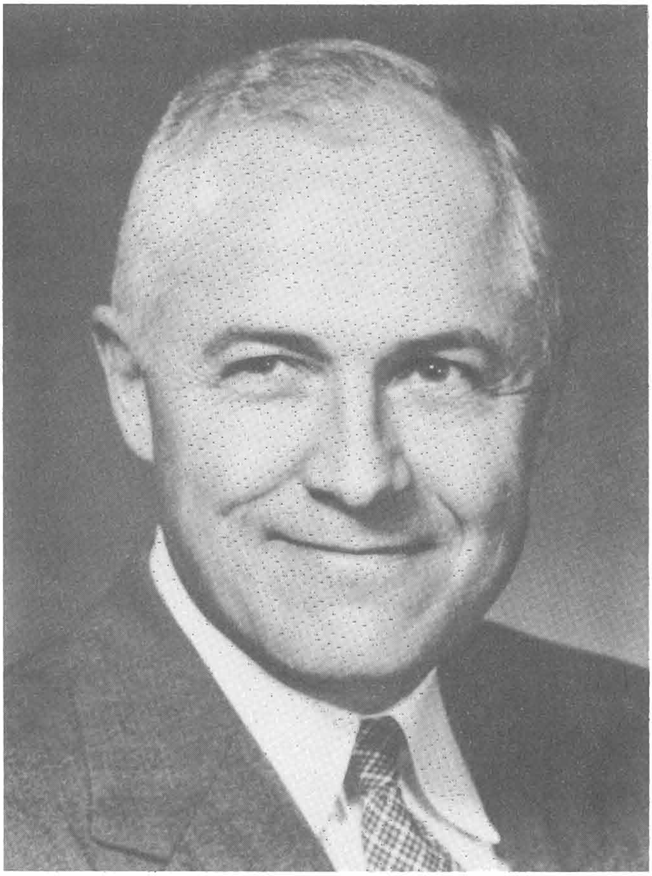
NATIONAL ACADEMY OF SCIENCES

THOMAS KILGORE SHERWOOD

1903—1976

A Biographical Memoir by
HOYT C. HOTTEL

Biographical Memoir



Thomas K. Sherwood

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BY HOYT C. HOTTEL

THOMAS KILGORE SHERWOOD was, by any standards, one of America's great chemical engineers. His scholarly work on mass transfer under molecular and turbulent-flow conditions made him a world authority in the area. He was the author of five books, two of which had enormous influence on the teaching and practice of chemical engineering. Taking strong stands on the problems of engineering education was one of his hallmarks. In the early stages of World War II he was the finder of talent for military research in chemical engineering; in the war's late period he was in Europe gathering intelligence. He was one of the founders of the National Academy of Engineering. He was respected and admired by his peers; countless numbers of them called him friend. He had warmth, charm, orderliness, and a conscience that drove him to use his talents to the fullest to advance chemical engineering in theory and practice. The world has his number—the Sherwood Number.

Thomas Kilgore Sherwood was born to Milton Worthington Sherwood and Sadie Tackaberry Sherwood on July 25, 1903, in Columbus, Ohio, but spent most of his early youth in Montreal. With a B.Sc. degree from McGil University, in

1923 he came to M.I.T. for graduate work in chemical engineering. Upon receiving his M.Sc., he became an assistant to W. H. McAdams in distillation and heat transfer. The next year he began research on his S.D. thesis under W. K. Lewis on a subject which—and under a man who—would have a lifelong effect on his career. The drying of solids sounds prosaic, but it touches on all the phenomena, some recondite and chemically controlled, related to transport of a vapor or liquid through and between phases. For Sherwood that was the first step in a lifelong dedication to mass transfer in chemically related systems. A two-year appointment as assistant professor at Worcester Polytechnic Institute was followed by one in chemical engineering at M.I.T., where he completed his doctorate in 1931. He became a professor in 1941 and was appointed the first professor of chemical engineering to the Lammot du Pont chair in 1966. When the time for retirement came, he left M.I.T. for California to become, from 1970 to his death, a visiting professor in chemical engineering at the University of California, Berkeley.

Though Sherwood's early papers showed his inclination to move frequently from research to industrial practice—papers on heat transfer, rubber vulcanization, wet-bulb hygrometry, optimization of ammonia condensers, plate-column entrainment and flooding are examples—his dominant research up to World War II was in mass transfer, papers on Drying of Solids I-VII, absorption, extraction, packed-tower and bubble-cap column performance. But his most important contributions to chemical engineering in that prewar period were two books exerting far-reaching influence on chemical engineering teaching. *Absorption and Extraction* (1937) was the first significant book in that area. The second, *Applied Mathematics in Chemical Engineering*, (1939), written with C. E. Reed, began as a graduate subject. Sherwood would have been the first to deny any claim to being a mathematician. But any mathematical defects in the book were far more than offset by the many stimulating examples of application to industrial practice; the book influenced chemical engineering curricula throughout the world. A much-revised edition, prepared chiefly by H. S. Mickley, appeared in 1957.

By 1940 it was clear that the United States might be involved in war. At the instigation of Vannevar Bush the National Defense Research Committee was set up, and Sherwood was appointed a technical aide. His job was to line up chemical engineers who would be available for military research if war came. He later became section chief for Miscellaneous Chemical Problems in NDRC's Division 11 and a consultant to the Baruch Committee concerned with synthetic rubber development. Under his supervision were such diverse problems as new hydraulic fluids for use at very high and very low temperatures, antifouling coatings for ship bottoms, the inerting of gas spaces in aircraft fuel tanks, the development of large screening-smoke generators, and the production of concentrated hydrogen peroxide. In addition to supervising NDRC contracts, Sherwood had his own research programs at M.I.T., the drying of penicillin, evaporation of falling drops, mixing in commercial reactors, and the manufacture of formaldehyde for making RDX.

In 1944 Sherwood was made a member of the first of two successive committees to assess the status of jet propulsion in the United States, the so-called Whitman Committee. That fall, as an expert consultant of the War Department, he was made one of a small group of scientists operating in Europe behind the Allied lines, charged with gathering scientific intelligence on German technical developments, particularly in the nuclear and rocket areas.

When World War II ended, Sherwood returned to M.I.T. for teaching and research. The next year, however, he was appointed dean of engineering. In that position he had the difficult task of seeing the institute through its period of postwar adjustment. Although his research, directed particularly to the area of heat, mass, and momentum transfer in turbulent flow systems, did not stop, he showed an increasing tendency to address problems outside his area of technical expertise. Papers and lectures on science in education, teacher development, research in education, creative accomplishment, and new frontiers in science were characteristic of that period. But his preference for research, teaching, and the organization of parts of chemical engineering science in book form pulled him out of administration after six years as dean, to return to his scientific and technological interests. A quote from a paper given years later at a symposium on mass transfer and diffusion measures him:

> We have much more concern with complex physical phenomena, and we have not yet arrived at a point where all can be left to the computer. In a way I hope we never will, for chemical engineering is so much more fun when we don't know very much.

Despite his coauthoring a book on mathematics, he had a strong preference for physical and chemical phenomena over theory. A study of interfacial phenomena in liquid-liquid extraction produced some exciting results. For example, the rate of water-extraction of acetic acid from its solution in isobutyl alcohol (immiscible with water) may be expected to be affected by addition of a base to the water phase. Then-existing theory predicted a maximum twofold increase in rate of extraction. Instead, the rate climbed tenfold with increased base concentration, and violent interfacial turbulence showed up, even forming submerged droplets. Completion of the study of this phenomenon, important in determining the size of extraction equipment used by chemical industry, was left to others. Sherwood went on, continuing to mix scholarly research with such practical problems as mechanical draft cooling towers, vacuum dehydration using liquid absorbents, separation of hydrocarbons with an adsorbent slurry, and desalination by freezing or by reverse osmosis.

Two of Sherwood's books have been mentioned. The second edition of *Absorption and Extraction,* revised with R. L. Pigford, appeared in 1952. Then came *Properties of Gases and Liquids,* coauthored with R. C. Reid; a *Course in Process Design*; *The Role of Diffusion in Catalysis,* coauthored with C. N. Satterfield; and a much-expanded and far more comprehensive edition of his first book, with title changed to *Mass Transfer,* coauthored with R. L. Pigford and C. R. Wilke. Sherwood's talent for organizing, for identifying the most significant defects of a technical scheme, process, or design and for designing an experiment to supply the most needed new knowledge caused him to be sought out for many organizing activities. He was technical adviser to the Office of Saline Water of the U.S. Department of the Interior from 1952 to 1961; in 1960 he chaired a planning committee for the Research Study at Woods Hole on Salt Water Conversion. He was a member at large of NRC's Division of Engineering and Industrial Research (1962–65). He was a founding member of the National Academy of Engineering (1964). At M.I.T. he chaired the Committee on Staff-Administration (1964). In 1967, when NAS–NRC again went with intensity into desalination, he chaired a planning committee for the Desalination Research Conference. That year he was also chairman of the Long-Range Planning Committee for M.I.T. libraries and a trustee of the M.I.T. Pension Association. From 1967 to 1969 he was chairman and then a two-year member of the NAE Committee on Air Quality Membership, and in 1974 a member of the NAE Task Force on Energy.

Sherwood's later-life associates think of his avocation as having been mountaineering, particularly in the Canadian Rockies. Personal experience suggests a postscript to that: A year after the death of his first wife, Betty, Tom, Reg Wynn—Tom's closest Montreal high school associate—and I spent an idyllic month in the Tetons. On a Grand Teton climb (up by the exciting Glenn Exom route; the Grand Teton was America's Matterhorn, and Exom had climbed the Matterhorn solo at age seventeen), our guide chose Tom to be the first, on our way down, to make a 110-foot rappel down a cliff. As he prepared for the back-jump off the cliff, leaning out to prevent his chin from hitting the edge as he dropped, his foot caught in a crevice and in pain he dropped his rappel rope! But his belaying rope, monitored by the guide, saved him. So I was elected to make the first rappel. Waiting at the end of my 120-foot rope and speculating on whom the guide would send down next, I saw Tom in a few moments, inching his way down the curved cliffside. When he joined me, still whitefaced, he said, "Hoyt, I am never going to climb a mountain again." But the next year he married Virginia, and she made him into a mountaineer.

Outstanding among the many invited lectures given by Sherwood were the Priestley Lecture at Pennsylvania State, the King Lecture at Johns Hopkins University, and a comprehensive review of his fifty years of interaction with his special interest, "The Development of Mass Transfer Theory," presented in 1973 at a University of Houston symposium. His many memberships and honors are listed below; outstanding among the latter were honorary doctorates, from Northeastern University, from his first alma mater McGill University, and from the Technical University of Denmark. He was honored by his colleagues by having a dimensionless number used in scientific literature in relation to mass transfer—previously called ambiguously the Nusselt number for mass transfer or the reciprocal of one of the Taylor numbers—renamed the Sherwood Number, a nomenclature now almost universally accepted. Sherwood was one of the giants of twentieth-century chemical engineering.

HONORS AND DISTINCTIONS

MEMBERSHIPS

National Academy of Sciences (Chairman, Section of Engineering, 1962–65)
National Academy of Engineering (Founding member)
National Academy of Arts and Sciences
American Society of Engineering Education
American Chemical Society
American Institute of Chemical Engineers (Councillor, 1947–49)
American Society of Mechanical Engineers
Sigma Xi, Tau Beta Pi, Alpha Chi Sigma
Chemical Institute of Canada (Honorary Life Member)

AWARDS AND HONORARY DEGREES

1941 William H. Walker Award, A.I.Ch.E.
1947 Doctor in Engineering, Northeastern University
1948 United States Medal for Merit
1951 Doctor of Science, McGill University
1963 Founders Award, American Institute of Chemical Engineers
1972 Warren K. Lewis Award, A.I.Ch.E.
1972 E. V. Murphree Award, Industrial and Engineering Chemistry
1974 Doctor of Science, Technical University of Denmark

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