NATHANIEL ARBITER

1911–2008

Elected in 1977

"Contributions to research and education in processing low-grade ores and the development of new hydro-metallurgical processes."

BY PONISSERIL SOMASUNDARAN

NATHANIEL ARBITER was born January 2, 1911, in Yonkers, New York, to David and Ida Cora (Rockman) Arbiter. He contracted polio at the age of 12 and overcame the resulting mobility challenges, walking with braces and crutches for the remainder of his life.

He won a scholarship to Columbia University and completed a BA in chemistry in 1932, then began a career spanning 70 years in the mining industry. Early contributions included the following:

1943–44, at Battelle: Application of silica flotation to iron ore concentrates in the laboratory and pilot plant, anticipating processes now used on low-grade iron ores.

1944–51, at Phelps Dodge: Development and patenting of chemical processes that are used for separation of molybdenum from copper concentrates. Pioneering use of ion exchangers combined with electrowinning of copper, anticipating the current use of liquid ion exchangers for the same purpose. Earliest studies of scale-up problems with flotation machines. Use of grinding kinetics in conjunction with grinding circuit control.

1951–68, at Columbia University: Research in mineral process engineering, in contrast to the prevailing emphasis at the time on process chemistry and physics. Pioneering work in design and scale-up studies of flotation and grinding equipment. Innovative use of the kinetics of flotation and grinding as tools for process modeling and scale-up. Patents on flotation of both oxidized copper ores and tin ores, the latter developed through pilot plants and commercial plants in Bolivia and England. Major contributions to the successful processing of refractory New Brunswick lead-zinc ores.

After early retirement from Columbia in 1968, Nat and his wife, Carolyn (née Metz), moved to Tucson, where he was invited to join the Anaconda Company's Extractive Metallurgical Research Division (EMRD), recently relocated from Montana.

Anaconda needed to maximize the efficiency of all domestic operations as it faced severe technical and economic challenges exacerbated by several events. In addition to the nationalization of Chilean assets, the US Clean Air Act of 1970 strengthened the Clean Air Act of 1963 and the Air Quality Act of 1967 and authorized comprehensive federal and state regulations to limit emissions from both stationary (industrial) and mobile sources; and the EPA was created in December 1970 to implement and enforce these acts.

The Anaconda smelter in Montana shared with the 19 other domestic copper smelters the problem of copious emissions of dilute sulfur dioxide (SO_2) gas. The company's EMRD had been developing a "smokeless smelter," the Treadwell process, but insurmountable obstacles had arisen and senior management believed that a fresh perspective was needed. Nat was given the responsibility of leading a new technical program, culminating in the Arbiter process, which was intended to supplement and eventually replace the Montana smelter.

EPA had determined by about 1972 that the first entity to successfully commercialize a solution to the SO_2 problem would establish "Best Available Control Technology," creating an opportunity for licensing to others. Unfortunately, this led

to a race that prioritized *quick* process development over *low-risk* process development!

The Arbiter process used selective aqueous oxidation of copper sulfide mineral flotation concentrates, dissolving and complexing of the copper with ammonia, solid/liquid separation, solvent extraction and electrowinning of copper, sulfate disposal, ammonia regeneration, and residue flotation for recovery of precious metals. The commercial plant was a technical success, but there were equipment shortcomings and operating expenses were excessive, largely because of high energy consumption and the rapidly rising cost of natural gas in the mid-1970s. Two other copper producers developed competing processes, but neither was a commercial success.

Nat's last technical paper, "Problems in Ammonia Leaching of Copper Sulfides," was published in the *Proceedings of the Randol Copper Hydromet Roundtable* in 2000. It was intended to allow future metallurgists to make an objective evaluation of potential applications of ammonia and its compounds to the production of high-purity copper from copper sulfide mineral concentrates.

After his retirement from Anaconda he continued to work—as a research consultant, visiting faculty member (at Columbia, the University of California, Berkeley, and the universities of Utah and Arizona), and lecturer (at universities in Australia, Japan, and Chile)—into his early 90s.

For his achievements he was named professor emeritus at Columbia and received numerous other professional honors, including the AIME Robert H. Richards Award (1961) and Mineral Industries Education Award (1971) and election as an Honorary Member of AIME (1976). He was recognized as a Distinguished Member (1975) of the Society for Mining, Metallurgy, & Exploration (SME) and was selected for SME's Antoine M. Gaudin (1979) and Arthur F. Taggart (1980) Awards. The latter was particularly special to Nat as Taggart was one of his mentors—he kept Taggart's picture on display and was always grateful for that experience.

For seven decades Nat was a leader in metallurgical research. But he considered his greatest success the accomplishments of those he mentored in the classroom and in the field of mineral processing. On the occasion of the creation of the Nathaniel Arbiter Scholarship (1985) at Columbia's Henry Krumb School of Mines, Nathaniel wrote that he treasured the knowledge that he had been and continued to be a part of the community of scholars. The scholarship was established by five of his former students: Thomas Mackey, Itzhak Hoffman, Takeshi "Ken" Nagano, Charles O'Neill, and Immo Redeker.

Nathaniel Arbiter is one of the few individuals in the broad field of extractive metallurgy with outstanding accomplishments both in the industry and in academia. He made significant contributions to not only knowledge of the engineering aspects of processing ores for mineral recovery but also the design of new plants for processing ores. While he was at Columbia, he developed and patented a process for the successful flotation of cassiterite (tin ore), something that eluded many other distinguished professors of his time. And he hosted one of the earliest International Minerals Processing Council (IMPC) conferences, in New York in 1964.

In addition, his early work on the surface chemistry of flotation is still referred to by those doing research in the field, and some of his papers on kinetics and energy consumption in grinding (size reduction) have been the basis for further research. In fact, his accomplishments in flotation machine design and analysis are becoming even more valuable since lower-grade ores now necessitate the construction of much larger-scale processing machines.

John A. Herbst wrote that Nat redefined the scope of the field of mineral processing through research in mineral separations. In 1975–77 he spent time with students and faculty at the University of Utah in Salt Lake City exploring hydrometallurgical options. He worked with the renowned hydrometallurgy groups of Milton Wadsworth and Jan Miller; Herbst, director of the US Bureau of Mines' Generic Mineral Technology Center on Comminution; and the center's students and professionals. He gave numerous seminars on all aspects of mineral processing,

and through his presentations conveyed his deep concern for professional ethics and love of family. He earned the admiration of all the students, postdocs, and faculty.

Nat was liked, admired, and respected by his coworkers. Terry McNulty described him as a gifted metallurgist, intensely curious, and with a fine sense of humor. Terry also noted that Nat made light of his physical disability and never sought sympathy. He was a strong and dedicated swimmer, and decades of using crutches created powerful forearms, resulting in a handshake that was bone crushing!

Nat passed away at age 97 on October 5, 2008, just 8 days after it was announced in Beijing that he had been awarded the prestigious IMPC Distinguished Service Award for his outstanding contributions to the activities of the council.

Nat was a great teacher, mentor, and, above all, a great human being. I still remember how well he treated me—in 1964, I believe—in his office even though I was only a student about to graduate. I try to emulate him in that regard. I am glad that he at least got the news about the IMPC award while alive.

There is no doubt that Nat Arbiter is one of the very foremost mineral processing engineers with distinguished accomplishments in engineering applications of interest to industry as well as to the professional societies.

He is survived by Carolyn; children Jane Arbiter Latane, Jerome Arbiter (Kathi), Robin Arbiter, Dorothy Arbiter (Robert Green), and Corinna Arbiter; grandchildren Julia Latane (James Graham), Claire Latane, Jasper Latane (Jet), Michael Arbiter (Melissa), Connor Arbiter, Rachel Green, and Cora Arbiter; and great-grandchildren Grace, Jacob, and Levi Goode, Michael Alan Arbiter, and Beaumont Latane.