ChE founder

"Doc" Lewis of MIT

Few men have had a greater influence on his students — and/or the profession, — than Dr. Warren Kendall Lewis of Massachusetts Institute of Technology. This article was prepared for **CEE** *by Professor E. R. Gilliland.*

IN THE FALL of 1901 a farm boy from Delaware entered M.I.T. to study mechanical engineering but a year later, at the suggestion of one of his classmates whose family operated a tannery, he transferred to a new course called Chemical Engineering. For over sixty years Dr. Warren K. Lewis has had a leading role in the creation, development and growth of this new engineering discipline. He has been a profound influence on the whole profession and on many of its leaders.

Dr. Lewis was born on a farm near Laurel, Delaware, on August 21, 1882. After early schooling in Laurel, he transferred to high school in Newton, Massachusetts, and entered the Massachusetts Institute of Technology in 1901. He had planned to return to the farm, but following graduation Dr. William H. Walker offered him an assistantship which he accepted.

The chemical industry was undergoing a major transformation at this time. The first syntheses of rayon were struggling to solve their industrialization difficulties. The advent of the automobile found the rubber industry with problems of producing tires with properties far exceeding those then obtainable in the rubber goods that had been produced, and petroleum refining was shifting to gasoline as its major product. M.I.T. had introduced a new educational program in the Chemistry Department in 1888 under the leadership of Professor Lewis M. Norton and named it Course X, Chemical Engineering. Norton died a few years later and in 1902 the Institute brought Dr. Walker from industry to head Course X.

In 1906, Dr. Lewis was awarded an M.I.T. fellowship for graduate work in Europe and he went to the University of Breslau, Germany, and studied physical chemistry under Abegg, receiving his Ph.D. in 1908. He returned to M.I.T. as a research associate in applied chemistry and then in 1909 joined the N. H. McElwain Company, a tannery in Merrimack, New Hampshire, as a chemist. Dr. Walker was successful again in attracting him to M.I.T. with an appointment as an Assistant Professor in 1910 and a full professorship followed in 1914.

In 1920 Course X was separated from the Chemistry Department and Dr. Lewis became the first head of the new department, a position he held until 1929 when he resigned to devote full time to his teaching.

Doc's career has covered many areas but his most important professional contributions were his leading role in the development of the profession of chemical engineering, his contributions to individual chemical and petroleum processes, his advice to students, associates, industry and government and his development of men.

FROM THE START of his teaching career, Dr. Lewis concentrated on utilizing the resources of basic knowledge in physical chemistry and physics to solve the engineering problems of chemical industry. He had an extraordinary understanding of basic science. He knew clearly the experimental facts that made him believe in atoms, in molecules, in kinetic theory, in forces between molecules and in the conservation of energy. His interest in and understanding of science and his ability to apply it was always a joy to behold. In tackling a new problem he always went back to these fundamental concepts. Distillation, heat transfer, fluid flow and absorption were ripe for this treatment, and he soon developed an integrated complex of research and teaching which resulted in a concept known as Unit Operations. Chemical processes are many and varied, and the Unit Operations made it possible to have a systematic discipline for the design and engineering of these complex operations. This was an exciting era of exploration and constant change for Lewis and his assistants — a time of no text-books, when classroom notes became obsolete shortly after they were distributed. By 1923 the product of these years was published by Walker, Lewis and McAdams as "Principles of Chemical Engineering" a text which profoundly stimulated the evolution of the profession.

He realized that while the applied physics and physical chemistry of the Unit Operations should be a strong component of chemical engineering that it alone was not a sufficiently broad base for those who were to be the leaders in the chemical profession. He believed that the special characteristic of a chemical engineer should be his understanding of chemistry and his ability to engineer it into industrial operations.

Leaving largely to others the further development of the Unit Operations, Lewis was soon engaged in introducing subjects in stoichiometry, industrial chemistry and in materials. In stoichiometry he enjoyed showing the student the great power of simple material and energy balances as tools for obtaining insight into a process. This work lead to his book with Radasch on "Industrial Stoichiometry." His subjects in industrial chemistry were not descriptions of current practice, although he had a very broad knowledge of industry from his consulting work, but were instead detailed analyses of a limited number of industrial processes. Each step of a process was analyzed on the basis of the material and energy balances, the physical chemistry, the chemical kinetics, the unit operations, the rate limiting steps involved and the choice of equipment. He would have detailed discussions with the students on what alternatives were possible and the pros and cons of each. Many of the discussions led to worthwhile innovations for the industrial operations. Professor Lewis recognized that materials, particularly non-metallic materials, were an important area for the future of chemical engineering, and soon after the publication of PCE he was engaged in formulating subjects on the basic principles involved in the understanding of surface chemistry and physics and of colloidal and amorphous materials such as gels, clays, textiles, plastics, leather, paper and rubber. This new material was quickly incorporated with the Unit Operations in both the undergraduate and graduate programs in chemical engineering at M.I.T. and lead to his book on "The Industrial Chemistry of Colloidal and Amorphous Materials."

Doc's career has covered many areas but his most important professional contributions were his leading role in the development of the profession of chemical engineering, his contributions to individual chemical and petroleum processes, his advice to students, associates, industry, and government, and his development of men.

HE WAS A superb teacher both as a lecturer and in the classroom. His lectures were beautifully organized and he had an unforgetable and unlimited supply of stories to illustrate all key points, but his greatest enjoyment was to challenge the students, or his colleagues, or anyone who would listen on some problem or principle. One of his favorite techniques for developing creativity in his students and the habit of defending their ideas was his famous "dollar to doughnut" bets. He admired the man who had ideas and who would defend them as long as he was convinced they were correct. A number of Doc's stories and quotes were collected and published some years ago in a volume entitled "Dollars to Doughnuts."

Dr. Lewis has always been an enthusiastic and prolific inventor and has received over 80 patents on his inventions, many of which have been widely applied in the chemical and petroleum industries. He attacks all problems with the viewpoint that there is a better solution, and proceeds to develop such a solution on the basis of clear and simple pictures of the fundamental relationships involved.

Dr. Lewis began consulting with industry early in his career under the guidance of Dr. Walker. While Dr. Walker had emphasized the necessity of basic science as the foundation of chemical engineering he believed that it was vital for an engineer to understand and to be involved in industrial practice. He himself was an active industrial consultant to the chemical industry and for a number of years Walker was a partner with A. D. Little in the consulting firm of Little and Walker.

Before World War I, Doc was working with Goodyear and Standard Oil Company of New Jersey. At Goodyear he did both consulting work and gave courses to the research group on applied physical chemistry, chemical engineering and materials. At this time the field of macromolecules was a maze of empirical knowledge although some of the bases of the modern interpretations had already been suggested. Working with the men in the Goodyear chemical department, he stimulated the development of a coherent working hypotheses of the structure and behavior of macromolecules, which was helpful in guiding the development of rubber technology. His work correlated the confused theories as to the nature of rubber and showed the relationships between the macromolecules of rubber and similar ones encountered in leather, cellulose, and other materials.

FOR MORE THAN forty-five years he has been a consultant to Humble Oil and Refining Company and the Esso Research and Engineering Company (formerly Standard Oil Development Co.) both of which are affiliates of Standard Oil Company (N.J.) One of his first contributions was an improved method for the vacuum distillation of lubricating oils in which he showed the advantage of reducing the resistance to flow of the vapor from the evaporating liquid to the condenser. He worked with Professor A. A. Noyes on an analysis of Sorel's and Hausbrand's work on the rectification of alcohol and saw the potentialities for such an operation in many chemical and petroleum separations. He was responsible for the first large scale application of continuous rectification in the petroleum industry: an installation of columns on a series of shell stills for the sharp separation of naphthas and gas oils. He later played a leading role in the development of the pipe still and in the development of super fractionators for the preparation of components for synthetic rubber and aviation gasoline.

Dr. Lewis was actively involved in petroleum cracking developments. In thermal cracking, coke formation was a troublesome problem because it would frequently deposit at a rapid rate in localized regions and stop the operation. He formulated models for the formation of coke by the cracking operation indicating that the reactions involved the production of active species which condensed, recracked and by a repetition of this cycle led to coke. Understanding that some basic steps of this reaction sequence were higher than first order, he proposed that the localized production of coke was due to the concentration of active species in these areas and that by mechanical design and by conditions that would dilute and rapidly wash out these constituents the coke problem could be licked.

Doc as the prime factor in the professional development of many men who are now leaders in the chemical and petroleum industries.

The work on thermal cracking and on reservoir engineering and petroleum production led to his pioneering studies on the high pressure vapor-liquid equilibria, in both the P-V-T and interphase equilibrium constant areas. His work on petroleum production also led to his investigations of two-phase liquid flow through porous media which he integrated with his work on inter-facial surface properties that had developed in his surface chemistry and physic subjects

Prior to 1938 it was difficult to carry out heterogeneous reactions between gases and solids in those cases where large energy effects were involved or in which the solid rapidly deactivated and needed frequent regeneration. A number of important reactions were limited in this way and required expensive reactor construction and complicated operating procedures. For example, it had been known for many years that silica-alumina catalysts were effective for the cracking of hydrocarbons and that the products had higher octane numbers than those obtained from conventional processes However, it was difficult to make the operation practical because, first, the catalyst deactivated rapidly due to carbon deposition, and second, the cracking operation was highly endothermic, while the catalyst regeneration stage, i.e., burning the carbon off the catalyst, was highly exothermic. Frequent and complicated cycles were involved to maintain adequate catalyst activity and to prevent explosion by the mixing of oxidizing gas and the hydrocarbons. In addition complicated reactor designs were employed in order to supply heat during the reaction cycle and to remove heat during the regeneration cycle. Th complications of the cycles were such that they were made longer than desirable, resulting in lower average catalyst activity.

DR. LEWIS pioneered the fluidized powdered solid system which was a much more effective method of handling such reactions. By fluidizing the solid and producing a system that could flow like a fluid, it was possible to pass the catalyst rapidly between a reaction zone and a regeneration zone thereby maintaining high average catalyst activity within the reactor. Likewise, the rapid flow of catalyst from the regenerator to the reactor made it possible to carry heat from one vessel to the other by the sensible heat of the solid, thereby eliminating any heat transfer through the walls. In addition, rapid mixing within the fluidized bed gave almost complete uniformity of temperature in both the reactor and the regenerator.

The process was so outstanding in its advantages that the type of reactor previously employed for catalytic cracking was abandoned within a relatively few years. The fluidized process was developed just as World War II was beginning and accounted for a large fraction of the aviation gasoline produced by the United States. The fluidized solid operation has outstanding advantages for heterogeneous reactions involving large heat effects or whenever it is desirable to move solids through the reaction zone rapidly, and as a result has been applied to the coking of heavy petroleum residues, hydroforming of naptha, burning of limestone, processing of sulfide ores, production of silicones, oxidation of napthalene, and many other chemical reaction. It has probably had a more rapid and extensive adoption than any other chemical engineering process technique in recent years, and, at the present time, the capital investment represented by the fluidized processes is several billion dollars.

Dr. Lewis was extensively involved with the government during both World Wars. During the first war he was active with the Chemical Warfare Service and the Bureau of Mines and was in charge of the development program for gas defense. In October 1918 he represented the Chemical Warfare Service at the Paris Interallied Conference on Gas Warfare. In 1940 — eighteen months before Pearl Harbor — Dr. Lewis joined the National Defense Research Committee (later OSRD) organized by Vannevar Bush, J. B. Conant, and Roger Adams for the attack on technical problems of concern to the military. He was also a member of the Senior Advisory Committee for the Manhattan Project.

Doc has been the prime factor in the professional development of many men who are now leaders in the chemical and petroleum industries. His teaching and his interest and success in the development of men trained to think creatively and practically in the field of applied-chemistry reveal his full character. Those who have been associated with him in the classroom, in research projects, and in industrial work consider this experience one of the most important and exciting parts of their professional career. Many of these men are now teaching and twelve of his former students have been elected to the National Academy of Engineering and six to the National Academy of Sciences. The success and contributions of these former students are his greatest satisfaction.

Doc has always been an enthusiastic and prolific inventor . . . He attacks all problems with the viewpoint that there is a better solution . . . Dr. Lewis pioneered the fluidized powdered solid system.

The characteristics that made Dr. Lewis outstanding as a teacher and builder of men were a tireless devotion to his work and to his ideals, a rare form of modesty in giving credit to others, sympathy for the man who made an effort (excellence preferred) but the effort was paramount, a wonderful enthusiasm for his profession and for tackling the tough problems, for making chemical engineering practice a vivid and colorful experience, and a knack for teaching and for inspiring the best in his students and associates.

THE CONTRIBUTIONS Dr. Lewis has made have been recognized by many honors and awards. He has received honorary doctorate degrees from the University of Delaware, Princeton University, Harvard University and Bowdoin College. He has received the President's Medal of Science and the President's Medal of Merit. He was honored by AIChE by the establishment of the Warren K. Lewis Award jointly sponsored by the Esso Research and Engineering Company and the Humble Oil and Refining Company which recognizes outstanding educators in chemical engineering. He has received the Perkins Medal of the Society of Chemical Industry, American Section (1936) ; the Lamme Medal of ASEE (1947) ; the Priestley Medal of the ACS (1947) ; the Gold Medal of the American Institute of Chemists (1949) ; the New England Award of the Engineering Societies of New England (1950) ; the Industrial and Engineering Chemistry Award of the ACS (1956) ; the API Gold Medal for Distinguished Achievement (1957) ; the John Fritz Medal given jointly by the five national engineering societies (1966) and the Founders Award of the AIChE (1958). In 1969 the faculty, friends and alumni of Course X established through contributions the Warren K. Lewis Professorship in Chemical Engineering at M.I.T.

At 88 years of age, Doc is still vigorous and active and willing to give anyone a lecture (and his solution) on technical or social problems.

He continues to be an inspiration for those who were associated with him and the chemical engineering profession has been very fortunate in having one of the outstanding teachers and engineers of the century in its rank.

ChE book reviews

Molecular Thermodynamics of Fluid-Phase Equilibria. J. M. Prausnitz, Prentice-Hall, New York (1969).

For those chemical engineers (and chemists) who wish a succinct evaluation of this book then I recommend you buy it! It provides an excellent, up-to-date reference source to allow one to interpret and correlate phase equilibrium data—and, in many cases to predict phase compositions *a priori* from theory.

A more detailed review should, of course, note the style, degree of clarity, aptness, and content. The first three of these attributes need little comment. The book is very well written, extremely easy to follow, and treats a subject which is of great import to the chemical engineering profession.

Regarding the content, two points seem worth noting, both of which are covered in the preface. First, Professor Prausnitz states that in the book, "no attempt has been made to be exhaustive." Topics were selected with which he was familiar and topics such as metal or electrolyte solutions were not considered. The point to be made here is, however, that in the material covered, it appears to the reviewer, that for solutions of organic materials, a very fair appraisal has been presented and the material well documented in the bibliography.

The second point to emphasize is the general philosophy of the book wherein the author defines his approach to the study of phase equilibria as one of "an engineering science, based on classical thermodynamics but relying on molecular physics and statistical thermodynamics to supply insight into the behavior of matter. In application, therefore, molecular thermodynamics is rarely exact; it must necessarily have an empirical flavor."

This latter statement sets the tone of the entire book. When it is possible to be rigorous, one finds a clear derivation of the significant relations. When such an approach is not possible, empiricism is introduced, but in a manner to try and extract generalizations from specific cases so as to allow the reader himself to extrapolate and interpolate and thus lead one to logical reasoning for different cases.

The first six chapters neatly condense those elements of thermodynamics necessary throughout the remainder of the book. In particular, emphasis has been correctly placed on the requirement for an accurate equation of state to obtain gas phase fugacities. Perhaps more emphasis could have been given to those mathematical difficulties encountered in obtaining liquid fugacities by integrating a fugacity expression across the two phase envelope, but this viewpoint is implied since the remainder of the book deals primarily with liquid phase models to determine activity coefficients. The straight-forward review of the principal concepts of intermolecular forces in Chapter 5 will be appreciated by most readers.

Chapters 6 and 7 treat excess functions and solution theories to allow one to handle liquid fugacities while Chapters 8 through 10 deal with the specific topics of the solubility of gases in liquids and solids and high pressure equilibria. Nine appendices are used to prevent detailed derivations from blocking the smooth flow of ideas in the text.

As a reference or as a class text, this book should be valuable for many years. Those active in the field might hope that this book might soon become obsolete. However, there is little chance of this occurring!

R. C. Reid
Massachusetts Institute of Technology