THE OPERATIONS AND PROCESS LABORATORY

A Unique Summer Course at Wisconsin

GLENN A. SATHER
University of Wisconsin
Madison, WI 53706

JOSÉ COCA
University of Oviedo
33007 Oviedo, Spain

THE "OPERATIONS AND Process Laboratory" has a long tradition at the University of Wisconsin. Since its inception in the 1916-17 academic year, the course has accommodated the evolution of chemical engineering by retaining some of the basic operations and philosophy while at the same time allowing students to explore the newer technologies. In those early years when chemical enginering was consolidating at Wisconsin, the course was named "Chemical Manufacture," and its contents, according to the University Catalog, were described as follows [1]:

> ***Laboratory practice supplementary to chemical machinery courses, tests of chemical machinery, manufacture and recovery of products, special problems.***

Today it is a five credit course, and the College of Engineering Bulletin (1986) describes it as follows:

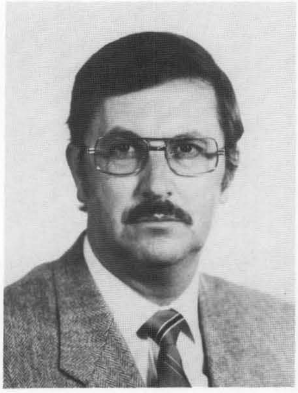
> ***Experiments in unit operations, and supervised individual assignments selected from areas such as: fluid dynamics, analogic methods, reaction kinetics, plastics technology, and use of computers in data processing and simulation.***

The course is offered in the summer and is taught in five-week sessions, with two sessions usually being offered. The course meets for a full eight hours each day, five days a week. The enrollment in each session is typically 35-45 students.

The Chemical Engineering Curriculum shows the course as being taken at the end of the junior year; however, approximately one-half of the students postpone it until the end of the fourth year of coursework. The prerequisites for the course are Transport Phenomena, Transport Phenomena Laboratory, Chemical Engineering Thermodynamics, and Fluid Flow and Heat Transfer Operations. While not formal prerequisites, Mass Transfer Operations and Chemical Kinetics and Reactor Design have been taken by a majority of the students when they enroll in the summer course.

THE COURSE PROGRAM

In the early years of the course the pattern of laboratory work was, to some extent, based on the interests and ability of the student. Typical projects consisted, for example, of setting up a distillation column or saponifying tallow to produce soap. After a library search, most of the work was left to the stu-



Glenn Sather received his PhD in chemical engineering from the University of Minnesota in 1959. He has been a member of the department of chemical engineering at the University of Wisconsin since 1959, and is presently Associate Chairman for Undergraduate Studies and Director of the Summer Sessions. He held a NSF Science Faculty Fellowship at Imperial College of Science and Technology, London (1966-67) and was a Dupont Year-in-Industry Professor (1973-74). His teaching interests in addition to the Operations and Process Laboratory are in material and energy balances and in thermodynamics. **(L)**

José Coca received his PhD in 1968 from the University of Salamanca in Spain. He spent two years (1968-70) as a post-doctoral fellow at the University of Wisconsin. As a visiting professor he has taught the Operations and Process Laboratory on several occasions. He joined the department of chemical engineering at the University of Oviedo in 1972 and is currently the chairman of the department. His research interests are in the area of separations processes: Liquid-liquid extraction, chromatographic separations and chromatographic reactors. **(R)**.

dent's ingenuity, and as a consequence, even the most talented students rarely were able to complete more than three experiments in the course.

After being discontinued during World War II, the laboratory was reinstated in 1948. At that time, Professor Olaf A. Hougen became chairman and several new experiments in process operations were set up. Some of these experimental units are still in operation today, though most of them have been remodeled or replaced with more modern counterparts.

At the present time the operation of several large units constitutes the core of the formal experiments and offers the students (in groups of six or eight) the opportunity to verify the principles in the areas of fluid flow (test of a centrifugal pump), heat transmission (heat transfer from condensing steam to oil), and mass transfer (distillation, extraction, and air-water contact). Schematic diagrams and photographs of these units, together with a brief description of the main purpose of each experiment, are shown in Figures 1-5. (See next page.)

The experiments are introduced by a lecture which consists of a review of the principles underlying the experiment and specific instructions on the operation of the equipment. Information on the formal experiments is also supplied in handouts which provide detailed descriptions of the experiments, mode of operation, *etc.*

In addition to the formal experiments, which every student is required to perform, a second series of informal experiments (usually four in number) is assigned by the instructors. These experiments are conducted by two-member groups and usually require a literature survey and a considerable experimental effort in constructing simple but reliable apparatus. The type of experiment depends on the instructor's interests and occasionally are related to present or future research projects. When possible, student interests are also considered in assigning these experiments. A few examples of informal experiments which have been used are the following:

- **Sedimentation of particles in the presence of coagulants or flocculants. Scale-up of a settling tank.**
- **Flow characteristics of a $CaCO_3$—water slurry.**
- **Hydrodynamic characteristics of a spouted-bed and an air-lift reactor.**
- **Evaporative cooling of water droplets.**
- **Mass transfer with single drops and coalescence of drops.**
- **Dissolution rate of limestone into an acid solution.**
- **Residence time distribution in a stirred tank and in a packed bed.**
- **Hydrolysis of methyl acetate catalyzed by an ion exchange resin.**
- **Hydrolysis of amyl acetate in a batch reactor.**

Another aspect of this course is that it serves as a good preparation for the profession. [It] is a comprehensive learning experience, and at the end of the course the students are expected to have acquired a fair amount of expertise with a variety of equipment.

- **Oxidation of sulphites with oxygen in a batch reactor. Catalytic effect of metal ions.**
- **Analysis of the dynamic behavior of a water heating system.**
- **Plant/model correlation for a first order system by pulse testing.**

Tutorial work is particularly intensive in this course because of the nature of the experiments and the time which instructors spend with small groups of students. Students keep in contact with the instructors through meetings in the laboratory or in a summer sessions office. All students are required to submit individual reports on the formal and informal experiments, usually within one week of the completion of the experiment. Report writing is an important part of the course, and requirements are rather stringent in this regard. A report which does not meet the standards may be returned to the student for rewriting. Students are occasionally asked to present an oral summary of their report to the class.

At the end of the course the students take a final examination based on each of the formal experiments. It includes questions which cover the fundamental chemical engineering principles that are involved in each of the formal experiments, equipment operation, and some specific calculations. The final examination accounts for ten to twenty percent of the course grade.

THE COURSE GOALS

The general purpose of the course is contained in the college bulletin description; however, some specific aspects deserve special mention. In order to understand the goals of the Operations and Process Laboratory, it has to be considered in the context of the other chemical engineering laboratory courses taken by undergraduate students at the University of Wisconsin. Two additional laboratories are required of all students: Transport phenomena laboratory and process control laboratory.

The Transport Phenomena laboratory is offered before the Operations and Process laboratory, while most of the students take the Process Control laboratory later. Both of the laboratories have a four-hour laboratory session each week for one semester. The

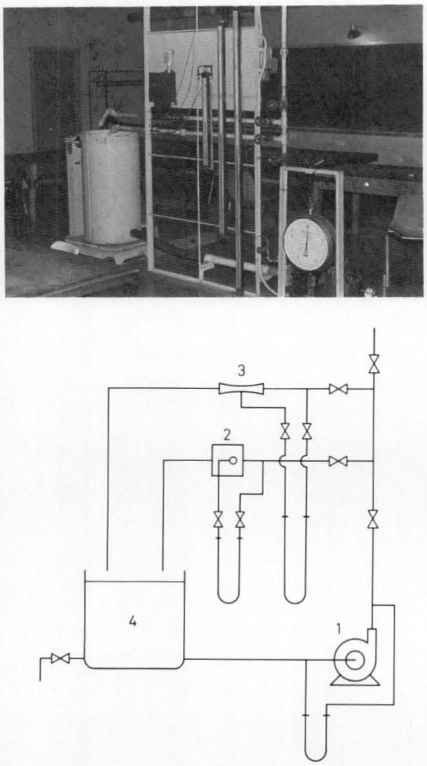


FIGURE 1. Centrifugal Pump. (a) Performance of the impact tube and the venturi meters, (b) computation of shaft power and hydraulic power, (c) total head developed by the pump, and (d) relationship between pump speed and its capacity.

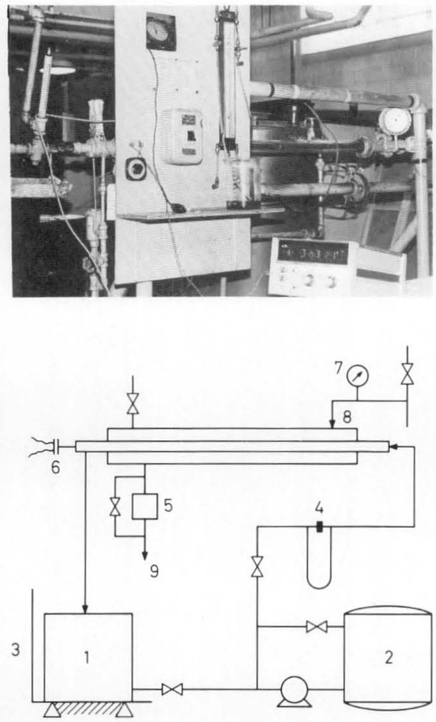


FIGURE 2. Heat Exchanger. (a) Determination of heat transfer coefficients for the oil side, steam side and overall, (b) estimation of the liquid side heat transfer coefficient using the Dittus-Boelter, Sieder-Tate and Colburn correlations, and (c) statistical analysis of data.

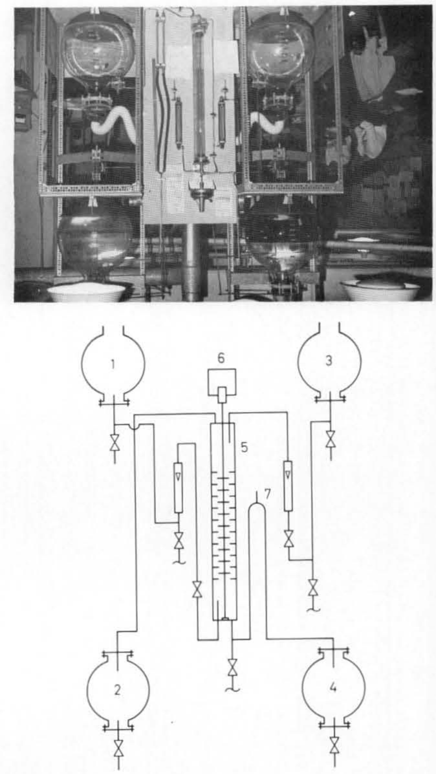


FIGURE 3. Liquid-liquid extraction in a rotating disc contactor using the system, kerosene-propionic acid-water. (a) Number of transfer units as a function of flow rates, rotor speed and height of the phase boundary, and (b) factorial design analysis to determine the important variables and their interaction in the process.

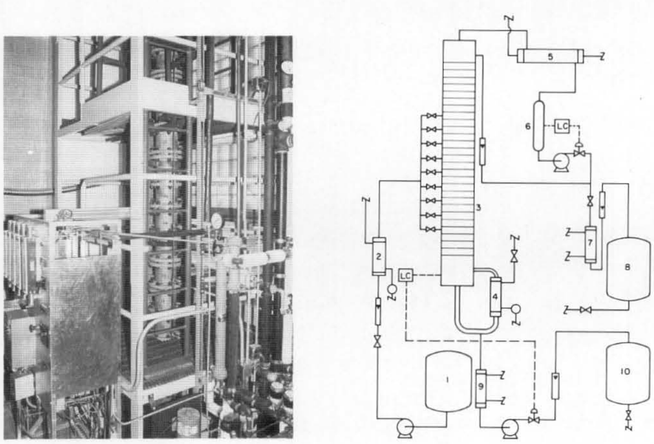


FIGURE 4. Distillation of ethanol-water mixture. (a) Performance of a 28 valve-tray, 8 inch O.D. column at total and finite reflux conditions, (b) tray efficiencies and overall column efficiency. (c) heat transfer coefficients for the reboiler and condensers, and (d) material and energy balance calculations.

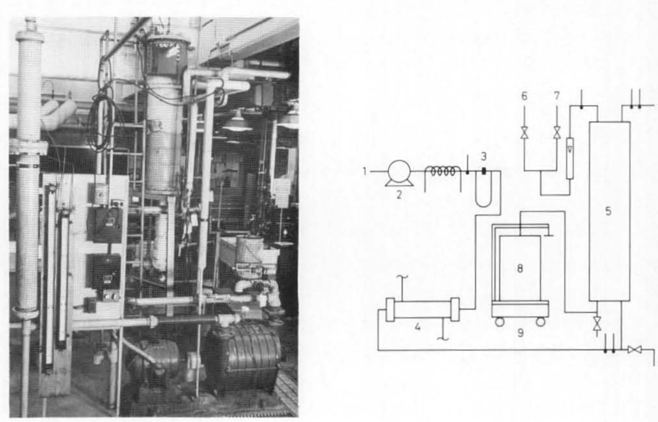


FIGURE 5. Air-water contacting in a spray tower. (a) Humidification, water cooling and dehumidification operations, and (b) effect of air and water rates on heat and mass transfer coefficients.

proportion of student-faculty contact hours in laboratory compared to lecture courses is shown in the sector diagram of Figure 6.

The Operations and Process laboratory is a good complement to the chemical engineering education of the UW students because of several special features:

- **It gives the students the opportunity to operate pilot-plant scale equipment.**
- **There is a challenge to work on modern chemical engineering problems of interdisciplinary nature through the assignment of informal experiments.**
- **Although the main emphasis of the course is on unit operations, the informal experiments give the students an opportunity to deal with chemical reactors and some less-traditional chemical engineering problems.**
- **It gives the students a chance to work as a team, and to obtain by this type of cooperative activity, a sense of chemical engineering practice.**

Another aspect of this course is that it serves as a good preparation for the profession. Some schools in Europe and in the United States have industrial practice as a substitute for laboratory courses. In spite of the importance of industrial experience, it has its disadvantages. It is usually limited to one piece of equipment, within a certain process, and obviously the operating variables cannot be altered at the student's will. The laboratory course at Wisconsin is a comprehensive learning experience, and at the end of the course the students are expected to have acquired a fair amount of expertise with a variety of equipment.

Despite budget limitations improvements are being made in the course. A new eight-inch valve-tray distillation column was recently installed and was fully utilized in the 1987 summer sessions. A shell-and-tube heat exchanger experiment is being constructed to replace the present double-pipe steam to oil heat transfer experiment, and a membrane separation experiment is in the planning stage. While improvements will continue to be made, it is expected that the general operation of the course will remain the same. The best proof that the laboratory achieves its goals is the positive feedback which the department receives from graduates who have been in industry for five to ten years.

PERFORMANCE AND REMEMBRANCE

Two awards are given to students at the end of the course. While their main purpose is to recognize ingenuity and performance, they also honor two faculty members who were particularly active in the course: Professors O. L. Kowalke and R. A. Grieger-Block.

The Kowalke-Harr Award is given to the pair of students who show the most outstanding performance

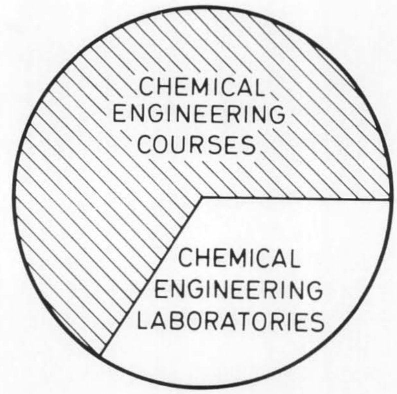


FIGURE 6. Proportion of student-faculty contact hours in the undergraduate chemical engineering courses at UW. Transport phenomena laboratory (6%), process control laboratory (6%), and operations and process laboratory (22%).

as a team. Professor O. L. Kowalke was chairman of the department from 1914 to 1940, during which period he helped develop and improve the summer laboratory. Mr. R. E. Harr, an alumnus and benefactor of the department, took this course as a student.

The Grieger-Block Award is given to the pair of students who exhibit the most creativity and resourcefulness in conducting experiments. Professor R. A. Grieger-Block was a faculty member from 1970 until his untimely death in 1980. He was known for his innovative approach to experimentation in the laboratory.

It has been a practice to take a group picture of the students and staff in each session. The department has pictures of all classes since 1948.

THE COURSE FACULTY

Six staff members are usually involved in each of the sessions. The staff consists mainly of professors with one or two graduate students. Numerous visiting professors and lecturers have taught the course. In addition to the United States, these visitors have come from Denmark, F.R. Germany, India, Israel, Nigeria, Norway, Latin America and Spain. One or two UW professors are involved in each of the sessions to assure consistency.

The international participation has been challenging in many respects. It provides opportunities to compare chemical engineering curricula, to discuss research projects, and to expose students to other languages and cultures.

REFERENCES

1. Daub, E. E., "Chemical Engineering at the University of Wisconsin: The Early Years." From *A Century of Chemical Engineering*, W. F. Furter, ed., Plenum Press, NY (1982).