



# Guest Editorial

## Special Issue: Ernest G. Cravalho Memorial Issue

This special issue of the *Journal of Heat Transfer* is presented as a memorial to Professor Ernest George Cravalho who passed away on April 13, 2021, at the age of 82. His career spanned 44 years on the faculty of the Department of Mechanical Engineering at M.I.T. where he established an exceptional legacy as a teacher, mentor, administrator, and researcher who was a distinguished pioneer in establishing the field of biomedical heat transfer. Ernie came to M.I.T. in 1967 after completing all three of his degrees at the University of California at Berkeley, with his Ph.D. in radiation effects at cryogenic temperatures. He was supervised by the eminent heat transfer scholar Professor Chang-Lin Tien who subsequently became Chancellor of UC Berkeley. Professor Tien advised Ernie, as he was setting out to build his career, that there were ripe opportunities for an engineer to make important contributions using cryogenic heat transfer principles and technology in biomedical applications. Upon arriving at M.I.T. Ernie was assigned to the Cryogenic Engineering Laboratory directed by Professor J.L. Smith where he worked with his first doctoral student (KRD) to follow Professor Tien's advice. At the time this was surely a novel direction to take for establishing a research career, but Prof. Smith was strong in his support of Ernie's novel endeavors. Many of the established engineering faculty at M.I.T. took a dim view of attempting to apply engineering analysis methods to living systems, plus some of the established leaders in the field of cryobiology were not welcoming to engineers invading their domain of expertise and predicted failure for this initiative.

However, Ernie was confident and resolute in this vision, as he was in numerous other pioneering endeavors that he subsequently undertook. Soon he had assembled a cadre of talented M.I.T. students in his laboratory to work on cryobiology as well as on other more traditional areas of heat transfer. Important support and guidance for this work came internally from within M.I.T. through Biology Professor David Baltimore, who was soon to earn a Nobel prize, and externally from Dr. Arthur Rinfret who was a senior leader in the Society for Cryobiology and Vice President of the Linde Division of Union Carbide, an early industrial developer of applications of cryobiology technology. Dr. Rinfret believed in Ernie's vision of using engineering tools to advance the field of low temperature medicine, and he arranged for a grant from Linde to cover the costs for Ernie to setup a cryobiology laboratory, including the purchase of a Zeiss microscope that was used to build the first computer programable cryomicroscope [1]. Ernie also developed a long and productive collaboration with Dr. Charles E. Huggins, a Professor of Surgery at Harvard Medical School, who was also director of the Blood Bank at Massachusetts General Hospital and inventor of one of the first practical methods of clinically cryopreserving human red blood cells.

Soon thereafter, work in the Cravalho Lab became recognized as a leading source of innovation in cryobiology research. Devices were invented, fundamental governing biophysical mechanisms were identified, process simulation models were developed, and a significant number of highly talented students were graduated who matriculated into academia and industry. Ernie's influence also spread to the broader emerging field of bioheat transfer and



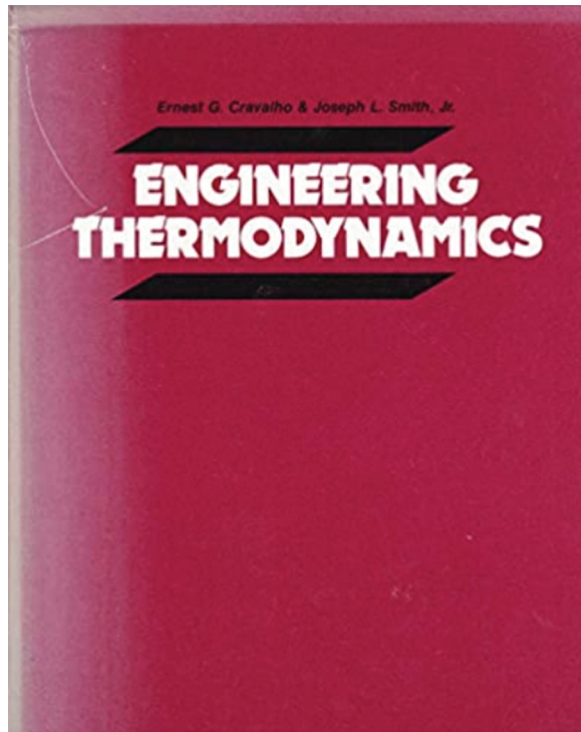
**Professor Ernie Cravalho shortly after joining the M.I.T. faculty in 1967**

bio-engineering. In particular, he was active in the formative stages of the ASME Bio-engineering Division and participated with current and former students in organizing numerous technical sessions at national meetings. Indeed, three of his former doctoral students eventually became Presidents of the Society for Cryobiology as did a third-generation student. Before this time, no engineer had ever led this life science and medically-oriented organization.

Ernie's professional impact extended well beyond his groundbreaking research in bioheat transfer applications. He also excelled as an educator, an administrator, and a very personal mentor. Soon after he arrived at M.I.T., he was assigned the responsibility of revising and teaching the core undergraduate curriculum in thermal fluids education, including the subject of thermodynamics for which he carried a strong concern to see students be able to develop a practical and intuitive sense of the field. Ernie personally had an exceptional capability for hands-on application of thermodynamics, including advanced expertise in automechanics design and repair. Indeed, during the interim period between the Fall and Spring semesters when faculty were encouraged to teach informal courses relating to their personal interests, Ernie secured access to an out-of-service repair garage in Cambridge and started a course in autodiagnosics and repair for members of the M.I.T. Community. This became a very popular offering, resulting in a stream of phone callers seeking his advice on how to fix their cars (perhaps an early version of the subsequent "Click and Clack" show hosted by M.I.T. alums). Ernie personally mentored more than 50 graduate students in his laboratory, nearly all of whom went on to distinguished careers in academics, industry, and government.

Ernie was renowned for being exceptionally committed to his students, both undergraduate and graduate and as a genuine

champion for diversity and the culture of inclusion long before these terms became so programmed and fashionable in today's academic environment. He was helpful to any student who needed help, plus he was kind and giving. He was truly a "special person" who touched countless young people to help them find and pursue their life trajectories.



**Thermodynamics text coauthored by  
E. G. Cravalho and J. L. Smith**

Ernie saw the need for improved educational resources for undergraduates in practical thermodynamics and undertook a many years-long writing project with his mentor Professor J.L. Smith resulting in the publication of a unique thermodynamics textbook that became foundational within the M.I.T. ME curriculum [2]. Ernie excelled as a teacher and was named a Margaret MacVicar Faculty Fellow in recognition of his exemplary and sustained contributions to the teaching and education of undergraduates. He also received the Everett Moore Baker Memorial Award for Excellence in Undergraduate Teaching. In honor of his father, also named Ernest, Ernie endowed the Ernest Cravalho Award for

Outstanding Performance in Thermal Fluids Engineering to be given annually to a mechanical engineering student.

In addition to his research and teaching, Ernie carried significant administrative responsibilities for many years. Shortly after earning tenure, he was appointed to be Associate Dean of Engineering. Continuing from that position, he was heavily involved in establishing the Harvard-MIT Division of Health Sciences and Technology and in the planning and construction of the Whitaker Building on campus. At this time, he was also involved with leadership in the Whitaker Foundation during the period when their primary philanthropic target was M.I.T. Subsequently he was named as Edward Hood Taplin Professor of Medical Engineering and Chief of Biomedical Engineering at Massachusetts General Hospital. From start to finish he was involved in high-level administrative roles for about twenty consecutive years at a time when biomedical engineering was becoming recognized and established as a new discipline in academia and industry. Thus, his influence in defining and shaping this important discipline was profound.

Ernie was recognized with some of the highest possible awards for career accomplishments including election to membership in the Institute of Medicine and the National Academy of Sciences, ASME Fellow, and American Institute of Medical and Biological Engineering Fellow.

The impact that Ernie Cravalho had on the field of bioheat transfer is reflected in the spectrum of topics covered by the contributions to this special issue of the *Journal of Heat Transfer*. Fourteen author teams took the opportunity to write in honor of his legacy in the field. Some were directly trained by him, some were trained by his students (third generation) and by his students' students (fourth generation), and some are simply admirers of his role in defining and opening this field. Truly, Ernie Cravalho's legacy in bio-engineering and bioheat transfer is exceptional, and it is with great pleasure that we offer this JHT special issue in his honor.

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## References

- [1] Diller, K. R., and Cravalho, E. G., 1971, "A Cryomicroscope for the Study of Freezing and Thawing Processes in Biological Cells," *Cryobiology*, 7(4-6), pp. 191-199.
- [2] Cravalho, E. G., and Smith, J. L., 1981, *Engineering Thermodynamics*, Pitman Publishing, London, p. 548.