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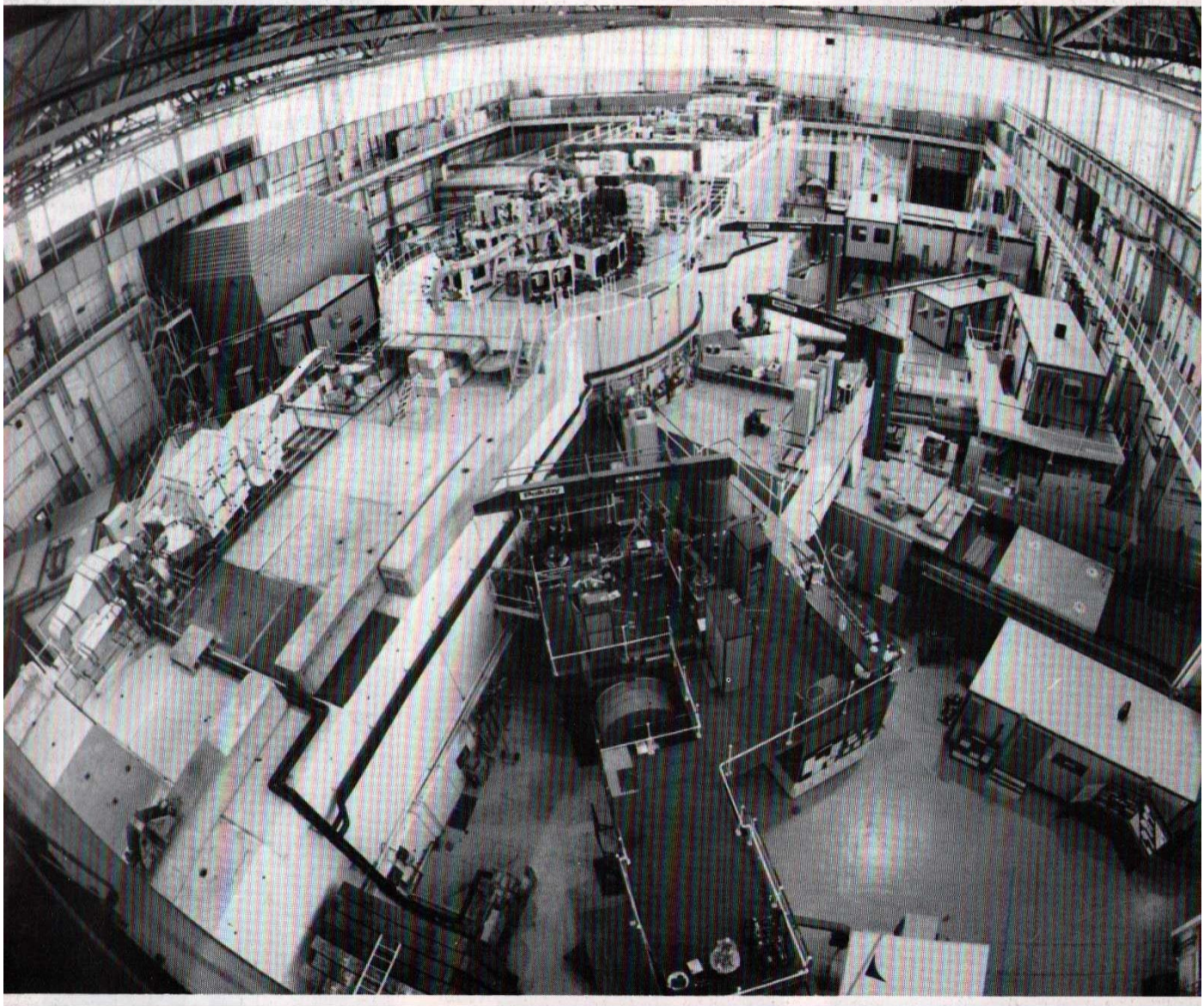

IN THIS ISSUE

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.

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SERC *Annual Report* (available from HMSO Bookshops) gives a full statement of current Council policies together with appendices on grants, awards, membership of committees and financial expenditure. ***SERC Bulletin,*** which is normally published three times a year, summarises the Council's policies, programmes and reports.

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Front cover picture

A view of the main ISIS experimental hall showing the extracted proton beam line at the bottom left, leading to the target station. On the right are neutron spectrometers. On the left are more neutron lines and the 5,500 tonne steel enclosure for the KARMEN neutrino experiment. ***See page 12.***

Techmart 1987

The Techmart Exhibition is establishing itself as a major forum for technology transfer. It is becoming a meeting place where ideas can be exchanged and innovation discussed. Now in its third year, Techmart, sponsored by Barclays Bank, is attracting ever-increasing numbers of companies, institutes and inventors. They have found that it is an ideal shop window to display their current projects and ideas to a wide international audience of business executives.

SERC exhibited at last year's Techmart and is doing so again this year. From 13-16 October on stand D50 in Hall 3a at Birmingham's National Exhibition Centre, SERC will be showing how the academic community and industry have formed a partnership to transfer basic academic research into the marketplace. The stand features projects funded by the Science Board, the Engineering Board, Biotechnology Directorate, Information Technology Directorate, the Teaching Company Scheme, the ACME Directorate and the Rutherford Appleton Laboratory. On the stand, SERC officials and academic investigators will be able to explain how this partnership with industry works.

With this issue you will find a special Techmart supplement which describes in detail the projects being featured. Extra copies can be obtained from the Public Relations Unit, SERC, free of charge.

Daresbury's 25th birthday

Daresbury Laboratory celebrated its 25th Anniversary on Friday, 24 July and held a Family Day on the Saturday. Tours of the facilities and special exhibits provided ample opportunity to recall memories of NINA days and to look at the extensive range of research now carried out at Daresbury. Visitors included representatives from universities, industry, the press, Members of Parliament and local civic dignitaries.

The Family Day on Saturday was a great success, attracting almost 2000 people including staff and their families, users and local residents. SERC Chairman, Bill Mitchell, also shared in the carnival atmosphere. Manned stopping points on all tour routes gave everyone a chance to learn about the facilities and the science, and light entertainment was provided by a brass band concert in the open air and trips along the Bridgewater Canal in a narrow boat.

Council commentary

Among the business considered by the Council at its meetings in April, June and July 1987 were the following items.

Croham Report and White Paper

At its April meeting, the Council discussed the report of the Croham Committee on the future of the University Grants Committee together with the White Paper *Higher education: meeting the challenge*. The Council attaches particular importance to the preservation and enhancement of links between the two limbs of the 'dual support' system of academic research. It sees this as the key to the efficient and successful operation of the new proposals insofar as they relate to getting the best value for the nation's investment in research and advanced training.

EISCAT

EISCAT (the European Incoherent Scatter Radar Facility) is one of SERC's smallest international collaborations. Located at three Scandinavian sites within the Arctic Circle, EISCAT is a collaboration of the UK with Germany, France, Norway, Sweden and Finland. Its purpose is to study the ionosphere and magnetosphere at heights up to 1000 km to understand the behaviour of the Earth's outer environment and of the complex processes that occur above the polar regions. At its April meeting, the Council heard a presentation on the work of EISCAT from Sir Granville Beynon, who had played a key role in the establishment of the EISCAT Association, and from Professor T B Jones of Leicester University, one of the present UK members of the EISCAT Council.

Cooperative Research Grants

The Cooperative Research Grants scheme was set up in 1978 with the aim of bringing academic departments and industrial firms together as equal partners in research projects, with SERC supporting the academic partner's costs in the joint venture. An annual report from the panel that monitors the scheme was presented by its chairman, Dr P G Wakely, at the April meeting of Council. The scheme has grown very satisfactorily to the extent that, in the 1985/86 session, 221 applications were received.

UK Schmidt Telescope

The 1.2 metre aperture UK Schmidt Telescope has been operated by SERC from a site at Siding Spring, in Australia, since 1973. It is situated close to the Anglo-Australian Telescope and it is now proposed that the two facilities should merge, with the aim of gaining scientific and managerial benefits as well as substantial savings in costs to SERC. The Council has approved the terms of the merger, which will now require the approval of the relevant Australian and British authorities.

LINK

The Council has established a panel of its members to consider proposals for programmes under the LINK scheme. These proposals will come up from the Boards, and the panel will advise the Council on relative priorities and keep under review SERC's participation in this new scheme that seeks to marry support for strategic research in programmes jointly funded by the Research Councils, Government Departments and industry. Participation by SERC in three LINK programmes has so far been approved by Council.

Interdisciplinary university research centres

The council approved a timetable for establishing interdisciplinary university research centres (URCs). The aim is to set up three such centres by October 1988 and a further three in the following April, although the extent of the programme depends on the provision of extra funds in the Autumn. Invitations for the first phase of the exercise have been issued.

CERN

In July, Council considered the UK's membership of CERN in the light of the interim report prepared by the CERN Review Committee under the Chairmanship of Professor Abragam. Council agreed that the report gave grounds for believing that future economies should be possible and should contribute to a healthier CERN. The full Abragam report is expected by the end of the year.

Major new grants

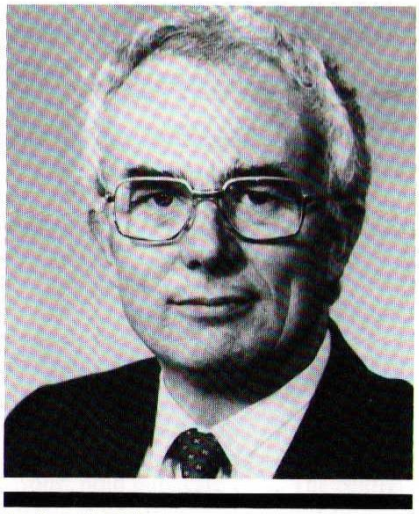
The following research grants, recently recommended by the Council, have now received the approval of the Department of Education and Science, required by virtue of their cost:

- £834,000 to University College, London, for the support of the Mullard Space Science Laboratory until July 1988.
- £557,000 to Manchester University for the programme of work at the Nuffield Radio Astronomy Laboratory until July 1988.
- £1 million to Glasgow University for the construction and use of a photon-tagging spectrometer at the Mainz Microtron.

New Council Member

Mr Kenneth Baker, Secretary of State for Education and Science, has appointed **Dr Ronald F Coleman** a member of both the Natural Environment Research Council and the Science and Engineering Research Council, on the retirement of Mr Oscar Roith CB, FEng. Dr Coleman has also succeeded Mr Roith as Chief Engineer and Scientist at the Department of Trade and Industry. Mr Roith was elected 1987-88 President of the Institution of Mechanical Engineers in May.

Ronald Coleman spent four years in industry as a research assistant with Chance Bros Glassworks after graduating from Birmingham College of Technology. He joined the UK Atomic Energy Authority on its formation in 1954 and remained there until 1973. During that period his research work involved many aspects of nuclear chemistry applied to weapons, reactors and non-nuclear areas such as forensic science and geochemistry. He then returned to the Civil Service as Head of Research Division of the Laboratory of the Government Chemist. In 1977 he moved to the National Physical Laboratory, becoming Deputy Director in 1980, and returned on promotion to the Laboratory of the Government Chemist as Government Chemist in 1981.



Dr Ronald Coleman

Holmes Hines Memorial Fund awards

Five small awards have been made during the past year under the Holmes-Hines Memorial Fund. This fund was created in 1981 when the Council received a bequest in the Will of the late Miss Frances Hines. The bequest stated that a Fund should be set up to provide annual prizes, scholarships, exhibitions or research grants, the incidental expenses of visiting scientists, the purchase of scientific apparatus and equipment and funds for such other purposes for the advancement of scientific knowledge as the Council shall select. It can be used to help individuals achieve their scientific aspirations and to sponsor activities related to science for which public funds are not available. Applications for awards from this Fund should be made to the Secretary of Council.

The five awards were:

- £100 to Miss Catherine Barr, a third-year ecology student at Leeds University, towards the cost of her participation in an Operation Raleigh expedition in New Zealand from 19 December 1986 to 7 March 1987;
- £300 to Miss C Siobhan Dower, being the second of three annual contributions to help during her studies for a combined Honours degree in Physics and Astronomy. Miss Dower obtained a Fine Art degree in 1984 and could not therefore obtain a government grant during her four-year study for a second 'first' degree;
- £250 to Mr Jonathan Klinger, a pre-university student, towards his travel expenses for participating in a youth science conference in Canberra during December 1986/January 1987;
- £275 to Mr David J C MacKay, a second-year science student at Cambridge, towards expenses incurred in attending the first International Conference on Neural Networks held in San Diego in June.
- £1000 to the British Olympiad Committee for selecting and taking a team of five sixth-form physics students to the 1987 International Physics Olympiad at Jena, East Germany in July (where C Sanders won a Silver Medal); and sending the top two students to the British Association for the Advancement of Science meeting at Queen's University, Belfast, in August.

Coordinator for Interfaces and Catalysis Initiative

Professor G C Bond of Brunel University has been appointed to aid coordination of the Interfaces and Catalysis Initiative. This programme aims to stimulate and support research relevant to heterogenous catalysis in areas ranging from surface science to chemical engineering. The expected commitment is £1 million a year over the next few years. He may be contacted at the Department of Chemistry, Brunel University, Uxbridge, Middlesex UB8 3PH; telephone Uxbridge (0895) 74000.

Professor G C Bond

Radio communication systems symposium

Results from about 100 projects in fundamental radio communication systems research were reported to a major two-day symposium on 7 and 8 July. The projects were supported under SERC's recently completed Specially Promoted Programme (SSP) in radio communication systems. Set up in 1983, the programme received some £4 million for research into areas such as mobile radio high frequency systems, signal processing, satellite systems and microwave systems.

Congratulations

Elected Fellows of the Fellowship of Engineering in July 1987:

R W Brander (British Telecom plc), member of the Engineering Board and Chairman of the Information Engineering Committee.

Professor J Bridgwater (Birmingham University), member of the Engineering Board and Chairman of the Process Engineering Committee.

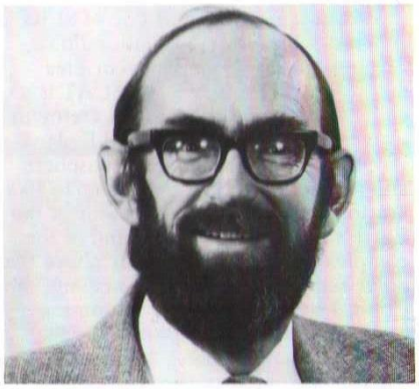
Professor F M Burdekin (UMIST), member of the Board of Marine Technology Directorate Ltd.

Professor G Fleming (Strathclyde University), member of the Environment Committee.

J D Rankin (ICI plc), member of the Process Engineering Committee.

Dr R G P Voss, Head of Engineering Division, SERC Central Office, Swindon.

New Director of RAL



Dr Paul Williams was appointed Director of the Rutherford Appleton Laboratory (RAL) in April. He has been Acting Director since the resignation of Dr Geoff Manning CBE in December 1986.

Dr Williams, who was Deputy Director of RAL from 1983 to 1986, took his PhD in high energy physics at Liverpool University. He has been associated with the Rutherford Laboratory since 1960 and has been employed by the Council since 1965. His appointments have included Project Officer for the High Power Laser Project at RAL, and subsequently Head of the Astronomy, Space and Radio Division and Head of Engineering Division at Central Office Swindon.

Royal opening of the James Clerk Maxwell Telescope

His Royal Highness The Prince Philip, Duke of Edinburgh officially opened the James Clerk Maxwell Telescope on the summit of Mauna Kea, Hawaii on 27 April. The Royal opening marked the culmination of a successful collaborative programme between SERC and the Netherlands Organisation for the Advancement of Pure Research (ZWO) to construct a world-class radio telescope for astronomy.

The ceremony near the 4,200 metre summit was attended by 130 distinguished guests representing local and international interests in the project together with members of the media.

Welcoming speeches by Professor Bill Mitchell (Chairman of SERC) and Mrs Lynne Waihee (wife of the Governor of Hawaii) were followed by the hand-over of the telescope from the Rutherford Appleton Laboratory to the Royal Observatory, Edinburgh. As demanded by local custom, the facility was blessed by Father George da Costa in a ceremony which included the sprinkling of consecrated water around the telescope enclosure.

Prince Philip opened the facility by unveiling a plaque, and Dr Richard Hills (Project Scientist) performed a demonstration by opening the giant doors and rotating the carousel, giving the guests a panoramic view and bringing the antenna to focus on the position of Venus.

Celebration dinner

A celebration dinner was held that evening at a hotel in the sea-level town of Hilo. It was a festive and informal occasion. The guests included representatives of the partner organisations, local dignitaries, distinguished scientists, people involved with the provision of the telescope, potential users and local staff and their spouses.

In the speeches which followed dinner, there was praise for those who had been involved in the design and construction of the facility and there were contributions from the partners who now looked forward to its exploitation.

Professor Mitchell thanked His Royal Highness for opening the telescope and presented him with a framed antique print, *An offering before Captain Cook in the Sandwich Islands,* from an engraving of 1784. This showed an Hawaiian priest offering a pig to Cook in a religious ceremony.

Prince Philip congratulated all the partners involved, saying that all Dutch-UK collaborations had been brilliant and always worked. He also remarked that working on the summit of Mauna Kea would not appeal to him. "As a pilot, I'm convinced the only place man should be at 14,000 feet is in the pressurised cabin of an aeroplane."

Canada joins the partnership

On the evening before the opening of the telescope, the National Research Council of Canada (NRC) signed an agreement to join Britain and the Netherlands in the use of the James Clerk Maxwell Telescope.

In the partnership, the University of Hawaii which operates the Mauna Kea Observatory has 10% of the total viewing time. The remaining time is divided in the ratio 20% ZWO (no change), 55% SERC and 25% NRC from the previous 80% which was allotted to SERC.

As a full partner, NRC will provide additional contributions over the coming years equivalent to its share of the costs of constructing the facility. The Canadians will also meet their share of future operational costs.

All three partners will jointly fund a major programme of investment in new instrumentation for the telescope which, over the next ten years, will ensure that the facility maintains its place at the forefront of submillimetre-wave astronomy.

HRH The Prince Philip is joined by representatives of the partner organisations: Dr Don Hall (University of Hawaii), Dr Albert Mulder (ZWO), Professor Bill Mitchell (SERC) and Dr Bernard Gingras (NRC).

World Data Centre anniversary

On 3 July 1987, the Rutherford Appleton Laboratory celebrated the 30th anniversary of its World Data Centre, one of a number of centres that holds geophysical data. This data collection started as part of the 1957-58 International Geophysical Year, when a great deal of information about the Earth was gathered.

The centre at RAL has a wide variety of information on solar terrestrial physics including extensive data on the ionosphere — that part of the atmosphere that extends from about 60 km to 1000 km above the Earth. Its information is used by scientists throughout the world. Increasing emphasis is being placed on providing on-line computer-based facilities.

At present there are some 27 active world data centres. Different centres deal with the different scientific disciplines, for example solid-earth geophysics, oceanography, meteorology, and rockets and satellites. Then, within each of these aspects, there are four centres which, for safety reasons, hold duplicate data. The centre at RAL is one of eight sited in Europe.

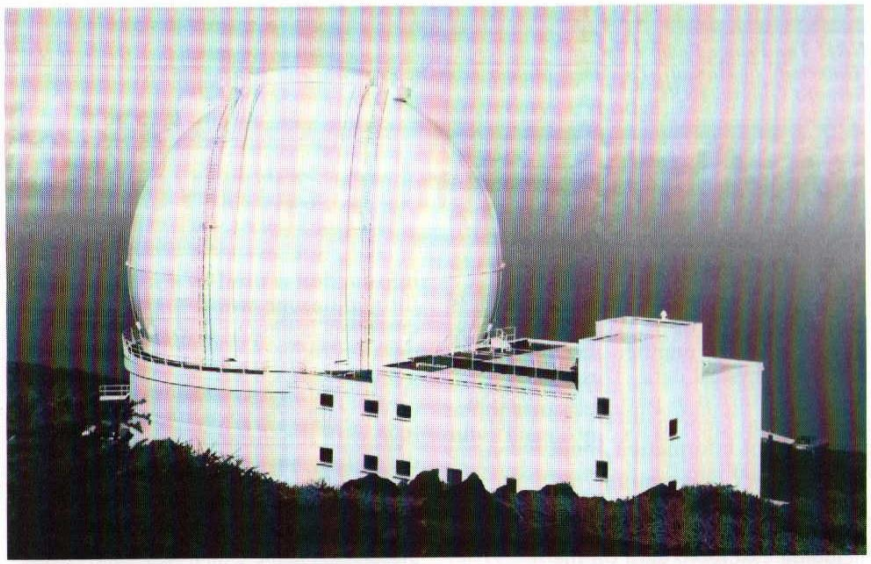
First light on the William Herschel Telescope

The 4.2 metre William Herschel Telescope (WHT) on La Palma in the Canary Islands begins operating this year. 'First light' on June 1 was witnessed by the SERC Chairman Professor Bill Mitchell, Royal Greenwich Observatory Director Professor Alec Boksenberg and Director of the Canary Island Astrophysical Institute Professor Francisco Sanchez. The construction of this telescope completes the orginal plan for three astrophysical telescopes built at the Roque de los Muchachos Observatory by RGO for astronomers in Britain, the Netherlands and Spain. It is described here by Professor Boksenberg and Dr Paul Murdin, Head of Astronomy and Astrophysics at RGO.

The design aim for the William Herschel Telescope quite simply was to produce the largest possible telescope with the finest possible technical specification within the money available. The excellence of the astronomical conditions on La Palma dictated stringent requirements for the sharpness of the telescope's images and the accuracy with which it tracked stars. The most important of these from the point of view of designing the telescope was the fine 'seeing', with star images of 1.0 arcsec or better 40% of the time; at their best, star images are 0.3 to 0.6 arcsec in diameter.

This year marks the end of a long project, after years of calculations and design work at RGO, of construction and testing in the Grubb Parsons factory and finally of erection and commissioning, under RGO project engineer Brian Mack, in its dome at 2400 metres on the Roque de los Muchachos. At RGO, Michael Morris has been responsible for the overall management of the project, Rowland Milner for the construction of the building, Ronald Adams for the dome and Lewis Jones for the computers and software. Robert Laing is the WHT Project Scientist and also is deeply occupied in producing the telescope control software, and Neil Parker has been in charge of the related instrumentation programme.

The WHT is the world's third largest telescope with a single main mirror. We expect that the already-proven excellent observing conditions on La Palma, together with the most up-to-date instruments and detectors, will give it the edge over its larger rivals, the 5 metre telescope in the USA and the 6 metre telescope in the USSR. For a time during its erection it was possible to push the 160 tonne telescope around by hand, but now the gears have been meshed and it can be accurately controlled by computer. It towers above the visitor who enters the dome at ground level. The dome is small and hugs the telescope, which is advantageous in minimising the space which could be filled with warm air that causes convection and therefore bad seeing.



The 21-metre dome of the William Herschel Telescope, with its up-and-over shutter and three-story annex of control, service and work rooms.

Altazimuth design

The telescope design is based on Nasmyth, a Victorian engineer, inventor of the steam-hammer and holder of numerous patents in canal making. A keen amateur astronomer, Nasmyth built the first 'trunnion-vision' telescope on an altazimuth mounting.

Altazimuth mountings are like guns, with the altitude motion of the telescope corresponding to elevation, and the azimuth corresponding to the bearing around the horizon; they were of course the commonest way of holding a telescope before the invention of the equatorial mounting. Nasmyth's idea was to add a third mirror to a Cassegrain telescope supported in an altazimuth mount, such that the light beam was deflected out of the telescope tube along the altitude axis, through the trunnion which supported the altitude bearing.

The altazimuth-mounted William Herschel Telescope has two Nasmyth foci addressed by means of a movable flat mirror (called the Nasmyth mirror), as well as the conventional Cassegrain focus. At the Nasmyth foci are two large horizontal platforms, which can take large instruments, holding them horizontal, fixed relative to gravity.

Nasmyth instruments

By contrast to the rigidly boxed instruments mounted at the Cassegrain focus, which moves to all attitudes, instruments at the Nasmyth foci can be simple, optical benches as if in a laboratory. This gives astronomers the opportunity to try out novel ideas on an instrument in an experimental way, without having to constrain their imagination as well as the components by enclosing the instrument in a rigid box.

The Nasmyth mirror gives astronomers who use the WHT another advantage: it is easily switchable to direct the light beam to either of the Nasmyth foci, or to fold out of the way so that the light beam can reach the Cassegrain focus. This makes it possible for groups of astronomers to have at least three instruments on standby through the night to deploy on their programmes as they wish. Alternatively they can switch advantageously from one instrument to another as observing conditions change through the night; in this way optimum use can be made by some astronomers of conditions which would be classed as adverse for others' programmes. Thus, scheduling of the telescope can be

flexible, without being constrained by the usual night-by-night division of telescope time.

Telescope drives and control

Because the WHT is symmetric relative to gravity, and compact, it is very responsive to its controls. Essentially, because the lengths of its structures are small, their frequencies of oscillation are high and they respond positively to low frequency pushes. For this reason, the altazimuth mount is liked by engineers. It is also economical since the dome it sits in has no wasted space, hugging the symmetric telescope closer than is possible with an off-centre equatorial mounting.

In normal use, all the telescope drives are controlled by a computer system from an operations desk. All the instrument turntables and cable wrap devices are controlled in sympathy with the telescope motion, as well as the positions of the dome observing slit and windscreen.

Telescope optics

To take advantage of the excellent La Palma seeing, the WHT has the finest large optics that money can buy. The telescope has classical Cassegrain optical configuration. The paraboloidal primary mirror is made of a glass-ceramic material (Cervit), having near-zero coefficient of expansion over the operating temperature range. As the temperature falls during the night, the mirror retains its expensively bought figure. The mirror has a clear aperture of 4.2 metres and a focal length of 10.5 metres, giving a focal ratio f/2.5. The precise diameter of 4.2 metres was determined by the availability of the mirror blank, made by Owens-Illinois as part of the 4 metres series of blanks for telescopes of the 1970s. The mirror, figured by Grubb Parsons, concentrates 85% of the light of a distant star into an area only 0.3 arcsec in diameter.

The optical performance of a telescope depends on controlling the deformation of the mirror surface when the mirror is contained in a mirror cell; a large mirror would bend by hundreds or thousands of times the optical tolerance if not mounted properly. The images would be useless. The problems for large telescopes become severe very rapidly, since the deflections of a telescope increase as the square of the telescope mirror size, so that a 4.2 metre telescope is about three times more difficult to make than a 2.5 metre telescope.

The WHT mirror's diameter-to-thickness ratio of 8 makes it thinner than those of most large telescopes built in recent years, but it is not really classifiable as a thin mirror and raises no unusual problems for its support system.

Calculations for the WHT mirror show that when it stands on edge in its cell pointing to an object on the horizon, a ridge or wrinkle appears at the lower edge, as the mirror compresses under its own weight; however, the height of the wrinkle is only 1/10 the wavelength of light and does not significantly disturb the figure of the mirror.

Dome and building

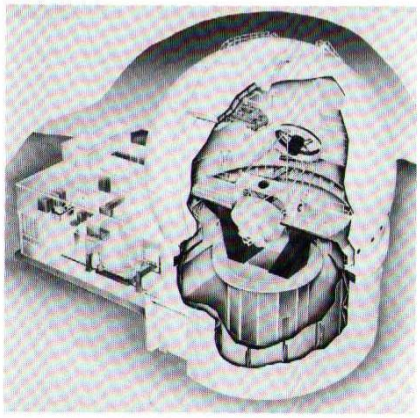
The telescope is supported by a reinforced concrete pier mounted on piles driven through the volcanic ash to a thick layer of basalt rock 20 metres below the surface. The 21 metre dome is onion-shaped to allow the up-and-over shutter to track back past the zenith. Sideways-moving bi-parting shutters are not used because they stick out from the dome like sails and not only spoil the flow of air over the dome but sustain enormous forces in high winds. The dome is supported on a rail set on a cylindrical concrete building structure. On one side of the cylindrical drum is a three-storey rectangular annex. This contains the mirror aluminising plant, the operations control room, computer room, dark rooms, workshops, offices and various services. Because no unnecessary activity takes place in the dome there is little thermal disturbance of the air near the telescope, which greatly improves the chance of achieving perfect 'dome seeing'.

Remote observing and future instruments

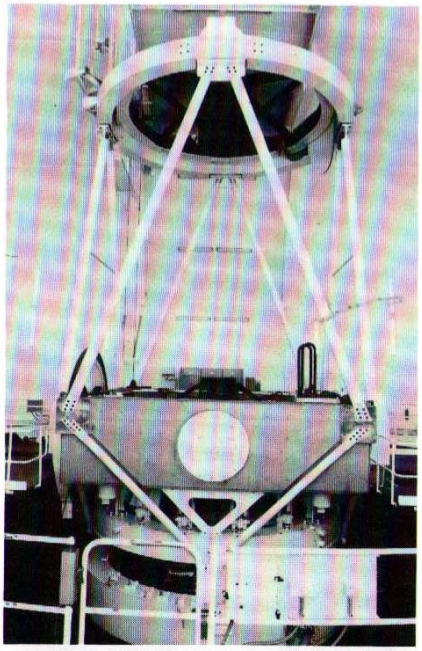
The WHT will be used at first with excellent stand-alone instruments, but in the near future RGO and its university partners will create for it a versatile operational infrastructure into which the instruments will be integrated. The 'switchability' of the Nasmyth mirror and the opportunity to reconfigure the telescope quickly means that instruments must be kept on standby, connected to the instrument control computer. Their standby heat is removed from the telescope by a refrigerated cooling system. All instruments will be controlled locally by their own microprocessors connected by a utility network using Ethernet. The instruments can be commanded with the aid of this network and the data sent to a memory system via a high-speed link. The VAX computer which is in overall charge of the instruments can host STARLINK-type software for data reduction and can be connected through intercontinental packet-switch networks to computers anywhere in the world. In this way astronomers will be able to observe on the WHT without leaving their home desks. In many cases this will be convenient and efficient but the real effectiveness of any telescope depends hugely on the capability of the instruments it feeds. Efficient instruments mean that as much as possible of the available light can be used.

Good seeing, good optics and good tracking mean that unwanted light from the sky can be excluded from the instruments and make the measurements clearer. The lack of artificial light in the La Palma sky (if lighting development can continue to be controlled) ensures that the unwanted light is, in any case, small. All this adds up to good prospects for making measurements of fainter stars, galaxies and quasars. And fainter means, usually, more distant: the William Herschel Telescope is designed for cosmological problems, and named fittingly after Britain's greatest and first observational cosmologist.

Professor Alec Boksenberg and Dr Paul Murdin
Royal Greenwich Observatory



Artist's impression of the telescope within its dome at the Roque de los Muchachos Observatory, La Palma.



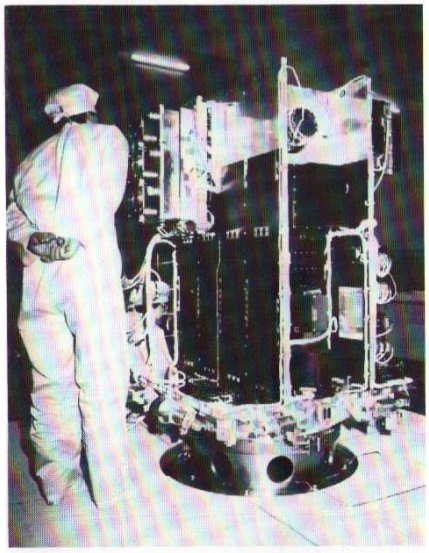
The giant 4.2-metre altazimuth-mounted William Herschel Telescope ready for operation.

The Ginga satellite and its experiments

ASTRO-C, the third Japanese X-ray astronomy satellite, was launched on an M-3SII rocket on 5 February (see *SERC Bulletin* Volume 3 No 8, Summer 1987). The launch proved very successful and the satellite was placed in a near circular orbit, at an altitude of some 500 km. On board the satellite were three experiments, the largest of which, known as the Large Area Counter (LAC), was built by a consortium consisting of Leicester University, the Rutherford Appleton Laboratory (RAL), and the Institute of Space and Astronautical Science (ISAS), Tokyo. The satellite was renamed Ginga (Japanese for Galaxy) after launch, and its experiments are described here by Bruce Patchett of RAL's Space Astrophysics Group.

The LAC experiment consists of eight identical detectors that are designed to be sensitive to X-rays in the energy range of 1 to 35 keV. This type of detector, known as Multi-Wire Array (MWA) Proportional Counters, has been developed over a number of years for flight on both British and European satellites. It was the availability of this expertise within the UK, especially in the area of low background detectors, that led directly to our collaboration in what was to be the first British scientific hardware launched by the Japanese.

The major scientific goal of the LAC is to measure, with high precision, the variability of known X-ray 'sources'. These sources have been discovered by previous X-ray astronomy missions, and considerable effort has been spent on trying to correlate them with objects visible at other wavelengths. In attempting this, it at once becomes clear that the Universe, when viewed at X-ray wavelengths, has a very different appearance to the more familiar visible images. The sun is still the most intense source of radiation, but only by virtue of its proximity, and it must be avoided by sensitive detectors such as the LAC. However the next most powerful single source of X-rays is the Crab Nebula, which is the remnant of a stellar explosion known as a supernova. The explosion resulting in the Crab Nebula occurred in 1054 AD, but, despite the apparent rarity of such events, several of the stronger X-ray sources that appear within our own Galaxy are the remnants of supernovae that occurred many thousands of years ago. They consist of clouds of dust and gas originating either from the initial explosion or from interstellar matter swept up in the expansion. Sometimes in their heart lies a spinning neutron star, a pulsar, flashing in the X-ray as well as in other parts of the electro-magnetic spectrum. Even today these supernova remnants are still expanding at several hundred kilometres a second, causing shock waves and turbulence that raise the temperature of the interstellar material to above a million degrees. It is this excited material that we see shining so brightly in the X-ray spectrum.



The Astro-C satellite (renamed Ginga in orbit) being assembled in the cleanroom at the Institute of Space and Astronautical Science in Japan, showing two of the eight proportional counters that made up the LAC experiment being connected. (Photo: ISAS)

Within our own Galaxy there are other common, and yet no less exotic, objects emitting strongly at X-rays. The majority of these are connected with stars, either single or in systems where two or more stars revolve around one another. A good example here is a class known as Interacting Binary Systems, where one of the pair of 'stars' is in fact a compact object (perhaps a neutron star or a black hole). In such systems the two stars are virtually in contact and the large gravitational forces strip away the atmosphere of the companion star: it is the release of gravitational energy, as this material accretes on to the compact object, that generates the high energy X-rays.

Moving to galaxies other than our own we find a particular class of galaxy that emits X-rays very strongly from their central nucleus. Known as Active Galactic Nuclei, these show dramatic changes in luminosity over timescales of hours, which would indicate that the energy sources can be no bigger than our Solar System. To try to work out physical conditions that explain how such enormous energy is generated in such a small volume is one of the most challenging problems in present day astrophysics. Over the next few years Ginga will be able to provide new data on such sources and, with an improved sensitivity and time resolution, that should put some important constraints upon many theories.

Although the scientific goals represent the fundamental motive for proposing and building astronomical satellites, the design and construction of the equipment make a fascinating story in themselves. For the UK hardware teams on the LAC experiment, this started in late 1982 when a proposal was submitted to SERC. The hardware development stage lasted from early 1983 through to the launch, a period of four years. One intriguing aspect of working with the Japanese was that their launch date, often a moveable feast in other agencies' programmes, never altered and, after the four-year development programme, the rocket was launched precisely on schedule.

When building instrumentation for satellites, it is quite normal for several institutions to become involved as a consortium. This has the advantage of reducing costs to any one institution and also, by dividing responsibilities suitably, the individual expertise available can be more efficiently used. In the aerospace industry, it is standard practice to develop at least two models, known as the engineering model and the flight model. The purpose of this system is to allow any new techniques to be tested before building the flight unit. For the LAC experiment, Leicester University collaborated with the Mullard Space Science Laboratory on the engineering model and with Rutherford Appleton Laboratory for the flight model.

The LAC programme called for the construction and testing of eight flight detectors and three 'spare' detectors. The spares had the dual purpose of first providing a back-up should a failure or accident occur to a flight unit; and secondly, they allow for post-flight calibration of a representative detector (to check for aging effects for example). Each counter is split into three major sub-units: the wire arrays, the counter body, and the electronic amplifiers. The wire array forms the heart of the system, and is constructed from many hundreds of stainless steel wires stretched between two end-plates located some 50 cm apart. During manufacture, each wire had to be carefully positioned and tensioned, a process not made any easier by the fact that each wire is no thicker than a human hair. Even very small deviations in position or thickness of the wire would cause the finished counter to

be rejected, and so a careful quality control method had to be implemented. A further critical component was the thin beryllium 'window' that sealed the top of the counters. The function of this was to retain the gas present in the detector, and yet be sufficiently thin for the X-rays to pass through with minimal absorption. In order to produce sufficiently thin sheets of beryllium (63 microns), the raw material was sandwiched between two layers of steel and then passed many times through a large rolling mill. The finished product then had to be checked carefully for any minute pinholes, since any such defect would allow the counter gas to escape into the vacuum of space.

On top of the counters, and immediately above the beryllium windows, a 'collimator' was positioned, the function of which was to allow only X-rays from a narrow range of angles to enter the detector. In appearance this was like a thick slab of honeycomb, and was manufactured from many sheets of steel. The angular field of view, when projected on to the sky, was similar to the apparent size of our Sun. Having passed through the collimator, and penetrated the beryllium window, the X-ray photon interacts violently with an atom of the detector gas, and an electron is ejected from the atom which liberates further electrons by ionisation. Some of the wires in the detector are given a large positive voltage that strongly attracts the free electrons. As a result, the electrons accelerate and, in the course of their journey toward the wire, collide with many more atoms, causing an avalanche of electrons to reach the wire. Finally, the charge is detected by the counter electronics, and the signal is amplified in preparation for its final journey from the satellite to the receiving dishes at the tracking station.

Following the hardware development, it is necessary to prove that each piece of equipment is capable of withstanding both the launch loads and the harsh environment it will meet later in space. Perhaps the most spectacular part of the 'environmental testing' is the vibration test. For this the equipment is attached to a machine which, as its name implies, gives it a hard shake to simulate the vibrational characteristics of the rocket launch. If the delicate equipment survives this ordeal, it is then placed in an evacuated oven, where it is first baked for several hours and then frozen at sub-zero temperatures. Only after the flight equipment has survived these tests will it be considered suitable for integrating with the satellite and, following integration and test, it will then repeat the entire test procedure along with the spacecraft and any other experiments.

The launch site, the Kagoshima Space Centre (KSC), is situated in a remote site at the southern tip of Japan. During the early stages of the mission several people from both RAL and Leicester University visited KSC to check out the experiment operation. This was a marvellous opportunity for the British team to work closely with their Japanese colleagues; few Europeans had previously worked at KSC, so this was an interesting time for all concerned. The language proved to be the least of the problems since the majority of the Japanese scientific staff were keen to practice their English. This did not apply to the locals, many of whom had never seen a European before, and the cooks from the village would often bring their children to view us over breakfast. This inevitably ended with the children rolling on the floor with laughter and being bundled out of the door by their embarrassed mothers. The food itself was excellent and, despite all the horror stories, the raw fish was delicious.

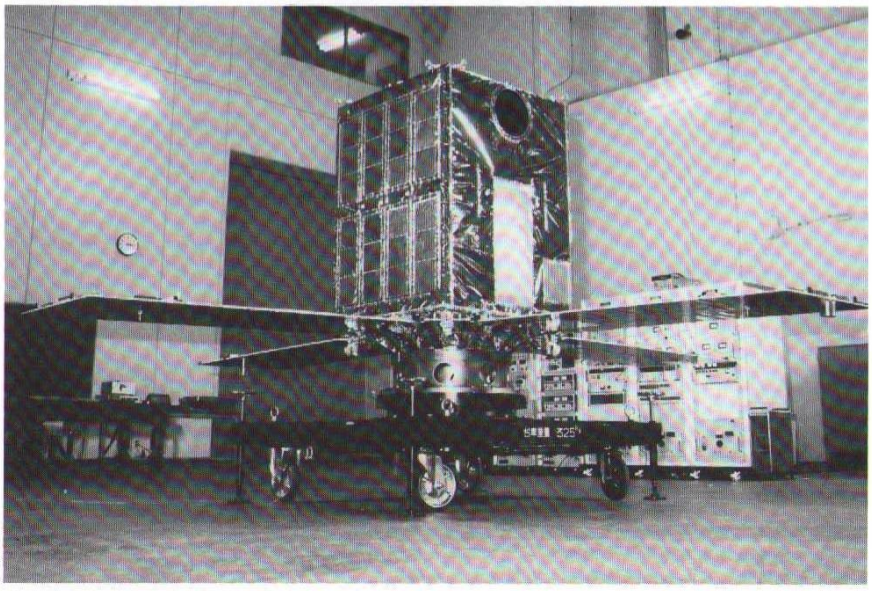
The satellite and its experiments have successfully passed their in-orbit checkout, and we are entering a period of observations that should last for several years. The time until September 1987 was chiefly used for calibration. This included studying the background signal which is due both to diffuse X-rays and to non X-ray-generated events, despite the built-in rejection features. Various known objects like the Crab Nebula are being observed to confirm the instrument's response. The Crab Nebula is a strong source with a simple energy spectrum which contains a pulsar enabling us to check our ability to observe rapid variations. X-rays are also produced near the heart of active galaxies. NGC 4151 is such a source which has been looked at by many previous missions, but which is still not well understood. Our observations confirm an absence of X-rays at lower energies due to absorption by hydrogen clouds.

Of particular interest will be the supernova which appeared in the Large Magellanic Cloud soon after the launch. This has been regularly monitored by the LAC experiment, but to date no strong emission of X-rays has been detected. The reason for this negative result is uncertain; probably the dust clouds in the expanding envelope absorb the X-rays that are almost certainly being generated and we must wait for them to clear. This particular supernova is so atypical that it is difficult to apply current theroretical models. Certainly there are noticeable variations occurring at visible wavelengths, and Ginga will continue to monitor this unique object closely over the coming months.

The Kepler Supernova was seen in visible wavelengths to explode in 1604. The remnant is quite a weak source, but a 6000-second exposure showed a clear signal of 6 keV X-rays indicating the presence of a considerable amount of iron which has an emission line at that energy. This is new strong evidence supporting the theory that this type of supernova was a dwarf star which had evolved and become unstable as matter continued to fall on to it from a companion. Such nuclear explosions are believed to account for the bulk of iron observed in the Universe.

The science phase began in September, and our collaboration during the construction phase has guaranteed us access to 20% of the viewing time, half in collaboration with our Japanese colleagues. We are eagerly awaiting each new result.

B E Patchett
Rutherford Appleton Laboratory



The Ginga satellite with solar panels extended. Under the eight thin thermal blanket panels that can be seen on the left side are the eight units of the LAC array. (Photo: ISAS)

First observation of zirconium-80

A new instrument, the Recoil Separator, has come into operation at the Nuclear Structure Facility (NSF) at Daresbury Laboratory. Already it has been used to make the first identification of krypton-72 and zirconium-80, the heaviest known nuclei with equal numbers of protons and neutrons (N=Z). As Bill Gelletly of Manchester University explains, the first experimental observation of these nuclei is interesting for the clues it may give to why certain nuclei have deformed shapes. The performance of the Recoil Separator heralds many more exciting experiments to come.

How and why nuclei change shape as the numbers of constituent neutrons and protons vary has fascinated nuclear physicists for a long time. With the development of new experimental facilities such as the NSF and a new generation of equipment of increased sensitivity and sophistication, there has been an explosion in our knowledge of the properties of nuclei far from the line of beta-stability. As a result we have obtained an increasing number of clues to the origins of deformation in nuclei. We now know that the pairing interaction between like nucleons competes for influence with the neutron-proton (n-p) interaction. The former favours a spherical shape while the latter promotes a variety of deformed shapes. When the conditions are right the n-p interaction defeats the pairing interaction and deformation sets in.

The detailed features of the n-p interaction and of the delicate balance between these different features of nuclear forces are still obscure, and they are difficult to study in stable, medium and heavy nuclei because the neutrons and protons occupy different orbits. A more promising hunting ground lies along the N=Z line. Here the nuclei are unstable but the neutrons and protons lie in the same orbits and one may hope to see clearly revealed the influence of the n-p interaction on nuclear deformation. Unfortunately, as the nuclear mass A increases, the N=Z line and the line of stable nuclei diverge and it becomes steadily more difficult to make and study the nuclei with N=Z.

One of the best ways we have found to produce and study the neutron-deficient nuclei on the N=Z side of the line of stability is the heavy ion-induced, fusion-evaporation reaction. Such reactions are studied ideally with the heavy ion beams from the 20 MV tandem Van de Graaff at the NSF. When two heavy ions, such as nickel-58 and magnesium-24, fuse together, the compound nucleus already lies between the N=Z line and the line of stability. In a simple picture, the highly excited nucleus which is formed is like a hot, spinning, charged liquid drop.

Dr Kim Lister, a 'new blood' lecturer at Manchester, opens the first bottle of Professor Morinaga's celebration champagne, while his collaborators and some of the support staff wait eagerly in front of Daresbury's Recoil Separator target position to enjoy it. From left to right: Amir Chishti, Hywel Price, Arthur James, Terry Burns, Bill Gelletly, Kim Lister, Brian Varley, Trevor Morrison and Gerry Platt.

In analogy with the evaporation of molecules from the liquid drop, the hot nucleus cools down with the evaporation of neutrons, protons, alpha particles and so on. This continues until the nucleus no longer has sufficient energy to emit particles, although it still has a lot of angular momentum. This angular momentum and the remaining energy is then emitted as gamma radiation, which carries information about the shape and hence deformation of the final nucleus.

This gives us a way of producing the nuclei we want to study, but there is a difficulty. Whereas each evaporated neutron leads towards the N=Z line, each charged particle emitted leads back towards stability. Since the evaporation of protons and alpha particles is increasingly favoured as we move towards the N=Z line, the probability for successive neutron emissions falls rapidly. And so, when magnesium-24 and nickel-58 fuse to form zirconium-82, the cross-section for the emission of two neutrons to form the N=Z=40 nucleus zirconium-80 is very small compared with the total cross-section. Studying the gamma rays from zirconium-80 requires an experimental technique which is sensitive enough to allow us to pick out the gamma rays from zirconium-80, the needle in a haystack of gamma rays from yttrium-80 and strontium-80, nuclei produced in reactions involving charged particle evaporation.

The detection of zirconium-80 has long been of special significance for nuclear spectroscopists both because it will reveal a lot about deformation and because it is difficult to study. The combination of the heavy ion beams from the NSF and a new instrument, the Recoil Separator, designed by A N James and T Morrison from Liverpool University and H G Price from Daresbury Laboratory, has made it possible. The Recoil Separator, based on crossed electric and magnetic fields not only separates the products of fusion reactions from beam particles but identifies them as well. By combining this device with an array of Compton-suppressed germanium detectors, a technique pioneered at Daresbury, it is possible to detect the gamma rays in coincidence with the recoiling zirconium-80 nuclei in the presence of the intense flux of gamma rays from yttrium-80 and strontium-80.

A group of physicists from Manchester (Lister, Varley, Chishti and the author) together with Arthur James from Liverpool, realised that this experimental set-up is ideally suited to the search for N=Z nuclei. In a series of experiments at the NSF, they identified

gamma rays from the three N=Z nuclei, germanium-64, krypton-72 and zirconium-80. The last of these is by far the heaviest N=Z nucleus that has been studied to date, and it turns out to be one of the most deformed nuclei known in nature. Although it is not as deformed as the states in the superdeformed bands seen at high excitation in dysprosium-152 (see *SERC Bulletin* Volume 3 No 7, Spring 1987), its deformation is comparable to that of the states in the superdeformed bands seen in the light cerium and neodymium nuclei with atomic weight approximately 130. The results also show that the nuclear shape is evolving rapidly as we move up the N=Z line from nearly spherical germanium-64 to deformed in zirconium-80 with evidence that prolate and oblate deformed states co-exist near the ground state in krypton-72.

As expected, these results pose a stiff challenge to any theoretical calculation of the nuclear potential energy surface. This work is also important, however, as the harbinger of many exciting results to come from the Recoil Separator. Already attempts to produce selenium-68 and strontium-76, the missing links in the chain of even-even, N=Z nuclei below zirconium-80, are scheduled on the NSF. The latter is expected to be the most deformed nucleus in the A~80 region. Further in the future lies the synthesis of tin-100, the doubly-magic nucleus with N= Z=50, which is expected to be spherical. Its properties and the properties of its odd-mass neighbours would provide a benchmark for all theoretical calculations of the properties of nuclei in this mass regime. The detection of tin-100 will be much more difficult than the discovery of zirconium-80 but we now have our sights firmly set on this target.

On a lighter note we can reveal that these experiments have attracted international recognition even before they have been formally published. In the early 1970s Professor H Morinaga of Munich University, who pioneered the study of prompt gamma rays from fusion-evaporation reactions, realised that zirconium-80 was of special significance in nuclear theory, and that its study was of importance for our understanding of how and why nuclear deformation occurs. He and his group tried to synthesise zirconium-80 but, because it has 20% fewer neutrons than the lightest stable Zr isotope, they found it impossible at that time. As an incentive, Morinaga offered a case of champagne to anyone who could do it. On hearing that it had been done at Daresbury, he duly despatched the champagne and the picture shows the first bottle being opened.

Dr W Gelletly
Department of Physics
Manchester University

Double event at Daresbury

Professor Bill Mitchell FRS, Chairman of SERC had a busy programme when he visited Daresbury Laboratory on 26 March, including two inaugurations - the FPS T-20 computer and the European Suppression Shield Array.

FPS-T20: ***The installation of the prototype FPS (Floating Point Systems) T-series computer at Daresbury reflects Council support for parallel processing in scientific and engineering computation. The picture shows the Chairman and Dr Martyn Guest, head of the Advanced Research Computing Group, with the T-20 transputer-based hypercube parallel processor. The development of effective algorithms and programs for the concurrent machine will be conducted through various academic and industrial collaborations.***

ESSA30: ***After the inauguration of the European Suppression Shield Array of 30 gamma-ray detector systems (ESSA30) by Professor Mitchell, a large group of Daresbury and university physicists, technical and industrial staff connected with it gathered around the apparatus at the Nuclear Structure Facility. Also present were representatives of the European collaborators in the ESSA30 detector system. Various groups have pooled resources, with financial support from the European Community, to assemble the largest such system anywhere.***

Progress on the ISIS facility

ISIS, the spallation neutron source at Rutherford Appleton Laboratory (RAL), has already been running at a level greater than three times the power of any existing pulsed accelerator-based neutron source. A full programme of science using neutron scattering techniques is well under way.

Machine and target station

Since ISIS was named by the Prime Minister in October 1985, the machine and target station have been progressively developed to reach 50 μA of proton current on to the target and the energy has been raised to 750 MeV (design is 800 MeV). The progressive increase in the power of the facility during running for science is illustrated in figure 1 which shows the integrated current delivered to the target in two-weekly scheduled periods of operation. For the period until the end of March 1987, the accelerator was run at an energy of 550 MeV using four of its eventual six radio frequency accelerating cavities. During the shutdown in summer 1986 and early in 1987 a large amount of work was done, especially on the 70 MeV injector, to improve reliability of operation and to commission sub-systems to the higher energy level.

The running in March 1987 showed that the reliability of operation was improved. During March the average current reached record levels. During the last four days of the run the average current was 42 μA. The current reached 50 μA on several occasions, corresponding to 6.2×10^{12} protons per pulse at 50 pulses per second. The current was mainly limited by the voltages induced in the RF accelerating cavities by the intense bunches formed by the RF system. At a few $\times 10^{12}$ protons per pulse, this beam-loading produces an induced voltage in the cavity of the same magnitude as the working voltage. A feed-forward system was developed to measure the bunch amplitude and to produce a voltage on the cavities to counteract the induced voltage. Further reduction in the beam loading has been achieved by lowering the impedance of the RF cavities using copper sulphate solution as a resistive load. This is expected to allow four times more proton current to be accelerated.

At the end of March 750 MeV protons were, for the first time, successfully accelerated at low repetition rate using all six RF cavities and the protons were extracted on to a beam dump in the synchrotron room.

This cleared the way for operations for the experimental programme with 750 MeV protons from April onwards. The yield of neutrons from the moderators in the target station increased as expected by 55% from the two moderators near the front of the target and by 90% from the two at the back. Some problems were revealed in running at 750 MeV, including a demonstration of the power in the beam when a malfunction resulted in some molten stainless steel inside the synchrotron vacuum vessel. Development of operating and monitoring techniques have gradually been improved so that operation at 750 MeV is approaching the reliability levels reached at 550 MeV.

During routine operations, the necessary control of particle loss to prevent irradiation of the components of the system has been demonstrated. Some 90% of particles from the 70 MeV injector go through the process of injection, trapping and acceleration in the synchrotron and extraction and transport to the target station. Most of the loss is at low energy in the synchrotron and 80-90% of the lost particles pass to collectors as designed and do not generally irradiate the synchrotron.

The target station has run well. The operating temperatures of the zircalloy-clad depleted uranium plates in the target have been as expected. The neutron yield from the two ambient temperature water moderators and the 100 K liquid methane and 25 K liquid hydrogen moderators has also been as expected.

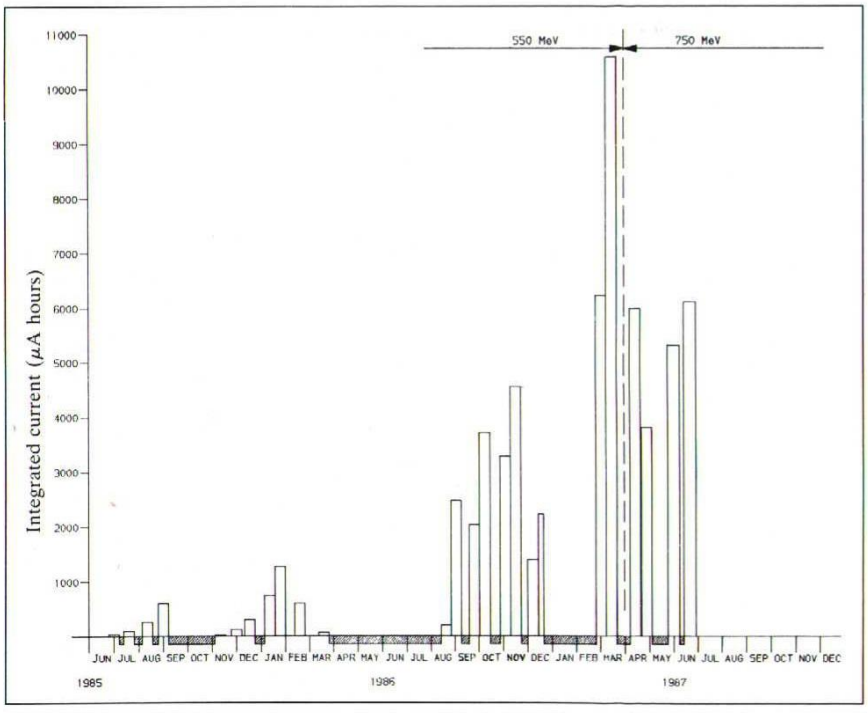


Figure 1: Time integrated current in μA- hours taken over two-week intervals. Planned shutdown periods are shown shaded.

Muon beam

The world's most powerful muon beam has been installed and commissioned at ISIS with international funding and the science programme using this is in its initial stages.

Running plans

It is planned to run to the end of 1987 based on a schedule of two weeks for machine development and four weeks for science. The last three months of the running programme is made possible by the contribution of 6 million francs by France towards the ISIS programme. It is intended to increase the current to 100 μA by the end of this period. Early next year there will be a shut-down for further improvements to operating systems on the target station and for the installation of new beam lines.

Experimental facilities

The experimental facilities on ISIS are gradually being expanded as funding allows. At present, 13 of the available 18 beam lines are involved. There are six instruments supporting a user programme with the redesigned small-angle scattering instrument LOQ starting a user programme in September, three development instruments and three new instruments under construction. Two of the latter group, PRISMA and MARI, are being funded from Italy and Japan respectively and

represent substantial contributions to ISIS from abroad. The performance of the operational instrument has been excellent and a few highlights from the scientific programme are given below. It should be remembered that these results have required, in addition to the instrument itself, a first-class data collection and assessment system and the necessary equipment, cryostats, furnaces and so on to control the environment of the sample.

The High Resolution Powder diffractometer (HRPD), with its 100 metre-long guide tube and backscattering detector, leads the world in high resolution time-of-flight powder diffraction. A spectacular recent result was the world's first accurate determination of the structure of one of the new high temperature superconducting ceramics and the first observation of subtle structural instabilities at certain temperatures — important contributions to an understanding of these exciting new materials. Figure 2 shows the structure of one type of ceramic, yttrium barium copper oxide, together with part of the diffraction pattern from which it was derived.

The Critical Reflectance Spectrometer (CRISP) is a recently developed instrument now in routine use. It uses the reflection of a thin 'ribbon' neutron beam at grazing incidence from surfaces and from samples in the form of thin films on either solid or liquid substrates. The latter is achieved by directing the incident beam slightly downwards into the liquid surface. Reflectivities as low as 10^{-6} can be measured. One example of the information revealed by this technique is shown in figure 3 which is from a Reading University programme on multilayers — of great current interest as a means of producing new semiconductor materials not found in nature. The difference between a model calculation (full curve in figure 3) and the observed data give information about the interdiffusion of the layers in the platinum-carbon sample and the deviation in densities from ideal values.

The Quasielastic Scattering Spectrometer (IRIS) was initially used with a detector systems from India which obtained energy resolution of the scattered neutrons by transmission and reflection in beryllium filters at different temperatures. An extension of the instrument is now being commissioned which uses back reflection from a bank of 180 pyrolytic graphite crystals to measure the energy of neutrons scattered by the sample. The energy resolution of the analyser is 15 μeV when using the 002 planes of the analyser crystals, close to the predicted value. The count rates are good and range of Q (the momentum transfer in the scattering event) is exceptionally large, a combination of properties only covered by several separate instruments at reactor neutron sources. These properties are illustrated in figure 4 which shows the results of a commissioning experiment — quasielastic scattering from ammonium bromide.

The motion of the ammonium ion within the bromine lattice occurs on a time-scale of 10^{-12} seconds and causes a broadening of the diffraction peaks in the time of flight spectra by a process analogous to the Doppler shift of a sound wave from a moving source. Each spectrum in figure 4 is produced by a different section of the detector and corresponds to a different value of Q. By measuring the widths of the peaks and the variation of width with Q, information about both the motion and the orientation of the ammonium ion can be obtained.

D A Gray and H Wroe
Rutherford Appleton Laboratory

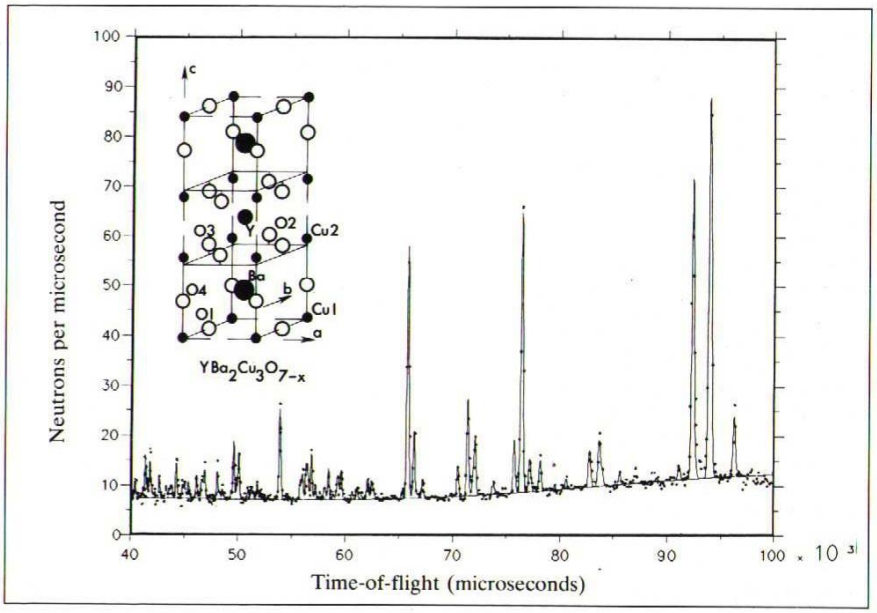


Figure 2: Structure of high temperature superconductor yttrium barium copper oxide and its time-of-flight powder diffraction spectrum measured on HRPD.

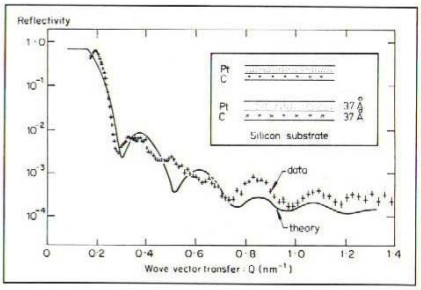
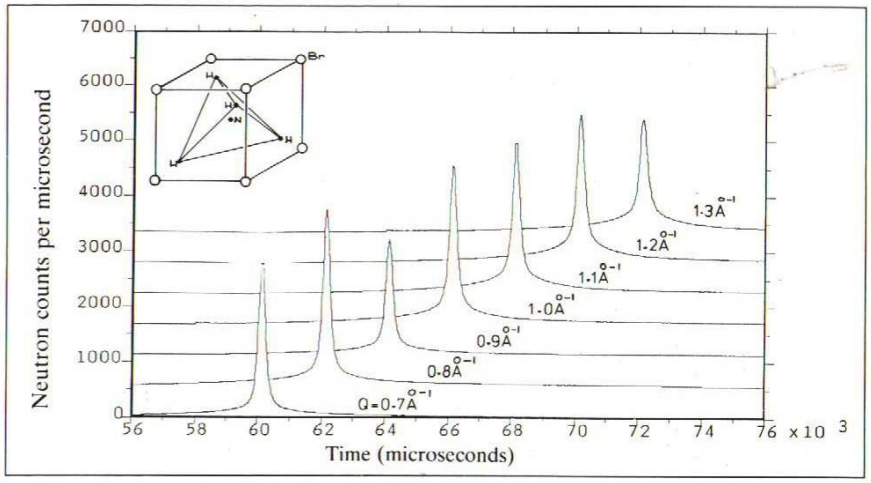


Figure 3 (right): Critical reflectance from three bilayers of platinum/carbon measured on CRISP.

Figure 4 (below): Quasielastic scattering from ammonium bromide measured on IRIS.



High critical temperature superconducting ceramics

The discovery only a few months ago of a new family of high critical-temperature superconductors has generated worldwide scientific activity on an unprecedented scale, writes Dr Jan Evetts of Cambridge University.

Although it is an exciting time for the researchers involved, the sheer pace of discovery brings attendant difficulties. The normal flow of scientific information has been disrupted; since April there have been at least seven major international meetings in Europe and the USA alone, and the list of published and otherwise distributed 'communications' now exceeds 500 items, many reporting work that is rushed and of uncertain quality. The scientific journals are overwhelmed and important manuscripts are unable to find an outlet in time to be of value for ongoing research. Naturally there is much duplication of research effort: an estimated 1000 research groups are active just in the USA, and in the UK about 100 groups or organisations are involved in one way or another. Research activity is building up rather more cautiously in the UK than in many other countries; in straight scientific terms this could be argued to be a sound and cost-effective strategy. However, in the wider interests of the UK as an industrial nation, caution and delay put at risk our chance to participate as equals in a remarkable new technology.

By mid-June the status of research on high critical-temperature (T_c) superconductors could be briefly summarised as follows. There are now a number of different ceramic compounds that can be classed as high T_c superconductors although most attention has focused on a pseudo-tetragonal oxygen-deficit layer-structure perovskite known as the 123 phase. The compound $YBa_2Cu_3O_{7-x}$ was the first 123 phase investigated. T_c depends strongly on the oxygen deficit and, when x is approximately equal to 0.2, the stoichiometric crystal has a T_c in the range 92-94 K. A key structural feature appears to be the ordered linear copper-oxygen chains that lie in the basal plane midway between neighbouring Ba atoms; it also appears important for the copper to have a mixed valence state. At elevated temperatures or for low oxygen levels, an order-disorder transformation to a tetragonal form degrades or destroys superconductivity. Although a wide range of elements has been successfully substituted to give superconducting oxides or oxy-fluorides, the precise structure of the phase responsible for the hints of superconductivity reported at temperatures near room-temperature is still not generally known. However, in recent weeks evidence has been accumulating for a metastable transitory phase that is superconducting above 250 K.

Rapid progress has been made in material synthesis in bulk form, as thin films and as wires. Powder routes include sintering of elemental oxides as well as the preparation of mixed oxides by sol-gel and co-precipitation routes. Thin films can be deposited both by sputtering and by electron beam evaporation and often then require heat treatment in oxygen to achieve optimum properties; apart from isolated reports from IBM, the quality of deposited films is generally poorer than bulk powder route materials. Many organisations are fabricating wire and it appears that some progress is being made in controlling and optimising the critical current density — a parameter of vital importance for applications. Bulk single crystals and epitaxial single crystal films have been prepared, measurements on single crystals indicating greatly increased critical currents and rather strong anisotropy in the upper critical field, of between 1:5 and 1:12. Apart from concern over extreme anisotropy, the nature and distribution of grain boundary phases seem to be most important in determining the critical current density.

Manuscripts reporting physical property measurements still come second to those reporting structural data and elemental substitutions but are nevertheless very numerous. Particularly important as an aid to elucidating the fundamental mechanisms for superconductivity are reports of the absence of an isotope effect for oxygen, reports on the Cu^{++}/Cu^{+++} ratio and details of the tunnel conductance, gap structure and density of states. Despite rapidly

Superconductivity and SERC

The Council has been active in response to the community's interest. Support has been provided to enable attendance by representative academics at a Materials Research Society symposium in Anaheim, California; the Commission of European Communities workshop in Genoa, Italy; and the International Atomic Energy Agency research conference in Trieste. SERC has organised a meeting of the UK community at the Rutherford Appleton Laboratory attended by more than 150 participants. There has also been a meeting at Birmingham University attended by about 200 people, mainly physicists. This meeting started at 18.30 and, in true superconductivity fashion, did not finish until approaching midnight.

Twenty-six applications with a requested value of about £3 million were received by the end of April (the delayed Round 3 closing date). These applications were considered by the relevant subcommittees of the Physics, Materials and Chemistry Committees. In several cases more than one subcommittee was involved because of the multidisciplinary nature of applications. In addition an ad hoc multidisciplinary panel was formed to provide an overview and recommend a priority list for support. In spite of strong competition for the funds available, the Council supported 11 proposals approaching three-quarters of a million pounds in total. In identifying those for support, emphasis was placed on providing manpower rather than equipment, and topics were chosen to provide a breadth in the research. Four research studentships earmarked to superconductivity projects have also been awarded.

Strategy for the support of superconductivity is, like the research itself, a fast moving topic. Detailed discussions are taking place between the Council and the Department of Trade and Industry with a view to a joint initiative in superconductivity from the 1987-88 session. The Science and Engineering Boards have already agreed to contribute £1 million each for commitment in the session and consideration is being given to the formation of two interdisciplinary university research centres for superconductivity (see page 3).

J E Farrow
Secretary, SERC Physics Committee

accumulating data on the unusual properties of these materials, the theoretical position is still uncertain. The normally accepted mechanism can be ruled out but it is difficult to choose between the three or four serious theoretical models that have been proposed.

These remarkable new materials have potential applications in microelectronics and computers, energy storage and transmission, transport, high technology engineering, sensors and instrumentation. We cannot yet say with confidence which applications will come to fruition and what the timescale for application might be. However, the rate of progress is so rapid compared to previous major technologies that information on the practical realities of major applications is likely to be available in months rather than years.

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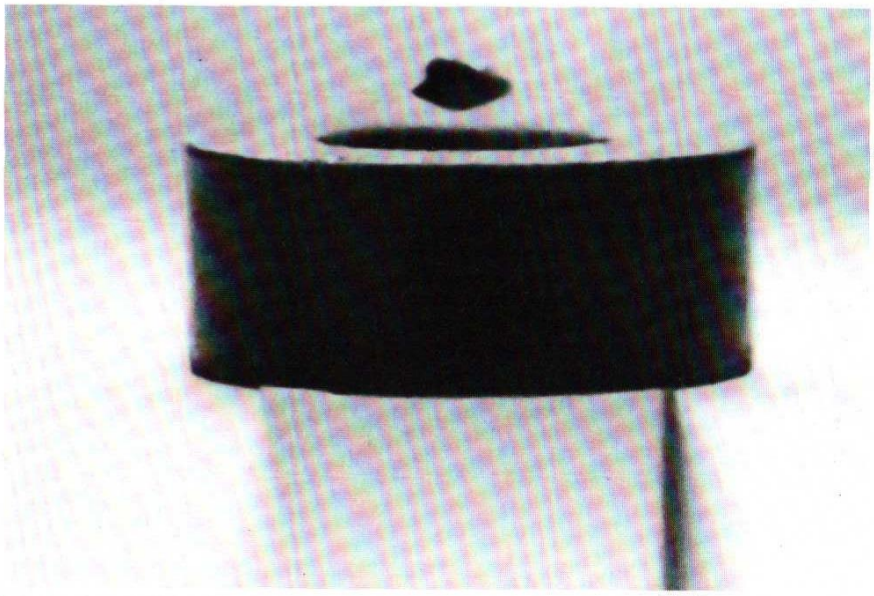
Department of Materials Science and Metallurgy
Cambridge University



A 6mm piece of yttrium-barium-copper-oxide in the superconducting state levitated over a ring of permanent magnet material. (Photo: Cambridge University).

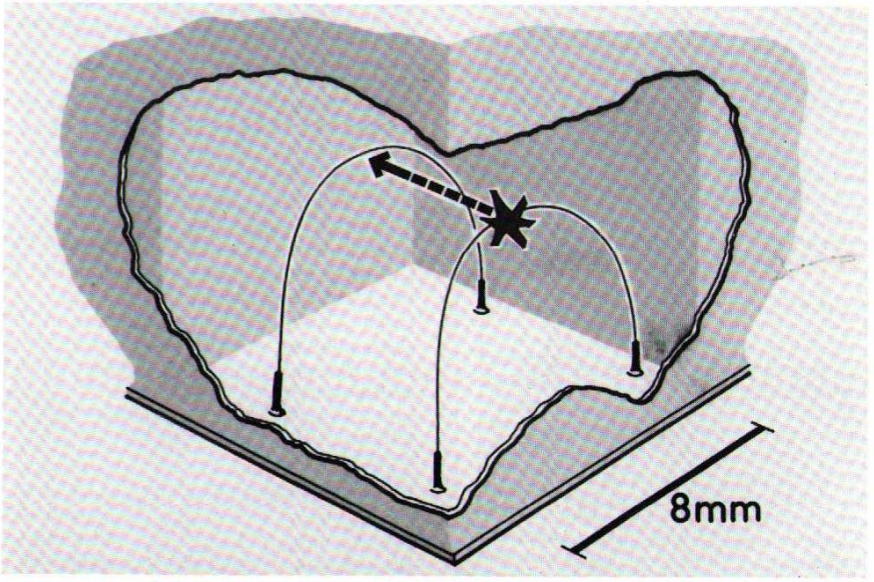
Superfluid helium: almost a vacuum

The extremely low temperatures available at Lancaster University (see *SERC Bulletin* Volume 2 No 10, Spring 1984) are opening up new fields in the study of superfluid ^{3}He. Liquid ^{3}He can now be cooled so far below the superfluid transition temperature that the density of quasiparticles (the 'normal fluid' particles) is virtually zero. Since the few remaining quasiparticles move without collisions through the superfluid (which behaves very much as a vacuum), 'atomic beam' experiments to probe the behaviour of the independent quasiparticles should be possible.

A new thermomechanical effect discovered at Lancaster is the first experiment of this type. A quasiparticle source at a specific location in the superfluid is provided by a high-speed wire resonator which creates the quasiparticles by local breakdown of the superfluid. The ensuing quasiparticle wind can be subsequently detected elsewhere in the cell by the mechanical impact on a second wire resonator, whose movement is detected by a superconducting 'SQUID' device. The necessary components of source and detector for a quasiparticle spectrometer have been assembled and preliminary experiments successfully completed. Since the interaction of quasiparticles with surfaces and with superflow fields is of great theoretical importance, this newly accessible experimental area should prove highly interesting.

Superfluid ^{3}He is a material of many surprises. Looking further ahead, one wonders if a virtually quasiparticle-free bath of superfluid ^{3}He (at, say, 90 μK, which is now possible) could not act as a new type of ultra-low energy particle detector (for dark matter, for example) in which the incoming particle deposits its energy as a quasiparticle shower, in analogy with the bubbles in a bubble chamber, but here with an energy-scale of only millikelvin.

Dr A M Guénault and Dr G R Pickett
Physics Department
Lancaster University



Schematic cut-out view of a low temperature cell showing the quasiparticle spectrometer operating at about 100 μK in superfluid ^{3}He. Each time the nearer wire resonator passes through the position of maximum velocity, a pulse of quasiparticles is given off which can set the further detector wire into motion. This spectrometer is the coldest mechanical device ever operated.

Electron beam resists for microlithography

Microelectronic circuits are produced by a series of patterning and etching processes interspersed with material deposition and ion implantation process. Present-day circuits require that the patterns from which they are produced should have features with dimensions between one and two microns wide. Future generations of circuits, however, will require minimum feature sizes of 0.4 microns and below. A collaborative programme of research and development, carried out at British Telecommunications Research Laboratories at Martlesham, the Plessey Company at Caswell, Philips at Redhill and at the Universities of Strathclyde, Liverpool, Stirling and Kent, is attempting to provide polymer resist materials for the UK with the capacity of sub-micron lithography and with the required sensitivity for use in the next generation of 'direct-write' electron beam lithography machines. The programme is described here by Richard Pethrick and Stanley Affrossman of Strathclyde University.

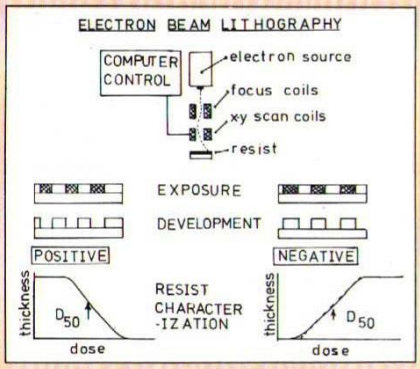


Figure 1: Electron beam lithography. Exposure of a thin polymer film with an electron beam leads to pattern generation either by crosslinking or degrading the resist.

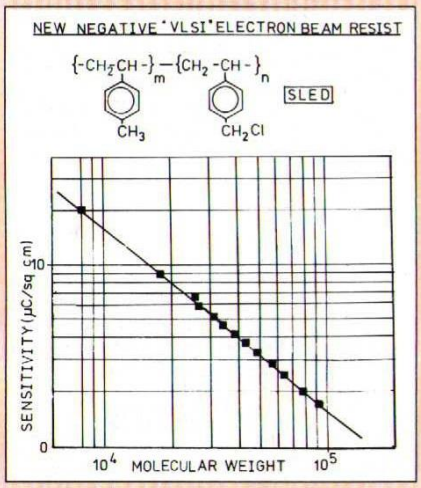


Figure 2: A new negative electron beam resist developed at Strathclyde and Liverpool Universities (SLED): influence of molecular weight on electron beam sensitivity.

At present, lithography is based almost entirely on opitcal technology using photo-resists. However, the feature size which can be produced using these materials is limited by the wavelength of the light that is used. Much effort has recently been put into attempting to achieve patterning with photoresists at the sub-micron level and it is possible that within the next ten years we may see excimer laser systems and photoresists being used for mass production at the 0.5 micron level; however, the masks to be used in such processes are likely to be made using electron beam lithography.

The research efforts supported by SERC and Alvey are helping to provide UK lithographers with new materials and development systems to help them keep pace with the world-wide drive for a reduction in circuit feature size required for the fabrication of the next generation of microchips.

Electron beam lithography

Irradiation of a polymer with electrons can produce either crosslinking or degradation of the material. If the polymer degrades this will generate a lower molecular-weight fraction which can be solvent-developed, leading to pattern generation. In contrast, if the polymer is crosslinked by the radiation, then the material which is not exposed remains relatively soluble and a reverse-toned image is produced. The processes associated with pattern generation in an organic resist overlaying a substrate are shown in figure 1. Much research effort has focused on the sensitivity of the resist. This is usually defined in terms of the minimum radiation dose to achieve a 50% change in the developed thickness of the material being exposed. So that a high resolution pattern can be produced, it is also necessary for the shape of the exposure-response versus dose-curve to be as close to a step function as possible. Other factors which must be considered in the design of a resist are: adhesion to the substrate, resistance to swelling on solvent development of the image, and ion and plasma etch resistance for transfer of the pattern to the substrate. In practice, few resists embrace all of these features and the efforts of the collaborators have been aimed at developing new resist materials to aid very large-scale integration (VLSI) manufacturers in achieving the sub-micron resolution target of the Alvey electron beam resist programme.

New negative resist

A number of negative commercial resists exist which are capable of being used for electron beam lithography. Many are based on styrene or one of its derivatives. As part of the Alvey activity, a new resist — SLED — has been developed based on a copolymer of chloromethylated styrene and vinyl toluene. The work on this resist was initiated by Professor Tony Ledwith at Liverpool and subsequently completed by one of the authors (RAP) at Strathclyde. These studies have shown that incorporation of small amounts of the chloromethylated monomer into the copolymer produced a substantial increase in the sensitivity of the resist and it is well able to meet the objective of 10 micro-Coulombs/cm^2(μC/cm^2) required for the 'direct-write' electron-beam exposure machine being developed in another Alvey project. Variation of the molecular weight distribution, molecular weight and the method of solvent development can all have a profound influence on the performance of this resist (figure 2). It is possible to produce resist materials with sensitivities ranging from 2-80 μC/cm^2 and the slower material is capable of achieving the 0.5 microns linewidth. Dr R G Jones at Kent University is undertaking a systematic study of the effects of structural variation on the properties of this resist, the methyl and chloromethyl substituent groups can be placed at different positions on the phenyl ring. This work has led to some of the best resolution achieved from the system.

Production of the resist material has been developed to a stage where it can be produced by a number of routes: solution, bulk and suspension polymerisation and, in the case of the latter process, material has been generated at the 40% solids level and in quantities of the order of 400g. The industrial collaborators have carried out extensive lithographic assessment of the material and have also evaluated its performance in a reactive ion etching environment. In all respects, this material is superior to the existing electron beam resists and it is hoped that it will be commercially available in the near future. An electron micrograph of lithography at the sub-micron level with this type of material is shown in figure 3.

New positive resists

Complementing this resist system, a new resist is being developed which is based on the initial work at Philips by Dr E Roberts. Almost ten years ago he developed a positive resist based on a

mixture of copolymers: poly(methylmethacrylate-co-methacrylic acid) and poly(methylmethacrylate-co-methacryloylchloride). The new material is based on the second of these components. This resist has proved to be extremely sensitive and has the capability of being used at the sub-micron level, though plasma etch resistance is poor. It has been found, however, that if the resist is treated with analine after development, the resultant resist material has a higher resistance to plasma etching. The work currently being carried out on this resist aims to establish the effects of molecular weight on the sensitivity of the resist, and to explore the way in which solvent development procedures can influence the performance exhibited by the material and to study methods for enhancing its plasma etch resistance.

Solvent development of resists

It is clear from the work being carried out in this programme and also from various reports in the literature, that the choice of solvent is crucial in defining the performance of a resist material. A study is being carried out by Professor J M Cowie at Stirling University into the use of cosolvents for the development of resists. Combinations of a solvent and non-solvent are being investigated both with a view to their application in electron beam lithography and to an understanding of the solubility characteristics of a polymer matrix. Selection of the best solvent or solvent combination can lead to significant improvement in performance by changing both the contrast and sensitivity of the resist on development. By altering both the solvent and the temperature, conditions can be achieved for the best resolution and sensitivity of the resist materials. This approach is allowing a better definition of the correct solvent combination for use in the development process. A new method of dynamically assessing the solvent system to be used with a particular resist system has been developed at Strathclyde and

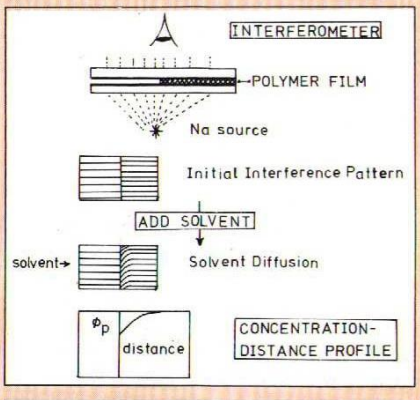


Figure 4: Interferometer method for study of the rates of solvent diffusion and swelling of resist films by solvent development systems used in electron beam lithography.

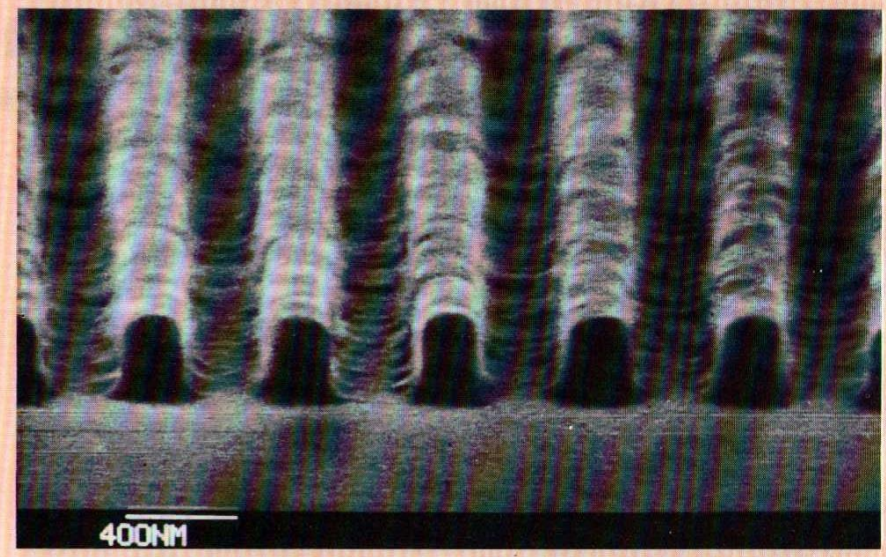


Figure 3: A 0.25 micron grid pattern generated using a SLED type of resist (Photo: Kent University and Plessey, Caswell).

involves the observation of the changes in the fringe pattern of an etalon containing a thin polymer film, as it is exposed to solvent. This is a further development of the system originally reported by Robinson and Parks and allows the diffusion of the solvent into the films to be assessed dynamically. Figure 4 shows the experimental system used in the solvent diffusion studies and figure 5 shows the way in which the good solvent diffuses faster than the poorer solvent, leading to the observation of the growth of a second boundary layer within the film which can be associated with deposition of the polymer by the non-solvent. The optimum solvent combination deposition is obtained when the diffusion coefficient of the mixture is almost zero, and this corresponds to the conditions for minimum swelling of the resist. The work at both Stirling and Strathclyde is providing an academic basis for the rather empirical selection of solvent developers currently used in the resist work, and allows a more rational selection of new solvent systems.

Professor R A Pethrick and
Dr S A Affrossman
Department of Pure and Applied Chemistry
Strathclyde University

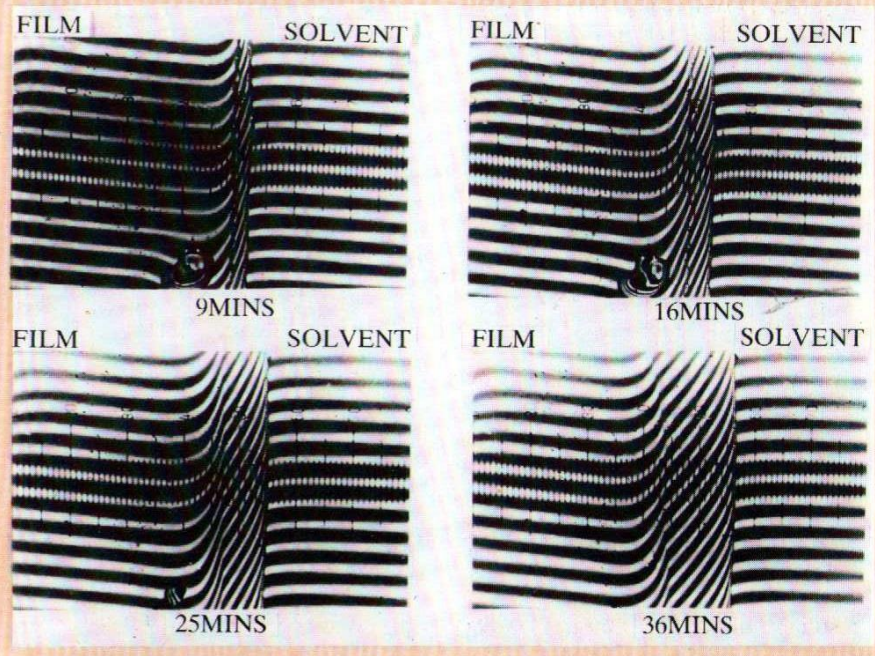


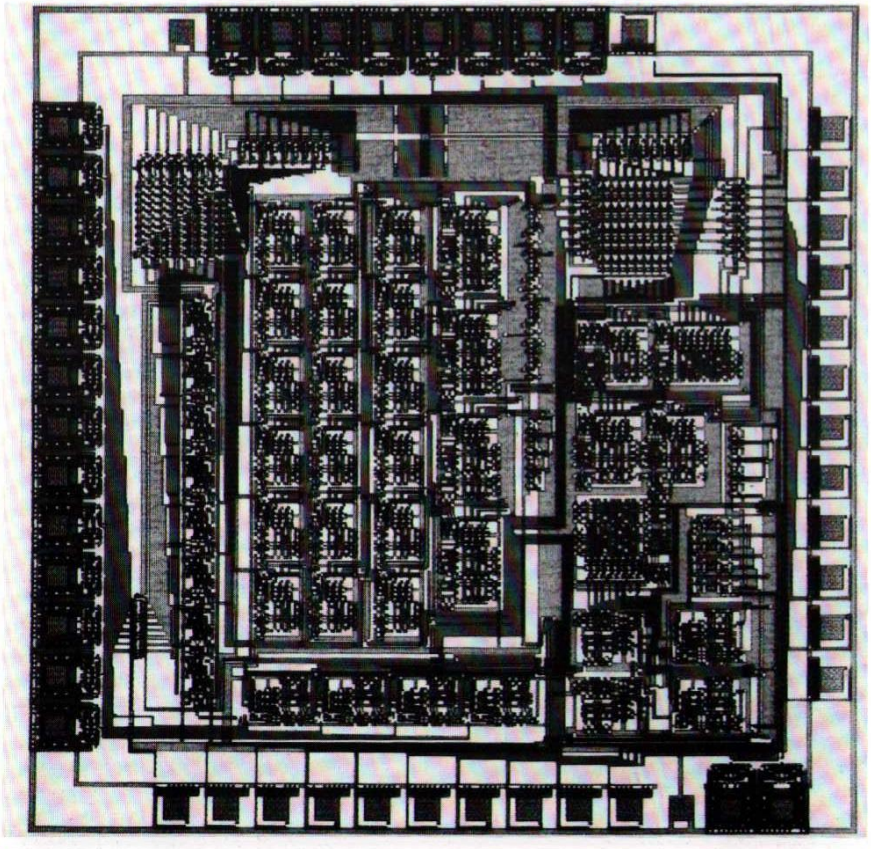
Figure 5: Interference patterns generated at various time lapses for the diffusion of 60% IPA in MEK into PMMA at 30°C. (Photo: Strathclyde University).

Integrated circuit design and test centres

The council has supported five centres for the design and testing of integrated circuits (ICs) since 1984. Two centres, at Newcastle University and University of Manchester Institute of Science and Technology, have proved particularly successful and are to continue to be supported, through new grants starting on 1 July. The centres have a dual role: to assist and train the microelectronically-aware researcher who wishes to realise his ideas on silicon; and to implement ideas on silicon for the user whose specialism is outside microelectronics. In this, the centres cover all aspects of IC design and testing from recommending a design and processing route to packaging and testing finished chips. They are described here by Andrew Kurzfeld, coordinator of the Microelectronic Facilities programme.

Andrew Kurzfeld, Microelectronic Facilities coordinator.

The design and test centres are complementary to the design services offered by the Rutherford Appleton Laboratory (RAL), which cater for the more knowledgeable user by providing comprehensive fully-supported CAD (computer-aided design) packages and advice on their use. RAL also offers a brokerage service to allow easy access to industrial and commercial processing. More flexible processing routes are available at the SERC-supported centres at Edinburgh and Southampton Universities, where a variety of CMOS, Bipolar and NMOS technologies are on offer. In addition, the Electron Beam Lithography Facility at RAL offers flexible mask-making, reticle manufacture and direct-write possibilities. The design and test centres can interface to all these facilities although each has its own particular specialisations and routes to silicon.



Layout of a floating point inner product step processor (Photo: Newcastle University)

Newcastle

The Newcastle University Microelectronic Design and Test Centre provides the academic community with access to and assistance in the use of VLSI (very large-scale integration) CAD software, particularly compatible with processes available from Plessey Semiconductors Ltd. The Centre can also see the project through the processing phase and give expert help and advice at the testing stage.

Software packages are available for full custom, semi-custom and gate array CMOS technologies down to 2.5 micron geometries. Some NMOS work is also possible. Typically, custom and semi-custom designs contain up to 30,000 gates (transistors) and gate arrays up to 10,000 gates. The Newcastle Centre has already designed or helped in the design of microcircuits which are to be applied in image and signal processing, instrumentation, control, logic and data communication circuits. Real-time processing is one area where the group sees great potential for custom design and is an area where the staff of the Centre have particular expertise.

UMIST

The UMIST IC Design and Test Centre has its own laboratory within the Electrical Engineering and Electronics Department and houses all the equipment necessary for the design and testing of microelectronic circuits. The services provided so far have focused on the use of Ferranti Electronics Ltd technologies and particularly on the use of their well established uncommitted logic array semi-custom technology. By using this pre-defined matrix of logic cells, which can be configured to produce the desired logic structure using a single interconnecting metal layer, it is possible to meet many requirements quickly and easily, particularly where speed of circuit operation and a high level of complexity are not the dominant factors.

Among the chips that have so far been created using the UMIST Centre are an intelligent sensor communication system for research at North Staffordshire Polytechnic, a microprocessor bus switch for work at King's College, London, a pulse-width modulated three-phase motor controller in-house at UMIST and a transputer supernode switch for Southampton University.

The future

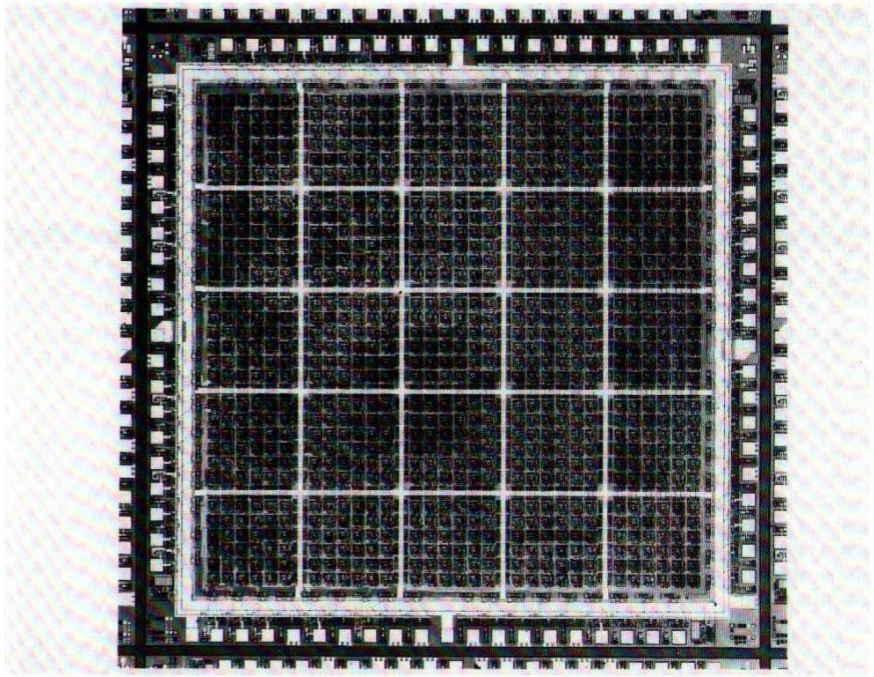
The new SERC awards will increase the number of staff available at each of the

two university centres by 50% and this means that there will be some capacity available for new users. The demand is likely to be high so if you are interested, you should make contact as soon as possible with one of those listed here.

Andrew Kurzfeld
Rutherford Appleton Laboratory

IC design and test centres contact points

	Telephone
Andrew Kurzfeld RAL	*Abingdon (0235) 445286*
Dr P J Hicks UMIST	*061-236 3311*
Dr G Russell Newcastle University	*091-232 8511*
Dr D R S Boyd RAL	*Abingdon (0235) 445167*



Three-phase motor controller using a Ferranti uncommitted logic array (Photo: UMIST)

Engineering use of transputers

The first phase of a new initiative in the engineering applications of transputers was launched in May. This £3.5 million programme, which is intended to run for four years, is being jointly funded by SERC's Engineering Board and the Department of Trade and Industry. Joint funding means that both industry and institutions of higher education can take part.

The aims of the programme are:

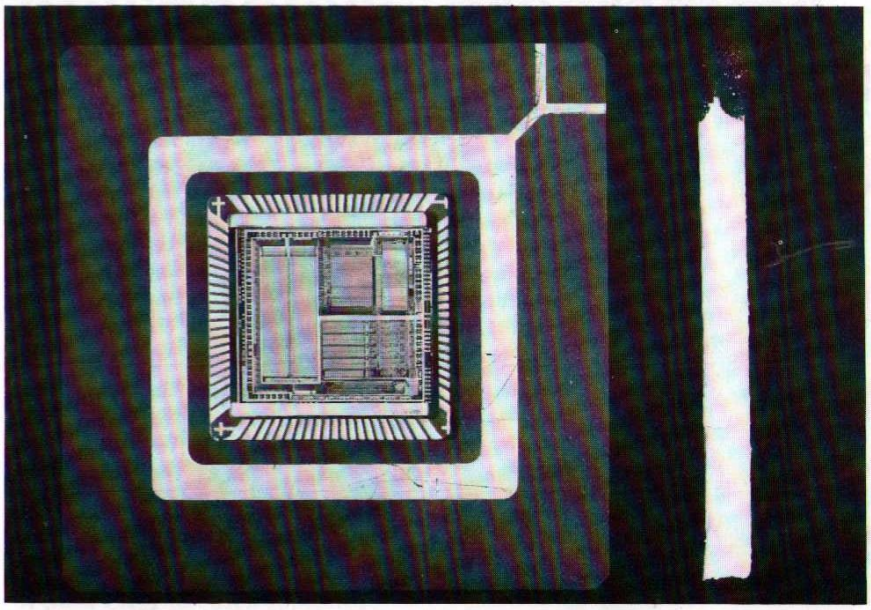
- To promote awareness of the potential of the transputer and associated technology and its applications to problems requiring parallel processing solutions;
- To capitalise on expertise within the academic community to develop a viable software base, regarded as essential for the exploitation of parallel systems in industry;
- To promote high-quality research using transputers;
- To facilitate technology transfer to British industry.

Through the programme, which is being coordinated at the Rutherford Appleton Laboratory, participants are offered access to appropriate transputer hardware, software and expertise through a loan pool and through four support centres to be established at academic sites.

The initiative arose from the recommendations of a working group of the Engineering Board's Computing Facilities Committee, chaired by Professor D Lewin of Sheffield University, which reported in 1986.

The transputer is a new super-microcomputer on a single silicon chip, designed and manufactured in Britain by Inmos Ltd. It is the first discrete silicon device in the world to provide an effective vehicle for parallel processing (the simultaneous application of many processors to the same problem). This is a technique which promises computer systems with a price: performance ratio several orders of magnitude better than those available today. Future parallel processors will greatly reduce the cost of tasks performed by today's machines and will solve important problems which are not feasible at present. Britain enjoys a world lead in parallel processing techniques but there is a narrow window of opportunity in which to exploit this lead.

For further information on the Engineering Applications of Transputers Initiative, contact Dr M R Jane, at Rutherford Appleton Laboratory, telephone Abingdon (0235) 445408.



The Inmos transputer compared in size with a matchstick. The chip contains about 150,000 transistors and is capable of executing 10 million instructions per second.

Microbial cyanide and nitrile biotransformations

Despite its high toxicity, cyanide is produced by many plants and microorganisms. The reasons are not always clear but, as Professor Chris Knowles of Kent University relates, there may be commercial potential for microorganisms that are able to degrade cyanide in poisonous industrial wastes. Microorganisms able to degrade organic cyanides (nitriles) may also form the basis of processes to detoxify industrial wastes or be of use for biotransformations to give high-value products.

Cyanide is the archetypal poison. It is therefore perhaps surprising that a wide range of living organisms is able to produce remarkable quantities of cyanide. More than 2000 species of plants, including several major crops such as cassava and sorghum, are known to form cyanide, as are many fungi, especially basidiomyces and ascomyces. A few bacteria, particularly *Pseudomonas* species and *Chromobacterium violaceum*, are prolifically cyanogenic.

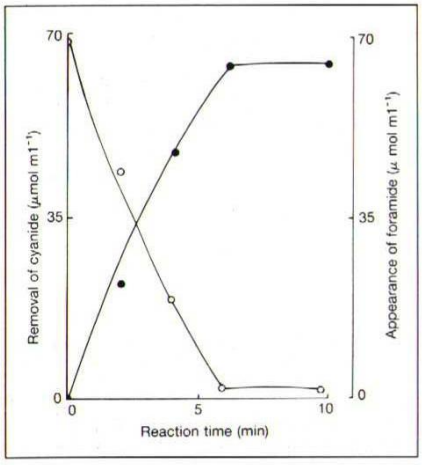


Figure 1: The complete conversion of cyanide (o) to formamide (●) by immobilised G. sorghi mycelia.

Microorganisms form cyanide as a secondary metabolite by oxidative decarboxylation of glycine by a membrane-bound enzyme system:

$$H_2NCH_2COOH \longrightarrow 4[H] + HCN + CO_2$$

Once formed, cyanide is converted to carbon dioxide and ammonia by cyanogenic fungi. In contrast, *C violaceum* converts cyanide to β-cyanoalanine by addition to σ-acetylserine or cysteine:

$$HCN + HS\,CH_2\,CH\,(NH_2)\,COOH \longrightarrow H_2S + NC\,CH_2\,CH\,(NH_2)\,COOH$$

The enzyme involved, β-cyanoalanine synthase, is apparently rather similar to the more common enzyme, cysteine synthase, which is involved in cysteine synthesis in many organisms.

Plants form cyanolipids, cyanogenic glycosides and other cyano compounds as secondary metabolites. Cyanogenic glycosides are formed form a range of amino acids:

$$\text{amino acid} \xrightarrow{-CO_2} \text{N-hydroxy amino acid} \longrightarrow \text{aldoxime} \xrightarrow{+[O]} \text{nitrile} \longrightarrow \text{α-hydroxynitrile} + \text{glucose} \longrightarrow \text{cyanogenic glycoside}$$

Figure 2: The ICI Bio-Products Business CYCLEAR product for degrading cyanide. (Photos: ICI plc).

When the plant is damaged, for example by harvesting or attack by a fungus, the cyanogenic glycoside is broken down to release cyanide by the sequential effect of a glucosidase and an oxynitrilase:

$$\text{cyanogenic glycoside} \xrightarrow{-\text{glucose}} \text{α-hydroxynitrile} \longrightarrow \text{ketone} + \text{cyanide}$$

The resulting high local concentration of cyanide is thought to deter attack by phytopathogenic fungi. However, cyanogenic plants are infected by fungi such as *Stemphylium loti,* which causes copper spot disease of bird'sfoot trefoil, and *Gloeocercospora sorghi* which promotes zonate leaf spot of cyanogenic sorghum species. This is because these fungi induce formation of cyanide hydratase when growing in the presence of cyanide. This enzyme detoxifies cyanide by conversion to formamide:

$$HCN + H_2O \longrightarrow HCONH_2$$

The conversion of cyanide to formamide by the hydratase requires only water as a cosubstrate. Also, high concentrations of cyanide can be completely degraded (see figure 1). We therefore felt that this enzyme had potential as the basis of a commercial process to detoxify industrial cyanide-containing effluents.

ICI Bio-Products Business is now marketing dried, extruded mycelia of the fungus *Fusarium lateritium* rich in the enzyme under the trade name CYCLEAR (see figure 2). The industrial potential is large, since more than a million tonnes of cyanide, mainly as KCN and NaCN, is manufactured worldwide every year for producing plastics, paints and so on, as well as for leaching gold and in electroplating baths. In addition, cyanide is produced as a by-product in other industrial processes such as coke and steel manufacture.

Many metals, for example nickel, zinc, iron, copper, silver and gold, complex very tightly to cyanide. Unfortunately, cyanide hydratase is ineffective against metal cyanide complexes. We have therefore searched for bacterial isolates able to grow on cyanide as the source of nitrogen. A novel 'vapour plate' enrichment technique has been developed and several strains of *Pseudomonas fluorescens* have been obtained that are able to utilise cyanide in liquid-fed batch culture. These bacteria are also able to grow on nickel

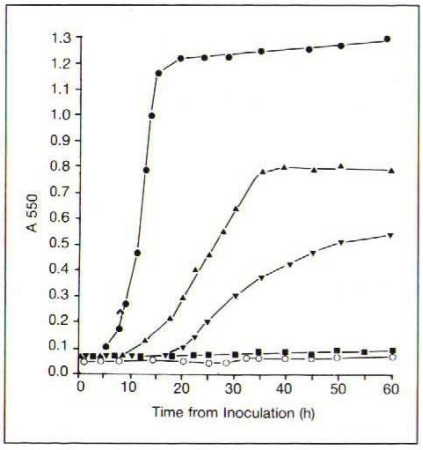


Figure 3: Growth of Pseudomonas fluorescens *on glucose as the source of carbon and energy and with ammonium sulphate (●), nickel cyanide (▲), copper cyanide (▼) or zinc cyanide (■) as the source of nitrogen, or in the absence of added nitrogen (○).*

and copper cyanide (see figure 3). The cyanide degrading enzyme system produced by these bacteria is an unusual oxidase, which we have termed cyanide oxygenase:

$$HCN + O_2 + NADH + H^+ \longrightarrow$$
$$CO_2 + NH_3 + NAD^+$$

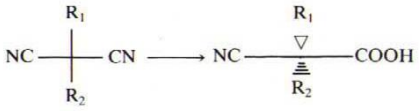
Aliphatic nitriles are used as sources of carbon and/or nitrogen by microorganisms through conversion to the corresponding amide and acid by nitrile hydratase and amidase enzymes:

$$RCN \xrightarrow{H_2O} RCONH_2 \xrightarrow{H_2O} RCOOH + NH_3$$

Aromatic nitriles are converted directly to the acid by nitrilase enzymes:

$$Ar.CN + 2H_2O \longrightarrow Ar.COOH + NH_3$$

There are many possible practical applications of such biotransformations. The Nitto Company in Japan has successfully developed a commercial process for the conversion of acrylonitrile to acrylamide, using immobilised bacteria. This is one of the few commodity chemicals to be produced so far by modern biotechnology. Novo Industri in Denmark is considering production of enantio-specific products from prochiral dinitriles:



Aldehydes can be converted to α-amino nitriles by the Strecker synthesis. We have recently demonstrated that bacteria can be isolated that convert them stereospecifically to L-amino acids:

$$RCHO \xrightarrow{NH_3,KCN} RCH(NH_2)CN \longrightarrow RCH(NH_2)COOH$$

We have investigated the possibility of degrading large-scale complex effluents from acrylonitrile manufacture. Such wastes are currently difficult to dispose of, since they contain a mixture of nitriles and other organic compounds that are bacteriocidal. As a result, activated sludge sewage systems are unable to acclimatise to degrade the wastes. A systematic approach has been undertaken, involving isolation of bacteria that grow on each of the major components of the waste. Mixtures of the bacteria are then developed that are sequentially acclimatised to each of the components of the waste until a robust 'custom blend' of bacteria is obtained. This is used in an activated sludge system which is able to degrade all the non-polymeric components of the effluent stream completely. The approach has great promise for degradation of a wide range of industrial effluents, many of which are unsuitable for biotreatment by currently available methods.

Work at Kent University has been supported by SERC's Biotechnology Directorate through grants and a CASE studentship, as well as by ICI plc, Schering AG (Diamalt) and Monsanto Company.

Professor C J Knowles
Biological Laboratory
Kent University

Animal cell biotechnology programme

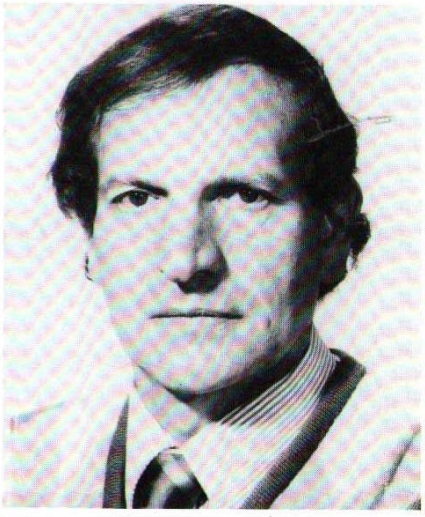
As biotechnology comes to market, the number of products manufactured by 'animal cell culture' — as opposed to bacterial or yeast systems — is likely to increase. Many of these products, especially those for human and animal health care and diagnostics, can only be produced in animal cells.

Universities and industry are collaborating in a research programme on animal cell physiology and genetics which, in the long-term, could be used by industry to produce cheaper recombinant DNA products and monoclonal antibodies from animal cell cultures.

In a national programme, SERC's Biotechnology Directorate is collaborating with five companies: Beecham, Celltech, Glaxo, Porton International and Wellcome Foundation. They will jointly fund coordinated research to the value of £1 million over the next four years. The research will be carried out at Kent, Oxford, Glasgow, Strathclyde and Surrey Universities and Manchester Polytechnic. Close interaction and collaboration between all the research groups will be actively encouraged.

The programme aims to apply to mammalian cell cultures many of the techniques already used to study bacterial growth and product formation. Thus the basis for protein synthesis and cell growth will be studied with the intention of improving commercial cell lines for the production of monoclonal antibodies and genetically engineered proteins.

Dr John Clegg has been appointed Programme Manager. He may be contacted at: 15 Elstree Hill, Bromley, Kent BR1 4JE; telephone 01-464 3722.

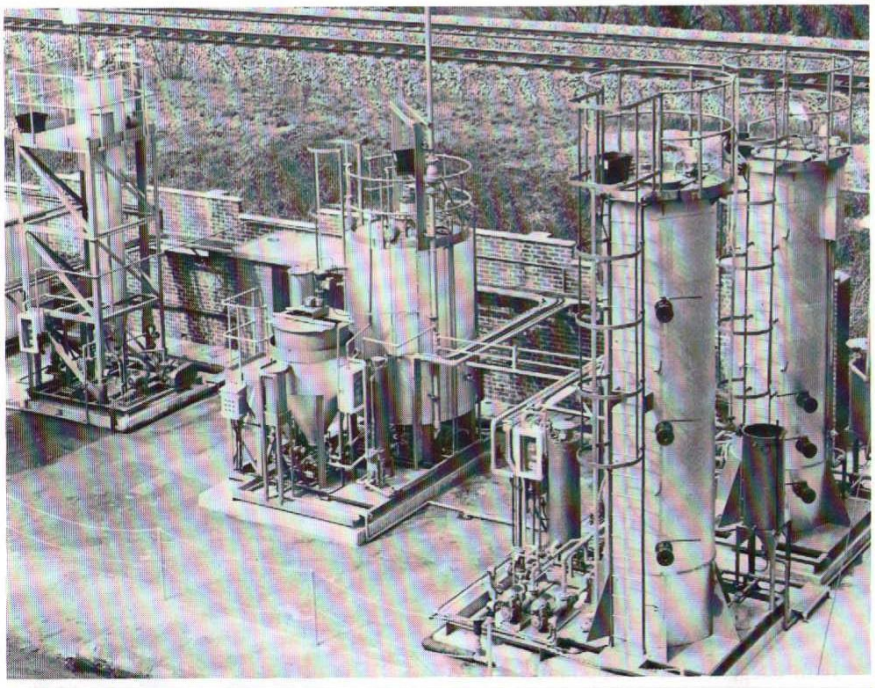


Dr John Clegg

Anaerobic waste treatment research

As part of research strategy into pollution control, SERC's Civil Engineering Subcommittee has funded the construction of a transportable anaerobic plant for the treatment of organic waste. The £230,000 plant is at present sited at the Birds Eye Wall's factory at Gloucester, where research projects involving universities, polytechnics and industry will be carried out. Unilever Research and Birds Eye Wall's are contributing £110,000 to the management of the project and SERC is providing £200,000 of research grants for an initial programme involving five academic institutions. These are the Polytechnic of Wales; Birmingham and Newcastle Universities; Cranfield Institute of Technology; and Imperial College of Science and Technology.

Sir Geoffrey Allen and Dr Hugh Tebbutt unveil the plaque at the formal opening of the anaerobic digester at the Birds Eye Wall's factory, Gloucester, on 24 April 1987.



The £230,000 transportable anaerobic digester plant, currently sited at the Birds Eye Wall's factory, Gloucester.

The facility was formally opened on 24 April by Sir Geoffrey Allen, Director of Unilever Research and Engineering Development and a former Chairman of SERC.

There is a growing use of anaerobic treatment for industrial wastewater particularly for effluents from the manufacture of food and drinks. But the best designs and operational procedures are not yet fully developed and results obtained in the laboratory have not always been translatable into full-scale applications. It is to bridge this gap, by improving the fundamental understanding of the operation of these reactions under realistic conditions, that SERC has funded this facility.

The research programme

The research programme will be divided into three phases.

Phase A: A six-month start-up period, to determine waste characterisation, colonisation procedures and biomass measurements.

Phase B: This two-year phase will cover the main research effort. It will involve programmed increases in loading to determine the side-by-side performance of the four reactors, to determine the optimum performance conditions.

Phase C: A further six-month programme to determine the response of the reactors to load and temperature shocks. The effects of starvation will also be determined. Recovery behaviour will be investigated in this phase and the efficiency of diagnostic and therapeutic procedures determined.

Studies on mixing characteristics, retention time and microbiological aspects of the processes will be carried out over the three-year period.

The advantage of anaerobic treatment

Wastewater arising from the home and industry contains many pollutants of which organic compounds are important because of their effect on the quality of receiving waters.

Organic matter is a food source for microorganisms and this fact is used in both natural self-purification systems and in engineered treatment systems.

With domestic sewage, and industrial wastewaters of similar strength, purification is usually achieved by organisms which work in the presence of dissolved oxygen (aerobic systems).

With high-strength organic wastes, such as those produced by the food and drinks industries, the oxygen requirement is so high that it is difficult to provide sufficient dissolved oxygen in an economic treatment system and the conventional aerobic process fails.

In the absence of oxygen — the anaerobic process — microorganisms use the organic matter as 'food' and in the process produce methane gas. Under controlled conditions anaerobic reactions can be economically attractive for the treatment of high organic-content wastewaters. The organic matter is stabilised and the gas produced provides a means of maintaining the elevated temperature necessary for effective treatment.

An anaerobic treatment plant comprises a reactor in which microorganisms come into contact with the food material; a gas collector; and some way of ensuring that the active microorganisms are retained in the system. Such a plant can remove a large proportion of organic matter but it will not reduce the organic content to the level required for discharge directly to a watercourse. The anaerobic plant effluent can however be further treated in a small aerobic plant or at a conventional sewage treatment plant with significant savings in treatment charges.

A number of different types of anaerobic reactors are being developed but there is currently a lack of appreciation of many aspects of anaerobic processes both from a fundamental viewpoint and in relation to their optimum design and operation. The new SERC facility will provide a unique installation for side-by-side studies of four different types of reactor operating under controlled conditions.

For further information on this project, please contact: Dr Hugh Tebbutt, Department of Civil Engineering, Birmingham University, PO Box 363, Birmingham B15 2TT. Telephone 021-472 1301 ext 2086.

Opening of Bristol's earthquake simulator

As part of its specially promoted programme of research in the civil engineering field, SERC has funded the building and operation of a 15-tonne capacity earthquake simulator (see *SERC Bulletin* Volume 3 No 4, Spring 1986). The simulator, or shaking table, has been built at Bristol University at a cost of approximately £600,000. The programme coordinator at Bristol is Professor Roy Severn.

The facility was formally opened on 27 March by the Hon William Waldegrave, then Minister of State for the Environment, Countryside and Planning, together with Sir John Kingman FRS, Vice-Chancellor Bristol University and former Chairman of SERC.

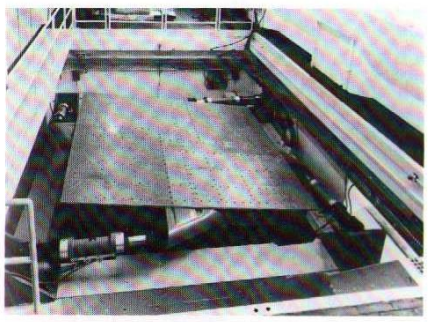
Recent earthquakes have highlighted the problems facing civil engineers in trying to design buildings, dams, bridges and other essential structures that will withstand the effects of severe shaking. Although Britain is not prone to such disturbances, British engineers need access to the necessary testing facilities if they are to compete successfully for overseas contracts. The simulator will also prove a useful tool for research outside the field of earthquake engineering. Vibration, which affects all engineering systems, can arise from wind, waves, machinery and traffic as well as from earthquakes.

The earthquake simulator at Bristol will be unique in its ability to perform controlled motion in six degrees of freedom: two horizontal, vertical, pitch, roll and yaw. It is this versatility, along with the associated network of microcomputers which control the table and process the data directly from testing, that makes this facility particularly useful. Another important aspect of this simulator is its ability to reconstruct 'real' situations, as the system can be programmed with past earthquake signatures.

The shaking table is available to SERC-supported academic researchers as part of the earthquake engineering research programme funded by the Civil Engineering Subcommittee. The involvment of the construction industry is also being actively encouraged.

This development will be of great benefit to UK researchers in civil engineering, providing a top class facility on a par with those in the USA, Japan, West Germany and Italy, enabling ideas to be tested more realistically.

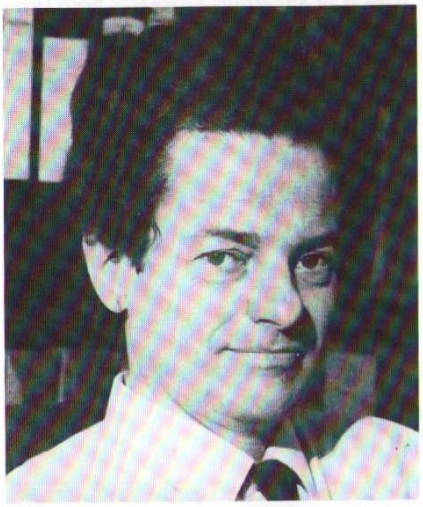
For further details on the earthquake simulator programme please contact Professor Roy Severn or Dr Colin Taylor, Department of Civil Engineering, Bristol University, Bristol BS8 1PR; telephone Bristol (0272) 303030 ext 3729.



The shaking table in the 'pit', showing the four horizontal actuators.

Sir John Kingman invites Mr William Waldegrave to press the button to activate the table.

Bridging the academic-industrial gap



Professor Roger Baker

At the end of September 1985, Professor Roger Baker of Cranfield Institute of Technology completed a one-year Royal Society/SERC Industrial Fellowship. Some reflections on the value of the year, reviewing some of the problems and opportunities that he encountered, may encourage others to take the opportunity offered by the Fellowship scheme to cross the academic-industrial divide.

After 13 uninterrupted years in academic posts, latterly as a head of department at Cranfield Institute of Technology with increasing management responsibility, I felt in need of a change, an opportunity to do some research, and I had a desire to cross the academic-industrial divide. The RS/SERC Industrial Fellowship scheme offered an ideal opportunity and at 44 I just fell within the age bracket.

I sought a company within commuting distance of home which would provide an interesting and stimulating environment and which would be willing to take me on. BP's Group Engineering and Technical Centre, at Britannic House in London, agreed to sponsor me and the RS/SERC scheme awarded me a fellowship accepting the condition that about one day a week on average should be spent at Cranfield running the department. My colleagues at Cranfield kindly looked after many of my jobs in my absence and a direct line to my BP desk made emergency communication possible.

The object of the exercise

The stated purpose of the Industrial Fellowship scheme is 'to enhance communication on science and technology and their application between those in industry and those in universities (or similar institutions of higher education) to the benefit of UK firms or higher education institutions or both. To this end, the scheme aims to provide opportunities, on the one hand, for academic scientists, mathematicians and engineers to hold a job in an industrial environment and undertake a project at any stage in the chain from fundamental science to industrial innovation; and, on the other, for industrial scientists, mathematicians and engineers to undertake research or course-development work in a university or polytechnic.'

My agreed project title was 'The assessment of the feasibility and accuracy of multiphase flow measurement including proposals for new methods with improved performance' and to achieve this I set myself the following technical objectives:

(i) to review existing methods;
(ii) to analyse data available within BP on two-phase (water-in-oil) flow measurement, with particular reference to the use of upstream mixers;
(iii) to model the effect of multiphase flows on flowmeters; and
(iv) to develop proposals for improved measurement methods.

In addition there were some personal objectives which I wished to achieve:

- to undertake a project in BP which was central to their needs and was within my area of expertise. The project was to be of sufficient size and length to ensure that I was fully engaged throughout my secondment;
- to complete the project to the mutual satisfaction of BP and myself;
- to stimulate new devices which would be more adequate, would reflect the value of the product, and would be more appropriate to the high level of technology in most oil extraction work;
- to work in an industrial engineering environment as opposed to a research centre;
- in the course of the project, to widen my knowledge of the technical area of the operation of a major company, and of the needs of instrumentation in the oil industry;
- to return to my post at CIT equipped to teach and research and to guide my colleagues better as a result of my experience.

The year's work

The scope of my work at BP turned out to be far wider than I had expected. Crude oil from production wells in the North Sea contains water and the accurate estimation of water content has enormous financial implications for the industry. The main part of my work while at BP was to predict the degree to which the water in an extracted sample of crude oil is representative of the mean water concentration in the oil. This has resulted in a program, now available on one of the BP computers and at Cranfield, which allows estimates to be made of the concentration uniformity in the pipe at the sampling location. In parallel with my theoretical work, experiments were being carried out on site by others to test concentration profiles and this allowed comparison between approximate theory and experiment.

BP ensured that as well as being closely involved in the work of one of their groups I had the opportunity to visit their field operations including Rotterdam, Kinneil, Finnart, Grangemouth, Forties Charlie North Sea oil platform and Sullom Voe oil terminal. I also took part in a recruitment interview programme with senior members of the division.

Some of the original objectives which I set for myself were modified, while others have essentially been achieved but often in unforeseen ways. The review of relevant existing methods is being continued by colleagues and students at Cranfield. The computer program is being used by BP staff but, in addition, BP have placed a contract with Cranfield to allow further development of the program. This work appears to be of increasing importance to BP with the transport in common pipelines of the products from different operators' fields. BP have also been generous in their agreement with Cranfield on use of the program and on publication of papers describing the work.

A restrospective view

In retrospect, the requirement to remain within reach of Cranfield and of my home was a correct constraint and helped to ensure successful completion of the year. The RS/SERC agreement to allow me to 'mind the shop' was also essential in the Cranfield context where complete absence by a department head is not easy. The funding should, in my view, incorporate an overhead element. The absence of overheads is highlighted in the Cranfield context, and made one more aware of the load one's colleagues were carrying. There can also be a problem of timescale during negotiation where the project timescale of the company may be shorter than the university and RS/SERC timescales.

A particular aspect which I found interesting and led to something

approaching a split personality was the role change between BP where I worked as one of the engineers and Cranfield where I was head of department.

The most important constraint, however, lies in the definition of a project. I was fortunate in that my project was close to my interests and knowledge, but sufficiently different to open new fields to me. It was of topical importance to BP so that I was using new prediction methods which I had developed on *immediate* problems. It was also achieveable within the timescale while leaving new and interesting avenues to be pursued in the future. I was able to benefit from recent publications describing key work going on elsewhere at the same time.

There were times when I wondered if I would see the year through when the pressures from both jobs were high. But the benefits were clear and are outlined below.

- *In new areas of knowledge.* The close collaboration with many people within BP and the various visits have enabled me to obtain a much greater understanding of this industry and of the instrumentation problems and opportunities.

- *In new R and D areas.* I have been able to get into a new field where I hope to continue to make a contribution with my colleagues. This is possible through contracts set up with BP for further related work.

- *In continuing links with BP.* I have got to know many people within BP and am in a strong position to develop links of all sorts within the organisation. I have also met people from other firms during the year whom I would not otherwise have met.

- *In the change.* The year provided a change and, although I kept my links with Cranfield, by the time I returned in October 1986 I felt much refreshed. After seven years in my Cranfield job and at age 44-45 I needed a change and this year met the need.

In closing, I recommend the scheme to others as a way of bridging the academic-industrial divide. I encourage them to note some of my constraints to increase the chances of success; particularly, I recommend them to find a group like the one I joined who took so much trouble to ensure the success of my year.

Professor R C Baker
Head of the Department of Fluid Engineering
Cranfield Institute of Technology

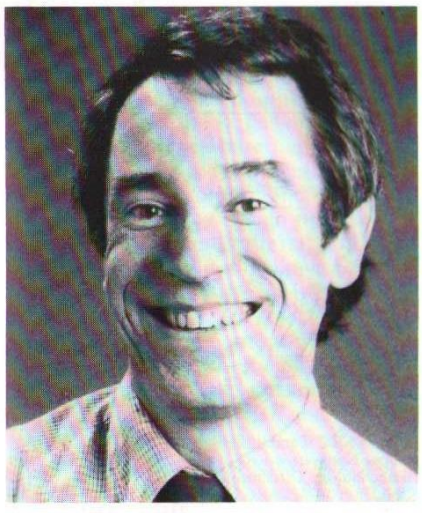
Reprinted from the Journal of *Physics E - Scientific Instruments* Volume 20-3 March 1987, courtesy of the Institute of Physics.

Senior Fellowships 1987

Senior Fellowships have been awarded to **Dr N O Weiss** of Cambridge University and to **Professor J C Dainty** of Imperial College of Science and Technology.

Professor John Dainty graduated at the Polytechnic of Central London in 1968 and after postgraduate and postdoctoral work at Imperial College held a lectureship at Queen Elizabeth College, London. From 1978 to 1983 he held appointments as Associate Professor in the University of Rochester in the USA. In 1984 he took up his appointment as Pilkington Professor of Applied Optics at Imperial College.

Professor Dainty has made important contributions to many topics within the general area of optical information processing, a field which has acquired particular significance in recent years since the development of the laser and optoelectronics, and has led to important technological developments.

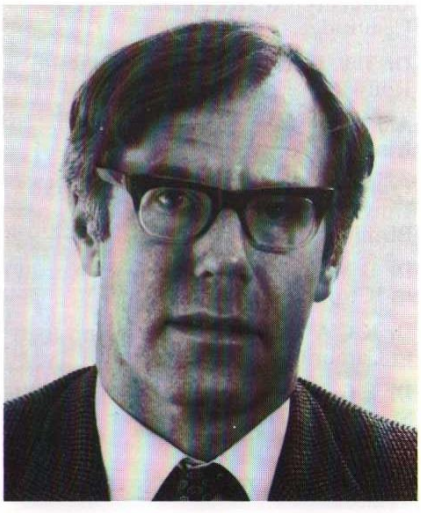


Professor J C Dainty

The research programme that he will carry out during his Senior Fellowship involves a set of related projects many of which have a cross-disciplinary element reflecting potential applications. For instance, work on scattering by particulate volume media has implications for solid state physics; the use of a recently developed high-resolution interference microscope in the study of integrated circuit wafers relates directly to the semiconductor industry; another study is exploring the use of hologram optical elements as an alternative to conventional refractive optics as a means of interconnecting elements in the electronic computer; and the use of a holographic multiplexing technique in the display of three-dimensional data has potential applications in medicine.

Dr Nigel Weiss took his PhD in the department of geodesy and geophysics at Cambridge and after a period at the Culham Laboratory returned to Cambridge where he is now Reader in Astrophysics. He is also a visiting professor in the School of Mathematical Sciences at Queen Mary College, London.

Dr Weiss occupies a leading position in theoretical studies in fluid mechanics and their application to the interpretation of observations of the Sun and stars. He has made major contributions to the study of non-linear interactions between plasma and magnetic fields in stellar convection zones like the Sun's, investigating models related to the detailed experimental observations of solar physicists: His work will be crucial to the interpretation of observations from the US High Resolution Solar Observatory and the European Solar and Heliospheric Observatory which will provide the focus of solar physical studies over the next decade. The principal technique used in Dr Weiss's work is numerical integration, and he will now exploit the power of the new generation of supercomputers in a programme of numerical experiments on three-dimensional non-linear convection, including the effects of compressibility and magnetic fields, which promises to lead to substantial progress in the fundamental problem of the activity of stars.



Dr N O Weiss

Fellowships 1987

Allocation, applications and awards in 1987 for the various Fellowship Schemes.

Type	Allo-cation	Appli-cations	Awards
Senior	2	11	2
Advanced	15	70	15
Postdoctoral	56	223	51*
Australian Bicentennial	2	8	1
RS/SERC Industrial	10	15	11

* In addition nine awards tenable in Europe were taken over from the Royal Society. A further two awards in the Natural Environment Research Council's field were supported under the NATO programme.

Industrial Fellowships

For 1987, Royal Society/SERC Industrial Fellowships have been awarded to:

Dr D J S Birch (Strathclyde University) to Edinburgh Instruments Ltd

Dr J S Colligon (Salford University) to V G Ionex Ltd, Burgess Hill

Professor A C Davies (City University) to British Aerospace plc, Stevenage

Dr H J Efstathiou (Queen Mary College, London) to Analysys Ltd, Cambridge

Dr M J C Gordon (Cambridge University) to SRI International, Cambridge

Dr T V Jones (Oxford University) to Rolls-Royce plc, Filton

A J H Lucas-Smith (ICL Ltd) to Kingston Polytechnic

Professor J A McGeough (Edinburgh University) to Technology Ltd, Birmingham

Dr D M Smith (St Andrews University) to ICI plc, Middlesborough

Dr K C A Smith (Cambridge University) to Cambridge Instruments Ltd

Dr F G Wilson (Fairey Holdings Ltd) to Surrey University (subject to confirmation).

PhD submission rates

Studentship awards beginning in 1982

Council views the writing up of results of a PhD thesis, within a reasonable time, to be an important and effective measure of whether the student's training has been satisfactorily completed; it also considers that the thesis submission rate of a department gives a measure of that department's ability to provide a good training in the methods of research. Following letters sent in 1985 and 1986 to universities and polytechnics emphasising the need for improved submission rates, Council in determining departments' quota allocations of research studentships this year applied sanctions in the case of 41 departments whose submission rate record was particularly poor.

The tables below set out the results of the latest annual survey — the seventh in the series — showing the submission rates for PhD theses by 1 October 1986, for SERC-funded research students whose awards began in 1982, 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 by institution

	No of students registered	No submitting by 1.10.86	No still registered at 1.10.86
Aston	36	15	13
Bath	41	25	16
Birmingham	86	55	21
Bradford	15	8	7
Bristol	61	42	17
Brunel	15	7	5
Cambridge	164	124	36
City	15	11	2
Cranfield Institute of Tech	20	7	8
Durham	43	24	14
East Anglia	27	15	10
Essex	9	4	3
Exeter	12	8	4
Hull	13	4	7
Keele	2	1	1
Kent	23	12	8
Lancaster	17	13	3
Leeds	77	37	30
Leicester	24	16	7
Liverpool	63	34	22
London			
Bedford	5	1	4
Birkbeck	11	7	4
Goldsmiths	2	-	1
Imperial	130	79	40
King's	25	16	6
King's College (Chelsea)	12	5	6
King's College (Queen Elizabeth)	14	10	3
Queen Mary	32	13	16
Royal Holloway	5	4	1
University College	54	31	16
Westfield	1	-	1
Wye	2	2	-
Other institutions	24	15	9
Loughborough	21	8	9
Manchester	88	58	17
UMIST	66	32	24
Newcastle	36	17	13
Nottingham	81	54	15
Open	2	1	1
Oxford	138	94	31
Reading	30	18	12
Salford	16	9	7
Sheffield	57	36	20
Southampton	74	46	25
Surrey	23	13	7
Sussex	40	21	12
Warwick	30	22	8
York	20	13	6
University of Wales:			
Aberystwyth	12	5	7
Bangor	21	9	10
Cardiff	28	12	15
Swansea	28	13	8
UWIST	15	11	4
Universities of Scotland:			
Aberdeen	19	14	5
Dundee	11	6	3
Edinburgh	57	28	23
Glasgow	48	32	15
Heriot-Watt	20	11	5
St Andrews	17	13	-
Stirling	4	2	-
Strathclyde	38	19	18
University of Northern Ireland:			
Queen's University, Belfast	1	1	-
Total universities	**2121**	**1263**	**661**
Total polytechnics*	**100**	**38**	**48**
Other institutions*	**21**	**12**	**7**
Grand total	**2242**	**1313**	**716**

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

Table 2: PhD submission rates by SERC Board

	No of students registered	No submitting by 1.10.86	No still registered at 1.10.86
Science Board:	1305	843	361
Biological Sciences	*481*	*296*	*153*
Chemistry	*511*	*365*	*106*
Mathematics	*126*	*72*	*39*
*Physics, Neutron Beam and SBA**	*187*	*110*	*63*
Engineering Board	715	349	274
APS Board	76	48	21
NP Board	59	40	16
ESRC-SERC Committee	49	17	25
Energy Committee	15	5	9
Biotechnology Directorate	23	11	10
Grand total	**2242**	**1313**	**716**

*SBA — Science-based Archaeology

The SERC design initiative

The aim of the first phase of the Design Initiative, which started in October 1985, was to make academic engineering staff aware that the SERC Engineering Board had endorsed the recommendations of the Lickley Report, the main one being the need for SERC committees to encourage grant applications with a major design content. This awareness has been achieved by regional seminars, the Coordinator's visits to most university and polytechnic departments, an exhibition, *From research to engineering design,* held at the Design Centre, London; and a seminar on *After Lickley: where now?* A Design Initiative Newsletter has been widely distributed to all heads of departments, committee members, the Engineering Council, the Fellowship of Engineering, and the professional institutions.

The most controversial topic which arose from the early discussions with academic staff was what was meant by 'design-based research'. The Design Management Committee, chaired by Professor Michael French, approved five typical categories which it considered needed research effort:

- innovative design leading to a new product, system, or process;
- fundamental analysis and investigations to provide new knowledge aimed at the long-term needs of designers;
- the influence of computer-aided engineering on the design process; design for costs, reliability, manufacture, maintainability, and safety; and
- adaptation of research results into forms which can be used by practising designers. Thus the academic design researchers should be contributing to the 'knowledge data base' for designers (see figure) as suggested by Professor David Morris (Swansea).

There was some concern that subcommittee members, when faced with new design-based applications competing with the larger number of 'traditional' science-based applications, might still apply the same criteria of 'timeliness and promise' and quality of scientific content to design proposals which need different criteria, and might reject them. Such doubts have been mostly dispelled by the awards of about £2 million to some 50 projects with an appreciable design content within the three rounds since the beginning of the Design Initiative. These have been made mainly to mechanical, civil and chemical engineering, with fewer to electrical engineering, medical engineering and materials.

Applications considered to have some design implications are selected by committee secretaries for review by the Design Coordinator who provides written comments and gradings on the design content to assist the committee's assessment. The directorates, particularly ACME (Application of Computers to Manufacturing Engineering), also seek the Coordinator's views on proposals they receive. A welcome move has been the support by the Teaching Company Directorate for design-based schemes, the Design Coordinator keeps in close touch with the Teaching Company coordinator, and indeed all the other SERC coordinators on proposals of common interest.

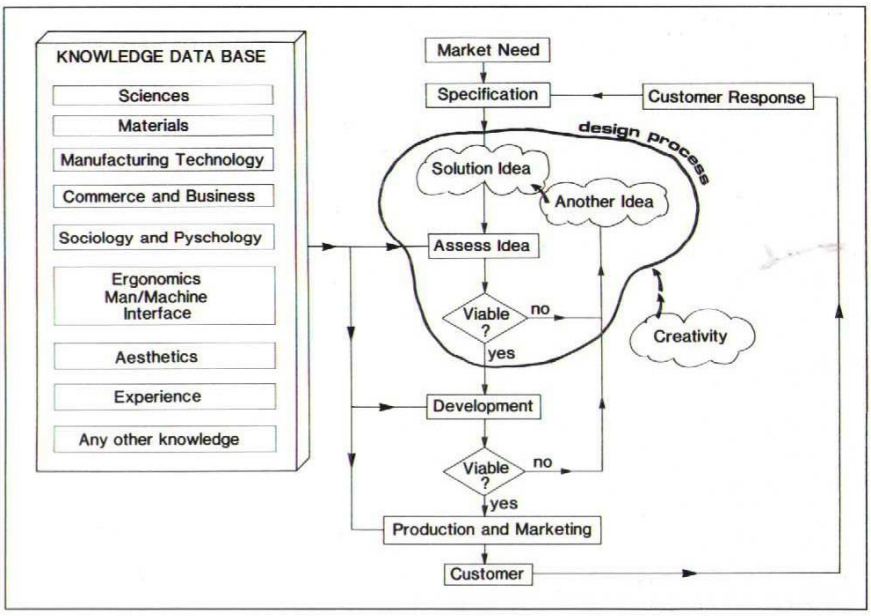
Another useful step forward in the SERC recognition of design has been the allocation of CASE studentships for joint projects with designers in industry. Seven of these have been awarded in the last round and more could be available if good projects are forthcoming.

These successes are an encouraging response but the grants made are still only a small part of the total SERC engineering budget. The Design Management Committee would like to see many more proposals which are predominantly design-based; for example there have been few applications covering the influence of computer-aided engineering or new areas such as design for safety, or reliability, or maintainability.

The smaller number of proposals from academic design staff than we had hoped for is not because of lack of enthusiasm but paradoxically can be attributed to the long-overdue recognition of the importance of design teaching on undergraduate courses. The Engineering Council requirement has imposed a heavy load on the relatively small corps of design teachers coping with increased teaching and supervision of increased student numbers. This situation has left them little time and effort to undertake personal research. The great expansion of the Teaching Company scheme into design is also absorbing the staff who otherwise might have been expected to take up the challenge posed by the Design Initiative.

For the second phase of the initiative the major effort of the Coordinator will be to seek the views of designers in industry and try to establish closer links with relevant academic staff who would like to collaborate with them. He will be exploring the possibilities of implementing another Lickley recommendation: the need to establish some Centres of Activity in Engineering Design which would be involved with postgraduate and continuing education as well as research. He will also be trying to reconcile the conflict between the commercial confidentiality required when a project is undertaken with an individual firm, to solve a problem for that firm, and SERC's general requirement to make the results of research widely available.

Our industrial and manufacturing recovery starts with good design as the rapid embodiment of our excellent research performance. It is essential that SERC should be an active partner in this vital process. The Engineering Design Coordinator, Professor Joseph Black CBE FEng, would welcome any further enquiries. He is based at the Design Council, 28 Haymarket, London SW1Y 4SU. Telephone 01-839 8000.



Flow diagram typifying the activities required for design, production and marketing of an engineering product. (Drawing: University College of Swansea).

Heat and moisture transfer in buildings

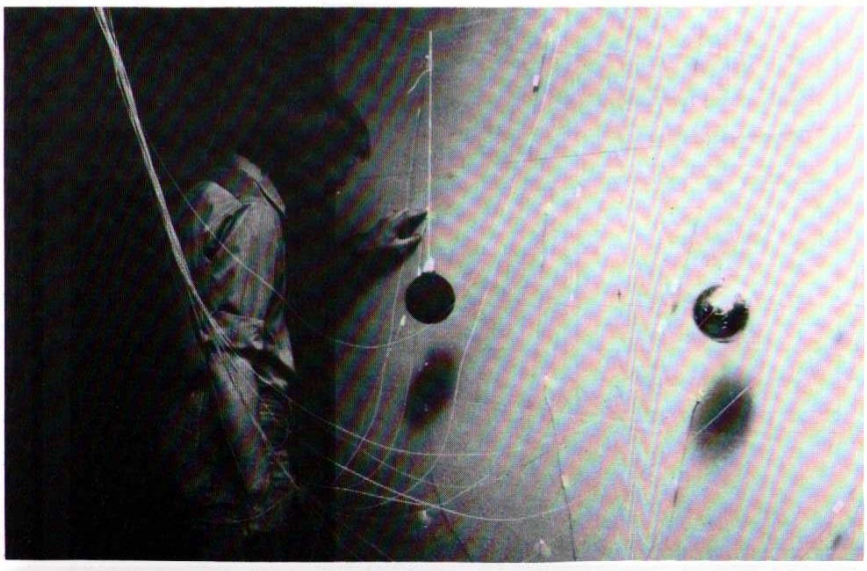
At Salford University, the special laboratory facilities built by the thermal section of the Department of Applied Acoustics are providing evidence of the long-term behaviour of thermal insulants, under both dynamic and steady-state conditions within wall and roof structures where interstitial condensation could occur. A better understanding of the processes of heat and moisture transfer not only gives realistic performance data for common building structures, but also shows where problems could occur. Dr Audrey Stuckes, Mr David O'Connor and Dr Tony Simpson describe the progress being made.

Heat lost from buildings represents a significant part of the energy consumption in Britain and relatively high standards of thermal insulation are now mandatory for almost all types of new building. At the design stage, the thermal resistance of each part of the structure is calculated from a simple model using the thermal conductivity of each component, assuming any thermal insulation is dry and that, for example, the outer and inner leaves of a masonry wall contain 5% and 3% moisture content by volume. However, there is no clear evidence of the standard of insulation being achieved in practice. Almost all structural building materials are porous, and thermal insulants contain a large volume of air; moreover, conditions within a heated building in winter are such that both heat and water vapour are driven through the structure from the inside. If conditions are such that water vapour condenses within part of the structure, the effective thermal conductivity of that part will increase so that the thermal resistance of the structure will decrease.

A simple model of one-dimensional flow for both heat and vapour predicts that, under normal winter design conditions (20°C, 60% relative humidity inside; 0°C, 96% relative humidity outside), the relative humidity will be 100% within the structure so that condensation could occur. In a normal cavity wall, the predicted region occurs within the cavity and when that contains insulation, although the start of the zone is driven towards the outer leaf, condensation is still expected within the insulation. The concept of zones of condensation is, however, questionable. Current theoretical arguments suggest that if interstitial condensation is predicted, it can only occur at the interface next to the cold side of relatively low vapour-resistant materials, such as thermal insulants.

Wall and roof studies

Test rigs have been built to study areas of about 9 m^2 of both walls and flat roof structures with the temperature and humidity controlled on either side. Not only is the heat flow measured but, by placing thermocouples throughout the structure, the thermal conductivity of each component can also be obtained *in situ*. In addition, use of a piercing probe hygrometer enables the relative humidity and vapour pressure across the structure to be measured.



Attaching thermocouples to a test wall.

The programme of work on walls was initially supported by SERC's Polymer Engineering Directorate, under whose auspices a test rig was built to investigate two walls, and is now funded by the Building Subcommittee. The two walls can be studied simultaneously in the steady-state, subject to the condition that the outer surface of each is maintained at a similar temperature. Different humidities can be maintained in each outer climatic chamber while the inside surface of each wall is exposed to its own environmental room in which temperature and humidity are individually controlled. A brick-cavity-aerated concrete-plaster wall was first studied and found to behave much as expected. The cavity was then filled with expanded polystyrene (EPS) beads and for about three months under design conditions, a major redistribution of temperature and moisture occurred. Ultimately after a couple of years, the mean value of thermal conductivity of the EPS beads was found to be only slightly higher than the value obtained with guarded hotplate measurements in the laboratory, there being an increase in the lambda-value of the beads adjacent to the outer leaf of about 5%. Although the relative humidity in this region was found to be 100%, no evidence was found of substantial interstitial condensation. Some accumulation of moisture appeared to occur at the brick/insulation interface and to increase the water content of the brick leaf and in particular of the mortar joints. At the same time, the inner leaf was slightly drier than expected (about 1% moisture content compared to 3% before cavity fill), with a slightly higher thermal resistance.

The EPS beads were removed from the cavity and replaced by ureaformaldehyde (UF) foam. The experiments showed that it took some 40 days for the moisture introduced by the foam to be driven out and several more months to reach moisture equilibrium. Relative humidity in the region of 100% was found within the cavity adjacent to the outer leaf but, as with EPS beads, the mean lambda-value of the foam was very similar to that obtained in the laboratory under 'dry' conditions. No evidence of substantial interstitial condensation was found. However, a crack in the UF foam was located away from the central monitored area of the wall. The effect of such cracks was investigated by placing a large heat-flow meter in its vicinity. The effective thermal conductivity of the foam did not increase much until the crack had been widened to about 50 mm.

However, when two such cracks were present some 300 mm apart, the effective thermal conductivity of the foam roughly doubled (a result confirmed by thermography). This increase in heat transfer was undoubtedly due to convective heat flow resulting from circulating air currents as the foam was also found to shrink away from both inner and outer leaves.

Interstitial condensation

Work is now in progress on a similar cavity wall containing blown-in glass fibre and indications are that no substantial region of interstitial condensation has occurred. The measurements on the three types of cavity insulation all lend support to the contemporary view that interstitial condensation tends to be restricted to the brick/insulant interface.

Work has just started on a timber-framed construction. At present the internal vapour barrier (essential to this type of construction) is intact but it is intended to introduce breaks of known magnitude and to monitor the effects. In addition to the usual measurements, moisture meters have been installed in the timber framework so that its moisture can be continously monitored.

An additional rig of very low thermal mass has been built to investigate the dynamic performance of a wall when daily environmental conditions are simulated by a precise sinusoidal temperature cycle. A similar wall structure to that studied under steady-state conditions has been investigated with and without EPS bead-fill. Although the programme has not been completed, differences have been found under cyclic dry and humid conditions but the magnitude is not sufficient to cause concern in terms of practical behaviour. However, the differences are significant to the development of models to explain heat and moisture flow. For example, there are differences of up to 3% between the heat flowing through the inner leaf and the outer leaf under humid conditions where interstitial condensation can occur.

Recently the roof rig has been used to study the effect of air flow on the performance of fibrous insulation in lofts. It was found that only at speeds above 1 m/s (far higher than normally found) was there any detrimental effect on the thermal performance.

It must be stressed that all experiments are carried out on realistic structures built by tradesmen to current (doubtless best) codes of practice. We are grateful to the Shell Chemical Company Ltd, British Industrial Plastics Ltd and to Pilkington Bros plc for providing and arranging the installation of the thermal insulation and to the Building Research Establishment for their continued advice and encouragement. As an extension of this work, the Thermal section has British Calibration Service accreditation for the measurement of thermal conductivity by both the plain and guarded hot-plate methods.

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Monitoring the performance with data logging/computer system. Control boards for each environmental chamber can be seen in background.

Research Councils' Cray supercomputer

Secretary of State for Education and Science, Kenneth Baker (centre) seated on the Joint Research Councils' Cray X-MP/48 supercomputer. The machine was officially inaugurated by Mr Baker on 15 April. With him are, left, Professor John Forty, whose report on advanced computing facilities prompted the installation of the Cray and, right, Dr Brian Davies, SERC's Director of Computing, who is responsible for running the Cray facility (see* SERC Bulletin *Volume 3 No 7, Spring 1987).

Injection moulding of powders

For many years, high-production injection moulding techniques have been used to manufacture a multitude of polymer-based components of extremely diverse size, shape and complexity. Recent research has paved the way to establish conditions by which sintered metal and ceramic parts may also be produced by injection moulding. Powders are compounded with thermoplastics which, when molten, act as flow vehicles to assist mould filling; the binder system is subsequently degraded thermally before full sintering occurs.

Individual research groups in powder metallurgy and plastics processing at Loughborough University of Technology have combined resources to identify that the interdependency of material formulation (powder characterisitics and melt viscosity of the compound), non-isothermal shear flow behaviour and debinding kinetics hold the key to exploiting this route to successful manufacture. The research is outlined here by Dr Peter James, Barry Haworth, David Issitt and Michael Martyn of Loughborough University.

In the early 1980s, injection moulding was identified as a priority area for research in powder processing technology, applicable to fine powder production and as a means of densification without massive post-sintering consolidation. Unlike conventional powder metallurgy die-pressing techniques, injection moulding is relatively free from component design and shape constraints, and offers considerable scope for extending the processing technology of powder metals to more complex and precisely-formed parts. The working principle is based upon an optimised formulation of powders with a thermoplastics-based binder system: the resultant, homogenised 'plastisol' flows under conventional shear forces to fill the closed mould. The binder can then be removed, either by solvent extraction or by thermal decomposition, before full sintering is applied. Although the part may undergo a volumetric shrinkage of up to 20%, the contraction is fully isotropic and final sintered densities of up to full theoretical values can be achieved.

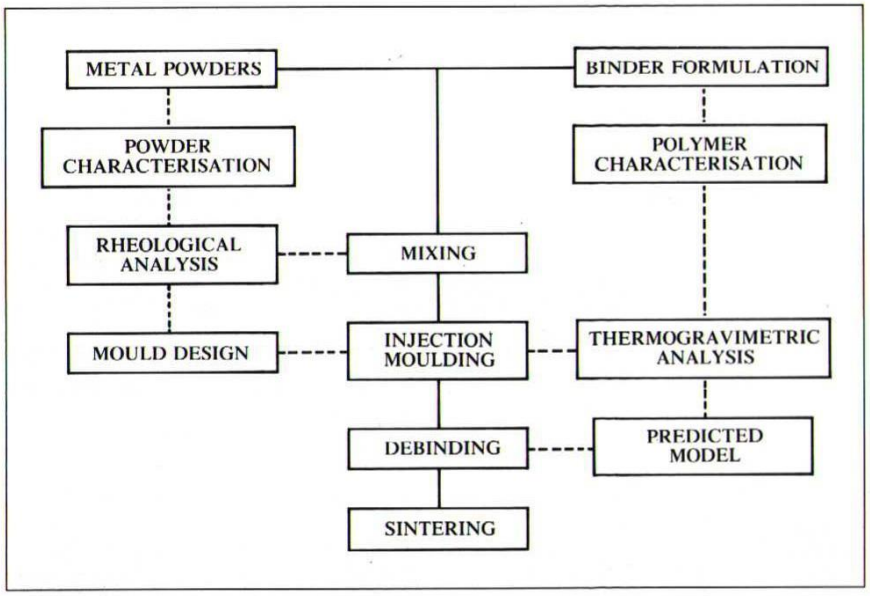

Figure 1: Injection moulding process flow chart to illustrate the individual phases of production and the input to the programme from our research studies (dotted).

In order to exploit the potential of this novel process for iron and hardmetal powders fully, an initial SERC-sponsored feasibility study at Loughborough was undertaken in 1983, followed by the award of successive grants from the Materials Committee (with the industrial support of BNF Metals Technology) to establish how binder formulation and processing conditions (moulding and tool temperature; pressure and rate effects) can be optimised to enhance mould filling and allow progressive debinding to occur, while minimising binder concentration in the plastisol formulation.

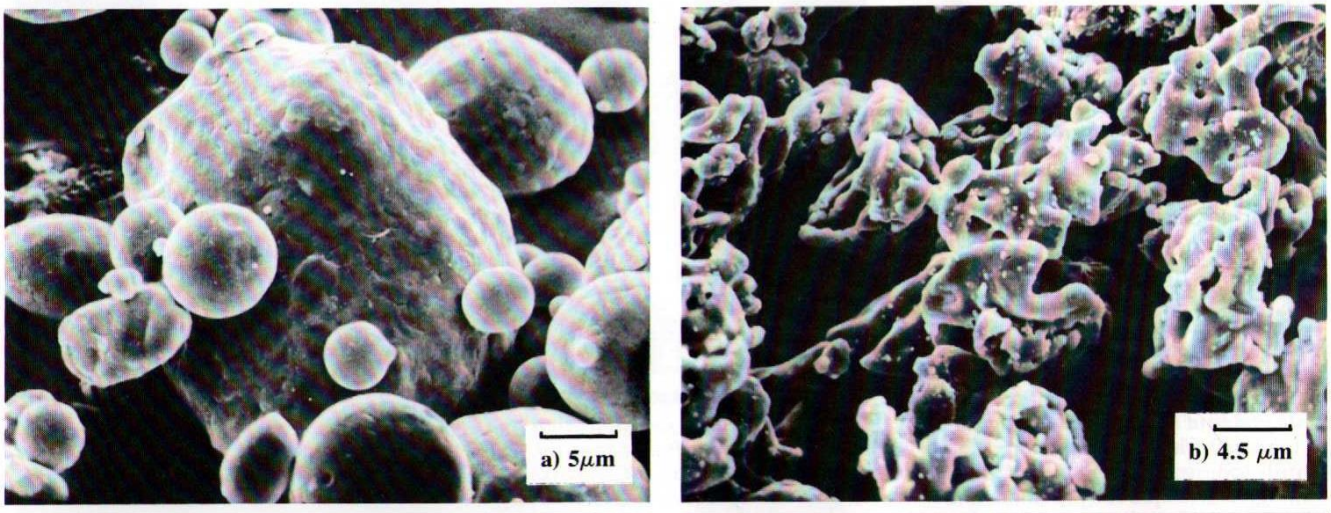

Figure 2: Scanning electron micrographs of (a) gas-atomised pure iron and (b) water atomised iron powders; the more uniform, spheroidal nature of the gas-atomised powders promotes more ideal flow behaviour and plastisols can be injection-moulded using a lower proportion of binder.

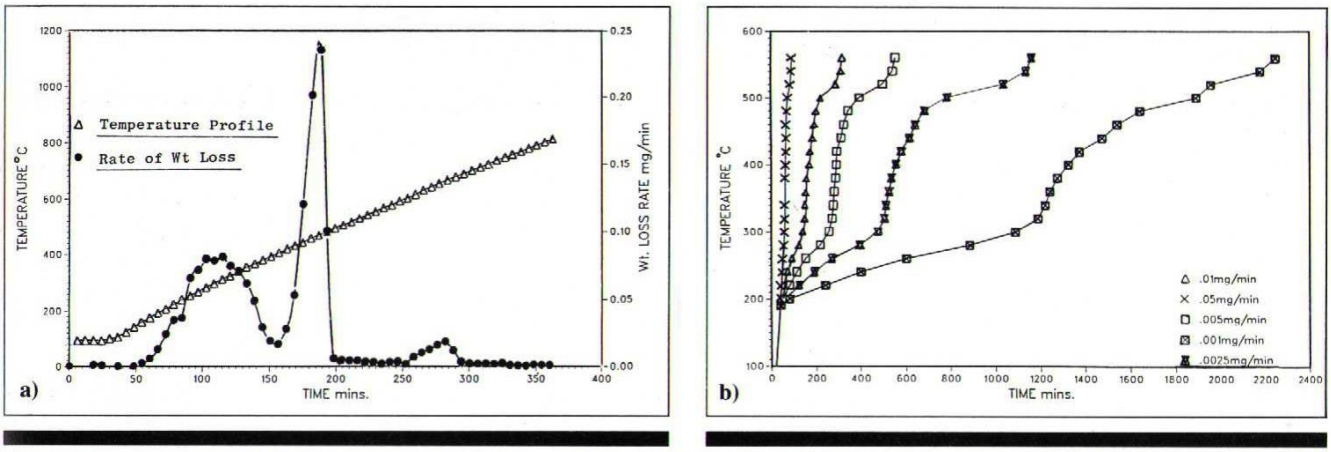

Figure 3: Thermogravimetric (TGA) data illustrating (a) typical debinding behaviour of polyolefin binder-based plastisols during a ramped, constant heating-rate scan, and (b) modelled data predicting temperature-time profiles to yield constant weight-loss rates.

The production flow chart in figure 1 illustrates the essential stages within the overall process; key research areas where progress has been made are shown by the dotted loops in the figure. It became apparent that the most critical area for immediate investigation was to formulate and mix plastisols which not only possessed the required rheological characteristics for injection moulding (low shear viscosity over shear strain rates in excess of 10^3 s^{-1}), but which also offered acceptable debinding kinetics before full sintering.

Mixing studies and rheological behaviour have been investigated on torque and capillary rheometers. While screw injection machines are recommended for fabrication, pilot scale moulding is also feasible on ram-type machines and on suitably upgraded and instrumented pressure die-casting equipment. Thermal cycles required to remove the binder at a relatively uniform rate have been determined on atmosphere-controlled thermal balances by thermogravimetric analysis. Final structural integrity and porosity assessment have been investigated by a range of optical and electron microscopic techniques.

Results have shown that the optimum balance between acceptable rheological behaviour and ease of debinding is achieved with spherical iron powders with particle size less than 10μm (for example, from the carbonyl process or by gas atomisation; see figure 2) in combination with binders based upon low molecular weight polyethylenes or other modified polyolefins; typical powder:binder ratios are 70:30 (by volume). Optimisation of the debinding cycle is possible if the volatilisation characteristics of each constituent proportion of debinder formulation are known; the data in figure 3 illustrate this point by example.

Current research programmes at Loughborough have been designed to lay a scientific basis for further commercial exploitation. Specific study areas include:

- technology of mould flow and design for highly filled plastisols;
- optimisation of debinding cycles;
- development of specific engineering components by injection moulding;
- cost analysis of manufacture by competing processes.

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New publications from SERC

Copies of these publications are available free of charge from the department indicated at SERC Central Office, Swindon, unless otherwise stated.

Complex stochastic systems

Copies of a brochure on the Mathematics Committee's initiative in statistical research, *Complex stochastic systems,* are available from Rachael Nicholls, ext 2313.

Science-based archaeology

Copies of a leaflet describing the *Oxford Radiocarbon Accelerator Unit* are available from either Fiona Clouder Richards, ext 2361, or from the Unit itself at Oxford (0865) 273939.

Biological membranes

Biological membranes is a report on the current status and future prospects of research on the molecular basis of membrane function in the UK, a new Biological Sciences Committee initiative. Copies are available from Dr Peter Fletcher, ext 2136.

Biotechnology

Two reports have been produced by the Biotechnology Directorate: *Biotechnology in Japan* and *Monitoring the biotechnology labour market.* These, and a leaflet, *How the SERC Biotechnology Directorate works with industry,* and the latest issue of the *Biobulletin,* are available from Mrs Audrey Williams, ext 2310.

Separation processes

Two reports, *Liquid-liquid extraction: a survey of current interests with recommendations for future funding,* by J D Thornton, and *The opportunities for exploiting centrifugal fields,* by Dr C Ramshaw, have been produced for the joint Biotechnology Directorate/Process Engineering Committee initiative in separation processes. Copies are available from Stephen Heseltine, ext 2160.

Process engineering

Copies of the *Process Engineering Committee report 1984-86* are available from Stephen Heseltine, ext 2160.

Electro mechanical engineering

A leaflet, *The strategy of the Electro Mechanical Engineering Committee*, has been produced to launch this renamed and restructured committee (formerly Machines and Power). Copies are available from Kay Lloyd, ext 2425.

Materials

Copies of *Materials Committee current grants, August 1986* are available from the Committee Secretariat, ext 2330.

Civil engineering

Copies of *Civil engineering: summaries of research reports, September 1987* are available from Stephen Cann, ext 2493.

ACME exhibit at Automan 87

The Council's ACME Directorate took part in this year's Automan 87 show at the National Exhibition Centre in Birmingham, in May. The Directorate featured a selection of the manufacturing research projects funded by SERC over the past few years.

The main central exhibit was a programmable machine, developed by Bath University in conjunction with Westland Helicopters, that generates precision machining fixtures automatically. Such fixtures are expensive to make and to store. Fixture kits have been available for some time and go some way towards solving these problems. However, the construction of a fixture from a kit of parts is a skilled job requiring much fine adjustment which takes some time. Also, once the fixture has been built and used, it is often stored rather than dismantled because of the effort that would be needed to recreate it. The Bath University project designed a kit so that the assembled fixture would be accurate by virtue of the shape of the kit parts alone without the need for adjustment. Furthermore, any given fixture can be designed using an interactive computer programme, then built automatically by a robot. This allows fixtures to be created, and then recreated repeatedly at any time. The idea has been patented by the British Technology Group who are currently seeking licensees.

Another exhibit which drew considerable attention was a computer software package developed by UMIST, to assist company managers to justify the cost of flexible manufacturing systems. Flexible automation provides more benefits than just a simple increase in productivity, and the research at UMIST has produced a computer-based method to quantify the intangible benefits in a way that is acceptable to company accountants.

A series of panels covered other completed projects including:

Error recovery in robotic assembly cells (Aberystwyth University in collaboration with Thorn EMI);

Computerised forging preform design (Leeds University in collaboration with Doncasters Monk Bridge);

Modular workhandling (Loughborough University in collaboration with Martonair); and

Robotic adjustment, testing and quality control (Portsmouth Polytechnic in collaboration with Turnright Controls).

The Bath University robot-controlled fixture kit.

The ACME stand at the Automan 87 exhibition.