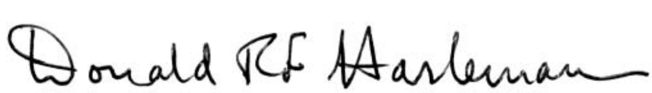

DONALD R.F. HARLEMAN

1922–2005

Elected in 1974

"For leadership in the development of theoretical and experimental techniques in the field of fluid mechanics."

BY RAFAEL L. BRAS, FRÉDÉRIC CHAGNON, ERIC E. ADAMS,
PETER S. EAGLESON, OLE MADSEN, SUSAN MURCOTT,
LEW THATCHER, AND PETER SHANAHAN

DONALD R.F. HARLEMAN, Ford Professor Emeritus of the Massachusetts Institute of Technology (MIT), died of cancer on September 28, 2005, on Nantucket, Massachusetts. He was 82 years old.

Born on December 5, 1922, in Palmerton, Pennsylvania, Don received a bachelor's degree in civil engineering from Pennsylvania State University in 1943 and then worked as a design engineer for the Curtis-Wright Corporation in Ohio during the last years of World War II. In October 1945, he arrived at MIT, a 22-year-old beginning graduate student in the Department of Civil and Sanitary Engineering with an interest in fluid flow. On that same October day, Dr. Arthur T. Ippen, a Caltech Ph.D. student of the renowned fluid dynamicist Theodore von Karman, also arrived in Cambridge to take up a new appointment as professor in charge of the department's hydrodynamics and hydraulic engineering program. Thus began a collaboration and friendship that continued until Ippen's death in 1973.

In 1947, Don Harleman completed his master's thesis, "The Characteristics of Density Currents," based on a problem Ippen encountered on one of his consulting jobs. A conclusion of that thesis paper reflects the principle of Don's subsequent research: "Any theory, in order that it may be accepted, must stand the test of experimental confirmation.... Accordingly, any conclusions as to the accuracy of the entire theory must be postponed until experimental results are available."

In his doctoral thesis, "Studies of the Validity of the Hydraulic Analogy to Supersonic Flow," Don investigated experimentally the nature of pressure variations around airfoils at supersonic velocities from measurements of oblique hydraulic jump characteristics resulting from airfoil-shaped obstacles in a supercritical flow. Because there were no adequate high-speed wind tunnels to test his thesis, Don designed and supervised the construction of a unique high-velocity tilting-flume facility, a testimony to his prowess as an engineer.

Upon completion of his doctorate in 1950, Don accepted an appointment as assistant professor of hydraulics at MIT. That year was most significant, though, because he married his beloved companion, Martha Havens, who remained his life partner until his death. On May 2, 2006, Martha died of complications of respiratory disease. She was 82.

Don had an extraordinary career at MIT. His appointment in 1950 coincided with the dedication of a new hydrodynamics laboratory. In 1970, with funding from the founder of the Ralph M. Parsons Company, the laboratory was doubled in size and rededicated as the Ralph M. Parsons Laboratory for Water Resources and Hydrodynamics. Don Harleman followed Arthur Ippen as director of the laboratory from 1973 to 1983.

Don was motivated to solve issues that would improve the quality of life and protect the environment. In pursuit of those goals, he changed research directions several times during his long career. His early work on stratified saltwater systems afforded a natural segue to thermally stratified freshwater systems (lakes and reservoirs). In the mid-1950s, he investigated engineering controls of stratified flow from freshwater reservoirs for the Tennessee Valley Authority. Don and his students established a fundamental model for predicting stratification based on meteorological conditions. The model relied on molecular diffusion for vertical heat transport, a formulation that avoided calibrating an eddy diffusion function to capture turbulent diffusion. As part of a series of studies of stratified reservoirs, Don then worked with other students to develop predictive techniques for water quality.

During a sabbatical at the International Institute for Applied Systems Analysis in Laxenburg, Austria, in 1977–1978, Don explored a topic related to his prior work on temperature—the trophic status of lakes and reservoirs. Algae grow in lakes and reservoirs in response to the availability of sunlight for photosynthesis and nutrients for the creation of cellular matter. Lakes enriched with nutrients are subject to eutrophication, the excessive growth of algae, which creates unaesthetic conditions. Don theorized that the physics of lakes and reservoirs could alter nutrient distribution, and hence eutrophication, just as temperature stratification affects dissolved oxygen.

Don's work on natural lakes and reservoirs led to related work on the heated lakes used to dissipate waste heat from the condensers of electric power plants. In places where cooling water is limited, closed-cycle cooling is used, most commonly wet cooling towers. But if sufficient land is available, cooling ponds (shallow bodies of water built by erecting perimeter dikes) or reservoirs (deeper bodies of water formed by damming streams) are useful alternatives. Because of their depth, cooling reservoirs provide greater thermal inertia than towers, helping to keep down peak temperatures caused by temporary extremes in weather. In addition, many cooling reservoirs also provide recreational opportunities. Fundamental studies by Don and his students were integrated into MITEMP, a computer program that contained a collection of hydrothermal modules applicable to ponds and reservoirs of varying thermal structure.

As a direct corollary of Don's leadership, MIT was arguably the leader in analyzing thermal discharges. Compared with wastewater outfalls, thermal discharges are characterized by generally larger flow rates, lower density differences, and shallower water depths; hence flow is dominated more by momentum than by buoyancy, and designs are strongly influenced by port velocity, elevation (surface vs. submerged), and orientation (in plan view). The results of these studies are incorporated in many popular computer models of initial mixing models.

Don's interest in estuary hydraulics and transport increased as graduate students became more adept at implementing computer solutions to the equations of fluid flow and fluid transport. Analyses of experimental and field data provided a relationship between the longitudinal salinity gradient and the effective 1-D dispersion coefficient, which made possible the numerical solution for studies of impacts of dredging, sea level rise, and other scenarios. Ultimately, Don's models represented the flow and transport of contaminants in estuaries, forming a basis for the more sophisticated, multidimensional models and tools used in environmental impact studies.

In the mid-1980s, when the city of Boston began planning the cleanup of Boston Harbor, Don's focus shifted from biogeochemical processes to wastewater treatment. The Boston Harbor cleanup was a hot topic, and he frequently took public positions, guided by his sense of civic responsibility and his conviction that scientists and engineers should take the lead in such debates.

It was widely accepted at the time that the problems in Boston Harbor were caused mainly by frequent discharges of untreated sewage combined with stormwater through combined sewer overflows (CSO). Don argued that conventional primary treatment followed by an activated sludge plant was not an optimal solution. Based on his knowledge of first principles and of the process known as "physical-chemical treatment," he recognized that making the first stage of wastewater treatment more efficient, prior to a biological step, made far more sense. He was also an early advocate of an ocean outfall, which ultimately became an integral part of the Boston Harbor cleanup.

During a visit to southern California in 1989, Don found evidence to support his case. In response to a California regulation requiring that 75 percent of solids be removed from effluents discharged into the Pacific Ocean, primary clarifiers at wastewater treatment plants serving more than 12 million people in the Los Angeles and San Diego areas had been retrofitted to accept chemical additives. The addition of low doses of primary coagulants plus polymers (an innovation not historically part of physical-chemical treatment with metal salts) increased the amount of solids and biochemical oxygen demand (BOD) removed.

Moreover, plant capacity was increased as a result of the shorter retention time in primary clarifiers and improved secondary efficiency and flow capacity (exemplified in the Los Angeles Hyperion Plant).

Don Harleman coined the term "chemically enhanced primary treatment" (CEPT) to describe the use of low doses of a primary coagulant, typically a metal salt, and potentially also a polymer, in the first stage of municipal wastewater treatment. He advocated the use of CEPT in the Boston Harbor cleanup, arguing that it would accomplish several sensible aims: it would halve the size of the proposed Deer Island plant and concurrently free financial resources for solving the "real" problem—CSO overflows. Despite his valiant efforts, however, Don lost the political battle to bring CEPT to Boston Harbor . . . an important lesson.

Don was convinced that water-related illnesses plagued developing countries, had huge impacts on human health and ecosystems, and impeded sustainable economic growth. The lack of municipal wastewater and sanitation infrastructure was the underlying reason for the spread of these illnesses, especially in densely populated urban areas, but also in rural areas. Don believed that Western-style treatment systems, particularly activated sludge systems, were not appropriate to address the problem because of their complexity, high cost, high-energy requirements, and complicated operation and maintenance requirements. He was especially upset that, in most cases, only a fraction of the wastewater in urban areas was being treated, typically in "showcase" activated-sludge plants. He believed it would be better to treat all wastewater to an adequate, initial level, thereby improving both public health and the environment.

Don's idea was for staged wastewater treatment for developing countries. The initial stage should provide only enough treatment for effective disinfection to meet immediate public health and environmental requirements. Only after all of the wastewater in an urban area had been treated to that level should more advanced treatment technologies be introduced to improve the effluent quality and meet higher environmental standards. The requirements for first-stage treatment technology were: (1) disinfection of the effluent; (2) frugal space requirements; (3) low cost; (4) simple operation; and (5) easy upgrades. He believed that CEPT was an excellent candidate for the first stage.

The 1989 Hong Kong Harbor cleanup plan called for a conventional primary treatment plant followed by a 30-km-long ocean outfall. This plan encountered strong opposition from local environmental groups and from Chinese authorities who opposed the export of pollution to Chinese waters. In 1994, the Hong Kong Environmental Protection Department asked Don Harleman to take part in an international review panel, which ultimately recommended using CEPT followed by ultraviolet disinfection and a shorter outfall whose location would be determined by a proposed model study. The Hong Kong government accepted these recommendations, and the Stone Cutters Island Sewage Treatment Works was inaugurated in 2001.

Don believed in good engineering to improve the quality of life and environment everywhere in the world. He loved traveling with his wife Martha and was a popular consultant throughout the United States and abroad. Besides Hong Kong, he worked in Hungary, Egypt, the Netherlands, Brazil, Puerto Rico, Australia, Portugal, Lebanon, China, Mexico, and Italy, where, beginning in the 1970s, he helped tackle the problems of the lagoon of Venice. In 1995, he joined a panel of experts to oversee the development of the environmental impact assessment of the system of tidal barriers proposed to protect the city and the lagoon from increasingly frequent, damaging floods. With typical conviction and aplomb, Don insisted on the highest standards, not only to protect the lagoon, but also to improve it. Don lived to see the project well into construction, and his beloved Venice was on his mind almost to the day of his death.

Don's signature approach was to find an analytical solution to problems using simple geometry, followed by meticulous experimental confirmation, often followed by application to actual situations. His many published studies, along with his textbook, *Fluid Dynamics,* written with Jim Daily in 1966, propelled him to the forefront of his field and led to his election to the National Academy of Engineering in 1974, among many other honors. He was an honorary member of the American Society of Civil Engineers and the Boston Society of Civil Engineers. In 1987, his alma mater, Penn State, named him Alumni Fellow.

Perhaps Don's greatest contributions to his profession were the students, colleagues, and friends he inspired. He and Martha opened their hearts and their home to students, colleagues, and friends in ways that cannot be described but that some of us were lucky enough to experience.

In March 2000, more than 300 friends, family, and colleagues gathered to honor Don and Martha by establishing the Donald and Martha Harleman Professorship of Civil and Environmental Engineering at MIT. This was a fitting recognition of an inseparable couple dedicated to improving the lives of students, faculty, staff, and partners. Nobody who ever met them will ever forget them. They are very much missed.

Don and Martha are survived by three children (Kathleen Harleman of Champaign, Illinois; Robert Harleman of Wilton, Connecticut; and Anne Krieger of New Cannan, Connecticut), six grandchildren, and innumerable friends around the world.