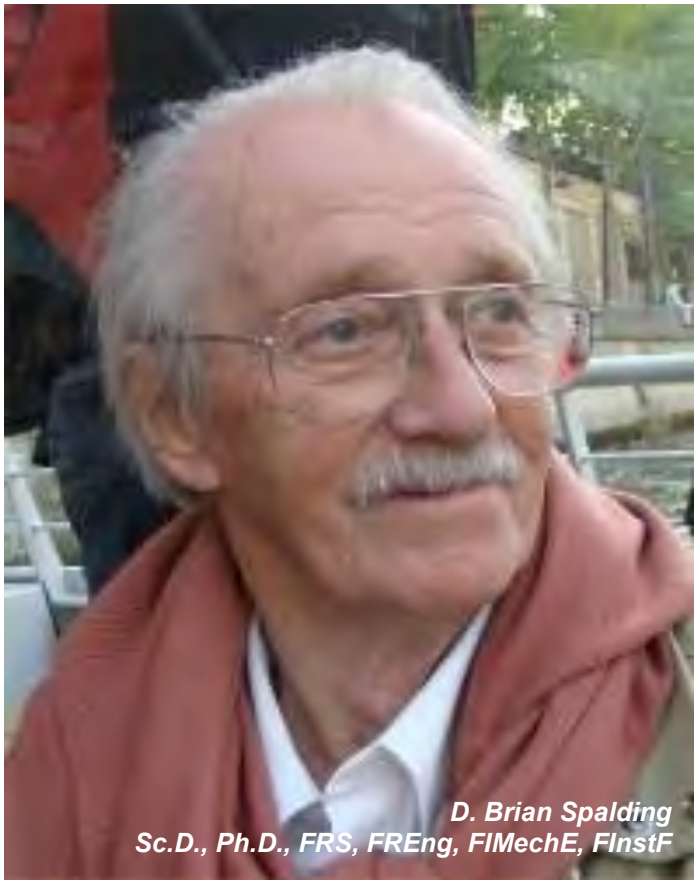
Tributes to an Exceptional Life

D. Brian Spalding

9 January 1923 – 27 November 2016



D. Brian Spalding
Sc.D., Ph.D., FRS, FREng, FIMechE, FInstF

Compiled & Edited by:

Prof. Akshai K. Runchal
Ph.D. Student of Prof. Spalding – 1965-1968
runchal@gmail.com

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Foreword

On 30th May 2017 a Personal Recollection and two Technical Sessions were held at the CHT-2017 Conference in Naples, Italy. A number of former students and colleagues paid tributes to Professor Spalding and talked about his influence on their personal and professional career. The Conference was co-sponsored by the International Center for Heat and Mass Transfer (ICHMT) and the American Society for Thermal and Fluids Engineering (ASTFE).

Prof. Spalding was the prime mover and a co-Founder of the ICHMT. He had a profound impact on the practice of Fluids and Thermal Engineering through his life-long contributions in Combustion, Fluid Flow, Heat and Mass Transfer and his innovations in Computational Fluid Dynamics (CFD). Though some core technologies that gave rise to CFD existed earlier, the CFD as we know it today was nurtured in the Heat Transfer Section (also called HTS and ThermoFluids) of the Mechanical Engineering at Imperial College London in the decade between 1965-1975 by Professor Spalding and his students. In the late 1960, Patankar and Spalding developed the Integral Profile and Finite-Difference methods for Parabolic Boundary Layer equations. Working in parallel, Runchal, Wolfshtein and Spalding developed the Finite Volume Method (FVM) and the high-Reynolds number stabilization schemes for two-dimensional Stream-Function-Vorticity form of the Navier-Stokes equations. By the end of 1968, this core technology that was to become the cornerstone of CFD practice, was in place. Later, in early 1970; a number of researchers, including Caretto and Curr, worked on developing a computational solution of the three-dimensional Navier-Stokes equations. These efforts, together with some key developments by the group led by Frank Harlow at Los Alamos, finally led to the of the SIMPLE algorithm by Patankar and Spalding. Throughout these developments Professor Spalding was the prime mover and the head of this HTS Section.

Professor Spalding's contributions are many and varied. Some of these have already been captured comprehensively in publications including: "*Brian Spalding – CFD and Reality: A Personal Recollection", (Runchal, IJHMT* ***52****, 2009.), "A Tribute to D. B. Spalding and his Contributions to Science and Engineering", (Artemov et al. IJHMT* ***52****, 2009), and "Emergence of Computational Fluid Dynamics at Imperial College-1965-1975" (Runchal, Journal of Heat Transfer,2012*). I also understand that the Royal Society has commissioned a biographical memoir on his professional life that should appear in due time.

A tribute to Brian Spalding has been published in *Int J Heat & Fluid Flow* by Gatski et. al. (*Tribute to Professor D. Brian Spalding, FRS, FREng*), The tributes that follow here are of a more personal nature. These are by his students, associates and colleagues whose life was profoundly influenced by Spalding either at a personal or professional level. As a matter of fact, anyone who practices the art and science of CFD today is doing so because of the seeds sown by Brian Spalding.

In 2013, Prof. Spalding's 90th Birthday was celebrated on the occasion of the ASME Summer Heat Transfer Conference meeting in Minneapolis. A Dinner Event was organized at the Hilton Hotel in Minnesota on the 13th July and a number of persons either paid a tribute in person and sent messages to be read. These tributes are included as Appendix A of this Monograph. Appendix B contains some of the contributed Photographs.

Professional Spalding, Brian to me, was an intellectual giant and an exceptional human being – a towering intellect, a founder of scientific institutions that endure to the day, a fighter for human rights who risked his professional career for the freedom of Soviet scientists, a poet, a linguist, a family man – and for me an intellectual father and a dear friend.

Most people today remember Brian for his technical contributions. He himself wanted to be remembered as a poet. Poetry was his lifelong passion and almost an obsession during his later years. This monograph therefore starts with the last known poem written by Brian and ends with his poetic rendering of his own autobiography.

Today is exactly one year since Brian passed away. On this day, this collection of tributes is being released to honor and remember him. Brian, we will miss you but generations will remember you for your contributions to science and engineering.

Prof. Akshai Kumar Runchal
Dharamsala & Los Angeles
November 27, 2017

A Last Poem by Brian Spalding
(Found November 28 2016)

I shall have no regrets when I am dead
Of deadlines, none will matter but my own.
Unwritten papers? Hopelessly misled
Inheritors? All claimants I'll disown.
Yet hope, while still alive, there'll be but few
Who think: I was a fool to trust him.
Now that he's gone, what am I going to do?
None I would hope; but guess the chance is slim.
Yet, in that soon-to-close window of time,
There's much I want to do; and think I can.
Always too optimistic is what I'm
Dismissed as. To disprove it is my plan.
"After such labours", I would have it said,
"It must be truly blissful to be dead".

Brian by Colleen

Choir Trip to Rome 2014. Brian was unused to being the "accompanying person" but managed with aplomb.

For me Brian was unique. He was brilliant, articulate, passionate, a great scientist, a lover of life, a lover of justice, a lover of poetry, and so much more. He was 93 and had an amazingly productive, rich and full life; the end of it came about unexpectedly and tragically swiftly. I thought that he was immortal – as had many others.

The tragedy is not that he died – we knew, logically, that time was diminishing. The tragedy is that he was ill so far from home and that, at his end, a man who lived through speech and writing could communicate via neither. Enough. Brian would disapprove of my "raging", he did not believe in it. He was a pragmatist, a logician, a philosopher, he would have said "move on". We try.

Brian's life revolved around, influenced, and was influenced by, **families**. He had a large **biological** family; he and Eda (his first wife) had 4 children, 8 grandchildren and 4 great grandchildren. We had 2 boys, William and Jeremy, (now men). There *were* times when his passion for science seemed greater than his passion for family. Indeed, given that he was not a great one for small talk, it could be more difficult for him to relax socially than to create a new equation, re-solve an old one, or extend his beloved PHOENICS. He was proud of his family, loved and supported them. The celebration *he* requested for his 90th Birthday was a family weekend. They are his legacy.

He had a HUGE **scientific** family: children, grandchildren, great grandchildren and, maybe, even great great grandchildren in the world of Computational Fluid Dynamics (of which Brian was a founding father), Combustion, Heat Transfer, Fluid Flow, Boundary Layer and Unified Theory, the SIMPLE algorithm, Finite Difference and Finite Volume Methods, Turbulence Modelling, Multiphase Flows, Heat Exchangers, and other aspects of his varied and beloved scientific work.

One of the things Brian most missed when he retired from his Chair at Imperial College was the day-to-day interaction with young and enquiring scientific minds. When we attended Conferences, he enjoyed young people "brave" enough to ask for a photograph or, even better, for a conversation. He was always happy to oblige. The last such requests came in Cologne in October and in Palermo in September 2016.

His scientific legacy will live on through his not-inconsiderable contributions which resulted in his reputation as a leading 20th century researcher in science and engineering. He would be long remembered for his PHOENICS software, the textbooks and papers he authored and co-authored, and the legacy he created through his extended academic family - many of whom in turn became leading researchers in their field. Physically he will not be there for the next generation to question his ideas and move them forward in the same, or a different, direction but I hope his academic family continues to honour his legacy of questioning the "prevailing wisdom" to come up with better solutions to pressing practical problems.

In addition to his academic scientific family, he had his **CHAM** scientific family. In the early 1970s Brian and Suhas Patankar published "Heat and Mass Transfer in Boundary Layers" which contained Genmix – Brian's first foray into coding I think. Prior to publication Brian set up CHAM (Concentration, Heat & Momentum Limited) within Imperial College offering consulting services to industry and, by so doing, founding *commercial* CFD. As computers became more prevalent and acceptable, Brian and his CHAM team developed innovative application-specific codes including ESTER, HESTER, CORA, FLASH,

TACT, PLANT and others. Brian moved CHAM out of IC to perform independently in the 1970s – it was a busy decade.

Also in the 1970s Brian was appointed Reilly Professor of Combustion at Purdue University, Indiana. This was crucial. Why? Whilst at Imperial Brian had colleagues who coded for him. At Purdue this was not the case so, rather than suspend his activities, he honed his Fortran skills and started to develop PHOENICS, his **P**arabolic, **H**yperbolic, **O**r **E**lliptic **N**umerical **I**ntegration **C**ode **S**eries the first general-purpose CFD code. PHOENICS came to the market in 1981 and continues today as, I think, pretty well the only *independent* CFD Code available commercially.

One of Brian's strengths was that he was not bound by an idea, precept or concept - even one of his own. If he saw a better way, or had a better idea, he unhesitatingly explored it and, if it worked, moved forward with it. One of his favourite precepts was "all decisions are for the future". Thus, having decided that individual computer codes would be better combined under one umbrella (PHOENICS); in his Nineties, he decided that individual codes (designed as SimScenes or industry-specific front ends) had a place as they enabled those without CFD knowledge to use software relating to their particular field without having to consider the underlying physics. He was designing SimScenes with his Development teams in London and Moscow up to his death. We at CHAM are attempting to bring them to completion and offer them to industry.

Over the years many Engineers, and non-technical staff, passed through CHAM's portals. Brian was, justifiably, proud of CHAM; he loved it and had every intention of working his standard seven day week for as long as he lived. He managed pretty well. We at the company will try to move Brian's vision forward and maintain a CHAM legacy.

There was his **Friends and Neighbours** family who joined in our celebrations from children's birthday parties to Brian's 93rd at the start of last year - all held in the home we loved. I close my eyes and see him, in his chair, in the garden room debating the meaning of life, and the political activities of the day, with glasses of single malt assisting the conversation.

There was his **Russian** family. After perestroika, he went to Russia often. In St Petersburg, he met an academic who translated his poetry from English into Russian and had four volumes of it published. That gave Brian *such* pleasure. In Moscow, he loved working with his research group. He was in "his" suite in "his" hotel with "his" group when he was taken ill. It is where he wanted to be.

Brian had a highly developed, and personal, sense of right and wrong. It did not always agree with the mores of the day because ***his*** beliefs were ***his***. He *would* change them but only after thought and deliberation and NOT because any external force wanted him so to do. Brian acted according to his own, strongly held, principles because "*it was the right thing to do*". This phrase represented him in so many aspects of his life.

Brian's passion for doing what he perceived as the right thing (whether it endeared him to his fellow man or not) meant that whilst I was with him in Moscow throughout what proved to be his last (and only real) illness I was supported by Jana Levich. We have been friends for 40 years because Brian decided, in the early 70s to take on the USSR and fight for the right of Academician Levich and his family to move to Israel. This alienated the bureaucracy of the time which was a sorrow to him but sorrow did not prevent him succeeding against all odds. *It was the right thing to do*.

Doing the "right thing" could have been problematic when, as a young man, he rescued his sister-in-law from East Berlin after the War. As I heard it, he "borrowed" a laundry van and drove to the Russian sector with a laundry list, in Russian, as his "authorization". He collected mother and (sedated) baby. Near the exit point a troop of Russian soldiers hove into view strung across the road. Had they stopped the vehicle *they* would have seen the laundry list as – a laundry list! Fortunately, they peeled off to either side and Brian drove on. *It was the right thing to do*.

When, even younger, he chose to do Engineering at Oxford he was informed, by a Master at King's College School, that they had not educated him so he could take a degree in the sciences rather than a double first in the classics. It influenced the young Brian not a jot. He started the way he went on – his, right, way. He "invented" turbulence models, he was a "father of CFD", he ran into trouble with those who believed computers were a "new-fangled notion", etc. He was still having new ideas and, recently, was passionately trying to put over his "discretised population model" to any audience to which he was invited to speak. I hope someone will take it up?

It typifies Brian that we spent what was to be our last anniversary in Cologne so he could lecture. It could not be any other way. We led independently co-dependent lives. Brian was not a great one for

social activities and I am so I (or we the family) would socialize and “report back” – he always wanted to share experiences and know what occurred. I attended his lectures, understanding not a word. He attended my concerts despite a dislike of “gloomy” church music.

To me, Brian was human, intelligent, intellectual, whimsical, humorous, indestructible, brilliant, kind, caring, he twinkled, was a gentleman and never boring - I could go on. He could also be somewhat irritable, stubborn, once set on a path was almost immoveable, believed in his scientific abilities in a way which may have driven others mad (yet was humble about his achievements), had little time for fools and less for small talk. He was set in his ways (as anyone who tried to intervene between him and work, or the ten o’clock news, realized). He loved to have the last word in any argument or discussion which, given his intellectual capacity and command of English, was not difficult.

Brian loved literature, Shakespeare, theatre, music, languages (he taught himself Russian, spoke German and could “get by” in French) sport, nature, walking, discussions over a glass of whisky, sitting in the garden in the sun (writing equations or doing the Times Crossword), he started pilates on his 90th birthday. He loved words particularly those which formed poetry. He read poetry voraciously and he wrote it. His poems reflect ***his*** attitude to life, and to death. He confronted death in poetry; I found a handwritten poem on the subject the day after he died (see page 5) which I found difficult to read then, and probably always will, but it summed him up in so many ways.

Above all, he loved **science**. He would be honoured that you have gathered in his memory today – though he would have preferred to be present to listen, comment, contribute – and, undoubtedly, describe some of the stories as apocryphal!

Words cannot say how much I, and others who loved him, miss him; he touched many lives across continents and areas of interest. Life will never be the same now he is gone.

Colleen I Spalding
Director, CHAM, cik@cham.co.uk

Brian at 90 with his Family

Should this be read out at my funeral
And some feel tempted to let fall a tear,
Thank you, I say but life’s ephemeral.
Be glad: no more I’ll grunting fardels bear;
Nor try to show off my Shakespearean knowledge;
Tell tales so trite table-companions groan:
How William said:” Dad works at JAM and PORRIDGE”.
And Jeremy: “I’ll do it by my own”.
To (plural) wives and families: Farewell.
To friends, acquaintances, fond lovers too;
And co-believers in my “What-the-hell”
Philosophy; to students old and new:

A sonnet ends when its last couplet's read.
Finished with this, I's satisfied; soon dead.

by Brian, from "My Sail Hoistings" published 2011

Professor Brian Spalding: Brilliant, Inspiring, Peerless – Rabi Baliga

It is an honor for my students and me to be considered as members of Professor D. Brian Spalding's extended academic family. Even though I was not fortunate enough to be one of his students, I have had the privilege and pleasure of having Professor Suhas Patankar as my Ph.D. supervisor (at the University of Minnesota, Minneapolis) and Professor Akshai Runchal as my instructor of undergraduate fluid mechanics (at the Indian Institute of Technology, Kanpur); and they have been my mentors ever since. Many years back, it was Akshai who kindly suggested that I should apply to the University of Minnesota to do my Ph.D. studies with Suhas; and that was one of the best things that ever happened to me.

At the University of Minnesota, Suhas taught me the subject of computational fluid dynamics (CFD) and many other things. His unbounded enthusiasm and passion for CFD and teaching were infectious. The brilliant seminal works in CFD of Professor Spalding and his group from the late 1960s and early 1970s inspired and brought me great joy. Even today, my face lights up every time I think of the following three groundbreaking works, for example, from those early days of CFD and introduce them to my own students: Professor Spalding's proposal of the general form of the governing equations (consisting of the unsteady, advection, diffusion, and source terms); the upwinding schemes proposed by Runchal and Spalding; and the semi-implicit method for pressure-linked equations (SIMPLE) of Patankar and Spalding, and its variants.

Over the years, I have had several direct interactions with Professor Spalding and his lovely wife (Colleen). Even though these interactions were brief, they were always wonderfully inspirational and enriching in many ways. Suhas and his beautiful wife (Rajani) have treated me as a member of their family, and the doors of their home have always been open to me. Akshai has been and continues to be a marvelous mentor to me. I have developed very rewarding friendships with several of Professor Spalding's former students, in particular, Pratap Vanka, Andrew Pollard, and Steven Beale.

In summary, Professor D. Brian Spalding was and will remain, truly peerless. He has influenced my life and the lives of my students in numerous wonderful ways. We will always be very grateful to him, and we wish him eternal peace and happiness.

B. Rabi Baliga
Professor
Department of Mechanical Engineering
McGill University, Montreal, Quebec H3A 0C3, Canada

Working with Brian Spalding – Steven Beale

I joined the computational fluid dynamics unit (CFDU) at Imperial College in 1986, following a recommendation from Prof. Chang-Lin Tien of the University of California at Berkeley. At the time I was in my early 30s. My main interest at the time, was in numerical heat transfer and heat exchangers. Previously I had worked in the Solar Energy Program at the National Research Council of Canada (NRC). At the time the CFDU was, perhaps 20-30 people; professors/lecturers, visiting scientists, professionals, post-doctoral fellows, and post-graduates. I recall in Spring 1987, Prof. Spalding taking the entire group up to the Physicochemical Hydrodynamics Conference at Oxford University. This was in honor of his friend Prof. V.I. Levich, the Russian-Jewish 'refusenik' on whose behalf Spalding had activated, politically and socially. It was at the PCH conference that I got to appreciate the amazing breadth of CFD, with numerous applications in a vast array of applications; metal casting, magnetohydrodynamics, membrane science, bio-medical applications, etc. etc. Mr. G. Liao and I gave a poster presentation on some side work we were doing for the Health and Safety Executive in developing CFD models of industrial goggles and respirators.

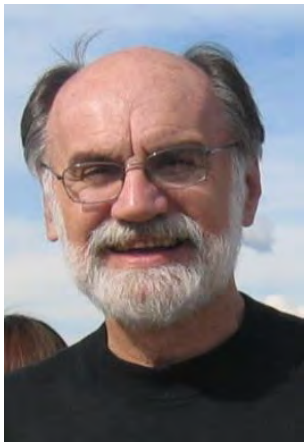
My PhD topic was flow and heat transfer in tube banks and other heat exchangers such as offset fins, but somehow the work kept expanding. At one point, Brian Spalding walked into the office and suggested (insisted) that I derive an analytical solution for potential flow in tube banks, from complex variable theory, for code verification This seeming distraction lead to several interesting sidelines such as three-dimensional stream functions and the solution to stress analysis problem using the finite-volume method, which of course Brian Spalding and others subsequently contributed-to, in no small way.

For the latter part of the thesis work, I was back in Canada at the NRC, and I used to regularly communicate with Prof. Spalding via email, rather than by facsimile (fax) which was the norm at the time. When it came to publishing the work, I became nervous about the timeline, and in response to my anxious inquiries, Prof. Spalding sent me an email apologizing for the delay and lamenting as to how he wished that "real life conformed to the SIMPLE algorithm whereby as the pressure rises - the rate of output increases". Alas the email is locked in a file somewhere on a VAX computer.

In the biographical memoir of the physicist Richard Feynman, the author Jagdish Mehra writes about two types of genius; the "ordinary" genius and the "magician". Brian Spalding was surely in the latter category. A magician of the highest order, he conjured up an entire subject, like a spell, out of nowhere, and then turned it into a practical business, relevant to almost every engineering application, from which countless ex-students and associates have subsequently profited. The scope of his knowledge was truly unique. It has been a very great privilege to have known and worked with him over these last 30 years.

Steven B. Beale
Professor, Institut für Energie- und Klimaforschung (IEK)
IEK-3: Elektrochemische Verfahrenstechnik
Forschungszentrum Jülich GmbH
52425 Jülich, Germany
s.beale@fz-juelich.de

Memories of Working with Brian Spalding – Larry Caretto



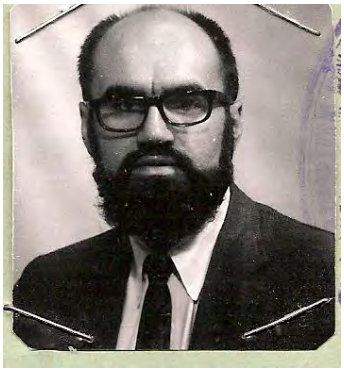
I first met Brian Spalding in the late 1960s when I was an Acting Assistant Professor in the Mechanical Engineering Department at UC Berkeley and Brian was a Visiting Professor there. I often found Brian in a keypunch room where he sat patiently preparing Fortran program cards in a room largely occupied by junior faculty and graduate students. Later Brian wrote a letter to our Division Chair, Ernie Starkman, asking if Ernie could recommend someone like myself to visit Imperial College for a year to work on CFD. I am not sure why Brian asked for someone like me, but I do remember that he was grateful when I showed him how to read the sort field on binary cards to properly rearrange a dropped binary card deck. I've deliberately used the split infinitive in the last sentence in memory of the first paper I wrote with Brian. I did not realize how much my American English allowed the use of the split infinitive until I counted the number of such grammatical errors in British English that Brian corrected in my draft.

I spent the 1970-1971 academic year working with Brian's group at IC. I remember several memos that Brian prepared for our group with ideas and suggestions usually followed by assigning tasks to individuals working on codes that became known as SIVA and SIMPLE. Brian's knowledge of the developing field of CFD, and his intuitive explanations of fluid phenomena and how to model them on computers, was an inspiration to our group. I also appreciated his willingness to change his mind when another member of the group convinced him that there was a better way to solve a problem.

I remember one time when Brian came into a room where I was working on a teletype terminal, then a new way to communicate with computers. I've forgotten what I was working on, but I remember that I was having problems, and in a discussion with Brian we both agreed to try a solution which we both thought had a dubious theoretical basis and little or no chance of success. Our failed try proved that our initial thoughts were correct. As I deleted the file, Brian commented favorably on the ability the terminal provided to try silly ideas with no worries that there would be any written records of their failure.

Brian was not only a font of ideas, but he also created a strong group of individuals who worked together on various projects related to CFD. When I started at IC the main team members working on three-dimensional parabolic flow project were David Gosman, Bob Curr, Devraj Sharma, and David Tatchell. Later that year I shared an office with Suhas Patankar and Aki Runchal. I remember spending most of one afternoon with Suhas helping him find the words for the SIMPLE acronym that he was determined to use for the algorithm he had developed for three-dimensional parabolic flows. I also discovered the meaning of serendipity when Aki found the solution to the convergence problem in applying SIMPLE to elliptic flows. A coding error produced no correction pressure adjustment for continuity. Although this meant there was no correct solution, it did show that the divergence in the correction pressure that had been plaguing the use of SIMPLE in elliptic flows had vanished. Adding an under-relaxation to the correction pressure algorithm provided the desired solutions.

After a sidetrack working on applying SIVA to free convection, I began work on the application of SIVA and SIMPLE to steady, three-dimensional elliptic flows. This work continued after I left IC in September, 1971. An initial publication of this work, modeling the wind flow around buildings, presented at the Third International Conference on Numerical Methods in Fluid Mechanics, was coauthored with David Gosman, Suhas, and Brian. (Brian's policy of placing the names of authors in alphabetical order often made me the first name on the list of authors.)

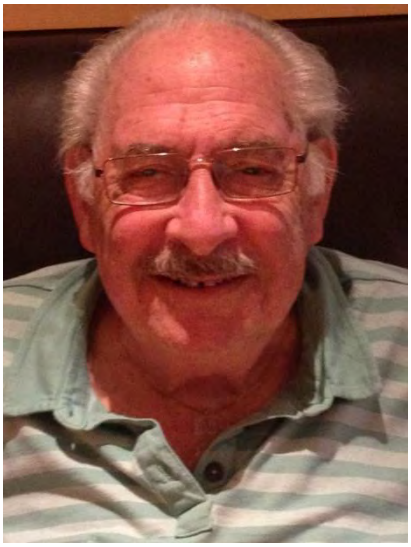


I also spent two summers at IC working on projects for CHAM modeling rocket exhaust flow (1972) and solution mining (1974).

I remember the time that I spent with Brian and his group as the most intellectually stimulating time of my career and I have always appreciated the opportunity Brian gave me to be a part of that group.

Larry Caretto, Professor Emeritus
Mechanical Engineering Department
California State University, Northridge
Northridge, CA 91330-8348
lcaretto@csun.edu

My Interactions with Spalding - Graham de Vahl Davis



Brian Spalding was the creator of CFD/HT, a solution method many of us have spent our lives using. My first contact with Brian was around 1970 - sorry, I can't remember the exact year - when I spent a sabbatical with him when he was at Imperial College. We have been in contact ever since. In May 2008, I had the privilege of organizing an ICHMT conference in Brian's honor in Marrakech Morocco. And of course, many of us contributed to "A tribute to D.B. Spalding and his contributions in science and engineering", which was published in IJHMT in 2009. He will be sorely missed.

Graham de Vahl Davis
Honorary Professor of Mechanical and Manufacturing Engineering
UNSW Sydney
g.devahldavis@unsw.edu.au

One Note in Memory of Professor Brian D. Spalding - Milorad Dzodzo

During my work on M.Sc. Thesis at University of Belgrade, in 1982, I was struggling with some numerical method implementation details. These were my first attempts at creating a CFD program which could simulate, converge and even produce some logical and meaningful results. At that time the number of papers related to CFD details was limited.

Fortunately, Professors Zoran Zaric and Naim Afgan from Vinca Nuclear Institute, in Belgrade, had informed me that the XIV Symposium of the International Centre of Heat and Mass Transfer (ICHMT) devoted to Heat and Mass Transfer in Rotating Machinery was scheduled in

Dubrovnik that year and that Professor Spalding, one of the ICHMT founders, will most likely attend. I seized the opportunity to meet Professor Spalding and had a short but very useful chat about some numerical issues I was facing. At that time I was not aware how lucky I was to get an advisory and consultation session during two relaxing Symposium coffee breaks, instead of scheduling an appointment in his office with his secretary one or two weeks in advance. The right words at the right time aided me in overcoming the outstanding issues and the program finally converged.

Written correspondence with Professor Spalding had continued after I obtained a M.Sc. and resulted in a privileged British Council Fellow Scholarship that allowed me to spend the 1985/86 school year, and 1986 fall semester as a research associate, at the Imperial College, Computational Fluid Dynamic Unit, where I studied CFD and observed the very beginning of commercial CFD software creation.

Professor Spalding's unique style of efficient knowledge transfer was at that time adjusted to the dynamics of the Unit and the needs of each already highly specialized visitor who had their own arrival time, planned duration of stay and specific interests. Well organized and prepared printed lectures with Figures, diagrams and short notes, which were in fact predecessors of today's popular Power Point presentations, were available and recommended to the newcomers first, and followed by an assigned list of papers and reports. After that, one to one office consultations, scheduled at week in advance, were the most prized learning opportunities.

The mood in the department was very calm except when somebody in the group would report success and obtained good results, or figured out how to generate proper input. I was asking myself if this was a result of proper work environment, or just a difference in culture and climate. Perhaps this was the British way of doing business, which was drastically different from the Mediterranean norms.

However, everywhere else in the cosmopolitan London the world renowned British calm demeanor was not as prominent. Everything was more akin to the Mediterranean culture that I was accustomed to. In some cases emotions and humor were at an even higher elevation, especially during the soccer games, after a variety of TV humor series, or longer Friday's stays in pubs.

Finally, one day I had a chance to understand how a collected and determined spirit is nurtured when I attended an unofficial out of the office lecture by Professor Brian Spalding. Fortunately, it was at the very begging of my stay at IC, so I had a chance to adjust early.

Visitors from the Navy were scheduled to visit IC CFD Unit and colleagues were preparing poster presentations for two weeks. Each poster was discussed several times and carefully reviewed by Professor Spalding. The day of the visit in the morning the posters were nicely positioned near each other in the entrance hall of Tizard dorm just across the street from the IC Mechanical Engineering Department.

The poster session was scheduled in the afternoon after lunch. The whole Unit and visitors were in good mood but after entering the dorm entrance hall everybody had noticed something strange. Lots of papers littered the floor. The posters were damaged and atop of some that were left intact, pacifist protesters wrote messages against the military complex. Everybody was surprised and looked to each other without saying anything but the obvious question was – what are we going to do now? The standstill was broken when Professor Spalding calmly took a piece of paper from the floor, figured out to which poster it belonged, placed it back and kept it at the right spot and asked the planned presenter to start their

presentation with an apology to the visitors and an explanation that we needed to change the order of presentations due to the unplanned circumstances. The rest of the poster presenters followed in the same manner and all of the planned posters were presented. Once back in the department, Professor Spalding calmly asked the secretary to prepare one letter addressed to the Deans office and that was most likely the only action and reaction to the incident in the dorm.

Later on, from time to time in my life and career, I encountered similar situations where a sudden loss needed to be recovered, or when work needed to start again from the scratch. The difference was that now I was on the spot to lead by example. Several times, having in mind that scene in the entrance hall of Tizard dorm, I was able to convince colleagues to calm down, disallow emotions to waste our time and energy and concentrate on recovering what could be recovered and then proceed ahead. Sometimes when crisis is over, I just tell my colleagues that in spite of my Mediterranean background I was able to keep calm thanks to the fact that I had spent some time in Britain. On rare occasions I would disclose to my closest colleagues the whole story which inspired my perspective. I would like to thank Professor Brian Spalding, for that unexpected and perhaps most valuable unofficial out of the office lecture that served me well and that I always attempt to pass to the younger generation.

Milorad B. Dzodzo
Fellow Engineer
Westinghouse Electric Company
Global Technology Development
1000 Westinghouse Dr., Suite 305
Cranberry Twp., PA 16066, USA
dzodzomb@westinghouse.com

Memories of DBS - Marcel Escudier

My first encounter with Brian was in 1960 when he taught thermodynamics to first year undergraduates at Imperial College. In the academic year 1964/5 he was my supervisor on a postgraduate (DIC) project involving a simple theory for the calculation of the Reynolds analogy factor and the temperature recovery factor for a turbulent boundary layer. This was an enjoyable year, not least because Brian was using the results of my calculations in his postgraduate lectures, which I attended, and we met far more often than he did with most of his students. As a consequence, in October 1964 when I started my PhD under his supervision, we knew each other pretty well and had already developed a good working relationship. My PhD was concerned primarily with analyzing published experimental data to extract information about the entrainment rate, develop a correlation for the entrainment function, central to the Unified Theory of Friction, Heat Transfer and Mass Transfer in the Turbulent Boundary Layer and Wall Jet, and carry out numerical integration of the ordinary differential equations Brian had developed within the theory. At some stage, he informed me that every well-rounded PhD had to include an experimental aspect. He suggested a hot-wire anemometer investigation of a turbulent boundary layer with blowing upstream and subjected to a severe adverse pressure gradient. I was the first to use hot-wire anemometry in the heat-transfer laboratory (according to someone, it was the problems I encountered, and detailed in my thesis, that led Jim Whitelaw to develop LDA with Franz Durst.) A major problem in the recirculating wind tunnel I was using was dust build up on the heated wires causing major calibration drift. When I went to see Brian about this he just said 'fly papers', expecting me to collect the dust by installing fly papers ahead of the working section. I didn't find this to be the most helpful advice! However, he arranged for me to discuss my problems with Peter Bradshaw, at that time at the National Physical Laboratory in Teddington, which proved very useful.

Brian had been asked to review a paper submitted by a well-respected academic from Southampton University to the Proceedings of the IMechE. It was about hot-wire anemometry about which Brian said he knew very little (see above!) and so asked me to do the review, with an explanation to the editor saying that he felt I was an appropriate choice as being 'suitably imbued with disrespect for his seniors'.

Personally, I found Brian very easy to work with, and not in the least condescending or intimidating. The latter was probably due to my naivety and unawareness of him as a major international figure in our community. I should have been alerted to this by the number of high profile visitors to the Thermofluids Group, including Bill Kays and Bill Reynolds from Stanford, Roger Eichhorn from Kentucky, and Samson Kutateladze and Aleksandr Leont'ev from Novo Sibirsk. I recall other research students being incredibly nervous about meeting with Brian. One (no names) would empty his pockets beforehand of anything, such as keys and coins, that might cause a distracting noise during their meeting. Arranging such a meeting to discuss day-to-day progress was tricky if you followed the official procedure of arranging the meeting through his secretary, Marjorie Steele. I discovered the trick was to knock on his door after she'd left for the day: he'd always see me.

Kutateladze and Leont'ev had written a monograph with the title ‘Turbulent boundary layers in compressible gases' which Brian had translated from Russian into English. A remarkable feature of the book is that Brian's comments as footnotes more than doubled its length. Shortly after its publication (in 1964), Kutateladze and Leont'ev came to visit. A meeting was arranged at which each of Brian's research students (I believe Suhas was also there) was asked to say what they were working on. Brian acted as translator. After every presentation, Kutateladze said they'd already done whatever it was. Towards the end, when it came to my turn, I just said 'there's no point saying anything, they've done it already.' With a straight face, Brian translated. There was a shout in Russian from Kutateladze which Brian translated into English as 'sacrilege' to laughter all round.

I fell out with Brian on only one occasion when he said I should leave out of a paper the lengthy appendix giving all the details of the analysis I'd been doing on a drag law correlation. I actually threw a pencil across his office I was so angry. He didn't react and although the incident was never mentioned, it may go some way to explaining the following.

In spite of his legendary insight Brian wasn't infallible. On one occasion, he asked me to read the draft of a paper he'd written. He'd shown that the quantity $\partial\tau/\partial u$ at the edge of a shear layer is equal to the entrainment rate, an interesting result. He'd then correctly evaluated $\partial\tau/\partial u$ as the quotient of the spatial gradients of τ and u. I pointed that both gradients were identically zero at the edge of the shear layer but became non-zero when approximate expressions were adopted for the spatial gradients of τ and u. I only found out during the Stanford Conference in 1968 that he agreed with my assessment that this made no sense and so he binned it.

On another occasion, on a Friday afternoon, he gave me a photocopy of a manuscript he was working on, about 200 handwritten pages, and said he'd like my comments by Monday morning. I duly obliged with lots of suggestions in red ink which he largely accepted.

After finishing my PhD, I went to MIT which I found to be culturally very similar to Imperial College. It was only after I left MIT that I realized it wasn't like that everywhere. That made me even more appreciative of Brian and Imperial, and what a privilege it had been to work so closely with him.

Marcel Escudier
Emeritus Harrison Professor of Mechanical Engineering
University of Liverpool
Supervised by DBS 1963-64 (DIC), 1964-67 (PhD)
sqda@btinternet.com

The Value of Having a Reference – Norberto Fueyo

While I was his PhD student at the CFD Unit of Imperial College in the late 80's, I do not think I met with Brian more than perhaps five times.

In the pre-email era, our communications with (then) *Professor* Spalding would be primarily via memos -- quite a novelty for a Spaniard who had never seen such a format before.

I immediately became mesmerized by his writing style: concise and sharp, yet elegant; eminently technical, but interspersed with cultural references and witticisms; and often humorous in unpredictable ways.

To this day, I cannot think of any scientist who can write with the accurate, elegant, colorful, timeless style that Brian mastered.

A hot London afternoon in July I passed my viva; Professor Spalding went out of the examination room for some brief minutes and came back with two cans of Coke ("American Champagne"); we celebrated with the frugality that he professed; I joined his company CHAM; and Professor Spalding became simply Brian.

Working with him at CHAM I came to witness firsthand the many attributes that no doubt many others have also reported; notably Brian's ability to search for the essence of any problem, and to find unusual, ingenious solutions. Brian was often as demanding of others, but not any more than he was of himself; he was persistent but he was fair, and possessed an intellectual integrity that does not always go hand-in-hand with outstanding talent.

Brian's scientific stature was indeed paired with his ability to influence by virtue of his example. As his student, I am as grateful for the latter as I am for the former.

Norberto Fueyo
PhD Imperial College 1990
Professor of Fluid Mechanics
University of Zaragoza

Some Recollections on Brian Spalding - Kemo Hanjalić

"Professor Spalding, Imperial College!". That was the instant response of P.O.A.L. Davies' from Southampton early in 1965 during his short visit to Sarajevo when I had asked him if he could recommend me a place in the UK to do a PhD in heat transfer. That was my first encounter with the name of Brian Spalding. As a research assistant in the R&D Centre of "Energoinvest", a rising company in process and power engineering, I had just been awarded a nine-month scholarship from the British Fund for Yugoslav Scholars, which I saw as an opportunity to begin doctoral studies. But before I could reach Spalding (no web around then!), a letter from my stipend fund informed me that I had been enrolled in the Postgraduate School in Thermodynamics at the University of Birmingham with no alternatives offered. Discovering that my Dipl.Ing. degree was not sufficient to enlist in a PhD programme and that I wouldn't have an opportunity to work with Spalding, was disappointing. But I didn't give up. As soon as I passed the MSc exams in June 1996, I wrote to Spalding expressing my enthusiasm for pursuing a PhD in his group. He replied within few days that right then he had no vacancies but that he had passed my letter to his young colleague Dr. Brian Launder from whom I ought to hear soon. That indeed happened, and after a short interview in London, I enrolled for the MPhil degree to work on Launder's project sponsored by the CEGB, but formally under the supervision of Spalding - at least for a year or so until Launder was granted the status of a "recognized teacher of the University of London". Thus, apart from group seminars and semi-annual meetings of my thesis committee, throughout the whole stay I had almost no direct interaction with Brian Spalding.

Hence, I cannot say that I was a student of Spalding in the true sense. Did I lament that? Well, I never thought of it in such a way, since very soon I established cordial relation with Brian Launder that emerged into genuine friendship that still lasts. With Launder, I and a few fellow-PhD students, notably Bill Jones, discovered an opportunity niche in turbulence modelling that became our prime research focus. However, just being around in the Heat Transfer Section in that period was already a great privilege. Spalding's spirit permeated the whole section, filling our minds with his constructive criticisms and visionary ideas., To a great extent he shaped the future careers of just about every one of us! His intellectual dominance and self-confidence, his great striving for innovation and his passion for the then emerging CFD, had an overwhelming influence on the whole generation at the time and many afterwards. I did interact with his students, followed the developments in CFD, but, in parallel with my experiments, focused on turbulence modelling where Launder's group gradually took over the initiative emerging as a major hub in that field.

After defending my thesis in 1970 and before leaving the UK, I requested an audience with Professor Spalding to express my thanks and to say goodbye. That was my only visit ever to his office after which for years I had no contact except seeing him occasionally at some conferences.

About a decade later, our roads crossed again. After joining the Executive Committee of the *International Centre for Heat and Mass Transfer* (ICHMT), based in the "Boris Kidrič" Institute for Nuclear Sciences in Vinča near Belgrade, I began meeting Spalding more often. Even in the mid 60s, he had established a broad international network, but wanted to extend eastbound to enhance scientific communications within the global thermo-fluids community, especially in the Soviet Union. Together with several colleagues from the USA, France, Germany and Soviet Union, he became a powerful driver for the creation of the ICHMT based in Yugoslavia – one of the few European countries in the 60s and 70s that was easily accessible both to East and West. Indeed, it was Spalding, together with colleagues from the USA who pushed for an Adriatic location over Paris promoted by others. I still recall Spalding's constructive input in shaping the ICHMT profile and its mission. In fact, the very first global events organized by ICHMT, "*Heat and Mass Transfer in Turbulent Boundary Layers*" (1968) and "*Heat and Mass Transfer in Flows with Separated Regions and Measurements Techniques*" (1969), both held in Herceg Novi, were inspired by Spalding reflecting his main research focus of the time.

In 1989, I organized in Sarajevo an ICHMT conference on *Mathematical Modelling and Computer Simulations in Energy Systems* (Hemisphere Publ. Corp. 1990). Spalding kindly accepted my invitation to give a keynote lecture. At a small reception for keynote speakers in my apartment, I vividly recall a sparkling conversation (half in English and half in Russian) between Spalding and Russian academician A.A. Samarskii from the Keldish Institute for Applied Mathematics in Moscow, that went far beyond the research matters, opening the rivalry between the West and Russia, politics in general and "perestroika" in particular,

on the very eve of the dissolution of Soviet Union. Prior to leaving, Spalding discretely inquired if I ever contemplated leaving Sarajevo, and if I would be interested in joining his company CHAM.

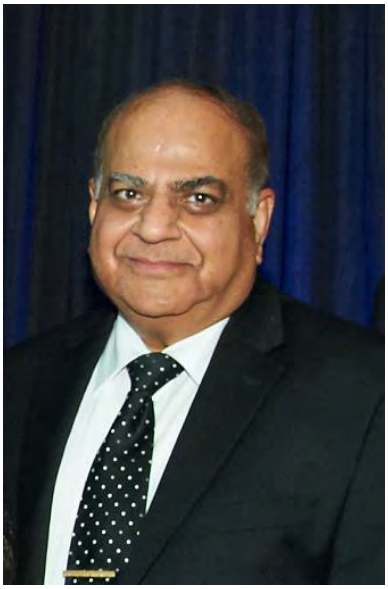
A few years later, in 1992, I invited him again to be a keynote speaker in another ICHMT event, a Forum on *Expert Systems and Computer Simulation in Energy Engineering* (Begell House Inc. 1994) held in Erlangen, Germany. He accepted and sent me a title "Friendly face of CFD". Acknowledging the receipt, I inquired if we should replace CFD by Computational Fluid Dynamics, arguing that many participants may not recognize what CFD implies. He promptly responded (rewording): no, keep it; many know, and those who don't, ought to learn.

We continued bumping into each other at various events. In May 2007, at a conference in St Petersburg dedicated to the 80th birthday of academician A.I. Leontiev, I was scheduled to talk after Brian's keynote. Before the session was to begin I walked into the lecture hall to upload my presentation and saw two groups of people gathered around two laptops facing two screens. Apparently, Brian wanted to give his presentation simultaneously in English and in Russian, as he did before on some occasions, but he now wanted also some sound effects that posed problems. In the end, everything worked well to great excitement of the predominantly Russian audience.

The last time I met Brian Spalding was again in Sarajevo, in September 2015 at the *Turbulence, Heat and Mass Transfer Symposium (THMT-15*). Among abstracts submitted we noticed one authored by Spalding, which we immediately upgraded to a special plenary lecture. The lecture hall was full: many, especially the young participants, were excited with a unique opportunity to see Brian Spalding in person and to listen about his new turbulence model for fully stirred reactors. Sadly, this was one of his last conference appearances.

Kemal Hanjalić, FREng.
Professor Emeritus
Delft University of Technology, Nl.
K.Hanhjalic@tudelft.nl

Professor Spalding: A True Genius - Yogesh Jaluria



When I first started working after my education, I had not even heard of Professor Spalding. Then, one day, while discussing the leaders in heat transfer, a colleague said, " the only true genius in this field is Professor Spalding." That comment encouraged me to pursue the work done by Professor Brian Spalding and his group. The more I read, the more impressed I got. A few years later, when I learned that he was editor of a book series, I immediately sent my manuscript on Natural Convection for consideration to be included in the series. He accepted it and sent extremely useful and insightful comments that I followed to improve the book. For much of my initial work on recirculating flows, in heat rejection, enclosure fires and solar ponds, I found great inspiration and information in the many papers written by him and his students. Similarly, the work on boundary layers and separated flows was valuable in my research.

Much later, in 1985, I had the great pleasure of spending about 10 days with Brian in Cesme, Turkey, for a workshop on Natural Convection. I distinctly remember his brilliant talks and comments. But what I remember most fondly is that he had checked everything, including his slides, on his flight to Turkey. The bags did not show up for a while and he was seen in the same clothes day after day. He was also forced to use his memory and imagination to prepare viewgraphs for his talks. It was an impressive achievement.

At another conference, where we were both invited to present our work, I was impressed when Brian presented a list of outstanding topics that critically needed further research. I was even more impressed when he said that the list was also presented about a decade earlier and almost nothing had changed, stressing that tough questions were not being addressed. Over the years, I interacted with him at various venues and always came away with clearer and deeper understanding of the problems at hand.

In summary, I go back to my friend's comment on Professor Spalding and fully agree that he has been one of the giants in heat and mass transfer, particularly in computational fluid dynamics and heat transfer. Like many of my contemporaries, I learnt a lot from his work and owe him much gratitude.

Yogesh Jaluria
Board of Governors Professor & Distinguished Professor
Rutgers, The State University of New Jersey
jaluria@jove.rutgers.edu;

My Brief Encounter with Professor Brian Spalding – Jerry Jones

I was not a student of Prof. Spalding, but I know many who were. I was educated in the MEAM Department at the University of Pennsylvania starting in the mid-1970s, receiving my MSME and PhD degrees there in 1975 and 1981, respectively. Among my thesis advisors was Prof. Stuart Churchill, who was starting to explore more and more the use of computers to solve the differential equations governing fluid flow and convection heat transfer. After hearing his brief talk on the solution of the Navier-Stokes and energy equations to simulate wave behavior emanating from a lightning strike, I was convinced I wanted to coax a computer to solve my problem on forced convection. However, a computer does not solve these equations by itself, it needs to be told how to do it. This is where Prof. Spalding and his students entered my life. I began to read the fluids and heat transfer literature authored by names like Patankar, Launder, and Runchal. The thread of commonality that ran alongside these names was a person named D. B. Spalding – who? Though it took me a while to figure out, I discovered in time that he was the intellectual source of so many grand ideas that spilled off the journal pages. With no Google or Wikipedia at the time, I struggled to learn who he was. This came later.

Fast forward to 2009. My career had taken me through the Los Alamos National Laboratory (LANL) and back to the U.S. east coast to Villanova University, not far from UPenn in Philadelphia. I was also a member of the Franklin Institute Committee on Science and the Arts in Philadelphia, which awards the prestigious Franklin Medals each year for outstanding contributions in six areas, including mechanical engineering. Was there ever a better opportunity to recognize the genius and outstanding contributions of Prof. Spalding? With the extensive help of Akshai Runchal, whom I finally met while taking a short course on CFD while at LANL, I advanced a case that awarded Prof. Spalding the 2010 Franklin Medal in Mechanical Engineering "for his seminal contributions to the science and art of Computational Fluid Dynamics, including integrating flow, heat, and mass transport into a single unified mathematical and computational framework, the Finite-Volume methodology, Exponential method, Staggered grid, SIMPLE algorithm, and the standardization of the k-e turbulence model among many others, and creating the practice of CFD in industry including developing the first commercial CFD code (PHOENICS) and company, thus paving the path for widespread application of CFD in industry." I had finally discovered the genius of Prof. Spalding.

Along with the awards ceremony in late April, 2010, a sumptuous black-tie affair under the impressive 82-foot tall dome of Franklin Hall at the Institute, a CFD symposium was held at Villanova University that featured world-renown experts speaking on CFD topics from the nanoscale to planets. Prof. Spalding spoke on his novel representation of combustion (some photos included in Appendix II). Several of his former students attended and a few presented. It was a truly great event. I spent perhaps less than a day's worth of time with him over this period and, above all, what impressed me about Prof. Spalding was his simplicity. He was a true gentle man who used words sparingly, but could easily be coaxed into heated language if moved to do so. The story he told me about his experiences with the Royal Society was one such example. I asked him about the title of one of his books, which I found curious. It was "Some Fundamentals of Combustion." What I asked was what he would title a new book once he discovered additional science in this area. I should have anticipated his answer. It was "Some More Fundamentals of Combustion" - simplicity.

He was a wonderful man.

Gerard F. 'Jerry' Jones
Professor, Mechanical Engineering
Sr. Assoc. Dean, Graduate Studies and Research
Villanova University
Villanova, Pennsylvania
gerard.jones@villanova.edu

A Tribute to Brian - Emma Jureidini

I started at Cham in July 1988, Reception had just moved into the front of Bakery House and Brian was about to retire from Imperial College, and at the time only worked three days a week in Wimbledon. It felt like a new start for everyone when Brian started full time at Cham and I was excited to be part of it. I was just 22 at the time and never could have imagined how much

influence working at Cham would have over the next 30 years on my life. My husband worked at Cham, and my dearest friends have all worked at Cham over the years, so looking back it has never just been a place of work, it has been a huge part of my life.

One of my lasting memories of Brian will be a more recent memory, he always came to work dressed in a suit and tie and was always first in and last out, seven days a week. During the last few years, once a week he would leave the office an hour early, having changed into his grey tracksuit, laptop in hand and ready for his pilates class, this always made me smile.

So although my contribution to the Cham family has been small (meeting, greeting and answering the telephone) I feel blessed to have had Brian in my life and shall miss him.

Emma Jureidini
Concentration, Heat and Momentum Ltd
ercj@cham.co.uk

Affectionate Memories of DBS – Brian Launder

My first fleeting encounter with Brian Spalding was in early 1961. He was the new Professor of Heat Transfer at IC while I was a final-year undergraduate who had come along to hear about research opportunities within the Thermo-Fluids Division that he led. Only it didn't work out that way. The college was then in the lengthy process of rebuilding on site and, with stunning (though later, I was to appreciate, entirely characteristic) honesty, Brian announced to the thirty or so students gathered to hear him: "If you stay here for a PhD you'll lose at least a year from the building works; so, if you want a speedy doctorate, go elsewhere".

On the basis of his advice I applied to half-a-dozen US universities along the east coast and, to my surprise, offers of admission with financial support started to arrive: a named scholarship at Princeton and an assistantship at MIT … but which should I choose? I requested an appointment with 'the Professor' and five minutes were graciously allocated. Briefly I explained my agreeable dilemma and, in 10 seconds flat, got his reply: "Go to MIT with Rohsenow. Princeton has Robert M. Drake but he's never done anything original!"

So, I went to MIT (but to the Gas Turbine Lab as they offered a RA post rather than a TA with Rohsenow). Three years later, thanks to a reverse-brain-drain initiative by the British Council, I had a range of UK post-doc positions to choose from at government and industrial research labs. Before deciding, however, I wrote to Brian wondering whether there might be a position as lecturer available at IC – indeed, I even suggested that one day I might hope to become a professor. In ten days (rapid given the leisurely pace of two-way trans-Atlantic airmail) his reply came: yes, an offer of a position would shortly be sent from the registrar's office though he regretted that he could not immediately meet "the full extent of [my] ambition."!

My first task at Imperial was to seek research funding and, since my doctorate at MIT had been mainly experimental, that was the area of the initial proposals. Two projects came through which largely occupied my research time and, as DBS had asked me to process research applications to the group, I was in an excellent position to scoop up as research students Bill Jones and Kemo Hanjalic (both of whom have had stellar research careers and elected Fellows of the Royal Academy of Engineering). DBS also allocated me a soft teaching duty lecturing to the MSc class, sparing me the rigours of the rebellious undergrads. However, when his parabolic solver, GENMIX, was undergoing testing, he asked me if I would like to join him in a consultancy project for the UKAEA using that software to predict condensation in steam flow through tubes. It was a struggle for me (at the time an experimentalist) to get to grips with the method and the code … but eventually we got there.

I remain grateful to this day for the opportunity that project gave me. But the code only had a rudimentary mixing-length model of turbulent transport. So, after the consultancy was completed, Brian encouraged me to redirect my research to improve the model of turbulence, which I did with my students, Kemo and Bill, re-directed from their initially experimental projects. Indeed, Brian and his students (Wolfgang Rodi and K. H. Ng) also pursued closely parallel research in friendly competition with us. Yes, that half-decade from 1969-1974 was an intensely interesting and happy time to be researching in the group. Brian's charismatic leadership stimulated major advances in the numerical solution of the equations of motion for two- and, subsequently, three-dimensional flow as well as the modelling of turbulence.

Well, this idyllic state couldn't – or, at least, didn't – last. Key students and post-docs moved on to careers outside the UK, several academics from the group decided to pursue their own visions independently while the writer moved to California for four years. Yet, while it is sometimes said that this marked the end of the group's influence, in many respects it was the reverse. Brian, released from running a major research team and all the academic problems of university life, had more time to devote to the development of his CFD-software company, CHAM, which he put to very great effect through the development of the first code that could credibly claim to be an all-purpose CFD solver, PHOENICS (an acronym for Parabolic, Hyperbolic or Elliptic Numerical Integration Code Series). Moreover, university CFD research centres and software companies led by former students or staff from the Imperial group emerged at a dozen locations around the globe. Thus, the current, relatively mature state of CFD applicable to complex, industrial problems owes an enormous debt of gratitude to Brian Spalding.

Since my return to the UK I've been regularly reminded of Brian's continuing presence and influence. Long past the time when even feisty academic warriors normally hang up their spurs, Brian would be engaging in what seemed a perpetual round of conferences and trips to receive honorific awards (all richly deserved). I particularly recall a dinner at Imperial College to celebrate his 90th birthday where he regaled the company with his observations on life – delivered in poetic form, of course! My final meeting with him was at a conference in Sarajevo in autumn 2015 where we both delivered invited lectures. At the end of mine, on a topic outside the main theme of the meeting - hurricanes – in the absence of interjections from elsewhere, he posed a sequence of thought-provoking questions.

Brian Launder
Professor B. E. Launder, FREng, FRS
University of Manchester
brian.launder@umist.ac.uk

Professor Brian Spalding- Sadly Missed, Fondly Remembered - Millie Lyle

When I joined CHAM in January 1992 I certainly did not expect to still be working here in 2017, some 25 years later. Most certainly Brian created a company that has given a true sense of family to its staff, both past and present. I have made many wonderful friends being part of that CHAM family. Brian is greatly missed at 40 High Street but I still feel his presence everywhere around the building. His passion for learning and life will remain with me always.

Farewell Brian and thank you for everything.

Mrs Millie Lyle
Concentration Heat and Momentum Ltd (CHAM)
ml@cham.co.uk

What Can I say about Brian? – Mike Malin

What can I say about Brian? He had a massive influence on my engineering career, and I will always be grateful for the assistance, training, and knowledge he imparted to me during our forty-year association together at Imperial College and CHAM. It was a privilege to have known and worked with him. I witnessed first-hand many examples of his technical brilliance and creativity, his deep physical insight and vision, and his encyclopedic knowledge of thermo-fluids. It seems to me that Brian's approach was to seek generic and economical solutions to practical engineering problems by making approximations based on physical intuition combined with analytical flair. He also had a remarkable ability to resolve convergence problems by devising novel algorithmic changes or linearization practices.

I think it is true to say that Brian created the CFD industry with the formation of CHAM in 1969. Another landmark achievement occurred during the late 1970s when Brian conceived and executed the revolutionary idea of creating the first ever general-purpose CFD code for simulating all thermo-fluid problems. This code was called PHOENICS, an acronym for Parabolic, Hyperbolic Or Elliptic Numerical Integration Code Series. It was launched commercially in 1981, and by this means Brian founded a worldwide industry based on the selling of CFD software and services into an ever-widening field of applications.

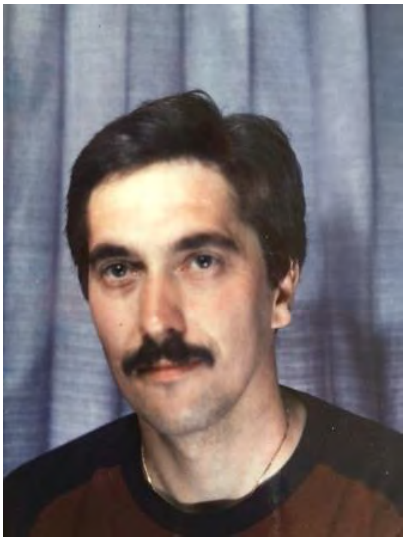
My own involvement in CFD began in 1976 when I joined Brian's research group at Imperial College to undertake a MSc in Heat Transfer Engineering. It is now easy to see that this was essentially the world's first post-graduate degree course in CFD. Brian, who was known to everyone in the group as DBS, delivered the course almost single-handedly, starting off with his brilliant lecture series entitled "Mathematical Modelling of Fluid-Mechanics, Heat Transfer and Chemical-Reaction Processes: A Lecture Course". These lectures provided an all-encompassing, everything-you-need-to-know description of the basic equations of fluid-flow, heat & mass transfer, turbulence, combustion, multi-phase mixtures and radiation; and how to present them in a unified and generic way, and then solve them by means of the CFD finite-volume method. At the time, these lectures were an absolute revelation to me, and I can see that even now they still provide a valuable reference source.

Evidence of Brian's impressive intuition and creative talent was abundant through our long association together. A few examples will suffice. In 1993 one of CHAM's engineers implemented a generic search algorithm to compute the nearest-wall distances for the low-Reynolds-number turbulence models I had just implemented in PHOENICS. When we briefed Brian, his response was that the method was far too expensive and cumbersome for use in industrial applications with arbitrary complex geometries. A day later he produced a technical note describing an ingenious and generic differential-equation method for calculating approximate values of the nearest-wall distance. Brian wrote: "I have devised a method of computing the turbulence length scale which will be more economical and more realistic than any other which we know of". This certainly proved to be the case when it was immediately applied to large industrial applications. The "wall-distance trick", as Brian liked to call it, was published obscurely in a poster session at the 1994 International Heat Transfer Conference. Thereafter, it was exploited, refined, and published by other researchers, and eventually the method or some variant of it found its way into most commercial CFD codes.

The invention of the wall-distance method emerged almost simultaneously with Brian's proposal for a zero-equation low-Reynolds-number turbulence model for situations in which fluid flows through spaces cluttered with many solid objects. Here, the grid density between nearby solids is often too coarse for any more advanced turbulence model to be meaningfully employed. The key elements of the so-called LVEL turbulence model were Brian's 1962 law of the wall and the "wall-distance trick". Brian said the model didn't offer any new scientific insight, but it would enable PHOENICS to be used with great practical advantage for the electronics-cooling applications we were carrying out for IBM. This proved to be the case, and following publication in 1996 the usefulness of the model was demonstrated by many other workers in the field. The consensus was that the model was as effective as the k-ε model, but with the big advantage of significant savings in computer time, sometimes by factors of three or higher. This inevitably led to the model appearing in commercial CFD codes dedicated to the thermal design of electronic equipment.

Brian's ability to recognize the need for engineers to get an adequate solution within reasonable computing time also led to the development of the IMMERSOL (i.e., immersed solid) radiation model in 1994. I was engaged on a contract for Radian Corporation, who wanted an economical radiation model for use on curvilinear meshes in a participating medium with complex geometry. Radian had previous experience of using the discrete transfer model in another commercial CFD code, but they found the model prohibitively expensive. I proposed we implement Rosseland's model, but Brian expressed the view that while this was a reasonable suggestion, he had something much more generic in mind. A few days later Brian sent me a technical note outlining his proposal for a diffusional model to represent radiation in arbitrary geometries for both optically thick and thin media. The model involved the solution of a diffusion equation for the radiosity with a diffusivity proportional not only to the medium's absorption and scattering coefficients, but also to the distance between solid walls (needed for transparent media). The radiosity equation was derived by simplifying the six-flux model, and the inter-wall distances were computed from the "wall-distance trick". Further notes in 1996 elaborated on how the model could be employed in conjugate-heat-transfer situations by reformulating the radiosity equation in terms of a radiant temperature. Subsequent application of IMMERSOL showed that whilst it doesn't necessarily procure close agreement with experiments, it always produces physically reasonable predictions with computer times that are only a fraction of those expended by more sophisticated models. Even so the model appears to have made little impact outside of CHAM, possibly because Brian didn't publish the model formally until an eloquent description appeared in a 2013 volume of Advances in Heat Transfer.

As a final example of Brian's technical brilliance on algorithmic work, I worked very closely with him during 1998 on a contract for S&C Thermofluids. This involved the extension of the PHOENICS parabolic solver to handle purely supersonic flow (hyperbolic) and under-expanded jets issuing into stagnant surroundings (transonic). The idea was to effect massive savings in computer time by switching from elliptic computations to the marching integration procedure offered by the parabolic solver. Brian devised and implemented very rapidly several algorithmic changes to the pressure-velocity coupling, and it was my role to create numerous cases to test and validate these enhancements, and then report on the results. This work was never published in the open literature, but the outcome was very successful and pleasing to the customer.



Brian was a remarkable engineer and scientist, and he had a profound influence on the field of engineering through his pioneering work in thermo-fluids and computational fluid dynamics. It is also a testament to Brian's ingenuity that numerous innovations from Imperial College and CHAM are employed in many commercial and open source CFD codes being marketed today.

Michael R. Malin
M.Sc. (1976-1977) Student of Prof. Spalding
Ph.D. (1983-1986) Student of Prof Spalding
Technical Support Manager
CHAM Limited, Bakery House
40 High Street, Wimbledon,
London SW19 5AU, June 2017.
mrm@cham.co.uk

A Tribute to Professor Brian Spalding - Adrian Melling

As a young undergraduate in Toronto I had developed a strong interest in thermofluid dynamics. Through a particular fascination with the boundary layer concept I had first found references to the name Spalding. For three years following my graduation in 1966 I worked as a teacher in Zambia and that posed two questions with respect to further studies. Would my interests have changed during this time and how could I identify the best university in UK for my purpose? I decided to minimize the first difficulty by choosing to re-enter academia through an MSc program rather than starting PhD research directly. Living in Zambia I relied on a subscription to the Manchester Guardian Weekly to maintain contact with the wide world. There in 1968 I found a timely advertisement for the HMSO publication "Scientific Research in British Universities and Colleges" which I promptly ordered. Working my way meticulously through this hefty document, I identified the MSc program "Thermal Power and Process Engineering" run by Spalding 's group at Imperial College as my first choice. I was extremely pleased to be offered a place on this course starting in September 1969. My first meeting with the famous professor himself was, of course, an exciting prospect. I did, however, have some reservations. Would I have forgotten too much from my undergraduate studies? Would I have to struggle to keep up with freshly graduated fellow students? Both fears proved to be groundless!

As well as the anticipated boundary layers, the MSc course introduced me to exciting concepts such as the Navier-Stokes equations, turbulence modelling and convective heat and mass transfer, ably and enthusiastically instructed by Brian Spalding and his colleagues. We were also granted insight into something very new at the time, computational fluid dynamics (CFD), presented in the case of boundary layer flows by Professor Spalding himself. His capable explanations of the computer program GENMIX helped me greatly in deciding with confidence to take up experimental rather than computational fluid mechanics! I willfully ignored Professor Spalding's assertion that sooner or later CFD would render experiments superfluous. 50 years later Brian's expectations have in many respects been fulfilled, but parallel developments in experimental techniques, especially those made possible by laser technology, have opened up new fields of experimental investigation.

Back at Imperial College in the1970's CFD doctoral workers were commendably required to undertake experimental work related to their project. Accordingly, it seemed only proper that I should demonstrate my limited ability to apply the CFD techniques learned in the MSc program: no complicated geometry, no turbulence model, just a laminar creeping flow over a double backward step. My measurements with laser Doppler anemometry (LDA) had established that velocity profiles far upstream and far downstream of the step were parabolic while those near the step clearly showed zones of recirculating flow. My calculations of stream function and vorticity using a CFD program developed at Imperial College (Gosman et al.) confirmed these features. In CFD jargon "the agreement was encouraging", at least until the flow rate was doubled. Flow visualization and LDA measurements then indicated a pronounced but stable asymmetry in the flow field. I left the predictions this time in more capable hands!

In the 1970's "we" (the experimentalists) had our "headquarters" in room 200. "They" (the computationalists) were frequently to be found nearby in a sparsely furnished annex of the Fluids laboratory: a couple of card punchers, a card reader, a line printer, one or two chairs and (most importantly) a large waste paper bin. The proximity of the two bases encouraged a degree of rivalry. "We" worked hard but by midnight we were normally on our way home. Two or three hours later some of "them" would still be standing near the printer, anxiously awaiting the print-out of their most recent jobs on the pile of seemingly endless paper. When each job finally appeared, a glance at the first page would often suffice before the disgusted researcher threw the whole pile into the bin. "Our" reaction varied from sympathy to contempt for the unhappy computationalist, whose latest tweaking of various parameters and "constants" in his program had been unsuccessful in bringing predicted results closer to the reference data.

Sometimes I regret the passing of such uncomfortable aspects of research. On this occasion, I regret the passing of a great and inspiring man!

Adrian Melling
Department of Chemical and Bioengineering
University of Erlangen-Nuremberg
melling.adrian@gmail.com

Recollections of Professor Brian Spalding - Dubravka Melling

I first met Brian, or Professor Spalding as I then knew him, at the cocktail party in 1971 for the International Conference on Heat and Mass Transfer in Trogir (Croatia). It was a surprise to me to see a famous professor dancing without a pause on the hotel terrace, instead of engaging in the academic work which I thought was a professor's sole occupation. Brian was the last one to leave the dance floor, yet the next morning he was fresh and fit while the rest of us were trying to shake off a hangover. The secret I discovered later: an early morning swim at 6 o'clock!

Another episode which I would like to mention dates back to December 1972, soon after starting my PhD studies at Imperial College. Brian had invited me to a party for students and staff and took the opportunity to ask how I would spend the Christmas period. When I told him that I intended to stay in London and work, he warned me that at Christmas London, the College and the hostel would all be very quiet and depressing. So Brian recommended to me to go home, but as an alternative he generously invited me to spend Christmas with his family. I was very grateful for the invitation, but in the end I took Brian's best advice and returned to my family in Belgrade for Christmas and the New Year.

Many years after I left Imperial College, our paths crossed again in 1987 at the 19th International Conference on Heat and Mass Transfer in Dubrovnik. Brian was approaching formal retirement but looked so well and so fit that my first question to him was: " When are you going to get old?". With two young boys to care for, there would be no retirement yet, Brian, and academic life in its new form was likely to remain busy. Around this time, I was living in UK between periods of residence abroad, so it was easy for our families to get together at the Spaldings' home or ours. We were also able to attend Brian's retirement party in 1988 in South Croydon before we moved overseas again. Thereafter we still met from time to time, notably when Brian was awarded an honorary doctorate from the University of Erlangen-Nuremberg. As I had expected, Brian did not stop working after retirement. I was able to confirm this in 2003 at the celebration of his 80th birthday in Richmond Hill and in 2013 at a dinner for his 90th birthday at Imperial College when I met him sadly for the last time.

Dubravka Melling
SAOT - Erlangen Graduate School in Advanced Optical Technologies
University of Erlangen-Nuremberg
dubravka.melling@gmail.com

Profound Impact of Spalding - Moscow Team

Six months passed but the soul still refuses to believe that he is no longer with us. Still are alive the feelings of night prayers for Brian's health.

Everything happened quickly enough. Three weeks of worries, anxiety, hope and strong desire to give ourselves to help him feel better. The words of physicians at times led to despair, at times – gave hope for recovery. At some point, there was a feeling that we prevailed: Brian started to recover, even spoke Russian with medical staff when the lung ventilation system was temporarily switched off. And we sent him from Moscow with full confidence that doctors in his homeland would ensure the continuation of the process of recovering. Therefore, we were all stunned to receive 2 days after his departure a message telling that he died. It was a great shock and we are still under its influence.

It is not important now whether it happened because of somebody's mistake or fatal coincidence of circumstances. The outcome is sad. Let us accept it as is destined by destiny.

What we remember about him. He was a bright and spiritual man, sincere, modest, infinitely wise, taking care of people. It was extremely interesting to deal with him. Sometimes he was persistent to stubbornness but also knew how to get out of any situation with dignity attracting new volunteers for implementation of his ideas. His enormous capacity for work forced us to work constantly, without regard for time and strength.

It was understandable: for each of us he was a TEACHER whom we immensely respected and loved. We tried to make a new breakthrough in development for his each visit, for our each meeting to see in his eyes notes of encouragement and glint from anticipation of new results. His each visit to Moscow was accompanied by a powerful impetus to continuous development. For us he was the one who led and pointed the way. In this he was unsurpassed Master. He always tried to solve any complex problem by splitting it into multiple simple and clear tasks. He knew how to see far ahead and anticipate the direction of further progress. In recent years he used to say that he could see solution of problems that had not been solved earlier. Not all his thoughts and ideas are realized. We'll try to realize them to the best of our abilities.

We were lucky to communicate with him for the last 20 years, so it seems that we are partly responsible for conveying to the scientific community the ideas that were of concern to him in recent years.

First of all, it is probably worth mentioning the direction which Brian called the population theory. His first ideas were used in development of the multi-fluid model of turbulence. Professor was not very happy with implementation of this model in PHOENICS. He waited for the occasion to improve it. However, he considered the population theory as being much wider than just a model of turbulence. He intuitively felt that in hydrodynamics, particularly with chemical reactions, there was a special place for random processes.

Another idea was related to awareness that only few could understand CFD methods whereas CFD results should be used by all engineers. It is important, therefore, to enable any engineer to make calculations even if he does not know the CFD features. In this direction a separate program, PHOENICS-Direct, was created, which Professor Spalding again spoke of at the OpenFOAM Conference one month before his decease.

Once again thoughts come back to reality in which he is no longer with us. When people in Russia want to commemorate a deceased person with kind words, they say: “May your memory be eternal.” So we, too, say: “May your memory be eternal, Brian Spalding. Rest in peace.”

Moscow Research Group:
Elena Pankova (worked with Professor Spalding from 2000 to 2016)
Nikolai Pavitsky (worked with Professor Spalding from 1997 to 2016)
Valery Artemov (worked with Professor Spalding from 1999 to 2014)
Alexey Ginevsky (worked with Professor Spalding from 1999 to 2016)
alexeyginevsky@gmail.com

Remembering Brian Spalding - Jayathi Murthy

I am one of Prof. Spalding’s academic grandchildren – one of his sprawling “family of the mind.” The name of my adviser, Suhas Patankar, is forever entwined with that of Brian Spalding, and so, in a strangely intimate way, I too am connected with this far-flung family. I came to the University of Minnesota to work on my PhD with Suhas in 1981, and though I knew practically nothing about CFD, already the words “Patankar-Spalding” could send a thrill of excitement down my spine. In time, I came to understand and appreciate the sheer creativity of their work together, the clarity of thought, its rootedness in physics, and most of all, its beautiful simplicity. And of course, I heard from Suhas and Rajani the fabled tales of their days at Imperial College, and about the great man himself. I felt like a part of a great legend.

I remember the first time I met Prof. Spalding. I believe it was in 1982, at a summer conference in Seattle, if I remember correctly, and a number of graduate students from Suhas’s group were attending. I remember us milling together, out of place and a bit intimidated, looking across the room at Prof. Spalding. And finally, the introduction by Suhas, and Prof. Spalding’s extraordinary kindness and interest in each of us. We talked about it for days afterwards.

My own professional life is inextricably intertwined with Prof. Spalding’s work. Our work on unstructured solution-adaptive finite volume methods could not exist without SIMPLE and the class of pressure-based finite volume methods, it goes without saying. And it is fascinating to see the evolution of CFD through the years, from a research tool to be used by the enlightened few to a design tool well-integrated into the product cycle. I feel fortunate to have been closely involved with both the intellectual and commercial evolution of this fascinating subject. But more than the specific methods themselves, the most valuable thing I have inherited is a way of thinking, and for this, I will forever be grateful. Thank you, Brian Spalding.

Jayathi Y. Murthy
Ronald and Valerie Sugar Dean
Henry Samueli School of Engineering and Applied Science
University of California, Los Angeles
jmurthy@gmail.com

What I Learned from Professor Brian Spalding – Siva Parameswaran

I worked with Prof. Brian Spalding from September 1977 to July, 1983. When I joined Imperial College in September 1977, Prof. Spalding (his students affectionately called DBS) was trying to extend his famous GENMIX computer program to compressible flows with shocks. GENMIX is a general-purpose computer program, developed to solve two dimensional, boundary layer flows for incompressible or subsonic flows with low Mach numbers. In order to solve high-speed compressible flow in a boundary layer, DBS correctly figured out that he had to let the pressure field to vary inside the boundary layer (for incompressible flows, free stream pressure is impressed inside the boundary layer, thus pressure does not vary in the direction normal to the stream lines). He came up with an algorithm to correct the vertical pressure field (normal to the marching direction) downstream if the flow is supersonic and upstream if the flow is subsonic. The algorithm worked very well if the flow is fully supersonic or if it is fully subsonic. However, the algorithm failed if the flow goes from supersonic to subsonic through a shock. DBS maintained that we made some programming error and there was nothing wrong with the algorithm. It took me two semesters and lot of writing back and forth with DBS that I finally convinced him the algorithm is flawed because it created more equations than the unknown pressures. I demonstrated this by solving the transonic flow through a 1D, divergent duct but, it cost me additional 5 years to finish my doctoral degree!! My struggles with the compressible flow algorithm made me resilient and prepared me for an academic career. I owe this to Professor Brian Spalding.

Dr. George Carroll was my mentor at Imperial College and we shared the room 484 in the 4th floor of the Mech. Engineering Department. Over the years George has become a good friend of mine and helped me in many ways unknown to him, During my struggle with the compressible flow algorithm, George always encouraged me not to give up.

Siva Parameswaran
Professor, Texas Tech University
siva.parameswaran@ttu.edu

Meeting at Texas Tech University October 2013

Brian Spalding: A Kind and Generous Man – Rajani Patankar

I am not Professor Spalding's student. I know nothing about engineering. So I cannot comment on Brian's ground-breaking contributions to heat transfer. However, I got to experience the kindness and generosity of this exceptional individual. This is why I am paying this tribute to him.

My husband, Suhas Patankar, worked with Brian for his Ph.D. After finishing the degree, he returned to India and soon thereafter we got married. Suhas started working at IIT, Kanpur in India. However, Brian kept urging Suhas to return to England to work with him. So, after three years, we came to London with our little daughter. Brian came to the airport to receive us and waited for three hours before we came out. To my surprise, he had made arrangements for us to stay in their home in Wimbledon. Actually, we ended up staying there for two months before we moved into our apartment. I was new to England and to the western culture. So, I was observing the norms of this new culture. Brian and Eda (his first wife) were very kind, supportive, and understanding. They went out of their way to make us feel comfortable in their home. Their tremendous generosity and kindness touched my heart. The experience of staying with the Spaldings has made a lasting impact on our life. We felt a mutual bond of affection with Brian and Eda. That same closeness has continued with Brian and Colleen. Over the years, we have met many times at conferences, we have visited them a few times in London, and they have come to our house in Minneapolis. Every time, we experienced their closeness and affection towards us. We feel that this has been the greatest gift to us. We will cherish that feeling for the rest of our life. I want to pay my respects to Brian Spalding, who has shown us how to be kind and generous towards others. We will miss him very much.

Rajani Patankar
patan001@umn.edu

Professor Brian Spalding: My Guiding Star – Suhas Patankar

No person has made a more profound and lasting impact on my professional and personal life than Brian Spalding. In 1964, I came to London to work as a Ph.D. student under his guidance. Soon we became good friends and that friendship lasted forever. He was a brilliant scientist and a skillful teacher. Moreover, he was very kind and generous to me and my family.

Brian's scientific work is noteworthy not only for the variety of subjects he covered but also for the strong impact of his inventions. None of his work made just an incremental contribution. It was always a significant breakthrough, opening the door to many scientific opportunities that did not exist before. His vision and creativity provided a quantum increase in our scientific understanding and predictive capability. His specific scientific contributions represent lifelong fireworks of his creative ideas. He was not only successful in creating scientific methods of practical utility but also in establishing them in industry. Today's phenomenal advance in engineering can be traced to the vision and early actions of one man, Brian Spalding.

For me, he was a great source of inspiration. He taught me how to grasp complex problems and pursue grand ideas. I learned from him how to teach and communicate effectively. He is largely responsible for my professional success and personal joy.

I am associated with two scientific breakthroughs. Both were accomplished when I got to spend a lot of time with Brian. The first happened in 1966 when we both traveled to the USA to attend the International Heat Transfer Conference in Chicago. We attempted a finite-volume method for two-dimensional boundary layers. This work led to a very popular book and a computer program for this application. In 1971, the Spaldings hosted my family for two months. At that time, Brian and I would take the train every day from Wimbledon to South Kensington (where Imperial College was). During our train ride, we would discuss possible methods for three-dimensional boundary layers and recirculating flows. Often, I would propose a method and Brian would express his objections. Next day, I would describe a modified method and hear new objections. However, one day, he tentatively approved what I proposed. I quickly implemented the method in a computer program and solved a substantial problem. With great excitement, I went to show him the results. I distinctly remember the joy and the glow on his face. We both knew that we had achieved something big. That was the birth of the SIMPLE algorithm.

Over the years, I have enjoyed my interactions with him and his family. It has been a pleasure to host them in our house in the USA. I have marveled at his intelligence and sharpness right up to the final moments in his life. For his teachings and friendship, I remain forever grateful to him.

Suhas V. Patankar
Ph.D. (1964-1967) Student of Prof Spalding
Professor Emeritus, University of Minnesota
President, Innovative Research, Inc.
patankar@inres.com

Remembering Professor Brian Spalding - Darrell Pepper

In my early days of CFD model development, I spent many hours reading about the fluids modeling efforts of Brian Spalding and his students, A. K. Runchal, S. V. Patankar, A. D. Gosman, and M. Wolfshtein. Their work, under the tutelage of Brian, essentially exploded the application of computational fluid dynamics and made the solution of the Navier Stokes equations actually feasible. The implementation of the finite volume technique for discretizing these nasty, highly nonlinear equations of fluid motion, and especially combustion processes, were insightful, and created interesting and exciting solutions (even the non-real ones). My first interaction with Brian, and later with many of his legacy students, began in the mid 1970's, and I became even more adamant about exploring CFD after listening to one of his talks at a conference – he made modeling fluid flow seem so straightforward. Later, when I began to venture into finite elements (or as Brian would tell me – the dark side of CFD), I began to appreciate even more the magnitude of his work and creativity, and using his work to verify and justify our efforts to employ an alternative numerical method. Over the ensuing years, we would have friendly jousts about finite element versus finite volume (especially during conference presentations). Some years ago, when I introduced the use of meshless methods in lieu of mesh-based techniques, he thought I was at first jesting, but then realized it was an interesting approach. I later boasted that the next logical evolution of numerical modeling would be the absence of points – or the pointless method. He turned to his neighbor in the audience, and asked if I was serious – then he began to smile at me as he quickly grasped the jest of my statement – a priceless moment.

Darrell W. Pepper
University of Nevada Las Vegas
Department of Mechanical Engineering
Las Vegas, NV 89154, USA
darrell.pepper@unlv.edu

Reflections on My Academic Father Professor Brian Spalding - Andrew Pollard

In the annals of human endeavour, few people can measure up to DBS; he was unique to his time with us. In no order of preference, he defined uniqueness as a person, as a scientist, as an engineer, as a fighter for freedom and justice, as a leader in many forms of communication be they scientific or literary and as a role model. He packed so much into his 70 plus years in academe and business it makes one's head swoon.

I have been, and continue to be, influenced by him in all those above-mentioned parts that made up this extraordinarily accomplished man. First introduced to him through an undergraduate lecture on the law of the wall and DBS' novel reformulation of it, and a perchance acquisition of the Patankar-Spalding book on heat and mass transfer in boundary layers, I knew my future was to be influenced by him. I did not appreciate at the time, as a third-year undergraduate student, the magnitude of that influence. Now as a professor emeritus, I know I have immeasurably benefitted from standing on the shoulder of an academic giant. He and his work are historically significant in the evolution of our subject matter and his impact has become legendary.

I have had the fortune to be present and participate in many milestones and events in his life. From his retirement as Chair of Heat Transfer, through to his various birthday celebrations, both he and Colleen have been integral to my journey. How do you thank someone whose has influenced me from a very earnest young Ph.D. student to an acknowledged expert in turbulence, computational fluid dynamics, heat and mass transfer and a successful mentor of others? How do you thank someone who, even in death, continues to give: his population model of turbulence, which I shall continue to work on, his lessons on coping from having consumed a little too much whiskey and his critical, often twinkling eye, now seen through mine, on everyday activities: the appreciation of novel science, the appreciation of well written verse and prose, his exuberance for life and the nurturing of promising new ideas that challenge students and practitioners of physico-chemical hydrodynamics?

To those who know him only through his written works, take heed for there you shall find clarity of thought and exquisitely argued and presented scientific and engineering principles. His books on combustion, mass transfer, turbulence and CFD are models for communicating complex ideas simply and elegantly. His papers, all 350 of them, are each a significant contribution with *The Numerical Computation of Turbulent Flows* having been cited over 12,000 times! His physical insight was legendary and he encapsulated this through simple experiments, both physical and numerical, which elucidated key phenomena. I particularly continue to enjoy Ricou and Spalding 1961 JFM paper on jet entrainment being a case in point.

He left a not insignificant legacy in print and in his academic children, grandchildren and great and emerging great-great grandchildren in whom he instilled directly and through generational diffusion his clarity of thought for unifying and insightful ideas and who each have gone on to make their own significant impacts both scientifically and personally in the world.

Brian Spalding received many awards and accolades including the Franklin Institute Medal and so I close with this quote from Benjamin Franklin: "If you would not be forgotten as soon as you are dead, either write something worth reading or do something worth writing." Brian Spalding succeeded admirably in both.

Andrew Pollard
Ph.D. (1975-1978) Student of Prof Spalding
FCAE, FAPS, FASME
Professor and Queen's Research Chair,
Queen's University, Kingston, CANADA
pollard@me.queensu.ca

Tribute to My Boss, Professor D. Brian Spalding – Jill Rayss

I first met Professor Brian Spalding at my interview on 27th April 1989, and started work as his Personal Assistant on 12th June 1989. I remember it being a short interview, with Brian passing me over to Colleen as soon as possible. I would later come to understand this; it took his time away from his work.

Over the years, I have a lot of memories of working closely with Brian on a daily basis. Some days I would arrive at the office to find an enormous amount of correspondence that he had written, his handwriting getting more and more illegible. Other days I wouldn't see him at all, as he would be in his office concentrating on coding or lecture writing, and did not wish to be disturbed. Frequently he would say "have I not said good morning to you", when I would knock on the door to say "goodnight"; he always looked at his watch whenever I said I was leaving. I remember many times tidying up his office to find snippets of poetry that he had written, something he enjoyed doing.

Brian was courteous as a boss, and always expressed gratitude, that is not to say, he couldn't be difficult, if he made up his mind to do things his way, he wouldn't be moved. I admit to being irritated with him on occasion, but if he ever was with me, he didn't show it. He was thoughtful and nearly always brought me back a bottle of Russian Vodka from his frequent trips to Moscow, which I would find waiting for me on my desk.

Brian disliked taking time out of the office for mundane things, like taking his car to the garage, paying bills, going to the bank, or organizing the servicing of his caravan, and he was always ready to pass this on to me. I helped him with numerous personal tasks, and I am grateful for the trust he had in me. One of the last things I did was go with him to the florist to purchase flowers for Colleen's birthday.

Brian was not fond of small talk, and any CHAM social event, usually held late in the afternoon, always ended up with our engineers and Brian in one corner of the room discussing technical issues. After one such event in 2011, I did manage to get a photograph with him, the only one I have of the two of us together. I share this with you here. Unfortunately, I did not manage to get a photograph of Brian, doing an impression of Mick Jagger on the dance floor at a CHAM Christmas party, no doubt aided by the amount of whisky he had consumed.

Spalding & Jill Rayss

In later years, Brian would ask me not to come in to his office while he took a short rest, or if he was changing into his tracksuit to go to Pilates, but I caught him a number of times in his stockinged feet, working out on his treadmill.

The final email I received from Brian was just after he arrived in Moscow on his last ill-fated trip. It was a 'thank you'; for organizing his travel, and hotel accommodation, and said that his journey had been uneventful.

I knew Brian in his role as a well-respected and eminent scientist, as well as a business man who would discuss everyday issues and as a family man who would share thoughts with me. He was a kind and generous man whom I felt very privileged to know and thought of with a great deal of affection, and would describe as a 'true gentleman'. I miss him very much.

Jill Rayss
Personal Assistant to
Professor D. Brian Spalding
Concentration Heat & Momentum Limited (CHAM)
Tel: +44 20 8947 7651, jpr@cham.co.uk

My Encounters with Brian Spalding – Wolfgang Rodi

My first encounter with Brian Spalding was in 1967 when I spent a year at the University of Minnesota in the Heat Transfer Laboratory of Prof. Eckert. During that time Brian came by and gave a seminar on Numerical Flow Calculations. I was so fascinated by that topic that I applied to him to pursue a Ph.D. study on the topic. I got accepted and he put me on the development and testing of turbulence models, and that is what I did at Imperial College under his supervision for 5 years during 1968 – 1972. I was very fortunate to have this opportunity as I could participate in one of the most exciting and momentous developments in fluid mechanics at the time - the dawn of Computational Fluid Dynamics (CFD), i.e. the early stages of numerical flow calculations and sophisticated turbulence modelling. It was indeed an exciting and in fact turbulent time, sometimes a bit tough, as it was not easy to follow the pace of Brian. It laid the foundations for my later career as Brian put me on the increasingly important subject of turbulence modelling and taught me a lot on how to work and how to write. He was not too happy with the first draft of my Ph.D. thesis and gave very clear and helpful instructions on how to improve the writing. I followed these and he was then much happier with the second draft which inspired him to write a poem on the margin. I had abbreviated “equation” as “equat”, which reminded Brian of 19th century comic verse and stimulated him to write:

:

The Akhund of Swat
Said “Please tell me what
(For I’ve quite forgot)
Is an equat?
Does it stand or squat,
Smoke hash or pot?
If it drinks a lot
I would much rather not
Receive it in Swat.”

After I finished my Ph.D., Brian wanted me to work for a newly established software company in Germany, I think related to Prof. Argyris, but I had an attractive offer from the University of Karlsruhe (now Karlsruhe Institute of Technology), which I accepted and stayed there for good. After my return to Germany, I kept in contact with Brian and we exchanged scientific ideas and publications, and we met at various conferences.

In 1988 Brian helped with the birth of ERCOFTAC (European Research Community on Flow, Turbulence and Combustion) and with choosing its name. He became the first chairman of its Scientific Programme Committee and put ERCOFTAC scientifically on track. At that time, he got me into ERCOFTAC and I became very active in this organization, an involvement that continues until now.

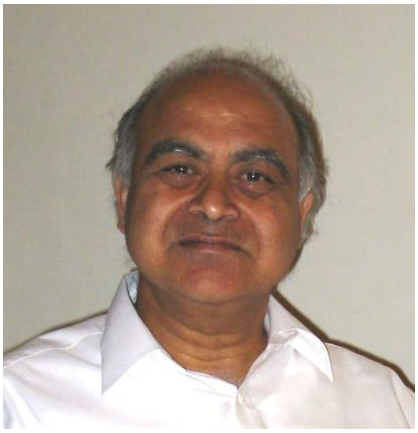
(Photographs Courtesy of Easy Conferences)

Then we met at various celebrations and events: 1988 at Brian's retirement dinner in South Croydon and in January 2003 at his 80th birthday celebration in Richmond Hill. In September 2007, he came to my retirement event in Karlsruhe and gave a philosophical talk on my work in turbulence modelling. In 2008, we had a very enjoyable conference in Marrakesh held on the occasion of Brian's 85th birthday, and we celebrated his 90th birthday in 2013 with a dinner at Imperial College, where he delivered a very interesting and entertaining autobiographical poem summarizing the key elements in his life. I was then fortunate to be with him at his last conference, namely ETMM11 in September 2016 in Palermo, where at the age of 93 he attended many lectures (first picture) and asked pertinent questions and delivered a lecture on combustion modelling (second picture). The last picture shows him at the conference dinner, which he clearly enjoyed and where he was given a small gift. At the dinner, I had the opportunity to say a few words on this very special conference participant and expressed the hope to have Brian back at the next ETMM conference in 2018 - but this unfortunately cannot come true and we are all extremely sad and sorry that we have to continue without this great man.

Wolfgang Rodi
Karlsruhe Institute of Technology
Karlsruhe, Germany
Ph.D. (1968-1972) Student of Prof. Spalding
rodi@kit.edu

Brian Spalding at ETMM11 Conference, Palermo, Sept. 2016

A Tribute to an Exceptional Life: D. Brian Spalding – Akshai Runchal



It is tough deciding what to say about Brian Spalding. Where do I begin? That he was an exceptional man. That he made exceptional contributions to science. That he was a multi-dimensional personality who had expertise in multiple branches of science and spoke multiple languages fluently. That he was a man who would risk valuable professional relationships for the sake of a principle – that of right to freedom of a scientist from a dictatorial regime. That in spite of an age difference of 20 years, **I** could sit with him on a verandah in Kanpur, have a beer, admire the sunset and watch the world go by. That because a flight was cancelled he would risk a drive of 250 miles overnight in a beat-up old taxi in an unknown land - from Delhi to Kanpur - so he could keep an appointment. That he would trust a young undergraduate enough to say 'you decide which courses you want to take'. Or that he was a man who would jot down some quick incisive thoughts (Spalding Missives) on the train from Wimbledon to South Ken that could take days for us, mere mortals, to unravel. Brian was all that and much more. An accomplished poet. An excellent squash player. A very good swimmer. Whatever Brian decided to do – and he decided quickly – he did with gusto.

Brian said he would want to be remembered for his poetry. That may well turn out to be so. But surely, Brian's contribution to science will be remembered for generations to come. Most scientists make their mark in a niche and distinct field. Not so with Brian. Although he is most recognized today for his contribution to the field of CFD, what is less known is that this was just the icing on the cake because, by the time he turned his attention to CFD, he had already made his mark in multiple fields of science and engineering. First, he made seminal contributions to Combustion; this led him to the theory of Mass Transfer where he has the rare distinction of having a non-dimensional number (Spalding Number) named after him. He then unified the basic theories of fluid flow, heat and a mass transfer which led him, finally, to CFD.

For me personally Brian was not just an Icon but a living legend. His nurture and mentorship led me to where I am today. His advice to me, to concentrate on what needs to be done rather than on the obstacles to the doing of it, has been a guiding beacon. Though he was born in a land far away, I found his advice to be so much in tune with the teachings of Bhagvad Gita which – for me – is the book for living a conflict free life. I considered him my intellectual father and I will miss him in so many ways.

Brian once made a memorable statement that has stayed with me. Man inhabits Fluid and Fluid inhabits Man. Now Spalding permeates this fluid space. Alas, he is no more but his legacy will endure for a long time.

Akshai Runchal
Ph.D. (1965-68) Student of Prof D.B. Spalding
Professor, CFD Virtual Reality Institute
Founder, ACRi Group of Companies
Los Angeles, Nice & Dharamsala
runchal@gmail.com

Tribute to Brian Spalding – Yelena Shafeyeva

My contact with Prof. Brian Spalding started through Begell House. Dr. William (Bill) Begell, first met Prof. Spalding at an International Conference of Heat and Mass Transfer in early sixties. Many years of professional interactions, friendship and joint projects started and continued first through Hemisphere and later with Begell House Publishers.

I first met Prof. Spalding during my visit to Moscow with Academician Aleksandr Leontiev. For me, it was very surprising to meet a British professor who translated A. S. Pushkin from Russian to English. I was intrigued and naturally, there were many things I wanted to discuss with him. Bill and I kept close relationship with Brian and met him on many occasions. After Bill passed away I had the great pleasure to interact with Professor Spalding during my regular visits to Imperial College and to CHAM headquarters in Wimbledon. Over the years, Hemisphere and Begell House have published many of the important contributions of Prof. Spalding in the areas of CFD and Heat Exchanger Design. I had very good interaction with Prof. Spalding during Minnesota meeting in 2013 as well as ICHMT Rutgers conference in 2015th. Spending good time with great memories of friends and beautiful Colleen - and of course many jokes during reception parties."

Many of Begell House editors, executive staff had a pleasure to work of various writings of Professor Spalding and I am much honored to be among close circle of considered to be friends.

Yelena Shafeyeva
Publisher, Begell House
elena@begellhouse.com

Brian in My Life – V. Siddhartha

"----- Take a neeewww thowght, and make it be-atter! be-atter! be-atterrr!" -----might have been his brand line, but Brian didn't waste his time -- he told me -- with the common-room addictions of students in the late sixties -- The Beatles, and color TV.

Brian took me in for a Ph.D. on the recommendation of Arthur Lefevbre at Cranfield, under whom I got a PG qualification in Rocket Propulsion in 1966. But I was probably the only student whom he directly supervised who disappointed him in that I did not continue with CFD and Heat Transfer in my professional life.

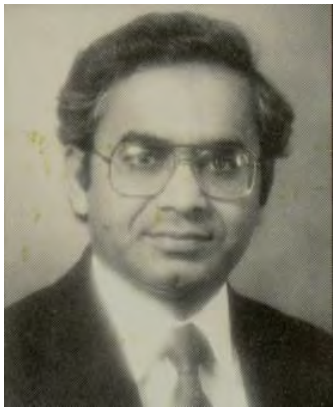
When still a student under Brian, he came to our flat in Putney Heath to a very South Indian vegetarian dinner cooked by my mother (my father was then posted as *The Hindu* newspaper's correspondent in London). Asked questions about the difference between what he was partaking of, and "curry" as common noun then in use for all Indian food. When Brian came to Bangalore, in 1978 or '79, my wife thanked him for "training my mind". I was with the Indian Space Research Organization (ISRO), and I had the opportunity of taking-him around the then nascent ISRO Satellite Centre located then in a large shed in Peenya Industrial Estate on the outskirts -- as it then was -- of Bangalore. Years ago, for one of his birthdays which was being celebrated in London, his (then new) wife asked many of his students for memories of their experiences. I did write a piece I recall in which I mentioned that Devraj Sharma and I became converts to the fountain pen with the broad italics nib, Brian's 'signature' style; our hand-writings started to match! I have become a Lamarkist: The discipline and habits of mind that Prof. Brian Spalding inculcated into his students will be inherited by their progeny -- and theirs.

V. Siddhartha
Adjunct Faculty, NIAS, Bengaluru, India
Ph.D. (1971) Student of Prof D.B. Spalding
scatopsa@gmail.com

Personal Tribute to Prof. Brian Spalding - Ashok Singhal

Brian was truly a legend who touched lives of so many in several ways. He will be missed and remembered fondly by many of us**.**

I had the privilege of working closely with Brian for 12 years (1974 – 1986). This included 3 years as a PhD student and 9 years as the Technical Director of CHAM of North America. Prior to this, during my Master's degree at IIT Kanpur (1968-1970) with Prof. Suhas Patankar, I started admiring Brian as a prolific writer with a unique ability to intersperse analogies for various life lessons in his technical writings. Then in 1972, I met Brian and his wife during their visit to Bombay, India, and got the glimpses of Bran's interests in history, philosophy and various mythologies.



In addition to his lifelong contributions to Combustion, Heat & Mass Transfer, and finally Computational Fluid Dynamics, I also admired and benefited from his perseverance for pursuing and advocating new ideas till these were adopted in scientific communities and then in the business world.

Ashok K. Singhal, Ph.D.
Ph D student: 1974 - 1977
Chairman, CFD Research Corporation
Huntsville, AL 35806
aks@cfdrc.com

Close Encounters with the Life of a Genius – Roy Singham

FIRST ENCOUNTERS: I first met Brian Spalding in 1954. We joined the staff of Imperial College, Mechanical Engineering Department, at the same time, he as a Reader, I as a lecturer. At first, I felt somewhat intimidated by this self-assured character - I had no idea of the vast hidden depths that justified this self-assurance. Before long he was made Professor of Heat Transfer and encouraged me to assist him by taking charge of the Heat Transfer Laboratory. It was a time of expansion for Imperial College and there was no shortage of funds for equipment and we felt under an obligation to spend without due consideration. I remember thinking at the time that it would be better to buy gold sovereigns for spending wisely at a later date but this was not a permissible option.

COOLING TOWERS: One day during our early years I received a phone call from a Mr L-----, asking if he could speak to Professor Spalding. Brian was away at the time so I asked if I could help him. He told me that he was speaking for a firm who were in the business of building large natural-draught cooling towers. They wanted to bid for a contract offered by the Central Electricity Generating Board for eight such towers. But the firm needed consultants who could prepare designs to the Board's specification. I said I would tell Professor Spalding about this when he returned. So, a few days later I told Brian. His first reaction was to say that he did not want to take the job away from me. I pointed out that I had simply taken the call for him. After some discussion, we entered a blunt agreement: he would tell me how to do it; I would do it; we would share the fees 50/50. Neither of us was skilled in the detailed civil engineering side of the matter so Brian recruited a colleague who would take care of that side of it. After a long period of unsuccessful bidding for several such contracts Mr L-----'s firm gained a contract and Brian and I found ourselves in receipt of consultancy fees that lifted our personal finances on to a different plane. The work also generated some ideas for research projects.

START OF COMPUTER PROGRAMMING: I recall a moment in the late 1950s. Brian had taken on a new research student, a Mr G. As was often the case I was helping with day to day supervision and we were in my office with the student. He had been given a task which required a good deal of computation and was reporting on his progress. Much to our surprise he had finished the task in what seemed record time. The college had recently been given an (apartment-sized) IBM computer which the student had made use of. He was conversant with 'computer programming' which Brian and I knew nothing about. Brian concluded that the student had outreached him and that he could no longer act as his supervisor: it was time for him (and me) to become programmers. The college was running courses in the new art and he and I attended one and gradually became 'programmers' ourselves.

START OF CHAM: There was an occasion, early in the 1960s I think, when I was chatting with Brian in his office. He was feeling happy and excited and shared his thoughts with me. He had had a discussion with the Rector (the head of Imperial College) and had been given permission to set up his own research and consultancy company. He duly went ahead and founded the company to which he gave the name CHAM (Combustion, Heat And Mass Transfer). This was gradually to become the great international company that we have been familiar with for many years. I remember joking with him about the Chinese sound of the name.

COLLEEN KING AS SECRETARY OF CHAM: Brian's first secretary at Imperial college was a Miss S. She was loyal and efficient but as the years went by she became over-devoted to the point of possessiveness and Brian found this troublesome. Somehow, he managed to break the bond and appoint a younger and rather stunning replacement, Miss Colleen King. She occupied an office outside that of Professor Spalding and you had to confront her before gaining access to him. She would greet you with a warm and devastating smile but at the same time would manage to indicate that you had to have a good reason to gain access to him. As CHAM grew so did the business of handling the company and in due course separate premises were established in Wimbledon. Colleen King became company secretary and supervisor of CHAM's secretarial business. She became his wife.

The IJHMT: I recall Brian happily telling me one day that he had now got his own journal: The International Journal of Heat and Mass Transfer. It was one of several prestigious publications sponsored by Robert Maxwell, a well-known publisher, based in Oxford. Later Mr Maxwell spread his net rather wider and acquired the Daily Mirror, a paper with a wide circulation. There was a memorable occasion when Mr Maxwell decided to give a dinner party, ostensibly in honour of Professor Saunders,

head of the Mechanical Engineering Department at Imperial. Brian was invited and asked me to accompany him. We drove up to Oxford in Brian's car, wondering who would be in a fit state to drive back. The dinner was a lavish affair with plenty to eat and drink. I remember how at one-point Mr Maxwell was rather patronising to Professor Saunders while holding a phone conversation with the Mirror editor (I presume) about the next day's issue. I did not keep an eye on Brian - I was too busy enjoying the food and drink followed by a best Havana. But I know that he drove us safely home.

Most of the papers in the new journal were beyond my ken, but from time to time Brian would send one to me to assess prior to publication.

PARTIES AT RIDINGS: When I retired from Imperial College in 1990 I thought that would be the end of my relationship with Brian Spalding but that turned out not to be the case. I met him by chance after our mutual attendance at the funeral of an old and much-loved colleague, Peter Moore. I had not intended to attend the 'wake' after the funeral but Brian persuaded me to go along with him. From then on, our relationship was on a personal, rather than academic, basis. Colleen was giving wonderful garden parties at their house, Ridings, attended by the many young friends of their two grown-up boys. My wife and I were invited. Neither Brian nor I had much in common with these young people and so we tended to gravitate towards each other. Both he and I enjoyed a glass or two of whisky, usually blended but sometimes Laphroaig single malt, and it loosened our tongues: who would have thought that he was as familiar with the ballad-song 'Begin the Beguine' as I was?

DEEPER DISCUSSIONS: I have always been in the habit of questioning my fundamental beliefs but in more recent years I got the idea of setting down in a couple of pages 'my credo'. I thought there must be a website where prominent people were doing the same but I was wrong. So, I decided to create my own primitive website, calling it 'mycian.com', an acronym for My Credo In A Nutshell. On it I invented the credos of five prominent figures from the past, adding as an aside my own. Brian, it turned, out had never thought of writing his credo and was very interested in mine, including my conclusion that our minds are distinct from our brains. The latter is purely physical and can be weighed, probed and measured; the mind is non-physical and cannot be measured, only discussed. Of course, better minds than mine, e.g. Karl Popper's, have discussed this idea, but not 'in a nutshell'.

RUSSIA: Although I had nothing to do with it, I am aware that for many years up to his last Brian had a prestigious appointment in Russia, overseeing technical matters at a high level (I believe he was introduced to Russia's leader, Vladimir Putin). He visited Russia frequently, sometimes accompanied by his wife Colleen. I remember seeing a fun video of a party in which the two of them were being, separately, entranced and beguiled in a kind of fairy-land. On his last and final visit in 2016, he was taken ill, flown home and never recovered.

John Roy Singham
Professor Emeritus
Mechanical Engineering Department
Imperial College
jroysok@gmail.com

Brian - William Spalding

Brian meant a great deal to a lot of people, and in that sense he has always been more than just our father.

If, as I assume, this collection will be mainly for those of his science family it may be better to give the main voice to those “children” rather than overshadowing it with a more personal vibe that they may or may not provide.

Therefore, as part of me does, indeed, wish to include something, in a tribute to Brian, I will just say that we will always and forever have our memories and an ability to share them.

William Spalding
Concentration, Heat and Momentum Limited (CHAM)
Bakery House
40 High Street
Wimbledon Village
London SW19 5AU, England

Brian, with Jeremy and I
Relaxing after being made a Global Energy Laureate by President Medvedev in Moscow, 2009

My Memories of Prof. D. B. Spalding - Pratap Vanka

Guru Brahma Guru Vishnu, Guru Devo Maheswara, Guru Sakshat Para Brahma, Tasmai Sri Guravenamah

I salute to my teacher who is my Brahma (the creator), the Vishnu (the caretaker), and Shiva (the caretaker of final days)

I had the great fortune of being one of Prof. Spalding's students. I learned a great deal of technical, speaking and writing skills which greatly influenced my academic and personal lives. I first met Professor Spalding when we received him at Bombay airport on Dec. 3, 1971. This was a day to remember in every way. It was not only the day that essentially started my future academic life, but also was a day to remember because of the start of the India-Pakistan war. Between the blacked-out nights, flight delays and tea stallers suspicious of foreigners, we entertained Prof. and Mrs. Spalding for two days. This subsequently led to my joining the Imperial College group as a research assistant on a SRC sponsored project on 3D duct flows. My doctoral research was to study the effects of curvature and rotation on flows through ducts in which the flow is predominantly one way. We had several publications from this effort, published in reputed journals. I subsequently worked for CHAM for two years prior to coming to the United States in 1978.

Professor Spalding was a visionary, a deep thinker and a strong advocate of precision in thinking, writing and speaking. He was very sharp throughout his life, until his final illness. I very fondly remember celebrating his 60th, 80th, 85th and 90th birthdays with celebrations, books and conferences. We were all looking forward to celebrating his 100th birthday with a great conference with him giving the plenary talk. We may still celebrate it with his spirit looking over us!

Professor Spalding will be missed most not only by his immediate family, but by the entire CFD and CHT communities globally. I will always remember him for the rest of my life.

Pratap Vanka (V. S. Pratap)
Research Professor and Professor Emeritus
University of Illinois at Urbana-Champaign, Urbana, IL. USA
spvanka@illinois.edu

Autobiographical Poem – My Three Lady Friends - D. Brian Spalding

Introduction by Colleen Spalding

Brian wrote the following poem after his 90th birthday celebration dinner on March 23 2013, attended by many Colleagues, held at Imperial College (58 Princes Gate, Exhibition Road, South Kensington). That evening, as on many previous occasions, I had been "encouraged" to raise the topic of writing his Autobiography with him. I needed no encouragement and had been trying to persuade him to undertake the task for some 15 years. It will not, now, be written. However, I present to you here what he sent after that occasion.

This poem was subsequently read by me at the Personal Memorial Session held in honour of Brian on the May 30 2017 at CHT-17, Naples, Italy. I thank all those who arranged this day in memory of Brian and all who have contributed. He would have appreciated it though also have been somewhat embarrassed by it. I thank you on his behalf. I would also like to thank William and Ashley (our son and daughter-in-law) for taking time to accompany me to Naples – I could not have done it without them.

Introduction by Brian Spalding

Dear Friend

Colleen has told me that several of those present at Saturday's dinner suggested that I should write my autobiography. "Oh dear!" I thought. "Don't they recognize that I **have** written it? And that I have just **read** it to them?" Since you may have been among those to whom I did not make myself clear, I have re-titled my poem and added some explanatory footnotes. Here it is. With thanks to you for your attendance and for your so-kindly-expressed good wishes,

Brian"

My Three Lady Friends[1] -by Brian Spalding

I have three kindly lady friends
And honour every one;
Each her unique persona lends
To all I've ever done.

The first tells me each week: "*I'm bored;*
"Invent a newer game:
"Fresh goals, fresh rules bring fresh reward."
Restlessness[2] is her name.

The next sweeps mental store rooms clear;
So, if by any chance
New thoughts float in, they find space there.
Her name is **Ignorance[3]**.

The third, who nothing does all day,
Has brought me most success
By urging: "*Find **some simpler way***."
Her name is **Laziness[4].**

That they let other men enjoy

Their charms I do not mind,
But, all the same, some care employ
So they're to **me** inclined.

To show I share the attitudes
Restlessness advocates,
I shun cliches and platitudes;
So now we are soul mates.

To **Ignorance** my gratitude
I show by letting new
Unlikely notions be reviewed;
And sometimes keep a few.

Dear **Laziness** I gratify
By proving **she is right**:
There **is** a simpler way. That's why
She visits me each night.

When DNS[5], then LES[6],
Wasted my energies,
"*To discretise;"* said **Laziness**;
"Gets pdf's[7] with ease".

Prandtl and Karman, clever guys,
Linked **u**plus with **y**plus.[8]
Too hard for me; so I devise
Yplus as f(**u**plus)[9].

"You want the distance from the wall?
"Use your imagination",
Says **L**; *"It isn't hard at all.*
'Just solve Poisson's equation'.[10]

Which I did later useful find
For transfer (radiative)
Of heat **and noise[11]**. A vacant mind
Can be, by chance, creative.

I studied finite elements[12]
Till stopped by **Laziness**;
For F**V**M (it's common sense!)
Can model **any[13]** stress.

These friends say none more ignorant
Nor lazy[14] they have found;
So of their aid I'll nothing want
Till I lie underground.

"E'en then", wise **Restlessness** has said,
"You'll not have long to wait;
"For I can help the restless dead
"Quickly re-incarnate".

A genius she has, or two,
Now waiting in the womb
For me; so, to **our** precepts true,
My life I can resume[15],

If I shall promise, **as I do**,
Daily all three to bless:
Kind **Restlessness**; **Ignorance** too;
Last … lovely **Laziness**.

Footnotes:

1. For me, innovation means imitation with a touch of originality. Here I am imitating Rudyard Kipling's "Six honest serving men". http://www.kipling.org.uk/poems_serving.htm.

2. 'Restlessness' is not of course an unqualified virtue; and too often, alas, I have moved on to the next subject before properly completing the last; but 'fresh rewards' have always been for me like the 'fresh woods and pastures new' of Milton's Lycidas: http://www.dartmouth.edu/~milton/reading_room/lycidas.

3. The same can be said of 'ignorance'. But sometimes it is best **not** to know that the *cognoscenti* have declared to be impossible what one is just about to attempt. Or that someone else has already succeeded. Thus I was unaware that the failure of others to solve the two-phase-flow Navier-Stokes equations had led them to determine, perhaps as an excuse, that the solution problem was 'ill-posed'; nor that Frank Harlow had displayed an equal lack of knowledge: http://www3.nd.edu/~gtryggva/CFD-Course/JCP-Harlow-2004.pdf. (I'll skip the references from now on. This isn't a PhD thesis.)

4. Just as 'telling lies' is sometimes euphemised as 'being economical with the truth', so can 'laziness' be defined as 'being economical with the effort'. And this truly **is**, I believe, a virtue. Moreover, if to restlessness and ignorance there is added lack of practical skill, searching for 'a simpler way' is the **only possible** way. Here are some examples.

    - In the 1950s gas-turbine designers wanted to know the burning rate of kerosine droplets; which G.A.Godsave was skilled enough to measure. I could create only a clumsy one-inch-diameter copper sphere, covered with liquid fuel. Fortunately measurements on that enabled a more general theory to be developed and tested.

    - Others wanted to know the propagation speed of an adiabatic flame, *i.e.* one far enough from boundaries to lose no heat. Felix Weinberg's cleverly-devised flat-flame burner could measure it. Mine could measure only that of a heat-**losing** one; but it was easier to construct and to operate. That however also turned out to yield unexpected information of a more far-reaching kind. Laziness had struck lucky again.

    - Hirschfelder and Curtiss used mathematical methods to **calculate** the flame speed which were far beyond my reach. So I had to extend Schmidt's easy-to-understand **graphical** method (for unsteady heat conduction) to chemically-reacting mixtures. It is true that I was studying the wrong process, *i.e.* **transient** not steady flame propagation. But transients become steady in the end; one just has to use a large-enough number of time steps.

    - Years later, it was the difficulty of finding polynomial or other formulae to fit boundary-layer temperature **profiles**, which led Patankar and me to choose the simplest-of-all **piece-wise-linear** ones, refinement of which led us to invent, or rather re-invent, the 'finite-volume method'. 'Profile methods' we thenceforth abandoned.

    - Looking back on my career, I have to admit that 'finding the easy way' has been my constant practice. Although this is regarded by some as morally reprehensible, I am not ashamed of it.

    - Oh! yes; and sometimes I have 'moved the goal-posts'. Equally reprehensible; and profitable.

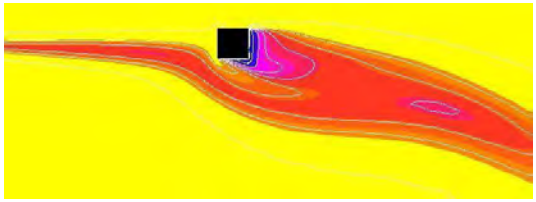
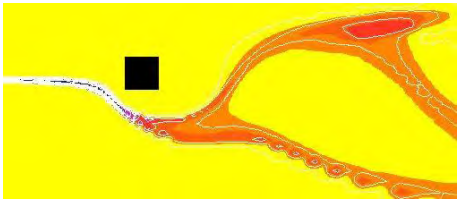
5. DNS stands for Direct Numerical Simulation of turbulence. This is a practice which continues to consume enormous amounts of computer time, with, so far, little practical advantage; or so my friend Laziness believes.

6. LES stands for Large Eddy Simulation, about which she has similar doubts.

7. They differ. So the question is: which is the more correct? **Nobody knows**, even though the experiments would be easy to perform; but one can be sure that the discretised model gives the better representation of the mixing **upstream** of the obstacle (on the left); while it is possible that LES represents better the **downstream** region (on the right). If only discretisers, LES practitioners and experimentalists would talk together! But **they have no common tongue**. I am trying to provide one.

8. Pdf's are 'probability-density functions', which are what engineers would need if they were to turn the results from DNS and LES to practical account, for example for predicting combustion rates within, or thermal radiation from, turbulent burning gases. Curiously, DNS and LES practitioners rarely present their results in pdf terms, having perhaps lost sight of, or never been interested in,

practical outcomes. My following the advice of Laziness to 'discretise' has enabled me to procure such information at much less computational expense. On the left below is a contour diagram of one ordinate element of the pdf of concentration, when a bluff body is placed in an approach stream having non-uniform concentration and velocity. On the right is the corresponding diagram computed by means of LES for the same circumstances.

9. The reference here is to the so-called 'law of the wall'. Experiments had shown that the velocity profile in a turbulent stream near a wall had a linear shape at small distances and a logarithmic one at large ones; and attempts had been made, by Prandtl and von Karman, to represent its total shape via 2- and 3-part equations. These had the dimensionless velocity, uplus, to the left of the = sign and the dimensionless distance, yplus, to the right.

10. Probably other clever researchers have obtained greater accuracy by formulating 4- and 5-part expressions. But it occurred to me that if one placed **yplus** on the **left** and **uplus** on the **right**, it was easy to devise a 1-part formula which would cover the whole range. I had 'moved the goal-posts'; after which kicking the goal was so easy that even I could not miss.

11. In order to **use** the law of the wall, one needs to know how far away the wall is from the point in question. If the space is cluttered with solid objects of various shapes and sizes, it is far from clear how one should proceed. Indeed even how to **define** the 'distance from the wall' is questionable. I cannot now either recall or understand what prompted my guess, namely that solving a certain Poisson-type equation would yield distances which were exact very close to the nearest wall, and never unreasonable when many objects were almost equally distant. Inspiration by Lady Laziness, coupled with the vacancy of mind provided by her sister, Lady Ignorance, furnish the most plausible explanation.

12. As luck would have it, the Poisson equation yielded not only the distance from the wall but also the 'distance **between** walls'. This is exactly what one needs when creating a mathematical model of radiative heat transfer that is simple enough to be used in engineering calculations. So Lady Laziness had turned once more into Lady Luck, presenting me with another easy-to-exploit simulation tool. What is more, in **just the last few days** I have seen how it can be extended to simulating the spread of noise also. If Twelfth-Night Maria's formula ('some are born …', 'some achieve …', and 'some have … thrust upon …') were applied to scientists, I should have to place myself in the third category.

13. When the finite-element-method (*i.e.* FEM) furore first broke out, I was too busy with CFD to give it attention; but I did take notice when its promoters recommended FEM as being good for solving fluid-flow too. However, my mathematical knowledge did not suffice; so Laziness turned into Leave-it-alone; which saved me much time.

14. Later, I saw how the finite-**volume** method (*i.e.* F**V**M), if it treated displacements like velocities, could solve solid-stress problems as easily as **fluid**-stress ones. So I built the capability into PHOENICS; but I did no proselytising. Now however I recognise the FVM/FEM dichotomy as being comparable with those between Protestant and Catholic, or Sunni and Shia. That is to say that it promotes needless conflict; and expense; and loss of opportunity. I have characterised the conflict as being between N-UWFists and UWFists, because the FEM camp has needlessly carried over from pre-computer solid-stress-analysis days the practice of multiplying the differential equations by Non-Unity Weighting Factors (N-UWFs). The FVM camp, by contrast, uses Unity Weighting Factors (UWFs); which is to say that they use **no weighting at all**. They are all the better for it.

15. Nor '**more opinionated'** either, I can imagine some of you saying.

16. Re-incarnation is a widely-believed-in but not-yet-sufficiently-proven way of prolonging one's contribution to mankind. I'll give it a go; but meanwhile I take any opportunity of transmitting what I have learned *via* a written record; like this, my autobiographical poem.

APPENDIX A: Tributes at 90th Birthday Celebrations 17 July 2013 in Minneapolis

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At

The Windows Restaurant, Marquette Hotel, Minneapolis

During

The ASME Summer Heat Transfer Meeting

D Brian Spalding, FRS, FREng by Colleen Spalding


Brian in 1923

Brian was born on January 9 1923 in New Malden, Surrey, son of Harold and Kitty Spalding the local Lloyds Bank Manager and his wife. He was their second child as they had a daughter, Katie, born three years before.


Brian, Kitty & Katie, late 1920s

He spent his youth, and most of his life, within ten miles of the place in which he was born and made up for his lack of geographical movement by his technical accomplishments which moved him, and the scientific fields with which he was, and is, associated, forward further than his colleagues, and often he himself, thought would be the case.


Prep School

After attending a local prep school Brian moved to Kings College School Wimbledon where he remained until he was 18. He has always maintained that one of the major causes of any academic success was that he adhered to the rules and obeyed the Masters. Whilst not wishing to take issue with this statement he does also point out that he had a discussion with a French master who insisted that whilst the French for Paris was Paree the French for London was not Londres but...London. He also recalls sitting in the headmaster's garden after being offered a place to read Engineering at Oxford and being told by a senior master that they had not educated him to read some newfangled science but, rather, to read the Classics. Why did he read Engineering? Brian maintains that many stories about him are apocryphal but he himself has said that one of the reasons was because, during the war, KCS pupils had to play out a lot of wire during CCF (Cadet Corp) activities which then had to be wound tidily onto a spool sometimes when pupils had to repair to bomb shelters. Something about caught his attention and he proceeded with the course, and the interest, which is still occupying his life – unravelling puzzles, rescuing, finding logical solutions.


At KCS 1934


KCS Prefect 1941

He moved from KCS to The Queen's College Oxford where he obtained a BA(Hons) in Engineering Science in 1944 and an MA, also from Oxford, in 1948.

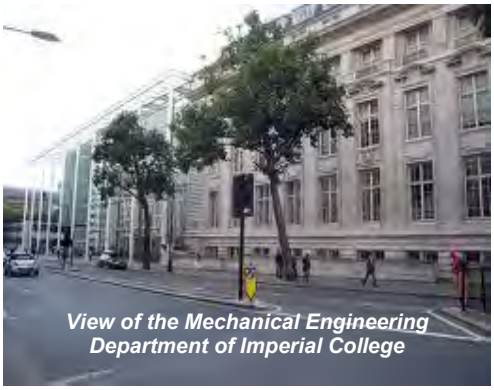

The Queens College Oxford

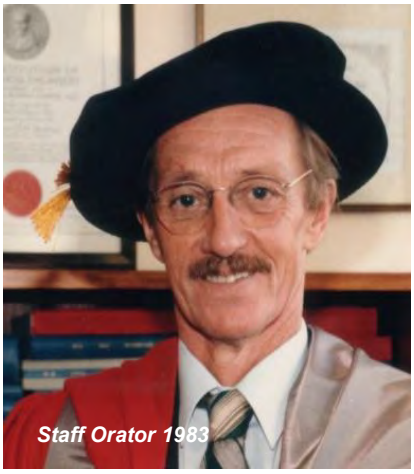

The Engineering Class of 1944 in 1994


1945

During the war years he spent time afloat making a contribution to the war effort which included nearly sinking the ship he was on when, having cleaned the bilges, he forgot to secure them and water made its way in. The war, or rather the period after it, was also meaningful in that Brian was sent to Germany and was allocated a translator/ photographer who was to become his wife, Eda.


Pembroke College, Cambridge


View of the Mechanical Engineering Department of Imperial College


Staff Orator 1983

From Oxford his natural progression was to Pembroke College Cambridge where he obtained a PhD in the Combustion of Liquid Fuels at in 1952. He was later, in 1966, awarded an ScD from Cambridge.

After completing his PhD Brian and Eda remained at Cambridge from 1948 to 1954 until, whilst a Research Fellow and Engineering Demonstrator there he was invited to join Imperial College of Science & Technology as Reader in Applied Heat.


Brian & Eda with their children around 1960

The family – Brian, Eda, Eddi, Michael, Sylvia and Peter, moved to London and he and Eda lived, initially, off Kingston Hill and then in Vineyard Hill Road in Wimbledon.

Brian was awarded the Chair of Heat Transfer at Imperial in 1958, held the post of Head of the Heat Transfer Section from 1958 until 1981 when he became, Head of the Computational Fluid Dynamics Unit a position he held until his retirement in 1988. As part of his responsibilities at IC he was the Staff Orator in 1983.


HTS Party in 1977

His last connexion with the College was when, in 2014, he was made Doctor of Science (Engineering) Honoris Causa in a ceremony at the Royal Albert Hall. A memorial day will be held at Imperial in 2018 where he will be remembered at the institution where he spent so much of his working life.

Brian's interest in computers and their use in modelling fluid flow led to his pioneering, and being one of the founding fathers of Computational Fluid Dynamics (CFD) at Imperial College and worldwide. As part of this activity Brian set up a company in 1970 to expand his scientific interests into the world of business. Concentration, Heat & Momentum Limited (CHAM) was the first commercial CFD Company. It originally operated within Imperial College but, after a few years, moved back to Brian's roots in New Malden and, from thence, to Wimbledon Village where it still operates as a software and consultant engineering house and was, until his death, run by its founder and Managing Director. CHAM specializes in computer modelling of fluid-flow, heat transfer and combustion in industry and the environment. It has a Branch in Japan and Agents in many parts of the world and had a branch in North America of which Brian was the Founder, Chairman and Director, from *1977 to 1991.*

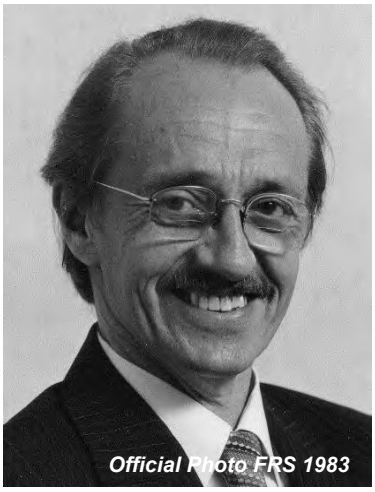
CHAM as it was

Brian rescued a local book shop which now operates within CHAM's shop front area.


PHOENICS User Meeting, Cannizaro December 2007

CHAM's major product was, and is, the PHOENICS computer code, which was the first commercial CFD code, which Brian created, and continued to develop, with his team until 2016. From 1988 he ran the company, and promoted applications of CFD in industry worldwide, on a full-time basis. There has been a PHOENICS Journal, and PHOENICS User Meetings held across the world.

From January 1978 to April 1979 Brian was Reilly Professor of Combustion at Purdue University, West Lafayette, Indiana, USA. In addition to the Reilly Professorship, he held positions as Visiting Professor at MIT, the University of California Berkeley, and the University of Minnesota over the years.


Official Photo FRS 1983

In 1983, he was made a Fellow of the Royal Society and, over the years, received a number of honours including an Honorary Doctorate (2013), Moscow Energy Institute, Russia; the Huw Edwards Award (2011) the Physics Institute, England; the A V Luikov Prize (2010), Academy of Sciences of Belarus, Minsk; appointment as a Franklin Laureate (2010) and recipient of the Franklin Institute Medal for Mechanical Engineering, The Franklin Institute, Philadelphia, Pennsylvania, USA; appointment as Global Energy Laureate (2009), by the Global Energy Foundation, Russia; the subject of a Festschrift Issue (2009) of the International Journal of Heat and Mass Transfer; the holding of an ICHMT Conference to honour and celebrate his 85th birthday in 2008, in Marrakech, Morocco.

He was made an Honorary Member (1999) of the Scientific Council of Institute of Thermophysics, Siberian Branch of Russian Academy

Brian Receiving the Global Energy Award from President Medvedev 2009

of Sciences; a Dr-Ing Eh (1997), Technical Faculty of the Friedrich Alexander University of Erlangen-Nurnberg; became a Member (1994) of the Russian Academy of Sciences and (1994) of the Ukrainian National Academy of Sciences. He is a Fellow (1989) of the Fellowship of Engineering - now The Royal Academy of Engineering and (1983) of the Royal Society of London and a member (1979), Royal Norwegian Society of Sciences and Letters.

He received the Luikov Medal (1986) from the International Centre for Heat and Mass Transfer, the Bernard Lewis Metal (1982) from the Combustion Institute, the Medaille d'Or (1980) from the Institute Francais de l'Energie, the Max Jakob Award (1978) for Services to Heat Transfer, the James Clayton Prize (1970) from the Institution of Mechanical Engineer.

Brian was not much of a Committee man. He much enjoyed discussing any aspect of his scientific interests - Computational Fluid Dynamics, Turbulence Modelling, Heat Transfer, Two-Phase & Multiphase Flow, Chemical Reaction and Stresses in Solids amongst others, with colleagues, past students, young people who share his interests today but he was adamant he did not much enjoy sitting on committees.

Brian about to receive the Franklin Medal 2010

He did, however, sit on various British Aeronautical Research Council Committees from1952 to 1979 and has been the Honorary President of ERCOFTAC (European Research Centre on Flow Turbulence and Combustion), Steering Committee Member & Chairman Scientific Program Sub-Committee of ERCOFTAC (1988 - 1991), an Investigator on the Hermes Space Program, a member of the Executive Committee of the International Centre for Heat and Mass Transfer, a Member of Scientific Council - International Centre for Heat & Mass Transfer (1994 - 1998) and Chairman, Technical Activities Committee, International Centre for Heat and Mass Transfer.

Brian with Naim Afgan 1988

The ICHMT was important to Brian. He was one of those responsible for founding it to facilitate scientists from the East and the West being able to meet and share their knowledge during the days of the Cold War. The Headquarters were in Belgrade in what was then Yugoslavia and were run by Zoran Zaric and Naim Afgan. Conferences were held in idyllic places such as Dubrovnik and we have fond memories of attending them accompanied by small children.

Brian with Zoran's daughter Milana

Brian has been associated with various scientific Journals. He was the Founding Editor of PhysicoChemical Hydrodynamics: an International Journal (1978-1989) published by Pergamon Press. This came about as part of an ongoing campaign to persuade those in power that Benjamin Levich, an Associate Member of the Russian Academy of Sc8iences, should be allowed to leave Russia. Brian worked tirelessly to achieve this aim visiting Ben in Moscow, working with various institutions in London and abroad, starting a series of PCH Conferences the first and the last of which were held in Oxford. The first was held before Ben and Tanya came to the west but was attended by their sons Alexander and Yevgeny. The last was meant to be a celebration of the 10 years Ben had spent in Israel and New York but, in the event, became a celebration of his life as it occurred just after his death.

Brian with Ben & Tanya Levich in Vienna in 1978

Brian had close links with Pergamon Press, was a founding Editor of the IJHMT (International Journal of Heat and Mass Transfer and successfully involved with Robert Maxwell's successful efforts to reclaim Pergamon Press during the 1970s.

Other scientific publications with which he was involved include acting as Editor-in-Chief of the HMT Book Series: The Science and Applications of Heat and Mass Transfer; Editor, International Communications in Heat and Mass Transfer; Editorial Board Member, Applied Mathematical Modelling; Editorial Board Member, Computer Methods in Applied Mechanics and Engineering; Editorial Board Member, International Journal for Numerical Methods in Fluids; Member, Conseil Scientifique International Revue General de Thermique; Editorial Advisory Board Member, Numerical Heat Transfer; Editorial Advisory Board Member, Combustion and Flame; Editorial Advisory Board Member, Advances in Transport Processes; Editorial Board Member, International Journal of Turbo and Jet Engines; Editorial Advisory Board Member, Heat and Technology.

Starting in 1949, Brian has published some hundreds of papers and many books including papers on thermodynamics, combustion, heat transfer, boundary-layer theory and computational fluid dynamics. Many of his papers can be accessed via the CHAM website (www.cham.co.uk).

His published books are listed below.

1. Spalding D B (1955). *'Some Fundamentals of Combustion',* Butterworths, London
2. Spalding D B (1963) *'Convective Mass Transfer',* Edward Arnold, London(and under McGraw Hill imprint)
3. Gosman A, Pun W M, Runchal A K, Spalding D B and Wolfshtein M (1969) *'Heat and Mass Transfer in Recirculating Flows',* Academic Press, London
4. Patankar S V and Spalding D B (1970) *'Heat and Mass Transfer in Boundary Layers' (2nd Editio*n), Intertext Books, London
5. Launder B E and Spalding D B (1972) *'Lectures on Mathematical Models of Turbulence',* Academic Press, London and New York
6. Cole E H and Spalding D B (1974) *'Engineering Thermodynamics' (3rd Edition),* Edward Arnold, London
7. Afgan N and Spalding D B (Editors) (1977) *'Heat Transfer and Turbulent Convection' vol I and II,* Hemisphere Publishing, Washington DC
8. Spalding D B (1978) *'GENMIX: A General Computer Program for Two-Dimensional Parabolic Phenomena'* HMT Book Series, Number 1, Pergamon Press, Oxford
9. Spalding D B (Editor) (1978) *'PhysicoChemical Hydrodynamics' Proceedings 1st International Conference, vols, I & II,* Advance Publications, London
10. Spalding D B (1979) *'Combustion & Mass Transfer: A Textbook with Multiple Choice Exercises for Engineering Students'* Pergamon Press, Oxford
11. Kakac S and Spalding D B (Editors) (1979) *'Turbulent Forced Convection in Channels and Bundles'* Volumes I and II, Hemisphere Publishing, Washington DC
12. Spalding D B and Afgan N (Editors) (1979) *'Heat and Mass Transfer in Metallurgical Systems',* Hemisphere Publishing and McGraw Hill, Washington DC
13. Schlunder E, et al (Editors) (1982) *'Heat Exchanger Design Handbook',* Hemisphere Publishing, Washington DC
14. Spalding D B (1983) *'Numerical Prediction of Flow, Heat Transfer, Turbulence and Combustion' Collected Works* Editors: Patankar S V, Pollard A, Singhal A K, Vanka S P, Pergamon Press Oxford & New York
15. Afgan N and Spalding D B (Editors) (1989) *Heat and Mass Transfer in Gasoline and Diesel Engines,* Hemisphere Publishing and McGraw Hill, Washington DC

There are, undoubtedly, many aspects of Brian's life missing from this brief synopsis. He worked a 7 day week at CHAM. He attended conferences, wrote papers, and had a research group in Moscow which he visited regularly. Outside of work he walked across Wimbledon Common every weekend, used his rowing machine at home each morning, had a treadmill in his CHAM office, swam every Friday night and took up Pilates on his 90th birthday.

He comes from a family which lives to quite an age. His sister in South Africa will be 98 in December 2017 and one of my favourite pictures is of Brian with 2 cousins in 2007 when Brian was the "baby" at 84, Frances was 88 and Cyril 92 (I think!). He was also delightful to track down the grave of his grandfather who had been banished to Australia and died in Vancouver.

A family Gathering, February 2013

His 90th birthday, the actual day, was celebrated with his family in South Africa but he would have preferred to be working at CHAM to visiting the Botanical Gardens in Johannesburg however beautiful.

There was then a family party in February followed by a most pleasant evening at Imperial College in March.

Brian speaking at a most enjoyable evening at Imperial College & a greatly appreciated gift.

Despite these celebrations, or perhaps because of them, I think Brian did not much like being 90. However, I am sure that events such as that in Marrakesh to mark his becoming 85, and in Minneapolis to celebrate 90, both of which were scientific and gave him the opportunity to interact with colleagues, past students and to meet those who will take "his" subject further brought more pleasure that "just another party".

Marrakesh in 2008

At the Franklin Awards in 2010

Perhaps, to end, I should mention that Brian had a second family. I like to think that helped to keep him young. Our sons, William and Jeremy, and William's wife Ashley, joined me in wishing Brian happiness when he was half way through the first year of his ninth decade.

Father of the Groom September 2012

This piece was written in somewhat of a hurry but I hope that, whilst there were sins of omission and commission, it gave somewhat of a flavour of a life which was long and fruitful. The owner of it accomplished much.

One of the things which I had hoped would be accomplished was HIS version of a life extraordinary – it was not to be.

Tribute to Brian Spalding by Larry Caretto

Although I knew the name of Brian Spalding from my graduate-student research, I met Brian when he was a visiting professor in the Mechanical Engineering Department at UC, Berkeley in the late 1960s. At that time, I was a member of the research staff and an acting assistant professor at Berkeley; Brian had recently started his work on general computer codes. I was surprised to meet him in a room with key-punch machines and teletypes, which was generally used by graduate students, research staff members, and junior faculty. From that meeting and subsequent conversations, he invited me to be a visiting member of his research team at Imperial College.

At the time, I joined his research group in September, 1970, I was assigned to a project which sought to develop computational methods for three-dimensional parabolic flows. At that time, the term CFD had not yet been invented, and there were only a few groups in the world working on numerical methods in fluid dynamics. However, Brian had a vision that future advances in computing power would bring to engineers the ability to model complex flows phenomena using numerical tools.

Brian was not a distant research supervisor, but an active participant in the research. He would write detailed memoranda outlining his ideas and suggesting specific tasks that members of the research team might undertake. Although his memoranda would give forceful statements of his ideas, he was always willing to entertain debate and would willingly write another memorandum correcting his previous one if he found a team-member's argument to be persuasive.

Brian's approach to the numerical solution of the Navier-Stokes equations was an elegant combination of mathematical reasoning and physical insight. He taught us to regard the numerical grid as a collection of cells with the computations modeling a physical flow from one cell to another. I still remember the term "false inertia". I have forgotten what that means, but I remember that working on algorithms using this concept by Brian for one or two weeks and quickly abandoning this when it proved not to be fruitful.

I still regard the time that I spent at Imperial College with Brian and my fellow researchers as one of the most stimulating research experiences of my career.

Happy 90th Birthday, Brian!

Larry Caretto, Professor Emeritus
Mechanical Engineering Department
California State University, Northridge
Northridge, CA 91330-8348
lcaretto@csun.edu

A Message to Brian Spalding from Anil Date

Dear Prof Spalding,

Many many congratulations on your 90th Birthday and to know that you have agreed to go to Minnesota for the felicitation. I met you in 2007 in Xian, China and it would have been my honour and privilege to meet you again now. But, circumstances have prevented me from attending the conference.

On this occasion, I am reminded of your first visit to India in 1971 for the National Heat Transfer conference. On return to IC, you agreed to meet the Indian students who were keen to know of your impressions. What I distinctly remember is the surprise you expressed about almost everyone (you met at that conference) posing you the question ' what was latest in Heat transfer ? '. And, your answer was: whatever Indian industry and society needed should be the latest! How true.

You are of course world famous for the pioneering contributions in both academic and Industrial CFD. But, I have found your very early contribution of ' Reynolds Flow Model - Reynolds Flux Hypothesis and the Spalding number B' in the book ' Convective Mass Transfer ' (1963) very useful in a variety of applications involving Heat and Mass Transfer in analyzing simple 'People's Technologies' from India's rural areas. What is heartening is that papers analyzing H & M Transfer in a Clay-Pot Refrigerator (IJHMT, vol 55, p 3977-3983, 2012) and Wood Burning Cook Stove (Comb Sc & Tech, vol 183, p 321-346, 2011) are now found acceptable in peer reviewed international journals. From the reviewer's comments, I could of course deduce that acceptance was greatly influenced by my reference to the work of D B Spalding.

Yes, I have benefitted and been enabled to lead a satisfying professional life - thanks to my 4-year association with IC-Heat Transfer Section and the rich writings of D B Spalding.

With respectful regards and, as a cricket fan, am certain that you will cross 100.

Anil Date
Professor Emeritus, IIT Bombay
awdate@me.iitb.ac.in

Message for Brian Spalding from Graham De Vahl Davis

I wrote to Brian on the occasion of his actual birthday back in March, apologising for my inability to attend at that time. I was in fact listening to a performance of the bawdy and irreverent Carmina Burana at the time, and I raised a glass to Brian during the interval. The opening and closing *O Fortuna* of that music is the most-played classical music of the past 75 years in the United Kingdom. I suspect that PHOENICS is the most-used CFD code of the past 30 years in the world.

There is nothing bawdy or irreverent about the father (or perhaps we should say grandfather) of computational fluid dynamics. You are, on the contrary, a SIMPLE man. I pay a humble tribute to you and treasure the memory and privilege of six months working with you some time ago, and the honour of your friendship (and that of Colleen) over many years.

As we say in the Jewish community: “ad mea v’esrim” – you should live to be 120.

Graham de Vahl Davis
Honorary Professor of Mechanical and Manufacturing Engineering
UNSW Sydney
g.devahldavis@unsw.edu.au

Best Wishes from Said Elgobashi

Dear Professor Spalding,

All my best wishes for a Happy Birthday and many happy returns. I wish I were able to join the July celebration in Minneapolis.

Said Elghobashi
Professor, UC Irvine
selghoba@uci.edu

Tribute to Brian Spalding from Marcel Escudier

I have nothing but positive memories of Brian. He was an excellent teacher (lecturer) and research supervisor who always found time to discuss progress. I attended classes he taught in 1963/4 as part of the DIC course during which he also supervised my project. From 1964 to 1967 I was one of Brian's many research students, Earl Baker, Suhas Patankar, Peter Duffield and Bill Nicoll, with whom I worked very closely, being among my contemporaries. Jim Whitelaw and Brian Launder were young lecturers at the time, both working with Brian, who also contributed to a wonderful group spirit. The feeling that we were part of a special group was enhanced by visits from eminent researchers such as Bill Reynolds, Bill Kays and Roger Eichhorn from the USA as well as Samson Kutateladze and Aleksandr Leont'ev from Russia. I feel greatly privileged to have worked with Brian and am greatly indebted to him. The recent dinner in London to celebrate his 90th birthday was a warm and memorable occasion. I'm sure the dinner in Minnesota will be just as successful.

Marcel Escudier
Emeritus Harrison Professor of Mechanical Engineering
University of Liverpool
Supervised by DBS 1963-64 (DIC), 1964-67 (PhD)
sqda@btinternet.com

A Message from Sir John Horlock

I first knew Brian when we were lowly demonstrators together in Cambridge. That group included several future vice-chancellors and fellows of the Royal Society. Brian was senior to me by several years and it was clear he should have been promoted to a lectureship. But before this happened he was stolen by Professor Saunders at Imperial College who immediately found a readership for him.

My memory of Brian in those days is of his incredible work rate, coupled with the succession of books and papers which kept appearing at a great rate. His concentration was intense - callers at his office were faced with a notice outside his door, which simply said "Will a note do?"

We both enjoyed publishing much of our work through the old Aeronautical Research Committee, where he chaired the Combustion Sub-committee and I chaired the Propulsion Committee. But I did not have the pleasure of working with him in more recent years, when he worked at Imperial and CHAM with such staggering success.

Not the least of Brian's achievements has been the mentoring of a series of research students and associates who subsequently attained considerable distinction. I am delighted that so many have gathered together tonight to honour such a distinguished, bat modest engineer. My only regret is that I am unable to join you all this evening because of my immobility.

Sir John Horlock,
Formerly Vice-Chancellor of the Open University.

A fragment from my many memories of DBS by Brian Launder

In 1971, while I was a lecturer at IC, DBS suggested that a case should be made for my promotion to a readership in fluid mechanics. My pertinent data and publications were forwarded to him and these were duly sent off to the external assessor, Professor John Horlock. A few weeks later DBS told me that the external assessor had felt the case was premature … but invited me to provide a persuasive rebuttal that he might send to Horlock. Well, I did indeed prepare a highly inflated draft letter for DBS, greatly exaggerating the importance of my contributions. I've no idea how much, if any, of my draft was used but a short time later DBS sent me a note saying that the external was now fully satisfied that my promotion should go ahead. Brian then commented that he knew whom he should contact if he ever wanted a letter of recommendation for himself!

In reality, of course, Brian's standing in the world has been so outstanding and widely appreciated that he has hardly needed letters of support, even from people of far greater eminence than me.

The DBS 90-Birthday Dinner at IC in March was one of the most memorable and fun occasions of the year for my wife and me and I trust the celebratory dinner in Minneapolis is equally as enjoyable.

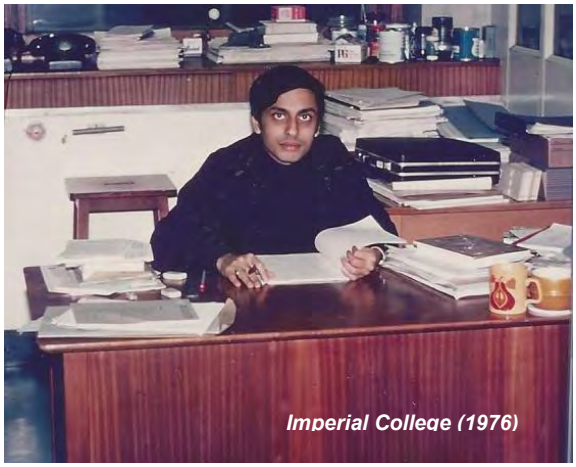
Brian Launder
Professor B. E. Launder, FREng, FRS
University of Manchester
brian.launder@umist.ac.uk

My Association with Professor Brian Spalding by Alok Majumdar

I first met Professor Spalding at IIT Kanpur in 1971 when I was a doctoral student at Central Mechanical Engineering Research Institute (CMERI), Durgapur, India. In my dissertation, I used Stream Function-Vorticity Method that was developed at Imperial College under his guidance. I received many useful advises from him through mail correspondence during my Ph.D. work. After completion of my Ph.D. he offered me a post-doctoral position at Imperial College. I worked with Professor Spalding from 1975 to 1977 on Numerical Methods for Rotating Flows. I consider those years in Heat Transfer Section at Imperial College as the most productive and educative period of my career. I had the opportunity to meet many distinguished research workers in a vibrant and active academic environment that made a very deep impact in the development of my professional career. I had the opportunity to publish several papers with him on Turbo-machinery during this period. My daughter, Bipasha was born in London while I was doing my post-doctoral work.

On completion of my fellowship in Imperial College, I returned to CMERI and continued to collaborate with him. In 1980 I joined CHAM of North America in Huntsville, Alabama, a sister organization of CHAM which he founded in London during 1970's. I had the opportunity of writing my first CFD code on Cooling Tower Performance while working at CHAM. Since 1985, I started working for Aerospace Industries and for last twenty years I have been working on the development of a Generalized Fluid System Simulation Program (GFSSP), a thermo-fluid system analysis program for Propulsion System Analysis for Liquid Rocket Engine (https://gfssp.msfc.nasa.gov/). GFSSP is a finite-volume based network flow analysis code for analyzing complex thermo-fluid system. Two very important things that I learned from Professor Spalding that have influenced my work are: (a) Finite Volume Formulation of Conservation Equation, and (b) concept of separating solver from the user interface which is a key for developing a general-purpose code.

Professor Spalding conceived the power of Computational Thermo-Fluid Dynamics back in 1960's and laid the foundation of this emerging field that has transformed the design of Thermo-fluid systems around the world. I congratulate Professor Spalding on his 90th Birthday and wish for his good health and many happy returns of his birthday.



Imperial College (1976)

NASA Marshall Space Flight Center (2010)

Alok Majumdar
NASA/Marshall Space Flight Center
Huntsville, Alabama, USA

Best Wishes from Nicolas Markatos

Dear Brian,

I send you a few words from Heart. Brian Spalding is certainly the man who "discovered" Computational Fluid Dynamics, at least in practical terms i.e. for solving real technological problems. It is amazing that people are proud today for doing things which we were doing, because of Brian, in the late Seventies! I thank you Brian for directing me into a most interesting and sometimes puzzling but always exciting discipline.

Long ago, during dinner in Brussels, you were in very good mood and you told us "I have a very good family hereditary, my grandfather reached the age of 102, I intend to reach that age too, so do not hope to get rid of me soon!' I am certain that the grandfather part was not true but I am also certain that you will be here at 102 celebrating; and I sincerely hope that everybody with you today will also be here with you in 2025!

My sincere Best Wishes. HAPPY 90th BIRTHDAY and many happy returns of the day!

Incidentally, do not forget to come to my 90th Birthday party at the Rose and Crown, in 2034, around 19.00 please!

Nicolas Markatos
Professor Emeritus, Former Rector
National Technical University of Athens
n.markatos@ntua.gr

A Message to Brian Spalding from Suhas Patankar

Dear Brian:

Congratulations on your 90th birthday. We are delighted that you will be honored in Minneapolis. We are eagerly looking forward to the event.

You have made the most significant impact on my professional life. I clearly remember two distinct periods in which we spent a lot of time together. One was in 1966 when we shared an apartment in the MIT graduate dormitory and worked at NREC. During this time, our intense technical interaction led to the creation of the boundary layer calculation scheme. The other period was December 1970-February 1971. During this time, my family and I stayed in your house in Wimbledon. Again, the day-to-day interaction between you and me produced the SIMPLE calculation scheme. These periods were not only very productive but also very enjoyable. I am very grateful for the opportunity.

Since I began working with you in 1964, you have been a role model for brilliant ideas, creative thinking, and lucid writing. You have been a constant source of inspiration. Your professional contributions to Heat Transfer and CFD have set a new standard for what is truly possible.

On the occasion of your 90th birthday, my wife Rajani joins me in wishing you good health, happiness, and many more productive years.

Sincerely,

Suhas V. Patankar
Professor Emeritus, University of Minnesota
President, Innovative Research, Inc.
Ph.D. (1964-1967) Student of Prof Spalding
patankar@inres.com

What goes around comes around! by Andrew Pollard

Andrew joined Brian's group in September 1975, arriving from the University of Waterloo in Canada with recommendations from Suhas Patankar and George Raithby. Andrew's thesis concerned three dimensional laminar and turbulent flow in tee-junctions, in both Cartesian and cylindrical-polar coordinates, which included wall mass transfer as an analogy for wall shear stress. He performed both computations and experiments, and has continued throughout his career to enjoy the interplay between these approaches to unravel the underlying physico-chemical processes in many other complex thermo-fluid problems. Because of Brian's broad interests, Andrew, too, embraced combustion, turbulence and heat and mass transfer: he graduated in 1978 and returned Canada.

Today, Andrew holds a university Research Chair in Fluid Dynamics and Multi-scale Phenomena at Queen's University at Kingston, Canada and looks back on a career that has produced over 250 publications, a number of edited volumes, graduated over 50 graduate students and post-doctoral fellows. The open, inquisitive and unified approach to transport processes engendered by Brian instilled the confidence to tackle myriad problems and most recently spontaneous combustion of re-useable low carbon fuels and biomass densification and torrefaction technologies. He continues to probe the intricacies of fundamental turbulence using direct and large eddy simulations and detailed optical and probe-based experimental techniques. These include drug delivery to the lungs, quantification and destruction of air emboli during cardiac surgery, non-homogeneous wall roughness modifications to the "log-law" and the effects of mean shear, intermittency and passive flow control in jets.

He has been happily married for over 40 years, with two children Richard (Ph.D. Cantab, 2009), Michael (CPGA).

In 2013, we celebrate Brian as he reached the age of 90 and Andrew is 65: Andrew had the pleasure to be in attendance at Brian's 65th retirement from IC in 1988……what goes around, comes around!

Andrew Pollard
FCAE, FAPS, FASME
Professor and Queen's Research Chair,
Queen's University, Kingston, CANADA
Ph.D. (1975-1978) Student of Prof Spalding
pollard@me.queensu.ca

Happy Birthday Wishes from Heqing Qin

生日快乐

Happy Birthday

永远 健康，长寿，智慧永存！

Healthy, Long life forever,

May your genius remain undimmed!

Regards.

Heqing Qin
hqq@cham.co.uk

A Tribute to My Intellectual Father by Akshai Runchal

It is rare to come across an individual who is a good researcher, a good teacher and fun to be with socially and at the pub. Brian, you, are that rare individual. Your numerous and outstanding scientific achievements are well known. After all how many engineers get a non-dimensional number named after them or get a Franklin Memorial Prize. Today I will talk of you as a person.

When I first met you in 1965 as your Ph.D. student I asked you what courses I should take and your surprising answer was "none". You instead assigned me to do an in-depth literature survey over the next 3 months and get familiar with your Unified Theory. That demonstrated your hands-on approach to life and your essence as an engineer. Do something practical and useful – theory will fit in as needed. Not to talk of your risk-taking – trusting an undergraduate from a foreign university of unknown standing!

Over the next 10 years I worked closely with you. When I would bring a problem to you, I found that you understood the essence of it before I did and your questions clarified the cob-webs in my mind. Working closely with you was taxing by any account. More often than not, there will be a missive from you that you had just compiled on your trip from Wimbledon to South Ken that might take days for me to unravel.

After I joined IIT Kanpur, I invited you to India. Kanpur is somewhat of a remote place and the only flight of the day from Delhi got cancelled. This is before the days of mobile phones and I started preparing to postpone your seminar. To everyone's utter surprise you landed late at night (or was it early morning?). You had hired a Taxi to drive the odd 300 miles from Delhi to Kanpur. Given the drivers in India, the road conditions, and a foreigner at that, nobody would consider that well-advised! Even today I would certainly prohibit anyone – including myself – from doing that. It shows your single-minded determination to focus on the problem at hand and find a solution.

After I was done with the ψ-ω Navier Stokes solver in 1967, Micha, my partner in crime, was writing his thesis, and since the main thrust of our work was common, it would have been better if both theses came out together. So I asked for a meeting with you. To my utter consternation, you agreed that I had done enough for the thesis but informed me that there was a University of London provision, that a Ph.D. thesis in engineering must have an experimental component. So, I spent a year doing experiments and completed my thesis in 1968 instead of 1967. Brian, you, then had to explain to the external advisor that my numerical work was "original" and not boot-legged from Micha's. It was only in 2011 that you told me – with an enviable smile - that you had made up that rule! I guess I had not spent enough time with you! In my defense, there were no web-sties of university regulations in those days! But on the positive side, I must say having done those experiments gave me a very different perspective that has come very handy in my professional life.

I must say I am more than glad for the time I spent with you. You gave me excellent intellectual training and provided personal support and advice when most needed. In 1969 I had an offer from IIT Kanpur, but was reluctant to go due to personal considerations. You advised me to go and said if I don't I may regret having missed an opportunity. It would have been easy for me to stay and for you to have me around. Yet that advice changed and enriched my professional and personal life.

I consider you to be my "intellectual" father. My father lived to be 101 and in good health - I wish so would you. And need I remind you that I fully expect you to attend my 90th Birthday. Best wishes for a long and healthy life from Chanchal and me. Here is to you - the next drink for your good health!

Akshai Runchal
President & CEO
Analytic & Computational Research, Inc.
Runchal@gmail.com

Prof. Brian Spalding, FRS by Ashok Singhal

We admire and appreciate your legacy of over 60 years contributions to combustion and CFD.

Your bold initiatives for industrial use of CFD have lead tens of thousands of practitioners around the world

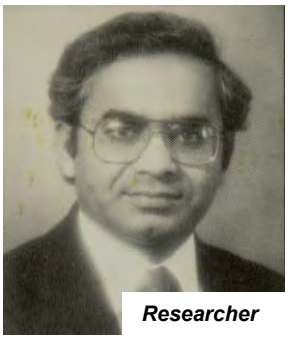
It has been my privilege to learn and work with you for over 12 years.

Along with Sangeeta, Andrzej Przekwas and all other employees of CFDRC, I wish you the very best of Health and Happiness in coming years!

Thanks to Pratap Vanka and Akshai Runchal for organizing the 90th Birthday

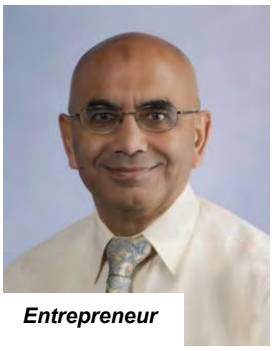
Health and Happiness in coming years!
Happy Birthday

Ashok K. Singhal, Ph.D.
Chairman, CFD Research Corporation



Researcher

➔ Loss of Hair



Entrepreneur

Best Wishes on 90th Birthday by Pratap Vanka

1973

Dear Professor Spalding,

I consider it a distinct privilege to have been your student. I very much remember the nice comments by Sir Lighthill on our helical coil papers to JFM, and the comments by Sir Hawthorne on the partially-parabolic computations of flows in curved ducts that you presented at an ARC meeting. I have learned a lot from you on effective writing, speaking, and identifying key scientific issues.

2013

The SIMPLE algorithm has made many professors, millionaires and executives and has resulted in a culture of its own, as a consequence of your vision, and intelligence.

Raj and I wish you a Happy 90th birthday, and many, many happy returns of such birthdays.

Pratap Vanka (V. S. Pratap)
Research Professor and Professor Emeritus
University of Illinois at Urbana-Champaign, Urbana, IL. USA
spvanka@illinois.edu

Best Wishes by Nikos Vlachos

Please convey my warm greetings to all. I thank you for your kind invitation to celebrate the 90th Birthday of Prof. Brian Spalding. As I could not, regretfully, join you, let me take this opportunity to refer to some experiences with this great scientist and research leader.

I met DBS in August 1970 as a postgraduate student at Imperial College. I was fascinated by his seminars and those of Suhas Patankar in Heat Transfer. In April 1971, I was asked to modify a CFD code (with its endless STRIDE routine!) in order to handle curved boundaries with Cartesian grids. Thus, I entered the fascinating world of CFD with the help of my classmate, Jim McGuirk. Indeed, the results from a flow in a bend of a circular glass tube matched very well my LDA measurements, taken under the supervision of the late Jim Whitelaw.

Looking for employment with CHAM Ltd in June 1976, DBS asked me to show a listing of TEACH3D which we had developed with my colleague, the late Pepe Humphrey, under the supervision of David Gosman. The next day DBS returned the listing with a handwritten comment: "*Nick, thank you for the listing. The code is very well organized, but surely it is not in a form for commercial use!*" Incidentally, Pepe introduced many of us to developing our codes electronically rather than using the bulky punch-cards. We spend endless hours at the *Terminal Room* with Pratap Vanka, Alan Morse, Paul Watkins, Essam Khalil, and young Steve Pope and Alex Taylor! I also remember Dave Gosman, Fred Lockwood and Aki Runchal coming to run their codes!

In July 1976, I joined Nikos Markatos and Stathis Ioannides at CHAM Ltd in Wimbledon, working with curvilinear grids on the flow around a ship for Admiralty Works. We had an interesting time in Bakery House, helped very much by the skillful office management of Colleen King. I recall David Tatchell asking how things were going. Things were not going because we were stuck in handling the free boundary. And then… success! DBS proposed a simple solution that left Nikos and me fascinated by the ingenuity of the man.

On another occasion, I had been working for almost 2 days to finish a project on the mixing of exhaust gases of a GE gas turbine for Boeing. After we prepared the card-deck and the user manual, I rushed from Wimbledon to Imperial College. Entering his office, DBS walked towards me saying: "*Is it all done, Nick?*" I replied: "*Yes Sir!*" Then with his usual smile he offered: "*Well done Nick, you will be rewarded in heavens*!"

In August 1988, I left the U of Illinois at Urbana-Champaign to join CHAM North America in Huntsville-Alabama, where I enjoyed 3 years of interesting work for NASA Marshal (global model for space shuttle main engine) and the US Department of Energy (model for flue gas desulfurization). For reasons of loyalty to DBS, the late Toni Mukerjee and I resigned the day after we received his letter referring to the difficulties he was facing with CHAM NA, I guess because of the cuts in the NASA program by the Reagan administration.

Dear Colleagues - Transport phenomena are in the heart of energy, environment, transport, fusion, but also circulation of blood in our arteries and of air in our lungs. Fluid flow is a nonlinear phenomenon that produces unique images, but also gives difficulties. Although the Navier-Stokes equations were formulated in 1840-1850, there exist only few analytical solutions. Unfortunately, experiments are expensive and provide only point measurements, while we are afar from plane or volume measurements. Thus, CFD has provided useful results and, undoubtedly, DBS has been a pioneering authority in its development.

Having started my engineering education at the Technical U of Athens, I am indebted to my colleagues at Imperial College for 12 years of innovative research. Whatever I achieved is due to the excellent supervision of Jim Whitelaw and Dave Gosman, and to the sharp thinking of DBS. Indeed, I am grateful to Professor Spalding for his support on two difficult occasions, and I hope to be able to join you all in celebrating the 100th birthday of this unique and gentle man, wishing him wholeheartedly good health and longevity.

Nicholas S. Vlachos
Professor Emeritus U of Thessaly
Meg. Alexander 94, 15124 Marousi-Athens, Greece
vlachos@uth.gr

My life with Brian by Micha Wolfshtein

In 1962, I decided that I want take some graduate studies. This was already 8 years after graduation, my math was very rusty. I had some practical experience in Heat Transfer and I decided to enroll to the MSc degree at the Technion. At the end of the academic year I gained some confidence in my ability and I decided to enroll for a Ph.D. I was already 31 years old, married with two children, and I suspected that I may have difficulties getting some financial support. Therefore, I wrote to about 30 Heat Transfer experts in American universities. My recognition of the international heat transfer community was very limited, and the most important name I knew was that of Eckert of "Eckert and Drake" textbook. Naturally I was hoping for an assistantship in the University of Minnesota. Surprisingly, it took me 51 years to reach this destination on DBS 90th birthday.

Sometime towards the end of summer 1962 somebody gave me a paper on analytical solution of laminar boundary layers. The author was an anonymous man for me, a D. B. Spalding from Imperial College in London. I read the paper and was very impressed. The next day I added yet another application to my records and started waiting. I knew that answers to such applications are due in the spring, say February to April, and I was surprised to get a proposal from Professor Spalding in November. I had some queries and we exchanged a couple of letters and by the end of December the moment of truth came. Brian sent me a complete proposal and I had to decide: take it or leave it. The decision was not simple. If I reject the proposal I may lose what appeared as a very good proposal, although all I knew of Professor Spalding was some journal publications. On the other hand, accepting the offer would mean rejecting all the unknown promises (?) of the other 30 applications.

This was one of the most difficult decisions of my life. I decided to jump into these uncharted waters, and accepted. Looking back, it was a very successful decision, and one of the most important decisions of my life. Thus I found myself in London in the autumn of 1964. The first year was very difficult. My English was very poor, and my theoretical background was still limited. Living in London with a family proved more expensive than I estimated, and the family had some social difficulties as well. On top of all this, Brian asked me to write a literature survey on the chosen topic of my research, but when I submitted it he returned it to me because the English was poor. I thought that I shall have to pack up and return to my industrial practice. To my surprise Brian was willing to wait until I improved my English (British Council course for foreign students), and eventually he read the paper and let me continue into what turned out, after two more years, into a Ph.D. Thesis from London University and a DIC from Imperial College. This was the first (but not the last) time that Brian gave me a hand when I was in real need of help.

Years have passed. My relations with Brian became more and more friendly, but his ability to penetrate the very heart of a problem and to offer a solution which was always simple and convincing, but somehow invisible, is still surprising me every time we meet.

Thank you, Brian. As much as you are a friend, you are still my teacher, and so you will always remain.

Best wishes and regards to you and Colleen from

Aviva and Micha Wolfshtein
Professor Emeritus, Technion
Haifa, Israel
aer0902@aerodyne.technion.ac.il

Happy Birthday! by Jeremy Wu

Dear Professor Spalding,

Whenever I think of you, I feel so grateful. I want to thank you from the bottom of my heart for your supervision, support and the kindness you have shown to me and my family for over 30 years of my life since 1982 when I became your student.

May this birthday bring you all the happiness you deserve! Wish you a good health and a long life!

Happy Birthday!

Jeremy Wu
jzwwu@yahoo.co.uk

Best Wishes from Michael Yianneskis

Dear Brian,

With my best wishes to a most inspiring teacher, colleague and friend.

For a truly wonderful and memorable 90th birthday.

I hope to have an opportunity to give my wishes in person soon.

Michael

Professor Michael Yianneskis
CEng CSci FRSA FIMechE FIChemE FKC
Honorary Professor, University College London
Emeritus Professor of Fluid Mechanics, King's College London

APPENDIX II: PHOTO GALLERY

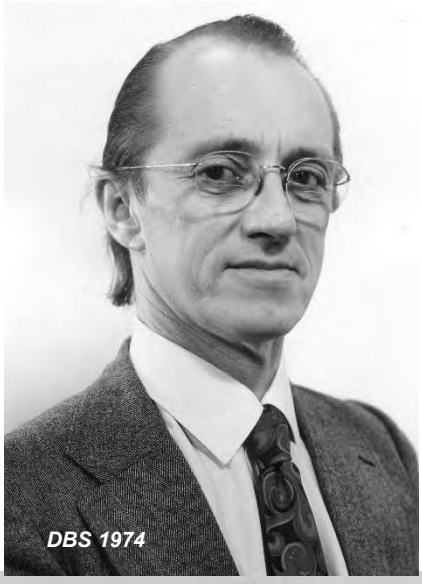
Brian 1923

DBS 1927-28

DBS 1944

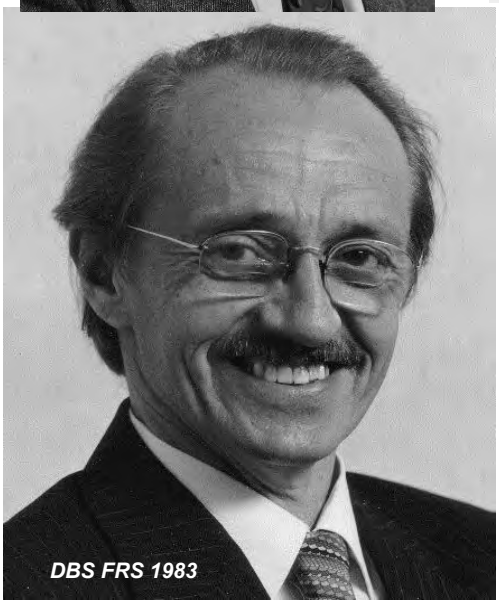
DBS Combustion Inst. Meeting, 1960

Sylvia, Peter, Eda, Edd, Brian, Michael in the 1960s

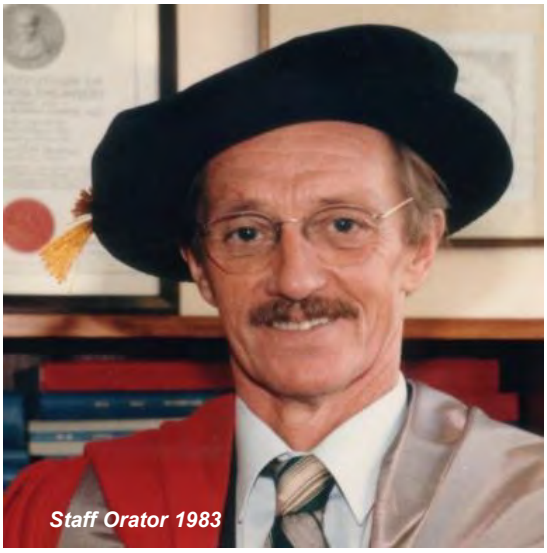


DBS 1974

DBS 5th Heat Transfer Conf. Tokyo, 1974



DBS FRS 1983



Staff Orator 1983

DBS CHAM 1985

DBS St. Petersburg 2005

DBS Franklin Awards CFD Conf., Villanova, 2010

DBS Franklin Awards CFD Conf., Villanova, 2010

90th Birthday, London, 2013

Palermo Univ. Lecture, 2016

Brian Robed at IC, 2014

Palermo Univ. Reception, 2016

Duomo Piazza, Syracuse, 2016

Thinking in Syracuse, the home town of Archimedes, Sep 2016

London, Spalding Home, November 2007

Brian carving a Roast
DBS Home London July 2007

Brian & Colleen
DBS Home London July 2007

Chanchal, Brian & Colleen
DBS Home London July 2007

Spalding, Colleen & Family

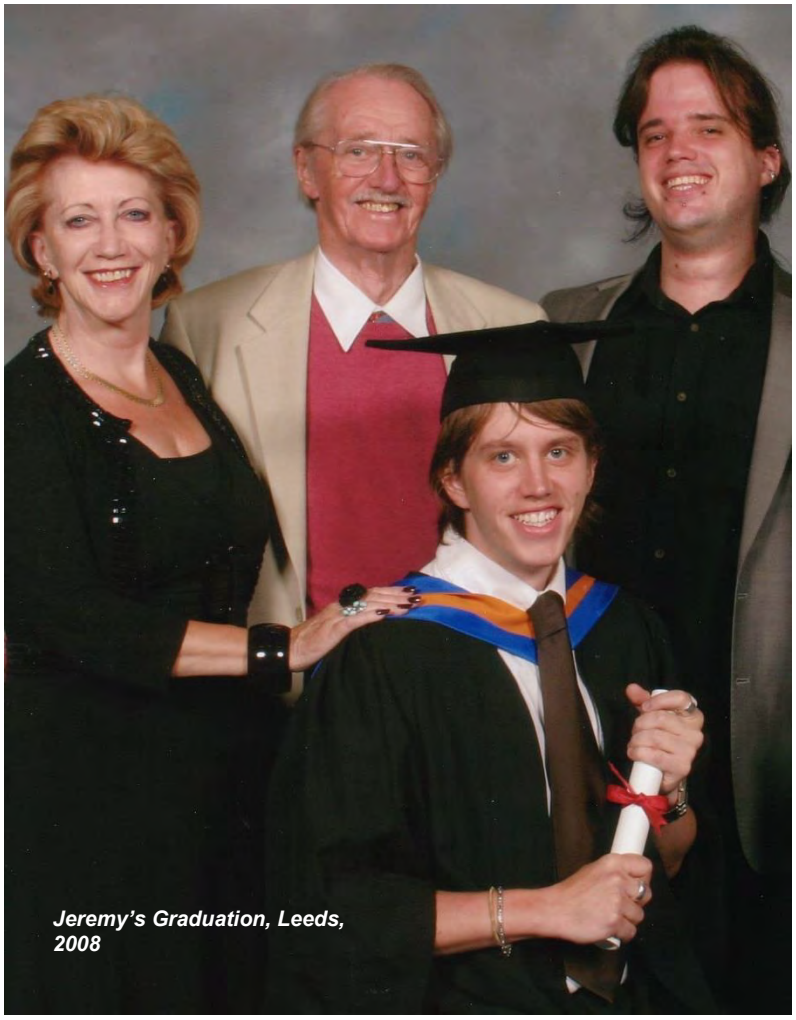
Rome, 2014

DBS 90th Dinner, Imperial College, London, March 2013

Rajini, William, Colleen, Jeremy & Brian London

Dressed for a 30's Charity Event, London,

Family, June 2016, The Petersham



Jeremy's Graduation, Leeds, 2008

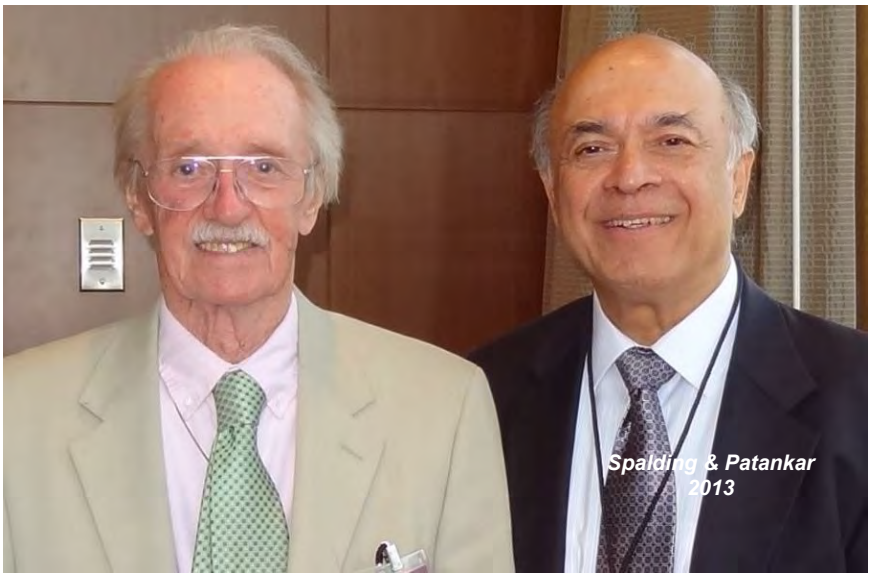
White Water Rafting, Yosemite, 2005
Brian (back right)

Sister Katie's 90th Birthday, South Africa, 2009

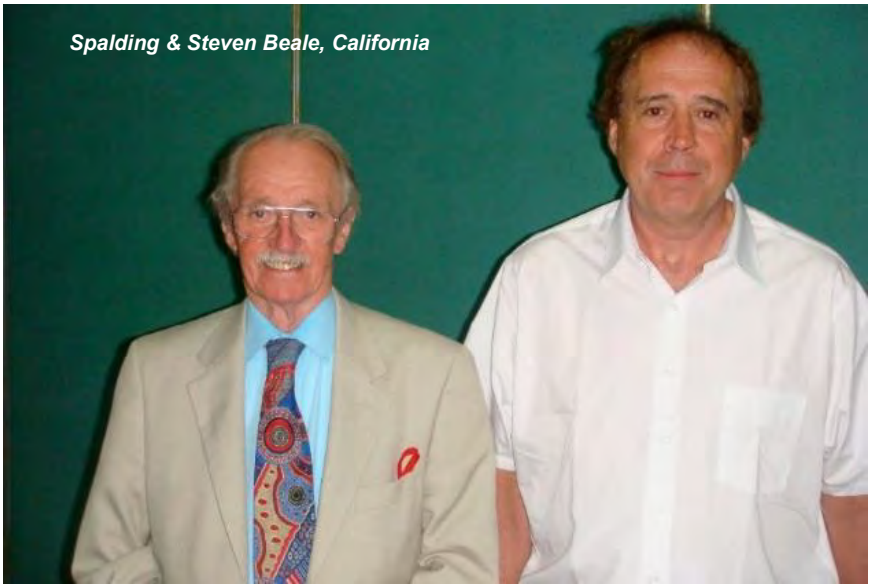
Brian's Family 90th February 2013

Brian One on One

Runchal & Spalding
Franklin Awards 29 April 2010



Spalding & Patankar
2013



Spalding & Steven Beale, California

Spalding & Heqing Qin
London, 2011

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Spalding & Prof. Churchill
Sydney - CHT August 2006

Gerald Jones &
Spalding
Franklin Awards
29 Apr 2010

Jayathi Murthy & Spalding
Villanova, 2010

Patankar & Spalding
London 1999

Spalding & Steven Beale

Spalding & Bill Jones,
Royal Albert Hall, 2014

Brian in a Small Group

Colleen, Brian, & Yogesh
CHT Bath 2012

Gerald Jones, Runchal & Spalding
Franklin Awards 29 Apr 2010

Artumov, Spalding, Ginevsky & Pavitsky
Moscow

Spalding with Leontiev, Irvine, Hatnett and others
Moscow, 1984

Jeremy Spalding, Runchal, Baliga, Spalding, Beale, Colleen
CHT, Sydney , 2006

Colleen and Brian Spalding, Yelena Shafeyeva & Bill Begell, Sydney 2006

DBS and Colleagues at the NATO Natural Convection Workshop, Cesme, Turkey, 1985

Jayathi Murthy, Luigi Martinelli, Gerald Jones, Brian Spalding, Gretar Tryggvason, Phillip. Marcus, Thomas Gatski & Akshai Runchal, Villanova, 2010

Suhas, Brian & Rajni, Rutgers, 2015

Spalding, Runchal & Patankar
Rutgers CHT 2015

Rajni, Suhas, Brian & Colleen
Rutgers CHT 2015

Oronzio Manca, Pepper, Spalding & Jaluria
Rutgers 2015

De Vahl Davis, Date, Spalding, Patankar, Vanka & Runchal
Rutgers CHT 2015

Manca, Pepper, Spalding,
Colleen, Jaluria & Jeanie Peppe
Rutgers 2015

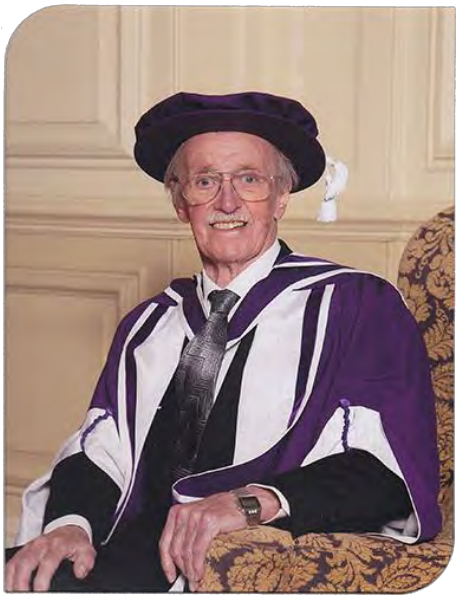
Heat Transfer Section Party
London, 1977

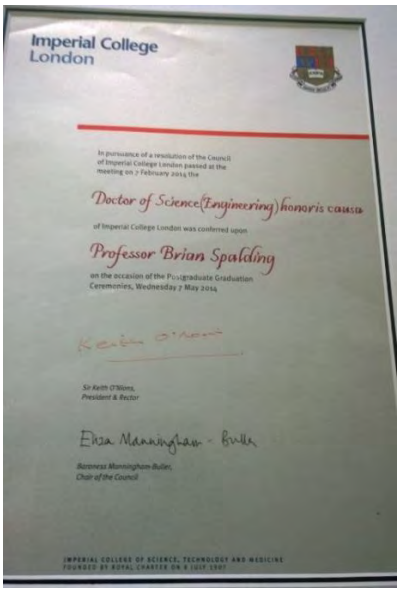
DBS Birthday Party
London

CHAM Wear Red Day
London

Franklin Awards April, 2010

Doctor of Science (Engineering) Honoris Causa, Imperial College, May, 2014





Brian's Last Lecture, Cologne, October 2016