A Course in

INDUSTRIAL POLLUTION CONTROL

FRANCIS S. MANNING
University of Tulsa
Tulsa, Oklahoma 74104

IN 1971 THE Chemical Engineering graduate students formally requested a graduate level course in pollution control. From 1971 through 1973, Tulsa University conducted a M.S. level, EPA-sponsored program of training of engineers in oil-related water pollution control. This program created a need for a graduate course which would familiarize B.S. chemical engineers with industrial pollution control practices and design procedures.

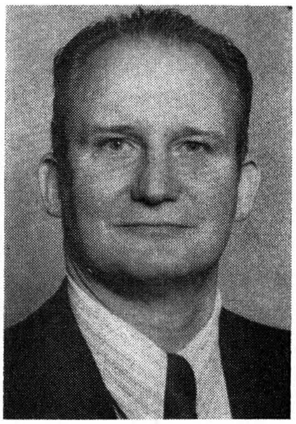
Since 1974 the ChE Department has administered the University of Tulsa Environmental Protection (UTEPP) program—a non-profit, cooperative, petroleum industry-sponsored research program committed to studying present and future environmental protection problems in petroleum and related industries. Obviously, students working in UTEPP also require graduate-level instruction in industrial pollution control.

COURSE OBJECTIVES

INDUSTRIAL POLLUTION CONTROL not only focuses on the general theories of industrial pollution control to provide breadth of understanding, but also emphasizes petroleum-related design examples to provide the required specialization. Current industrial pollution control practices and design procedures are introduced as painlessly as possible. This is accomplished by emphasizing the relevancy of conventional, undergraduate chemical engineering. In other words, biological oxidation processes are described as chemical reactors; but, of course, new concepts such as the inherently varying wastewater "feed" volume and concentration and the sensitivity of "bugs" to shock loads are carefully described. Similarly, ammonia stripping is discussed using standard ChE desorption nomenclature; and liquid condensation in pressure-relief lines is treated as a standard thermodynamic "flash calculation."

TEACHING FORMAT

WHILE THE TRADITIONAL lecture format is maintained, formal lecturing is minimized. For the past two years "Industrial Pollution Control" was taught via the Oklahoma Higher Education Televised Instruction System (Philoon, 1974) thus allowing engineers from Conoco in Ponca City and Phillips Petroleum in Bartlesville to participate. This televised procedure permitted maximum use of class time because an overhead TV camera made it possible to project printed pages on the TV receiving screens. This minimized the timeconsuming writing of notes on the blackboard and the laborious copying by students. While two texts were recommended (but not required) the majority of the course material was selected from recent articles (see references for a partial listing). The references must be updated every year because of the great current interest in this field. Frequently students were



Francis S. Manning is Professor and Chairman of Chemical Engineering at The University of Tulsa. He holds the following degrees in Chemical Engineering:—B. Eng. (Hons.) from McGill University and M.S.E., A.M., and Ph.D. from Princeton University. He is a professional engineer, registered in Oklahoma, Pennsylvania and Texas.

supplied with reprints of key articles not readily available in the library.

Because "Industrial Pollution Control" covered such a wide range of topics, expert guest lecturers were used:—e.g. Paul Buthod for petroleum refining; Erle Donaldson for subsurface disposal; Dick Martin for noise control and Robert Reed for combustion and incineration. Plant trips to Sun Oil Company's Tulsa refinery and to William Brothers Analytical Laboratory were included.

Since 1970, the University of Tulsa has sponsored ten one-week short courses for industry on wastewater and air pollution control as applied to petroleum refining and related petrochemicals. These short courses have featured many nationally-known authorities such as Milton Beychok, Frank Bodurtha, Marion Buercklin, Lee Byers, Burton Crocker, Wes Eckenfelder, Davis Ford, Bill Licht, Leon Myers, Robert Reed, George Reid, Jim Seebold and others. Students ennrolled in "Industrial Pollution Control" have always been encouraged to attend these short courses (free of charge) and were given complimentary notes for the short course. These short courses have enriched "Industrial Pollution Control" immeasurably. Last fall, for example, the students attended 35 hours of lectures on air pollution control and received approximately 200 pages of notes and design case histories. In-class treatment of air pollution then consisted of discussing points of student uncertainty and working extra problems.

Students were graded on 1) their solutions to the design problems; 2) two "term-papers" or more comprehensive design projects; and 3) their in-class presentation and defense of their design projects.

COURSE OUTLINE

• **Petroleum Refining** (1 hr lecture) A brief discussion of refining with emphasis on unit processing steps and the major sources and types of wastes is conducted. The chief concept presented is: increased processing is accompanied by increased production of potential pollutants. Nelson (1968).

• **Refinery Wastewater Treatment** (1 hr lecture) A brief summary is given of major uses of process water in a refinery emphasizing current recycling of process water and methods of minimizing volume of wastewater produced. Advantages of segregated sewers. Overview of primary, secondary, and tertiary treatment with emphasis on arrangement of treatment steps. Manning (1973).

• **Characterization of Industrial Wastewaters** (1 hr lecture) The problem of describing a wastewater in terms of a relatively few, standard analyses such as BOD, COD, TOC, SS, etc., is explained. FWPCA (1967).

The course not only focuses on the general theories of industrial pollution control to provide breadth of understanding; but also emphasizes petroleum-related design examples to provide the required specialization. Current industrial pollution control practices and design procedures are introduced by emphasizing the relevancy of conventional undergraduate ChE.

• **Biological Treatment** (2 weeks, 3 problems) Biological phenomena and related importance in understanding biological waste treatment are presented. Laboratory methods for modeling aerobic growth kinetics. Current design methods for sizing activated sludge and aerated lagoons including treatability studies, common start-up and operating problems and solutions, effluent qualities typically realized, and economic aspects. API (1969); Eckenfelder and Krenkel (1972); Thackston and Eckenfelder (1972); Adams and Eckenfelder (1974).

• **Sludge Handling** (1 week; 1 problem) Sludge handling is discussed in depth with emphasis upon alternative methods—sludge conditioning, thickening, dewatering, drying and digesting. Ultimate disposal methods such as land farming and landfill were reviewed. Dick (1972); Eckenfelder and Krenkel (1972).

• **Pretreatment** (2 weeks, 3 problems) The role of pretreatment on the operation of biological treatment such as activated sludge or aerated lagoons is discussed. Detailed design procedures for equalization basins; neutralization; oil separators (API and CPI); and dissolved air flotation units. Adams and Eckenfelder (1974); Ford and Manning (1974).

• **Tertiary Treatment** (1 week, 2 problems) Biological nitrification—denitrification are reviewed. Carbon adsorption and mixed-media filtration as effluent polishing steps are discussed. Emphasis is placed on the implications of EPA effluent criteria on the selection of processes, design procedures, and effluent qualities obtainable in industrial operation. Adams and Eckenfelder

(1974); Thackston and Eckenfelder (1974).

• **Subsurface Disposal** (1 hr lecture) The design and operation of underground disposal wells is reviewed including geology; economics; and the pros and cons of subsurface versus surface treatment. Donaldson (1974).

• **Water Quality Standards** (1hr lecture) BPCTCA: BATEA: new source standards and 1985 "Zero Discharge" regulations are reviewed, while emphasizing their effect on current treatment practices. Federal Register (1974).

• **Source and Ambient Air Sampling** (1 hr lecture) Procedures for stack sampling of particulates and gaseous procedures are reviewed with emphasis upon relevant case histories—isokinetic procedures for particulates, and analysis of SO_2, NOX and hydrocarbons. Crocker and Schnelle (1970); Hesketh (1972).

• **Meteorology** (2 weeks, 3 problems) Fundamentals of meteorology are presented, including mixing processes; DALR; atmospheric stability; Pasquill and Turner's classifications; dispersion models using Gaussian models; plume rise. Design case histories are used to illustrate calculation procedures, including variations in ground-level concentration, time averaging, multiple stacks, etc. Crocker and Schnelle (1970); Schnelle and Noll (1972); Hesketh (1972).

• **Removal of Particulates** (2 weeks, 3 problems) The basic design criteria for particulate control with emphasis upon fundamental principles and mechanisms are reviewed. These principles are used to develop basic collector models, determine effects of dust size distributions, energy requirements, and optimal design criteria. Inertial separators (cyclones), filters, electrostatic precipitators, and wet scrubbers are included. Crocker and Schnelle (1970); Byers and Licht (1974); Hesketh (1972).

• **Control of SO_2 Emissions** (1 week) Control of SO_2 emissions from combustion and process gasses by limestone/dolomite injection, limestone and MgO slurry scrubbing, catalytic oxidation and alkaline scrubbing, and Claus recovery plants are discussed. Byers and Licht (1972).

• **Incineration** (2 weeks, 3 problems) Combustion fundamentals are reviewed, including fuel characteristics, fuel: air ratio, combustion temperature, heat transfer and mixing effects, effect of water vapor, heating value of fuels, speed of combustion, odor control by incineration and design methods for fluid bed and atomized suspension incinerators and for flares. Reed, R. D. (1973); Eckenfelder and Krenkel (1972).

• **Hydrocarbon Losses; NOX Reduction** (1 hour lecture, 1 problem) Methods of controlling NOX emissions such as low excess air firing, staged combustion, flue gas recirculation, and inert injection are reviewed. Sarofin and Bartok (1973).

• **In-Plant Noise Control** (1 week, 1 problem) An introduction to the nature of noise, health aspects, pollution economics, major national sources, main concepts of in-plant noise (design versus external treatment), inplant noise legislation and basic physics of noise generation is presented. Kannapell and Seebold (1975).

• **Air Standards, Environmental Impact Studies** (1 lecture) We review federal legislation including the Clean Air Act of 1970, establishment of national air quality standards, implementation plans and emission standards for new and existing sources. Environmental Impact Statements are discussed. Beychok (1973); Hesketh (1972).

TYPICAL PROBLEMS

THE MAJORITY OF CLASS TIME is spent discussing design problems which are carefully formulated to reflect actual engineering practice. The students are not required to memorize typical operating conditions; but, hopefully they develop such engineering judgment by working with realistic numbers. These problems illustrate how the student's basic ChE knowledge can be applied to pollution control. This teaching philosophy is illustrated below in typical problems.

• **Biological Treatment** In addition to designing activated sludge and aerated lagoons by conventional methods (Adams and Eckenfelder, 1974) the students fit laboratory treatability data with 3 variations of the first order kinetics: thus discovering the empirical nature of the assumed kinetics. Also, if time permits, the students compare Beychok's (1970) data on aerated lagoons with plug-flow and perfectly-mixed reactor models. They are surprised to find that both models can fit the biological degradation data over the limited variation in residence time, etc. (Soper et al, 1975).

• **Neutralization** Students plot the daily amounts of base required to neutralize an acid coke and chemicals wastewater (pH=2.5) on probability paper. They test whether the daily requirements are normally distributed and learn what is meant by designing for the 90 or 95 percentile.

• **Equalization** Students plot the daily COD load from a typical (but hypothetical) refinery on probability paper. They then design an equalization basin using Novotny and Englande's (1974) method which assumes random fluctuations. Class discussion compares the results of the Novotny and Englande method with a rigorous, numerical, computer solution. This shows how a major spill produces a non-Gaussian distribution, and also indicates when Novotny and Englande's method should and should not be applied.

For the past two years "Industrial Pollution Control" was taught via the Oklahoma Higher Education Televised Instruction System—thus allowing engineers from Conoco in Ponca City and Phillips Petroleum in Bartlesville to participate. This televised procedure made it possible to project printed pages on the TV receiving screens.

• **Stripping** Students first reconcile the design equations listed by Smith (Thackston and Eckenfelder, 1972, p. 140) with the standard ChE formulations for counter-current columns. They examine the relative magnitudes of the gas and liquid phase resistances. Finally the overwhelming effect of temperature on the feasibility of stripping is illustrated by sizing several towers. If time permits, Beychok's approach to high temperature, stripping of H_2S-NH_3 mixtures is discussed (API, 1969, revised chapter).

• **Atmospheric Dispersion** Dispersion of SO_2 is estimated using the Pasquill and Turner approach. The estimates are repeated for multiple stacks and at least two plume-rise formulae. Finally the differences between continuous point sources, and instantaneous "puff" sources are illustrated not by dwelling on the mathematical derivations but by working suitable examples. Students estimate the dispersion coefficients thus emphasizing the uncertainties inherent in the final answers. If time permits, students estimate the ground concentration of H_2S and/or mercaptan produced by releasing H_2S and/or mercaptan from a safety release valve. The resulting ground concentrations are then compared with odor thresholds and EPA air quality standards.

• **Flare Stack** The design of a flare stack includes estimating potential carbon escape, steam demand for smoke suppression; sizing storage space for liquid knock-out facility; ground-level radiant heat fluxes. Wherever possible students are introduced to alternative (and sometimes contradictory) design rules-of-thumb. In fact one assignment is to criticize a very misleading paper.

• **Sludge Incineration** This incineration design includes complete mass and energy balances; sizing combustion volume for a specified residence time; and specifying insulation. Sludge atomization using steam is examined.

ACKNOWLEDGMENTS

This course "Industrial Pollution Control" was made possible only by the advice, support, and contributions of many students, faculty, including adjuncts, industrial friends, and short-course lecturers. The author regrets that space limitations prevent individual recognition; but special thanks are due Marion Buercklin (Sun Oil Company) and Leon Meyers (E. P. A.) for serving as "founding fathers." □

REFERENCES

Recommended Texts

Hesketh, H. E. (1972), *Understanding and Controlling Air Pollution,* Ann Arbor Science Pub., Ann Arbor, Michigan.

Thackston, E. L., and W. W. Eckenfelder (1972), *Process Design in Water Quality Engineering,* Jenkins Publishing Company, Austin, Texas.

References

Adams, C. E., and W. W. Eckenfelder (1974), *Process Design Techniques for Industrial Waste Treatment,* Enviro Press, Nashville, Tennessee.

American Petroleum Institute, (1969), "Manual Disposal of Refinery Wastes Volume on Liquid Wastes," A. P. I., Washington, D. C.

Beychok, M. R. (1970), "Performance of Surface Aerated Basins," Chemical Engineering Progress Symp. Series, No. 107, Vol. *67,* p. 322.

Beychok, M. R. (1973) "Air Pollution Control Legislation," Tulsa University Short Course Notes, January 15.

Byers, R. L. and W. Licht, (1972), "Processes for Control of SO_2 Emissions," AIChE Advanced Seminar, AIChE, N. Y.

Byers, R. L. and W. Licht, (1974), "Design Fundamentals of Particulate Collection for Air Pollution Control," AIChE Today Series, AIChE, N. Y.

Crocker, B. B. and K. B. Schnelle, (1970), "Introduction

(Continued on page 186.)

scheduled period of 18 hours. Scenarios were produced on:

- Evolution of steel-making technology (1975-2000)
- The competitive balance between the steel and plastics industry in 1985.
- Plastics recycle technology in 1985.

The final results lack the authority and balanced viewpoints of professional reports. They are by no means academic exercises, however, and have provided some interesting insights into the future stance of industries important to the regional and national economies. Beyond any doubt the authors have a truer view of the nature of these industries and of the environment in which they will probably be operating during the students' working careers. We believe that as a result of this training, this group may accommodate more quickly to the realities of the industrial and business worlds; and thus make their presence felt to their benefit and to the benefit of society in general. □

H. P. Schreiber graduated with B.Sc. and M.Sc. degrees from the University of Manitoba and obtained his Ph.D. at the University of Toronto. Following post-doctoral work at N.R.C. Ottawa, he joined Canadian Industries Ltd. in 1955, and served until 1973 as research chemist, Research Scientist and Group Leader, concentrating on polymer. He is Professor of ChE Ecole Polytechnique. Dr. Rigaud is a graduate of Ecole Polytechnique, Montreal, and holds bachelors, masters and Ph.D. degrees from that Institution in metallurgical engineering. Until 1974 Chairman of the Metallurgical Engineering Department, he is currently Associate Director for Research at Sidbec-Dosco, Contrecouer.

REFERENCES

1. E. Jantsch, Technological Forecasting in Perspective O.E.C.D. Paris (1967).
2. J. R. Bright and M. E. F. Schoeman, A Guide to Practical Technological Forecasting. Prentice-Hall (1973).
3. A. T. Olenzak: "Technological Forecasting: A Pragmatic Approach" Chem. Eng. Progress (No. 6) p. 27 (1972).
4. D. M. Kiefer "Chemicals 1992" Chem. and Eng. News, July 10, 1972 (p. 6).
5. H. Kahn and Bruce—Briggs: "Things to Come, Thinking about the 70's and 80's." MacMillan, New York (1972).
6. R. U. Ayers, Technological Forecasting and Long-Range Planning. McGraw Hill, N. Y. (1966).
7. J. P. Martino, An Introduction to Technological Forecasting. Gordon and Breach (1972).
8. J. P. Martino, Technological Forecasting for Decision Making. American Elsevier, N. Y. (1972).
9. J. H. Hallomon "Technology and the Productive Process" Lecture, Sloan School of Management, M.I.T. June (1974).
10. 1974 Engineering seminar conference on Technology Assessment. University of Michigan, Ann Arbor (1974).
11. D. Meadows, Donnella Meadows, J. Randers, W. Behrens III. The Limits to Growth. Potomac Associates (1972).

POLLUTION CONTROL: Manning

Continued from page 173.

to Air Pollution Control," A.I.Ch.E. Today Series, AIChE, N. Y.

Dick, R. I., (1972), "Sludge Treatment," Chapter 12 in *Physicochemical Processes,* W. J. Weber, Jr., Ed. Wiley Interscience, N. Y.

Donaldson, E. C., (1974), "Subsurface Waste Injection in the U.S.," U.S.B.M. Information Circular 8636.

Eckenfelder, W. W., and P. Krenkel, (1972), "Advanced Wastewater Treatment," AIChE Today Series, AIChE, N. Y.

Federal Register (1974), "Petroleum Refining Point Source Category," Vol. *39,* No. 91, May 9, p. 16559-16575.

Federal Water Pollution Control Administration, (1967), "The Cost of Clean Water: Industrial Waste Profile No. 5, Petroleum Refining," Washington, D. C.

Ford, D. L. and F. S. Manning, (1974), "Oil Removal from Wastewaters," Presented at Short Course, Vanderbilt University, Nashville, Tennessee, Nov. 11-15.

Kannapell, P. A. and J. G. Seebold, (1975), "Introduction to Noise Control in the Process Industries," AIChE Today Series, AIChE, N. Y. also Seebold's T. U. Short Course Notes, October 1974.

Manning, F. S. (1973), "Petroleum Refinery Waters and Wastewaters," Presented at PAHO Short Course, Trinidad, W. I., December 3-7.

Nelson, W. L. (1968), "Petroleum" *Encyclopedia of Chemical Technology* Vol. *14,* 2nd Ed., p. 835, J. Wiley & Sons, N. Y.

Novotny, V., and A. J. Englande, Jr., (1974), "Equalization Design Techniques for Conservative Substances in Wastewater Treatment Systems," *Water Research* *8,* No. 6, p. 325.

Philoon, W. C. (1974), "Use of Talk-Back Closed Circuit Television in Continuing Engineering Education," Proc. 9th Annual Midwest Section A. S. E. E., Wichita, Kansas, March 28-29.

Reed, R. D. (1973), "Furnace Operations," Gulf Publ Co., Houston, Texas.

Sarofin, A. F. and W. Bartok, (1973), "Methods for Control of NOX Emissions," AIChE Advanced Seminar, AIChE, N. Y.

Schnelle, K. B. and K. E. Noll (1972), "Meteorology and Air Pollution Control," AIChE Today Series, AIChE, N. Y.

Soper, M. L., D. H. Atwell, and F. S. Manning (1975), "Mixing Effects in Surface-Aerated Basins," Water Research (accepted for publication).