

BIOGRAPHICAL MEMOIRS

Brian Eyre CBE FREng. 29 November 1933 — 28 July 2014

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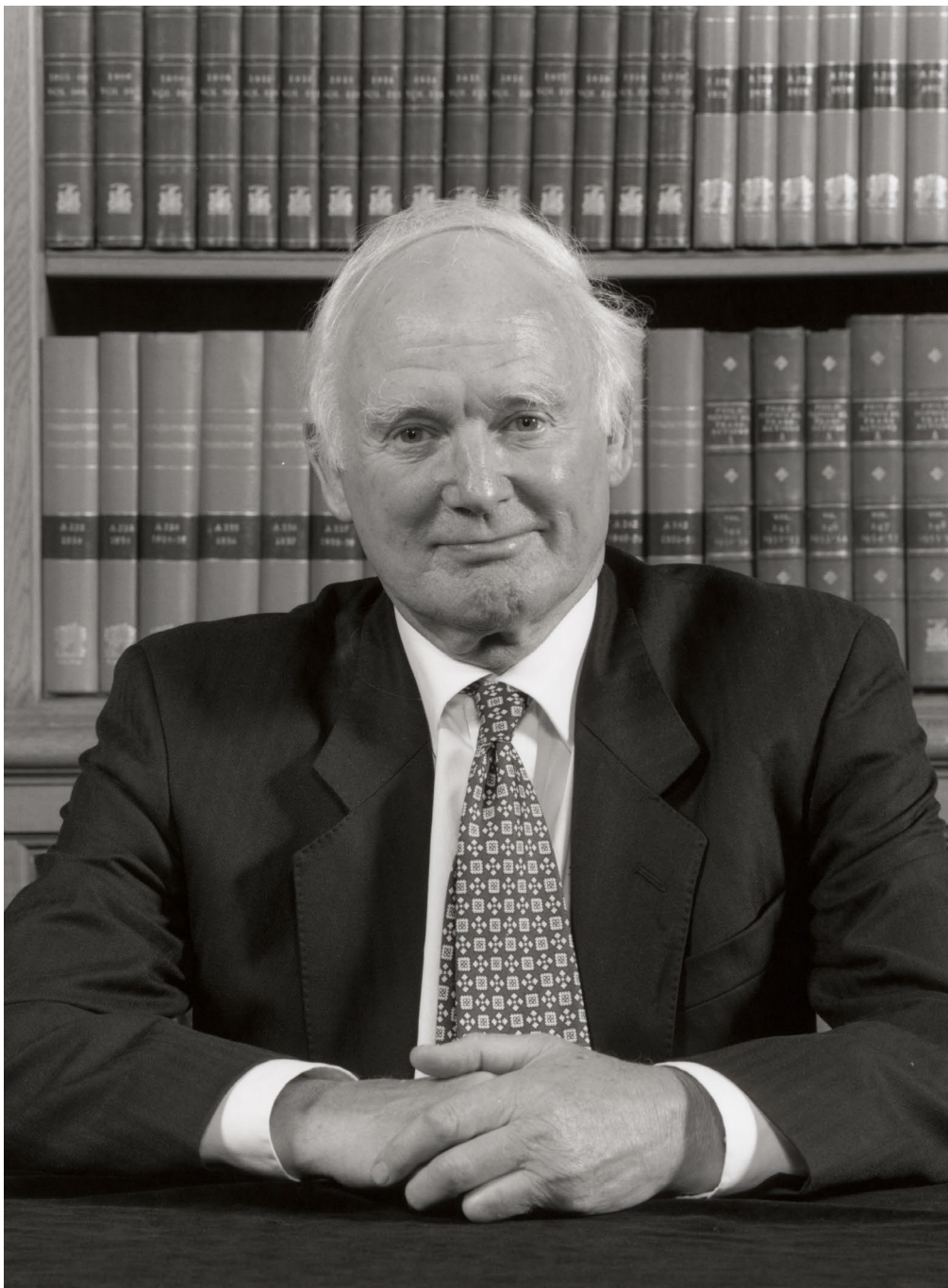
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Elected FRS 2001

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Brian Eyre was an outstanding metallurgist who played a leading role in the development of nuclear engineering materials. His experiments on irradiated metals enabled a theoretical understanding of the mechanisms of radiation damage, and in particular the formation of voids and void swelling in structural steels. His work on the fracture of metals advanced our understanding of intergranular embrittlement and helped define the specifications of the structural components in nuclear reactors. He rose from a humble upbringing in London's East End to become Chief Executive of the UK Atomic Energy Authority (UKAEA). He was instrumental in transforming the UKAEA from a organization whose mission was to develop nuclear power generating systems into the privatized AEA Technology, which worked on a wide range of technologies on a customer–contractor basis.

THE EARLY YEARS

Brian Eyre was born on 29 November 1933 in East London, the first child of Mabel Eyre (*née* Rumsey) and Leonard George Eyre in what he called a 'working class' family home: a small terraced house in Forest Gate.|| His father had trained as a mechanical fitter but had periods of unemployment in the 1930's. His mother was a skilled dressmaker. Brian was six years

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|| Always organized, Brian left us comprehensive notes about his early life, on which we have based these first sections.

old when he attended his first school, Northolt Primary. At the age of 11 years he was one of very few pupils from the school to pass the 11-plus examination to be selected for Greenford Grammar School.

Brian recalled that he did not enjoy grammar school and did not relate to most of the teachers, the exceptions being a mathematics teacher in his middle years and a history teacher during his last two years. He spent much of his time on extracurricular activities. When he was 13 years old he joined the Air Training Corps, which was particularly important in broadening his experience. He was introduced to flying and obtained a glider pilot's certificate. He also spent much time with friends in aero modelling. Pocket money to finance these activities had to be earned, so he had a paper round delivering newspapers before school each day, as well as a Saturday job. The consequence was that schoolwork had a low priority and he left Greenford Grammar at 16 years of age without either matriculating or obtaining the school certificate, which were the basic qualifications at the time. Looking back he realized that getting a place in a grammar school was a privilege denied to most state-educated children, and he felt that his years there had been largely wasted.

THE FIRST EMPLOYMENT: FAIREY AVIATION, 1950–55

On leaving school, his first few months were spent in dead-end jobs as an office boy and garage pump attendant. But towards the end of 1950 he obtained a place at Fairey Aviation in Hayes, Middlesex, as a technical trainee working in the materials laboratory. The pay was very low but crucially he was given one day off per week for part-time education, during which he embarked on an Ordinary National Certificate general science course at Wandsworth Technical College. He had an inspirational teacher, Mike Pay, who opened Brian's eyes to the importance of formal qualifications as a passport to a professional career.

The early 1950s were a particularly exciting time for the UK aircraft industry, and Fairey's was in the vanguard. While Brian was there the company was working on the Fairey Delta 1 and 2; the latter made a major breakthrough, increasing the world speed record to 1132 miles per hour.

Brian recalled that the atmosphere at Fairey's was rather autocratic. The Chief Metallurgist, W. E. Cooper, sat in a glass-fronted office, emerging to shout orders when he felt that his minions were not working hard enough. Brian's initial placement was working in the metallography laboratory under Arthur Greenwood, a very experienced metallurgist who was particularly knowledgeable on the microstructure and properties of alloys used in the aircraft industry. Some of the work was tedious, involving polishing sections from large alloy forgings and castings for routine examination under the microscope. Other work that he found more fascinating included learning about microstructures and the use of successive etching treatments to identify and analyse the phase distributions in alloys.

The job at Fairey's had some of the atmosphere of a school—there were about 20 trainees, all of a similar age. Formal courses for one day a week, and nine hours of evenings plus homework, as well as keeping on top of their jobs, were a major challenge. In Brian's view most of the people he studied with at night school were equal to or more able than many of the university graduates with whom he subsequently worked.



Figure 1. The Battersea Polytechnic Institute. (Illustration by James Akerman, published in *The Building News*, 3 April 1891.)

THE TIN RESEARCH INSTITUTE, 1955–57

In 1955, having gained an Ordinary National Certificate, Brian moved to the Tin Research Institute as an assistant metallurgist with responsibility for their metallography laboratory. The institute was a much smaller organization than Fairey's. Funded by the tin producers it provided technical support to organizations using tin-based materials.

Brian continued to receive the concession of one day off per week to continue his professional studies: he embarked on a Higher National course at Battersea College of Technology. His manager was the Chief Metallurgist, Dr Edwin Eldred. Under Eldred's guidance Brian published his first two papers as sole author, on the microstructures of tin and its alloys and the phase diagram of tin–antimony alloys (1, 2)*. This was before he had gained any professional qualifications.

BATTERSEA COLLEGE OF TECHNOLOGY, 1957–59

In September 1957, on gaining a Higher National Certificate, Brian was encouraged to continue his education on a full-time basis and study for the newly introduced Diploma in Technology at Battersea Polytechnic Institute (figure 1). The institute had a long and distinguished history, having admitted its first students in 1894 and providing access to further and higher education for the poorer inhabitants of London.

He found moving from part-time to full-time study quite a change of pace. In the early days, working at the level of intensity to which he had become accustomed, he raced ahead on coursework and assignments; his tutor advised him to slow down and take more time to read around his subject. In the spring of 1959, before finals in his last year at Battersea, he suffered a setback, which he characteristically overcame. An accident on his motorbike resulted in a complex fracture of his left leg, requiring an extended stay in hospital. He was unable to carry out a practical final-year project and instead conducted an extensive review of brittle fracture in ferritic steels. This turned out to be invaluable training for his later research. Immobility

* Numbers in this form refer to the bibliography at the end of the text.

also enabled him to revise for finals more than he might otherwise have done and he gained a first-class honours Diploma in Technology (DipTech Metallurgy) at the age of 25 years.

CENTRAL ELECTRICITY GENERATING BOARD, 1959–62

On leaving Battersea in 1959 Brian was recruited by the Central Electricity Generating Board (CEGB) as a Research Officer, one of a cohort of graduate staff to form the nucleus for the planned Berkeley Nuclear Laboratories in Gloucestershire. He was to work under Bryan Edmondson on the steel surveillance-testing programme for the Magnox pressure vessel. He was seconded to the Culcheth Laboratories of the UK Atomic Energy Authority (UKAEA) near Warrington in the north of England, to work under Roy Nichols in the shielded laboratory.

Around 1959 he visited Constance Tipper, Reader in the Engineering Department at Cambridge. Tipper had worked for most of her career at Imperial College and Cambridge on the fundamental aspects of deformation and fracture in ferritic materials. She was about to retire, so she let him have a collection of iron single crystals grown by the strain anneal method; this proved to be a very fortunate event for him. Brian had the single crystals fabricated into small tensile specimens and arranged for them to be irradiated, together with some thinned, rolled and annealed sheet samples of a low-carbon iron, in the Herald reactor at the UK Atomic Weapons Establishment at Aldermaston in Berkshire. This was a small light-water-moderated research reactor, in which it was possible to achieve relatively high doses in the comparatively short time of a few months. In late 1960 he received the irradiated iron crystals and conducted tensile testing, resulting in cleavage fracture at liquid nitrogen temperatures. He used the elderly Phillips Elmiscope 100B electron microscope to study replicas taken from the fracture surfaces, exploring the effects of neutron irradiation on the topography of the fracture surfaces.

Soon after he arrived at Culcheth a potential crisis arose regarding the irradiation-induced deformation of the fuel cladding in the Magnox reactors that were shortly to come into service with the CEGB. A crash programme was mounted in late 1959 under the direction of George Hardy. The team worked on this through the Christmas holidays and developed a modification to the fuel element design that fixed the problem.

Brian moved to Berkeley Nuclear Laboratories in January 1959. Although the building work on the laboratories had been completed, the services were not fully installed. Indeed, there was no heating and the surrounding grounds were a sea of mud. He also had to find accommodation. He rented, together with Barry Jones and Arthur Smith, a house: Hornshill Farm. Barry had been president of the Sheffield University Mountaineering Club and they made frequent trips to North Wales and the Lake District for rock climbing and mountain walking. Barry and Brian remained lifelong friends, and each acted as best man at the other's wedding in the 1960s.

Brian was also encouraged by his Section Leader, Kingsley Williamson, to continue his basic research on irradiation damage in iron. Initial studies of the effects of irradiation on slip-band morphologies in iron had shown a transition from diffuse wavy slip bands in unirradiated samples to much sharper and straighter slip bands after irradiation. This transition was dependent on both irradiation dose and temperature. The observations were consistent with earlier observations on irradiated face-centred cubic metals. The sharpening of the slip bands was interpreted as being due to dislocations sweeping out irradiation damage clusters, a phenomenon called dislocation channelling (3). During this period, Brian also reported the



Figure 2. Brian Eyre (left) in 1979 with Metallurgy Division colleagues John Evans, John Williams and Merfyn Davies. (Photograph supplied by Eric Jenkins, courtesy of the NDA Photo Library.)

first-ever direct observations of neutron irradiation damage in α -iron, using the new technique of transmission electron microscopy (4). The development of dislocation configurations in irradiated material was studied, as well as the interaction of these features with point defect clusters. This was a *tour de force*, involving the development of novel methods for specimen preparation, as well as very painstaking and skilled microscopy.

HARWELL METALLURGY DIVISION, 1962–69

In the spring of 1962 Brian moved from Berkeley Nuclear Laboratories to the Metallurgy Division of the Atomic Energy Research Establishment at Harwell (figure 2). Harwell had been set up in the late 1940s under Sir John Cockcroft FRS to be the central research establishment for the UK's nuclear programme. Through the 1950s it established itself as one of the world's leading centres for research in the nuclear sciences.

On arrival Brian was given two support staff, Edgar Joyce and Arthur Bartlett. Edgar was a General Worker with responsibility for looking after the laboratory; Arthur was a Scientific Assistant with the task of assisting him in his experimental work. Brian was to build on his research on irradiation damage in iron performed at Berkeley. The facilities at Harwell, in terms of research reactors and tools for structural analysis, were excellent. In collaboration with Arthur Bartlett, a detailed study was performed on the post-irradiation annealing of neutron-irradiated iron (7). Brian was to establish an interaction with Ron Bullough (FRS 1985) in the Theoretical Physics Division that lasted the whole of his career at Harwell and beyond. Brian's systematic and rigorous approach, his emphasis on careful and thorough experimental work, his use of a range of techniques to focus on a single problem, his insistence on using the highest purity materials, and his detailed and active collaboration with leading theoreticians all made him a major international figure in the field of nuclear materials.

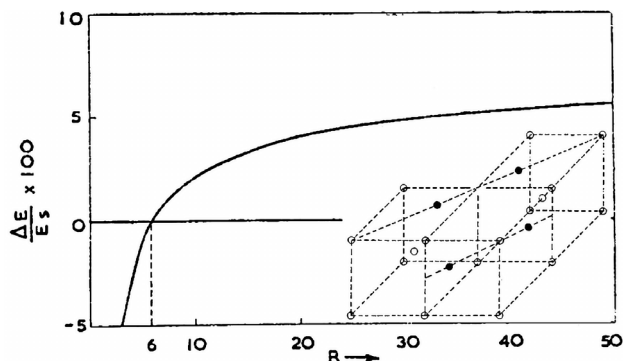


Figure 3. The percentage energy difference between equivalent square and circular interstitial loops as a function of loop size in units of the core radius (R). The inset shows the configuration of bi-interstitials in a body-centred cubic lattice, as first proposed by R. A. Johnson (Johnson 1964). (From (6).)

An early success of Brian's collaboration with Ron Bullough was a theoretical model for the development of interstitial dislocation loop geometries in body-centred cubic metals. Interstitial atoms tend to place themselves within the lattice at the point of lowest energy. The inset in figure 3 shows how two split interstitials (represented by the four black atoms) place themselves in the smallest possible loop. As the number of interstitials grows, they may form a single extra layer of interstitials—a 'stacking fault', enclosed within a dislocation loop with Burgers vector $\mathbf{b} = (a/2)\langle 110 \rangle$. Their work detailed how the stacking fault may be eliminated by lattice shears along either a $\langle 100 \rangle$ or a $\langle 110 \rangle$ direction to produce loops with $\mathbf{b} = (a/2)\langle 111 \rangle$ or $(a/2)\langle 100 \rangle$, respectively. As the loops grow they become visible by experimental electron microscopy; many measurements of the shape, size and orientation of interstitial loops were subsequently made. These could be explained by analytical calculations of their elastic energy. Analytical calculations were made of the energy of both square and circular interstitial loops as a function of their size and orientation. The original theoretical model by Eyre and Bullough (6) correctly predicted the observations that interstitial loops are initially rectilinear but as they grow they become circular.

Early on, a young graduate, Mary Downey, joined Brian; this enabled them to broaden the irradiation damage studies to include another body-centred cubic metal, molybdenum. Thin foils of molybdenum suffer considerably less surface contamination than iron in the electron microscope, facilitating a more detailed analysis of the irradiation damage structures. They were able to analyse irradiation-induced point-defect cluster damage in molybdenum quantitatively as a function of irradiation conditions and post-irradiation annealing (5).

In the mid 1960s Dennis Maher, who had completed his PhD at Berkeley under Gareth Thomas, joined the group. Brian's group embarked on an extensive programme to study irradiation damage in molybdenum, including the nature, geometry and distribution of damage clusters as a function of a wide range of irradiation and post-irradiation annealing conditions. They developed methods for analysing the structures. This involved interacting with Ron Bullough and Roy Perrin in the Theoretical Physics Division, where computer simulation was used to analyse the geometries of small dislocation loops. This enabled them to gain insights into the development of irradiation damage structures in molybdenum and the mechanisms governing post-irradiation annealing behaviour. This work, which was reported in a series of papers in *Philosophical Magazine* (10–13), formed the most comprehensive study of irradiation damage in a body-centred cubic metal.

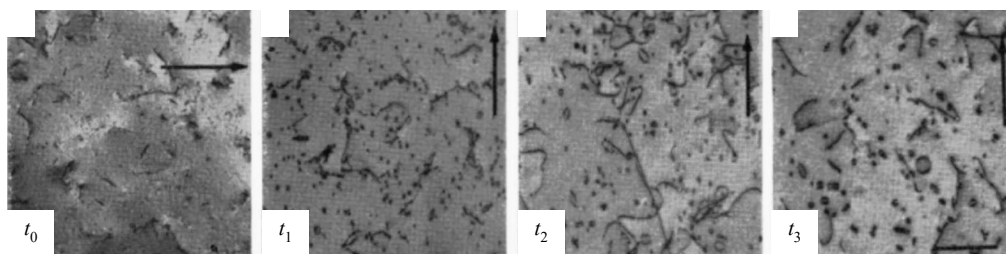


Figure 4. Electron micrographs of pure molybdenum irradiated in the Harwell DIDO reactor at 473 K and subsequently annealed at 1173 K for effective times of 0 (t_0), 12 s (t_1), 10 min (t_2) and 60 min (t_3). The scale marker (black arrow) represents 400 Å. (From (13).)

Figure 4 shows an example of the work in (13). Pure molybdenum samples irradiated to an integrated dose of 7×10^{19} neutrons cm^{-2} at 473 K in the DIDO reactor were then annealed in a furnace at 1173 K for various durations. The images show dislocation loops as multi-sided polygons. It is clear that the average size of the loops increased with the annealing time, and the paper assessed this quantitatively and fitted these measurements to analytical theories.

In the mid 1960s John Evans joined Brian's group, and they initiated experiments to determine the effects of composition on the structure and physical properties of molybdenum. A particular focus was to study the kinetics of nitrogen-rich cluster formation in quenched Mo–N alloys as a function of ageing time and temperature, using a range of techniques including transmission electron microscopy, resistivity and internal friction (8).

John Evans also conducted experiments to study damage structures in molybdenum irradiated in an accelerator at temperatures above 500 °C. He discovered the formation of a void lattice with a body-centred cubic structure; a transmission electron micrograph showing the void lattice was published on the cover of an issue of *Nature*. A seminal paper by Bullough, Eyre and Perrin on the modelling of void growth was published in 1970 (9).

On moving to Harwell in 1962, Brian initially lodged at Ridgeway House, a former Royal Air Force officers' mess used by the Atomic Energy Research Establishment as a hostel for single graduate staff. In 1963 Brian moved out to a flat in Abingdon, sharing with David Ogden from the Medical Research Council at Harwell, and Jim Hastie and Peter Ford from Culham nuclear fusion laboratory. They all had an interest in mountaineering; David and Brian joined the Oxford Mountaineering Club. A highlight during this period was to go on a British Mountaineering Association rock-climbing course in Skye in 1964, enjoying perfect weather and climbing many of the classic routes in the Black Cuillen.

Brian met Elizabeth Carol Rackham, his future wife, in 1964 on one of the weekends in Wales. She was teaching in Abingdon and was rooming with another teacher, Denise Wood, also a member of the Oxford Mountaineering Club and a strong rock climber. Carol tried rock climbing with Brian on a couple of occasions but did not take to it: there was too much waiting around. Brian and Carol were married in June 1965; she 'retired' from rock climbing and they moved to their first home in Wootton near Abingdon. They had two sons, Peter John (born in 1966) and Stephen Andrew (1967).

THE UNIVERSITY OF ILLINOIS, 1969–70

As a result of his vacation stays at Harwell, Howard Birnbaum invited Brian to spend a year with his group at the University of Illinois. Brian, Carol and their two sons (then two and three years old) set off on the *Queen Elizabeth 2* liner in September 1969 for Illinois via New York. Although there was research at Illinois using electron microscopy, notably by Marvin Wayman to study martensitic transformations, there was no work using diffraction contrast analysis to study defect geometries. Brian gave a course of postgraduate lectures on the principles and methods of analysis of diffraction contrast techniques. At that time he also developed a mathematical model of the annealing behaviour of irradiation-induced dislocation loops. This was related to the experimental observations he had made at Harwell working with Dennis Maher; theory and experiment were reported in a major paper (13) that completed a series of five papers on irradiation damage in molybdenum.

RETURN TO HARWELL, 1970–76

When Brian returned from Illinois, Stan Pugh had succeeded Bob Barnes as Metallurgy Division Head at Harwell, and he asked Brian to form a new group to work on the fracture of structural alloys. Walter (later Lord) Marshall (FRS 1971) had launched the so-called ‘diversification programme’, a new direction for Harwell aimed at winning increasing external, non-nuclear, funding for their work. This marked the beginning of the run down of the government-funded nuclear programme. Brian’s group started to seek externally funded contracts as well as beginning new research programmes on fracture. New members of the group included recent graduates Tom Webster, Steve Druce, Hayden Wadley, Barry Edwards and Colin English.

In the period 1970–79 the group conducted a much broader based programme. In the irradiation damage field, Brian worked with Colin English on understanding the basic mechanisms governing the development of defect structures as radiation damage proceeds. They focused particularly on the role of displacement cascades in influencing the survival of point defects and their distributions in face-centred cubic and body-centred cubic metals (14, 16). A particularly significant outcome of this work came from Brian’s continuing interaction with Ron Bullough. Together with Kanwar Krishan, a visiting scientist from India, they developed a theoretical model of how the collapse of the vacancy-rich centres of displacement cascades influenced the separation of vacancy and interstitial point defects and the effect of this on the temperature dependence of void swelling (17).

During the 1960s, void swelling in the cladding of fuel elements in fast reactors had become a major issue after observations on stainless steel cladding samples after irradiation in the Dounreay Fast Reactor. The study with Bullough and Krishan drew on the classic work by Cottrell & Bilby (1949), on the interactions of interstitial solutes with edge dislocations in iron. They deduced that, as a result of the greater misfit strains around interstitial point defects relative to vacancies, they would interact more strongly and be lost preferentially at dislocation sinks, leaving an excess of vacancies to form voids. This work was later extended in a series of papers by Bullough and his colleagues (Brailsford & Bullough 1972) that developed a rate theory for predicting void swelling in metals and alloys under a wide range of conditions, as irradiation parameters and material structural parameters were varied. They developed a series of coupled rate equations governing all the stages and parameters of the

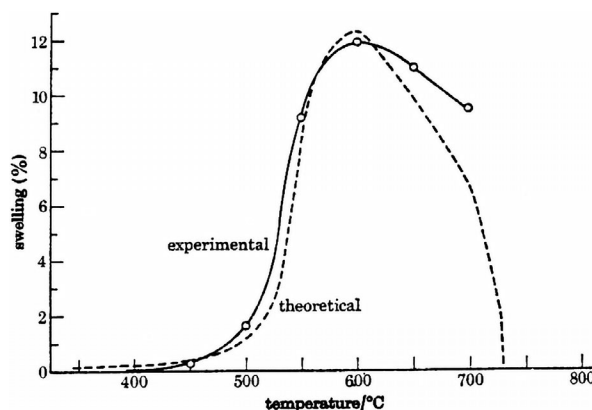


Figure 5. The swelling of type 316 stainless steel produced under irradiation by 1 MeV electrons to a total dose of 40 displacements per atom, as a function of temperature. (From (17).)

irradiation process. The irradiation dose, usually quantified as atomic displacements per atom, could be related to the simultaneous production of vacancy and interstitial atoms, or Frenkel pairs. Their aggregation into interstitial loops and their subsequent transformation into voids could all be expressed by analytical rate equations whose parameters could be deduced from experimental metallurgy. These rate equations could be solved numerically on mainframe computers to give predictions of the void swelling percentage that could be compared directly with the experimental observations, as in figure 5.

Pioneering work was also carried out on the irradiation of metals with helium ions, which results in the formation of bubble lattices (15, 19), and on irradiation with heavy ions, which provides a convenient method of producing displacement cascades that resemble the primary damage events occurring under irradiation with fast neutrons (18).

During the mid 1970s Brian worked closely with Colin English and Roy Perrin on the development of the theory of transmission electron microscope (TEM) diffraction contrast from small dislocation loops created by irradiation. In particular, they developed a programme based on two-beam dynamical theory to calculate the so-called black–white contrast of small dislocation loops lying close to the surface of a TEM foil. The fine structure of these images enabled them to determine the nature, Burgers vector and habit planes of loops in molybdenum produced by bombardment with heavy ions. They showed that $(a/2)\langle 111 \rangle$ loops often had shear components consistent with nucleation on $\{110\}$ planes, as previously predicted. They also developed a method for the determination of the nature of larger loops in particular orientations. This seminal work was reported in a series of key papers (20–23) that, decades later, still form the basis of the interpretation of TEM images of irradiation-induced defects in metals and alloys.

Brian's studies with molybdenum also continued in the field of fracture. Intergranular embrittlement had long been a problem with many metals. The problem was thought to lie in the segregation of impurity atoms on to the grain boundary surfaces within the metal. With Arvind Kumar, a visitor from India, Brian performed one of the first systematic quantitative studies of these effects. They first prepared samples of ultrapure molybdenum, containing only 6 atomic parts per million of oxygen, and then made a range of different carbon additions. Using Auger electron spectroscopy they were able to measure the concentrations of oxygen and carbon atoms on intergranular fracture surfaces, and to correlate these with the

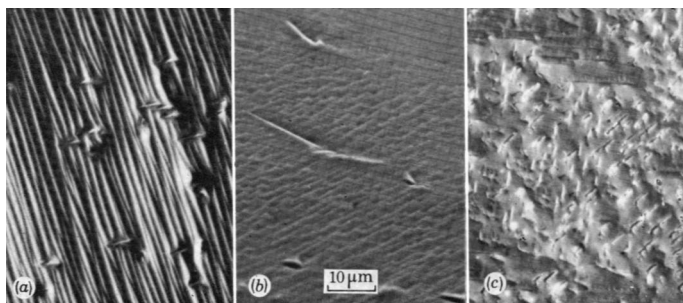


Figure 6. Scanning electron micrographs of the fracture surfaces of molybdenum containing variable amounts of carbon. The alloys contain (a) 1.6, (b) 4 and (c) 300 carbon atoms per 10^6 atoms and show increasing amounts of the molybdenum carbide precipitates. (From (24).)

low-temperature fracture stresses of individual grain boundaries. In a classic paper (24) they demonstrated that decreasing the grain-boundary oxygen level from 0.47 to 0.11 of saturation coverage resulted in an increase of about 60% in the work of fracture, and that this effect was partly lessened when carbon was added. Carbon was shown to partly suppress the segregation of oxygen, as well as precipitating carbides, which acted as sources of mobile dislocations and hence improved the ductility of the alloy.

Figure 6 shows scanning electron micrographs of the intergranular fracture surface of alloys containing very different amounts of carbon. Boundaries that were low in carbon but high in oxygen content showed striated or faceted structures (figure 6a). At intermediate oxygen and carbon levels the boundaries appeared more uniform (figure 6b), whereas at high carbon levels there was direct evidence of molybdenum carbide precipitation in the interfaces (figure 6c).

THE UNIVERSITY OF LIVERPOOL, 1979–84

In the spring of 1979 Brian was headhunted by the University of Liverpool to take the Chair of Materials Science, succeeding John Stringer. This was a difficult decision, involving a significant drop in salary as well as the challenge of teaching a range of undergraduate materials courses from scratch and setting up new research projects for the first time. At the time Liverpool did not have a strong presence in electron microscopy and Brian would have to make the case through the research councils and the university for substantial new funds.

The challenges were even more formidable than he had expected, particularly in preparations for a series of undergraduate courses for both materials and engineering students. He encountered considerable goodwill from both the university and the research councils in helping to set up his research activities in both irradiation damage and the fracture of structural alloys. Several very able research students joined his group, and considerable momentum had been established by the end of the second year.

He also became more involved in university affairs, succeeding Derek Hull (FRS 1989) as Head of Department after two years. Brian and his two sons were regular attendees at Anfield during Liverpool Football Club's great period in the late 1970s and early 1980s.

THE HIGHER MANAGEMENT YEARS, 1984–97

Brian was eventually persuaded to return to the UKAEA in the summer of 1984, replacing George Hardy, who was retiring as UKAEA Director of Fuel and Engineering. This gave him charge of the three ‘Northern Research Laboratories’ at Risley, Springfields and Windscale, headed respectively by Roy Nichols, John Shennan and Harry Lawton, all very able lieutenants and immensely experienced in nuclear power. Brian’s job was to create, correct or strengthen the technology needed for the advanced gas-cooled reactors (AGRs) and the sodium-cooled fast reactor, and for plant decommissioning and waste management. Controlling the oxidation of the stainless steel fuel cladding and of the graphite moderator in AGRs and preventing steel cracking in the liquid sodium/water heat exchangers in the Prototype Fast Reactor at Dounreay were just two of the substantial challenges he faced.

Brian had become frustrated by the complex, anarchic management of university departments. It is therefore ironical that external events would very quickly demand major changes to the UKAEA’s management arrangements that he liked so much, changes that he himself eventually had to drive through and make work. Many of his later years with the UKAEA were devoted to strategy and management, at which he proved just as effective as he had in hands-on science and technology. This was in no small measure because Brian always recognized the importance of networking; he and Carol gave a great deal of their time to making sure he knew well the people with whom he and the UKAEA had to interact, and vice versa.

Few realized it at the time, but 1984 and 1985 were the last years of a quiet, fairly stable period for nuclear power in the UK. The CEBG had largely abandoned the use of oil for high-load-factor power generation because of its cost, and the Department of Energy had forbidden the use of gas in this way because the headline North Sea reserves : production ratio was rapidly reducing as demand grew. In electricity, the Department of Energy had adopted the so-called ‘CoCoNuc’ (Conservation–Coal–Nuclear) strategy, with nuclear a key factor. The Thatcher government was strongly in favour of nuclear power, especially after its important role in keeping the lights on during the 1984/85 miners’ strike. Walter Marshall’s influence as CEBG chairman and confidant of the prime minister was considerable; he believed that the UKAEA had a useful role in nuclear technology and had much to offer other industries.

The Sizewell B Inquiry into the case for Britain’s switching from AGRs to pressurized water reactors closed in March 1985. The assumption was that, once the industry had decided which reactor it should build in Britain, the government would support it and the CEBG would commission several of the chosen plants. Moreover, because nuclear power was expected to grow fairly quickly around the world it was easy enough for the UKAEA to argue that uranium prices would inevitably rise, making the fast reactor competitive. Finally, the UKAEA had been put on a ‘Trading Fund’ basis in 1985, giving it more flexibility to pursue commercial work through its ‘AEA Technology’ brand, largely out of Harwell.

The outlook changed for the worse in 1986. The disaster at Chernobyl created widespread distrust of nuclear power. The collapse in oil prices meant that new nuclear power plants no longer looked economically attractive compared with new fossil-fuel stations. The subsequent falling out between Lord Marshall and the Thatcher government over the way to privatize electricity generation, the industry’s division into several companies, and Marshall’s departure, eliminated his pro-nuclear influence in the electricity industry. The pressure to make use of the torrent of cheap natural gas then pouring from the North Sea was becoming irresistible, eventually leading to the ‘dash for gas’. The last straw for nuclear power was the very public



Figure 7. A visit to Harwell in 1987. From the left: (standing) Ron Bullough FRS, Tony Hughes, David Livesey and Ron Sowden; (seated) Brian, David Clark and Bill Mitchell FRS. (Photograph supplied by Eric Jenkins, courtesy of the NDA Photo Library.) (Online version in colour.)

recognition that the decommissioning costs of early nuclear plants would be much larger than the value of their further generation, effectively making them impossible to privatize.

John Collier returned to the UKAEA from the CEBG in 1986, becoming its chairman in 1987, and he and Brian immediately became close partners in changing the UKAEA to cope with these difficult times and also in fighting for a continuing role for new nuclear plants for UK power generation. Collier very quickly replaced the UKAEA's geographically based management structure with a function-based one in which Brian became the board member responsible for the major nuclear 'programmes', in parallel with Graeme Low as the member for 'sites' to whom the site directors of Harwell, Dounreay, Winfrith, Culham and the Northern Laboratories reported. Brian quickly realized that the programmes that had previously been funded by the government would have to become commercial businesses if the customer base were to be broadened sufficiently to sustain the technical capabilities of the UKAEA in the future (figure 7). The global management consultants, McKinsey & Company, employed by Eyre and Collier to look at broad options for the UKAEA in these troubled times, came to the same conclusion.

There was little dissent within the UKAEA, but for a few months arguments raged about what should be its prime focus. Should it focus on the capabilities that it was trying to sustain or on the businesses that it was trying to develop? In personal terms this would determine the relative importance of site directors and business CEOs, and Brian found himself pitted in argument against Peter Iredale, who was then the director of Harwell. By this time John Collier had been asked to take over the nuclear part of Britain's power generation, which could not be privatized, to be left in the public sector for the time being. One of Brian's great strengths was persuasion, and these arguments effectively ended when he succeeded



Figure 8. The Technical Advisory Group on Structural Integrity (TAGSI) on 25 October 2005 with Ron Bullough, Sir Peter Hirsch FRS and Brian at the centre front. TAGSI was set up in 1988 with Brian as its first chairman; he held office until 1993. Originally a UKAEA committee, it was later sponsored by the nuclear industry, the Ministry of Defence and the Health and Safety Executive. It still exists today. (Photograph supplied by Eric Jenkins, courtesy of the NDA Photo Library.) (Online version in colour.)

in persuading two of the major site directors, Derek Pooley at Winfrith and Stuart Nelson at Risley, to acknowledge the supremacy of the new businesses, despite their immediate personal interest in maintaining the influence of site directors.

Brian became the overall UKAEA CEO in 1990, when Collier left to run 'Nuclear Electric' and was replaced by a non-executive chairman, John Maltby from Burmah Oil, who had been a UKAEA non-executive director for a few years. As CEO, Brian set about making the new organization work; he showed enormous enthusiasm, commitment and drive, managing to inspire his lieutenants to do the same. On the basis of McKinsey's analysis, nine businesses were set up (five nuclear and four non-nuclear), each of which set out to broaden its customer base, reduce costs and improve profit margins, mostly with considerable success.

But the UKAEA already faced a threat to its largest nuclear programme, which was fast reactor development. After 1986 it rapidly became clear that world demand for uranium would not, after all, grow very quickly. The repercussions from Chernobyl and low prices of fossil fuels effectively brought new nuclear plant orders to a complete halt. Moreover, the fuel reprocessing and plutonium-fuel fabrication that are essential for the fast reactor fuel cycle were both looking much more difficult and expensive, after various difficulties at Sellafield. The case for a continued fast reactor programme was consequently much weakened and the government decided in 1988 that the Dounreay Prototype Fast Reactor should close in 1994, leaving only a small fast reactor research programme in place. Collier and Eyre immediately and successfully campaigned to persuade the nuclear utilities to pick up some of the costs of keeping the fast reactor going. An example was the founding of the Technical Advisory Group on Structural Integrity (TAGSI) in 1998 with Brian as its first chairman (figure 8). It was later part funded by the nuclear industry and by the Health and Safety executive. They subsequently tried to pressure the government not to abandon it completely. In this they might



Figure 9. Robert Jackson MP with Brian Eyre, Stuart Nelson and Stephen White promoting AEA Technology in 1992. (Photograph supplied by Eric Jenkins, courtesy of the NDA Photo Library.) (Online version in colour.)

well have succeeded but for an ill-timed technical problem at the fast reactor that eliminated the contribution of electricity sales to its costs for some time. Oil leaking from the bearings of a pump circulating liquid sodium caused carbon build-up at some sub-assembly entry channels, restricting flow and requiring a long reactor shutdown, from which the project never fully recovered. This torpedoed the attempt to sustain its operation beyond 1994.

In addition, although Sizewell B had gone ahead in 1987 with first electrical power in 1995, there were no further orders in prospect in the UK. Both Nuclear Electric under John Collier and the UKAEA under Brian made strenuous efforts to find ways in which new plant orders could be justified in this barren period. Nuclear Electric tried to launch Sizewell C, as either a single or a twin station replicating the Sizewell B design; it was argued that the technical and project management risks would now be small. From the UKAEA, Brian had an important role in chairing a subcommittee that examined the economics of new nuclear stations in the UK. However, in the hostile environment of low fossil prices, especially the very low prices of North Sea gas (then being produced in excess of UK demand) and the tightening of restrictions on many nuclear activities after the Chernobyl disaster, the exercise was in pursuit of a forlorn hope.

Meanwhile Brian's 'day job' as UKAEA CEO in the early 1990s required him to concentrate on making sure that the new commercial businesses were successful. It had long been recognized that the formal name, United Kingdom Atomic Energy Authority, was not ideal for a commercial brand, and so 'AEA Technology' was introduced and launched commercially in 1988.

When a Monopolies and Mergers Commission review of the UKAEA was published in 1992, momentum really developed (figure 9). It endorsed Brian's approach completely, saying that AEA Technology's business activities needed to be removed from the public sector to give the organization the commercial freedom of manoeuvre that it needed. There should be a separate organization to take over the nuclear-related plant, together with the associated decommissioning and radioactive waste treatment and disposal programme.

The Commission also completely endorsed the move from the site-based organization to businesses and to corporate services. The government was persuaded. When John Maltby's term as chairman ended in June 1993, the Department of Energy appointed Sir Anthony Cleaver as chairman, to strengthen the UKAEA's top management commercial expertise for the transfer of AEA Technology to the private sector. Cleaver and Brian moved rapidly to divide the organization into three parts at the start of 1994/95: a UKAEA Government Division, with Pooley as CEO, to become the 'residual' UKAEA when privatization was complete; 'AEA Technology', with Nelson as Operations Director while a new CEO from the private sector was recruited; and a Facilities Services Division, with Andrew Hills as Managing Director, anticipating a trade sale to a sites services organization.

This was all achieved very quickly. The Facilities Services Division was sold to Procord for £12 million in March 1995. AEA Technology was vested as public limited company at the end of March 1996, and its shares were sold in September 1996 for £224 million. Brian remained as UKAEA deputy chairman and chairman of the UKAEA Government Division until formal separation was complete; he then chose to remain with AEA Technology as its deputy chairman until his retirement in 1997. For some time, AEA Technology was a darling of the stock market, its shares rising quickly more than threefold. But its character was rapidly changed by Cleaver and Watson through several trade sales and acquisitions and eventually, long after Brian had left, it failed, sinking into administration from whence it was acquired by Ricardo in 2012 for only £18 million. The UKAEA still exists, now concentrating primarily on fusion research. Its role in nuclear decommissioning and management was eventually subsumed into a new Nuclear Decommissioning Authority.

RETIREMENT, 1997–2014

No one who knew Brian was even slightly surprised to find that he worked just as hard after retirement as before. He threw himself into work with many parts of the British science and engineering community, often through his Fellowship of the Royal Academy of Engineering (1991) or of the Royal Society (2001).

Inter alia, he was a member of the Materials Commission of the Science and Engineering Research Council, a member of the Council of the Particle Physics and Astronomy Research Council and chairman of the Council of the Central Research Laboratories of the Research Councils. He was a member of Council of the Royal Academy of Engineering and of the Royal Society's Committee on the Scientific Aspects of International Security and its Plutonium Working Group. He was a visiting professor at the University of Liverpool, at University College London and at the University of Oxford, supervising postgraduate students and continuing to publish scientific papers. He was a member of the UK Ministry of Defence's 'Defence Nuclear Safety Committee' from 1994 to 2006. He had an important role in resolving the technical problems of the nuclear submarine HMS *Tireless* that caused it to be immobilized in Gibraltar, to the great annoyance of Spain, the great embarrassment of the UK and the great delight of the international media.

He was equally in demand and just as highly regarded outside the UK, becoming a foreign associate of the US National Academy of Engineering in 2009. He replaced Lord Marshall of Goring as the Senior Overseas Advisor to Kansai Electric's Institute of Nuclear Safety System Inc. (INSS) in Japan. It would probably be too much to claim that the creation of INSS and the involvement of Marshall and Eyre caused Kansai to avoid the dreadful nuclear



Figure 10. In retirement: Carol and Brian enjoying their hobby of sailing. (Photograph supplied by Carol Eyre.)
(Online version in colour.)

plant problems that later beset Tokyo Electric Power, but it certainly helped. The Japanese were anxious to establish and support the good working relations with the Oxford Materials Department that Brian helped facilitate. He was also appointed by ESKOM, the South African utility, to be an Independent Member of the Technical Advisory Committee of the Pebble Bed Modular Reactor Board. Brian had long appreciated the possible safety and efficiency of small, modular, high-temperature reactors. He was once again happy to be involved in a project that might help nuclear power make the contribution to securing future energy supplies and combating climate change that he passionately believed it should.

Despite being so busy he always tried hard to make time for his love of boats (figure 10), although as Carol's multiple sclerosis advanced, real sailing became impossible and they had to move to boats that were easier for one person to handle and easier for Carol to board and leave. Because Carol's condition became seriously debilitating, Brian was also forced to take over much of the cooking. He became an expert cook, so that being invited to dinner with the Eyres remained a high-class gastronomic experience, right to the last year or so of his life. Carol's neurological problems were a serious difficulty for them both, but Brian tackled them on all fronts, becoming chairman of the Hampshire Neurological Alliance, a charity dedicated to supporting the family and careers of people with neurological conditions in south Hampshire, where Carol and Brian had their holiday home. Only in the last few months, as the cancer finally overwhelmed him, did his remarkable energy and determination to make things happen, so characteristic of his life, finally fade.

HONOURS AND AWARDS

- 1992 Fellow of the Royal Academy of Engineering
- 1993 Commander of the British Empire
- 2001 Fellow of the Royal Society
- 2009 Foreign associate, US Academy of Engineering

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The frontispiece photograph was taken in 2001 by Prudence Cuming Associates and is reproduced with permission.

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