# WARREN M. ROHSENOW

*1921–2011*

Elected in 1975

*"For contributions to boiling and condensing liquid-heat transfer and the teaching of the concepts of heat and mass transfer."*

BY ARTHUR E. BERGLES

WARREN MAX ROHSENOW, an outstanding engineering educator and heat transfer researcher, professor emeritus of mechanical engineering at the Massachusetts Institute of Technology (MIT), died on June 3, 2011, not long after celebrating his 90th birthday.

Warren, or "Rosie" as he was often called, was born in Chicago on February 12, 1921, but lived in Fort Worth and Kansas City before moving back to Chicago and entering college. Attending various schools, he became an accomplished musician—particularly on drums and piano—and participated in many dance bands and orchestras. While he was heavily involved with accelerated academics, music, clubs, and sports, he still found time to earn his Eagle Scout badge before he graduated from high school at age 16.

He attended Northwestern University and received a BS in mechanical engineering in 1941. Of course, he continued to make music with the orchestra and marching band, filling in with anything that was needed, as well as many professional gigs. Continuing in mechanical engineering at Yale University, he earned a master's in 1943 and rapidly completed the requirements for the D.Eng., which was awarded in 1944.

He was an instructor during his graduate program, teaching mechanics, thermodynamics, and heat power engineering.

After graduating from Yale he received a commission in the US Navy, serving with the gas turbine division of the Naval Engineering Experiment Station to develop temperature instrumentation for a domestically produced gas turbine considered for ship propulsion. He wrote one of his early papers on thermocouple error when measuring hot gas temperatures. A number of other engineering problems related to the war effort occupied his attention during his two-year active service.

In 1946 he joined the MIT faculty, working in the Heat Measurements Laboratory, teaching undergraduate thermodynamics and heat transfer, and developing the first graduate courses in heat transfer at the institute. He published papers on improving gas turbine regenerators and began an extensive research effort on boiling heat transfer initially sponsored by the Office of Naval Research. The latter work focused on forced convection subcooled boiling, covering the entire range of heat fluxes, including burnout. This program led to the installation of two 36 kW motor generators for direct-resistance heating of the test tubes. To avoid physical destruction of the tubes, a dynamite-cap switch was developed to interrupt the current as the tube temperature rapidly increased at the initiation of burnout. The dynamite switch was lost to the mists of time, but the motor generators were used by many students for the next 60 years. A laboratory report series was initiated in 1950 to facilitate rapid dissemination of research results, and a steady stream of papers appeared in conference proceedings and in research journals. He was coauthor of the first report (1950) and the last, number 106 (1990).

Warren Rohsenow's most important paper started out in report form in 1951: "A Method of Correlating Heat Transfer Data for Surface Boiling of Liquids." The proposed method was simple but effective: The boiling curve for forced convection subcooled (surface) boiling was considered a superposition of single-phase forced convection and nucleate pool boiling.

The pool boiling component obtained by subtraction was then correlated by dimensionless groups. The exponent of each group was found to be approximately the same for many liquids, leaving only to be determined the lead constant, Csf, which depends on surface and fluid. In the past 50 years, many researchers have used this general approach. Testifying to the staying power of this approach, the paper earned him the ASME Classic Paper Award in 2002; he coauthored two related papers in 2004.

The laboratory was renamed the Heat Transfer Laboratory in 1956, with Professor Rohsenow as director. A wide variety of studies of very complex phenomena was undertaken: boiling and condensing of liquid metals, forced convection film boiling, thermal contact resistance, condensation of refrigerants, improvement of cooling towers, enhancement of heat transfer, and heat transfer in underground electrical cables. He was an author on more than 100 journal papers as well as several hundred conference papers, book chapters, and technical reports.

For many years, he headed the Thermal Science Division of the MIT Department of Mechanical Engineering. He was largely responsible for developing the graduate program in heat transfer, which was highlighted by his courses in conduction and convection heat transfer. He also had a much broader responsibility, serving as graduate officer of the department for nearly 30 years.

His research and teaching experience led to the 1961 textbook *Heat, Mass, and Momentum Transfer,* coauthored with H.Y. Choi. One of the first undergraduate heat transfer textbooks written, the book was used for many years in undergraduate and intermediate heat transfer courses at MIT. He was also senior editor and contributor to the definitive *Handbook of Heat Transfer* (1973), its two-volume successor, *Handbook of Heat Transfer Fundamentals* and *Handbook of Heat Transfer Applications* (1985), and the 3rd edition of the *Handbook of Heat Transfer* (1998). The typical handbook chapter summarized the fundamentals and gave a comprehensive list of formulas that could be used to estimate heat transfer coefficients. In 1960 he organized a

two-week intensive summer course, Developments in Heat Transfer, that was offered for the next 16 years.

Professor Rohsenow's research primarily involved graduate students working toward their degrees, and he supervised more than 150 graduate theses in mechanical engineering, nuclear engineering, and ocean engineering. He was doctoral supervisor of more than 40 students, half of whom assumed professorships at leading universities,

A member of ASME since 1943, he chaired the Boston section (1955–1956) and the Heat Transfer Division (1961–1962). He was an early proponent of the International Heat Transfer Conferences, now held every four years. He was a founder and president of the International Center for Heat and Mass Transfer. He was a founding member of the editorial advisory board of the *International Journal of Heat and Mass Transfer* and served on the advisory boards of several other journals. He was a member of delegations establishing cooperative programs with other countries, notably the US-USSR Cooperative Agreement in Heat and Mass Transfer (1979).

Besides being an outstanding leader in heat transfer and thermal power research and education, he had deep insight into engineering challenges and technology development. He consulted for many major corporations, including courtroom appearances. In 1957, he cofounded Dynatech Corporation (initially Microtech Research) in Cambridge, Massachusetts, and served as chairman of its board of directors. The consulting and manufacturing company grew to 3,000 employees worldwide and was listed on the New York Stock Exchange before it was sold in 1997.

Warren Rohsenow's accomplishments were recognized with major professional society awards: the Pi Tau Sigma Gold Medal (1951), ASME Henry Hess Award in 1952, election to the American Academy of Arts and Sciences (1956), ASME Heat Transfer Memorial Award (1967), ASME Life Fellow (1969), AIChE and ASME Max Jakob Memorial Award (1970), NAE election (1975), ASME Centennial Medallion (1980), ASME Honorary Member (1988), and ASME Medal (2001). In 1997 the ASME Gas Turbine Committee of the Heat Transfer

Division awarded the first Warren M. Rohsenow Prize for the best conference presentation. In 2004 the first ASME Bergles-Rohsenow Young Investigator in Heat Transfer was recognized.

With all of this professional activity, it is a wonder that Rosie had time for other pursuits. But he surely did. On the piano, he led an ensemble that provided background music at many MIT functions. He enjoyed golf, tennis, skiing, and traveling. It could be said that his passion was getting to know people, and he made it a point to know professional and personal acquaintances as individuals. He and his wife, Towneley, gave impromptu concerts (she singing and he on piano) at professional meetings all over the world.

He was married to Towneley for 55 years until she passed away in 2001. They had moved from their suburban Boston home in Waban to Falmouth, Maine, in 1991. Rosie became increasingly disabled over the last 20 years of his life, but he adapted to his condition, with the major concessions being that he gave up sports, restricted traveling, and switched from the piano to the xylophone. He kept up a spirited correspondence with the aid of voice activation of his computer.

Warren Rohsenow is survived by five children and their spouses, four grandchildren, and five great-grandchildren. He was devoted to his family, always finding time to spend with family members. The Rohsenow household was cheerful and loving, invariably filled with music.

He retired from MIT in 1985 but his spirit lives on there. The laboratory was renamed in his honor in 1992: the Rohsenow Heat and Mass Transfer Laboratory. After an extensive renovation, it was again renamed in 2010, the Rohsenow Kendall Heat Transfer Laboratory.

In many respects, Warren Rohsenow's passing signals the end of an era. He helped create a golden age of research in heat transfer. The field was undeveloped in 1946 and much work needed to be done to design heat transfer equipment. He made the most of the opportunity during the next 50 years. Simplified models of heat transfer phenomena based on classical analysis are now no longer fashionable. Instead,

computational fluid dynamics (CFD) codes have become the standard tool of research and industrial design.

With the passage of time, many pertinent studies performed decades ago are now sent into oblivion, removed from the reference lists of recent papers and textbooks. It can be asserted, however, that Warren Rohsenow's contributions to heat transfer will endure. Furthermore, his contributions as a person will continue to inspire students and researchers alike.