Frank A. McClintock

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1921–2011

Elected in 1991

"For pioneering and sustained contributions to the understanding of the process of ductile fracture of engineering materials."

BY ALI S. ARGON

FRANK A. McCLINTOCK, a pioneering professor of engineering, died on February 20, 2011, at the Briarwood Health Care Facility in Needham, Massachusetts. He was 90 years old.

Frank was born on January 2, 1921, in St. Paul, Minnesota, son of Professor Henry Lacy McClintock and Charlotte Smith. He was educated in St. Paul before going on to earn an SB (1942) and SM (1943) in mechanical engineering from the Massachusetts Institute of Technology. During World War II he worked for three years at the Pratt & Whitney Aircraft Company, where he was one of eight engineers working on the development of the company's first jet engine. In 1946 he moved to California, where he earned a PhD in 1949 at the California Institute of Technology with a doctoral thesis on "The Fatigue Properties of Single Crystal Iron," the beginning of a lifelong absorption in the fundamental performance-limiting characteristics of engineering materials.

In 1945 he married Mary Whitmore and they raised a daughter and three sons in Concord, Massachusetts.

In 1949 he was attracted back to MIT as an assistant professor in mechanical engineering to start a distinguished academic career in mechanics and materials. He was promoted to professor of mechanical engineering in 1959 and taught and conducted research at MIT until his retirement in 1991. In 1968

he was also an honorary visiting research associate at Harvard University and in 1969 a visiting research professor at Brown University.

McClintock's research and professional activities, from the early 1950s to the late 1990s, revolutionized the understanding of the major design-limiting failure processes in advanced engineering structures and replaced much empiricism and data gathering with a search for understanding the fundamental mechanisms of fracture and fatigue. His landmark publications of that era started with the presentation of a paper on "The Growth of Fatigue Cracks Under Plastic Torsion" at the International Conference on Fatigue of Metals in 1956 in London. The paper was awarded the James Clayton Prize of the Institution of Mechanical Engineers of Britain. This was followed in short order by an equally trendsetting publication, on the plasticity of the growth of fatigue cracks in 1963, that introduced the first mechanistic rationale on the growth of fatigue cracks by irreversible cyclic crack tip distortions in ductile metals. In an equally significant paper McClintock published the first mechanistic theory of ductile fracture of metals by the growth of holes nucleated from adventitious inclusion particles. Other allied developments on "crack growth in fully plastic, grooved tensile bars" followed in 1969. These pioneering fundamental developments were summarized in 1971 in a comprehensive chapter in volume 3 of *Fracture,* part of a series of books with the same title edited by H. Liebowitz. This chapter, combining the mechanics of crack tip plastic strain distributions under local concentrated stress and negative pressure with microscopic fracture criteria involving cavitation at inclusion particles, was a model of breadth and conciseness, wedding theory with probing experiments. It quickly became a classic for creating order in a previously ill-understood, very important field of engineering.

These and other pioneering developments that brilliantly clarified complex phenomena in engineering structures to both contemporary professionals and graduate students were best put into context by Morris Cohen, the "grand old man of physical metallurgy," in a letter supporting the nomination of

McClintock for a prestigious award in 1976. Cohen wrote:

> In my opinion, Frank McClintock should be recognized as one of the world's leading authorities on the fracture of materials. I have had a special opportunity to observe his effectiveness and scope in this respect through our joint membership on the DARPA Materials Research Council. This is a group of some twenty-five experts in materials science and engineering, drawn from various disciplines such as mechanics, metallurgy, ceramics, physics and chemistry. From that vantage point, I have come to appreciate that Frank is truly extraordinary in his ability to combine many branches of knowledge, ranging from atomic forces and dislocation dynamics to continuum mechanics and macro-behavior of materials, in elucidating the nature and control of fracture. He is virtually in a class by himself in being able to interact with, stimulate and understand the foremost engineers and scientists in relevant fields, who have all important, but otherwise disconnected contributions to make in relation to the fracture phenomenon and the elastic-plastic stages leading up to the fracture event.…

McClintock's pioneering research in the mechanics and mechanisms of fatigue and ductile fracture represents only one facet of the man. Unlike many successful researchers who might be content to let their publications speak for themselves, McClintock took on with missionary zeal the task of disseminating the fundamental developments in the mechanisms of inelastic deformation and fracture of engineering materials to both students and professionals alike in the field.

In the early 1960s, I had the pleasure to collaborate with him together with Ali Argon, in thoroughly modernizing the teaching of mechanical behavior of materials to undergraduates in mechanical engineering. This involved the outfitting of a modern undergraduate laboratory and the introduction of project-type laboratory exercises where students learned to apply directly the micromechanical and mechanistic approach to complex mechanical behavior problems of their own choice. This effort also led to our coauthorship of a text on

Mechanical Behavior of Materials (Addison-Wesley, 1966) that was recognized the world over as the most authoritative educational treatment of this newly developing subject and has been translated into several foreign languages, including Russian.

McClintock's other educational innovations included the development of teaching programs for self-study of the principles of limit analysis and slip-line solutions of plane strain plasticity. In addition, he pioneered a totally new teaching concept of a "desktop experiments kit" containing common materials such as chalk, paper clips, Plasticine, silicone putty, rubber bands, and balloons with which fundamental phenomena of brittle fracture, yielding and fatigue in torsion, rubber elasticity, and strain rate effects in fracture could be investigated by the students, literally on "the tops of their desks" at home. This successful idea, which he had pilot-tested on his young children, was adopted by other educators of materials science.

McClintock gave numerous invited lectures and keynote lectures at international and national conferences, special workshops, and many universities both in the United States and abroad. He was active as a consultant to industry and introduced his consulting experiences into his teaching. In midcareer he gave his time generously to professional service activities such as the ASTM Committee E-24 Task Group on Fracture Mechanics. He served for nine consecutive summers on the Materials Research Council of Advanced Research Projects Agency (ARPA), considering a far-ranging set of materials problems of national interest in both the civilian and military sectors. In the mid-1970s he chaired a National Research Council study committee on the Mechanical Properties of Infrared Transmitting Materials for the Defense Department and another on erosion.

After his formal retirement in 1991 from active academic duties McClintock continued to make signal contributions to the understanding of the fracture phenomenon in highly important large-scale engineering applications. In one of these, in collaboration with Professor David Parks of the MIT

Mechanical Engineering Department, he participated in a DOE-supported three-way research activity pairing him with a group at the Idaho National Engineering (and Environmental) Lab (INEEL) and another of the DOE Savannah River Lab. In this collaboration the task was to deal with potentially catastrophic fracture problems in old rusting and corroding massive storage tanks of liquid radioactive waste at the DOE Hanford Reservation. McClintock's contributions were considered key. In another postretirement activity McClintock collaborated extensively with Professor Tomasz Wierzbicki of MIT's Ocean Engineering Department in research on the impact and crash-worthiness of naval structures. In that research, supported by the US Navy as well as by some automotive companies and the aluminum industry, McClintock's contributions were also considered decisive.

In addition to the James Clayton Prize mentioned above, McClintock's professional accomplishments were recognized by a series of prestigious honors and awards, including fellowship in the American Academy of Arts and Sciences in 1959, the Arpad Nadai Award of the ASME in 1978, an honorary doctorate of law degree from the University of Glasgow in 1981, an honorary fellowship of the International Congress on Fracture in 1989, the Howe Medal of the ASM in 1991, election to the National Academy of Engineering in 1991, the Griffith Medal of the European Structural Integrity Society in 1999, and the Daniel Drucker Medal of the ASME in 2004.

He was a member of ASME, ASM, ASTM, and ASEE. In all his activities, whether research on fracture or teaching or professional service, McClintock always strived uncompromisingly for perfection and set very high standards of achievement for himself and for his colleagues and students alike.

Throughout his life, Frank passionately enjoyed skiing, competing as a young man in downhill and cross-country skiing as well as ski jumping. He was equally devoted to hiking and rock climbing in the East and throughout the West. As a boy he learned technical rock climbing with his father, an elected member of the American Alpine Club, particularly in

the San Juan and Needle Mountains of southwestern Colorado as well as the Tetons in Wyoming, where McClintock Peak was named to honor the first ascent made by Frank and his father. He shared his love of Colorado rock climbing and route finding with his children on many summer camping trips, centered around the mining town of Ouray, Colorado, nestled in the mountains. A former Eagle Scout, he served as a Boy Scout leader in Concord. He was active in the First Parish Meetinghouse as a member of the Humanist Group and served in diverse ways including as usher, church school teacher, member of the standing committee, and deacon.

He is survived by his wife of 66 years, Mary, his daughter Martha and her husband Joel Charrow of Chicago, Illinois, and his three sons: Roger and his wife Jane Jeffries who are sailing the world, currently in Borneo; David and his wife Nancy of Lyman, Maine; Richard of Denver, Colorado; as well as five grandchildren and a great-granddaughter.