International Journal of Heat and Mass Transfer 109 (2017) 657–658

Contents lists available at ScienceDirect

International Journal of Heat and Mass Transfer

journal homepage: www.elsevier.com/locate/ijhmt

In Memoriam

Professor D. Brian Spalding (1923–2016)

It is with a profound sense of loss that we note that Professor D. Brian Spalding passed away on November 27, 2016 after a brief illness. This happened less than two months before his 94th birthday. He was an intellectual giant, who made ground-breaking contributions to heat transfer, mass transfer, combustion, turbulence, multi-phase flow, and computational fluid dynamics.

Professor Spalding was born on January 9, 1923 in New Malden, England. He got his BA and MA degrees from Oxford University and his PhD in 1952 from Cambridge University. His thesis was on the combustion of liquid fuels, where he employed an innovative idea using the extrapolation of laboratory measurements. He joined the faculty of Imperial College, London in 1954 and was offered in 1958 the youngest ever professorship, at that time, at Imperial College. He retired from Imperial College in 1988. During this period, he also held visiting professorships at various universities in the USA. In 1974, he founded a software and consulting company known as CHAM. He actively worked at this company till the very end.

Professor Spalding was a prolific writer, who published many books and countless journal papers. He lectured all over the world and attracted doctoral students from many countries. His writing and speeches were very clear, fluent, lucid, and interesting. He used the English language with mastery, precision, and skill, perhaps due to his education at Oxford. His impact will live on for many years, not only through his publications but also through the hundreds of researchers that he has guided and inspired.

It is not surprising that Professor Spalding's contributions have been recognized by numerous awards and honors. They include: Max Jakob Award, Luikov Medal, Bernard Lewis Medal, Benjamin Franklin Medal, Global Energy Laureate, Fellow of the Royal Society, Fellow of the Royal Academy of Engineering, Foreign Member of the Russian Academy of Sciences, and Foreign Member of the Ukrainian Academy of Sciences. He was given honorary doctorates by Imperial College and by Moscow Energy Institute.

Professor Spalding was a founding editor of the International Journal of Heat and Mass Transfer. He was also responsible for creating the International Center for Heat and Mass Transfer (ICHMT). In May 2008, ICHMT organized an international conference on Computational Heat Transfer in Marrakech, Morocco to celebrate his 85th birthday. In July 2013, at the ASME Summer Heat Transfer Conference in Minneapolis, Minnesota, he was honored on the occasion of his 90th birthday. At the forthcoming ICHMT conference on Computational Heat Transfer in May 2017 in Naples, Italy, there will be a special symposium in memory of Professor Spalding.

Professor Spalding's work is noteworthy not only for the amazing variety of subjects he has covered but also for the strong impact of his inventions. None of his work makes just an incremental contribution. It is always a significant breakthrough, opening the door to many scientific opportunities that did not exist before. His vision and creativity provide a quantum increase in our scientific understanding and predictive capability. His specific scientific contributions represent lifelong fireworks of his creative ideas.

Even before he made his breakthrough contributions to Computational Fluid Dynamics (CFD), he had made revolutionary advances in combustion, mass transfer, and boundary layer theory. He was always motivated by his desire for a predictive capability, which made his fundamental work extremely useful in practical applications. Whereas most fluid dynamics researchers would be concerned only with fluid flow, Spalding envisaged a general unified framework that included heat and mass transfer, combustion, turbulence, and two-phase flow, as well as the conventional single-phase flow. The strength of his research emanates from his desire and ability to generalize a given concept, formula or procedure. His work always showed the urge and capability to reach extraordinary heights through bold generalization.

His development of the finite-volume methodology was a brilliant combination of mathematical derivation and physical insight. He saw the finite-volume equations as expressions of the conservation principles (such as the conservation of mass, momentum, and energy) applied to a small volume. He also recognized that the equations could be viewed as the integrated forms of the parent differential equation with a subdomain weighting function. He was one of the first researchers to identify that the convection terms needed a different treatment when the flow rates were large. This led him to invent the upwind, exponential, and hybrid schemes. This single invention was a significant breakthrough; it enabled us to solve problems at high Reynolds numbers. Other-

http://dx.doi.org/10.1016/j.ijheatmasstransfer.2017.02.038

wise, all prior attempts were successful only at very low Reynolds numbers (which were of limited practical interest).

Professor Spalding did not invent the staggered grid; it was already in use by the group at the Los Alamos National Laboratory. However, Spalding was the first one to explain why we needed it. This understanding was crucial to any later attempts to modify, extend, or replace the staggered grid. His formulation of the SIMPLE algorithm was a significant development; it provided a convenient way of calculating three-dimensional elliptic flows and essentially replaced the prior techniques using stream function and vorticity.

As the method for computing complex three-dimensional flows was being formulated, Spalding rightly addressed the issue of computing turbulent flows. He created a framework for the "mathematical models of turbulence", in which he was able to fit early attempts such as Prandtl's mixing length theory and propose advanced models such as the two-equation turbulence models. It is this combination of a calculation method for complex flows and a satisfactory representation of turbulence that made CFD a practical tool for industrial problems. Otherwise, the calculation method would have remained an academic exercise.

Professor Spalding did not stop at formulating turbulence models for fluid flow. In his usual style of generalization, he extended the models to turbulent heat and mass transfer and to turbulent combustion. Later, he created CFD techniques for two-phase or multi-phase flows. Here, he interestingly saw the possibility to come up with a new kind of turbulence model. A turbulent flow can be seen as a two-phase flow that is made up of a laminar fluid and a turbulent fluid. Similarly, he proposed a new model for combustion by considering the fluid as a two-phase mixture of burned and unburned gases. These ideas have the potential to explain and predict certain experimental observations that are beyond the reach of conventional turbulence models.

Engineering is obviously a practical field. The success of engineering research lies in the widespread adoption of its outcome in industry. Professor Spalding was not only successful in creating CFD methods of practical utility but also in establishing them in industry. A large international community of researchers and practicing engineers adopted his methods and put them to practical use. Subsequently, Spalding saw that he could transfer the fruits of university research to industry by providing consulting services and, more effectively, computer programs. His work in his consulting company CHAM led to the construction and distribution of the first commercial CFD product PHOENICS.

By now, commercial CFD products have become essential strategic tools for all industries dealing with fluid flow and heat transfer. There is a billion-dollar industry for creating and supporting CFD products. All this advance can be traced to the bold vision and early actions of one man, Brian Spalding.

In addition to his prolific scientific accomplishments, Professor Spalding had a passion for art, music, poetry, and the Russian language. In fact, he began to write poetry by translating the works of the Russian poet Alexander Pushkin and subsequently wrote his own poetic creations. He was a warm and sensitive individual with a keen sense of friendship and concern for others.

We remain forever grateful to Professor Spalding for making valuable contributions to heat transfer and for setting an inspiring example for all of us.

Suhas V. Patankar *
Professor Emeritus, University of Minnesota and President, Innovative Research, Inc., Minneapolis, MN 55447, USA
* Corresponding author.
E-mail address: patankar@inres.com

W.J. Minkowycz
James P. Hartnett Professor of Mechanical Engineering, University of Illinois at Chicago, Chicago, IL 60607-7022, USA

Available online 24 February 2017