CACHE NEWS

NEWS ABOUT COMPUTERS IN CHEMICAL ENGINEERING EDUCATION

No. 38 Spring 1994

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 (ComputerAids for Chemical Engineering) Committee. The CACHE Committee was initially sponsored by the Commission on Education of the NationalAcademy 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. 38 Spring 1994

Call for Contributions to 25th Anniversary CACHE CD-ROM

By Peter R. Rony, Virginia Tech, CACHE ad hoc Task Force on CD-ROM Technology

CACHE plans to celebrate its 25th anniversary at the San Francisco AIChE National Meeting, November 13-18, 1994. Timed shortly after this meeting will be the publication of a 25th Anniversary CACHE Monograph (edited by Professor Brice Carnahan) and the distribution of a 25th Anniversary CACHE CD-ROM (edited by Professor Peter Rony). Chemical engineering departments are invited to submit electronic advertisements for graduate study, and chemical engineering faculty are invited to submit contributions to the CD-ROM.

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Call For CD-ROM Files

In this call for CD-ROM files, we seek to identify: (a) those individuals or organizations who desire to contribute to the CD-ROM; and (b) individual or organization memory requirements for the CD-ROM, in quantities of either 1 MB, 2 MB, 3 MB, 5 MB, 10 MB, or 25 MB.

OBJECTIVES

The objectives of the CD-ROM are: (a) to demonstrate new computer technology (e.g., digital images, audio, video, animation, sequential presentations, visualization, and multimedia presentations) useful in chemical engineering education; and (b) to provide a set of software "deliverables" to the target audience—ChE students and faculty—for the CD-ROM. This is an exciting endeavor that we hope will positively influence chemical engineering education during the 1990s. We encourage and solicit your participation.

PRODUCTION AND DISTRIBUTION SUMMARY

One CD-ROM will be provided at no charge to each CACHE member chemical engineering department and to its local AIChE student chapter. CD-ROM discs with associated single-user licenses will also be sold to individual ChE students and faculty for a modest price that has yet to be determined. There will be an initial production run of 200 or more CD-ROM discs. Because of software license restrictions of some software, the 25th Anniversary CACHE CD-ROM might not be sold to individuals or organizations within industry or government. The decision concerning sales of CD-ROM discs to individuals other than students and faculty (i.e., to chemical engineering professionals) has yet to be made.

DEADLINES

The absolute deadline for submission of files will be August 1, 1994. The series of deadlines required to facilitate the production of the CD-ROM include the following:

May 1, 1994
Deadline for submission of intention to contribute to the CD-ROM (advertisement, software, demo, multimedia presentation, and so forth). Submission will include estimate of number of megabytes required.

June 1, 1994
Notification of acceptance of contributions and amount of megabytes that will be made available to each contributor.

August 1, 1994
Absolute deadline for submission of CD-ROM files. Preferred method of submission: HD floppy diskettes for small files (use PKZIP compression techniques); Internet, 128 MB optical discs, or CD-R discs for large files.

September 15, 1994
Completion of a demonstration write-once CD-R disc.

September 15 to October 15, 1994
Testing of demonstration CDR. Removal of bugs in CD-R files.

November 13-18, 1994
Distribution of CD-ROM discs at AIChE National Meeting in San Francisco.

TARGET PLATFORMS

The CACHE CD-ROM target platforms will be DOS and Windows. Each CD-ROM will be ISO-9660 formatted, so perhaps files for Macintosh and UNIX platforms can be included.

ADOBE ACROBAT

CACHE hopes to become an official Acrobat User Group, which would permit it to distribute Acrobat Reader on each CD-ROM. Acrobat Exchange or Acrobat Distiller will be used to create Portable Document Format (PDF) files for all manuals and documents on the CD-ROM. PDF files are already available for the manuals associated with PICLES, DIGEST, POLYMATH, and University of Michigan interactive modules.

CD-ROM REPLICATION

The proposed initial production run will be a minimum of 200 CD-ROM discs.

CONTRIBUTED FILE SIZES

The proposed file space allocated to an individual or organization who contributes to the CD-ROM will be one of the following memory amounts: 1 MB, 2 MB, 3 MB, 5 MB, 10 MB, and 25 MB. Exceptions will be negotiated depending upon the demand for memory space on the CD-ROM.

ADVERTISING AND CONTRIBUTION COSTS

While newspapers and magazines have advertising rates that are dependent upon column inches or a fraction of a page, with CD-ROM discs the "contribution" costs are dependent upon the total number of Megabytes (MB) required. Proposed costs for academic contributors are expected to be at the following levels:

Memory	Cost
1 MB	$ 5.00
2 MB	30.00
3 MB	40.00
5 MB	60.00
10 MB	100.00
20 MB	200.00
25 MB	250.00

Such costs are based upon a guaranteed distribution of one CD-ROM disc to each CACHE member department plus one CD-ROM disc to each AIChE student chapter of a CACHE member department. An initial production run of a minimum of 200 discs is anticipated.

NATURE OF CONTRIBUTIONS

Highest priority for the CD-ROM will be files of interest to chemical engineering students—jobs, graduate schools, executable software, information about ChE professional organizations, software demos, ChE textbook tables of contents, data acquisition software demos, data visualization techniques, and so forth. Based upon brainstorming sessions at the St. Louis CACHE trustees meeting (November 1993), potential contributions to the 25th Anniversary CACHE CD-ROM include, but are not limited to, the following:

A. *CACHE-distributed Software and Electronic Versions of Manuals*
PICLES version 3.1.
DIGEST version 2.1.
POLYMATH version 3.0.
CHEMSEP.
Brice Carnahan templates and manual.
25th Anniversary CACHE Monograph (electronic version). Excerpts from one Purdue multimedia-based simulation video. Example of case study (electronic version).
CACHE catalog of products (electronic version.

B. *Chemical Engineering Department Advertisements for Graduate Study*
The advertisement could range from the electronic version of a one-page printed advertisement (e.g., a black-and-white bitmap image) to a multimedia file of no greater than 25 MB. Only a limited number of 25-MB contributions will be possible on a CDROM disc limited to 640 MB total. Contributions could be more extensive than advertisements in CEE.

C. *DIPPR Software and Electronic Version of Manual*
DIPPR 100-compound student version.

D. *CCPS/SACHE*
"Sampler" of Activities (possibly prepared by a multimedia company).

E. *University of Michigan Interactive Modules*
Introduction, Fluids, Kinetics, and Separation modules, including electronic versions of manuals.

F. *Contributions from Chemical Engineering Faculty*
Coverage of specific chemical engineering areas, such as thermodynamics, transport phenomena and unit operations, kinetics and reactors, controls, laboratory experiments, biochemical engineering, and so forth? Individual areas under the editorial responsibility of associate editors of the CD-ROM?

G. *Listing of Chemical Engineering Department Faculty and Userids*
University of Texas version? [NOTE: Would it be possible to make this listing available to faculty electronically, and thus at lower cost? Updated database version of ChE Bitnet and Internet userids?]

H. *Contributions from ChE Textbook Publishers*
Tables of Contents from chemical engineering textbooks?
Special (perhaps multimedia) contributions from textbook publishers?

I. *Contributions from ChE Software Vendors*
Demos, suitable for execution on different platforms, of ChE software?

J. *Contributions from Employers of Chemical Engineers*
Multimedia presentations directed at job opportunities for ChE students?

K. *Contributions from AIChE*
Presentations provided from AIChE divisions? Presentation from AIChE summarizing organization activities? Information on jobs? This material should be directed toward ChE students.

L. *Essays on Chemical Engineering*
Sources could be from academia or industry. Could be electronic versions of classic essays that have been published during the past 20 years? CEE should have a number of good articles.

M. *CACHE History and Archives*
Electronic versions of past articles on CACHE? Biographical sketches of all past and current CACHE trustees with black-andwhite bitmap photos or caricatures?

N. *Contributions from Foreign ChE Organizations and Individuals Any ideas?*

O. *Contributions from Vendors of Visualization and Multimedia Software and Hardware*
Demos of specific visualization and multimedia application packages from Adobe, Software Toolworks, Microsoft, Kodak PhotoCD, and so forth?

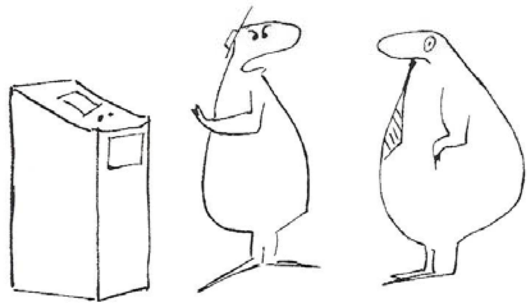
P. *Contributions from Vendors of Data Acquisition/ Control Software and Hardware*
Demos of specific software from Laboratory Technologies, Keithley-Metrabyte, DataTranslation, Camile, and so forth?

Q. *The Pursuit of a Job*
Information from a variety of sources — AIChE, ACS, and so forth — on the process of finding a job.

R. *Information on Internet and Networking*
"Cruising Internet" manuscript? "Gopher" manuscript? WINSOCK TCPIP for Windows manual?

S. *Information on Technical Writing and Communication*

T. *Information on Modern Computer Visualization Techniques*
Observe the use of question marks. The campaign for contributions to the 25th CACHE anniversary CD-ROM begins with this article in CACHE News.



Words of a Graduate Researcher:

"It doesn't matter if you are an endowed professor. It will still take three months for me to fix this equipment."

The Portable Document Format (PDF) in Chemical Engineering

CACHE ad hoc Task Force on CD-ROM Technology

By *Peter R. Rony, Virginia Tech*

Introduction

Since one week before the CACHE trustees meeting at Mt. Crested Butte (July 1993), the chairman of the CACHE ad hoc task force on CD-ROM Technology has used Adobe® Acrobat™ Exchange (Windows, Macintosh) for creating, viewing, printing, annotating, and collating electronic documents; Acrobat Distiller (Windows, Macintosh) for converting PostScript® and Encapsulated Postscript files into Portable Document Format (PDF); and Acrobat Reader (DOS, Windows) for viewing PDF files. This report to CACHE members summarizes some personal observations and conclusions associated with the use of Acrobat technology in chemical engineering.

Purpose and Features of Acrobat Technology

The fundamental purpose of Acrobat technology is to reduce the amount of paper that is created, communicated, duplicated, and archived in organizations. The title of an Adobe Press (copyright 1993), inexpensive paperback entitled, "Beyond Paper" [1 says it all. The basic "gimmick" of the technology is a universal electronic file format, the Portable Document Format (PDF), that reduces the barrier to the communication of information among different computer platforms—DOS, Windows, Macintosh, and Unix. Consider the creation of a complex document consisting of text, embedded images, and equations. With Acrobat software, the following is possible:

- Use of any computer platform—Macintosh, Windows 3.1, DoS, or UNIX [2]—to create the document.
- Use of any application program on these platforms.
- Merging of text, images, figures, and equations.
- Merging of both black-and-white text and color images.
- Inclusion of special "Notes" within the complex document.
- Provision of "Bookmarks" that simplify search within the complex document.
- Provision of "Thumbnails" that simplify search of a single page within the complex document.
- Provision of "Links," which are Hypertext-like capability that facilitate searches within the complex document.
- Reduction in the electronic size of the complex document through the use of compression techniques.

In all cases, the ultimate work product on a given platform is one or more *.PDF files that can be communicated to others as individual files or, alternatively, merged into a single *.PDF file. It should be noted that the Acrobat software for the UNIX platforms will be available commercially by spring 1994. The author has been a beta tester for Acrobat Reader for DOS, which was distributed nationally starting December 23, 1993. Consider the dissemination of a single *.PDF file of a complex document. Once the file is in the possession of the recipient, the following is possible:

- Use of any computer platform—Macintosh, Windows 3.1, DOS, UNIX—to read the document. One restriction is that the processor for Windows or DOS must be at least an 80386.
- Ability to view color images within the complex document.
- The retention of text as strings of individual characters, not as objects that cannot be altered.
- Ability to use "Bookmarks," "Thumbnails," and "Links" to simplify the search process of the complex document.
- Ability to add "Notes" to those that already are present.
- Ability to add "Bookmarks" to those that already are present.
- Ability to add "Links" to those that already are present.
- Ability to search and "Find" a specific word.
- Ability to "Copy" text and images to a clipboard for insertion elsewhere.
- Ability to "Zoom In" and "Zoom Out" to enhance readability of the complex document.
- Ability to "Print" pages within the complex document

at any resolution from the 200 dots per inch characteristic of a FAX machine to 300 or 600 dots per inch characteristic of laser printers.

- Ability to "View" the document on a variety of monitors.
- Ability to "Delete" individual pages from the complex document.
- Ability to "Insert" other *.PDF documents, thus making the document even larger.
- Ability to "Crop" individual pages to remove unwanted spaces or information.
- Ability to adjust viewing on the monitor to "Width of Window," "Fit Page to Window," 50%, 100%, 200%, 400%, 800%, or other sizes within the limits of 50% to 800%.
- Ability to create a "Notes File." Therefore, the proper way to view the potential of Acrobat technology is as follows:
- Basic capability: The ability to convert an electronic document into *.PDF format suitable for multiplatform viewing.
- Value-added capability: The ability to enhance the use of the *.PDF document, through the use of the Notes, Bookmarks, Links, Thumbnails, Zoom, View, and Find capabilities of Acrobat Exchange.

The "basic capability" is already an important step forward primarily because the *.PDF document can be viewed on any platform and because *.PDF files are not limited to black-andwhite printing. The "value-added capability" improves the value of the *.PDF document to a user by saving his/her time in reading and using it.

How Does One Use Acrobat Technology? Acrobat Exchange

The viewing of a *.PDF document is simple. Execute Acrobat Exchange or Acrobat Reader on any platform, open the desired *.PDF file, and view it using Acrobat features. If only viewing is desired, the less-expensive Acrobat Reader should be employed to save costs. Acrobat Exchange permits "value added" modifications to the received *.PDF document, for example, Notes, Bookmarks, Thumbnails, and Links.

The creation of a *.PDF document is relatively straightforward. In its simplest form, using Acrobat Exchange a new "printer," called PDFWriter, is added to your list of selectable printers. Once you finish work with an application program and are ready to print your work, you select PDFWriter (pick specific options) and print directly to a *.PDF file. You can print an entire document to a single *.PDF file, or individual document pages to individual *.PDF files that can be merged at a later date. Each *.PDF file, of course, requires a unique file identification.

When you have embedded figures or bitmaps, PDFWriter may fail as a printer driver to create a *.PDF file. In such a situation, you instead use a PostScript or Encapsulated PostScript printer driver and print directly to a *.PS or *.EPS file. Then you use Acrobat Distiller to convert the PostScript file to *.PDF format.

How Does One Use Acrobat Technology? Acrobat Distiller

Situations exist in which PDF Writer does not have the power to create an acceptable *.PDF file. For example, a complex document with figures or embedded, color images may not yield an acceptable *.PDF file using PDF Writer software. The same situation may occur with embedded equations containing Greek or other symbols. In such cases, Acrobat Distiller is used, and the process of creating a *.PDF file has two steps rather than one:

Step One. Using the application program, you print your work to a PostScript (*.PS) or Encapsulated PostScript (*.EPS) file. This is almost always possible with applications that yield complex documents.

Step Two. Using Acrobat Distiller, you convert the *.PS or *.EPS file to a *.PDF file.

This two-step process takes more time than PDFWriter, but it yields outstanding results. An important characteristic of both Acrobat Exchange and Distiller is the existence of compression of the original file. Acrobat Distiller has failed only once in the author's hands: the conversion of a PostScript file of a Spanish language document. In this case, Acrobat PDFWriter applied to the original Word for Windows document in Spanish succeeded in producing the correct *.PDF file.

Color "Printing" Using Acrobat Technology

Most laser printers are black-and-white printers. Applications programs that have color output must be converted to black and white either prior to printing, or during the printing process (when colors are converted to a gray scale). A Texas Instruments microLaser Plus printer can perform either PostScript or HP II printing, but both yield hard copy that is black and white. An applications program that prints to a PostScript or Encapsulated PostScript file using the TI microLaser PS17 printer driver produces a black-and-white file. Acrobat Distiller can convert the PostScript or Encapsulated PostScript file to a *.PDF file, but it still will be in black and white; in fact, color images may look terrible in gray-scale black and white.

A "gimmick" suggested by John Henry Gross (July 16, 1993) of Adobe Systems in Vienna, Virginia neatly solves the problem of producing color that can be viewed by Acrobat Exchange software. John suggested the inclusion of an additional "virtual" printer driver, the NEC Colormate PS/80, as a printer option within Windows 3.1. Documents that contain color bitmap images are printed to a color Encapsulated PostScript file for this hypothetical NEC Colormate PS/80 printer; such a file, in turn, is converted to a color *.PDF file using Acrobat Distiller. This technique has been tested in Blacksburg and it works perfectly. Time is required for the file conversions since Acrobat Distiller is more computationally intensive than PDFWriter; also, the bitmapped color files are more complex and larger in size. Still, when is the last time that you purchased a conference proceedings that had color images? Or a chemical engineering textbook that had color drawings? Color and chemical engineering seemingly have been inherently incompatible in "the great scheme of things" [i.e., Wiley, Prentice-Hall, McGraw-Hill, and other commercial publishers] over which authors and textbook purchasers have had little or no control.

Personal Experience with Acrobat Technology

The author has had extensive with Acrobat software as of February 1994. Acrobat software technology is excellent. It has met or exceeded expectations. The following are several examples of the use of Acrobat Exchange and Acrobat Distiller.

Acrobat Exchange and Acrobat Distiller were installed on Windows 3.1 without difficulty. Adobe Type Manager (ATM) Type 1 fonts were installed as part of the process.

A 75-page manual written by Paul and Peter Rony using Word 2.0 for Windows was converted to a *.PDF file, TUTCAD9A.PDF, in 4.5 minutes using Acrobat Exchange while in Word 2.0 for Windows. The PDFWriter was selected as the "printer" for the document. TUTCAD9A.DOC had an initial size of 2.467 Mb, which was compressed to only 0.864 Mb for the version of TUTCAD9A.PDF. In this version, all 75 pages have Thumbnails, and there are approximately 60 Bookmarks, 15 Links, and 10 Notes. Only several hours were required to learn and apply Acrobat Exchange to TUTCAD9A.DOC.

Two Lotus Freelance Graphics 1.0 color presentations, CDROM_04.PRE (21 screen color images) and SACH_01.PRE (36 screen color images) were converted to files CDROM_04.PDF and SACH_01.PDF, respectively, using PDFWriter operating within the printer capability of Lotus Freelance Graphics. Surprisingly, PDFWriter produced *.PDF files that exhibited the full color of the original Freelance presentations. There were no embedded color bitmap images, *.BMP, in these two presentations.

One Microsoft PowerPoint color presentation, DATAAQ01.PPT (23 screen images, most with color), was converted to file DATAAQ01.PDF using PDF Writer operating within the printer capability of Microsoft PowerPoint. As with Freelance, the *.PDF file exhibited the full color of the original PowerPoint presentation.

Conversion of Interleaf Publisher version 3.5 Encapsulated PostScript files to *.PDF format using Acrobat Distiller for Windows. The conversion process retained the fine resolution of the "Getting Started with APT" manual edited by the author.

Conversion of the manuals for DIGEST, PICLES, POLYMATH, DIPPR, the Brice Carnahan style sheets, and the University of Michigan interactive modules into *.PDF format. Software such as Aldus Pagemaker for Macintosh, Microsoft Word for Macintosh, and Microsoft Word for Windows 2.0 were employed.

The University of Michigan manuals arrived as self-extracting archive files from either Aldus Pagemaker for Macintosh or Word for Macintosh. The Pagemaker files were printed to Encapsulated PostScript files on the Macintosh and then converted to *.PDF files using Acrobat Distiller for Macintosh. The Word for Macintosh files were opened, then exported to Word for Windows 2.0 files, which were subsequently massaged on an IBM platform, printed to a PostScript file, and then converted to a *.PDF file using Acrobat Distiller for Windows. During this process, color bitmap images of the University of Michigan modules were substituted for the existing black-and-white bitmap images. This multi-step process took time, but the result was worth it.

About fifteen individual files from the collection of Virginia Tech library research guides and database guides (single-page, two-sided guides that facilitate the use of specific sections in or capabilities of the library) existing in WordPerfect 5.1 for DOS format were converted by first importing the DOS files into WordPerfect 5.1 for Windows, then using PDFwriter to create *.PDF files. [February 1994].

A complete manuscript, "MSE Communications Handbook," co-authored by Susan Stevenson and Steve Whitmore, School of Engineering Science, Simon Fraser University, Burnaby, British Columbia, was converted chapter-by-chapter to PDF format using PDFWriter and Word 2.0 for Windows. This manuscript is being tested in a junior-level ChE controls laboratory. [February 1994]

Finally, a Spanish version of Microsoft Word for Windows 2.0 successfully converted, using PDFWriter, a document to a *.PDF file. The resulting *.PDF file correctly exhibited the special Spanish characters.

One failure must be reported. A third Lotus Freelance Graphics file, AICHE05.PRE, which contained about 12 embedded color bitmap images (*.BMP files), took a long time to be converted by PDFWriter and produced a huge *.PDF file that contained poor black-and-white versions of the color bitmaps. The use of the TI microLaser PS17 driver (to create an AICHE05.EPS file) and Acrobat Distiller (to create the corresponding AICHE05.PDF file) succeeded in producing poor black-and-white versions of the color bitmaps. John Henry Gross, as reported above, suggested the solution to the problem: produce AICHE05.EPS using the NEC Colormate PS/80 color PostScript printer driver instead of the TI microLaser PS17 black-and-white PostScript printer driver. This tactic succeeded.

Applications of Acrobat Technology to Chemical Engineering

The task force would like to propose specific applications for Acrobat technology within chemical engineering. The following includes speculations on the logistics associated with the use of Acrobat.

Conferences: The Distribution of Publication Responsibility

Assume a ChE conference with approximately 150 participants. This number of participants places the conference at the low end of the scale of CD-ROM production. Nimbus Information Systems has a minimum order of 200 CD-ROMs, but other manufacturers offer their services for as low as 100 CD-ROMs pressed. Nimbus Information Systems quoted, more than a year ago, $1000 for mastering costs, $250 for pre-mastering costs (assembly of files in the proper order on a large hard disk, conversion to ISO-9660 format), $2.00 per CD-ROM in quantities of 200-500, and $1.65 per CD-ROM in quantities of 500-999. Assume also the following:

- One CD-ROM of the final conference proceedings sent to each participant.
- One CD-ROM of the final conference proceedings sent to each of 100 CACHE member departments.
- 100 CD-ROMs of the final conference proceedings reserved for sale to other organizations.

A total of 350 CD-ROM disks need to be pressed, at a total cost of $1950, or $5.57 per CD-ROM disk if Nimbus Information Systems is selected as the manufacturer.

Now consider the logistics of the creation of the files for this CD-ROM. Like the Instrument Society of America and other organizations, the Conference organizers would provide style sheets that request each speaker to submit final copy in a certain style: font sizes, font types, figure sizes, margins, spacing, alignment, and so forth. Speakers would be free to select their computer platform and their application program (word processor or desktop publisher), but they would be expected to adhere to a certain character font style (for example, Times Roman rather than Helvetica, Arial, Bookman, or Courier). In other words, the responsibility to adhere to a specific manuscript style becomes distributed, rather than focused in a single person, for example, the secretary to a co-chairman of the conference.

If the speakers have Acrobat Exchange and/or Acrobat Distiller, they can be encouraged to produce a final, *.PDF file for their contribution to the conference. This situation may exist within two years, but it does not exist as of February 1994. Alternatively, the speakers are asked to print their contribution to a single PostScript or Encapsulated PostScript file, which is sent to a co-chairman of the conference. The secretary to this co-chairman has Acrobat Distiller, and converts the *.PS or *.EPS file to a *.PDF file. This secretary then focuses her time not on the retyping of manuscripts, but rather on "value-added" tasks such as the provision of Bookmarks, Thumbnails, Links, and perhaps even Notes to the individual *.PDF documents.

The co-chairman is responsible for making arrangements for a CDROM manufacturer to place the *.PDF documents on the ChE conference CD-ROM. The CD-ROM would contain 50 to 100 individual *.PDF documents that could be viewed using Windows, Macintosh, DOS, or UNIX platforms.

Acrobat Pricing: Evolution vs Revolution

One "chicken-and-egg" problem remains: Would the speakers and participants have Acrobat Readers to view the conference CD-ROM with its contained *.PDF files? In two years, they may; today they do not. For commercial organizations, list prices are:

Acrobat Exchange	$195
Acrobat Personal Distiller	$695
Acrobat Reader (50 users)	$2500
Acrobat Starter Kit	$1500
Network Distiller	$2495

Mail order software firms such as PC Connection (800-800-5555) or Micro Warehouse (800-367-7080) offer Acrobat software at one-copy prices of approximately:

Acrobat Reader for Windows	$ 25
Acrobat Exchange for Windows	$125
Acrobat Personal Distiller for Windows	$430
Acrobat Starter Kit	$670
Acrobat Network Distiller for Windows	$1550
Acrobat Reader (50 stations)	$1560

The Acrobat Starter Kit is a superior purchasing strategy for corporate organizations; it contains 10 licenses for Acrobat Exchange and 2 licenses for Acrobat Distiller. For academic institutions, an "evolutionary" strategy would focus on alternatives that provide initial quantities in the range of 25 to 100 copies of Acrobat Reader, Exchange, or Personal Distiller.

1 Acrobat Exchange	$99
5 Acrobat Exchange	$250
25 Acrobat Exchange	$1125
50 Acrobat Reader	$750
100 Acrobat Reader	$1200
100 Acrobat Exchange	$4395
1 Acrobat Personal Distiller	$295

For academic institutions, a "revolutionary" strategy would attempt to provide access to Acrobat technology to an entire campus, including students. Academic prices will be, according to a January 15, 1994 proposal:

500-1999 Acrobat Exchange	$36	each*
2000-4999 Acrobat Exchange	$34	each**
5000+ Acrobat Exchange	$32	each***
Acrobat Personal Distiller	$295	each
Acrobat Network Distiller	$750	each

Notes:	*	500 to 4999 Acrobat Readers are $4 each
	**	5000 to 19999 Acrobat Readers are $3 each
	***	20000+ Acrobat Readers are $2 each

With the quantity pricing for Acrobat Exchange and Acrobat Reader, there is a required "Subscription Service Fee" of 15% per year for the initial contract amount. Also, Educational Network Distiller can be purchased for $750 each.

Confirmation of these prices can be obtained from Mr John Cook, The Douglas-Stewart Co., 2402 Advance Road, Madison, Wisconsin 53704. Phone: 1-800-279-2003. FAX: 608-221-5217. Email: 73324.1105 @ CompuServe.COM.

A mail-order price of $125 for Acrobat Exchange is not unreasonable for any organization, including an academic department. Keep in mind that two versions of Acrobat Exchange are contained in the software package, one for the Macintosh and one for Windows. Based upon the above prices, the cost of reading a conference CD-ROM also can be distributed to the recipients. It is recommended that, where possible, Acrobat Exchange be purchased, not Acrobat Reader (which provides no value-added editing capabilities to *.PDF files).

CACHE Should Collect/Archive Electronic Files

CACHE should collect and archive the original electronic files to the documentation that it provides along with CACHE-marketed software. All CACHE Case Studies should be held by CACHE in electronic form (if not past case studies, then future ones). CACHE should from this point forward act as if its future distribution mechanism will be exclusively electronic. The option to print electronic files to hard copy always exists, but not the reverse (unless scanner technology is used). Does CACHE wish to move "beyond paper?"

CACHE Software Distribution: *.PDF Files of Software Manuals

The distribution of software marketed by CACHE can be subdivided into two categories, (a) executable files, and (b) manuals and publications. Manuals for CACHE-marketed software offer an immediate target for Acrobat technology. Consider the manual, "Chemical Engineering Optimization Models with GAMS," which is Case Study No. 6 of the CACHE Design Case Studies Series. This 50- to 100-page manual could be converted into a single *.PDF file, which probably could be distributed on a single 3.5-inch HD floppy diskette suitable for reading either on Windows, DOS, UNIX, or Macintosh platforms. The cost of printing the manual, or portions thereof, is distributed to the recipients. CACHE saves printing, storage, inventory, and postage costs by relying on Acrobat technology for its manuals. Further, the manual, being in compressed Acrobat Exchange format, could be sent electronically to a department by Internet.

CACHE Distribution: Internet Transmission of CACHE Products

Acrobat Exchange and Distiller technology both compress files and permit their presentation in the very appealing *.PDF format when viewed with Acrobat Exchange. Using shareware XXDECODE techniques, the *.PDF file can be converted to a character-based *.UUE file that can be transmitted by email over Internet. The recipient would use XXDECODE techniques to decode and restore the original *.PDF file. Alternatively, FTP servers could be used to transfer the #.PDF file in binary form directly from an anonymous file server to a user.

The Future for the Portable Document Format (PDF)

Quantity discounts can be obtained for CACHE member departments if Acrobat software is purchased under the umbrella of CACHE as an Acrobat User Group. Adobe Systems has an excellent track record with its PostScript and Encapsulated PostScript file formats as well as its Adobe type fonts. It should be equally successful with the Portable Document Format (PDF). Adobe is likely to be a winner in this area, so CACHE should be cognizant of the opportunities that will present themselves when PDF becomes a standard. In a private communication with an Adobe Systems marketing specialist in Vienna, Virginia, the task force chairman learned that the American Chemical Society has been evaluating Acrobat technology since January 1993. Apparently they like the technology and are considering its use in a number of different applications.

From Beyond Paper (see footnote 2) comes the following concluding paragraph in the section on "The Future" (page 116):

> "Adobe Acrobat technology will address the needs of the many organizations that publish documents written in the Standard Generalized Markup Language (SGML), or other file formats, such as RTF (Rich Text Format). New Acrobat extensions and products will enable both

file by combining the native file and its structure with the corresponding PDF file; filters will identify the structure of numerous other file formats, such as Microsoft Word, WordPerfect, and FrameMaker. Automated links, structure-based full text searches, and other features, such as the ability to extract SGML from a "structured" PDF file, will give professional and commercial publishers all the benefits of electronic document exchange without losing document structure.

These and other technologies will ultimately change the economics of publishing. The physical constraints of paper and the associated restrictions of its delivery will eventually disappear. Information will still be printed, but it will no longer be a necessary step in the distribution process. In a few years it will cost less to deliver phone books to the entire country than it now costs to deliver them to one small town; it will cost less to deliver 10,000 color catalogs than it does today to deliver one; it will cost less to deliver all the business magazines than it does today to deliver a few sheets of paper."

In the 1990s, it is the combination of the huge capacity of CDROM disks — 640 Megabytes — plus their low cost — $1.50 per disk in large quantities — plus a standardized, portable document format-PDF — that will now revolutionize technology that previously has vitally depended upon the printed page. The point is that with a *.PDF file, any reasonable computer, and a laser printer, highquality hard-copy production is always available. But it will be discretionary...and distributed.

For Additional Information...

John Cook, of The Douglas Stewart Co., has recently provided the following information about Acrobat and PDF:

(a) "Chapter 2. Overview," pp. 5-14. This is an excellent document that explains the detailed structure of a PDF file. The general properties of such a file are: PostScript language imaging model, portability, compression, font independence, single-pass file generation, random access, incremental update, and extensibility.

(b) Adobe Acrobat Product Features and Benefits, 4 pp.

(c) Adobe Acrobat Products and Technology, 2 pp.

(d) Adobe Acrobat Press Backgrounder, 7 pp.

(e) Adobe Acrobat advertising brochure.

(f) Current Evaluators of Adobe Acrobat (January 28, 1994).

(g) Press releases: "Aldus Announces Support for Adobe Acrobat" (October 20, 1993); "Adobe Acrobat pdfmark Support Featured in Corel Ventura 4.2 Software" (October 20, 1993); "Frame Technology Expands On-Line Authoring and Distribution Capabilities" (October 20, 1993); "Adobe Systems Licenses Adobe Acrobat Software to J. P. Morgan" (October 20, 1993).

(h) "Key Features of Acrobat Search and Composer." Software beta testing to begin in March, product to begin shipping in June. Composer is an index-creation tool that extracts the entire text of a PDF file and creates a separate index. Search looks at the Composer index file rather than at the entire document.

References

1. Patrick Ames, "Beyond Paper," Adobe Press, Mountain View, CA, 1993.

2. Acrobat software for the Unix platform will be available commercially sometime in spring 1994.

Teach Hands-On Process Control With PICLES Version 3.1

By Douglas J. Cooper, University of Connecticut

Introduction

Picles, the IBM PC compatible Process Identification and Control Laboratory Experiment Simulator, is now being used in more than 30 process dynamics and control courses around the world. Picles is an easy-to-use educational simulator that lets students obtain extensive hands-on experience while studying this often abstract and mathematical subject.

Picles contains several real-world processes which students can use for experimentation and study. They can manipulate the input variable of any of the processes, shown in color-graphic display, to obtain pulse or step test data for identification analysis. Picles lets them print their own plots and data files so they can use whatever methods you teach them for this analysis and for controller design. After designing a controller, they can return to Picles and obtain immediate, visual feedback on controller performance for set point tracking and for disturbance rejection.

One real power of Picles is that students can quickly and easily explore real applications of most of the theoretical concepts you teach in your course. You can assign homework problems throughout the semester which can be completed in only 20 or 30 minutes that strengthen their understanding and their motivation as their appreciation for the subject increases. Such continual reinforcement in application of theory combined with the laboratory experiences already at your school creates a learning environment never before possible for process dynamics and control.

In this article, a review of Picles' processes and controllers is first presented. Then, the focus shifts to highlight some of the new features of Picles version 3.1. The discussion of new features is organized to illustrate how students can use Picles to gain hands-on experience in the application of a few subtle but important theoretical concepts in only a few minutes time.

The Picles Processes

Picles has six processes for study, including:

- Gravity Drained Tanks-In-Series Pumped Tank
- Heat Exchanger
- Design a Process
- Mystery Processes, and
- Distillation Column

The Gravity Drained Tanks-In-Series is shown in Figure 1. The manipulated variable is the flow rate of liquid entering the first tank and the controlled variable is liquid level in the second tank. This process displays a nonlinear behavior

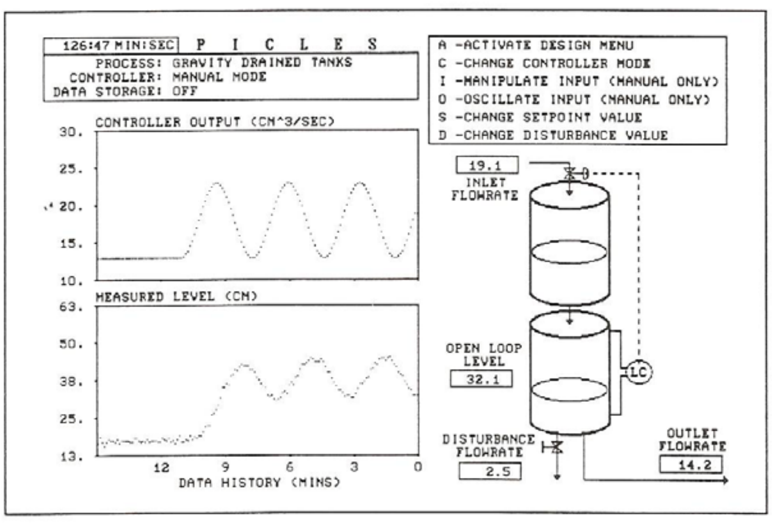


Figure 1 - Gravity Drained Tanks in manual mode with oscillating controller output.

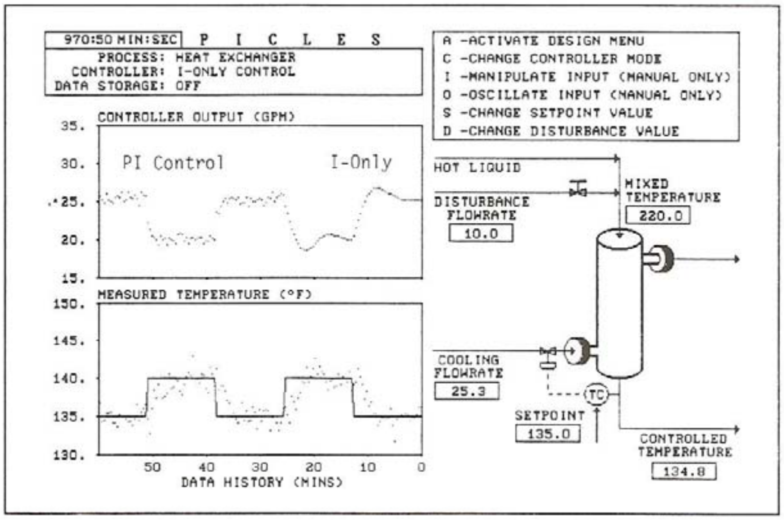


Figure 2 - Heat Exchanger first under PI control and then Integral only control.

because drain rate from each tank is proportional to the square root of the hydrostatic head.

The Pumped Tank (not shown) is a single tank with a pump on the discharge line, rather than the gravity drain of the previous process. The manipulated variable is the flow rate out of the bottom of the tank and the controlled variable is liquid level in the tank. This system presents an interesting control challenge because of the integrating nature of the process.

The counter-current Heat Exchanger is shown in Figure 2. The manipulated variable is the cooling flow rate on the shell side and the controlled variable is temperature exiting the exchanger on the tube side. This nonlinear process has a negative steady state gain and also a nonminimum phase or inverse disturbance response.

Design a Process has a menu shown in Figure 3 which permits students to input individual transfer functions describing process input/output dynamics and disturbance/ output dynamics. As shown, users can specify a steady state process gain, up to three lag time constants, a dead time, and one lead time constant. Thus, students can isolate and study specific process characteristics as well as study problems found in textbooks. Once the simulation is started, students see bar graphs similar to those displayed in commercial equipment in the process graphic area.

The Mystery Processes (not show) are processes with the gains, time constants, dead times and degrees of nonlinearity pre-specified and hidden from the student. Because there is no *a priori* indication of process behavior, the student must rely on analysis and experimental procedures they learn in class for controller design and validation. This is similar to the procedure which must be followed when tuning controllers from a remote control room. The Mystery Processes are ideal for project work later in the semester.

The Distillation Column (not shown) separates water and methanol. There are two interacting control loops on this process. The top loop manipulates reflux rate to control distillate composition. The bottom loop manipulates steam rate to the reboiler to control bottoms composition. Picles offers static and dynamic decoupling controllers so students can explore these model based methods for minimizing loop interaction.

DESIGN A PROCESS

PROCESS TRANSFER FUNCTION

$$Gp(s) = \frac{Kp\ (TLs+1)\ \exp\ (-DTs)}{(T1s+1)\ (T2s+1)\ (T3s+1)}$$

DISTURBANCE TRANSFER FUNCTION

$$Gd(s) = \frac{Kp\ (TLs+1)\ \exp\ (-DTs)}{(T1s+1)\ (T2s+1)\ (T3s+1)}$$

DESIGN MENU

	PROCESS	DISTURB	
Title NEW FEATURES			
Process Gain:	1.78	1.00	
First Time Constant:	121.0	150.0	SEC
Second Time Constant:	43.0	75.0	SEC
Third Time Constant:	17.0	0.0	SEC
Dead Time:	9.4	0.0	SEC
Lead Element:	- 32.0	0.0	SEC

Figure 3 - Design a Process menu for specifying process character with a transfer function.

The Picles Controllers

The control algorithms in Picles are all PID (ProportionalIntegral-Derivative) and can be custom tuned and implemented with just a few key strokes. The Picles controller selection menu offers:

- Manual Control
- P-Only Control (Manual Bias)
- I-Only Control
- 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 Decouplers (Distillation Column Only)

Although PI and PD controllers are not explicitly listed, PI can be implemented for any of the PID selections by setting the derivative time to zero, as was done in the example shown in Figure 4. A PD controller can be approximated by setting the reset time to its maximum value for any of the PID controllers.

This list of controllers permits exploration of a variety of concepts. The PID Position algorithm lets students observe the consequences of reset windup. The PID with Derivative on Error algorithm lets them learn about derivative kick. The Smith Predictor enables students to learn the benefits of model based dead time compensation and the Feed Forward element lets them learn how disturbance rejection works using both static and dynamic compensators. Finally, for the Distillation Column, decouplers can be employed so students can explore methods for minimizing loop interaction.

Computer System Requirements

Picles is designed to run in the DOS environment on IBM compatible personal computers. The computer must have EGA or VGA graphics capability and the processor should be an Intel '386 or faster.

New Features

Oscillating Input

One new capability in Picles 3.1 is an oscillating input generator. As shown in the commands listed in the upper right corner of Figure1, the user simply presses "O" and a menu pops up (not shown). The user then specifies the desired mean value, amplitude and period of oscillation on this menu, presses the "home" key, and then watches as the process responds to their input oscillation specifications.

In this example, the upper plot of Figure 1 shows the controller output as it manipulates the inlet flow rate to the top tank. The lower plot shows the open loop measured level in the second tank as it responds to this input trace. As expected, a steady oscillation in the input variable produces a steady oscillation in the output variable.

So after you discuss frequency domain concepts such as amplitude ratio and phase lag in class, students can spend a

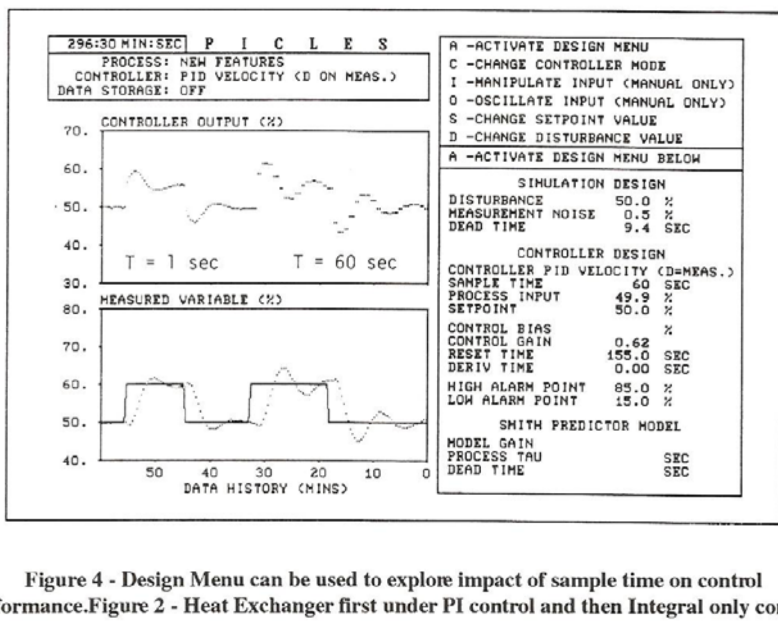


Figure 4 - Design Menu can be used to explore impact of sample time on control performance.Figure 2 - Heat Exchanger first under PI control and then Integral only control.

few minutes on Picles and see for themselves what these concepts mean when the process under discussion is not simply a hypothetical transfer function. After some exploration, they can use the new plotting option discussed later in this article to create plots to submit as part of a homework assignment.

Additionally, they can use Picles to understand that amplitude ratio and phase lag will change as operating regime changes for nonlinear processes. Another idea is to have them run and plot a sequence ranging from low to high oscillation frequencies and literally generate information for a Bode plot from a process they can see and relate to. Combine this with the abstract transfer function discussions typical of the classroom and student understanding will soar.

Integral-Only Controller Mode

Figure 2 shows one quick study of the Integral mode of a PID controller. The application for this study is the Heat Exchanger process. The lower plot of Figure 2 shows a series of two square wave set point steps represented as a solid line. Tracking this set point trajectory in the lower plot is sampled data from the controlled heat exchanger outlet temperature. As shown, the measured temperature data has a fair amount of random noise. (Noise level can be adjusted at the user's discretion by using the Heat Exchanger Design Menu, which is similar to that shown in Figure 4).

For the first set point square wave, a PI controller is employed. For the second set point square wave, an integral only (I-Only) controller is employed. Controller tuning was adjusted in the Design Menu so that the set point tracking performance of measured temperature was similar for both controllers.

The feature of interest in this study is displayed in the upper plot. As shown, the PI controller computes a controller output (and thus process input) which is noisy in correspondence to the noise of the measured temperature shown in the lower plot. This results from the Proportional mode of the PI controller, which computes each controller output adjustment as directly proportional to the current controller error. The measurement noise is reflected in the controller error (defined as set point minus measurement) and thus the computed controller output.

The controller output shown in the upper plot for the second set point square wave, where the controller is I-Only, shows a virtually noise free trajectory. This is because the Integral mode is a successive summation of controller error. One result of this summation (or integration) is that noise is smoothed or averaged over time.

Thus, class lecture can present the mathematics of Proportional versus Integral mode, and diagrams can be drawn to explain the what's, how's and why's. But a Picles session in which students see this and similar phenomena play out on the screen, using processes which are tangible and intuitive, is an extremely effective way to educate and help students translate abstraction into reality.

Design a Process

Most every course in process control, sooner or later, devolves into an extended discussion of transfer functions. Picles 3.1 now has a Design a Process feature, shown in Figure 3, which makes the study of transfer functions significantly more concrete to students. Design a Process lets students specify the complete process input/output and disturbance/output relationship.

Students can now specifically explore the open and closed loop behavior of a true first, second or third order process quickly and easily. They can compare controller performance for different dead times and then study the benefits of dead time compensation by using the Smith predictor. They can study how different disturbance characteristics impact feed back control and feed forward control design and performance. And they can study and understand the implications of a lead element (process zero) with just a few key strokes.

One interesting idea is to approximate the behavior of the Gravity Drained Tanks-In-Series, Heat Exchanger or even one of your laboratory processes with a linear transfer function. This approach is the one taken in the popular textbooks for controller design. Then, they can use Design a Process to study this simplified representation and develop process understanding and a controller design. Finally, they can return to the original Picles process or to the laboratory and see first hand the strengths and weaknesses of a linearized process approximation when the application is a real-world process with noise and nonlinearities.

Controller Sample Time

Another new feature is the ability to adjust controller sample time, as shown in the Design Menu of Figure 4 under the Controller Design heading. This figure shows the closed loop response of a process to square wave set point steps, represented as a solid line on the figure. The process under study is a Design a Process with parameters specified as shown in Figure 3.

A PI controller is being employed in this study. This can be determined because a PID Velocity (Derivative on Measurement) controller is specified in the Design Menu. However the Deriv Time is set to zero in the Menu, thus yielding a PI controller.

Figure 4 shows two sets of responses. The first set point square wave shows the performance of the PI controller, with settings as shown in the Design Menu, except that controller sample time is set at 1 second. The second set point square wave shows performance when all parameters remain constant except controller sample time has been increased to 60 second. As shown, performance clearly degrades as controller sample time is increased.

Thus, students can now explore with little effort the implications of sample time relative to closed loop performance. They can study the relationship between sample time and the overall time constant of a process to develop

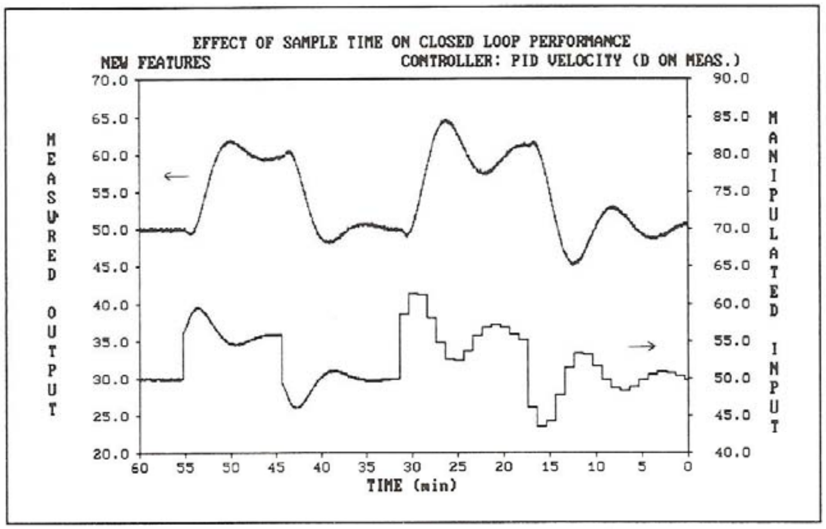


Figure 5 - Demonstration of new Plot facility.

rules for setting this important parameter. They can also explore how much the closed performance of a system will suffer if, for example, the computation load on a real control computer forces them to specify a sample time that is longer than they might normally desire.

Plotting Facility

Picles 3.1 now has a flexible plotting facility so students can quickly and easily prepare plots for homework. Figure 5 shows one possible Picles plot of the same response shown in Figure 4. The plotting facility enables a user to display the measured output against either the manipulated input or the set point trajectory.

The plotting facility permits the user to specify the tick mark spacing, to set the maximum and minimum values for the major axes, and to turn a plot grid on or off as desired. Plots can be produced on most dot matrix and laser printers using the DOS "Graphics" command. Thus, students can generate and customize plots for homework as required to defend their engineering decisions.

Final Notes

As several users have reported, simple exercise such as those discussed here can be the difference between glazed eyes and broad smiles. More ideas for using Picles in the classroom can be found in [1,2].

For additional information about Picles and available teaching materials, contact:

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Acknowledgements

I would like to thank the students whose creative efforts and hard work have made PICLES possible. These include *Architects*: Allen Houtz, Jerry Bieszczad, Robert Schlegel and Adam Lalonde, and *Builders*: Scott Ferrigno, Ralph Hinde Jr., Larry Megan, C. Steven Micalizzi, Phil Pearson and Yan Wan. I would also like to thank Prof. G. Michael Howard for his input and sage advice.

Literature Cited

[1] Cooper, D. J., "PICLES: A Simulator for Teaching the Real World of Process Control," *Chem. Engr. Education*, **27**, 176 (1993).

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The Adobe Acrobat User Group Program

By Rye Livingston, Adobe Systems

In an effort to promote Adobe Acrobat technology, Adobe Systems announced the Adobe (TM) Acrobat (TM) User Group Program late in 1993. The bottom line is that only a single $100 payment is required for two copies of Acrobat Distiller, two copies of Acrobat Exchange, and copies of Acrobat Readers to all group members. Though not applicable to academic environment, readers of CACHE News may have their own ideas for user groups. CACHE has already submitted an application to participate in the Adobe Acrobat User Group program.

The key issue is the definition of a user group. According to the Adobe License Agreement:

> "1.4 'User Group' means a computer user group that meets, at a minimum, the following criteria: (i) the User Group must have elected or appointed officers that represent the Members, (ii) the User Group must have existed for at least six (6) months prior to the date the Application is executed, (iii) the User Group must have a minimum of forth (40) Members; (iv) the primary purpose of the User Group must be to disseminate information regarding computer hardware and/or software usage, and (v) the User Group must have an established means for distributing information, e.g., via a newsletter Adobe may, in its sole discretion, waive one (1) or more of the above criteria on a case by case basis."

CACHE meets all five criteria. An accompanying letter read as follows:

> Dear User Group Officer,
>
> Thank you for your interest in the Adobe Acrobat User Group Program. We have designed this program to provide user groups with all of the software needed to begin communicating electronically using Adobe Acrobat. For details, please review the "Questions & Answers" below. By providing Acrobat Reader to all members of your group, you can distribute your newsletters, meeting minutes and other user group communications in the most time-efficient, cost-effective way—electronically, instead of on paper. Don't miss this unique opportunity to help your group speed ahead on today's digital highways. Send us your application today!
>
> Rye Livingston, User Group Manager
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> Mountain View, CA 94039-7900
> Phone: 415-961-4400
> FAX: 415-961-3769

Adobe Acrobat User Group Program Question & Answers

What is the Adobe Acrobat User Group Program?

The Adobe Acrobat User Group Program is designed to give computer user groups an easy way to explore the electronic communication capabilities of Adobe Acrobat Software.

What is Adobe Acrobat?

Adobe Acrobat is a family of software products that enable users to create and distribute electronic documents in a cross-platform file format, the Portable Document Format (PDF). PDF files preserve the essential look and feel of a document, regardless of the originating hardware platform, operating system, application software, or fonts.

What kinds of products does Adobe Systems develop?

Founded in 1982, Adobe Systems Incorporated develops, markets and supports computer software products and technologies that enable to create, display, print and communicate all kinds of electronic documents.

Where should I direct technical questions?

As an Adobe Acrobat User Group Program participant/ member, you receive the same technical support services as other Adobe Acrobat Reader users. At no cost, except for phone charges, you can access basic support services: an electronic bulletin board and an automated technical support phone system. You can also choose from a selection of extensive fee-for-support services.

How do I apply?

Obtain and complete the Adobe Acrobat User Group Application and License Agreement and mail them with your $100 payment to:

Adobe Acrobat User Group Program
Adobe Systems Fulfillment Center
P. O. Box 6458
Salinas, CA 93912-9899

You will receive a response within four weeks. And if your business or organization is approved, your Acrobat software will arrive in four to eight weeks.

If approved, what will I receive?

- One Acrobat Distiller (TM) package (including a 2-user license for Macintosh (R) or Windows (TM)).
- Two Adobe Acrobat Exchange packages.
- One CD-ROM containing Acrobat Reader software for distribution.
- Information to help you get started.

Who is eligible for the user group program?

Every user group that meets the requirements on the License Agreement and Application is eligible to apply.

How do I start distributing electronic files?

Each program receives two copies of Acrobat Exchange. This software allows you to convert any electronic document you create, on a Macintosh or Windows system, into a PDF file for distribution. You also receive Acrobat Distiller, so you can convert any PostScript (TM) language file, regardless of origination, to PDF. And you receive a disk of sample PDF files for your library.

What are some of the ways in which my user group can take advantage of Acrobat?

In user group environments, Acrobat software can electronically link members and officers, for the first time, to global libraries of visually rich information. You can also use Acrobat to develop and share electronic reports, newsletters, meeting minutes, product reviews, proposals and other documents that incorporate text, photos, graphics, illustrations and fonts.

What are the minimum system requirements needed to run Acrobat Reader?

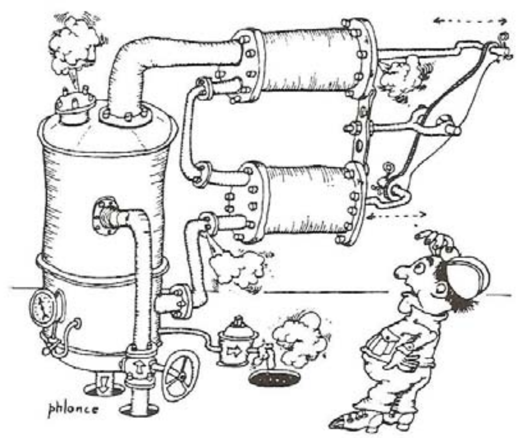
For Windows (TM)

- 386- or 486-based personal computer (486 recommended)
- Microsoft (R) Windows 3.1
- 4 MB of RAM (8 MB recommended)
- VGA, SuperVGA or higher-resolution display adapter supported by Windows 3.1
- 1.44 MB 3.5" floppy disk drive

For Macintosh (R)

- Macintosh Plus, SE, Clasic (R), LC, II, PowerBook (TM), Centris (R), or Quadra (TM) (II, PowerBook, Centris or Quadra recommended)(Trademarks or registered trademarks of Apple Computer, Inc.)
- Apple (R) System Software version 6.05 or greater (version 7.0 or greater recommended)
- 2 MB of application RAM (4 MB recommended)
- 800K or Apple SuperDrive floppy disk drive

Windows is a trademark of Microsoft Corporation. Acrobat is a trademark of Adobe Systems.



Graduate Research at the University is conducted only on the most modern equipment.

WAMMAS - A Program to Aid Industrial Waste Minimization

by Anthony G. Collins, Clarkson University
Donald E. Smith, Jr., Coyne Textile Services
Joseph V. DePinto, State University of New York at Buffalo

This article describes a computer program developed for the New York State Center for Hazardous Waste Management. The material for the article is taken from the final report to the center. Of most potential benefit to the educational community is the tutorial component of the program that teaches the concepts of waste minimization. Readers may also find the example application of expert system technology of interest and use.

While many segments of the community (e.g. industrial, legislative, and academic) agree that, currently, suitable techniques exist to control, monitor, and reduce the production and disposal of industrial hazardous materials, little has been done to introduce these known techniques or identify areas requiring innovative approaches. One of the primary reasons for this situation is the lack of a real understanding as to how a waste minimization audit can identify waste minimization alternatives. A less obvious reason is the reluctance of many industries to allow external assessment of their production processes by knowledgeable waste reduction experts in what are often viewed as sensitive areas. This attitude slows the transfer of existing technology and the development of new approaches.

Rule-based expert systems are one of the new techniques available that have possible application to waste minimization. Potentially these systems can provide a rational input to production decisions regarding the control and minimization of hazardous wastes. Expert systems could be constructed from a knowledge base consisting of a waste minimization audit, applicable regulations, and production alternatives. The system output will provide management with production decision guidance regarding hazardous waste issues.

To meet the goals of improving technology transfer and evaluating the applicability of expert system technology, the Waste Minimization Management Advisory System (**WAMMAS**) was developed under the sponsorship of the New York State Center for Hazardous Waste Management. The computer program is intended to focus industrial attention on reducing waste at its source rather than through the traditional, end-of-pipe techniques (treatment, storage, and disposal). A combination of tutorial activities and reports of successful waste minimization techniques meets the technology transfer objective. The program also presents an innovative approach, via two examples, to the manufacturing decision making process through an expert system management aid. The management aid demonstrates how industry can account for the environmental impacts of an industrial process.

The original project proposal submitted to the New York State Center for Hazardous Waste Management to develop the program called for 1) implementation of a waste minimization audit at an ALCOA facility (located in Massena, NY), accumulating information regarding relevant legislation and the identification of process alternatives to minimize waste , 2) development of a rule-based expert system using the information gained under the first objective as the database, 3) evaluation of process alternatives that would minimize hazardous waste generation through the use of the rule-based expert system, and 4) evaluation and documentation of the methodology of the approach.

At the request of the NYS Center for Hazardous Waste Management, a significant change to the original project proposal was incorporated. In addition to demonstrating the feasibility of the expert system approach to minimizing hazardous waste at an industrial site (ALCOA), other components were to be incorporated to assist with the dissemination of hazardous waste management principles to all New York State industrial generators of hazardous waste.

Background

Many economic, regulatory, and legal incentives exist to motivate an organization to undertake a waste minimization program. Raw material, waste disposal, and energy costs continue to rise. Present state and federal regulations require a waste minimization program to be in place. This policy was announced by the federal government in the Hazardous and Solid Waste Amendments (HSWA) to the Resource Conservation and Recovery Act (RCRA) in 1984.

The New York State Department of Environmental Conservation has a set of similar policies via the 1987 Organization and Delegation Memorandum #87-13. These policies have lead to regulations calling for a waste minimization program to be in place to reduce the volume and toxicity of wastes generated. Other regulations restrict the dumping of industrial by-products in landfills. The list of compounds requiring permits is increasing as more information becomes available on these substances. There are also laws in place which make any party who handles hazardous substances liable for its ultimate disposal. The incentives to develop a comprehensive waste minimization program are, therefore, numerous and obvious.

How does a waste minimization program work? Traditionally industries treated and disposed of wastes generated by their process almost as an afterthought to their operation. Wastes were collected as they arose from the industrial process and were often treated en *masse*. These end-of-pipe wastes were generated by industries without regard to minimization and were typically high volume, dilute, and complex which made them difficult and costly to treat. The goal of hazardous waste management is to encourage management and staff to think in terms of a waste management hierarchy. The priorities are ranked as follows.

1. Waste Elimination
2. Waste Reduction
3. Recovery and Recycling
4. Treatment
5. Storage and Disposal

The first two priorities are referred to as source reduction. Together with the third priority, recycling, they define waste minimization. Only as a last resort should treatment, storage, and disposal techniques be utilized.

Source reduction is any activity that reduces or eliminates hazardous waste where it is generated, usually within an industrial process. This elimination or reduction may be accomplished in a number of ways:

- input material changes,
- process technology alterations,
- product substitution/modification, and
- good operating practices.

Recycling includes any recovery and reuse of materials either on- or off-site prior to treatment, storage, or disposal. Source reduction and recycling are effective tools for saving money, reducing liability, complying with regulatory limits, and protecting human health and the environment.

WAMMAS Development

WAMMAS has been developed to be used by a range of individuals, from owner/operators of small industrial concerns to the environmental engineering specialists employed by major industries. The advisory system demonstrates how a materials balance, which attempts to account for all inputs (raw and recycled materials and water) and outputs (product, processing losses, waste streams, treatment discharges, treatment residuals, etc.) for a given production system, is at the heart of a waste audit. A waste audit in turn should identify, amongst other things, the sources, quantities, and types of waste being generated. After reviewing this material, the advisory system user is then in a position to construct a materials balance for their own process, obtain information from the materials balance regarding their most important areas of concern and receive advice from the system not only to initiate a waste minimization strategy, but to also obtain constructive examples and ideas about waste minimization opportunities.

To meet these educational and technology transfer goals, **WAMMAS** contains three sections specifically designed to tutor the user about waste minimization. The first section walks the user through a waste audit example, stopping periodically to interact with the user or highlighting key aspects of the audit procedure. Helping the user develop their own waste reduction ideas is the goal of the second section. The user is exposed to several waste generating processes and the applicable waste reduction techniques for those processes. The third section contains abstracts of several successfully completed waste minimization projects. After reviewing this portion of the program, the user would be familiar with waste audit procedures, waste reduction alternatives, and case studies of proven waste minimization applications.

To achieve the project objective of exploring expert system technology, a waste minimization audit was undertaken at the ALCOA Massena plant in a manner consistent with the currently accepted procedures for such audits. The materials balance model developed from the audit together with relevant legislation and process options formed input data for the decision making process of the expert system. After formulation of the relevant data into production rules, the expert system to assist production scheduling to minimize one waste generating source (PCBs discharging from an industrial sewer system) was completed following verification and validation.

The PCB sampling and analysis program atALCOA took longer than initially estimated and the opportunity was taken to approach other industries with a view to evaluate their potential for expert system applications. These industries included Occidental Chemical Company in Niagara Falls, NY, Dresser-Rand, Olean, NY, a manufacturer of compressors, Frito-Lay, Kirkwood, NY, a food processing company, and Coyne Textile, Syracuse, NY, an industrial laundry.

Initial investigations of these industries revealed that while, in general, the operation of individual unit processes remained constant within each industry, the waste stream concentrations emanating from these processes would fluctuate. The question then arose, "What caused in waste stream fluctuations if the specific processes do not change their operating parameters?" The answer lay in the fact that there were situations where either concurrent operation of intermittent processes or the properties of the raw materials used by the processes varied, thereby causing fluctuations in pollutant loadings to a wastewater treatment stream potentially violating discharge limits. Therefore, if the environmental impact of each individual process could be determined, then it would also be possible through the use of an expert system to take into consideration these environmental impacts along with other manufacturing decisions and schedule the processes to avoid these violations or peaks. This essentially became a scheduling problem, much like the ALCOA situation.

There were therefore two necessary criteria for potentially useful expert system applications of this type. The first is that the industry must have a waste stream that fluctuates in strength. Secondly, good environmental data must be available to develop correlations between the process operation and environmental consequences. The ALCOA scenario met both the criterion. Also, Coyne Textile Services had a situation which could potentially be developed. These two industries were selected to be the expert system demonstration examples

Hardware/Software Environment

The hardware requirements for WAMMAS are an IBM PC-AT or compatible computer with a harddrive, 3.5 inch disk drive and a VGA screen. The program requires approximately 3 MB of disk space during installation and approximately 2 MB once installed. **WAMMAS** is written in C and the expert system inferencing engine **CLIPS** (the **C** **L**anguage **I**ntegrated **P**roduction **S**ystem, a NASA product) is embedded within the C program. A choice was made to steer clear of commercial software and program the graphics portion of the program to avoid royalty expenses and to maintain control over program development.

Results

Five components make up the **WAMMAS** system (Figure 1). The **Main** or **Introduction** component is an introduction to waste minimization which reviews the concepts and terms involved with reducing the waste generated by an industrial process. The **Waste Audit Tutor** is an interactive tutorial that educates the user on the waste audit procedure. Reduction strategies for various processes used by New York State industries are given in the **Waste Reduction Information** component and the **Case Studies** component documents successful waste minimization projects. The last component, the **Expert System Examples**, demonstrates the feasibility of

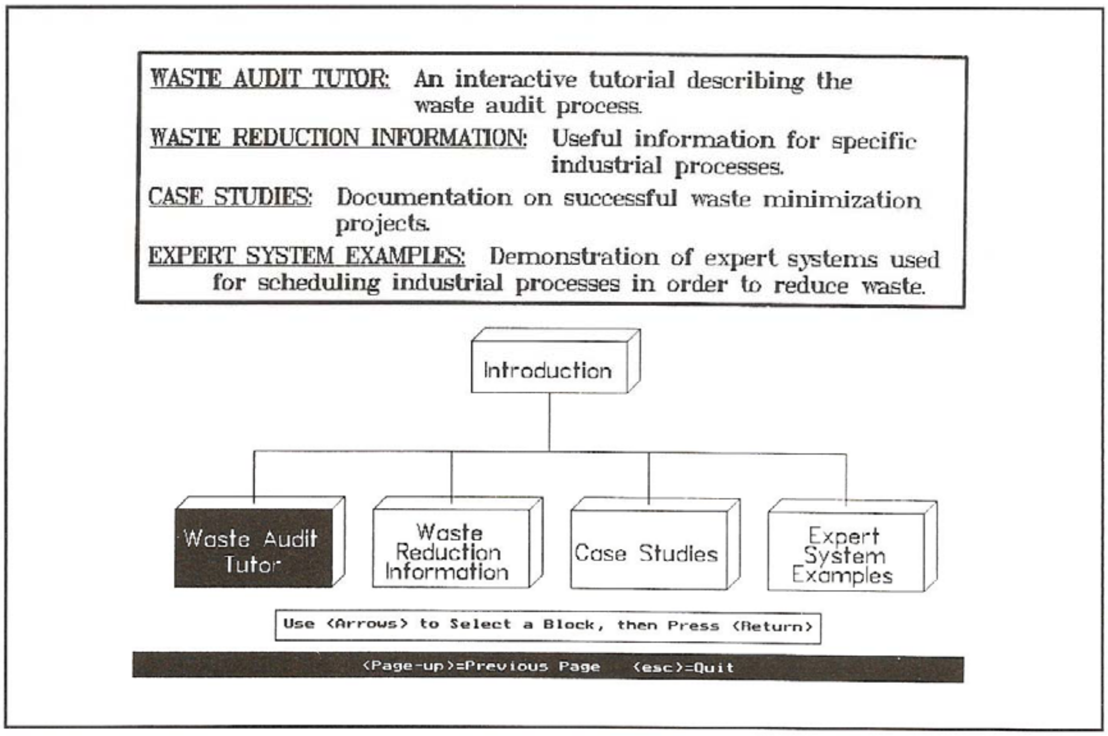


Figure 1 - The Five Components of WAMMAS.

the expert system approach to manage the hazardous waste generated through the two industrial process examples. Each component of **WAMMAS** is discussed further.

Main Component

The **Main** component of **WAMMAS** serves a number of purposes. A waste minimization novice is exposed to the terms and concepts involved with the process of waste reduction. Due to the emerging state of waste minimization technology, the use of terminology is mixed. Therefore, the introduction of **WAMMAS** acquaints a user, even one accustomed to waste minimization, with the terms and concepts used in the **WAMMAS** system. Once familiar with the material, this section can be skipped during subsequent tutorial sessions. All other components of **WAMMAS** are accessed from this component.

The concept of a waste management hierarchy is introduced or reaffirmed in this component. The hierarchy emphasizes that the elimination of waste from an industrial process should be evaluated as the highest priority; waste should then be reduced to the maximum extent feasible. When the alternatives for eliminating and reducing industrial wastes are exhausted, recycling options should be considered. **WAMMAS** defines recycling as any on- or off-site use, reuse, or reclamation of a material. One option for industries is to market their waste as a raw material for another industry. This process of finding alternative markets for waste is attractive considering that an expense (the cost of waste disposal) is turned into a profit (the market value of the waste). Not only is it economically practical, but it is environmentally appealing even if no profit is made. The liability associated with waste disposal will be eliminated. As a last resort, the hierarchy stresses proper treatment and disposal practices. Treatment and disposal options are not covered by **WAMMAS**.

***Waste Audit Tutor** Component*

A waste audit is the necessary initial undertaking to provide a detailed analysis of a production process that eventually guides the selection of waste minimization options. **WAMMAS** outlines four steps for undertaking a waste audit. The first step is to understand the process from an environmental standpoint. Information on raw materials and finished products is usually easily obtained. However, all streams entering or leaving the industrial process must be accounted for. With this in mind, the next step is to gather input information. It follows that the output information will then be collected. Once all of the information is assumed to have been accumulated, a mass balance is performed on the

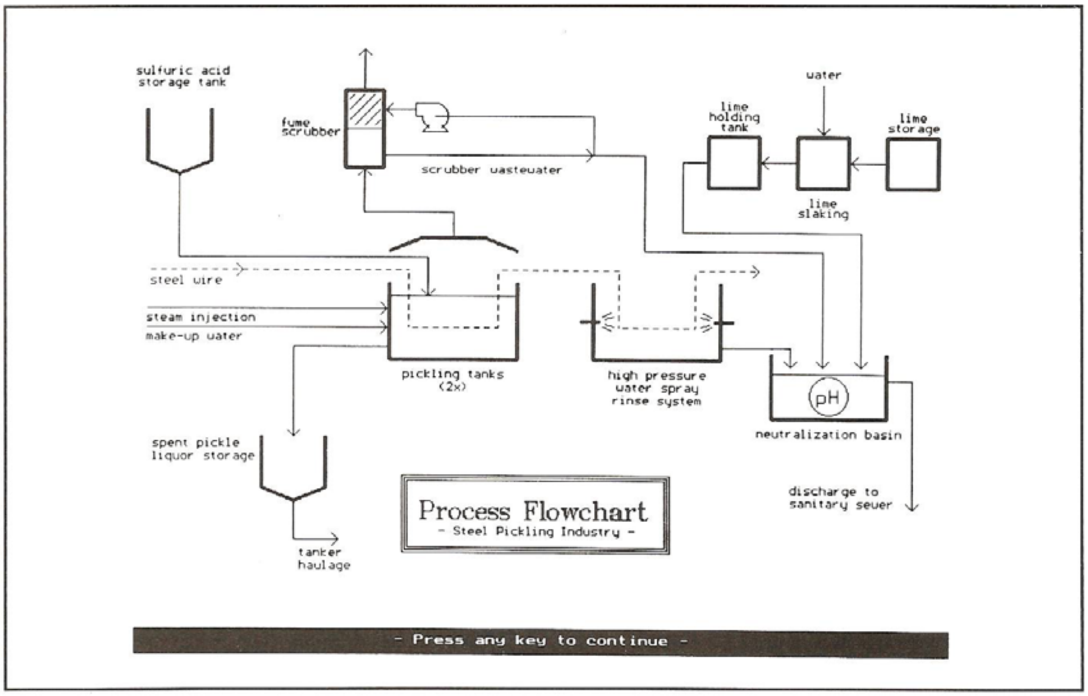


Figure 2 - Steel Pickling Process Example

process. The mass balance ensures the auditor that all waste streams have been tracked through the industrial process. When the four steps described above are completed, the waste audit should:

- define the sources, quantities, and types of waste being generated,
- bring together information on unit processes, products, raw materials, water usage, and waste generation,
- highlight process efficiencies and inefficiencies,
- identify areas of wastage and loss problems,
- help set targets for waste reduction,
- permit development of cost-effective waste management strategies, and
- increase employee knowledge of the production process and concern for waste minimization.

While the procedures for conducting a waste minimization audit have been specified for generic production process situations, site-specific auditing requires considerable interpretation for effective implementation.

The Waste Audit **Tutor** component is designed to aid the user in tailoring the approach to their own situations. The user is guided, step by step, through an example of an industrial waste audit on a steel pickling process (Figure 2). This component interacts with the user in several ways. Questions with multiple choice answers are asked (Figure 3). If an incorrect response is given, a helpful hint is displayed and the user is prompted to try again. After the input and output information is gathered for the steel pickling example, the user is asked to solve a mass balance. The solution is a simple mathematical one. It is not the intent of **WAMMAS** to carry out an extensive waste audit, but to show the user that the mass balance is the heart of the waste audit by accounting for all inputs and outputs associated with an industrial process.

The information acquired during the waste audit is collected from many in-plant sources. The **Waste Audit Tutor** guides the user to a number of these sources as most of the information needed for the mass balance can be acquired with a careful search of purchasing records, flow charts, hazardous waste manifests, and employees, just to name a few sources. The waste audit should greatly improve the understanding of an industrial process and serves as a basis for developing waste minimization alternatives.

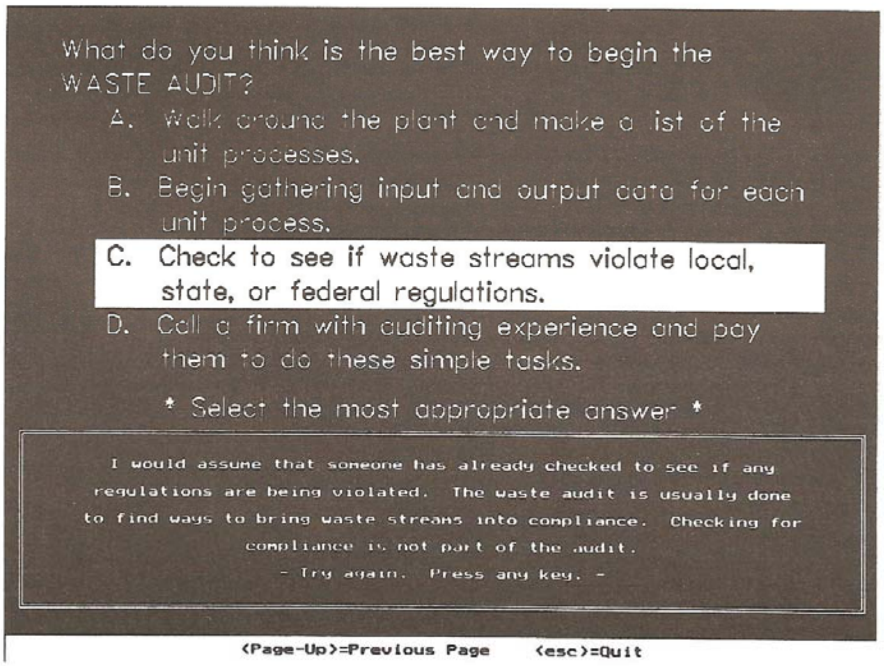


Figure 3 - Example Screen From Waste Audit Tutor

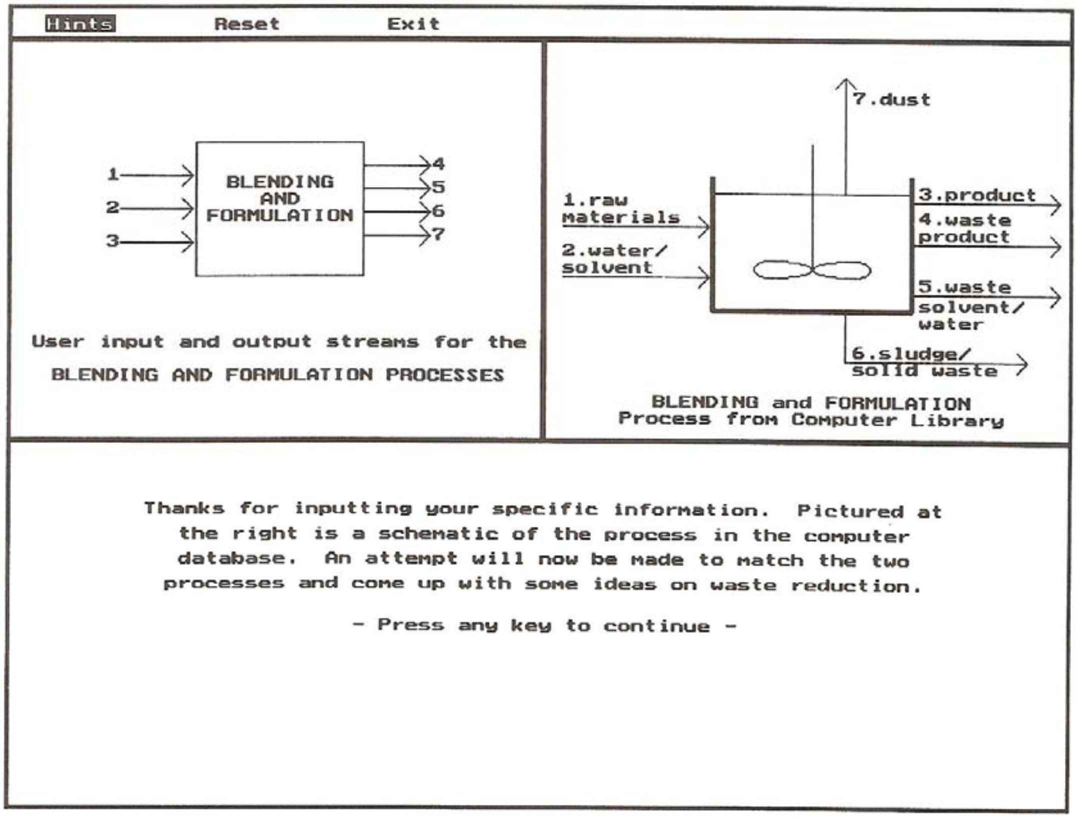


Figure 4 - Cross-Referencing User and Program Data

Waste Reduction Information Component

The **Waste Reduction Information** component was developed to transfer information about proven waste reduction techniques. This component of **WAMMAS** has a data base consisting of waste reduction options for a number of industrial operations. Reduction alternatives are provided for emissions of all phases (gas, liquid, or solid) if the technology exists for the operation.

The user selects the unit operation he/she is interested in from a list of processes contained in the database. The program then asks the user for specific information on their industrial process. This information is cross-referenced with the process information contained in the database (Figure 4). The user is then asked to compare his/her process to the process in **WAMMAS**' database. The program checks for inconsistencies between the user's process and the process contained within the database. Waste reduction suggestions are then given for streams which the user has matched, then reduction alternatives are given for streams which the user has not identified. For example, the program may say, "You have indicated that your bath process has only two output streams, are you aware that drag-out of residual solution is considered an output even though it is not measured? Drag-out can be reduced by optimizing the dip time or by decreasing the solution viscosity"

A summary of waste reduction options is displayed at the end of the interactive session. The user also has the option of computing a simple mass balance on the unit operation. The importance of the mass balance is again heavily stressed in this component of **WAMMAS**.

Case Studies Component

The purpose of the **Case Studies** component is to transfer information on successful waste minimization projects. Each case study has the following information:

- company name,
- type of industry,
- material(s) subject to reduction,
- economic information (payback time, total cost),
- abstract of how the waste minimization technique was applied, and
- reference number indicating where more information can be obtained.

There is an emphasis on the industrial application of the five waste minimization techniques (input material substitution, technology modification, product alteration, good housekeeping, and recycling). When the case study is accessed, the appropriate waste minimization technique is highlighted at the bottom of the screen (Figure 5).

Each case study can be accessed by either the waste minimization technique used or by the material subject to reduction. Once the pathway is selected, a list of appropriate industries is displayed. The user can then choose the industry of interest. The user also has the option of viewing the definition of any of the five waste minimization techniques. The definitions of the techniques used by WAMMAS are given to avoid any confusion and are included in this section to emphasize their application to industry.

Expert System Examples Component

Good operating practices or the efficient management of an industrial process involving procedural, administrative, and organizational activities are one of five waste minimization techniques. Expert systems can contribute to this area of waste minimization. The expert system technology evaluation was originally a unique project, however, incorporation into **WAMMAS** expands the scope of educational benefits provided by the program. Anyone reviewing **WAMMAS** now has the option of learning about expert system technology as it can potentially be applied to waste minimization, thus providing one more alternative for the reduction of waste generation.

The expert system development could have taken one of two directions. A "feedback" type of system which would have diagnosed a problem with production wastewater and

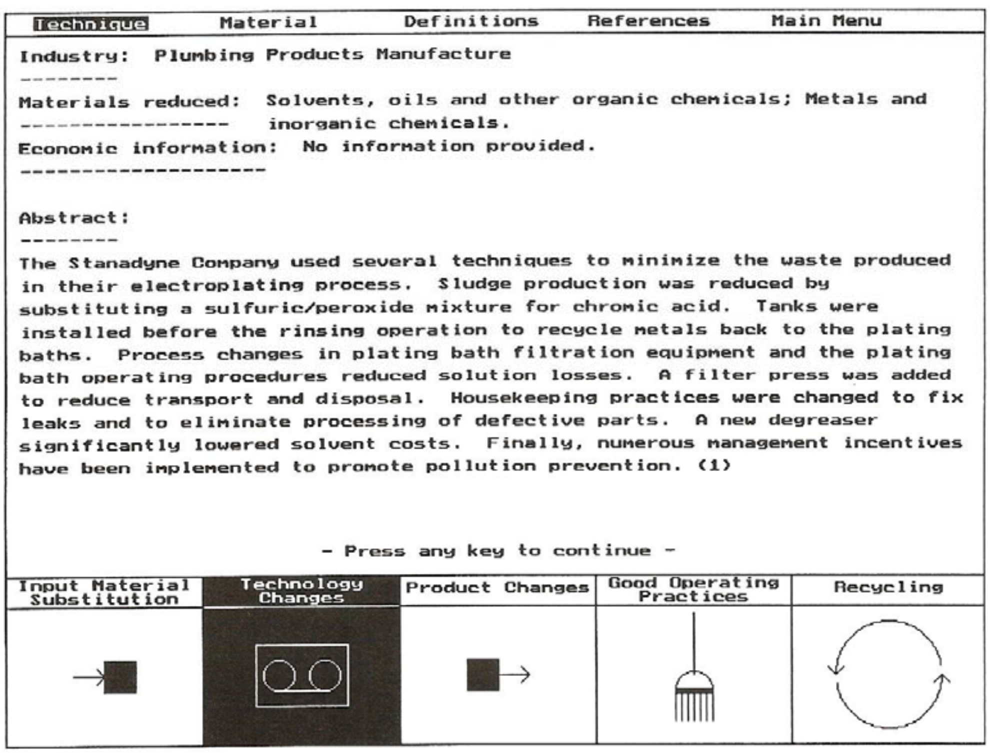


Figure 5 - Example Case Study.

THE INFORMATION YOU JUST ENTERED INDICATES TOO MUCH
LEAD
IS ENTERING THE WASTE STREAM

WHAT FOLLOWS IS A SUMMARY OF WHAT IS NEEDED TO CORRECT THE SITUATION:

```
****************************************************************************
```

THE FOLLOWING ACCOUNTS HAVE BEEN SWITCHED FROM Tuesday:
a11 b4 d7 d10

REVISED SCHEDULE FOR Tuesday

		SCALED CONCENTRATION FACTORS FOR:		
ACCOUNT #	TOWELS USED	LEAD	ZINC	OIL & GREASE
a8	9145	22	45	22
b1	10243	10	20	20
d9	4879	9	14	14
b5	4095	5	5	15
np	1707	1	5	6
b6	970	1	1	3
c6	514	1	2	1
e6	679	0	2	2
a10	304	0	1	0
b9	303	0	0	0
345	5000	15	25	5
DEVIATIONS FROM THE AVERAGE CONCENTRATION	=>	3	5	-10

WOULD YOU LIKE TO VIEW THE 'REVISED' SCHEDULE FROM ANOTHER DAY? (Y/N)

Figure 6 - Output From Export System Component.

then decided what corrections could be made to eliminate the problem. Or a "feedforward" system which would decide on the best operational scenario given a set of operating conditions. The "feedforward" system was chosen because it conforms with the waste minimization theme of preventing pollution at the source.

As indicated previously, the development of the last component, the **Expert System Examples**, involved two industries, ALCOA-Massena and Coyne Textile Services. Both the expert system examples in **WAMMAS** are designed to help control fluctuations in the mass flow rate of contaminants from multiple wastewater sources to a dischage point. If treatment occurs before dischage, then a consistent mass flow rate will maximize the treatment efficiency and minimize the potential for discharge violations as would be the case for situations where treatment does not exist. For example, if two processes which both generate excessively high concentrations of a contaminant are running simultaneously, then a possible solution may be to simply schedule the processes to run at different times. The expert systems use this approach to check for violations in waste generation, investigate alternatives for correcting the problem, and disclose their conclusions to the user (Figure 6).

Conclusion

A system such as **WAMMAS** has potential as an improved training method. **WAMMAS** provides a learning environment that is interactive and nonthreatening as well as having the capability for continual updating. This environment also allows the user to receive helpful, friendly advice. The **Expert System Examples** component demonstrates the potential of rule-based expert systems as aids in the management of waste minimization strategies. The focus of the two demonstration systems has been on scheduling. Two criteria were identified as being important to a successful implementation. The industry must have a waste stream that fluctuates in strength and environmental data must be available to develop correlations between process operation and environmental consequences.

Acknowledgements

This work could not have been accomplished without the interest and cooperation of ALCOA-Massena and Coyne Textile Services.

Multimedia Project in Chemical Engineering Classes

By Bruce A. Finlayson, University of Washington

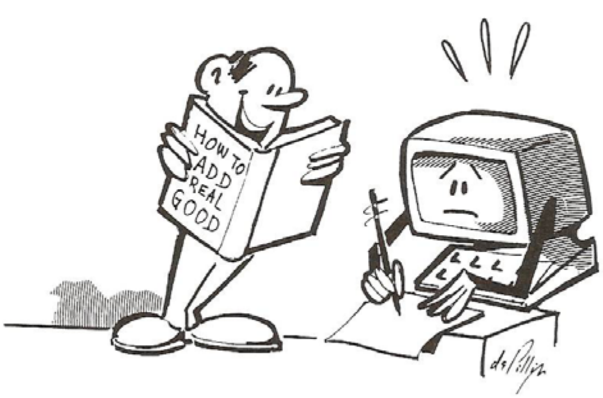
Chemical Engineering students at the University of Washington got a chance to develop multimedia lessons for one of their courses. The program Action! from MacroMedia was used in Ch. E. 475, Computer Analysis in Chemical Engineering, which is taught by Professor Bruce Finlayson. He divided the class into teams of three, and gave each team a topic the class had studied. He asked them to design a multimedia demonstration of that topic. The topics were the Newton-Raphson method for solving nonlinear equations, Stiffness for sets of ordinary differential equations, StableTime Steps for integrating ordinary differential equations, and Standard Deviations to be used in analyzing experimental data. The students designed the lessons and Professor Finlayson programmed them in his personal copy of Action!

First, a video from MacroMedia was displayed showing what could be done, then the video was augmented with printed information that would be needed to create the scenes, i.e. how the students wanted their graphics and sound introduced. Next the students made a lesson plan, thus practicing teamwork (a skill currently in vogue) while preparing their lesson. They also learned presentation skills when Professor Finlayson sat down with each group and went through the lesson on the computer, asking them questions about their displays, and suggesting other ideas on occasion. The class used pictures from books, drawings they made, equations they wrote, sounds they obtained or recorded, one movie clip, and a variety of visual effects.

Professor Finlayson used his Macintosh computer (at home) with his personal copy of Action! After the students previewed their lesson, and changes were made, all of the lessons were displayed to the class (plus many interested faculty) in a classroom that had video display equipment and a Macintosh. The faculty graded the lessons, and a prize was awarded to the group that received the top score.

No formal evaluation was carried out, but several qualitative observations could be drawn. Professor Finlayson found the students were very interested in the multimedia educational materials and worked hard in preparing them. Some of the lessons were good and some were not so good, but all were satisfactory given the limited interaction the students had. The students especially appreciated seeing their name appear in the credits and seeing visual effects similar to those seen on TV. One aspect they really liked was Professor Finlayson recording each student saying his or her own name, and then introducing the words when their name appeared in the credits.

This may be an example of the first multimedia project done by students in a chemical engineering class. Has any one else done this? Let us know if you have.



Old Saying:
If you really want to learn something, teach it to someone.

Newer Saying:
If you really want to learn something, teach it to a computer.

ANNOUNCEMENTS

Proceedings of the Second International Conference on Foundations of Computer Aided Process Operations (FOCAPO '93)

Editors: David W.T. Rippin, John C. Hale, and James F. Davis

Sponsored by the CAST division of the AIChE and CACHE Corporation, FOCAPO II was a significant contribution to the field of process operations. The 29 papers of these proceedings clearly demonstrate the increasing interest in scheduling, integration, flexibility, and manufacturing management essential today for successful process operations. The proceedings emphasizes successful industrial applications, quality and safety management, maintenance and reliability and process monitoring. In addition, a selection of contributed papers covers a variety of relevant topics. The 500 page volume presents a current and future view of computing in process operations and is relevant to both industrial and academic interests.

The FOCAPO II Proceedings will be distributed by the CACHE Office at the price of $39.50 plus $5.00 shipping and handling.

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To order the FOCAPO II Proceedings, please complete the standard order form on page 29.

Microcomputer Chemical Engineering Programs (Developed by Professors)

By Bruce A. Finlayson

This Column has been in operation since April, 1987 and 23 programs have been made available to the Chemical Engineering community through the CACHE News. However, we have not had a submission in the last year. Currently, there is a demonstration of programs at the Autumn, AIChE meeting. Also, using the Internet and ftp it is possible for everyone to get copies of the programs transferred to their site easily. In light of these events we have decided to terminate this column.

This still leaves one hole, however. Where is a central location that lists what is available? How do you find out about a program if you do not go to the display at the AIChE meeting, or it is some times past the meeting? The AIChE does publish a software directory each year, but this is oriented to commercial packages (which should be considered for educational use). If anyone thinks we should prepare a bulletin board keeping copies of programs developed by professors, please send an electronic message to me at **finlayson@cheme.washington.edu.**

ANNOUNCEMENTS

Fifth European Symposium on Computer Aided Process Engineering (ESCAPE 5)

Organized under the sponsorship of the European Federation of Chemical Engineering (EFCE)

Bled, Slovenia, Europe, 1995, June 11 - 14

The major aim of ESCAPE-5 is to review the latest developments with the use of computers and information tools in design and operation in the process industries.

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- Computing, graphics and numerical methods, expert system, artificial intelligence, logic, neural networks in process systems engineering

Authors' deadline: 30 April 1994

For further information please contact:

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CD-ROM Technology Watch

By Peter R. Rony

The February 22, 1994 issue of PC Magazine (Volume 13, Number 4, $2.95) provides several interesting articles that would be of use to faculty considering the purchase of CD-ROM drives:

1. John R. Quain, "CD-RROM Drives Going Mainstream," pp. 110-154.
2. Lori Grunin, "Kodak Photo CD: A Photographic Memory for the Digital Age," pp. 157-169.
3. James Karney, "Sharing a CD-ROM," pp. 171-178.

The PC Editor's Choice for SCSI-based CD-ROM drives include the Chinon CDS-535, and the Plextor DM-3028 DoubleSpeed PLUS. For a proprietary interface, the PC Editor's choice is the Sony CDU33A, which is "available at a street price of about $220." The article on PhotoCD is an excellent introduction to this important digital color image technology. When purchasing a CD-ROM, you are reminded to seek, at a minimum, a double speed, XA-ready, PhotoCD compatible drive.

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