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# International Journal of Multiphase Flow

journal homepage: [www.elsevier.com/locate/ijmulflow](http://www.elsevier.com/locate/ijmulflow)

## Obituary

### Clayton Crowe – teacher and pioneer researcher in multiphase flow



It is with profound sadness that we report the death of a much loved and greatly revered colleague and friend – Professor Dr. Clayton T. Crowe. In a career spanning nearly 50 years his contribution to the study of multiphase flow has been immense: he made seminal contributions to practically all aspects of the subject from the deeply fundamental, to the industrial application. He was not only a brilliant scholar and engineer but also a gifted teacher and great mentor for students and young colleagues. Throughout his career he devoted much effort to the teaching of fluid mechanics and two phase flow. His book “Engineering Fluid Mechanics”<sup>1</sup> has been one of the most popular undergraduate fluid mechanics textbooks for over 35 years. More recently his graduate textbook “Multiphase flows with droplets and particles”<sup>2</sup> has become a standard text book for teaching. He was also the driving force and editor of the CRC “Multiphase Flow Handbook” which covers all aspects of multiphase flow and is a testament to his vast knowledge of the subject.

Clayton Crowe was born on July 6, 1933, in Kelowna, British Columbia. He received his BSc degree in Aerospace Eng. from the U. Washington in 1956, MSc from MIT in 1957, and PhD from the U. Michigan in 1962.

The first 7 years of his career were spent as a rocket scientist at the United Technology Center in California where he worked on solid fuel combustion related to rocket launching applications.

In 1969 Clayton joined the Department of Mechanical Engineering at Washington State University (WSU), where he enjoyed a creative 32-year career in teaching and research. In the mid-1970s he developed and applied the well known ‘Particle-in Cell’ Model. He also worked with his WSU colleague Dave Stock in developing computational schemes for predicting the performance of electrostatic precipitators and cyclone separators. He also developed and patented a range of multiphase flow devices from metering low-quality steam flows to a novel slurry jet pump.

Spray drying has been an enduring part of his research and a motivation for developing a number of modelling and numerical

procedures to capture the thermal and momentum coupling between the dispersed and carrier phases. He became the world authority on the subject and his advice and opinion were widely sought in industries as far away as Nestlé in Switzerland. He was one of the developers of the well known Euler–Lagrange approach.

Since the mid 1980s, Clayton was devoted to tackling some of the very fundamental issues of two phase dispersed flows. He was deeply interested in two-fluid modelling and how one obtained the ‘continuum’ equations from the various averaging procedures. He was also interested in turbulence modulation and particle segregation in turbulent structures. He and his students Gore and Giland demonstrated the significance of particle diameter/fluid length scale ratio in determining whether or not the addition of a dispersed phase would cause an increase or decrease in the carrier phase turbulence. Most recently he and his student John Schwarzkopf obtained transport equations that describe the effect of particles on the carrier phase turbulence.

Along with his WSU co-workers Chung and Troutt, he was the first to identify experimentally the phenomenon of particle clustering in the large scale coherent structures found in turbulent shear flows. They performed a number of simulations and experiments on particle dispersion in mixing layers, free shear and wake flows in which they characterised the segregation according to the particle Stokes number and found the segregation to be a maximum when the Stokes number is  $\sim 1$ . The importance of this phenomenon in enhancing collisions and particle agglomeration/droplet coalescence in a number of environmental and industrial flows has been the subject of intensive research in the last 20 years.

Throughout his long career, he won many awards for both his research and teaching. Perhaps of all these, he treasured most the International Multiphase Flow Award which he received in 2001 at the ICMF in New Orleans. He was a Fellow of ASME and supported the Society in many of its activities, both as an Associate Editor for JFE and in organizing technical sessions at FED meetings.

In spite of all his achievements Clayton showed modesty and humility. Many will recall his wonderful whacky sense of humor and infectious laughter which could ‘set the table on a roar’. With his outstanding interpersonal skills, his sense of humor and his impeccable scientific credentials, he was an excellent ambassador for the multiphase flow community.

Clayton Crowe was indeed a unique and special human being and we all share with his family and friends their great sense of loss.

Stathis Michaelides,  
Michael Reeks,  
John D. Schwarzkopf,  
David Stock,  
Lian-Ping Wang

<sup>1</sup> Co-authored with John A. Roberson and with D.F. Elger and B.C. Williams joined recently.

<sup>2</sup> Co-authored with John D. Schwarzkopf, Martin Sommerfeld and Yutaka Tsuji.