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By H. K. Moffatt

Early life

John Arthur Shercliff was born and bred in Eccles, Manchester, the youngest of a family of three. His father, William Shercliff, was a teacher of geography, together with some physics and mathematics, at Eccles Grammar School; Arthur's lifelong interest in the application of mathematics to practical problems of science and engineering owed much to his father's influence during his early years. His mother, Marion Prince Shercliff (*née* Hoult), was also a qualified teacher with a keen interest in the humanities and literature, an interest that complemented the more practical skills of her husband, and provided a stimulating and liberal environment for the flowering of natural talents.

Arthur displayed these natural talents at an early stage. He attended Monton Green Council School, and in 1938 won a scholarship to Manchester Grammar School, where he remained till 1945. At the outbreak of war the school was briefly evacuated to Blackpool; Arthur recorded in a letter from Blackpool 'It's rotten having no relatives with you' and he further maintained that the 3d then charged on the miniature railway was a fraud!

Arthur spent two years at M.G.S. on the Classical side, followed by two years on the Science side where he came under the influence of the great teacher H. A. Field. After achieving nine distinctions in the School Certificate of 1942 he spent three years in the mathematical sixth form, where, according to his own notes of that period, he was taught by F. L. Heywood and H. G. Maugham, 'two absolutely outstanding teachers who instilled knowledge and habits of thought that would prove good for a lifetime'. They certainly proved good for the Higher School Certificate which Arthur took in 1944 with five more distinctions in double mathematics and physics, thereby winning State and County Scholarships. He then went on to win an Open Scholarship to Trinity College, Cambridge, in the examination of March 1945, and came up to Cambridge in October of that year. A letter from F. L. Heywood to Arthur's father survives from that period; it reads, 'Your young man owes less to me than anyone else in the class. He is supremely gifted (in music also from what I heard last night) and is modest enough to follow every lead and work as hard as his fellows. What more can one ask?'

Early scientific career

Arthur's undergraduate career at Cambridge was equally distinguished. He read for the Engineering Tripos, and at the end of his first year won the Percy Pemberton Prize which is awarded annually to the 'Trinity undergraduate who has most distinguished himself in his studies during his first year of residence'. He duly achieved a First in Part I in 1947 and was awarded the Rex Moir Prize as the candidate who acquitted himself 'with the greatest distinction in that examination'. He spent the summer of 1947 at R. V. Southwell's summer school on relaxation methods, no doubt a misnomer as far as the work was concerned, and he spent some time also at R.A.F. Farnborough. He then returned to Cambridge to take a further First in Part II Engineering, specializing in aeronautics. Among other activities, including choral singing, he gained a half-Blue at lacrosse, participating in the defeat of the 'other place' on two occasions, and he was also President of the Cambridge University Congregational Society, a Fellowship that he greatly valued throughout his life, and with whom in later years he would meet for mountaineering reunions in the Pennines, the Lake District and North Wales.

After graduation in 1948 Shercliff was awarded the Joseph Hodges Choate Memorial Fellowship, which enabled him to study for one year at Harvard in the Graduate School of Arts and Sciences where he took a Master's degree (S.M.) in 1949. At Harvard he encountered one of the earliest computers in the shape of the Harvard Mark I, which he described as 'Babbage's dream realised'. There also he met L. Brillouin and R. Von Mises, who stimulated and encouraged the mathematical approach to engineering problems that came so naturally to Shercliff in later years.

He returned to England to spend two years as a graduate apprentice with A. V. Roe & Co. Ltd in Manchester, where, with characteristic down-to-earth realism, he later recalled the 'plumbing' side of the work—fitting pipes together in the wings of the early Avro 'Vulcan' aircraft. Shercliff's first two publications (1, 2)* are reports on 'Theory and tests on an air ejector for de-icing' and (significantly) 'Mechanical computation and aero-engineering'.

In 1951 he returned to Cambridge to undertake research towards the Ph.D., under W. R. Hawthorne, in liquid metal magnetohydrodynamics

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

under an A.E.R.E. Harwell research contract. Magnetohydrodynamics (MHD) was then in its infancy, certainly as far as engineering applications were concerned, and it was this aspect of the subject that Shercliff was destined to dominate during the great development of the subject in the late 1950s and the 1960s. A major influence on Shercliff during his early researches in MHD was W. Murgatroyd, who introduced him not only to MHD, but also to nuclear engineering generally and to problems of irreversible thermodynamics. He was also much influenced by G. K. Batchelor, F.R.S., whose 1950 paper (*Proc. R. Soc. Lond.* A **201**, 405) had stimulated interest in the problem of magnetohydrodynamic turbulence; the common interest in MHD between the Faculties of Engineering and Mathematics later led Shercliff to present an annual course of lectures (1958–63) on magnetohydrodynamics within Part III of the Mathematical Tripos.

Within his first year of research Shercliff had completed his first paper (3) in MHD on 'Steady motion of conducting fluids in pipes under transverse magnetic fields' and had submitted it for publication to *Proc. Camb. phil. Soc.* The only previous work on this topic of any note had been that of Hartmann & Lazarus (*Mat.-Lys. Meddr* **15**, no. 7 (1937)), who had studied the effect of a transverse magnetic field on flow of a conducting fluid in a two-dimensional channel, and had discovered the boundary-layer character of this flow at high M. Shercliff studied the effects of the side walls of a rectangular channel and found that boundary layers appear on these also; this was an important discovery because it is these side-wall layers (or Shercliff layers as they are now called) that are of dominant importance in the relation between volume-flux and pressure gradient for such a flow. This is because the thickness of the Shercliff layers is of order $M^{-\frac{1}{2}}$, i.e. a factor $M^{\frac{1}{2}}$ greater than that of the Hartmann layers. Shercliff's solution gave remarkably good agreement with experimental results of Hartmann & Lazarus, and must represent one of the earliest points of contact between theory and experiment in the history of a subject that has not been noted for such contact.

From a practical point of view, different combinations of applied magnetic and electric fields may be used to provide electromagnetic pumps or generators or flowmeters; and it was to the last of these applications that Shercliff devoted most attention during the mid-1950s. The principle of the electromagnetic flowmeter had been recognized by M. Faraday, F.R.S., who (as Shercliff delighted to tell his Part III MHD class in the late 1950s) had unsuccessfully attempted to measure the potential difference induced by the flow of the river Thames across the Earth's magnetic field, with a view to deducing the flow rate. As Shercliff himself said in the preface to his book (19) on the subject of 'the theory of electromagnetic flow measurement': 'As magnetohydrodynamic devices go, the flowmeter may appear a little unglamorous, but it is at least the one which has the longest record of useful service in many areas of science and engineering'. Glamour was the last thing that Shercliff looked for in his work; and yet in the practicalities of the flowmeter problem he found a field in which his mathematical and experimental skills found elegant expression, and the book (19) that emerged as the culmination and distillation of his series of papers on electromagnetic flowmeters (4–12) is a minor classic of exposition, full of insight and shrewd common sense, which can still be read with pleasure and profit, despite the considerable subsequent development of the subject with the passage of time.

Electromagnetic techniques for flow measurement had been used for many years in a number of contexts involving fluids of moderate electrical conductivity, particularly for the measurement of ocean currents via the principle envisaged by Faraday, and for the non-intrusive measurement of blood flow in human arteries. A new field that emerged in the postwar years, however, was stimulated by the use of liquid metals (particularly liquid sodium) in the primary cooling circuits of fast-breeder reactors. The full complications of magnetohydrodynamics are present when a liquid metal flows through an electromagnetic flowmeter—particularly the Lorentz force that reacts back upon the fluid dynamics—and it is largely due to Shercliff's efforts of the 1950s that we have a good understanding of the operation of these devices in the liquid metal context.

Cambridge, 1955–1964

Shercliff took his Ph.D. degree at Cambridge in 1955, and in the same year was married to Daphne Margaret Llewellyn in Emmanuel Congregational Church, Cambridge, where they had met in their student days. From 1954 to 1957 he was a demonstrator in the Engineering Laboratory, and in 1957 was appointed to a University Lectureship, a post that he held until 1964. In 1958 he was elected to a Fellowship of Trinity College, where he became a Director of Studies in Engineering. He was a popular lecturer and supervisor, with a great zest for his subject, and a great wit and good humour that never failed to engage his audience. In 1958 he wrote an amusing article for the Cambridge University Engineering Society under the pseudonym Fred Carnot B.A. (failed) CANTAB, with the title '778 and all that', which gives an engaging glimpse of his humour as directed at Engineering undergraduates of the day:

> 'One thing is made clear at the outset. It is positive that work is to be got out of your system. This theme is elaborated with the aid of *Q*'s and *W*'s preceded by what appear to be holes from miniature violin bellies, sometimes transfixed by a circle so as to resemble up-ended, wrought ironwork London Transport signs. Little d's sometimes invade the scene, but can be struck out when they appear as a common factor. One result of this is that $p\mathrm{d}v$, $v\mathrm{d}p$, $\mathrm{d}pv$ and the other permutations are more or less interchangeable, provided one keeps a

spare change of sign handy as the answer draws near. Statistical appraisal soon shows that taking logs to the base *e* in every third calculation has a high chance of success . . .'

In 1955 the Royal Society held a discussion meeting on magnetohydrodynamics, to which Shercliff contributed a paper (7) 'Some engineering applications of magneto-hydrodynamics'. (The hyphen was evidently inserted by a scrupulous editor; perhaps hydro-dynamics was once hyphenated also!) Other participants at this meeting included Sir Edward Bullard, F.R.S., H. Alfvén, B. Lehnert, V. C. A. Ferraro, T. G. Cowling, F.R.S., S. Chandrasekhar, F.R.S., all from the geophysical or astrophysical side, and also R. Hide, W. Marshall and W. B. Thompson from A.E.R.E., Harwell. Shercliff delivered the only paper involving explicitly engineering applications of MHD, a significant indication of the status that he already enjoyed, and of the role that he would continue to play. He confined himself to a discussion of the flowmeter problem, but it is interesting to note his final remarks: 'In conclusion, it should be added that there are other applications of magnetohydrodynamics in engineering. Two examples are the stirring of molten metal in eddy current induction furnaces and the motion of liquid metal brushes in high current electrical machinery.' Shercliff was 20 years ahead of his time in recognizing the magnetohydrodynamic character of these problems, which only in the mid-1970s began to attract serious theoretical and experimental investigation.

A characteristic feature of Shercliff's work was to seek simplicity through generality, a trait that became evident in his first venture into gas dynamics (13), 'Some generalizations in steady one-dimensional gas dynamics', in which he showed the simplification that could result from treating a single-phase fluid or a mixture of fluids in equilibrium without any specific assumption concerning an equation of state. This approach was readily adaptable to the problem of one-dimensional flow of electrically conducting gases in transverse magnetic fields, a problem that excited great interest in the late 1950s as a natural extention of incompressible magnetohydrodynamics. Shercliff wrote two definitive papers in this field (16, 17), the first of these being on flow in a purely transverse field and presented at the International Union of Theoretical and Applied Mechanics (IUTAM) Symposium on Magnetofluid Dynamics at Williamsburg, Virginia, in January 1960, one of the first truly comprehensive and international meetings on MHD. The second paper considers the effect of a magnetic field with component in the flow direction, and includes an exhaustive treatment of shock waves in the presence of a field oblique to the wave. Although there was widespread activity in the field of magnetogasdynamic (MGD) shock waves, Shercliff's particular contribution provided a remarkably clear picture of the categories of transition permitted by the overall conservation equations. Despite this work, however, Shercliff was aware of the slightly academic nature of this kind of work, and indeed he sounded a warning in a paper (15) to the Royal Aeronautical Society in 1959: 'It should be clear that magnetogas-dynamics is sufficiently interesting and potentially useful to warrant further studies of its application to aeronautics, but it is necessary to stress the necessity of choosing realistic magnitudes. Many of the interesting phenomena which occur in astrophysical or thermonuclear magnetohydrodynamics do not appear in aeronautical situations because the electrical conductivity is not high enough.' This warning did nothing to prevent the extraordinary world-wide explosion of research activity in problems of MHD and MGD in the early 1960s, much of it of a sterile nature; but it perhaps explains Shercliff's own reluctance to be drawn further into problems of MGD, and his return in 1961 to the more practical and promising field of liquid metal MHD. His own experiments with mercury were no doubt an important factor in this choice: Shercliff liked to *see* his fluids in motion and to describe the effect of the Lorentz forces in strongly visual terms.

This visual urge, and a natural intuition in the design of simple experiments with mercury, led to one of Shercliff's most memorable creations, the film (23) 'Magnetohydrodynamics' produced as one of a series under the U.S. National Committee on Fluid Mechanics Films in 1965. This film closely reflects the general philosophy espoused in Shercliff's well-known *Textbook of magnetohydrodynamics* published in the same year by Pergamon Press: the emphasis was on the *rotationality* of the Lorentz force, and on its consequent ability either to suppress vorticity or to generate vorticity, depending on the relative orientation of magnetic field and flow. These effects were clearly demonstrated in the film, as was also the *redistribution* of vorticity that occurs in the Hartmann flow problem. The film is also notable for its attempt to demonstrate Alfvén waves both through an ingenious feedback mechanism in a sequence of current loops, simulating a perfectly conducting fluid, and through propagation of a pulsed current through an annular tank containing NaK. This was a modification of an earlier experiment carried out in Cambridge by Shercliff's research student, A. Jameson, and published in 1964 (*J. Fluid Mech.* **19**, 513).

University of Warwick, 1964–1980

In 1964 Shercliff was appointed Founding Professor of Engineering Science at the new University of Warwick, and Head of the Department of Engineering. Two of his research students at the time of his move to Warwick were M. K. Bevir (now at Culham) and J. C. R. Hunt (now Reader at Cambridge University) who recall well the novelty and excitement of the situation: Mike Bevir writes as follows:

'When being formally interviewed by Arthur at Warwick just before going, there were three builders' huts on the site—two with builders and one with professors hiring staff. Arthur had just had a good lunch, possibly softening up the local businessmen or some such activity, and, waving an expansive hand around the mud-bespattered building site, he said "Whatever else we do not have, we do have money". This claim almost backfired later on when I had done some theory on flowmeters and wanted to start experiments, since just at that time it appeared that the UGC had done its sums wrong and were even threatening not to honour commitments already taken on. So I was sent away to do more theory, which actually turned out to be much more successful than the first attempt.

'The MHD group at that time consisted of Chris Alty, newly appointed as a lecturer, and four research students: Julian Hunt, who had already been there a year before the formal start and who had set up an experiment with mercury duct flow in a magnetic field in laboratory space lent by a local firm; David Malcolm (from Saskatoon), who was measuring mercury flows with hot wire anemometers, purchased abroad and often broken by customs officials examining the strange contents of the parcels; Bill Bolton, myself and our technician Alf Webb.

'Bill Bolton shared an office with me and, as far as I remember, was tackling annular axisymmetric flow in radial magnetic fields in mercury. The three of us who had just started went through Arthur's book on MHD with him, including the questions at the end of which were almost sufficient for a Ph.D. thesis by themselves. Later on we built the mercury grotto, a $30' \times 10' \times 8'$ or so plastic room with 5 cubicles containing various types of D.C. magnet and a mercury distribution system, air extractors, etc. etc. It was designed as an MHD mercury facility but never really fully used since there were not enough of us to do so.

'. . . I suppose my final comment is that I never really thought of Arthur so much as an engineer, i.e. primarily interested in devising or designing gadgets, but rather as a teacher which, given his family background, would be understandable.'

The reference to Shercliff's interaction with the local businessmen in the above is not without significance, for it is a fact that the University and the School of Engineering Science at Warwick were generously endowed by industry, with consequential benefits for the rapid expansion of the School particularly in the area of automotive, control and production engineering. Shercliff was active in promoting industrial links from the outset, not least through the appointment of visiting 'associate professors' from industry, to help both with lecturing and with the direction of research projects oriented towards industry.

It was natural that Shercliff should be preoccupied in his early years at Warwick with the development of a sound and flexible degree course in engineering science, and with the underlying principles of an engineering education. It should perhaps be said that his views in these matters were by no means universally accepted, particularly at Cambridge where Shercliff had experienced some frustration over the compartmentalized structure of the Tripos courses, which did not in his view adequately exploit the powerful unifying influence of mathematics. His translation to Warwick gave him the opportunity to put his ideas into practice. He set out his views with admirable clarity in a paper (24) on 'Engineering science courses' presented to the Institution of Mechanical Engineers in 1966. Here he wrote:

> 'The Engineering *Science* course recognizes explicitly that it cannot teach professional competence, and so escapes the remorseless pressures to cram the syllabus and can concentrate on making sure that what is taught can be absorbed thoroughly to the point at which it becomes a basis for creative action, even in the face of unfamiliar situations. The main aim is to produce a confident, critical, apprais-ing attitude towards physical situations and industrial practices based on sound knowledge and an active imagination.'

Shercliff was perhaps idealistic in his aims and in his estimate of the capabilities of the average student of engineering; but it was nevertheless on these principles that he developed the Warwick course, and in a manner that allowed students considerable flexibility in the choice of course combinations within the fields of mathematics, physics, engineer-ing and computer science.

Shercliff's attitude to mathematics for students of engineering was set out after a decade of experience at Warwick in a paper (43) published in the *Bulletin of the Institute of Mathematics and its Applications*, in which he posed the question 'Can mathematics form the heart of the engineer-ing curriculum?' Again the idealism shines through: 'For the Engineer, mathematics should become synonymous with the ordered structure of the physical world, the mastery of which enables him to bend it to his will in creating new systems and devices. Mathematics then *is* the heart of the curriculum.' And yet the idealism is tempered by realism in his estimate of the engineering student's attitude to mathematics: 'He is generally a "doer", motivated to achieve a useful outcome, and is unlikely to be impressed by assertions (tacit or otherwise) that certain knowledge is good for his soul or is part of mankind's intellectual heritage, or by the need to find the Mathematics Department something to do! He will want to see the relevance of the material to engineering activities.' Shercliff's dual theme of motivating mathematics via real-world problems, and of demonstrating the unity of underlying principles via mathematics, is developed in his textbook *Vector fields*, published by Cambridge Uni-versity Press in 1977.

In May 1967 Shercliff spent two weeks in the U.S.S.R. as a guest of the Academy of Sciences, visiting Moscow, Leningrad and Riga. In Riga he visited the famous MHD laboratory, and met O. Lielausis, H. Branover, A. Tsinober and others, all well-known for their experimental work on MHD duct flow. It was during this visit that he encountered what is now known as the 'weld-pool' problem, which had been briefly discussed by V. N. Zhigulev in the Russian literature in 1960. This is the problem of the fluid flow that arises when a large electric current enters a body of conducting liquid at a more or less concentrated point. The current spreads out radially into the fluid and interacts with its self-magnetic field to produce a Lorentz force which drives the fluid motion. Shercliff analysed this process in a brilliant paper (30), which ruthlessly eliminated irrelevant complications (associated for example with boundary shape and finite dimension of the current source), and focused attention on the key feature of the problem that makes it one of novel fluid mechanical interest: again the *rotationality* of the Lorentz force, and the associated generation of vorticity in the fluid. Shercliff found the relevant (inviscid) similarity solution describing a jet-type flow away from the boundary. There are many variations on this problem that have been the subject of extensive researches by others; but it was typical of Shercliff that he should be content to set out the principles of the problem and the essential character of the solution in a single definitive paper, and then move on to other things.

This work was completed during a term of sabbatical leave at Caltech in 1968, a refreshing break from the burdens of office at Warwick. A second important paper (28) emerged from this visit concerning the anisotropic character of the surface waves on a layer of fluid containing a horizontal magnetic field and current, the wave propagation speed being dependent on the angle between the wave crests and the current vector. Shercliff gave a beautifully simple analysis of the problem, and pointed out the analogy that could be drawn with the more complex problem of magnetoacoustic waves.

The power of analogy appealed to Shercliff's versatile mind, and he was to emphasize this power at a later date (42) in a contribution to the 2nd Batsheva Seminar on MHD and Turbulence, a triennial meeting organized by H. Branover following his emigration from the Soviet Union to Israel. Shercliff attended the first three of these seminars (1975, 1978 and 1981) and indeed did much to help establish these meetings as a recognized international forum for engineering magnetohydrodynamics. His concluding remarks in the paper (42) delivered to the 2nd Seminar were particularly revealing:

> 'It should now be clear that analogies within MHD and between MHD and other subjects, particularly fluid mechanics, are well worth pursuing in the search for understanding and progress at all levels, whether in elementary pedagogy or at the research frontier.

Even when the analogy is incomplete (as in that between **ω** and **B**), it can be very suggestive of fruitful conjectures which can be tested rigorously. Where the analogy is exact (even though phenomenological laws or the kind of geometrical configuration which is of physical interest may differ in detail in the two cases) complete mathematical methodologies can be transferred across and exploited. And under the most favourable conditions of all, it is merely a matter of borrowing entire solutions, with, one hopes, always a due acknowledgement to the originator of the borrowed solution, for piracy is surely not in keeping with the traditions of Science. However, if one is realistic, every man's apparently original thoughts are but a distillation of all his earlier learning experience and, deep down, the forces of analogy are continually at work in propelling our trains of thought forward. So we are all—praise be—guilty.'

In 1971 Shercliff (with Julian Hunt as co-author) published a review (32) of 'Magnetohydrodynamics at high Hartmann number' in *Annual Review of Fluid Mechanics*, in which the accumulated experience of twenty years on problems involving Hartmann and Shercliff layers (both on fluid boundaries and, more interestingly, in fluid interiors) is compressed and distilled into 25 highly readable pages. There followed three lean years with no research publications, coinciding with the period during which Shercliff was Chairman of the Science Faculty at Warwick. While recognizing the importance of such a position, one must surely regret that any such appointment should have been allowed to suppress the intellectual creativity of which Shercliff was so clearly capable. Is it really in the best interests of British science that university administrative burdens be quite so crippling?

The removal of this particular burden saw an immediate return to productive research. In a change of field with his paper (34) 'Seepage flow in unconfined aquifers', a study of flow with a free surface in a porous medium, Shercliff explains why, and under what circumstances, a naïve one-dimensional theory may give results that are much more accurate than might reasonably be expected. The paper includes an exact treatment of the problem of a horizontal line source on the inclined base of a porous medium, and a Hele–Shaw experiment that agrees well with the theory. It also contains a beautiful photograph of the free surface instability that occurs when the inclination of the boundary is greater than $\frac{1}{2}\pi$, but makes no attempt to analyse this phenomenon.

In 1976 Shercliff returned to the problem of Alfvén waves (36), but now with a view to assessing the possibility of technological exploitation in connection with energy storage. As Shercliff said: 'Athough the Alfvén wave has several manifestations in astrophysics, it is quite remarkable how little it has figured in technology since it was first predicted by Alfvén.' It was typical of Shercliff to bring astrophysics down to earth in this way: he had little time for astrophysial MHD unless he could see some possibility of terrestrial exploitation! The Alfvén wave is so strongly dissipated on length-scales of the order a few metres that technological exploitation is hedged about with difficulties; Shercliff addressed these difficulties and indicated how in principle they might be overcome. The particular complication of the secondary flow associated with the propagation of a pulsed Alfvén wave in a cylindrical annulus was treated in detail in a subsequent paper (39).

In 1977 Shercliff spent two terms of sabbatical leave at the Culham Laboratory, Abingdon, where he became involved in engineering aspects of thermonuclear fusion devices. Chief among these is the problem of heat transport and fluid flow in the lithium 'blanket' that may be used both for the breeding of tritium, and for cooling. In the presence of a strong temperature gradient, a significant thermoelectric current (proportional to the temperature gradient) will be generated; equally the current makes a contribution to the heat flux. This complex of new phenomena, involving interaction between velocity, temperature and magnetic fields, constitutes the subject of thermoelectric magnetohydrodynamics (or TEMHD), a subject to which Shercliff devoted much continuing effort over the next six years, and in which he must surely be recognized as a pioneer. In the first of these papers (44), he discussed orders of magnitude for liquid lithium, and showed that the Lorentz force associated with thermoelectric current interacting with a magnetic field of 1T could generate velocities of the order of $25\,\mathrm{cm\,s^{-1}}$, which would make an important contribution both to heat transfer and to the mixing of impurities. He then treated both of these effects in detail, first through analysis of the duct flow geometry, with which he was already so familiar, but now with the inclusion of a spanwise temperature gradient, and secondly through analysis of the effects of a localized impurity, giving a spherically symmetric distribution of the thermoelectric power S, in the presence of a uniform temperature gradient; this combination drives a meridional current that interacts with a uniform magnetic field to generate a zonal flow. Such a flow in itself would not be efficient for stirring, but as Shercliff points out, it is prone to instabilities that could greatly augment the stirring effect. The implication is that a magnetic field and parallel gradient of temperature can conspire to maintain a well mixed melt.

While at the Culham Laboratory in 1977, Shercliff also worked on the problem of the magnetostatic equilibrium of a plasma contained in a two-dimensional geometry by the magnetic field of external line currents. Using the hodograph method, he found a new family of solutions in which the plasma is confined within a curve, which may (in limiting circumstances) exhibit cusps (45). A similar complex variable technique was to prove useful three years later, when Shercliff tackled a problem that he encountered through contact with R. Moreau and his group at the

Madylam Laboratory in Grenoble, namely the shaping of a column of liquid metal with the high-frequency magnetic field associated with a.c. currents in external circuits. Here again, it was no doubt a process of reasoning by analogy that led Shercliff to the appropriate solution (51), in which the fluid boundary again exhibits cusps (in the limit of small surface tension).

Shercliff's long-standing interest in the reform of engineering education led him to serve for three years (1976–79) on the Committee of the Engineering Professors' Conference; this was during the crucial period when evidence was being assembled for the Finniston Inquiry into the Engineering Profession. During his time at Warwick his involvement in problems of blood flow measurement by electromagnetic techniques led him to serve also as Chairman of the Advisory Committee to the Coventry Area Health Authority on Medical Engineering, and then for a period (1975–80) as Vice-Chairman of the Authority itself. A parallel interest in the interface between art and engineering in the design area led him to serve also on the Council for National Academic Awards, and on its committee for Art and Design.

Return to Cambridge, 1980–1983

In 1980 Shercliff was elected to the Fellowship of the Royal Society, and almost simultaneously to the Hopkinson and I.C.I. Professorship of Applied Thermodynamics at Cambridge, succeeding his former supervisor Sir William Hawthorne, F.R.S. At the same time he was re-elected a Fellow of his old college (Trinity). He returned to Cambridge with his family in August and set up house in Huntingdon Road, next door to Sir Harold and Lady Jeffreys. Almost immediately he was involved in major plans to reform the Cambridge Engineering Tripos, partly in response to the microcomputer revolution. Sadly, ill health was to intervene, and he was unable to see these plans through to completion.

Also in 1980 Shercliff accepted appointment as an Associate Editor of the *Journal of Fluid Mechanics (JFM)*, to which he had been a regular contributor since its inception in 1956. The 25th anniversary of the journal was celebrated in May 1981 with the publication of a special 'birthday' number (volume 106) to which each Editor contributed an article in informal vein. Shercliff's 'Reflections of a new editor' (54) provide a valuable insight into his view of his own editorial role, and of the likely future development of the subject. On the first, he wrote:

> 'Referees and potential authors alike may feel the need for a clarification of the editorial position on papers on engineering fluid mechanics. I can only speak for myself, but essentially I think the position is that, of course, *JFM*'s normal high standards of scientific writing must apply (and the jargon-ridden, inept prose that disguises

woolly thought in so much engineering reporting must be avoided) and that as well as a certain amount of novelty, of advancing the art, the paper should above all show physical insight. In the context of true engineering, i.e. design as distinct from engineering science, this ingredient is absolutely crucial because it is only through broad physical insights that creative manipulation of the physical world, the essential job of the engineering designer, becomes possible.'

And on future developments Shercliff predicted and advocated more 'active intervention' in the control of fluid systems. He wrote: '. . . I have in mind the *active* or *interventionist* posture that the engineer is increasingly adopting in the face of cheap micro-computing . . .. It becomes possible to envisage much more intervention in the operation of physical systems than ever before'. He goes on to discuss such possibilities as active control, via feedback mechanisms, of a compliant boundary, and of the more esoteric controls available in MHD where the engineer can 'escape from the frustrating position of being able only to push the fluid at its edges and instead grab and manipulate it in midstream'. (Here he wrote in the blunt and direct manner characteristic of his speech.) And then he says 'Engineering, or interventionist, fluid mechanics seems to be offering endless scope for rewarding investigation, with rewards which one hopes will go beyond the intellectual satisfaction of the practitioner to the prosperity of industrial enterprises and to benefits to the community at large'. Shercliff's appointment to *J. Fluid Mech.* did in fact attract a good number of papers with strong engineering content to the journal, although the interventionism that he urged is still at a fairly primitive level.

In 1980 the International Union of Theoretical and Applied Mechanics (IUTAM) agreed to sponsor a Symposium on Metallurgical Applications of Magnetohydrodynamics, to be held in Cambridge in August 1982 under Shercliff's chairmanship. Shercliff had an unusually wide range of contacts in the world of industrial metallurgy as well as in university magnetohydrodynamics, and he succeeded, as no one else could have done, in bringing them all together and in constructing a programme of lectures of exceptional range and interest covering problems of stirring, shaping, forming, solidification, and particle segregation, with the use of applied electromagnetic fields (both a.c. and d.c.), in a number of industrial contexts: aluminium smelting, continuous casting of steel and other metals, the operation of the coreless induction furnace, arc welding, etc. These were all fields to which Shercliff's own contributions were highly relevant; it was tragic that he was struck by cancer in the weeks before the Symposium, and was in the event unable himself to participate. The Symposium Proceedings, published by the Metals Society in 1984, stand as a tribute to Shercliff's own contributions to the subject of magnetohydrodynamics in metallurgical contexts and to his rare ability to combine mathematical and physical insight with a down-to-earth appreciation of the realities of industrial technology.

Although unable to attend the Symposium, Shercliff took a close interest in all the papers submitted to it, and read them during the months of forced physical inactivity that followed. Despite severe discomfort during this period, he wrote one further paper (58), in which he addressed 'the problem of identifying efficient and accurate methods of calculating the mean magnetic force field . . . from given magnetic field data . . . in order to allow analysis of the resulting fluid motions.' This paper, published posthumously in *Metals Technology* (a publication of the Metals Society), refers to 19 of the Symposium papers, and may be regarded as Shercliff's definitive postscript and seal on the meeting.

In January 1983, with great courage, Shercliff resumed his full duties in the Department of Engineering at Cambridge. He had already been appointed some time previously to succeed Professor W. A. Mair as Head of Department on the latter's retirement in September 1983. In view of the seriousness of the illness that he had been through, and the dubious prognosis of which he was well aware, it would have been entirely understandable if he had withdrawn from this obligation. In the event, however, he did assume the heavy burden of responsibility of Head of Department in October 1983. The vigour and vision that he brought to this position was sadly to be short-lived. His illness recurred late in November, and on 6 December 1983 he died in the Evelyn Nursing Home in Cambridge. His funeral was held in Emmanuel Congregational Church, where he and Daphne had been married 28 years before, and with which they had maintained a close association.

Family and pastimes

Arthur left two sons, David and Hugh, both engineers, and a daughter, Helen. His younger son Hugh attended Arthur's lectures in the Engineering Tripos, and went on to graduate with first class honours in 1984. David is married, with two young children who were a great joy to Arthur in his last years. Arthur was very much a family man. David's tribute at the funeral is revealing:

> 'There was never a dull moment. With Dad's sense of humour and his intense interest in everything about him, he made the simplest things exciting. The ingenious games we used to play to pass the time, the interesting walks, even sitting round the breakfast table could turn into a science lesson. In his play as well as in his work he pursued an idea to the end. We used to joke that after one of Dad's holidays we all needed a holiday . . . driving across America in a car, camping among the grizzly bears, climbing every mountain in sight on one of our mountain walking holidays . . .'

Music was a shared interest for Arthur and Daphne, who had sung together since their student days with the Cambridge University Musical Society, and later while at Warwick with the St Michael's Singers in Coventry Cathedral. As a research student, Arthur took up the clarinet, and played to Daphne's piano accompaniment. In his late forties Arthur discovered a latent artistic talent, and on holidays in Devon (where his father lived in retirement), he painted in oils a number of beautiful landscapes, interiors, and still-lifes; his painting of the interior of St Petrock's Church in Parracombe is one of Daphne's favourites. He also painted portraits of the family, and a self-portrait, in pastel. His paintings were exhibited in Coventry, together with those of other local artists.

All who knew Arthur Shercliff comment with great affection on the warmth of his character and on his spontaneous wit and bluff good humour. I recall two occasions when he was in relaxed mood and when I experienced this warmth and humour at first hand: the first in Israel following the 1975 Beersheva Seminar, when we toured upper Galilee together; the second in 1980 when, after a summer school in MHD in Udine, we together visited Aquileia. On both occasions Arthur was marvellous company and his open good-natured enthusiasm combined with an artistic sensitivity to make him an ideal companion in these excursions in the ancient world.

He was a man of broad talents and generous disposition who gave unstintingly of his time and energy both in his role as University Professor and in the wider range of public service to which he was drawn. His influence and achievements at Warwick and Cambridge have been fittingly commemorated through the establishment of the Arthur Shercliff Memorial Trust whose objective is to provide travel scholarships for engineering students at Cambridge and Warwick Universities. Through this Trust, under which the first awards have now been made, the memory of an idealistic and gifted engineer and teacher will surely live on.

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The photograph reproduced was taken by Godfrey Argent in 1980.

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