happening in the computer area, provided the following comments in August 1992 on the subject of the encryption of files:

> "Encryption on public networks is a funny topic. The government does not allow encryption technology to be shipped outside of the U. S. without permission, so the large software repositories (like SIMTEL-20) do not have it. On the other hand, it is readily available from sources in other countries, which makes the whole business kind of stupid."
>
> "Depending on what exactly you want, it's really pretty easy to write encryption programs that will resist casual prying. One way is to XOR the password with your plaintext file, block by block. (The XOR, or Exclusive-OR, is reversible. If A XOR B gives C, then C XOR B gives back A.) This is easy to break, so there are many different ways to get more security. A slightly better one is to use the result of encrypting the first block to encrypt the second block, and so forth. This is not really secure against a sophisticated attack, but it does take some effort to break. I haven't really looked into the more secure methods, but I would expect that references are available (e.g., Knuth). The only encryption program that I have is part of a file compression utility called PKZIP. I can send it to you, if you want. It's a PC .exe file, so we would need to use some encoding method."
>
> "The DES is the "standard" encryption technique for much of the data exchange for banks and the like. I have seen it described in the text by Andy Tannenbaum (don't remember the title - he has several books, but this was the one on networks), and Press, etc., Numerical Recipes has something about it, but not a complete encode-decode pair. Because of the U.S. export restrictions, I don't think that a DES program is posted anywhere in this country. Probably there is one in some other country, though."

In a recent article by Steve Higgins, it was pointed out that "When Brian Veil sent copies of Lotus Development Corp.'s Notes to his Fortune 500 company's foreign office, he committed a crime that could have cost the company a half-million dollars and limited its ability to do business abroad....To comply with the law, Veil had the branch office send back the U.S. edition of Notes in exchange for the export version." "Last month, computer industry vendors, including Microsoft Corp. and other members of the Software Publishers Association (SPA), met in one of an ongoing series of meeting with federal officials to remove the teeth from the law. They claim it is outdated, pointless, unenforceable and harmful to their ability to do business." [9]

Pkware, Inc. deals with this problem in the following manner: "Due to US Government regulations, we are not permitted to export our encryption technology to the following countries: Afganistan, Albania, Bulgaria, Cambodia, Cuba, Czechoslovakia, Hungry, Iran, Iraq, Libya, North Korea, People's Republic of China, Poland, Romania, Soviet Union, Syria, Vietnam, Yemen." [8]

In practice, CACHE would provide an authorized user with a password, when used in conjunction with PKUNZIP, that would decrypt a single encrypted CD-ROM subdirectory. The author has tested PKZIP/PKUNZIP with the following subdirectories: POLYMATH 3.0, CACHE-TOOLS, GAMS, POLYMATH (older version), PICLES version 2.0, APT version 1.3a, Introduction to Modules (Michigan), Separations Modules (Michigan), Kinetics Modules (Michigan), and Fluids/Transport Modules (Michigan). The encryption/decryption process worked perfectly in all cases.

Commercial Sharing of a CD-ROM

CD ROM, Inc., in their spring 1992 catalog of optical products (CD-I, CD-ROM, M-O, and WORM), presented on page 10 the concept of Cost-share (TM) CD-ROM. A few quotes from their advertisement are appropriate [3]:

> "Imagine the price of CD-ROM manufacturing falling 80% overnight....If you are a CD-ROM publisher or user, you can increase your profits and vastly increase the number of things that you can use CD-ROM to accomplish. Password access for your authorized users is provided to your encrypted infobase. Software search engines must have a password protection scheme. The manufacturing prices . . . reflect projected costs as of January 7, 1992."

The cost per CD-ROM disk depends upon the number of disks ordered and the total amount of memory used. The following total prices have been computed from their price schedule as been applicable to the needs of CACHE:

Table I. Cost-share CD-ROMs: Quantity Ordered versus Amount of Memory Used

Number of CD-ROMs ordered by CACHE	5 Mb	10 Mb	20 Mb	80 Mb	120 Mb
10	$334.60	$343.60	$364.60	$524.60	$604.60
25	460.50	470.52	490.50	650.50	730.50
50	618.50	628.50	648.50	808.50	888.50
100	842.00	852.00	872.00	1032.00	1112.00
150	996.00	1342.00	1368.00	1582.00	1688.00

It is not anticipated that CACHE would pursue this route, but the alternative is being presented here.

Recent Developments

This article was finalized for publication in the fall 1993 issue of CACHE News on July 29, 1993. Recent developments since the

February 1993 date at which the draft was written include:

(a) Larry Boden, General Manager has left Nimbus Information Systems, CD-ROM Division, P.O. Box 7427, Charlottesville, Virginia 22906. The CACHE contact is now sales representative Joe Cannariato, Phone: (804) 985-1100, extension 459. The ROMWARE project is temporarily on hold. Larry is starting a CD-ROM production facility in California.
(b) Mike Cutlip, chairman of CACHE, has identified an "introductory special" for CD-ROM replication. For a total cost of $950, one obtains mastering, 200 CD-ROM replicas, 2-color printing, and jewel boxes. Call Larry Boyd at (909) 629-7084. The firm is J & S Tech, Inc., 207 Erie Street, Pomona, CA 91768. 10- Day service is provided for the $950.
(c) CACHE CD-ROM #2 will test video digitization techniques for the Purdue, Mobil videotape, a SVHS copy of which is already in the possession of the ad hoc task force.
(d) The author wrote a manuscript, "The Portable Document Format (PDF) in Chemical Engineering" for the CACHE trustees meeting in Colorado on July 23-24, 1993. The 9-page manuscript summarizes the capabilities of Adobe Acrobat technology, and then reports several personal experiences using it.
(e) Academic discounts are available for Acrobat Reader, Acrobat Exchange, and Acrobat Distiller. The author's academic contact at Adobe Systems in Vienna, Virginia is Deborah Kudovic, (703) 760- 7870. Mention Peter Rony when you call her.
(f) The Portable Document Format (PDF) is one, successful solution to the problem of replacing hard copy of the proceedings of professional meetings with electronic files that can be read, searched, printed, and annotated using Acrobat Exchange. A "CACHE pool" should be created to put money on the exact month when AIChE decides to use the PDF format to publish the proceedings for one of its national meetings.

In summary, exciting developments are occurring with CD-ROM, CD- R, and PDF technology. Within a few years, they all will change how you view computing opportunities.

References

1. This section was published in the Winter 1993 issue of CAST Communications. Portions are reproduced in CACHE News for the benefit of ChE faculty who are not members of the CAST division.
2. Rich Malloy, "COMDEX: Bigger Than Ever," Byte 18 (2), 41-42 (February 1993).
3. CD ROM, Inc. spring 1992 catalog.
4. Steve Floyd, The IBM Multimedia Handbook, Brady Publishers, 1991.
5. For a description of The MultiMedia Lab, please see Part I of this contribution in the spring 1993 issue of CACHE News.
6. IBM Institute for Academic Technology (IAT), P. O. Box 120117, Research Triangle Park, NC 27709. Phone: (919) 560-5042.
7. Frank J. Derfler, Jr., "Ethernet Adapters: Fast and Efficient," PC Magazine 12 (3), 191-226 (February 9, 1993). The 3Com EtherLink III card is an "Editors' Choice."
8. Product Catalog Spring-Summer 1992, Pkware, Inc., 9025 No. Deerwood Dr., Brown Deer, WI 53223.
9. Steve Higgins, "Breaking U.S. encryption statute could be costly," PC Week, 1 (February 8, 1993).

ANNOUNCEMENTS

Purdue-Industry Laboratory Modules

A series of computer simulations of state of the art industrial processes were developed to be used as part of the Chemical Engineering laboratory course. The emphasis of these modules is on planning of the experiments and analysis of experimental data rather than detailed process design. Each module is posed as an industrial problem caused by a change of conditions in an existing process, requiring an "experimental" study to re-evaluate the characteristic constants of the process such as reaction rate constants, equilibrium constants, heat transfer and mass transfer coefficients, and phase equilibrium constants. The student teams are expected to design "experiments" (and run it on the computer) which will enable them to evaluate the needed constants.

After the constants are determined, the students can validate these by using them in a "computer simulation", and comparing the simulated and experimental results. After verifying that their constants are reliable, the students use these parameters to study an existing or new process focusing on aspects such as efficient startup, effect of scale up on heat transfer requirements, controllability at desired steady states, optimizing catalyst regeneration schedule, or analyzing the performance in other specific ways.

The project begins with a twenty-minute video-taped "tour" of the process. Each project is given some degree of realism also by assigning financial budget and time constraints. The problems are open-ended in that the conditions of experiments, such as temperature, pressure, flow rates and compositions are under the students' control. The cost and the associated time duration of running experiments vary with the type of experiment and are also functions of operating conditions. Instuctor-controlled statistical fluctuations are built into the simulations so that the results of duplicate experiments are not identical. The students must plan their experiments to obtain data from which, with proper analysis, the required constants may be determined without exceeding their budgetary and time constraints.

The following modules are available:

1. Amoco Resid Hydrodesulfurization Process.
2. Eastman Chemical Methyl Acetate Reactive Distillation Process.
3. Mobil Research and Development Corporation Catalytic Reforming Process.
4. Dow Chemical Company Styrene-Butadiene Polymerization Process.

Two additional modules nearing completion are the Air Products Hydrogen Reactive Cooling and Ethyl Corp. Ethylene Oligomerization processes. Decision on an NSF proposal to port these modules to HP, DEC, IBM RISC and Silcon Graphics workstations is pending. A consumer item based Procter & Gamble process will be the subject of an upcoming multimedia module.

Apart from the undergraduate design laboratory, the computer modules have also been used successfully in reactor design and process control courses in several schools. The programs are configured to run on Sun Sparc workstations with 12 MB of memory. Each module uses less than 10 MB of disk space. Features include easy to use point-and-click user interface and context-specific on line help. The readers are referred to the following articles for more infromation:

References

1. R. G. Squires, G. V. Reklaitis, N. C. Yeh, J. F. Mosby, I. A. Karimi and P. K. Andersen, Purdue-Industry Computer Simulation Modules - The Amoco Resid Hydrotreater Process. *Chem. Engr. Educ.*, 25(2), 98-101, 1991.

2. R. G. Squires, P. K. Andersen, G. V. Reklaitis, S. Jayakumar and D. S. Carmichael, Multi-*media Based Educational Applications of Computer Simulations of Chemical Engineering Processes. Comp. Appns. Engr. Educ.*, 1(1), 25-32, 1992.

3. S. Jayakumar, R. G. Squires, G. V. Reklaitis, P. K. Andersen and L. R. Partin, Purdue-Industry Computer Simulation Modules: (II) The Eastman Chemical Reactive Distillatin Process. *Chem. Engr. Educ.*, 27(2), 136-139, 1993.

Note: The order form for the Purdue Modules is located on page 23 of this newsletter.

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Description of Item	Quantity	Unit Price for Departments		Total
		Supporting	Non-Supporting	
AI Monograph - Volume 1		$15	$15	
AI Monograph - Volume 2		$15	$15	
AI Monograph - Volume 3		$15	$15	
AI Monograph Set		$35	$35	
AI Case Study - Volume 1		$15	$15	
AI Case Study - Volume 2		$15	$15	
AI Case Study - Volume 3		$15	$15	
AI Case Study Set		$20	$35	
GPSS • (license agreement must be signed first)		$25	$25	
PIP		$50	$75	
Process Design Case Study - Volume 4		$15	$35	
Process Design Case Study - Volume 5		$20	$40	
Process Design Case Study - Volume 6		$55	$80	
CACHE Tools [ ] 3 1/2" PC diskette [ ] 3 1/2" Mac diskette		$160	$250	
ChemSep (without/with documentation) • (license agreement must be signed first)		$100/$135	$115/$150	
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PICLES • (license agreement must be signed first)		$95 inital fee with an annual fee of $75	$115 inital fee with an annual fee of $95	

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Interactive Computer Modules for Chemical Engineering Instruction

PICLES: The Process Identification and Control Laboratory Experiment Simulator

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