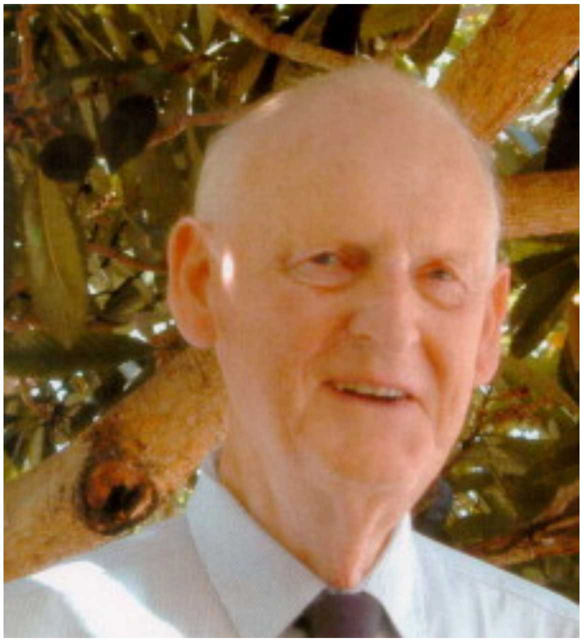

Professor Frederick Alexander Leckie (1929 – 2013)

Obituary by David R. Hayhurst and Robert M. McMeeking in the International Journal of Mechanical Sciences, Vol. 76, pp 166-169, November 2013:

He introduced simplified methods of analysis; benefitting the Nuclear Industry and Aerospace-Rocketry.
Fred Leckie, who has died aged 84, made a significant contribution to the safety of Nuclear Power Systems, and to the use of Ceramic Matrix Composite materials in advanced engines for aerospace and rocket systems, by aiding the understanding of how materials and structures deform, damage and fail when stressed at very high temperatures.
Traditional industrial design methods involve procedures that focussed on elastic operation and considered failure by fatigue due to repeated loading and unloading, and usually excluded the possibility of failure by repeated plastic deformation or creep rupture {progressive plastic deformation and failure at temperature under constant load}. However, for the design of the world's first nuclear reactors in the 1950s and 1960s such procedures were inadequate. Because of nuclear irradiation the possibility of replacing particular components in a reactor system that had reached the end of their serviceable lifetime was not an option (as was the case for gas and steam turbines, and components in the petro-chemical industry); and new design methodologies were required that dealt with lifetimes of 25 years or more.
The key issues were twofold: firstly, **the shell-like nature of the pressure containment vessels**, which are fabricated to connect with supply and return pipework systems, meant they are subjected to stretching and bending loads that change in a complex manner with the duty cycle; secondly, the materials are operated at very high temperatures and are susceptible to progressive plastic deformation and creep rupture. Leckie realised that the combined complexity of structural geometry and material behaviour was such that the most advanced computers of the day could not be used to analyse proposed designs. In addition, the material creep data available at that time was sparse and the quality was inferior, and certainly not good enough to describe in detail the expected deformation, damage and rupture over the long term. In this circumstance, Leckie spotted the need for methods of analysis that were simple enough to avoid the use of big computers, but at the same time were precise enough to compensate for the inferior quality of the available materials data. His approach was

extremely successful in the period 1965–1985 within the Nuclear Industry; and, in the more recent period of 1988–2000 he employed the same techniques for the use of Ceramic Matrix Composites {CMCs} within high temperature engines and rocket motors in the aerospace sector. Here the problems are associated with materials that utilise the high-strength of very thin ceramic fibres housed within ceramic matrices, and separated only by a thin interphase fibre coating. Such composites are capable of operating at 1300 °C and above, significantly higher than the 600 °C encountered in nuclear reactor components, and have to withstand time dependent creep, matrix cracking, damage and fracture. He was enormously successful at mapping over his earlier understanding of nuclear components to that needed for CMCs in military gas turbines and advanced rocket motors used by NASA for hypersonic flight {over 5.5 times the speed of sound}.

Leckie, a Scot of humble Dundonian origins, became a world leader in his field through an exceptionally broad international education. He graduated in Civil Engineering from St Andrews in 1949, and those who worked with him would admire his firm grounding in Mathematics and Natural Philosophy stemming from his undergraduate years. After Civil Engineering practice in London; and service in the RAF; he read for the **PhD degree at Stanford University, USA, awarded in 1958, with Wilhelm Flügge on "Bending theory for shells of revolution subjected to non-symmetric edge loads".** Following Stanford he worked in 1959 with Eduard Pestel at the Technische Hochschule, Hannover, Germany, on the mathematics of matrix methods; techniques that in the next decade became ubiquitous, and today are the cornerstone of engineering computer simulation. In 1963 he published with Pestel "Matrix methods in elasto-mechanics", which became a standard reference text.

In 1959 he was appointed Lecturer in Engineering, and Fellow of Pembroke College, at the University of Cambridge. There, in 1963, he published with Jim Prentice "Mechanical vibrations: an introduction to matrix methods"; this book served to educate generations of undergraduates. Leckie was a prodigious lecturer; a student, later a 1st class honours graduate, was heard to say as he left one of Leckie's more challenging lectures "that was some performance – he almost made me feel as though I understood it!"

It was in the early 1960s that Leckie, working in Cambridge under Lord Baker, another eminent Civil Engineer, realised the challenges ahead for new design standards in Nuclear Reactor structures; and recognised the relevance of his work at Stanford with Flügge to the shell-like pressure vessels in the Nuclear Power industry. Early work on creep with Dr. Douglas Marriot led to the award of a Science Research Council research grant on the analysis and design of engineering structures undergoing creep. Subsequently, he cemented a partnership with Professor Roy Penny who came from Pratt and Whitney's USA laboratories, where state state-of-the-art work was already underway. Penny was a former employee of the UK Central Electricity Generating Board {CEGB} which subsequently became the leading UK support centre for nuclear plant. The Cambridge laboratory was set up with a combined activity on theory and analysis, and on experimentation with model structures; the predictive capability of the former being tested by the data from the latter. As a result of this activity, new design methods were taken up by industry through the CEGB links. At this point he set up links with Professor Alan Ponter and Professor David Hayhurst that have continued to be productive until recent times. They were both part of the Leckie-Penny group; however, in 1968 both Leckie and Penny took up chairs, in Leicester and Liverpool respectively. In his transition to Leicester, Leckie established a reconfigured laboratory that was suited to longer-term activity on: deformation, damage and **failure of pressure vessel shell structures**; and on theoretical work related to extreme thermo-mechanical loading and failure by plastic ratchetting. Links with the CEGB and the United Kingdom Atomic Energy Authority were strong and many key methods and analysis techniques were taken up by these institutions and by industry. During the Leicester epoch, his summers were spent, with the family, in New Haven, USA, where he cemented a long-term research collaboration with Turan Onat.

In 1978 Leckie moved to the University of Illinois, USA; Dean Dan Drucker, whose standing in mechanics had always been admired by Leckie, spotted his combined materials-mechanics talents and arranged a joint appointment in Mechanical Engineering and in Theoretical and Applied Mechanics {TAM}; he later became head of TAM and grew it from a faltering unit to a world-class department that strongly underpinned local and national industries. Leckie's interests in shakedown and ratchetting overlapped with those of Professor Socie on the lifeing of engineering components subjected to random fatigue loadings, and synergies developed. At that time the microprocessor was starting to show its potential and, with Professor Norman Miller and Professor Darrell Socie, they exploited its local computing power to set up a very successful company for on-line fatigue health monitoring of bridges and agricultural machinery. Whilst with TAM, Leckie's expertise on nuclear structures was keenly sought after; and he served with: the US Department of Energy, the UK Nuclear Inspectorate, Euratom, the US Army Corps of Engineers, the Pressure Research Council and numerous committees of the National Science Foundation. He was particularly proud to carry out structural integrity assessments of the nuclear power source used to power the spacecraft of a NASA interplanetary mission. It was in TAM that Leckie set up his long-term working relationship with his fellow Scot Professor Bob McMeeking, where they were extremely productive in the modeling of crack-tip behaviour, failure in composite structures and modeling of manufacturing processes.

It was in 1988 that Leckie was headhunted by the University of California to become head of department in Mechanical Engineering at Santa Barbara {UCSB}, his colleague Bob McMeeking had earlier made the same transition, and it was there that he started collaboration with the Welshman Tony Evans, Professor of Materials at UCSB. A unique feature of Santa Barbara has been that academic staff in Materials and Mechanical Engineering can have joint appointments with the effect that cross-disciplinarity is commonplace. The late Tony Evans was a world leader in Ceramic Matrix Composites, and over the years Leckie-Evans-McMeeking and co-researchers held large research contracts on the use of CMCs for applications in military gas turbines and for use in ramjet and scramjet hypersonic flight vehicles and missiles. The barriers to progress with these applications were almost identical with those that Leckie encountered in the 1960s, namely plastic behaviour, large thermo-mechanical loadings, damage, and ratchetting. Leckie's expertise was in high demand, and along with Evans and McMeeking he made seminal contribution to knowledge and huge steps in the harnessing of this output by US industry. Whilst head of department at UCSB, Leckie observed some of the most dramatic changes in technology experienced in Mechanical Engineering, and played a central role in the reinvigoration of curriculum; in particular the introduction Micro-Electro-Mechanical System {MEMS}, and the start-up and growth of research and teaching in Bio-engineering. Leckie was a visionary, always able to spot an opportunity for change and progress, and committed enough to lead the way. This visionary streak is reflected in his last textbook published in 2009 "Strength and Stiffness of Engineering Systems," co-authored with Dom Dal Bello; it is essentially a modern day textbook on Strength of Materials that traditionally would have been used by Mechanical or Civil Engineers; however, it is rich with examples drawn from contemporary devices and applications such as skateboards and gyroscopes on electronic computer chips. The book reflects the ability of this great man to adapt to change and to embrace the modern idiom.

Frederick Alexander Leckie was born on 26th March 1929 in Dundee, Scotland, the second child of Frederick Leckie and Mary Barclay Leckie. Educated at The Morgan Academy, Dundee; and then at the University of St. Andrews, where he gained a First in Engineering, and was the Engineering Medalist in 1949. He then left Scotland to take up a position with Civil Engineering Consultants Mott, Hay & Anderson in London; he had warm recollections of this period, and with those he knew well he would recall his formative experiences on site with senior partners; two examples are: the shaping of tunnel supports for the London underground line extensions in the 1940s to take account of tunnel curvature and depth changes; and the examination of the truss beam connecting the columns of Tower Bridge for Word War II bomb damage – all without the fuss of an i-Pad or Health and Safety enforced harnesses; Leckie accompanied the senior partner, who operated at 300 feet above the river Thames with leather shoes, a bowler hat, and a black walking stick with silver handle! From 1951–1954 he took a short service commission in the Royal Air Force and was Sword of Honour at his passing out commissioning parade. On the award of a Commonwealth Scholarship, he moved to Stanford University, USA where he earned M.S. and Ph.D. degrees in Mechanical Engineering in 1955 and 1958 respectively; it was there that he met Elizabeth Wheelwright of Greenwich, Connecticut. They married in downtown New York, and he was a devoted husband of 43 years.

In his pre-professorial days Leckie could appear somewhat daunting to his undergraduate students as a tall individual with ginger hair, craggy features, omnipresent with a Scottish lilt and a razor-sharp intellect; however, with time one would discover a caring, gentle disposition, willing to nurture and provide good advice. At Pembroke College he was Director of Studies and moral tutor to Law students; this brought him in touch with the likes of Ray Dolby, of Dolby Sound Systems; and many members of Cambridge Footlights, who went on to be the Goodies and Monty Python, were his students. To an unusual extent he had a broad academic approach, always looking for cross disciplinary synergy over a wide circle of friends from many disciplines. What he found uplifting was to tap youthful energy and humour, sample lateral thought, unconventional views and opinions – a process he continued throughout his life that kept him amazingly alert and in touch. These aspects of his job he extended to his post graduate students, those studying under his supervision for the PhD degree; and, it was here that he melded his caring/social skills with his research drive and thirst for knowledge and understanding. Unlike today, when some academics feel it is smart to concurrently supervise more than ten PhD students, Leckie always advocated that three at any time is the correct number; any more, then the job is not being taken seriously. Of the 40+ PhD students he graduated and the 20+ post PhD students he worked with, he kept in touch with the majority until the final weeks of his life; these were spread throughout the world – UK, Illinois, Poland, Université Paris 6, where he spent several sabbaticals, Peradeniya University, Sri Lanka, where he collaborated with Prof Muni Ranaweera, Santa Barbara, USA; they are referred to by his French research collaborator Jean LeMaitre as the "Leckie family in Mechanics".

Although Leckie had an even-handed socialist streak to his core, he was without question an admirer of the capitalist system where those with vision and energy have space to realise, and profit from their dreams. Somewhere within this engineering researcher was an impish entrepreneur, always looking to see how technological advancement could help society, and generate wealth for its originators. However, sense would usually prevail, and research, knowledge advancement and understanding were the yardsticks of success. Whilst he received an honorary degree from the University of Leicester, The Halliburton Award from the University of Illinois, and the Nadai Medal from the American Society of Mechanical Engineers, his greatest achievement is the large number of intellects and visionaries that he has helped groom, that are now distributed around the world to continue his legacy of the use of Engineering Science to improve and sustain the quality of human life.