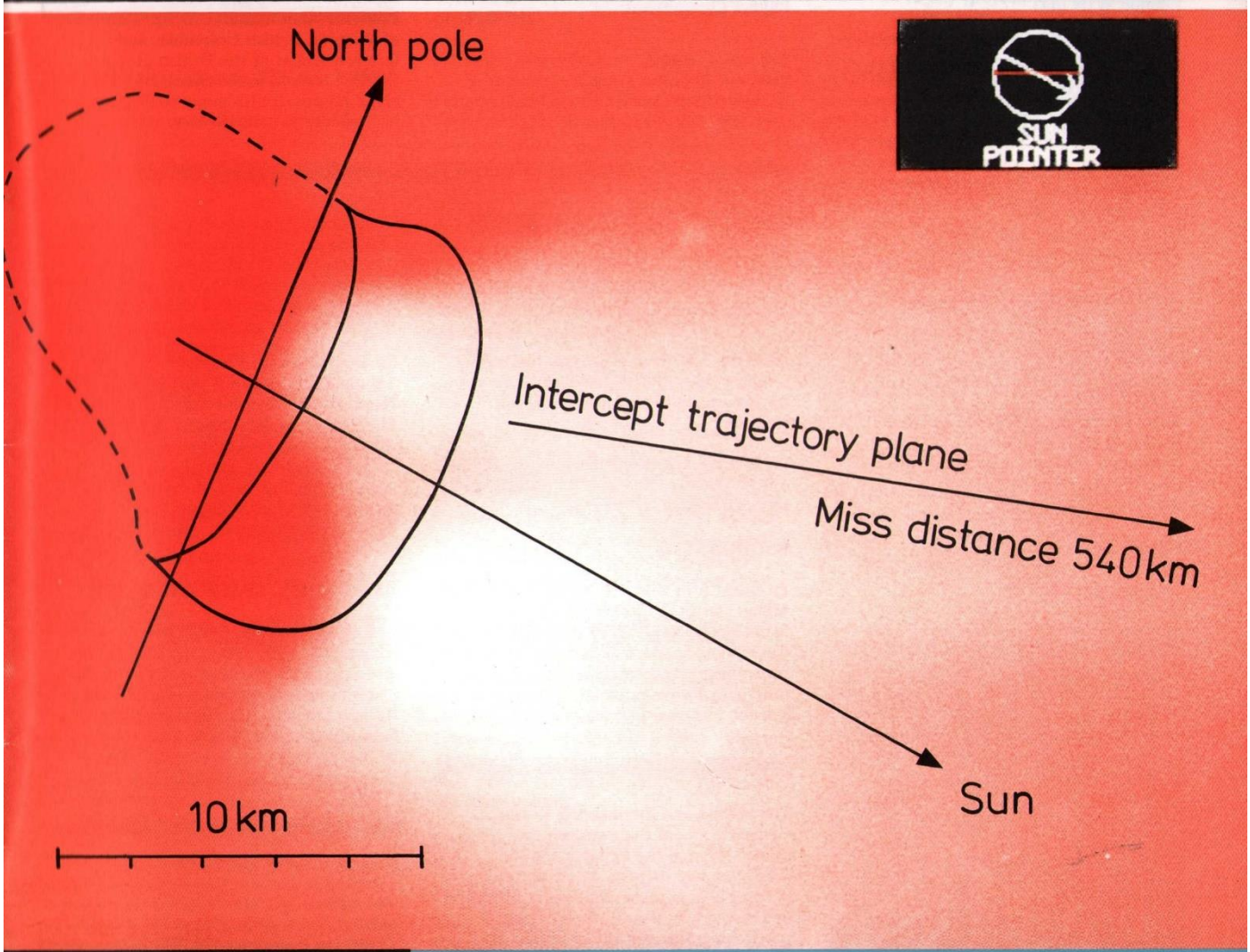
SERC BULLETIN

SCIENCE & ENGINEERING RESEARCH COUNCIL

Volume 3 Number 5 Summer 1986

HALLEY MULTICOLOUR CAMERA



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London Office SERC has moved its London Office from Charing Cross Road to 160 Great Portland Street, sharing the premises with the Agricultural and Food, Economic and Social, and Natural Environment Research Councils. All correspondence for SERC should still be sent to the Swindon address.

Daresbury Laboratory has had a new 'direct dialling in' telephone exchange installed. The new number is Warrington (0925) 603000 (the last four digits being replaced by the extension number for direct access to an extension).

Erratum

In *SERC Bulletin* Vol 3 No 4, Spring 1986, the telephone number for Professor Joseph Black CBE, FEng, the Engineering Design Coordinator, was misprinted; the correct number for Professor Black is 01-839 8000. We regret any inconvenience this may have caused.

Congratulations

Elected Fellows of the Royal Society:
Professor E W J Mitchell CBE, Chairman of SERC; **Professor A N Broers** (Cambridge University), member of Solid-State Devices Subcommittee; **Dr P Day** (Oxford University), member of Chemistry and Neutron Beam Research Committees; **Dr J O Thomas** (Cambridge University), member of Biochemistry and Biophysics Subcommittee; **Dr C J Leaver** (Edinburgh University), SERC Senior Fellow and **Professor D J Wallace** (Edinburgh University), member of Physics Committee.

Britannica Award:
Professor Malcolm Longair, Director of ROE and Astronomer Royal for Scotland (one of five winners, and the only Briton) for "exceptional excellence in the dissemination of learning for the benefit of mankind."

Glazebrook Medal and Prize:
Dr Geoff Manning, Director of the Rutherford Appleton Laboratory, for his wide-ranging contributions to the application of physics in the work of RAL, particularly in high energy physics, computing and the new spallation neutron source, ISIS.

Rutherford Medal and Prize:
Professor Alan Astbury, of the University of Victoria, British Colombia, and formerly leader of the British group at CERN involved in the discovery of the W and Z bosons, for his many contributions to high energy particle physics.

Major new grants

Approved by Council

NUCLEAR PHYSICS

Professor J M Reid (Glasgow University): a rolling grant of £457,000 over three years for experimental research in nuclear structure.

Dr R R Betts (Oxford University): a grant of £557,000 over one year for experimental research in nuclear structure.

ENGINEERING

Professor R M Burstall, Professor A J R G Milner, Dr G D Plotkin and Dr D T Sannella (Laboratory for Foundations of Computer Science, Edinburgh University): two rolling grants totalling £483,700 over four years for research in computer-assisted formal reasoning (see page 24).

SCIENCE

Sir Sam Edwards, Professor D J Thoulness, Professor V Heine and Dr R J Needs (Cambridge University): a grant of £164,000 to be incorporated within an existing rolling programme grant of £531,000 over four years for research into computational physics of complex processes in semiconductors (including low dimensional structures), metals and surfaces.

ASTRONOMY, SPACE AND RADIO

Oxford and Reading Universities: an increase to £4,299,000 in the level of grants associated with the Improved Stratospheric and Mesospheric Sounder (ISAMS), to be flown on the NASA Upper Atmosphere Research Satellite (UARS) due for launch in 1989.

The Science and Engineering Research Council is one of five research councils funded through the Department of Education and Science. Its primary purpose is to sustain standards of education and research in the universities and polytechnics through the provision of grants and studentships and by the facilities which its own establishments provide for academic research. *SERC Bulletin* summarises the Council's policies, programmes and reports.

Enquiries and comments are welcome and should be addressed to the editor, Miss J Russell, at the Science and Engineering Research Council, Polaris House, North Star Avenue, Swindon SN2 1ET; telephone Swindon (0793) 26222.

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Front cover picture

The nucleus of Halley's comet (on left of picture), taken from a distance of about 18,000 km from the GIOTTO spacecraft (see page 5). Two bright jets of dust emanate from the sunlit right edge of the nucleus and extend at least 15 km towards the Sun. Shortly after the picture was taken (at 00:06 UT on 14 March), GIOTTO passed through the lower and brighter of these jets. The lines indicate the outline of the 7 x 14 km solid nucleus and the intercept plane of GIOTTO. (Photo: Max-Planck-Institut für Aeronomie).

European participation in ISIS and ESRF

At a ceremony on 10 December 1985, Ministers of France, Italy and the United Kingdom agreed to cooperate in the development of the spallation neutron source (ISIS) at the Rutherford Appleton Laboratory. In addition, these countries and West Germany agreed to proceed with the preparatory phase of the proposed European Synchrotron Radiation Facility (ESRF) to be sited in France.. Long-term agreements will now be drawn up with the object of signing them in 1987.

Molecular electronics

A report of the Molecular Electronics Advisory Group was presented by its Chairman, Professor Gareth Roberts, to Council in January. The future possibilities in this area are immensely exciting both for science and in terms of applications. Council favours an interdisciplinary approach to this subject with its Science and Engineering Boards supporting a coordinated programme.

Marine Technology Directorate

Final details are being settled for the transfer of SERC's highly successful Marine Technology Directorate to a new body called MTD Ltd under the aegis of the Fellowship of Engineering. The Council will contribute up to £100,000 per annum for the next three years towards MTD's operating costs, which will also be supported by the Department of Trade and Industry. Admiral Sir Lindsay Bryson has been nominated as Chairman of the Board of MTD Ltd.

Advanced fellowships for 1986

Council has approved the award of 12 advanced fellowships to start in 1986. These awards, made for a maximum of five years, are for the support of outstanding researchers who are well qualified for academic careers but who do not have a permanent post. Council also agreed that in future the period of tenure of these fellowships may be interrupted for up to two years to allow the fellow to take up an offer of a sabbatical period, for example at an academic institution abroad or in UK industry.

Forward look

The major item of business before the Council at its February meeting was the formulation of the Forward Look which details expenditure by programme over the three years from 1987/88. Council agreed outline proposals and selected, from new developments that have been proposed, those to be funded as priorities and those to be the subject of the bids for additional funds when the Forward Look document goes to the Advisory Board for the Research Councils (ABRC).

Cooperative Awards in Science and Engineering

Financial contributions - Council has decided to increase the present level of minimum contribution by the collaborating firm in the Cooperative Awards in Science and Engineering (CASE) scheme by £300. The new rate will apply to projects submitted after the 31 January 1986 closing date, and to any projects carried forward.

Abolition of closing date - In order to make it easier for CASE research studentships to be taken up, the closing date for the nomination of students to work on approved CASE projects has now been abolished. Students may now be nominated for any approved award as long as it remains available for take-up. Revised detailed regulations have been sent in a letter to institutions.

Cooperative Research Grants

Council received a report from its Cooperative Research Grants Panel. Council wishes to encourage this form of support and instructed the Panel to develop further its activities in the strategic areas of science and engineering.

Mr R B Horton

Mr Horton has resigned from the Council on his appointment as Chairman of the Standard Oil Company, in the United States.

The future of the Royal Observatories

Council considered in January a report from a working group chaired by Sir John Kingman, former Chairman of Council, on some aspects of the future provisions for UK research in astronomy. The UK ground-based astronomy programme is now conducted wholly overseas, its major centres being the telescopes on La Palma and Hawaii. The need to have resident staff at these sites, coupled with restrictions in the future funding, calls for a re-examination of the UK 'base' - which at present is centred on the Royal Observatories at Herstmonceux and Edinburgh. After a discussion of the topics presented in the report, Council decided to put in hand an exercise to investigate all of the implications, including scientific and economic, of some specific options for changes to the existing site arrangements.

At its meeting on 19 March, Council decided that it wished to move the Royal Greenwich Observatory (RGO) from its present site. It favours three options, in order of priority: association of RGO and the Royal Observatory, Edinburgh (ROE) on the Blackford Hill (Edinburgh) site, or the housing of RGO on the campus of either Cambridge or Manchester Universities. It decided to seek the views of the staff of its two establishments and the research community that they serve on the three options.

It took the decision to move on the basis of a detailed consideration of the scientific and technical benefits inherent in a number of options open to it for reorganisation. These options were presented to the Council by its Chairman, Professor E W J Mitchell CBE, FRS, following a series of visits which he and the Council Secretary, Dr J A Catterall, had made to the country's leading academic centres of astronomical research, and backed up by an appraisal by the Council Works Unit.

In the light of the new methods of working through observing from island sites and the associated requirement for research and development in the home-bases, Council, in January, concluded that the activities of the RGO would benefit from being carried out either in direct collaboration with the activities of the ROE or on a university campus with a good relevant academic environment, especially in astronomy but also in disciplines related to instrument development - physics, computing, microelectronics, and control and instrumentation engineering. Council believes that moving the RGO from its present site will lead to a substantial benefit for the research community. There is everything to be gained from association with either the ROE or a university campus, but ultimately the gain will only occur if people want to take advantage of the potential interaction. Council aims to provide an atmosphere in which that will occur and develop.

The Chairman of the Council is currently overseeing a detailed assessment of the practical problems inherent in each case before arriving at the final choice, which he expects to be able to recommend to Council in June 1986. It is not envisaged that any move will take place until about 1990.

Halley the man

Even before the current media hype, if members of the general public recognised the name Edmond Halley at all it would almost certainly have been because of the comet which now bears his name. Yet Halley's cometary work was only a small part of his output and astronomy only one, if to him the most important, of his interests.

As a young man Halley had all the advantages. He was outstandingly clever, his family wealthy, his father indulgent and he was blessed with an attractive personality and considerable good looks. He was already beginning to make his name in the scientific world when, at 16, he went up to Queen's College, Oxford. At the age of 18 he was corresponding with John Flamsteed, the first Astronomer Royal, at Greenwich and the two men became, initially at least, friendly; but the association was to turn sour in later years when Halley became embroiled in the great confrontation between Flamsteed and Newton over the publication of the former's observations.

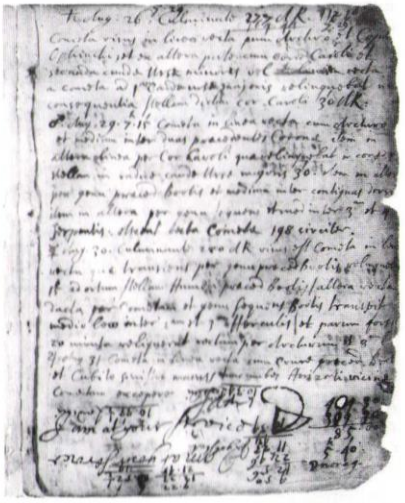
At the age of 20, Halley went to Saint Helena and set up a small observatory from where he made the first scientifically accurate survey of stars in the southern sky. This early passion for astronomy never waned. He was the first to suggest that nebulae were probably vast clouds of interstellar gas with formation processes taking place within them, and the first to try to apply Newton's concept of gravity to the theory of the Universe. He also made outstanding contributions to calculating the distance of the Sun from the Earth and to measuring longitude at sea. When he became Astronomer Royal at the advanced age of 63 he embarked on and completed the observation of a 19-year lunar cycle.

The sea was another passion. He was made a Captain in the Royal Navy in order to undertake a series of voyages to research methods of measuring longitude, mapping magnetic variations and coastal surveying. These were the first naval expeditions for purely scientific purposes ever funded by the British government and Halley created the methods we still use today in mapping trade winds and plotting lines of magnetic variation. In 1693 he was asked to calculate both the total acreage of each of the counties of England and the country's total land mass. His answer to the latter was 38,660,000 acres, an estimate we now know to be about 3% too high, a remarkably accurate figure given the methods available at the end of the seventeenth century.

When insurance companies today use tables to calculate life expectancy they are consulting figures first calculated by Edmond Halley. When naval divers explore the oceans in diving bells and suits they are using the modern equivalents of equipment first designed and tested by the same man. Halley had not only enormous energy and drive but also, more importantly, great ingenuity and attention to detail, two sure signs of genius.

The story of the publication of Newton's *Principia* in 1687 typifies Halley's character. He it was who first suggested to Newton that he should publish his theories; Halley provided Newton with constructive criticism, dealt with printers and booksellers for him and introduced the great work to the Council of the Royal Society. The Council was unanimous in agreeing that the *Principia* should be published but could not afford to do so from the Society's own funds. Halley then stepped in again and paid the whole cost of publication himself. In later years Newton paid him the graceful compliment of referring to *Principia* as 'Mr Halley's book'.

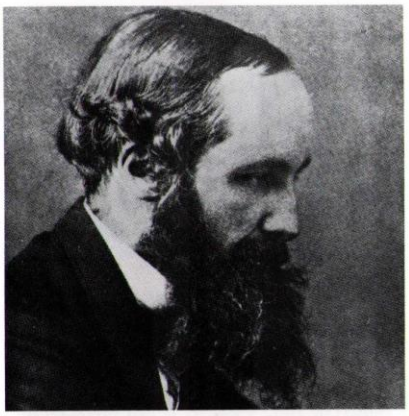
Edmond Halley: an engraved portrait by Vertue after the original oil painting by Phillips. (RGO Archives).



Halley's calculations for the orbit and return of the great comet of 1682 (Halley's Comet). (RGO Archives).

Halley deserves to be remembered for this, and for so much else, as well as for his comet.

Janet Dudley
Royal Greenwich Observatory



James Clerk Maxwell

James Clerk Maxwell Telescope

The millimetre-wave telescope currently under construction at the Mauna Kea Observatory on Hawaii (see *SERC Bulletin* Volume 3 No 1, January 1985) has been named the James Clerk Maxwell Telescope. When it opens next year, it will be the largest telescope in the world for observations in the millimetre and submillimetre regions of the spectrum. It is being built jointly by the UK and the Netherlands, with funds provided in the ratio of 4:1 by SERC and ZWO (the Netherlands Council for the Advancement of Pure Science).

James Clerk Maxwell (1831-1879) was born and educated in Edinburgh. After three years at Edinburgh University he went to Cambridge University and graduated there in 1854. He occupied Chairs at Marischal College, Aberdeen (1856-1860), King's College, London (1860-1865), and Cambridge (1871-1879), where he planned and developed the Cavendish Laboratory. His contributions to physics spanned a wide range of experimental and theoretical topics but he is particularly remembered for his work on the kinetic theory of gases and his electromagnetic equations. His theory of the nature of visible light led (after his death) to the discovery of the complete electromagnetic spectrum.

Halley's comet reveals its secrets

In the first few minutes of Friday, 14 March, ESA's GIOTTO satellite passed within an estimated distance of 540 km of the nucleus of Halley's comet, revealing information on the composition and structure of this famous celestial body. UK scientists played an important role in this prestigious mission, leading two of the ten international teams which developed and operated scientific instruments on board.

ESA's GIOTTO satellite, built by British Aerospace, was launched by an Ariane launcher from Kourou in French Guiana on 2 July 1985 (see *SERC Bulletin* Vol 3 No 2, Autumn 1985). After three revolutions in its transfer orbit, the spacecraft was injected into heliocentric orbit, starting its 700 million kilometre journey towards Halley's comet. During its 'cruise phase', GIOTTO performed faultlessly. All on-board experiments were tested during autumn and winter of 1985/86 and made ready for their intensive period of activity during the satellite's encounter with the comet on 13/14 March 1986 - a period of a few hours when GIOTTO flew through the coma of the comet at an estimated distance of 540 km from the nucleus. To target the satellite precisely, information on the comet's position gained by the USSR satellites Vega 1 and 2 and Japan's Planet A, which flew by Halley's comet earlier in the month, was used.

GIOTTO had a payload of ten scientific experiments - a camera for imaging the comet's nucleus, three mass spectrometers for analysis of the elemental and isotopic composition of the cometary gas and dust environment, various dust impact detectors, a photopolarimeter for measurements of the coma brightness, and a set of plasma instruments for study of the solar wind/comet interaction. Two of these instruments were developed by UK groups leading international consortia: the Johnstone Plasma Analyser (JPA) and the Dust Impact Detection System (DIDSY).

GIOTTO achieved its main objective, which was to penetrate as close as possible to the nucleus of comet Halley. In doing so it obtained an image of the nucleus which showed a body that was larger than expected (15 km long by at least 5 km wide) and darker. Emission of gas and dust from the nucleus was confined to three or perhaps four well-defined jets on the sunward side (see front cover picture).

The spacecraft entered one of the jets 30 seconds before closest approach and encountered high densities of dust particles for the first time. The dust impacts produced a high density of hot plasma from the vaporised materials. At two seconds before the expected closest approach, dust impacts caused a nutation of the spacecraft spin axis which caused periodic dropouts of telemetry at the ground station. However, data were lost for no more than one minute in total. All experiments performed perfectly up to two seconds before encounter, but at that stage the dust bombardment put several out of action.

DIDSY

Dust impacts, which were critical to the surival of GIOTTO, were the focus of study by DIDSY, the instrument developed by an international team led by Professor Tony McDonnell, Kent University, supported by the Rutherford Appleton Laboratory. DIDSY, which was mounted on GIOTTO's dust shields, first registered an impact on the piezoelectric sensors on the 1 mm-thick dust shield at 275,000 km from the comet's nucleus. A fairly low, but increasing, level of activity followed: the capacitor impact sensor responded at a distance of 141,000 km, and the impact plasma sensors at 250,000 km. The relatively quiet approach to the nucleus was one order of magnitude lower than modelling predictions, reflecting for the larger masses a decrease of nuclear activity over the previous day; for smaller and faster masses it indicated that the spacecraft was not encountering the jets coming from small active regions on the nucleus. This changed dramatically in the last pre-encounter minute, however, with activity increasing to nearly 100 dustshield perforations per second.

The Johnstone Plasma Analyser

Plasma experiments also revealed some unexpected features of Halley's comet. The JPA experiment, built by a international team led by Dr Alan Johnstone from the Mullard Space Science Laboratory, University College London, first identified hydrogen ions of cometary origin at 16:00 UT on 12 March when still 7.8 million km from the nucleus. During the next 24 hours the solar wind flow, which seemed to be very steady and relatively slow (350 km/s) up stream, became increasingly disturbed by wave motion stimulated by the interaction with the cometary hydrogen ions. Between 19:30 UT and 20:15 UT on 13 March there were a number of large oscillations in the velocity and density of the solar wind which ultimately produced a flow which was slower, deflected away from the comet, and in which the temperature was increased. This transition region, which is 200,000 km thick at a distance of 1 million km, corresponds to the anticipated bow wave caused by mass-loading. Near the comet, as expected, it moved out of the field of view of the JPA sensors. Although one of these sensors failed 1½ hours after closest approach, the second continued to make observations for the next 27 hours and obtained a complete profile through the comet.

GIOTTO's future

Despite the damage done by the dust jets from Halley's comet, GIOTTO was recovered and the overall spacecraft systems and subsystems remained functional. An attitude manoeuvre was successfully performed in the early hours of 15 March to maintain the telemetry link with the ground and, on 19 March, GIOTTO was put into an orbit which will bring it close to the Earth in 1990. ESA scientists have now to decide what will happen to it when it returns.

The British National Space Centre

In January 1986, Council agreed to participate in the British National Space Centre, subject to further negotiations over detailed structure and functions.

The British National Space Centre (BNSC) was established in November 1985, when the Director General, Mr Roy Gibson, was appointed. The BNSC will have two main Divisions: the Policy and Programmes Division situated at Millbank Tower, and the Projects and Technology Division which will call on existing support facilities of partners, including the Royal Aircraft Establishment, Farnborough, and Rutherford Appleton Laboratory. The BNSC will coordinate the space-based activities of several government departments and research councils - the Department of Trade and Industry, Ministry of Defence, SERC and Natural Environment Research Council among others - by developing an overall UK policy for space through a national 'space plan', and by developing effective mechanisms for coordinating projects and technology work at RAE, RAL and other appropriate establishments.

SERC expects to play a full part in the work of the Centre. SERC has substantial programmes in astronomy and geophysics which require space techniques, and small but growing programmes in space-based engineering research. Subject to successful negotiations, these programmes will form part of the activities of the BNSC.
As part of its activities in preparation for participation in the BNSC, SERC has developed a plan for its future programme of space-based research; this plan was endorsed by Council in February 1985 and was submitted to BNSC in early March.

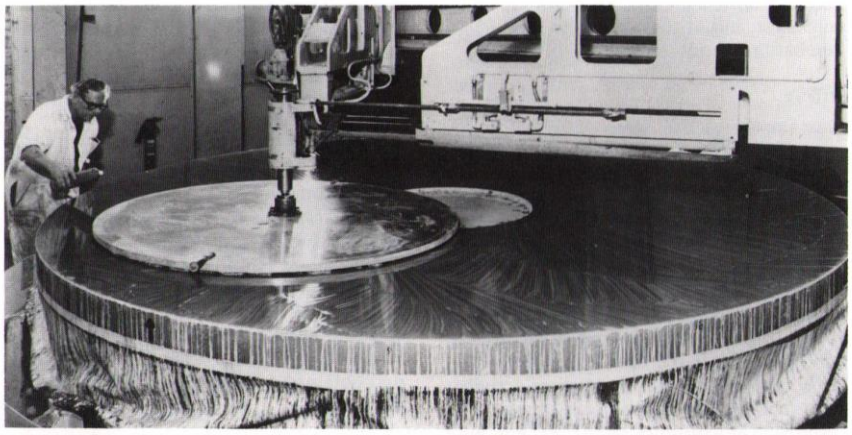
The 4.2 m mirror for the William Herschel Telescope

The primary mirror for the 4.2 m William Herschel Telescope under construction on La Palma has been completed and accepted by the Royal Greenwich Observatory from NEI Parsons plc. The mirror is believed to be the smoothest of its size ever made and was figured in the NEI Parsons optical workshop in Newcastle by Dr David Brown. It was due to arrive on the Canary Islands in April.

The mirror blank, a piece of glass-ceramic called CerVit, made by Owens-Illinois of Toledo, Ohio, cost some £0.5 million. The figuring of the mirror to obtain its accurate surface cost the same amount, making the total value of the mirror £1 million.

Tests on the mirror surface show that, overall, the surface departs from ideal by less than one 24,000th of a millimetre. On a small scale, over a 2 cm^2 area, the surface is much smoother than this, with a roughness of about one 160,000th of a millimetre (1/80th the wavelength of light).

The reason that the mirror surface is specified this way is connected with the properties of the atmosphere on La Palma. At any one time the air over the mountain top is made up of columns of perfect air tilted in relation to one another - much like the facets in a pane of frosted glass. The bigger the facets, the clearer the view through the window, and on La Palma the facets of pure air are often as big as 50 cm in diameter. Thus, over an area of 50 cm^2 or less, the Herschel mirror has to be almost perfect.



The mirror for the 4.2 m William Herschel Telescope undergoing final polishing at the Newcastle works of NEI Parsons.

Not only was the manufacture of the mirror successful in the near-perfect smoothness of its surface but also less of the edge of the mirror was wasted than had been thought necessary. A margin of 2 cm at the edge had been set aside for errors in the figuring process. NEI Parsons kept the waste zone to 7 mm, so donating more than 40 cm^2 of additional telescope collecting area to the British, Dutch and Spanish astronomers who will use the telescope from 1987.

When it is completed in 1987, the William Herschel Telescope (named after the British astronomer, best known for discovering the planet Uranus in 1781 and also a pioneer of modern cosmology) will be the third largest single-mirror telescope in the world and it is expected that the exceptionally good observing site at La Palma, together with the use of the most modern light detectors and the superb quality of its mirror, will make the Herschel telescope the best in the world.

NASA awards for AMPTE project team

Dr John Harries (left), an associate director at the Rutherford Appleton Laboratory, receives the certificate for the NASA achievement award for RAL's work on the AMPTE project (see SERC Bulletin *Volume 3 No 2, June 1985). NASA's AMPTE project manager Gil Ousley (right) also presented some 50 certificates to other members of the UK element of the AMPTE mission, including the institutions that provided the experiments and British Aerospace who were responsible for some of the engineering of the satellite. AMPTE was a three-satellite mission involving the UK, USA and West Germany in a project to explore the effect of the solar wind on the Earth's magnetosphere. Although a fault closed down the UK satellite after five months, the experiments worked so well and efficiently that in those five months more data was obtained than was envisaged in the original nine-month lifespan. So far some 70 research papers have been written analysing the data obtained.*

Bubble chamber holograms replayed at RAL

Bubble chambers have conventionally used imaging photography to record the tracks of ionising particles in the chamber and, by studying the photographs obtained, much has been learned about the properties and interactions of elementary particles. Recently, holographic recordings have been used to supplement or replace conventional photography in several bubble chamber experiments.

The most ambitious of these projects is one involving the 15-foot bubble chamber at Fermilab, USA, where both holographic and conventional cameras are being used to record the interactions in the bubble chamber liquid of neutrinos produced at the world's highest energy fixed-target accelerator. Physicists from several UK institutes (Birmingham University, Imperial College, Oxford University and Rutherford Appleton Laboratory), as well as groups from Europe and the USA, are participating in the experiment. The UK and European groups have collaborated to design and construct a novel machine to replay holograms recorded in the bubble chamber, and the machine, sited at RAL and named HOLRED, ('hologram reduction') is currently being used to analyse holograms taken at Fermilab last summer.

The interest in using holography in bubble chamber experiments arises from the discovery, in the past decade, of several families of particles whose lifetimes are such that they travel typical distances of only a few millimetres between their production and decay points. To obtain a clear view of the tracks produced by such particles, high optical resolution is needed.

With conventional optics, this can only be achieved over a very limited depth of field; for instance, for a resolution of 100μm, the corresponding depth of focus is about 1 cm. In the Fermilab experiment, the incoming beam of neutrinos, being electrically neutral, cannot be focused into a plane of this depth; interactions may take place over a large fraction of the volume of the chamber. Holography overcomes the problem of obtaining high resolution over a large depth because a hologram does not record the image of an object, but rather the interference of the wavefront coming from the object with a reference beam derived from the same coherent source.

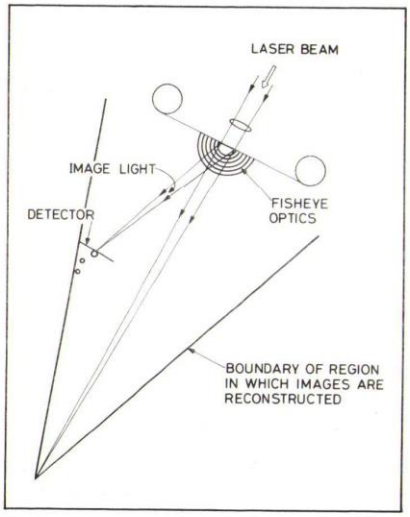
The hologram is replayed by illuminating it with a time-reversed version (ie going backwards) of the original reference beam. The interference fringes recorded in the photographic emulsion then diffract part of the illuminating beam to produce a real image of the original object. If the recording and replay systems are optically identical, an unaberrated image is produced, which has unit magnification. It is this principle which underlies the design of HOLRED: a copy of the original bubble chamber optics, including fisheye lenses, is present in the machine, and the wavelength of the pulsed ruby laser used to take the holograms is achieved in replay by using a continuous wave dye laser tuned to the ruby wavelength.

One unavoidable difference between recording and replay conditions is that the space filled with a liquid hydrogen-neon mixture in the chamber is occupied by air in HOLRED; the corresponding refractive index change leads to a demagnification of the image by a factor of about 2. This is a fortunate feature of the optics, as it necessitates a machine whose base measures 'only' 4 m x 3 m.

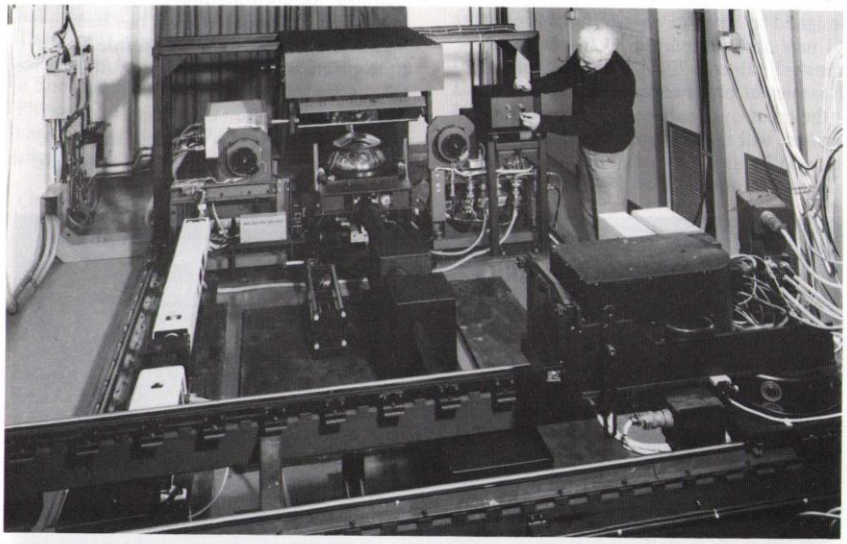
The replayed images are observed by TV and photographic cameras mounted on a stage which can be driven to any point on three axes in the reconstructed bubble chamber space. Using coordinates of interesting interactions observed and digitised on the lower resolution photographic views, the stage is driven under computer control so that the holographic image can be viewed on a TV monitor or recorded photographically.

A further batch of data is expected from Fermilab later this year with various improvements made to the optics in the bubble chamber. The use of holographic optics in the chamber, and of HOLRED to replay the holograms, represents an application to particle physics of a technique unique to holography — that of large volume, high-resolution visual inspection.

R L Sekulin
Rutherford Appleton Laboratory



Principle of holographic replay to provide a real image of the object, detectable on a screen or by TV or photographic camera.



A view of HOLRED, showing the replay laser, a part of the beam optics, the holographic film transport systems, the replay fisheye optics and the cameras used to detect images.

Modernisation of the Institut von Laue-Langevin

The Institut Max von Laue - Paul Langevin (ILL) at Grenoble (France) with its High-Flux Neutron Beam Reactor (HFBR) is a European facility for research in physics of condensed matter, chemistry, biology, nuclear and fundamental physics, and materials science. The United Kingdom (SERC), France (Commissariat à l'Energie Atomique and Centre National de la Recherche Scientifique) and the Federal Republic of Germany (Kernforschungszentrum Karlsruhe) are the three partners sharing investment and operation of this research centre. This article gives a brief and highly selective account of some of the scientific consequences of the recent modernisation programme.

The operation of the HFBR and of the first associated instruments started in 1972. In 1979 the ILL partners decided to provide the necessary funds (104.2 million FF at 1979 prices) for a modernisation programme which was planned to run from 1979 to the end of 1985. The programme has resulted in new buildings to house the Central Computer and Biology and Chemistry Groups together with an out-station of the European Molecular Biology Laboratory. A second guide-hall was constructed in 1984 to house the guides and instruments to be fed by the second (horizontal) cold source which is itself to be installed in a year from now. Improvements in computing facilities and the development of sample environments, neutron selection and measuring techniques have been achieved to accompany a major instrument modernisation programme. The modernisation work has also facilitated a major intervention programme involving the overhaul of reactor parts exposed to high levels of radiation.

The improvements which followed the instrument modernisation can be described under three main categories. First there is a group of instruments which, when fully operational, will have no equivalent anywhere in the world. For example, the new spin-echo spectrometer (IN15) is designed to have an energy resolution of 0.1 neV and a minimum Q (momentum transfer) value of 10^{-3}Å^{-1}. Studies of the dynamics of polymer solutions, especially at the cross-over between various diffusion regions, will now be possible. The IN15 can also be used to study critical dynamics adjacent to magnetic and structural phase transitions and for research into spin dynamics and spin relaxation in disordered and low-dimensional spin systems. Another new instrument, DB21, is the small angle diffractometer for protein crystallography. Biological macromolecules and materials often exist as a complex of two or more distinct chemical species (chromosomes, for example, consist of protein and DNA). Contrast variation with H_2O/D_2O mixtures using neutron diffraction is a very effective method for distinguishing different components within a macromolecule.

Classical methods would require very high resolution, which in many cases is a formidable or even technically impossible undertaking. DB21 has been optimised for low resolution studies involving H/D labelling and the information provided will complement high resolution X-ray studies or indeed make a valuable contribution in its own right.

The second group of instruments includes triple-axis spectrometers, diffraction and time-of-flight machines, where the performance has improved by an order of magnitude. On the liquids and amorphous solids diffractometer (D4B), isotopic substitution experiments can now be performed on very dilute systems; for example, the coordination complex formed by Cu in amorphous As_2Se_3 has been investigated at very low (3 atomic % Cu) concentration. The new version of IN2, IN20, with its very high flux, allows inelastic polarisation experiments to be performed. Problems as disparate as the apparent degeneracy of certain magnetic and lattice excitations in USb and the identification of magnons in $RbFeCl_3$ are readily tackled on IN20. The improvements to IN1 (the hot-source triple-axis spectrometer) allowed an important experiment on nickel to be performed. The spin-wave modes were investigated as they encountered the dense region of Stoner excitations. It was shown for the first time that the spin wave continues to propagate - a result of considerable significance to band theorists studying the fundamental problems of the ferromagnetism in nickel. These experiments are possible because IN1 allows high energy excitiations to be studied at comparatively small values of Q.

Finally, several instruments were improved in a more modest way, but nevertheless will allow significant new science to be performed. For example, the science possible on the popular back-scattering instrument IN10 has always been limited by the low flux. The new analyzer crystals and the increased flux from the modified cold source have led to an improvement of about a factor of two. This will, for example, allow much cleaner studies of the dynamics of hydrogen in metals to be investigated because lower hydrogen concentrations can be used which means that there is less hydrogen—hydrogen interaction. Similarly, the isotope effect which occurs when hydrogen is replaced by deuterium can also be better characterised. The improved small angle scattering instrument D11C (replacing D11) has an important new facility: the distance between the sample and the detector can be varied from 1.2 m to 36 m. This means that, without disturbing the sample or its environment, regions of Q in the range 10^{-3} to 10^{-1}Å^{-1} which warrant detailed study, can be readily investigated.

The technological boost to the equipment induced by the modernisation programme was necessary to cope with the impressive number of experiments (800-850 scheduled runs per year) and the increasing experimental requirements. The Institut's high technological standard is undoubtedly an important element of its impact. The success of the modernisation will enable the ILL to look forward to another period of world class research in the field of neutron science.

Professor J E Enderby and Dr B Maier
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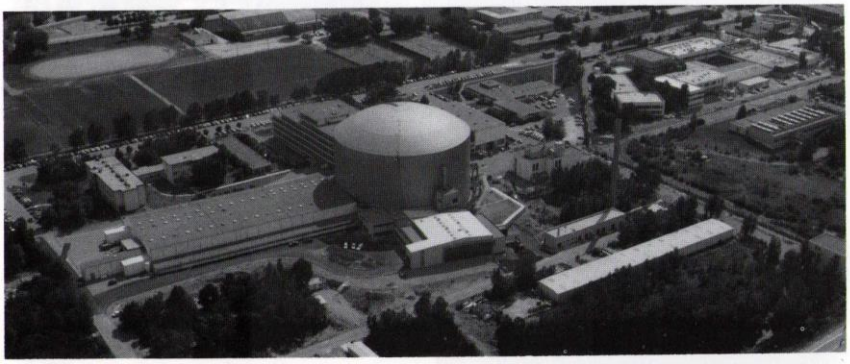

Aerial view of the ILL reactor and main buildings

High pressure research in UK universities

Recent advances in techniques, principally involving the diamond anvil cell (dac), have revolutionised the use of high pressure as a tool for the investigation of solid state phenomena. SERC supports experimenters using high pressure techniques from a wide range of disciplines, such as chemistry, physics, biology and material science. The support is given through a number of channels, including the High Pressure Facility provided at the Standard Telecommunication Laboratory (STL) at Harlow; SERC's Daresbury and Rutherford Appleton Laboratories; and direct grants to the scientific community. *SERC Bulletin* Volume 3 No 2 (June 1985) featured high pressure neutron facilities and, in Volume 3 No 3 (Autumn 1985), we reviewed work involving the Synchrotron Radiation Source. Here we discuss research in the academic community and a concluding article will describe work at the High Pressure Facility at STL.

The UK academic representation in high pressure research and its applications is relatively small and rather fragmented, although showing signs of growth. The aim of this article is to indicate the main areas of activity.

Equipment design and development

Substantial expertise in many aspects of high pressure design and technology, particularly with fluid-pressure systems, is centred on the Mechanical Engineering Departments at the Queen's University, Belfast and at Leeds. The increasingly popular diamond anvil high pressure cells are designed and marketed worldwide by Diacell Products Ltd, which is based upon the research group at Leicester University (Chemistry Department, the author).

In reviewing applications it is helpful to divide the field into 'making' and 'measuring' aspects.

Making things

Both the chemical and geological communities use elevated pressures in synthetic and mechanistic work. At the very low pressure end (a few hundred atmospheres), valuable work has been done by Dr R Whyman (ICI, Runcorn) and Dr M Kilner (Durham, Chemistry Department) on reactions of low-valent metal complexes with CO, hydrogen and hydrocarbons, chiefly with mechanistic problems related to homogeneous catalysis in mind. The main analytical tool used is infrared spectroscopy. A related interest is represented by Dr J Burgess (Leicester, Chemistry Department) with his studies of volumes of activation of reactions of inorganic complexes in aqueous solutions at pressures up to about 0.2 GPa.

Strictly preparative-scale organic synthetic use of high pressure (up to 1.5 GPa) is focused upon Dr N Isaacs and Dr A V George (Reading, Chemistry Department) who attract a steady stream of applicants and combine mechanistic insight with preparative skills. A national preparative high pressure facility at Reading has recently been funded by SERC's Chemistry Committee. A pressure of 2.5 GPa is probably the useful limit for such work, both from a technique viewpoint, and because viscosities then become too high to permit the movements associated with molecular interactions and rearrangements. The combination of temperature upwards of several hundred degrees C with high pressures leads, *via* Dr B Cleaver's studies of molten salts (up to 2 GPa) (Southampton, Chemistry Department), to geological interests.

Measuring things

High pressure physics is thinly represented in the UK. Although some kind of high pressure device can be found in a good many departments, and perhaps three or four can be rated as centres of knowhow and activity, none can reasonably be described as having a world lead in the sense that the Japanese have in multi-anvil press design, or the Geophysical Laboratory in the extremes of diamond anvil cell use. A group at Reading (Physics Department) has long experience with tetrahedral anvil presses (7 GPa): there is another such device at Imperial College, London (Chemical Engineering). This design type is useful especially when samples are needed which are larger than can be accommodated in a dac. The same can be said of Drickamer cells, in which the sample is compressed within an alkali halide matrix by tungsten carbide anvils. These cells, with an upper limit of about 20 GPa, have been extensively used by Dr W F Sherman (King's College, London, Physics Department) in studies of a wide variety of cations and anions doped into alkali halides.

Other applications tend to centre on the study of low-dimensional solids. Dr A Adams (Surrey, Physics Department) has used the pressure variable for some years with effect in aspects of semiconductor research, and is currently able to generate pressures to 8 GPa in combination with 100 K. Similar interests are represented by Professor Stradling (Imperial College, Physics Department), Dr Yoffe and several of his collegues (Cambridge), Dr P Reidi (St Andrews), Professor E A Davis (Leicester) and Dr J Wilson (Bristol).

Our group at Leicester (Chemistry Department, the author) has worked for many years on phase relations in inorganic solids, chiefly using vibrational spectroscopy. Many new high pressure phases have been discovered and phonon shifts with pressure determined. The latter data are important contributions to theoretical studies of solids, helping to define interatomic potentials. The same stimulus has prompted a move to energy dispersive X-ray powder diffraction activities using synchrotron radiation in order to obtain the pressure dependencies of lattice constants (the author; Dr P D Hatton, Edinburgh, Physics Department). Others with high pressure X-ray interests include Professor Saunders (Bath, Physics), Dr R Nelmes (Edinburgh, Physics); and Professor M Hart (Manchester, Physics) and Dr W F Sherman (King's College, London, Physics) who have used Drickamer cells in connection with synchrotron radiation.

The total picture is thus one of significant activity which shows signs of real growth. A recent collaborative programme involving six universities (Cambridge, Imperial College, Nottingham, Oxford, St Andrews and Surrey) and STL, centred on the SERC-funded facility at Harlow, as part of the Low Dimensional Structures Programme, is to be welcomed. X-ray crystallography at very high pressures is one area in which UK could potentially assume a world lead.

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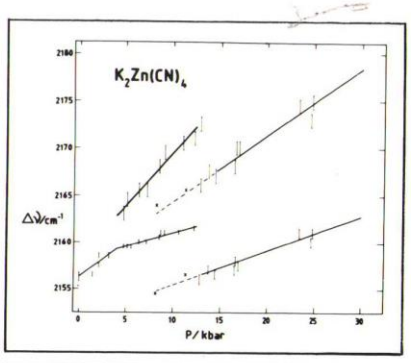


Phonon shift plots for $K_2Zn(CN)_4$ (D M Adams and P D Hatton).

Nonlinear systems

The area of research that can be labelled nonlinear systems has developed remarkably in recent years. It has become one of the most lively and rapidly expanding parts of applied science. It now excites wide attention among physicists, engineers and biologists as well as mathematicians, and its interdisciplinary ramifications contribute largely to its present vigour. Examples include turbulent transition in aerodynamics, barolinic instabilities in meteorology, laser devices and fibre optics, toroidal plasmas in thermonuclear fusion experiments and studies of population dynamics and of patterns in biology. The growth of interest arises from the great range of useful applications promised by new developments in the basic understanding of nonlinear processes.

Three modern developments have given impetus to current research on nonlinear systems. First, on the purer mathematical side, there is the increasingly prevalent use of abstract analysis, qualitatively exact but 'non-constructive', in application to realistic problems arising from applied science. When allied to classical analysis and modern numerical computation, this style of investigation can be incisive where more conventional methods of applied mathematics alone are insufficient. Thus, the old dichotomy between pure and applied mathematics has become less sharply defined.

Second, also on the mathematical side, we have seen the development of weakly nonlinear theories, by means of which complex field equations (the Navier-Stokes equations of fluid motion, for example) have been reduced to simpler, ordinary or partial differential systems (amplitude equations) in defined parameter ranges. Explanations have been given of important nonlinear physical phenomena such as the additional drag or torque associated with oscillations or vortices. Thus a bridge has been created to span the divide between linearised systems and truly nonlinear ones.

Third, on the experimental side, great advantages for research on nonlinear phenomena are provided by modern instrumentation, notably in the realm of signal-processing. The experimental precision thereby available offers great scope for research into, for instance, turbulence in fluids. Although good experiments in this field are never easy, the prospective rewards have been heightened by the greater precision attainable. This precision can best be utilised when guided by sound mathematical appreciation of the nonlinear phenomena.

Relevant research areas

It is convenient to divide into four sections the research activities which have been proposed for an initiative in nonlinear systems:

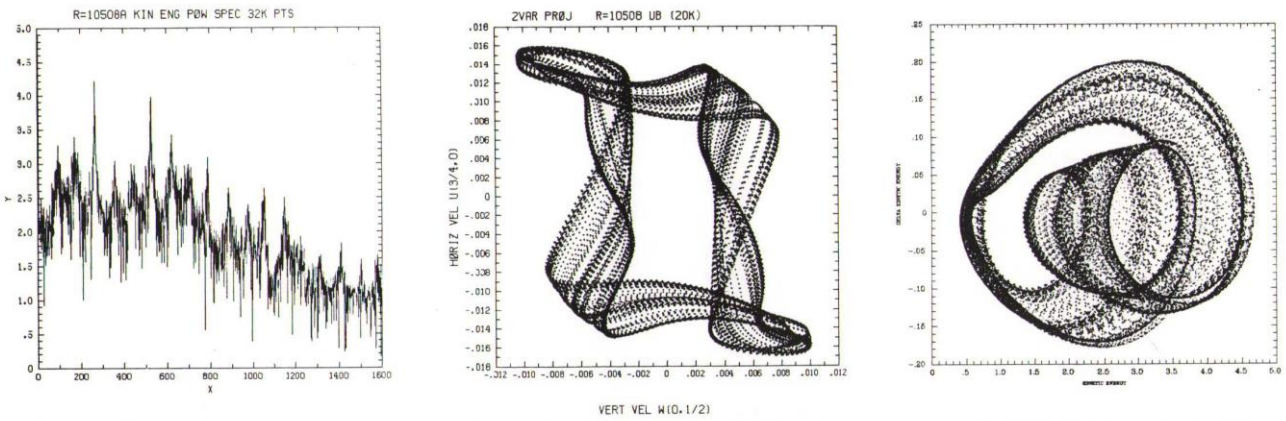
- ***Solitons and integrable systems***

This concerns what are known as integrable systems of nonlinear partial differential equations. In its simplest form, a soliton is a single hump or wave propagating in a system which might, for example, be a water surface, a fibre optical system or a laser device. Although the possibility of solitary waves of this type has been known for well over a century, it is only in the last two decades that important mathematical discoveries have been made, indicating that solitary waves may interact with each other and emerge unscathed except for a phase shift. In view of the nonlinearity of the systems concerned, it is a remarkable result and much is now known about the class of nonlinear partial differential equations whose solutions have this property. On the pure mathematical side, work is forging ahead on the algebra and geometrical structures of the equations, on associated Hamiltonian structures and on other integrable systems. The method of inverse scattering, by which solitons may be calculated, is one of the most important recent nonlinear developments.

- ***Chaos***

Although there were hints in the last century of well-posed initial value problems possibly leading to some indeterminacy, it is only in the last 10 or 15 years that the mathematical community has begun to grapple effectively with the structures lying behind such developments. Active mathematical work can be put into two categories. One of these is concerned with iterations on maps and involves the idea that a nonlinear iteration may produce first cyclical behaviour and then a chaotic behaviour as a parameter is increased in value. The second category concerns chaos in ordinary differential equations, and this is thus more directly concerned with actual physical systems. If a nonlinear system of higher order than second is defined as an initial value problem it is known that nondeterministic or chaotic behaviour *may* emerge after a lapse of time. The solution of the differential system remains bounded but is not periodic. In mathematical terminology, it is said to enter a strange attractor. There are many applications in the physical sciences, including particle accelerators, plasma physics, astrophysics, galactic dynamics and fluid motion.

The situation is still less clear for nonlinear partial differential equations, for example those of fluid motion, which have been studied over the past 100 years and much activity has been directed towards turbulence, namely the phenomenon of a random disordered character which frequently occurs in practice, in contrast to the simpler laminar flow configurations (as shown in the examples below). Weakly nonlinear



Chaotic convection in fluid mixtures: the use of heat and salt in water to analyse possible motion in oceans (illustrations: Daniel R Moore, Imperial College of Science and Technology).

theories (amplitude equations) give an early account of the development of wave motions towards transition to turbulence. There is a commonly held view that this aspect of the problem may be associated with chaos mentioned previously. Thus turbulence and chaos may be related, so that studies of chaos may provide answers to questions which are 100 or more years old.

● ***Nonlinear elasticity***

Field theories of the solid state are in a very different position from those applicable in fluid motion. Whereas for fluids we have a good model, namely the Newtonian one, to describe a great number of fluids and their motion, the same is not true for a wide class of important phenomena in elasticity and plasticity of the solid state. Linear theories break down under conditions which are not particularly extreme. Thus, a large amount of work is being devoted to nonlinear elasticity, as a prototype theory, involving therefore nonlinear relationships between stress and strain. There are important problems in assessing the qualitative behaviour of solutions to appropriate equations. Other equally important problems under study include those of phase transitions, the appearance of voids, fracture and buckling and the dynamics of aggregates.

● ***Experiment***

It need hardly be said that relevant mathematics must ultimately be made the subject of comparison with experiment or observation. This is just as true of a dynamical system as it is of theoretical work in other branches of the physical, engineering and biological sciences. One example is the famous and classical Taylor-Couette experiment involving fluid motion between two concentric cylinders. As the speed is raised, a succession of interesting phenomena emerge followed by turbulence, which may or may not be chaos; a connection has not been shown. A second example is that of laser optical systems where a similar interrelation between theory and experiment is of great value in promoting development and understanding. In the area of dynamical systems it is important, therefore, that relevant experimental work which is being carried on at present both in fluids and optics should be continued and should be given some support from this initiative in dynamical systems.

New initiative

The Science Board has recognised the importance of nonlinear systems and has allocated an additional £0.8 million in 1985/86 to enable the Mathematics Committee to establish an initiative in this area. This is being used to give extra support to a number of major groups, one with an experimental laboratory, and for smaller grants including provision of Visiting Fellows. It is hoped that this level of grant commitment will be possible for a further three or four years if good scientific proposals come forward.

Further information on the programme is available from Fred Hemmings, Secretary of the Mathematics Committee, SERC Central Office, Swindon, ext 2312.

Suspended aluminium particles display evidence of internal wave motion above convecting region (photo: H E Huppert and P F Linden, Cambridge University, courtesy J Fluid Mech.)

A centre of biological studies using NMR spectroscopy

SERC's Biological Sciences Committee has for some time been conscious of the growing need of biologists for access to sophisticated instrumentation. A particular problem has been the provision of nuclear magnetic resonance (NMR) spectroscopy.

NMR spectroscopy has benefited from substantial developments in instrumentation and techniques in recent years, and now has important applications across the whole spectrum of biology, from structural biochemistry to clinical medicine. There is increasing interest among a correspondingly wide range of biologists in using NMR to tackle their problems.

In view of the high capital cost of high-field NMR spectrometers, the Committee realised that it could only fund a limited number. To help meet the growing demand for access to such spectrometers for biological experiments, the Committee has decided to establish, together with Leicester University, a Biological NMR Centre under the direction of Professor G C K Roberts.

The Centre, which will be fully operational by Autumn 1986, will have a multinuclear 11.7T (500 MHz) NMR spectrometer on which up to 48 hours a week will be available to approved users outside Leicester.

The 500 MHz spectrometer will be equipped with a 5 mm ^{1}H probe and a 10 mm broadband multinuclear probe (23-202 MHz, including, eg ^{2}H, ^{13}C, ^{15}N, and ^{31}P). It will thus be suited for studies of proteins, nucleic acids, peptides etc, in solution, and for studies of metabolism in cell suspensions. A versatile pulse programmer and phase shifter will permit the use of a wide variety of pulse sequences, including homonuclear and heteronuclear two-dimensional experiments.

Users will be supplied with disk cartridges and tapes for data storage and will have access to a separate data station for data processing and plotting. A well equipped biochemical laboratory, together with cold-room facilities, will be available.

To oversee the operation of the Centre and to allocate time to outside users, the Biological Sciences Committee has set up a Management Committee under the Chairmanship of Professor R H Pain (Newcastle University).

Those intending to apply for more than two days of Centre time will be required to submit an application form giving details of the project and the samples involved. The completed forms should be submitted to SERC by 1 September. If additional resources (eg staffing, travel costs, consumables etc) are required at the user's home institution, then the normal research grant form RG2 should also be completed and submitted at the same time.

Copies of the NMR application form are available from Nigel Birch of the Biological Sciences Secretariat, SERC Central Office, Swindon (ext 2125), from whom further information can be obtained.

Those whose projects will take up less than two days *in toto* may make applications at any time, but in this case the completed forms should be sent to the Director of the Centre at Leicester.

Before submitting applications, all applicants are urged to discuss potential projects with Professor Roberts at the Department of Biochemistry, Leicester University, University Road, Leicester LE1 7RH; telephone Leicester (0533) 551234.

Restriction enzymes in DNA - protein interactions

Within any organism from *Escherichia coli* to man, the genetic information is stored as a sequence of bases in the DNA but this constitutes only a blue-print for that organism. The retrieval of the genetic information is absolutely dependent upon proteins that interact with the DNA. The molecular basis of DNA-protein interactions is being studied by a group at the Bristol University who have used the *Eco*RI restriction endonuclease, an enzyme widely used in genetic engineering, as the test system.

The DNA molecules that are found in nature vary in length from a few thousand base pairs to many millions of base pairs. The structure of DNA in solution is nearly always a double-helix, very similar to that proposed by Watson and Crick in 1953, and this structure will be more or less uniform throughout the length of the DNA. The exact sequence of the nucleotide bases within a given segment of the DNA has only a minor effect upon the three-dimensional conformation of the DNA. Yet many proteins are capable of recognising one particular sequence of bases on DNA amid thousands of alternative sequences. These proteins include many that control key processes in biological systems such as the replication and repair of DNA, gene expression and genetic rearrangements.

One example of a protein that recognizes a specific sequence of bases on DNA is the *Eco*RI restriction endonuclease. This enzyme interacts specifically with DNA at the sequence

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        ↓
5′ - G - A - A - T - T - C - 3′
3′ - C - T - T - A - A - G - 5′
                    ↑
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and cleaves both strands: the phosphodiester bonds between the bases that are split by *Eco*RI are marked by arrows. This sequence will occur, on average, once in every 4,000 base pairs of DNA.

Yet the enzyme virtually never cleaves DNA at any other sequence. Even sequences that differ from the recognition site by only one base pair are split orders of magnitude more slowly. Consequently, both *Eco*RI and other restriction enzymes have been massively exploited by molecular biologists: the applications of restriction enzymes in the dissection of DNA and the genetic engineering of novel DNA molecules have caused a major revolution in the biological sciences over the past 10 years.

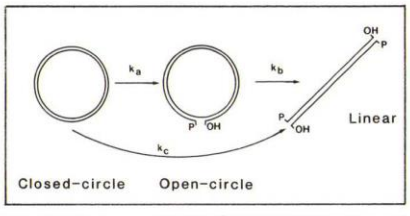


Figure 1: Two alternative pathways by which a restriction enzyme could cleave a closed circle of DNA that contains one copy of the recognition site; either k_a followed by k_b or k_c alone.

The recognition site for *Eco*RI is symmetrical in that both strands have the same 5′-3′ sequence. In addition, the *Eco*RI restriction enzyme exists in solution as a dimer of two identical protein subunits. Thus, when the protein binds to DNA, it can form a symmetrical complex in which the active site from one subunit can cleave one strand of the DNA while the active site from the second subunit can cleave the other strand. A complex of this type is indeed observed when the *Eco*RI enzyme binds its recognition site under conditions that prevent it from cutting the DNA. However, under these conditions, the enzyme binds to alternative DNA sequences more readily than it cleaves such sequences. Hence, static information about the structure of the complex cannot provide a complete analysis of this DNA-protein interaction. Dynamic data on the mode of action of this enzyme is also needed.

The reactions of *Eco*RI are most readily monitored when the substrate is a circular DNA molecule which contains one copy of the *Eco*RI recognition sequence. Many bacteria contain DNA (known as plasmids) which have these properties, one example being the plasmid pMB9. A closed circle of DNA, in which both strands are joined end to end, might be cut initially in only one strand to generate the open circle form of the DNA: subsequent cutting of the open circle in the second strand would finally yield the linear form of the DNA (figure 1). Alternatively, if both strands were cut in a single concerted reaction, the closed form of the DNA would be converted directly into the linear form (figure 1).

Figure 2 shows a profile of the reaction of *Eco*RI as it cleaves the closed form of the plasmid pMB9. In this experiment the DNA from the reaction was analysed by electrophoresis through agarose: the closed, open-circle and linear forms of the DNA have distinct mobilities, as shown by the side of the gel, and thus the amount of each can be determined. The electrophoretogram shows clearly that the initial product of the reaction is the open circle form of the DNA and that linear DNA is only generated towards the end of the reaction. Hence, the correct pathway from the alternatives in figure 1 is that involving two separate reactions (k_a and k_b).

Closed circles of DNA can also be distinguished from the open circle or linear forms by the binding of the fluorescent dye, ethidium bromide, to the DNA. Ethidium bromide is intensely fluorescent when bound to DNA but it binds to the closed form with a different stoichiometry from either open circle or linear DNA. Hence, when the reaction between *Eco*RI and pMB9 is carried out in the presence of ethidium bromide, the cleavage of the DNA simultaneously generates a large change in the fluorescence of the solution, due to a rapid change in the amount of ethidium bound to the DNA. This method was used in conjunction with rapid reaction techniques, and figure 3 shows transient kinetic data from the same time-scale as the life-time of the enzyme-DNA complex.

Analysis of the transient kinetics revealed what the protein actually did while it was bound to the DNA. First, the enzyme quickly located and then bound to the recognition site on the DNA, forming a symmetrical DNA-protein complex as described above. But in this initial complex, the two protein subunits of the *Eco*RI enzyme both lacked the ability to cleave the DNA and, in the subsequent reaction, the two subunits no longer operated in symmetrical fashion. Before cutting the DNA, the protein had to change its conformation but this change occurred in only one of the two subunits at

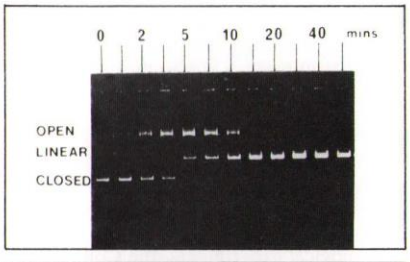


Figure 2: Analysis of DNA by electrophoresis through agarose. Each sample was from a different time point, as indicated above the gel, during a reaction of the EcoRI *restriction enzyme with (initially) the closed form of the plasmid pMB9.*

a time. Each subunit has its active site against one strand of the DNA so only one of the two strands, that faced by the subunit which changed conformation, gets cleaved. The DNA cut in one strand (the open circle form, figure 1) was then liberated from the enzyme. Finally, cutting the second strand of the DNA required the enzyme to repeat the entire process but now there was only a 50% probability that the subunit against the intact strand of the DNA was the one to change conformation.

The studies described here have used a wide range of techniques, from molecular genetics to biophysical chemistry, in order to shed some light on the behaviour of one particular protein while it is bound to DNA. This is just one example of DNA-protein recognition. But recognition events of this type are one of the fundamental processes in the biological sciences and are involved in virtually every function of DNA in biological systems.

SERC has generously supported this work, as have also many colleagues in this University.

Dr Stephen Halford
Department of Biochemistry, Unit of Molecular Genetics, Bristol University

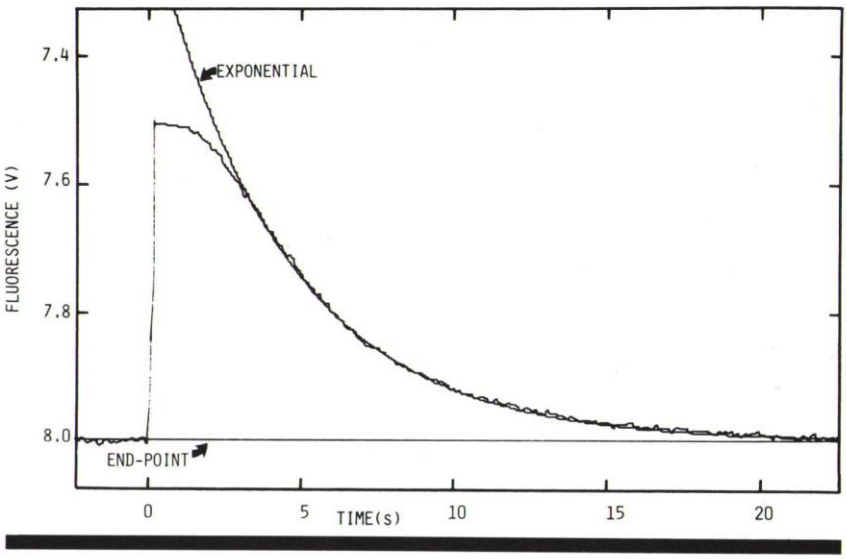


Figure 3. Fluorescence signal from the change in the amount of ethidium bound to DNA as the DNA is cut by EcoRI. *Solutions of* EcoRI *restriction enzyme and of the closed form of the plasmid pMB9, both containing ethidium bromide, were mixed together at the indicated time zero in a stopped-flow fluorimeter. This reaction contained a much higher concentration of enzyme than that shown in figure 2 and hence is on a shorter time scale. The approach to the reaction end-point follows the exponential curve shown but this is preceded by a lag phase. The conclusions about the mechanism of the enzyme were derived by analysing the kinetics of both the lag and the exponential phases.*

Major SRS modification

Even while the Synchrotron Radiation Source (SRS) at Daresbury Laboratory was being commissioned, an assessment was already underway to see what was needed to satisfy user requirements as far ahead as the 1990s. A two-year study completed in 1982 was able to demonstrate the feasibility of a major upgrade of the SRS performance to meet the increasing world-wide trend towards exploiting the very high radiation brightness possible in advanced storage rings. On the SRS this would require substantial changes to the arrangement of focusing magnets around the ring (known as the lattice) to produce a new High Brightness Lattice (HBL). The proposed modification was strongly supported within the SERC and the Medical Research Council added its encouragement. DES approval was finally received in May 1983 and the detailed design, construction and testing of the many components was begun.

The brightness enhancement is achieved by squeezing the electron beam more tightly to reduce its cross-section; the number of focusing magnets (called quadrupoles) will be doubled by adding compact new quadrupoles to the upstream end of each of the sixteen SRS straight sections between its main bending magnets. Many other correction magnets will also be necessary and this leads to great engineering complexity in the tightly packed straights. Much design ingenuity has been required, with significant space saving produced, for example, by incorporating a new beam monitoring system within the quadrupole magnets themselves.

The existing quadrupole magnets also require major uprating of their strength. In contrast the new lattice makes reduced demands on the installed radiofrequency system, a welcome bonus of the scheme. Much of the ultra-high vacuum system does however have to be rebuilt and this will dominate the actual installation programme. The smaller electron beam size does allow considerably reduced component sizes but this also implies significant consequent uprating of the pumping capacity to overcome the lower chamber conductance. The opportunity will also be taken to make improvements to the present vacuum system, in particular by installation of extra valves that are able to isolate each of the radiofrequency cavities; this should help to reduce the likelihood of any repetition of the problems experienced in 1983-84 with cavity window failures.

The SRS will be closed down from 1 October 1986 and a massive four-month installation exercise will then take place, requiring extraordinary efforts by a great number of Daresbury staff, including some unfamiliar shift working for engineering staff. Even so, such a timescale will only be possible by a great deal of intensive preparation work. Following a period of recommissioning all the accelerator systems and then understanding the performance of the electron beams in the new storage ring, it is planned to return to experimental exploitation in Spring 1987.

Some 30% of the cost of this project is being met by the Medical Research Council, an indication of the importance attached to the development of such high brightness sources for significant areas of biological research. However the gains will be experienced by all users, whether in improved resolution of monochromators, from being able to reduce entrance slit widths, or increased intensity on samples arising from a brightness enhancement by about one full order of magnitude. Much of the cost will also be funded from savings in the normal SRS running budget during the shutdown. The synchrotron radiation community at Daresbury is now working hard to extract maximum advantage from the SRS before October, but at least during the few months without beam they will be able to plan for a brighter future.

M W Poole
Daresbury Laboratory

Organometallic chemistry

Significance, challenges, and some recent British achievements

Organometallic chemistry (OMC) deals with compounds having some sort of bond between carbon and an element other than hydrogen, carbon, nitrogen, oxygen, sulphur, selenium, a halogen, or a rare gas; it has been the most rapidly expanding of all branches of chemistry. British scientists, aided by the SERC, have played a prominent role in its development.

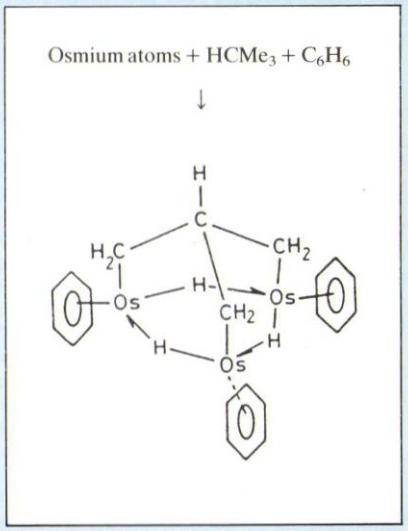
OMC impinges on many fields: valence theory, reaction mechanisms, organic synthesis, the chemical industry, and biology.

Synthetic OMC, which is particularly effectively pursued in the UK, is leading to the discovery of compounds for which traditional *valence theories* have proved inadequate. The classic example is that of ferrocene [$Fe(n\text{-}C_5H_5)_2$], but OM clusters are among more recent examples which offer a continuing challenge for the rationalisation of their molecular structures.

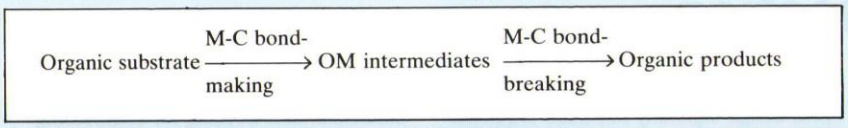
OMC has a crucial role in much of *organic synthesis and catalysis*. It provides pathways in which OM compounds are intermediates (equation 1) frequently providing chemical transformations without parallel in organic chemistry, or with a high rate-enhancement and selectivity.

catalysing enzyme-mediated reactions, which often have no parallel in metal-free organic chemistry (including the methylmalonate ⇌ succinate isomerisation of the Krebs cycle), is a riddle to which only partial answers are as yet available.

Sophisticated instrumentation plays a central role in much of today's OMC, and SERC funding has been crucially important to British chemists. Multinuclear, high-field FT nuclear magnetic resonance (NMR) spectrometers and X-ray diffractometers are essential for the study of molecular structure and dynamics. Matrix isolation spectroscopy (especially infrared) for the identification of transient intermediates in OMC is a British speciality. Electron and neutron diffraction are adding to our knowledge of the molecular structures of OM compounds in the gas phase or in the location of hydrogen atoms in crystals. Very many OM compounds are air-



Equation 2



Equation 1

Important British work in this area includes that on alkene hydrogenation and hydroboration, metal-mediated cycloadditions and other enantioselective reactions (particularly for natural products), and the use of reagents containing thallium, silicon or bismuth.

A number of OM compounds, especially metal alkyls, are of direct large tonnage *industrial use*. Alkyls of aluminium are intermediates for the manufacture of long chain alcohols for the detergent industry and as catalyst components. Methylsilicon chlorides are precursors to the silicone elastomers and fluids. Tin alkyls are used as stablisers for PVC and as fungicides and herbicides. Tetraethyl-lead is still an important anti-knock ingredient for petroleum. Transition-metal complexes are pivotal in the manufacture of petrochemicals and plastics from fossil fuels, by hetero- or homogeneous catalysis.

Biology and OMC are linked through the only naturally occurring biological OM molecule: cobalamin or coenzyme B_{12}, a Co^{III} alkyl. The mechanism of its action in

sensitive; consequently they are manipulated anaerobically and O_2- and H_2O monitored (ppm) glove-boxes are becoming a vital part of the armoury of OMC.

Mononuclear organometallic compounds

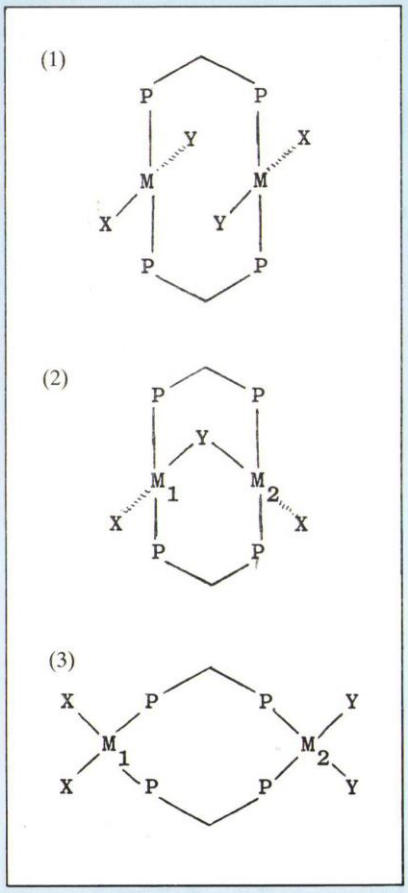
The design of novel *hydrocarbyl ligands* has been a significant British contribution to OMC. Until around 1970, it was widely held that transition-metal (TM) alkyls were inherently unstable. For example, it was noted that [$TiMe_4$] decomposed spontaneously even under ambient conditions. However, kinetic stabilisation of TM, or subvalent main group metal, alkyls can now be achieved by judicious choice of suitable ligands. Such compounds represent thermally stable compounds in which the metal is often in an *unusual oxidation state, coordination number, or bonding mode*. Modified cyclopentadienyls are also yielding exciting new chemistry.

A striking development in OMC has been the use of new *synthetic techniques*. Metal vapour synthesis appears to be particularly promising. A remarkable example relates to the activation of paraffins by rhenium or osmium atoms; a recent instance is shown in equation 2.

Transition-metal atoms, especially of the refractory metals, are difficult to generate; for example, tungsten requires temperatures of 3500°C at about 10^{-6} Torr, but a positive-hearth electron-gun furnace has been designed, which is capable of delivering several grammes per hour of the atoms of all metals; basic patents are owned by the British Technology Group.

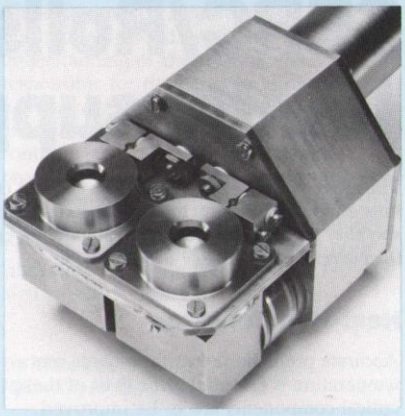
Organobimetallic chemistry

Organotransition metal (M) compounds and transition-metal hydrides usually have other ligands coordinated to M. The ligands which have had the most influence on the development of this area of chemistry are tertiary phosphines, PR_3. There are innumerable examples of PR_3 controlling the reactivity of M-C or M-H bonds in synthesis and catalysis. Tertiary phosphine- or phosphite-metal complexes are used as catalysts in industrially important petrochemical processes, and increasingly in synthesis of fine chemicals; almost invariably this has involved a single metal centre. However this chemistry has recently been extended to systems in which there are two OM centres within the same



Formulae 1,2 and 3

molecule by using diphosphines to bridge the two metal centres and form part of a flexible eight- or ten- membered ring system. Molecules can be constructed with two different metals in arrangements shown schematically in formulae 1,2 and 3 (X and Y are various organic or inorganic ligands).



Transition metal vapour synthesis unit and (above right) details of the electron gun furnace at the heart of the machine.

Organometallic cluster compounds

It is now apparent that the formation of metal cluster complexes features in the OMC of the second and third row transition-metals. One of the principal difficulties in studying these compounds has been in developing synthetic methods of general application. Recent work has, however, established methods for the rational synthesis of metal carbonyl clusters. The isolobal principle has been used to draw an analogy between metal carbonyl fragments and related organic species, and allowed the adaptation of some basic organic reactions for the preparation of metal carbonyl cluster complexes in a logical manner.

Complicated extensions had led to the synthesis of molecules containing rings, as in formula 4, or chains, as in formula 5.

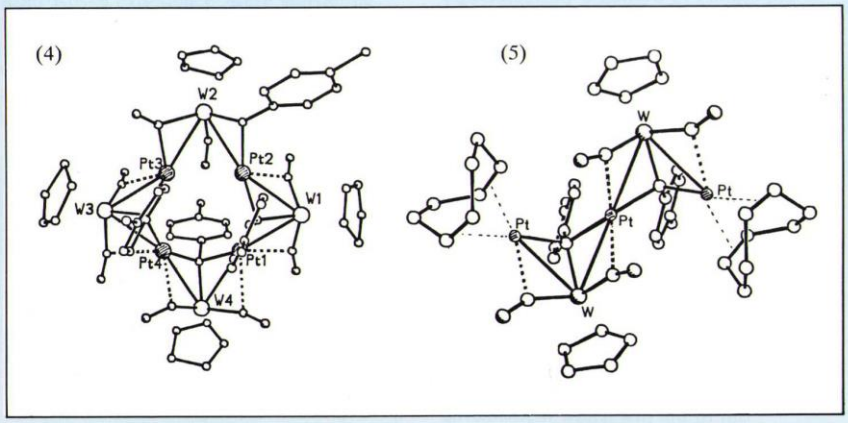
New types of cluster systems have now been established, such as the planar $[Os_6(CO)_{21}]$ 'raft' or metal assemblies involving high nuclearity, including $[Pt_{38}]$ or $[Ni_{38}Pt_6]$ aggregates. The chemistry and structures of the latter compounds may be related to the behaviour of small metal particles, while smaller clusters may be used as models for metal surfaces. The nature of cluster systems on supports, with their possible use in heterogeneous catalysis, is being studied.

It is evident that polynuclear OM complexes (clusters) have a very different chemistry from that of mononuclear analogues. For example, the bonding of simple unsaturated organic molecules to Ru_3 or Os_3 clusters leads to bonding to more than one metal centre with the fission of carbon-hydrogen bonds. Thus OM clusters represent a new domain of OMC, with exciting prospects for discovering new reactions, structured alloys on supports, and new materials.

Conclusions

Organometallic chemistry is clearly a flourishing discipline, which embraces a substantial spectrum of science. New finds continue to provide significant input into many facets of manufacturing industry, especially as catalysts in the fields of petrochemistry and plastics. There is evidence that OMC may play a vital role in the search for new materials for such devices as semiconductors and for information technology using metal organic chemical vapour deposition techniques. British chemists have been at the forefront of these developments and have provided much of the necessary fundamental scientific base; the role of SERC in providing support for these endeavours continues to be crucial.

M F Lappert, FRS
(SERC Senior Fellow 1980-85)
Professor, School of Chemistry and Molecular Science, Sussex University



Formulae 4 and 5

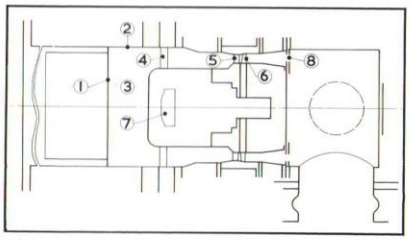
SERC/Rolls-Royce jointly supported research

The purpose of the SERC/Rolls-Royce Ltd cofunding arrangement is to encourage and support university investigations that contribute to improvements in gas turbine engines. It is based on the cooperative research grants scheme and enables proposals to be jointly judged on the way they address the company's advancing gas turbine technology. Each party commits £375,000 a year towards this collaboration. Three of the current activities are described here.

Heat-transfer rates

Accurate prediction of turbine-blade metal temperature is essential if the lives of these critical components are to be improved. Very significant contribution to the understanding of the relevant heat-transfer rates has been made by Professor Schultz and his team through transient measurement on the isentropic light piston compressor that was developed at Oxford University with SERC support. Their data lies at the heart of the company's design methods and provides a continuous check of the computer-based models employed. The experiments are now being extended, under the support of the cofunded scheme, from flows through stationary cascades to those in fully rotating stages.

The principle of the technique is outlined in the diagram. The free piston (1), driven down the five-metre long pump tube (2) by high pressure air, compresses and heats the gas in region (3) ahead of the piston. At the desired temperature, a fast acting rotating shutter valve (4) opens and the heated gas flows out into the rotating stage (5 - 6). The test turbine is run up to speed in a vacuum before the experiment by the small air motor (7). A second throat (8) behind the turbine disc establishes the desired turbine exit conditons. Specially developed fast-response heat-transfer gauges on the blades enable the rapidly time-varying heat-transfer rates to be measured.



Isentropic light piston compressor measuring heat transfer to turbine rotor blades.

Grants operating under SERC/Rolls-Royce cofunding

Fundamental aspects of combustion in gas turbines	*Prof D Bradley, Leeds*
Numerical modelling of swirling turbulent flows	*Prof B Launder, UMIST*
Microtransducers for film thickness measurements in gears	*Dr R S Sayles, Imperial College*
Influence of combined stresses on rolling contact fatigue	*Dr H A Spikes, Imperial College*
Effect of retained work on fatigue crack initiation	*Dr J King, Nottingham*
3D losses in turbine nozzles	*Dr J Denton, Cambridge*
Fatigue behaviour of defects in gas turbine alloys	*Prof T Duggan, Portsmouth Polytechnic*
Excitation and consequences of acoustic resonances in axial flow compressors	*Prof R Parker, UC Swansea*
Elastohydrodynamic lubrication	*Prof D Dowson, Leeds*
Design of membrane structures	*Prof H Fessler, Nottingham*
The oxidation resistance of overlay coated superalloys	*Dr G Tatlock, Liverpool*
Deposition of thermal barrier coatings by plasma vapour deposition	*Dr A Matthews, Hull*
Stall inception in axial compressors	*Dr N Cumpsty, Cambridge*
Study of unsteady secondary flows in turbines using sector NGVs; development of novel instrumentation	*Prof D L Schultz, Oxford*
Fluid flow tracing using radioisotopes	*Prof J Walker, Birmingham*
Investigation of rotor bearing assemblies using squeeze film	*Prof R Holmes, Southampton*
Heat transfer and fluid dynamics of gas turbines, especially rotating systems.	*Prof F Bayley, Sussex*
Creep fatigue and crack growth in aerodynamic components	*Dr J Webster, Nottingham* *Dr T Hyde, Nottingham*
Graphical man-machine environment for the presentation and analysis of aero engine control systems	*Prof J Gray, Salford*
Measurement and modelling of momentum and heat transport in idealised stator and rotor passages	*Prof B Launder, UMIST*

Oil distribution

A second major project, which forms the subject of a collaboration between a team led by Professor Walker in the Physics Department of Birmingham University, Rolls-Royce and Burmah Castrol, is directed towards measuring oil distribution and flows inside engines and rigs. The technique exploits positron-emission tomography that has already been used in medicine. However, the larger scale and severe vibration of engineering applications mean that completely new robust detectors had to be designed and built by the Rutherford Appleton Laboratory. A positron-emitting radioisotope is added to the flow under investigation and the pairs of co-linear photons, emitted simultaneously when positrons annihilate, are detected in

multi-wire proportional counters, placed on either side of the device carrying the flow of interest. After a sufficient number of photon pairs have been recorded, maps of the flow in selected planes through the test object are computed. The geometrical distribution of components within the engine is held within the computer to provide a sectioned view at the selected plane, and the radioisotope image at that plane is then superimposed.

Following full calibration of the performance of the system using sealed sources at Birmingham, initial demonstrations have been given of simple fluid dynamic situations such as jets in air and flow in weirs. More recently the motion of particles within fluidised beds has been displayed.

The picture shows a Rolls-Royce Gem engine mounted between the two proportional counters. The television display shows the computer graphics reconstruction of a vertical section through the rear bearings of the Gem engine indicating the oil flow passages. Tests on a running engine are scheduled at Rolls-Royce Hatfield during 1986.

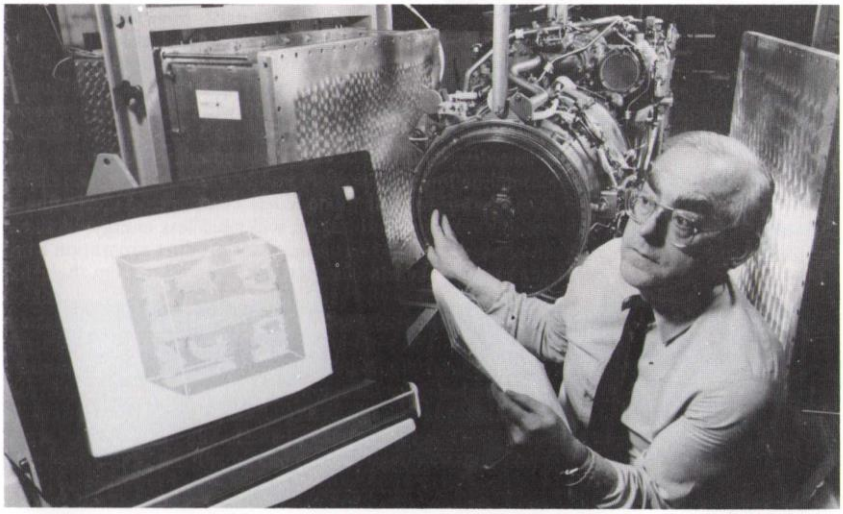
Rotor-blade vibrations

The third activity arose directly from observations made by Rolls-Royce during its compressor research programme. Significant unpredicted rotor-blade vibration was found to occur in various builds of research compressors. The vibration was found to be associated with acoustic resonances within the compressor annulus. Professor Parker of the Mechanical Engineering Department at University College of Swansea suggested vortex shedding as a possible cause of the excitation and he and colleagues set out to check the hypothesis, investigate the mechanism and suggest ways of avoiding the vibration without prejudicing the performance of the compressor. Experimental and theoretical investigations, closely linked to the Rolls-Royce experience, were started in 1980 and are continuing at Swansea. Active interchange on the mechanics of vortex shedding and the interaction with acoustic fields is under way with researchers at the Commonwealth Scientific and Industrial Research Organisation in Melbourne, Australia.

Numerical analysis of small-wave propagation in annuli for various modes shows that susceptibility to acoustic resonances is related to the annulus profile and work-input profile. A simple mathematical model has been developed to enable the behaviour of compressor designs to be examined under specified input conditions. Further work is proposed to develop reliable methods of representing the cascade acoustical properties and to allow for the fact that half of the cascade (the rotor blades) is moving.

The experimental research has so far resulted in a sound qualitative understanding of the phenomena responsible for the generation of acoustic resonances, which can cause forced vibration of turbo machine blades. The continuing research is aimed towards producing predictive models that facilitate evaluation of the deleterious effects of this type of excitation in commercial machines. Predictions will be checked against both laboratory results and Rolls-Royce tests on high-speed, multi-stage compressors.

Dr Mike Fox
Rolls-Royce Ltd



Rolls-Royce Gem engine mounted between positron-emission detectors with display of plane test section.

Further information on the scheme can be obtained from the joint coordinators:

for SERC, Mr L Airey, 72 Pierrefonds Avenue, Farnborough, Hants GU14 8PA; telephone (0252) 541989;

for Rolls-Royce, Dr M D Fox, Rolls-Royce Limited, PO Box 3, Filton, Bristol, BS12 7QE; telephone Bristol (0272) 791234, ext 1083.

Automated fringe analysis special interest group

The automated analysis of data represented by a pattern of fringes has become an increasing problem in many areas of technology. Typical areas where this problem arises are: the static and dynamic non-destructive testing of prototypes in the design process, for monitoring (including the human body) operational systems; the inspection and quality control process in production engineering; and the visualisation of fluid flow in gases and plasmas. Instrumentation techniques include holographic and speckle interferometry and moiré fringe methods.

The Automated Fringe Analysis Special Interest Group (AFA-SIG) was set up in November 1985 to create a community environment which will aid in the development of automated fringe analysis sytems. Initially this aim is being realised by holding informal meetings in which set presentations are made interspersed with general discussions. It is hoped that the SIG will evolve a more formal infrastructure to coordinate the diverse and dispersed activities in this field.

The initial steering group consists of:

Brian Tozer (Chairman), Central Electricity Generating Board; Ken Paler (Secretary), Rutherford Appleton Laboratory; Bryan Button, Trent Polytechnic; Graeme Reid, National Engineering Laboratory; David Robinson, National Physical Laboratory; and John Tyrer, Loughborough University.

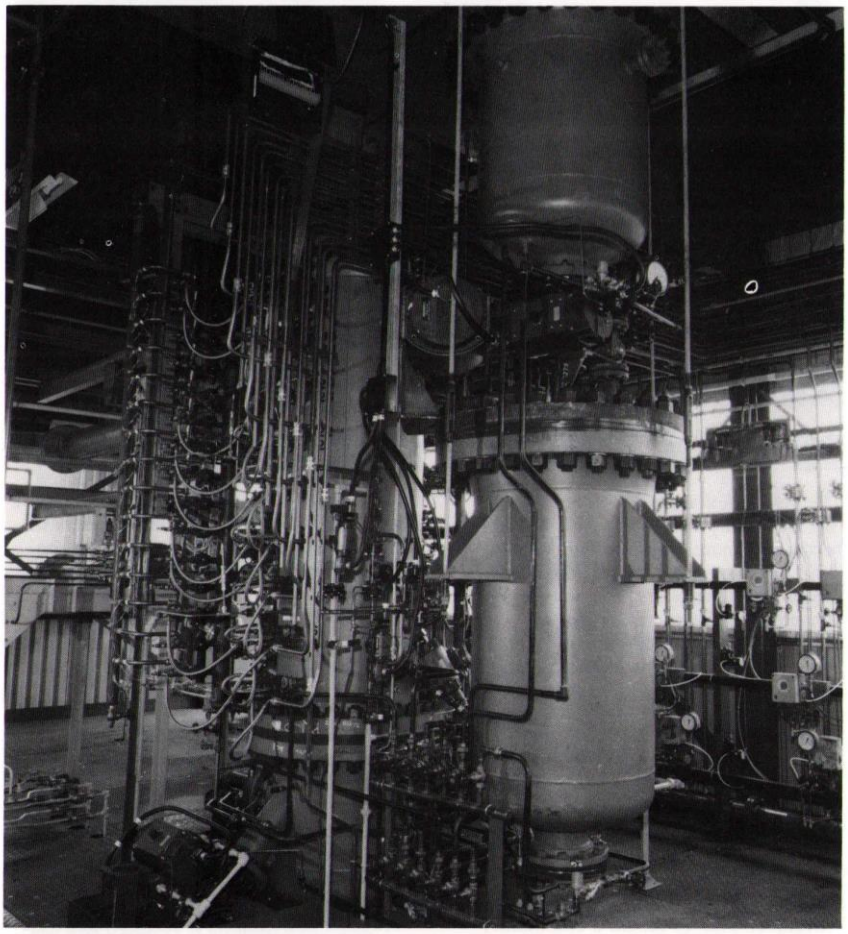
Anyone wishing to know more about the group should contact Dr K Paler at RAL, telephone Abingdon (0235) 21900 ext 6108.

Process engineering research opportunities

A working party of academics and industrialists was set up in June 1984 by SERC's Process Engineering Committee to advise on research themes which would be of benefit to the UK process industries in the next decade. Their report was presented to the Engineering Board in November 1985 and makes several important recommendations for future investment.*

Professor W J Thomas, Chairman of the Working Party on Research Themes.

The report states that there must be a deliberate move towards new opportunities for the development of less energy-intensive processes and the manufacture of new chemicals and materials if the UK process industries are to remain competitive and capture new overseas markets. There is no doubt that new opportunies exist. For example, there are possibilities of new processes to make a variety of sophisticated products using biochemical techniques. Materials with unique properties will require special process engineering manufacturing techniques. Processes that are adapted from existing projects, because of the desire to become commercially more competitive, will need less energy-intensive means of product separation and a greater process integration than their relatively inefficient predecessors. The speed with which these changes can be carried out will depend on both academic and industrial research. It is crucial to invest in specific research areas to enable industry to adapt as quickly as possible.



Research in combustion: 20 bar pressurised fluidised bed combustion facility at the Coal Research Establishment (Photo National Coal Board).

Three categories of research activity emerge from the recommendations of the report. First there is research which can be supported by the Process Engineering Committee. Such work would be undertaken primarily by process engineers focusing attention on areas specified as important for priority funding. Secondly, there are some important areas of research, such as the processing of materials, combustion and process control, which, although requiring further stimulation by injecting more money, overlap with the interests of other SERC committees. Consideration is being given to joint research initiatives. Finally, research and development programmes in enhanced oil recovery and the evaluation of physical properties data for process design may best be funded by consortia of, perhaps, industrial companies with the academic community giving vital support where it is needed.

Priority funding

One recommendation of the working party is priority funding for research in separation processes. The desirability of using less energy intensive processes in the manufacture of both commodity and specialised products stimulated the recommendation that research in product separation should receive special attention. Separation of small quantities of valuable product from large volumes of liquid can be achieved by the use of membranes and selective adsorbents. This is particularly the case in biological processing. The use of selective adsorbents is also of value for the separation of gases which have similar physical properties. Solvent extraction, accelerated mass transfer processes and high gradient magnetic and centrifugal separation are also novel separation techniques which require further research.

Particulate technology is a growth area of research activity and has already been identified by SERC as a Specially Promoted Programme. The working party report not only endorsed this, but urged

**Process engineering research opportunities,* copies available from Miss L J Pickett, SERC Central Office, Swindon (ext 2492).

that priority funding should be provided on an expanded scale so that the science of particle formation and the engineering involved in particle processing can underpin commercial progress. Extension of this programme to include hot gas cleaning will enhance progress in process design. Further advances in particulate technology are critical to improving the purity of materials, especially in the manufacture of some pharmaceutical products, fine chemicals and electronic devices incorporating sub-micron particulate matter.

Processing materials to achieve high performance will be a vital factor in winning new overseas markets. The creation of new high performance materials will undoubtedly require process innovation and it is therefore important to encourage interdisciplinary research. Polymer engineering is a good example where a combination of process engineering and materials research has been beneficial. Further research in processing more conventional materials will also speed up the move towards more efficient manufacturing.

There is both a national and commercial incentive to use energy efficiently. Consequently research on the efficient use of fuel is recommended by the working party. An examination of flow and mixing processes in turbulent combustion, and new combustion methods, including fluidised bed combustion and catalytic combustion, are just two examples of areas in which priority funding would be appropriate.

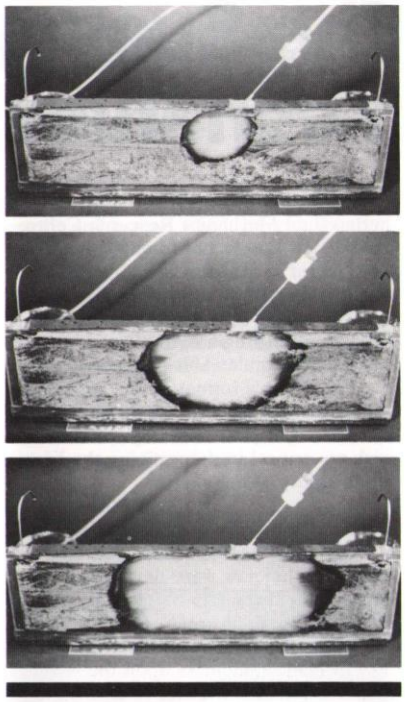
A major contribution to energy efficiency can also be achieved by more research in process integration, simulation and control. The working party report emphasised the importance of the controllability and operability of process plant and the development of computer-aided intelligence for design and control of plant. New devices are required for application in the emerging technologies such as biotechnology and electronic chemicals, so it is argued that research into the improvement of sensor capability is also important.

With the development of new processes and the adaptation of existing processes comes the responsibility of ensuring that obnoxious materials are not inadvertently discharged into the natural environment. Thus research in subject areas which contribute to a safe and healthy environment is regarded as essential.

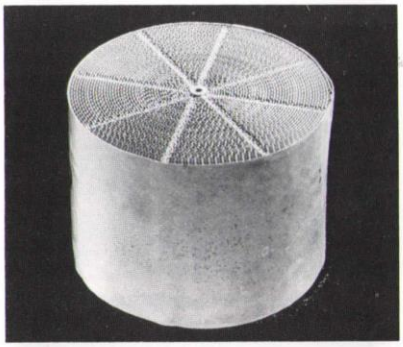
Enabling research strategies

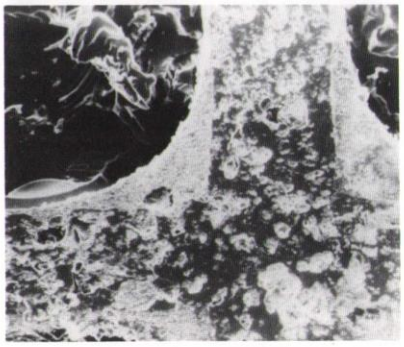
To enable the implementation of a worthwhile research policy which will benefit the process engineering industries, a number of operating principles may be adopted. It is clear that process engineering of the future will be increasingly concerned with processes which are intensive, use less energy and make demands for new equipment designs. In their report the working party concluded that much closer collaboration between the academic community and industry should be fostered. This could be achieved through a number of routes including the formation of closely integrated research teams and the inclusion of appropriate personnel in the policy making decisions of industrial companies and universities. It was envisaged that joint programmes of research between committees within SERC and with other research councils would help to create the necessary driving force for advances in process engineering research.

W J Thomas
Professor of Chemical Engineering
Bath University

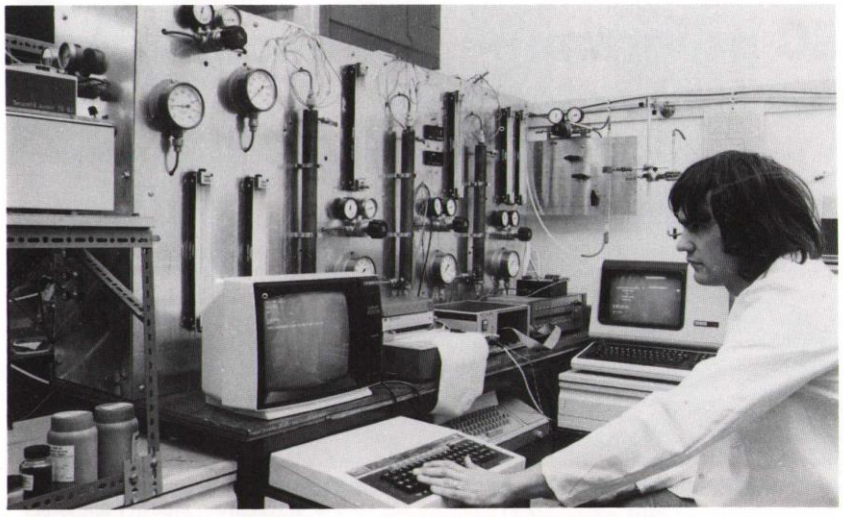


(Right) Research in enhanced oil recovery: Successive stages showing oil displacement in a sand section (Photos BP Research Centre).





Research in environmental engineering: Catalysed monolith for automobile exhausts (Photos Johnson Matthey Technology Centre).



Research in separation processes: Computer controlled experimental equipment for separating gas mixtures by pressure swing adsorption (Photo Bath University).

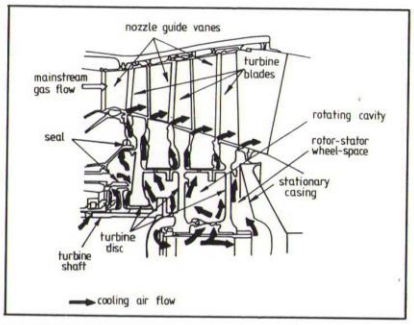
The Sussex Thermo-fluid Mechanics Research Centre

The laboratories comprising the Thermo-fluid Mechanics Research Centre (TFMRC) at Sussex University were built with a major grant from SERC in 1977. With these facilities, a substantial expansion of the research programme of the Mechanical Engineering Group at Sussex was possible. This programme has, since the Group's formation in 1966, been continuously concerned with investigations of heat transfer processes in gas turbines, which are critical in determining the life and reliability of the engines.

In the early years, most of the work was concerned with heat transfer to turbine blading. Techniques were developed for measuring heat transfer on conventional and permeable mainstream turbulence and, more recently, for measuring the effect of blade roughness upon the distribution of heat transfer rates around a wide range of modern blade sections supplied by Rolls-Royce Ltd and GEC Ruston Gas Turbines Ltd who have supported the programme.

Investigations have also proceeded throughout this time into the heat transfer processes associated with rotating discs. Over the last ten years, this aspect of the work has steadily increased until it now represents more than three-quarters of the total programme. Rotating disc systems in the gas turbine can conveniently be considered in two main classes, examples of both of which are shown in the accompanying diagram of a modern turbine.

First, and with which the work at Sussex began, is the rotor-stator system, in which one disc rotates close to a stationary surface. Several major problems arise in the design of such systems. One important aspect of the work was the determination, by both theoretical and experimental studies, of the heat transfer coefficients over the disc faces. In addition, the so-called 'ingress' problem was crucial in calculating the temperature reached by the highly stressed rotating member. This problem concerns the extent to which hot mainstream gas, flowing through the blades at the disc periphery, penetrates into the rotor-stator gap or 'wheel space'. The ingress problem was examined at Sussex in the early programme and, from this work, procedures for estimating the minimum rate of cooling air-flow into the wheel space to prevent mainstream ingress



An air-cooled gas turbine rotor

were formulated and widely adopted. Recently, however, at the request of the participating companies, attention has returned to examining the interactions between asymmetries in the external mainstream gas and the cooling air flow in the wheel space.

Before returning to the rotor-stator problem, attention had been concentrated upon the second main class of rotating disc systems, the cavity formed between two co-rotating discs. This arrangement is common in axial compressors, and occurs also in turbines, as the figure shows. In such systems the flows can be complex and a number of novel regimes have been identified. The nature of these regimes has a crucial effect upon the heat transfer coefficients in the system and currently two test rigs are in use to determine the coefficients under a wide range of conditions, simulating as closely as possible the conditions in modern engines. Two further test rigs, to examine the flows in long rotating cavities to model the conditions in hollow engine shafts, are now being built to study the potential of this system for de-icing nose-cones in aircraft. Analytical and experimental data from all this work are being incorporated into the design procedures of the collaborating companies, Rolls-Royce and GEC Ruston Gas Turbines. The recently announced extension for three years of the Cooperative Research Grant between SERC, the companies and the TFMRC will support the continuation of these investigations.

EC programme of education and training for technology

The European Commission has adopted a new programme for Community Education and Training for Technology - to be known as COMETT. It is designed to strengthen and to stimulate cooperation in training between higher education institutions and industry. The programme will encourage the joint development of training programmes, particularly relating to the development and application of new technologies.

COMETT will be implemented in two phases: a preparatory phase (during 1986) and an operational phase (1987-89).

The level of support to be provided between 1986-89 is expected to be about 65 million ECU (some £40 million). The mechanisms for providing support are expected to include:

- The setting up and development of a European network of University/ Enterprise Training Partnerships (UETPs) to organise joint transnational training schemes, involving the exchange of staff and trainees. Activities with a European dimension carried out by selected UETPs may qualify for up to 50% funding from the EC;

- Individual grants and fellowships for the transnational exchange of students and the staff of universities, industry and other undertakings;

- Support for the development and testing of training projects initiated jointly by universities, industrial and other undertakings in new technology areas and for the rapid dissemination of related research and development. Selected projects may qualify for up to 42% funding from the EC;

- Multilateral initiatives for developing multi-media training systems, using new information and communication technologies. Selected initiatives may qualify for up to 50% funding from the EC.

During 1986 the Commission will put into operation the mechanisms for running this programme but operations will not begin until 1987. Further information will be sent to academic institutions during the year.

Water treatment studies using fibre optics

Research at University College London has significantly advanced our knowledge of how of water treatment filters behave in use. The work, supported by the Council's Civil Engineering Subcommittee, is notable for its novel use of fibre-optic endoscopes which have enabled researchers, for the first time, to study the filtration bed without undue disturbance.

The behaviour of suspensions when filtered through sand, principally in drinking water treatment, has long been studied but never directly observed *in situ*. Previous research has examined samples withdrawn from a filter, or has relied on inferences drawn from radioactive or conductivity techniques. Previous two-dimensional models and boundary observations through transparent walls have never enabled direct viewing within the depth of the filter material.

Observation

The fibre-optic endoscopes which have proved to be useful are a rigid industrial type, where the light is conducted to the tip by an optical fibre bundle, but the image is viewed through a series of lenses located along the axis of the tube. This image can be viewed by eye or camera, with some magnification; but larger magnifications are possible with CCTV and a large-screen monitor. In addition to direct-viewing endoscopes, lateral view (45°, 90°) instruments have been used to look at upstream or downstream pores, or to inspect the details of the filter surface where a mat of deposit sometimes accumulates. Typically, an endoscope is 6 mm diameter by 200 mm long and views a volume containing about 10 sand grains (each about 0.5 to 1.0 mm across) and gives a picture of about three grains in focal distance.

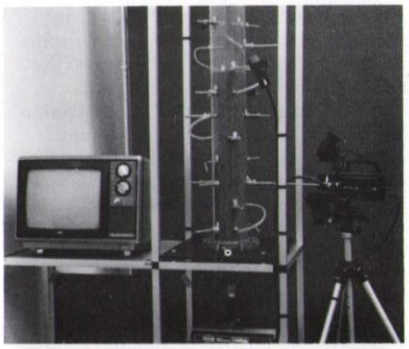
Revelations

The revelations of the internal mechanisms of water filters have confirmed some assumptions and theoretical predictions, but have also not supported the views of certain previous research. For example, it is well know that filters are not strainers, as the particles which are removed are much smaller (often $\frac{1}{100}$ th to $\frac{1}{10}$ th) than the pore opening size. But it has now been observed that even particles larger than the pore holes, formed by flocculation, may deform or break to squeeze through the pores, which was previously unsuspected. An argument about the significance of holes in the surface mat, which accumulates on the top of a filter, has been resolved by endoscope observation. The laminar flow pattern inside the pores has been confirmed, but the geometric models beloved of theoreticians assuming spherical grains and regular pores are very far from the truth. Tracking the particles through the pores is possible using video replay techniques; the shapes of deposits and observations of their microavalanches, the arrival and detachment of particles, and the dislodgement of deposits during the backwashing process which is used to clean filters : all are now subject to scrutiny by endoscopy.

Practical application

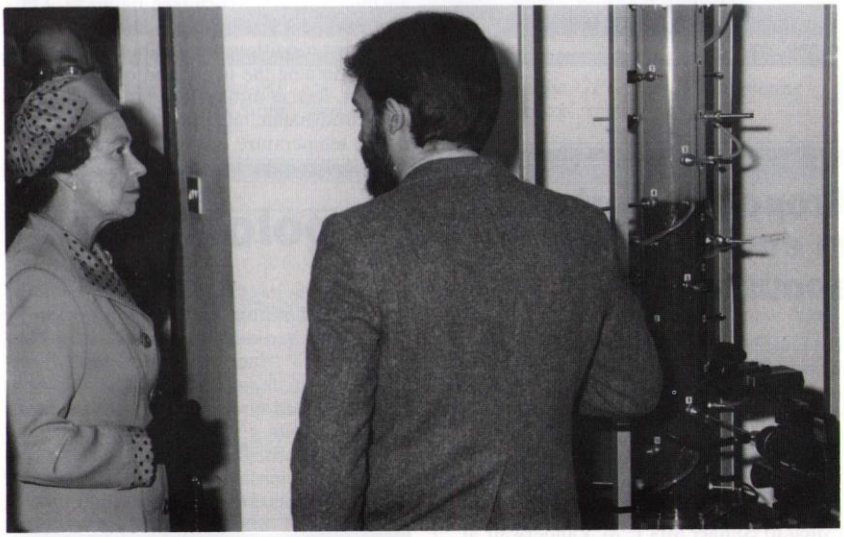
The endoscope technique is being incorporated into filters at a water treatment works through a contract between Anglian Water Authority and University College London. An industrial supplier of continuous filters is similarly arranging for UCL to fit endoscopes, and visitors to the UCL Public Health Engineering Laboratories to view the endoscopes for their own applications include various major firms from the extraction and chemical industries. SERC funds have provided a new insight into the old process of filtration.

Professor K J Ives
Department of Civil and Municipal Engineering, University College London



Sand filter column fitted with endoscopes at the surface and at depth.

Typical view through an endoscope; the grains are about 0.5 mm across.



HM The Queen visited University College London on 13 November 1985 to mark the formal completion of the main quadrangle, which includes the extension to the Civil and Municipal Engineering Department. She is seen here receiving an explanation of the fibre-optic endoscopy of filtration from research assistant Dr G Clough.

High conformity gears

Since Victorian times the involute gear tooth form has stood virtually unrivalled because of its ease of manufacture and tolerance of geometrical errors, both in manufacture and operation. It has been known for many years, however, that other tooth forms could offer higher load carrying capacity with lower frictional losses, and various alternatives to the involute form have been proposed. One of the most important and potentially useful examples of other tooth forms is the Wildhaber-Novikov (W-N) system using teeth having profiles in the form of circular arcs (see figure 1).

The attraction of the W-N system is that a higher degree of geometrical conformity at the contact between the mating teeth is obtained, thus giving lower contact stress for a given tooth loading. A further advantage is that contact occurs nominally at a point rather than along a line: this 'self-aligning' property makes W-N gears tolerant of misalignment errors.

In spite of the advantages of the W-N system, it has not been widely adopted in Western engineering practice. In the UK, Westland Helicopters have successfully pioneered the use of W-N gears in the Lynx and W-30 main gearboxes, where the advantages of higher load capacity, high gear ratio and tolerance of mounting flexure, inevitable in a lightweight gear casing, have resulted in a compact and competitive transmission solution.

SERC-supported research at University College, Cardiff, which has been carried out in close collaboration with Westland since 1979, has been concerned with improving two main aspects of W-N technology.

The first involves the development of a sound understanding of the geometry and kinematics of the system. Unlike involute profile gears, the W-N system is based on non-conjugate tooth action. By using helical gears, the instantaneous condition in a particular profile - at which the fundamental requirement that the normal at the tooth contact passes through the pitch point is satisfied - is repeated at all profiles along the axes of the gears as they rotate together. Thus, although the profiles are non-conjugate, uniform velocity ratio is achieved. It is, therefore, fundamental to W-N gearing that contact occurs, nominally, at a point. When the gears are loaded, this point becomes an ellipse due to elastic deformation. In a well-engineered design the contact ellipse is orientated with its major axis along the gear teeth and, as the gears rotate, the contact moves axially along the meshing teeth. The full and exact analysis of the geometry and kinematics of W-N gears provides the sound theoretical basis for the calculation of elastic contact stresses, the variation of contact conditions with centres-distance setting and the prediction and avoidance of potential interference between the gear teeth as a consequence of non-conjugate action.

The contact geometry and contact rolling velocity having been established, the generation of elastohydrodynamic lubrication (ehl) films in W-N gears has been studied using a specially-developed heavy load ehl analysis technique. In this way the thickness of oil film generated between the gear teeth may be studied over the full range of operating conditions encountered in practice (see figure 2). Oil film thickness and its dependence upon operating conditions is an important factor in determining the likelihood of surface distress, such as pitting. The ultimate limits of hydrodynamic lubrication imposed by rise in temperature of the lubricated surfaces have also been investigated.

The successful use of W-N gears in the critical application of a helicopter main rotor drive has encouraged their adoption for future helicopter gearboxes and has also led to interest from gas turbine manufacturers who are now becoming involved in designing high power/weight gearboxes for 'prop-fan' engines to be used in the next generation of fuel-efficient passenger aircraft. SERC-supported basic research is therefore seen as providing the sound basis for future exploitation of the W-N system by the aircraft industry.

R W Snidle, H P Evans, A Dyson

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Figure 1: High conformity gears manufactured by Westland Helicopters Ltd. The pinion, with convex teeth, is on the right; the wheel, with concave teeth, is on the left. (Photo: Westland Helicopters)

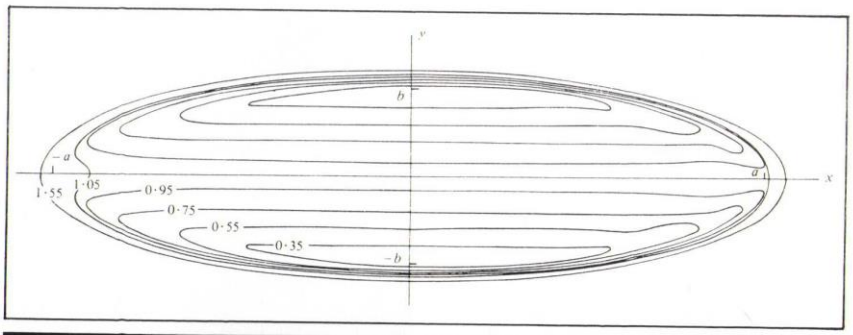


Figure 2: Contours of lubricant film thickness between the teeth of high conformity gears. Figures on contours indicate fraction of central film thickness (= 2.6μm). Corresponding Hertzian dimensions for dry contact are indicated by a and b. Lubricant entrainment is in the x-direction.

Proposed workshop in environmental acoustics

The Fluid Mechanics and Thermodynamics Subcommittee of the Engineering Board has identified the need for a workshop in environmental acoustics, particularly noise produced by enclosed machinery (especially internal combustion engines, turbines and aircraft engines). Those interested in this area of research are invited to contact Mrs E M Vanderwalt at SERC's Central Office, Swindon (ext 2200).

Polymer Supply and Characterisation Centre

The Materials Committee has confirmed its support of the Polymer Supply and Characterisation Centre (PSCC) for a further three years. The PSCC is based at Rapra Technology Limited (formerly the Rubber and Plastics Research Association) near Shrewsbury and has been supported continuously by the Council since the Centre was set up in 1969.

The Centre provides a broad service for the molecular weight (mass) characterisation of polymers based on gel permeation chromatography (GPC) and low angle laser light scattering (LALLS).

Although GPC with tetrahydrofuran (THF) as the solvent remains one of the principal services, over the last two years the most heavily used service has been that of high temperature GPC, principally for polyolefins. Generally the emphasis has been for the Centre to handle those samples which are the more difficult to characterise and GPC is now carried out in a variety of solvents. As an example of the breadth of coverage of the Centre's activities since January 1983, the Centre has carried out work on more than 80 SERC awards and for a considerable number of projects directly financed by universities and polytechnics.

In response to the increasing demand for high temperature GPC, some new GPC equipment is being purchased. These new acquisitions will upgrade the high temperature GPC and permit a greater degree of flexibility for non-routine GPC.

The principal services at the PSCC will remain GPC, with THF as the solvent, and also high temperature GPC; for these services, results are usually provided within two weeks (a small number of 'urgent' samples can often be processed in two or three days). Non-routine GPC, using other solvents, is often undertaken, when the turn-around time is dependent upon the problem and the equipment available.

GPC is the most generally useful technique for comparing the molecular weights and the molecular weight distributions of a range of polymers, but it is, nevertheless, a secondary measurement method. To support and add to the value of GPC, the Centre also is able to make absolute molecular weight determinations using LALLS. These measurements are usually made in the static (or 'stand-alone') mode although they can also be made on-line to GPC. LALLS is best when not applied to low molecular weight polymers.

A back-up service is available, from PSCC staff, to give advice on the interpretation of the GPC or LALLS results. The staff are also available to discuss the services with potential users and to give talks on the techniques to research groups or postgraduate courses.

Samples can be submitted directly to the PSCC at Rapra Technology Limited, Shawbury, Shrewsbury, Shropshire SY4 4NR together with the appropriate SERC (or other research council) grant or project numbers, or other details of the research financing. The service is free to research projects supported by the SERC or other approved bodies such as universities or polytechnics (normal commercial rates apply to consultancy work and industrial samples).

Further information on the PSCC or its services can be obtained from Dr Steve Holding or Mr Jack Maisey, both at Rapra Technology Limited, telephone Shawbury (0939) 250383.

Dr Steve Holding (left) and Mr Jack Maisey with some of the GPC and light scattering equipment at the Polymer Supply and Characterisation Centre.

Powder processing technology workshop

A workshop meeting on powder processing technology was held in London in October 1985 to review progress on the grants supported under the joint Materials Committee/Department of Trade and Industry powder initiative. The meeting was organised for the Materials Committee by the programme coodinator, Dr I Jenkins, and BNF Metals Technology Centre at Wantage. A total of 89 delegates attended, including 39 from academic institutions and with strong representation from industry.

A comprehensive programme of presentations and poster sessions examined the research areas of sintered engineering components, sintered high speed steels, forming technology and rapidly solidified powder and consolidation. There was whole-hearted agreement that the workshop had been a useful venture, resulting in a much better understanding between industrial and academic delegates of industrial needs and the contribution academic research could make towards achieving them. For the future, it was felt that greater priority should be given to sintered alloy engineering components and that in the grants awarded so far, there had been perhaps too much emphasis on aluminium alloys prepared by the rapid solidification process. There was a unanimous view that such review meetings should be held regularly, supplemented by discussion meetings on specific subject areas from within the overall programme.

Further details on the powder programme can be found in *SERC Bulletin* Vol 3 No 3, Autumn 1985. A report of the complete proceedings of the Powder Technology Workshop is available from the Materials Committee Secretariat, SERC Central Office, Swindon (ext 2277).

Information technology training initiative - three years on

The Information Technology Training Initiative (ITTI) was announced by the Government towards the end of 1982 in response to a perceived national need for large-scale increases in trained manpower in information technology (IT). The main objective was an increase in undergraduate education in the subject. However, in recognition that a boost in undergraduate training would take at least three to four years to have an impact on the employment market, the Government also planned a large expansion in numbers of places available on one-year postgraduate 'conversion' courses designed to take good-quality graduates in other disciplines and to convert them, by means of a year's intensive training in IT, into practitioners with an appreciation of and ability to use IT techniques.

In this context, information technology is taken to mean the set of technologies concerned with the collection, processing and presentation of information represented in electronic form and includes computing, electronic engineering, microelectronics, control engineering, communications, software engineering, knowledge-based systems, the man-machine interface and instrumentation.

As a result of the 1982 announcement, SERC became engaged in administering a greatly increased IT training budget which now provides for over a thousand additional advanced course studentships (the great majority of which are conversion awards), around 400 research studentships and 25 research fellowships a year.

The Institute of Manpower Studies Report

Following the announcement of the IT Training Initiative, it was recognised that it was essential to monitor the scheme in order to assess the extent to which it was meeting the national need for information technology skills. SERC therefore commissioned the Institute of Manpower Studies (IMS) at Sussex University to review the employment experiences of IT students graduating from the first year of the SERC initiative in information technology and to examine employers' demands for such graduates, now and in the future. The review related to 1983/84 postgraduate students, and it was compiled from the findings of a survey of all 1984 'home' graduates of IT advanced courses recognised for support by SERC (including non-SERC-funded students) on their immediate employment and other destinations after completing their higher degree studies (or grant entitlement) in 1984. Subsequently there was a six month follow-up survey of the 1984 graduates from IT advanced courses and research programmes, covering their employment destinations and jobs. As part of the review, interviews with a sample of 50 employers were conducted and a postal survey of a larger sample of 250 employers was carried out to extend and test the findings of the interview survey. There was also a survey of all departments teaching IT advanced courses.

The report concluded that the output from the Initiative had made a significant contribution to meeting the increased demand in the UK economy for professional qualified IT manpower. The labour market had successfully absorbed over 84% of those qualifying, the majority using their IT skills in their jobs. A further 8% had stayed on in higher education. Although it was evident that there was a very good level of demand for the products of all IT courses, the demand for specialist course students and for students from higher degree research programmes was slightly higher than for conversion course students. Nevertheless, almost all of the conversion course students, whose first degree backgrounds varied considerably, found employment relatively easily where they could use the skills learnt on their IT course. Moreover, arts and humanities students were as successful as scientists and engineers on conversion courses in finding IT employment although their actual jobs were often quite different.

The report found that there was only a small demand for conversion course postgraduates *per se;* for the majority of employers, postgraduates were considered alongside first degree graduates. In the case of graduates of specialist courses, however, their additional expertise had often been a valuable bonus to recruiters. For careers in research there was a demand for both MScs and PhDs. It was clear that IT conversion courses were a valuable means by which non-IT first degree graduates could gain employment within IT-related industries.

The IT Directorate regards the IMS review as evidence of a programme which is achieving the Government's aim of increasing the country's cadre of trained manpower in this field and of injecting retrained graduates into industry.

The future

Notwithstanding the findings of the IMS review, there is intensifying national concern about shortages of skilled IT manpower and the loss of UK market share in the rapidly growing IT sector. The demand for IT skills is expected to grow across all sectors of the economy over the next few years, the rate and pattern of such growth being affected by external factors such as economic growth, changes in the pattern of defence spending, the rate of adoption of IT by industrial users as well as employers' utilisation of existing skills.

In its first report, the Information Technology Skill Shortages Committee (a Government committee chaired by Mr John Butcher MP, Parliamentary Under Secretary of State at the Department of Trade and Industry), reported that the market could comfortably absorb more graduates with the requisite skills and that, given the rates of growth in the IT areas predicted by industry and commerce, additional graduate manpower with IT skills above and beyond the expansion already planned would be required for the rest of this decade and possibly beyond. In recognition of this, the IT Directorate proposes to maintain the present level of support for IT postgraduate awards over the next five years; it is also seekings ways of expanding the programme, although resources are not at present available.

The IMS report, *The destinations of 1984 IT postgraduate students* (No 109), is available from the Institute of Manpower Studies, Sussex University, Mantell Building, Brighton BN1 9RF.

New computing laboratory at Edinburgh

A new laboratory, unique in the UK, was formally opened on 17 January, at Edinburgh University as a centre for theoretical research in computer science.

The major aims of the laboratory's Director, Professor A J R G Milner, are to develop a sound foundation of theory for software engineering and to transfer powerful, mathematically-based techniques into industrial practice. The chief practical benefit of the research of the laboratory is likely to be improved software quality.

The laboratory has been established with the joint support of SERC and the Alvey Directorate. Support from SERC is in the form of grants for individual programmes of basic research totalling about £620,000, while the extensive Alvey support is intended to promote collaboration with industry and includes the provision of computing equipment and the costs of one support staff post.

After the Alvey programme: academic research in information technology

The Alvey programme of research in advanced information technology is now half way through its initial five-year period and is at present due to end in 1989. A decision on whether the programme should continue beyond that date, and if so on what basis, has yet to be made but must be made well in advance if there is to be adequate planning. The decision-making process will take time and will involve many sectors of the research community, as well as central Government. A working party of the Council's Engineering Board has been considering the possible future involvement of the academic sector in a follow-on programme, as part of the larger decision, and its report has recently been published.

The formation of a Committee representing the IT industry, the user community and the academic sector, to make recommendations for a follow-on programme, has now been announced. Its chairman is Sir Austin Bide. It is expected that any new initiative the Committee proposes will be concerned with the exploitation of technology as well as considering future support for research.

The Council's report argues that the field of information technology is of such vital importance to the UK that support for research must continue at a very substantial level for the foreseeable future.

The considerable success of the present Alvey programme in creating effective collaboration between industry and the academic sector is a powerful argument for maintaining this method of working in future, although some organisational changes would be necessary. However, overseas competition is so severe that European countries will only compete effectively in future if research and development is carried out on a European scale. Consequently United Kingdom programmes must increasingly be integrated into European programmes where possible, on the basis of agreed national objectives and priorities. The cost of the programme in the academic sector suggested by the working party is £25 million pa. It is not yet evident, however, whether resources of this magnitude could be made available; much will depend on the eventual decisions regarding the nature and scope of the national programme to be supported, and the financial resources made available to Council.

Comments on the report, *After the Alvey programme: academic research in information technology,* will be welcomed. They should be addressed to the secretary of the working party, Dr Mark Wilkins, IT Directorate, SERC Central Office Swindon (ext 2252), from whom copies of the report may be obtained.

Joint optoelectronics scheme extended

The Joint Optoelectronics Research Scheme (JOERS) is a collaborative venture launched by SERC and the Department of Trade and Industry (DTI) in 1982. The scheme has turned out to be very successful and further funding for it has recently been announced. In addition to the £25 million already invested, DTI and SERC have agreed to provide a further £6.75 million for the years up to 1989. SERC will provide £2.25 million and DTI £4.5 million. This, together with a matching £4.5 million from industry, will expand the scheme to a total of £36.25 million.

Optoelectronics can be described as the technology of producing optical switches and other components and systems which make use of light-guiding in thin films. It complements, and presents an alternative to, traditional integrated circuit technology and has many advantages such as speed, resistance to interference, the ability of optical fibres to handle larger bandwidths with lower signal loss than conventional copper conductors, and the economic advantages of silica over copper for interconnections.

The aim of the scheme is to support projects involving industrial and university laboratories at the early pre-competitive stage of research. The response to this initiative was immediate and many applications of very high quality were submitted. By Autumn 1984, 21 projects had been approved, involving 15 companies and 26 academic institutions. So successful has the scheme been that it has been the model for other initiatives aimed at improving the academic/industrial interface.

Typical of the projects being supported are the study of the basic technology of semiconductor waveguide optics (University College London, Glasgow and Sheffield Universities, Plessey and British Telecom) and the investigation of metal-organic chemical vapour deposition growth and assessment of optoelectronic materials based on indium phosphide (Liverpool and Oxford Universities, Queen Mary College, London, University of Manchester Institute of Science and Technology, STL, Plessey and British Telecom).

Progress is reviewed regularly and the results which emerge from individual projects will be made available to all the participating academic and industrial partners in the scheme. Although most projects have been running for less than two years, significant advances have already been made in several areas. For example, there have been considerable improvements in fabrication techniques for lithium niobate, the base material for monolithically integrated structures, for components of integrated optical systems which will find use in advanced instruments such as interferometers and optical switches. Major improvements have also been achieved in the purity and uniformity of materials for optoelectronic devices such as lasers and infrared light-emitting diodes.

Considerable progress has also been made in tunable fibre lasers, in which the ability to match the output of emitters to the optimum transmission characteristics of optical fibres and to couple laser amplifiers into the fibres themselves is of great interest. Another promising area has been the development of devices for the two-dimensional modulation of light.

Optoelectronic technology, in addition to its role in telecommunications, is expected to be incorporated into many of the systems needed in the fields of computing, control engineering and instrumentation over the next five to ten years. The announcement of further funding for this scheme is a welcome development which will maintain the momentum already generated in this important field.

D B Macdonald
Information Technology Directorate

PhD submission rates

Studentship awards beginning in 1981

Council views the writing up of results in a PhD thesis, within a reasonable time, to be an effective measure of whether the student's training has been satisfactorily completed.

The tables below set out the results of the latest annual survey - the sixth in the series - showing the submission rates for PhD theses by 1 October 1985, for those SERC-funded research students whose awards began in 1981, and the numbers of students still registered for a PhD by that date.

The information is set out by institution in Table 1 and by subject area in Table 2.

Table 1: PhD submission rates etc by institution

	No. of students registered	No. submitting by 1.10.85	No. still regist. at 1.10.85
Universities of England:			
Aston	51	22	20
Bath	42	17	23
Birmingham	87	47	32
Bradford	25	8	15
Bristol	68	37	29
Brunel	12	5	4
Cambridge	152	95	39
City	11	8	3
Cranfield Inst of Tech	18	9	3
Durham	34	22	5
East Anglia	27	17	7
Essex	13	4	8
Exeter	18	9	7
Hull	20	8	12
Keele	6	2	4
Kent	19	9	7
Lancaster	20	15	2
Leeds	78	43	27
Leicester	29	17	10
Liverpool	59	27	26
London			
Bedford	9	4	4
Birkbeck	10	5	4
Goldsmiths	1	1	—
Imperial	138	88	49
Kings	28	14	11
Queen Elizabeth	15	14	—
Queen Mary	33	11	19
Royal Holloway	10	1	9
University	57	24	28
Westfield	4	2	—
Wye	1	1	—
Other institutions	19	12	3
Loughborough	29	9	14
Manchester	91	52	28
UMIST	63	33	23
Newcastle	42	20	18
Nottingham	70	40	25
Open	7	1	4
Oxford	139	90	28
Reading	35	14	13
Salford	32	11	16
Sheffield	56	27	23
Southampton	71	40	29
Surrey	22	12	10
Sussex	41	20	15
Warwick	33	16	12
York	23	11	9
University of Wales:			
Aberystwyth	17	10	6
Bangor	11	5	5
Cardiff	24	10	14
Swansea	24	7	16
UWIST	15	8	4
Universities of Scotland:			
Aberdeen	22	14	4
Dundee	14	7	4
Edinburgh	59	26	24
Glasgow	48	22	17
Heriot-Watt	23	10	7
St Andrews	17	8	7
Stirling	7	5	1
Strathclyde	35	18	11
Total universities	2184	1144	797
Total polytechnics*	79	30	34
Other institutions*	18	8	6
Grand total	**2281**	**1182**	**837**

No students were registered for SERC-funded PhDs in Northern Ireland, most of whose awards are provided by the Department of Education for Northern Ireland.

*The numbers of students at polytechnics and other institutions were generally too low to make individual detail meaningful.

Table 2: PhD submission rates etc by SERC Board

	No. of students registered	No. submitting by 1.10.85	No. still regist. at 1.10.85
Science Board:	1282	757	402
Biological Sciences	*474*	*264*	*156*
Chemistry	*494*	*317*	*136*
Mathematics	*133*	*83*	*31*
*Physics, Neutron Beam and SBA**	*181*	*93*	*79*
Engineering Board	794	327	351
Astronomy, Space and Radio	76	39	33
Nuclear Physics Board	61	39	18
ESRC-SERC Committee	54	14	31
Energy Committee	14	6	2
Grand total	**2281**	**1182**	**837**

*SBA — Science-based Archaeology

Some new publications from SERC

Unless otherwise stated, all publications listed here are available free from the contact given at SERC Central Office, Swindon (telephone 0793 26222).

Science-based archaeology
A panel chaired by Professor M Hart FRS have produced a *Review of science-based archaeology: the funding of research in science-based archaeology in universities and polytechnics.* Copies of this and the *Science-based Archaeology Committee Report 1982-85* are available from Miss S Cooper (ext 2362).

Neutron beam research guide
Neutron beams: their use and potential in scientific research is a guide for users and potential users of the ISIS spallation neutron source at Rutherford Appleton Laboratory and the High Flux Beam Reactor at ILL Grenoble. Copies are obtainable from Ms J Milsom (ext 2411).

Science Board research themes
Science Board research themes 1986 defines the areas of research of each of the Board's Committees - Biological Sciences, Chemistry, Mathematics, Physics and Science-based Archaeology; copies are available from C Simmons (ext 2314).

Biological sciences
Copies of *Biological Sciences Committee research themes* are available from Mrs L Foster (ext 2491) and the *Annual report 1984-85* from N Birch (ext 2125).

Nuclear physics
The *Nuclear Structure Committee annual review 1984-85* and the *Particle Physics Committee annual report 1984-85* are both available, the former from Mrs T Douse (ext 2223), the latter from P Bussey (ext 2325).

Engineering reports
The *Chemical Engineering Committee annual report 1983-84* is available from Miss L Pickett (ext 2492) and the *Joint ESRC-SERC Committee annual report 1984-85* from Mrs J McMillan (ext 2153).

ACME report
Application of Computers to Manufacturing Engineering Directorate annual report 1984-85: copies are available from Mrs H Lennon (ext 2106).

After Alvey
Copies of *After the Alvey Programme: academic research in information technology* (reviewed on page 25) are available from Dr M Wilkins (ext 2252).

Biotechnology
Biobulletin: Volume 2 No 2 of the Biotechnology Directorate's occasional newsletter is now available.

Directory of research in biotechnology, October 1985: Now includes studentships as well as research grants, and is divided

Studentship numbers 1985-86

1985 report

In 1985 the Council's Boards and specialist Directorates allocated 4869 studentships, 273 more than in the previous year. Of these, 1712 lay within the general field of information technology (IT). The CASE scheme had 940 awards allocated to it.

By 1 November a total of 4686 awards had been taken up. This total, which was boosted by the impact of the information technology initiative, represented an all-time high. The 1985 studentship round was notable in that, with the main exception of candidates in the Science Board, most others received the appeals awards they sought. Actual demand for appeals was at its lowest for three years, with 642 applications (compared with 714 in 1984 and over 900 in 1983). Only four first class honours candidates failed to secure an award.

Demand for Cooperative Awards in Science and Engineering continued to lag behind Council's intentions in all the major areas. At the appeals stage, this shortfall was absorbed by additional commitments of research studentships by the Science Board and of advanced course studentships by the Engineering Board.

Within the broad area of IT, all eligible candidates received offers of awards.

Table 1 compares the take-up of studentships at 1 November 1985 with the Boards' targets. (NB: Information technology embraces both Alvey-funded awards and provision by the Engineering Board's Information Engineering Committee.)

Plans for 1986

The Council plans to allocate 4967 awards to the 1986 round (compared with 4713 awards in 1985), increasing the provision for awards in engineering and information technology, maintaining support for IT conversion courses and increasing the provision for SERC's specialist advanced courses.

The Engineering Board allocation has been increased by 96 awards (about 8%) with particular emphasis on standard advanced course studentships (87 awards) and CASE (31 awards). The commitment to 'instant' advanced course awards, which fell short in 1985, has been reduced.

The Science Board has increased its allocation of standard research studentships by 17. In recognition of the shortfall in take-up last year, the Board's CASE provision is reduced by 10.

The Information Technology Directorate has increased studentship provision in virtually all areas, reflecting the satisfactory demand for its awards last year. The increase overall amounts to 145 awards (about 9%).

Table 2 sets out the distribution of studentships to be made in 1986.

Table 1: Distribution of 1985 awards taken up by 1 November 1985

(1985 targets agreed by Boards in brackets)

	ASR	Engineering	IT	NP	Science	Biotech-nology	Total
Research Studentships							
Standard	70(69)	334(353)	289(255)	55(57)	885(861)	27(27)	1660(1622)
CASE	5(6)	200(260)	117(155)	8(9)	435(480)	30(30)	795(940)
Instant	3(3)	13(38)	8(10)	1(2)	69(70)	--	94(123)
Total RS	**78(78)**	**547(651)**	**414(420)**	**64(68)**	**1389(1411)**	**57(57)**	**2549(2685)**
Advanced Course Studentships							
Standard	1(21)	442(413)	333(302)	--	309(313)	29(30)	1134(1079)
Instant	-(1)	47(60)	3(30)	--	21(21)	--	71(112)
Conversion	--	--	911(960)	--	--	--	911(960)
Total ACS	**21(22)**	**489(473)**	**1247(1292)**	**--**	**330(334)**	**29(30)**	**2116(2151)**
Awards tenable overseas	**--(3)**	**13(20)**	**--**	**1(--)**	**5(6)**	**--**	**21(33)***
Total	**99(103)**	**1049(1144)**	**1661(1712)**	**65(68)**	**1724(1751**	**86(87)**	**4686(4869)***

* These figures also include four overseas awards provided on behalf of other Research Councils in consequence of SERC's responsibility to NATO, two of which had been taken up by 1 November 1985.

Table 2: Allocations decided by Boards for 1986

	ASR	Engineering	IT	NP	Science	Biotech-nology	Total
Research Studentships							
Standard	70	371	300	55	876	27	1699
CASE	8	291	130	7	470	34	940
Instant	3	20	10	2	70	--	105
Advanced Course Studentships							
Standard	21	480	300	--	313	30	1144
Instant	1	60	50	--	21	--	132
Conversion courses (IT only)	--	--	915	--	--	--	915
Awards tenable overseas	**3**	**20**	**--**	**--**	**6**	**--**	**32***
Total	**106**	**1242**	**1705**	**64**	**1756**	**91**	**4967***

* Includes overseas awards for provision outside the Council's field in consequence of SERC's responsibilities to NATO.

Publications (continued)

into the Directorate's current priority sectors.

Intensive training and novel biotechnology: A report commissioned from Dr D J Parsons of the Institute of Manpower Studies (IMS), Sussex University; and

Directory of short courses in biotechnology: Advanced courses of less than four weeks' duration relevant to novel biotechnology in the UK, as gathered by the IMS team during preparation of the report above.

Copies of all these publications are available from Ms J C Orme (ext 2310).

British space science
The history of British space science by the late Sir Harrie Massey and M O Robins (500 pages, Cambridge University Press) is available from booksellers, price £45.00, ISBN 0 521 30783 X.

Easier cleaning of oily water

North Sea operations generate about 10^8 tonnes per year of salt water, which has to have its oil content reduced before being discharged into the sea, to comply with the legal limit in the UK sector of 40 mg/kg. A new type of device has been developed, with SERC/Marine Technology Directorate support, at Southampton University for de-oiling the brine that is co-produced with crude oil. The device is a variant of the cyclone separator family, which uses fast swirling flow to sort dispersed material suspended in a continuous fluid of differing density.

Several special factors apply to the separation of oil droplets. For example, the droplets are tiny, with a relatively low differential density and, if exposed to excessive shear, they break up, and migrate towards the centre of the vortex; this means that the drops change shape considerably and become more difficult to separate. Also, hydrocyclones cannot be too large or their power consumption, manifested by pressure drop, will become excessive.

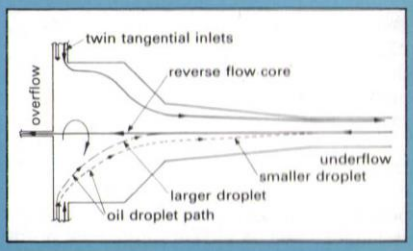
The de-oiling hydrocyclone developed at Southampton University is light-weight; it is insensitive to motion or orientation; modules can be added to it and it can be installed in confined places; and it has accurate prediction of scale-up because higher flows just use more units in parallel. These advantages are essential for topside processing facilities and floating production systems in the smaller fields discovered recently.

Close links have been built up between the University team and the licensee, BWN Vortoil. Field trials showed that some basic phenomena required further study. For example, how could droplet break-up be scaled and at what rate did dissolved gas evolve in a vortex core? Research continues with support from MTD, the equipment builders and the operators (British Petroleum, soon to be joined by Shell). Promising results have already been achieved in the Bass Straits. In the North Sea a plant designed to process 125,000 barrels a day has been operating satisfactorily since autumn 1985 and orders for other large assemblies, including a two-stage installation, have recently been received.

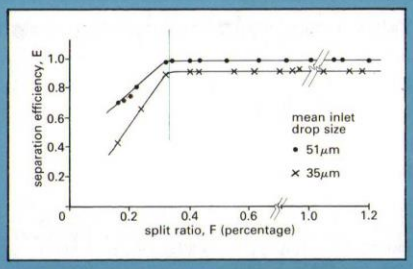
Further information: M T Thew, Department of Mechanical Engineering, Southampton University, Highfield, Southampton SO9 5NH; telephone Southampton (0703) 559122 ext 2427.

The principle and performance of the hydrocyclone

Figure 1 *shows that spin causes oil droplets to migrate inwards. The vortex is generated by using a carefully developed shape to promote axisymmetry and a low shear spin-up. The water, minus most of the oil but retaining heavy solids, pursues a spiral path and leaves the hydrocyclone downstream (underflow). In the centre of the hydrocyclone is a fast spinning core that reverses upstream because of changes in the radial pressure gradient and the wall shape. Larger droplets soon spiral in, while smaller droplets may only reach the core far downstream but are still carried back to the upstream port (overflow). The reverse flow is only a small percentage of the feed*



flowrate, unlike a typical hydrocyclone in which the overflow sees up to 90% of the feed. A typical feed oil concentration, k_i, will be 1000 ppm (by volume).



A key factor in operation is separation efficiency (defined as flowrate to overflow/feed flowrate). As ***Figure 2*** *shows, excessive reduction in the split ratio (F) causes a collapse in separation efficiency (defined as 1 - k_d k_i, where k_d is the oil concentration at the downstream outflow) owing to breakdown in the reverse flow. Like all devices relying on differential density, the hydrocyclone's separation deteriorates if the particles become too small.*

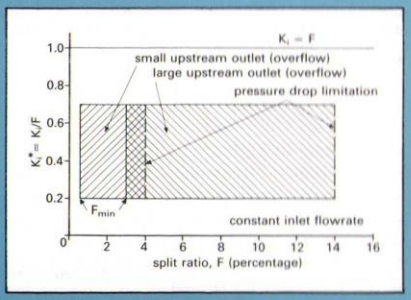
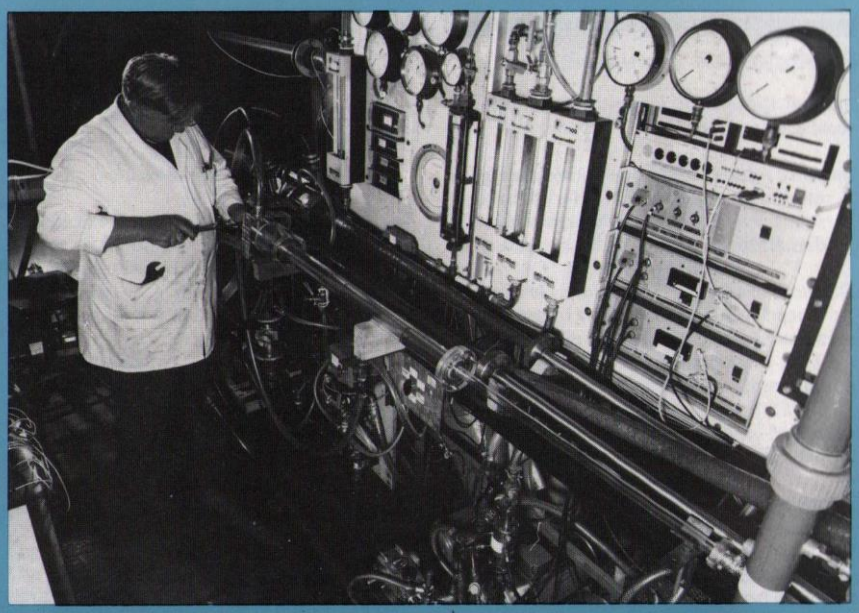


Figure 3 *shows how F, which is controlled by valves outside the hydrocyclone, should be in the shaded areas, which correspond to satisfactory conditions. Should K_i^* fall too low, it implies excessive water contamination of the oily stream. When F is too great it may also lead to excessive drop in the oily stream.*



Right: The Southampton hydrocyclone for oil/water separation