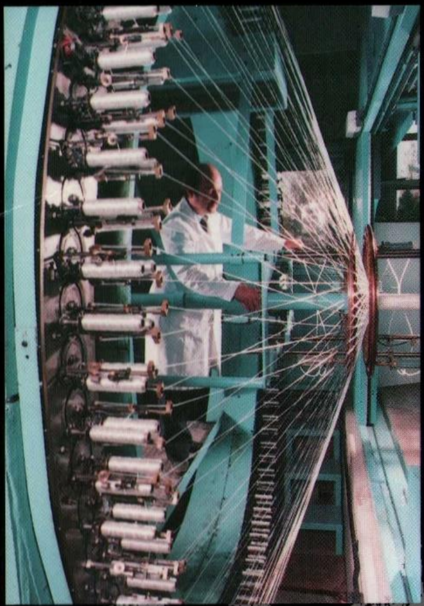
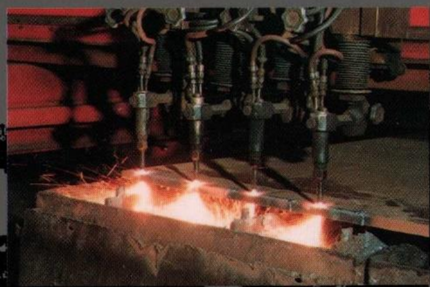
SERC BULLETIN

A SPECIAL ISSUE FOR
INDUSTRY YEAR 1986

SCIENCE & ENG
RESEARCH
COUNCIL





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INDUSTRY YEAR *1986*

The designation of 1986 as INDUSTRY YEAR was announced by the Royal Society for the encouragement of Arts, Manufactures and Commerce in April 1984. In the words of its President, HRH The Duke of Edinburgh:

"Industry is by far the most important activity in our national life. This is a fact, and it can do no good at all to give it a bad reputation or to call it a 'rat race'. This programme is intended to re-awaken appreciation and understanding of what industry is all about and that can only be to the benefit of all the people of Britain."

Industry - the provision of products and services which people need and want - is fundamental to almost everything we do. Industrial success is a necessary condition for the provision of food, shelter, and warmth; for the education of the young; for the care of the sick, old and handicapped; for a better quality of life for the individual and for the community as a whole. Yet in Britain we hold industrial activity in low social esteem and the causes of our relative industrial decline are deeply embedded in our cultural attitudes.

The aim of INDUSTRY YEAR 1986 is to encourage a better understanding of industry, its essential role, and its service to the community, and to win acceptance for it. Its purpose is to foster the pride of those who work in industry in their own achievements and contribution to the welfare of the nation.

Front cover pictures

Far left: As a result of a cooperative project with Liverpool Polytechnic, Babcock Wire Equipment Co Ltd have doubled the speed and spool capacity of their braiding machines. (See page 4)

Centre: The Microman 8 microprocessor-based robot system developed with the support of the Teaching Company Scheme. (Photo: British Federal Ltd)

Above right: The PED Thermovision system in use at Bradford University's Polymer Research Unit, for studying heat transfer aspects of polymer processing.

Below right: The work-time of a profile burning operation is assessed by a computer-aided estimating system developed jointly by ICI and the University of Manchester Institute of Science and Technology. (Photo: ICI plc)

Contents

Foreword by the Chairman

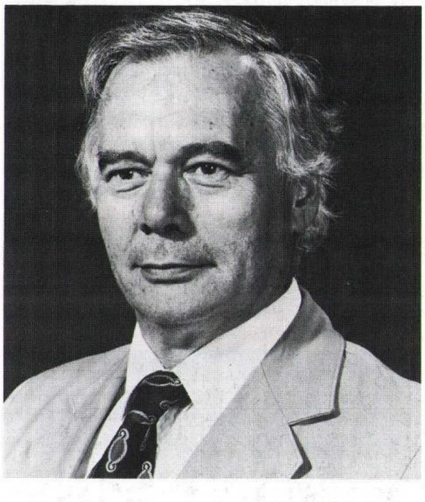
As one of its contributions to Industry Year, this special edition of the *SERC Bulletin* is devoted to a series of case histories illustrating the way that academic-industrial collaboration has developed in recent years and SERC's contribution to that process.

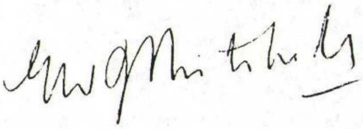
SERC, as the largest of the Research Councils and the one most generally responsible for support of science and engineering in UK universities and polytechnics, has had the promotion of such collaboration as one of its major objectives in recent years. It may be asked why SERC should encourage an involvement with industry at all and of course in many areas of basic science the industrial interest is minimal. However, it is the Council's firmly held belief that the health of many areas of strategic science and all areas of engineering supported by SERC can benefit from an interaction with industry. To start with, a knowledge of actual industrial problems and constraints will provide academics with real rather than artificial boundaries.

Such interaction must also be in the interests of industry. An increasingly large part of technology now raises multi-disciplinary issues with which even the largest companies find hard to cope. In these circumstances universities and polytechnics are the natural places to go for advice and for research collaboration. With this in mind, the Council has provided a number of mechanisms in recent years to facilitate collaboration between the academic community and industry. Three of these mechanisms (Cooperative Awards in Science and Engineering, Cooperative Research Grants and the Teaching Company Scheme) are referred to at the end of this *Bulletin*. However they are only part, though an important part, of the Council's general support for this kind of work and some of the case histories included in this report have originated quite independently of these mechanisms.

The case histories presented in this *Bulletin* are largely chosen at random from a wide field. They extend, on the one hand, from one of the spin-offs of fundamental particle physics, through the technologies of space to the development of the basic understanding of the behaviour of hydrostatic bearings. On the other hand, they illustrate the increasing penetration of information technology, biotechnology and materials technology into applications across an enormously wide field of industrial processes. While in no way presenting a complete picture, these examples nevertheless well illustrate the extraordinary range of scientific and technical expertise available in UK universities and polytechnics and the growing use of this expertise by UK industry.

Although most of this *Bulletin* is devoted to research, it is important to remember that an equally significant output from universities and polytechnics is trained manpower. As with research, SERC seeks to help the academic world and industry to meet and have a dialogue from which the end-result is postgraduate education which increasingly meets the nation's future needs.





Professor E W J Mitchell CBE FRS
Chairman of Council

Molecular electro-optics for industrial process monitoring

Electro-optics is the study of the change in one or more of the optical properties of a material when subjected to an electric field. For many years, electric birefringence and light scattering have been the bases of optoelectronic modulators used in laser optics, and the mode of action of liquid crystal display devices, respectively. A new generation of electro-optical methods is being used for the fast characterisation of molecules and particles in liquids, solutions and suspensions. Their adaption as in-situ monitors of particle behaviour has potential for industrial process control, as demonstrated in a current project within the Optics Group at Reading University, funded jointly by SERC and English Clays Ltd.

Electro-optical methods

Application of an electric field to a colloidal suspension results in a change in the orientational order of the particles. The field couples with any electrical dipoles and the particles rotate and align. The majority of particles are optically anisotropic so that the transition from a random array to a full or partial alignment can be detected by monitoring an appropriate optical property. Apart from birefringence and scattering, other optical properties which have recently been shown to exhibit anisotropic characterisitics include the optical adsorption, fluorescence, optical rotation, phosphorescence, dichroism and the inelastic scattering. These are all developed and exploited by the Reading University team for three purposes:

- ☐ New characterisation methods for macromolecular and colloidal media;
- ☐ Mechanisms for novel optoelectronic displays and devices;
- ☐ Optical sensing mechanisms.

Electro-optical effects are recorded in response to pulses of either electric fields or the pulsed optical field from high-powered laser beams. This research group pioneered laser induced optico-optical effects in polymeric and colloidal media.

An industrial problem

Many industrial processes involve the handling of particulate suspensions. High concentrations are preferred for the greatest handling efficiency. Unfortunately, at high concentration, particles aggregate or flocculate with intolerable increases in viscosity and resistance to pumped flow. Reagents are added to hinder the associations and keep the material free-flowing. To date, reagent is added under protective control and checked by subsequent laboratory analysis. This is time-consuming, labour-intensive and, at times, uneconomic. There is therefore a need for continuous monitoring of the efficiency of the reagent which can vary with product demand. Indications are that this aim can be met in this research.

The optical sensor

The optical monitor is based on electro-optical light scattering. Although the basic scattered intensity is a possible indicator of the size of the scatters, the field-induced *change* in the intensity is a much more definite indicator. The principle of the system is seen in figure 1. A laser beam passes through or reflects from a sample of the suspension. Changes in the back-scattered optical intensity are recorded via optical fibres as an electric pulse is applied across the sample. Both the response times and the magnitude of the transient changes are recorded. In the example of figure 2, differentiation between the independent and the flocculated particles is evident. The signal is used to regulate reagent addition and the complete optical system is arranged as a fibre-optical sensor.

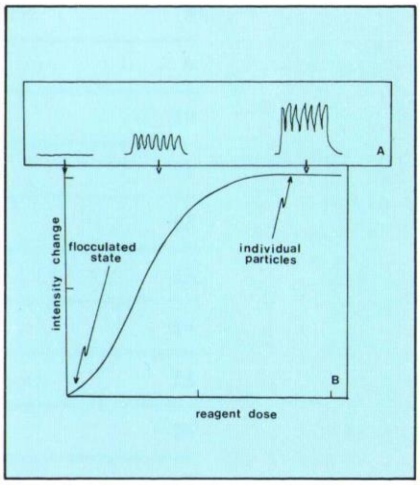


Figure 2: Electrically induced scattered light from a 30% china clay suspension, with added deflocculating surfactant. A: recorded scattering transients and B: relative intensity changes.

Figure 1: Arrangement for studying electro-optical scattering from concentrated suspensions. Optical fibres transmit the scattered light to photo detectors. Typical electric pulse characteristics are 10 kV cm^{-1} amplitude and 100 ms duration (photo Reading University).

Particulate suspensions of up to 60% solids content can be analysed. The method is appropriate for 'on-line' analysis as the suspension flows along a feed tube. The project has been active for two years and has already resulted in two patents and a commercial intrument. The project is under the auspices of the SERC Particulate Technology Specially Promoted Programme and is a good example of an application of a sophisticated optical research topic to an important industrial problem.

For further details of this project, contact:

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Physics Department
Reading University
Whiteknights
READING RG6 2AF
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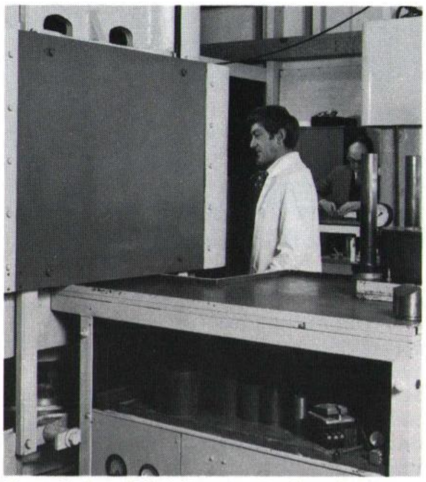
Research at high pressures

There is surprisingly little research at very high pressures, above say 1 GPa (10 kilobars or 10,000 atmospheres), probably because of the suspicion that such work is difficult and possibly dangerous. Why this is particularly to be regretted is because pressure is a major thermodynamic variable affecting physical properties and chemical behaviour, band structure and phase diagrams. Experiments based on its use continually reveal new and interesting information.

It also can be remarkably easy to do such experiments: the SERC High Pressure Facility, located at STL, Harlow, Essex, provides a variety of equipment and techniques to enable researchers to carry out experiments at high pressures, some of them of great complexity, with minimum effort and at little or no cost. Groups from some 15 universities and polytechnics have used the Facility and some recent work is outlined here.

- ☐ Measurements of dielectric constant and dielectric loss/conductivity were carried out on single crystals of uranium dioxide at pressures up to 9 GPa and at temperatures up to about 1500°C (Bath University);
- ☐ Ionic conductivity was investigated in silver azide and, as expected, fell exponentially with increasing pressure. This behaviour is typical for an ionic conductor and throws light on details of the conduction mechanism (Cambridge University);
- ☐ Transition metal ternary semiconductors of MPS_3-type were investigated to 9 GPa for effects on electrical conductivity. (That was progressively reduced by up to 7 orders of magnitude.) There was no evidence of either a high spin → low spin transition or a semiconductor → metal transition for the Co- and Fe-based crystals (Bristol University);
- ☐ NMR measurements on nickel were carried out to 5.5 GPa and up to 400°C in one apparatus and to 0.7 GPa at 77 K in another (it would have been possible to achieve 7 GPa and 110 K) (St Andrews University);
- ☐ Synthesis of amorphous SiS_2 was investigated. An orange glass was obtained by heating the elements at 4.5 GPa and 700°C (Cambridge University);
- ☐ Pressure enhancement of the Diels-Alder reaction was studied for 2-methoxy butadiene and methyl pyruvate as a model system for the synthesis of complex natural products (Leicester University).

Other interesting preliminary work at the Facility has included studies on polymerisation (50 cm^3 volume to 1.5 GPa and 100°C) and on the stability of the amorphous material SiO at 6.5 GPa and high temperatures (it separated into liquid silicon and silica: note that this pressure depresses the melting point of silicon by about 400°).



General view of High Pressure Facility, showing 500 tonne and 200 tonne hydraulic presses.

The Facility is at present being expanded both in equipment and in staff, with the appointment of two postdoctoral fellows. It is open to general use via the SERC Physics Committee. Anyone who is interested in using the Facility or who wishes to discuss proposed experiments before making an application should contact:

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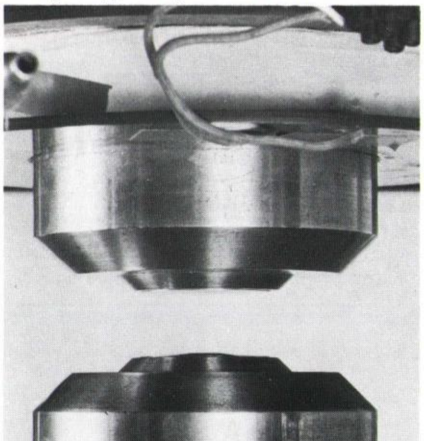
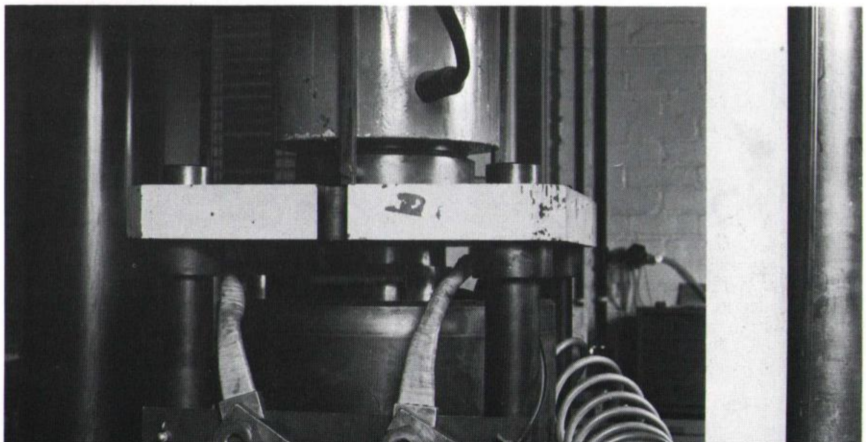
STL, London Road
HARLOW Essex CM17 9NA
Telephone Harlow (0279) 29531 ext 3308

Hall effect apparatus for 10 GPa and 79–350 K.



High temperature high pressure apparatus (to 3.5 GPa and 2000°C or, with smaller volume, to 7 GPa and 1500°C.)



High-speed braiding

'Survival of the fittest' is just as appropriate an expression to manufacturing machines as it is to natural species. It is the speed, efficiency and versatility of a machine that determines its standing in the market and its potential users. By doubling the speed and spool capacity of their braiding machines, Babcock Wire Equipment Co Ltd, of Bolton, Lancs, can reassert themselves competitively in their field on a world basis. With this as an objective, the company has been working in cooperation with Liverpool Polytechnic's Mechanisms and Machines Group on a new concept which has inherently better dynamic performance than existing machines. Life tests are currently proceeding in anticipation of prototypes of complete machines. The prototype development will be carried out with support from the Department of Trade and Industry.

Braiding is a process applied to textile yarns and metal wires to provide structure, reinforcement or electrical screening in a wide variety of products. Familiar products include hydraulic hoses, co-axial cables, ropes and shoe laces. Less familiar examples of applications, but important in high-technology developments, are those in the reinforcement of umbilical ducts carrying power and signal lines in undersea work, and in the laying up of glass and carbon-fibre reinforcements in composite structures for aircraft propeller blades. Figure 1 shows the strands stretching from their spools and converging on to the shank of the propeller.

The process may be described as weaving on a cylinder with weft and warp converging into helical lays on the cylinder from opposite directions of rotation. Many different braid patterns are obtainable by changing the sequence in which the strands are laid up. The primary interest of the production industry is in those patterns which are producible by automated means. The pattern in most general use, and forming the basis of several international standards, is one termed 'two-over-one', where each individual strand is crossed by a pair of strands arriving from the opposite direction.

The mechanisation of the under and over paths of the strands can be achieved by guiding the strand spools in contra-rotating undulating paths or by deflecting the strands as they are drawn off their respective contra-circulating spools. These two alternatives are associated with two broad types of machines in use. These are referred to, respectively, as the 'maypole', because of the similarity to the traditional folk rites dance, and the 'rotary'.

The cooperative research embraces fundamental studies on motion design and implementation for both types of machine, optimisation of path dynamics, spool and carrier dimensions for maximum material capacity and control of wire tension. Work on the maypole concept is near completion. Life tests under continuous operation are proceeding in a rig involving a single spool carrier traversing a figure-of-eight path with a transfer of drive at the centre intersection. Figure 2 shows the rig with the spool carrier equivalent moving at speed in the top right hand section of the path. Planning for a prototype and development of a complete machine is now under way in the company, with support for the project coming from the Department of Trade and Industry. Software has been developed to support the design and manufacture of machines in various sizes and spool number capacity.

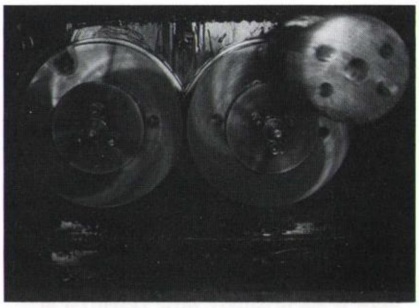


Figure 2: On the test rig, the single spool carrier equivalent (top right) moves at speed through a figure-of-eight path, with a transfer of drive at the centre intersection.

In order to ensure the effective transfer of technology to the cooperating company, they have appointed the Research Assistant engaged on the maypole concept to their staff.

Work on the rotary braider concept is at an earlier stage of development. Extensive use of both finite element theories and experimental test rigs have enabled kinematic and dynamic optimisation of the several major concepts employed. The areas of study include analysis of an oscillating wire, creation of formulated dimensional syntheses for designing the wire-deflecting mechanism, and assessment of a variety of bobbin carrier track-bearing media which include oil, air, electromagnetic suspension and roller bearings. The final machine design is an integration of the optimised component concepts which are now under test, as separate entities, before being incorporated in a prototype machine.

The problem is one of several involving motion design, implementation and control currently being investigated by the Mechanisms and Machines Group, under the auspices of SERC in cooperation with industry or under direct contact with industry. These have included packaging, textile and sheet metal working machinery, programmable machines and robots.

For further information on this project, contact:

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Liverpool Polytechnic
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LIVERPOOL L3 3AF
Telephone 051-207 3581 ext 2007

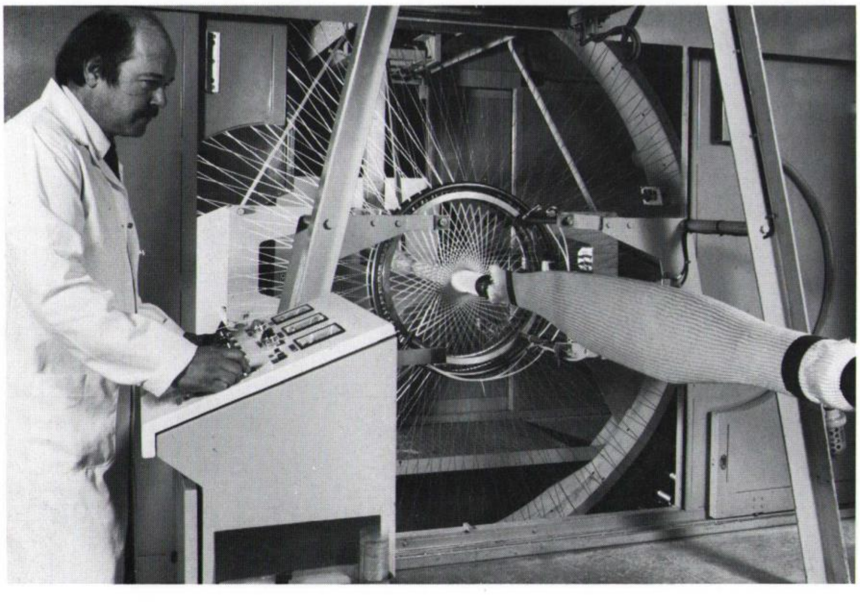

Figure 1: Laying up glass and carbon-fibre reinforcements for propeller blades: the strands stretch from the spools and converge on the shank of the propeller.

Process integration

By properly integrating a process, the engineer can save capital, save energy and improve both the control and flexibility of a plant. Process integration is the matching of individual processing operations such that they can be undertaken in the same items of equipment. Its classical, but not sole use, has been in the design of heat recovery systems. For instance, a process may require that one stream is heated, another cooled. These individual objectives may, or may not, be achieved by contacting the streams in a heat exchanger rather than using heating and cooling resources such as steam and cooling water. If the decision is taken to match the streams, the process becomes integrated. In making the decision, the engineer must consider economics, safety, subsequent ease of control and process flexibility (how the plant can be expanded and how it responds to changes in feedstock etc).

In recent years new techniques have been developed which allow the designer to identify and select the best process integration options available to him.

Application of this technology now goes well beyond the problem of heat recovery system design. Combined heat and power systems, separation schemes, integrated distillation column design and general process design have all been considered. The result is a total process engineering methodology which is radically changing the way in which process design is undertaken. This methodology has now been used in more than 500 industrial applications worldwide. The cost benefits in terms of both energy and capital have been dramatic (see table).

Successful commercial applications in the UK have involved both continuous and batch processes in industries as diverse as petroleum, general chemicals, petrochemicals, pulp and paper, food and drink, cement, steel, pharmaceuticals and fibres. A part of this success is due to the significant effort made by the Energy Efficiency Office of the Department of Energy to promote the use of this technology.

The work at University of Manchester Institute of Science and Technology is headed by Professor B Linnhoff who pioneered these practical techniques with his discovery of the 'pinch' concept. In addition to making the extension to general process engineering the latest research has resulted in the development of tools for the identification of the optimum trade-off between capital cost and energy cost in the design of new plants; tools for identifying the most cost-effective revamp to a plant (for both larger throughput and for energy saving); tools for assessing the controllability and flexibility of a plant before detailed design is undertaken; and tools for adding contingency into a process plant in the most cost-effective manner.

In addition to projects supported by SERC, a large research programme is funded by a consortium of companies which include some of the largest chemical companies in the world.

For further details of this project, contact:

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Department of Chemical Engineering
University of Manchester Institute of Science and Technology
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Telephone 061-228 7537

UMIST process integration consortium

Union Carbide
BASF
Proctor and Gamble
BP
EXXON
Norsk Hydro
Shell
Atlantic Richfield
Kinetics Technology International
Electric Power Research Institute (USA)
Lummus Crest
Unilever
DuPont
Dow Chemicals
Elf France
Linnhoff March
M W Kellogg

Process	Type of project	Energy Savings £/annum	Capital cost £	Payback months
Petrochemical	Retrofit	700 000	330 000	<6
Speciality chemicals	Retrofit	93 000	38 000	5
Speciality chemicals	Retrofit	55 000	4 000	<1
Inorganic bulk chemical	New	160 000	savings	–
Speciality chemical	New	50 000	saving: 75 000	–
Organic bulk chemical	New	400 000	same	–
Bulk acid	New	40 000	saving: 70 000	–
Organic bulk chemical	Retrofit	670 000	400 000	7
Edible oil	Retrofit	450 000	–	–
Whisky distillery	Retrofit	300 000	–	10-15
Synthetic resins (Batch - multipurpose)	Retrofit	250 000	–	3-24
Ethylene	New	430 000	saving: 470 000	–
Oil refinery	Retrofit	1 875 000	3 000 000	19

A process module at the Mossmorran natural gas plant (Photo: Shell UK Ltd).

Design and operation of short-haul aircraft

Although the public impression of civil air transport is based mainly on fast and large aircraft like Concorde and the Airbus, by far the largest part of the market, both in terms of number of aircraft and hours flown, is concerned with smaller general aviation aircraft. At the top end of this sector are commuter and short-haul aircraft performing flights between provincial airstrips or feeding passengers to and from the main airports. Typically, these aircraft will carry less than about 50 passengers and fly routes of less than 600 miles.

Recent changes in US legislation have further stimulated commercial interest in this type of operation, making the commuter market the fastest expanding part of the air transport industry. Short Brothers of Belfast was one of the earliest manufacturers of this type of aircraft and currently sells a range of medium to large commuter aircraft throughout the world. Keeping ahead of foreign competition and responding to new environmental and ecological pressures demands continuous application of advanced technologies. To this end, the collaborative research project with Loughborough University is aimed at improving traditional aircraft design and flight-planning techniques by the application of computer optimisation methods.

Large subsonic transport aircraft flying long-haul routes operate predominantly under cruise and cruise-climb conditions. The initial climb and final descent phases form a minor part of the total flight profile and the flight can be approximated to the cruise phase only. In such cases the determination of efficient flight conditions is relatively easy as cruise-climb analysis techniques are well understood. This type of aircraft is likely to be equipped with a sophisticated autopilot that can be programmed to follow complex speed-altitude patterns for efficient flight during the cruise. For commuter aircraft, flying short-stage routes, cruise procedures are inappropriate since the majority of the flight profile is spent performing the initial climb and final descent phases. In many short-range flights the cruise phase is altogether absent, the pilot flying what is known as 'saw-tooth' profiles. For these aircraft the pilot does not have the assistance of an autopilot and flies each phase at constant indicated airspeed and engine throttle setting. The values used for speed and throttle depend on the flight conditions and are pre-determined using flight manuals and charts.

The initial study at Loughborough modelled the entire flight profile (climb-cruise-descent) in terms of a number of control variables and linked this algorithm to a multivariate optimisation (MVO) method developed at the Royal Aircraft Establishment, Farnborough. This approach has been shown to have several advantages. First, a quasi-static analysis of the flight profile becomes possible, thereby avoiding the need to analyse the full dynamic motion of the aircraft. Second, the mathematical modelling of the characteristics of propeller-driven aircraft is straightforward and there is no need to utilise simplified thrust modelling. Last, and most significantly, the ability of the MVO routine to handle both equality and inequality constraints is used to represent various operational factors such as cruise height restrictions, maximum rate of descent and air traffic control constraints. This allows a more realistic analysis of the flight to be considered. The method can be applied to any conventional type of aircraft and will analyse multi-stage flights.

The application of the program to current commuter aircraft, such as the Shorts SD 360, indicates that significant fuel saving is possible compared to conventional flight manual techniques. Apart from fuel economy, the computer method can be used to minimise other objective functions, such as direct operating cost or flight time, and provide useful trade-offs for multi-parameter design studies. Equally important is the opportunity for immediate improvement in flight manual data which can be individually tailored to suit operators and their particular aircraft fleet and route structure.

The flight profile optimisation technique is not limited to general aviation aircraft. Recent relaxation of 'fifth-freedom' air transport rights by the Government now permits transatlantic operators to make inter-schedule stops at UK airports in transit to and from other European cities. These initial (or final) short-stage flights by large aircraft can be modelled by this new technique and substantial fuel savings shown.

Lloyd Jenkinson and Dimitri Simos study new aircraft designs.

Short Brothers' new commuter aircraft, SD360.

Optimum flight profiles can be evaluated not only for existing operational aircraft but also for projected or notional designs. This has led to an important extension of the technique which allows more relevant criteria to be considered when determining the design parameters and size of a new aircraft. Traditionally in aircraft project design, efficient cruise was regarded as one of the main performance criteria for the determination of geometric and aerodynamic parameters. For short-haul commuter aircraft, this is not appropriate as the entire flight must be considered in evaluating efficiency. A new program has recently been compiled which combines aircraft design synthesis, flight profile analysis and mathematical optimisation in a single entity. Aircraft design variables (wing area, aspect ratio, engine size etc) are optimised in parallel with the flight-profile control variables. For the first time in aircraft project design it is possible to determine true optimum aircraft to fly particular routes. The commercial benefits to the manufacturers using this procedure for new design are obvious, but operators may also take advantage of the technique to determine which aircraft best suit their particular route structures. Since design parameters can be fixed, rather than allowed to find optimum values, the program can be used to compare competing designs over particular missions.

Both the flight profile optimisation program (known as SCOPE) and the aircraft design/operation optimisation program (CASTOR) were funded under a collaborative SERC/Short Brothers research grant.

For further information on these projects, contact:

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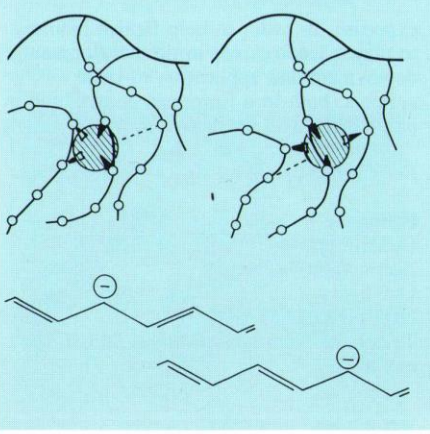
Polymers as battery electrolytes

Polymers have been developed in which inorganic salts may be dissolved. The polymers act as ionising solvents and the resulting ions enable the polymer to conduct electricity in exactly the same way as a conventional liquid electrolyte. The polymers are less highly conducting than liquid electrolytes but many of their other properties make them attractive candidates for use in today's specialist batteries. A team at Leeds University has been investigating the use of these polymer electrolytes and is collaborating with a manufacturer, Venture Technology, in evaluating new miniature batteries.

A polymer electrolyte is formed by combination of a polymer and an inorganic salt, such as lithium perchlorate. The polymer chain itself must be highly mobile and contain chemical units which are able to solvate and hence dissolve the salt.

When the salt dissolves in the polymer, it partially dissociates to form ions, and these charged particles are responsible for the passage of electric current through the electrolyte. The process is identical to that found in normal liquid electrolytes. In polymers, however, the extent of dissociation of the salt is low and hence the conductivity is often very much lower than found in the organic liquids at present used in lithium-based batteries. This disadvantage can be partly overcome by the fact that polymer electrolytes can be cast as very thin mechanically stable films. Indeed a lot of work has been done investigating the use of poly(ethylene oxide) as an electrolyte in a lithium-based battery which it is hoped may compete with the lead-acid battery used in cars.



Simplified views of conduction in polymers.

A: A polymer electrolyte. The ionic species (large shaded circle) is solvated by oxygen atoms (small circles) in the polymer. When the ion moves it must be able to change the oxygen atoms in its solvation sphere. In addition, the polymer chain must be very flexible so that the ion can easily find a new solvation site.

B: A polymeric electronic conductor. In this case conductivity relies on the presence of extended rigid conjugated systems which allow the delocalisation of electronic charge.

The poly(ethylene oxide) battery is, however, only useful at working temperatures above 100°C. The Leeds team has therefore aimed at developing electrolytes which may be useful at ambient temperature. They have also concentrated on electrolytes for use in situations where large currents are not required, such as in modern microelectronic devices. In these uses, the low conductivity of the electrolyte becomes less important. Best use of the other properties of polymer electrolytes can then be made, for example:

- ☐ Polymer electrolytes will not escape from a battery by leakage or evaporation;
- ☐ Polymer electrolytes can operate over a wide range of temperature, where normal liquids would freeze or boil;
- ☐ The polymers are less toxic, less reactive and less flammable than organic liquids commonly used in lithium batteries.

The most promising of these polymers consist of short lengths of poly(ethylene oxide) attached to a flexible backbone chain. These are known as 'comb' polymers where poly(ethylene oxide) forms the teeth of the comb. The nature of the backbone is not important, provided that it is chemically inert and that it is flexible. To some extent it is therefore possible to tailor the electrolyte to the specific requirements, for example, by incorporating other materials into the backbone or by cross-linking. The polymer electrolytes produced range from viscous liquids and soft rubbery cross-linked films to brittle partially crystalline solids.

Conductivity studies of a range of these polymers have been carried out, but high conductivity alone does not guarantee the production of a successful battery. It is necessary to examine the electrolyte in combination with working electrodes. For this reason Leeds is collaborating with a battery manufacturer, Venture Technology, to evaluate the polymers so far produced and to identify the most promising areas of use for these batteries.

Battery electrolytes represent only one application of these interesting polymers. As non-volatile or solid solvents they offer exciting prospects as phase transfer catalysts, membranes for chemical separation or membranes in chemical sensors.

For further details of this project, contact:

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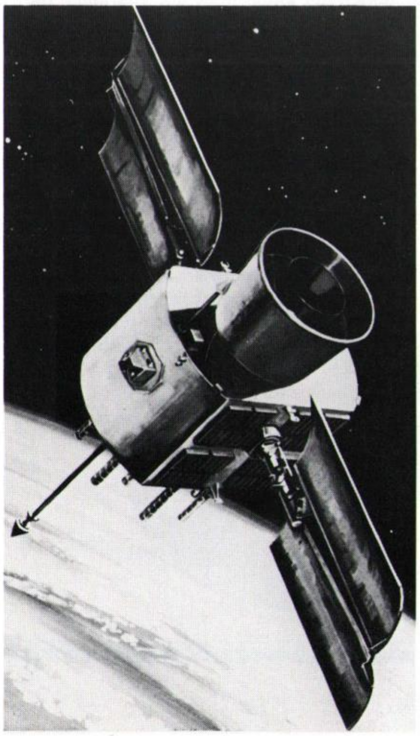
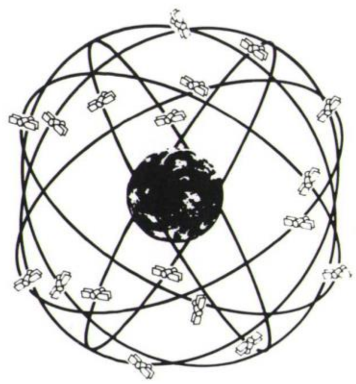
Engineering surveying by satellite techniques

With the advent of the Global Positioning System (GPS) of navigation satellites, it is becoming increasingly clear that satellite techniques will be used not only for military and scientific purposes, but also as a powerful substitute for traditional engineering surveying. It will soon be possible to position and orientate an engineering structure by GPS, to a very high degree of accuracy and with very little observational effort. This new capability will lead to a wide range of applications in the more traditional civil engineering, construction, transportation and offshore industries, as well as in the newer disciplines, such as earthquake engineering. Ultimately, 'position' will become an on-line direct read-out variable, similar to 'time', with suitable locators installed in every type of vehicle and carried around by the individual soldier or interested civilian.

GPS is expected to become fully operational by 1989, eventually replacing the Transit Doppler satellite system which is more than 20 years old. Principally, GPS is a military satellite navigation system developed by the USA Department of Defense, which provides a variety of bona fide users with a quasi-instantaneous absolute positioning capability to an accuracy of 10 to 25 metres. However, used in a 'carrier phase interferometry' mode, it allows the relative positioning of two or more receivers to a very high degree of accuracy. Tests carried out at Nottingham University and elsewhere, with prototype commercial receivers and algorithms and software developed 'in-house', have consistently led to 3-d relative positioning accuracies of a few millimetres for short baselines several hundred metres long and a few centimetres for 50 km long baselines.

A GPS Satellite





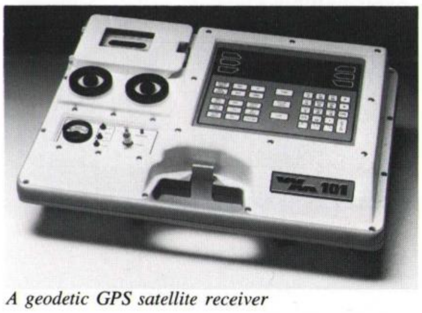
The Global Positioning System

These results are bound to have a profound influence on the concepts and practice of engineering surveying and geodesy. Classical geodetic networks consist of permanent pillar-monuments whose relative positions (horizontal and/or vertical) are determined by an elaborate series of angle, distance, azimuth and/or height difference measurements. These are used, in turn, to position individual detail points, relative to the coordinate system defined by the permanent control stations, by making additional measurements. Hence, the need and justification for establishing and maintaining a dense hierarchical system of triangulation and levelling networks on a national basis. These are used thereafter for topographical and urban mapping, and for engineering surveying. Once GPS positioning devices become commonplace and 'point coordinates' can be established cheaply and routinely, the need for permanent control networks will disappear.

At present, these high 3-d relative positioning accuracies require a GPS observation period of about 30 minutes to one hour. However, the development of more advanced hardware, algorithms and software, coupled with new field procedures, should make it possible to obtain these cm-level positioning accuracies in a matter of seconds. This will completely change the practice of engineering surveying on a construction site. Theodolite traversing and spirit levelling will give way to GPS surveying. The horizontal and vertical movement and orientation of an offshore platform will be determined easily and routinely. GPS will be used for setting out civil engineering structures such as roads, dams, pipelines and airfields. It will also enable the continuous monitoring of the deployment of a fleet of vehicles (trucks, trains or seagoing vessels).

Research at Nottingham University, on satellite positioning techniques and their scientific and engineering applications, began in 1974. This research has been supported by SERC grants, CASE studentships and industrial research contracts. Notable among these are contracts from British Petroleum, the Ordnance Survey, Decca Survey Ltd, Com-Rad Electronics, Racal Satellite Systems Division, Magnavox Advanced Systems Company of California, Messrs Wild Heerbrugg of Switzerland, and more recently the Ministry of Defence.

GPS is also leading the way for the development of new civilian commercial satellite systems for navigation, positioning and communication (eg NAVSAT, GRANASS and GEOSTAR). These will be much cheaper to set up, operate and use for a variety of applications, making the corresponding existing systems largely redundant. Academic and industrial research centres in the UK must take an active interest in these developments in space technology and the wide range of potential benefits they offer. SERC is clearly aware of the need to support such work and develop the existing UK



A geodetic GPS satellite receiver

expertise, in order to help British industry to play a leading role in the development, deployment and application of these systems, both in a European context and in partnership with the USA.

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New technology for space

Progress and innovation in space science and applications depend critically upon the possession and exploitation of new, advanced and pertinent technology. This article describes two examples of important advances in space technology which have grown out of SERC's space programme, and indeed have provided much of the impetus and competitive edge that enables SERC scientific space experiments to gain important flight opportunities with the European Space Agency, NASA and other partners. The first example is the development of a new kind of miniature mechanical cooler for the operation of sensitive detectors, and the second example is the development of millimetré wavelength microwave components and devices for use in space.

Mechanical coolers for spacecraft

There has been a long-standing requirement for the operation of cooled devices in space. These include infrared detectors, which need to operate at temperatures between 70 and 100 K (around -200°C). Even more sensitive devices can be operated at liquid helium temperatures or approximately 4 K. In the laboratory such temperatures are reached routinely with the use of liquid nitrogen or liquid helium. In space, these expendable cryogens have also been used, with the disadvantage of bulk, weight and strictly limited lifetime (typically months). Alternatively, passive radiative coolers have been used, which are bulky and inefficient, making heavy demands on spacecraft accommodation.

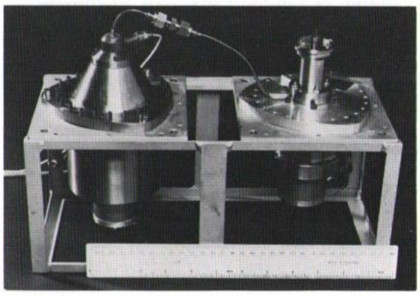

Figure 1: A long-life miniature Stirling Cycle Refrigerator developed for ISAMS and ATSR.

Figure 2: A 230 GHz Schottky diode frequency multiplier built at the Rutherford Appleton Laboratory.

At the Oxford University Departments of Atmospheric Physics and Engineering Science, in collaboration with SERC's Rutherford Appleton Laboratory (RAL),a new and highly efficient design of mechanical cooler has been developed, and versions of it will fly in two important scientific satellite missions due for launch at the end of this decade.

The cooler, shown in figure 1, is based on the Stirling Cycle and consists of two units, a compressor and a displacer. The function of the compressor is to modulate the pressure of the contained gas (helium at 10 atm pressure) while the second unit moves a sample of the gas from one end to the other of a chamber in synchronism with the pressure modulation and in such a manner that the gas is always compressed when it is at one end of the chamber, and expanded when at the other. The result of this is that one end of the displacer chamber is continually cooled (while the other is continually heated) and in this way a closed cycle refrigeration mechanism can be produced.

The use of such devices for space is not a new idea. However the design approach for the Oxford/RAL device, which has evolved from satellite instrumentation developed earlier in the course of their long-term programmes in space science, involves no rubbing parts and is able to function without appreciable degradation of performance for the duration of an entire satellite mission, which may be two or three years.

The performance levels specified for the Oxford/RAL cooler were 0.5 watts of cooling at 80 K with approximately 30 watts of input power; the levels achieved are 0.875 watts. The complete unit typically weighs 8 kg. It is intended that this device will be further developed, with the support of the European Space Agency and SERC, to produce multi-stage devices which will reach even lower temperatures with the ultimate goal of reaching liquid helium temperatures without the use of bulk cryogens. Versions of this device are also being developed in British industry for various applications besides space.

Millimetre wave technology for space

Microwave signals, usually with wavelengths of several centimetres, are widely used in space for communications, also for active and passive remote sensing of the Earth and its atmosphere. There are major advantages in using progressively shorter wavelengths, as the technology advances. This gives wider communication bandwidths, better spatial resolution for remote sensing, smaller and more compact hardware (especially the antennas) and, in the case of remote sensing of the atmosphere, well defined interactions with atmospheric constituents and pollutants.

A programme is under way at Rutherford Appleton Laboratory for the fabrication and manufacture of microwave devices to work in the very short wavelength (typically 1-3 mm) region for space applications. The type of devices being developed include Schottky barrier mixers and local oscillators involving frequency multiplication. Rutherford Appleton Laboratory, in collaboration with Heriot-Watt University, also designs and builds complete millimetre-wave systems for space applications. An example from this work is shown in figure 2.

An active and vigorous programme of development, in collaboration with a group at Kent University, aims to exploit superconducting insulating superconducting (SIS) junctions in the next generation of space-borne receivers at frequencies of up to 1000 GHz. These devices should give greater sensitivity and, equally important, use very low levels of local oscillator power. This will enable solid state devices to be used at much higher frequencies.

These devices and systems are finding applications in several important future space missions, notably NASA's Upper Atmosphere Research Satellite, where RAL and Heriot-Watt University are collaborating with the US Jet Propulsion Laboratory; and in the next generation of operational meteorological atmospheric sounders, where RAL is collaborating with the UK Meteorological Office.

Possible exploitation in industry

Most of these developments do, of course, offer some possibility for commercial technology transfer to industry and subsequent exploitation. The cooler design has been used in several applications by a number of commercial organisations including Oxford Instruments, British Aerospace, Lucas Aerospace and Horstmann Limited.

The millimetre-wave technology work has also been taken up by several companies which include Marconi Space Systems, Marconi Defence Systems, British Aerospace, and Farron Technology in the Republic of Ireland.

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Towards the rational design of herbicides

For many years, crop scientists have dreamed of the day when advances in the knowledge of plant biochemistry would allow them to cast aside the traditional 'spray and pray' methods and adopt a more rational approach to the design of herbicides. In 1980, a preliminary report by a West German group indicated that the successful broad-spectrum herbicide glyphosate was a specific inhibitor of one of the enzymes of the early common pathway of aromatic amino acid biosynthesis (the pre-chorismate or shikimate pathway). This observation stimulated the imagination of a number of scientists at ICI's Plant Protection Division at Jealotts Hill in Berkshire and focused their attention and that of many other plant scientists on the possibility of finding new herbicides which acted by inhibiting the biosynthesis of macromolecular precursors and particularly amino acids.

What was particularly attractive was the idea that the search could be made rational by concentrating attention on the synthesis of inhibitors for target enzymes on particular biosynthetic pathways; the potential inhibitors would be designed using knowledge of the mechanisms of the enzymes and their active site structures. The problem was the total lack of detailed information about the relevant biosynthetic enzymes in plants. Clearly some basic research was required in an academic laboratory to provide the necessary information to support the planned programme of chemical synthesis within ICI.

This is just the type of academic-industrial collaboration which the SERC Cooperative Research Grants Scheme is intended to support. To establish such a collaboration, ICI approached Dr (now Professor) J R Coggins of the Biochemistry Department at Glasgow University. Dr Coggins had extensive experience of the enzymology of aromatic amino acid biosynthesis in microorganisms and it was realised that the knowledge already obtained by his group could provide a useful starting point.

Neither side expected rapid progress since so little was known about the enzymology of amino acid biosynthesis in plants. The work with glyphosate had already indicated that blocking one of the enzymes of the pre-chorismate pathway was lethal to plants and attention was therefore concentrated on trying to design novel inhibitors for some of the other enzymes of this pathway. The enzymes had already been purified and partially characterised from various microbial sources by the Glasgow group and studies on the genes encoding these microbial enzymes were also well advanced. It was agreed the cooperative project should involve a programme of plant enzymology to run in parallel with the existing SERC-funded programme of microbial enzymology and molecular biology.

During the first three years of support, the Glasgow group made substantial progress with the purification and characterisation of the plant enzymes and clearly established that the microbial enzymes were useful models for the plant enzymes. Even though the enzymes were present at low levels in plant tissues, simple and rapid methods were developed for their purification; it was also established that the plant enzymes were predominantly located in the chloroplast. At ICI, some computer modelling studies were carried out and many compounds were synthesised and tested. However work on the truly rational design of inhibitors was still hampered by the lack of knowledge of the mechanisms and active site-structures of the enzymes. Fortunately other workers in the Glasgow group, using recombinant DNA techniques, have now established the complete primary structures of the pre-chorismate pathway enzymes from two microbial species. They have also over-produced all of the enzymes and this is greatly facilitating mechanistic studies and attempts at crystallisation. Within a year or two the mechanism and the detailed molecular architecture of several of these enzymes should be known. This progress has encouraged ICI and Glasgow University to renew the cooperative grant for a further three-year period.

Professor John Coggins using a Pharmacia Fast Protein Liquid Chromatography apparatus. This equipment is used for the rapid purification of small samples of plant enzymes. Its use has greatly facilitated the characterisation of several hitherto unstudied plant enzymes and allowed many potential inhibitors to be rapidly tested at the enzyme level.

Although no rationally designed herbicide has yet emerged from this programme, the work has clearly demonstrated that a jointly funded collaboration between an industrial and an academic group can successfully focus attention on an otherwise neglected area of basic science, in this case plant enzymology. The methods developed for purifying and studying the plant enzymes have turned out to be generally applicable, and the original concept of using microbial enzymes as models for the plant enzymes has also proved to be useful for other biosynthetic pathways. This has stimulated a great deal of research within ICI and a number of leads based on work on pathways other than the pre-chorismate pathway, are already being followed up.

Under the renewed cooperative grant, work will continue on the design of inhibitors of the pre-chorismate pathway. This project is now regarded equally as a 'blue sky' research aimed at establishing just how far it is possible to design herbicides rationally and as a vehicle for stimulating the exchange of ideas between the academic and industrial researchers. The information gained may not lead directly to a commercially successful product but it will undoubtedly provide the enabling technology that will eventually lead to a rationally designed herbicide.

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Magnetoresistive field sensors

M R Sensors Ltd, a spin-off company of University College, Cardiff, has just completed its first year of trading. The company's products have developed from the research carried out in the Wolfson Centre for Magnetics Technology, which is a major research group within the Department of Electrical and Electronic Engineering. The product range is based on thin-film, ferromagnetic magnetoresistive field sensors (see figure) and associated electronic signal processing systems.

The fundamental research on the deposition and characterisation of ferromagnetic films, produced by electron beam evaporation and radio-frequency sputtering, was supported by major SERC grants made to Dr A J Collins of the Wolfson Centre in the mid 1970s. This material deposition and characterisation work was supplemented by a further SERC grant to develop a high magnification Kerr-effect microscope and associated signal processing which was employed to investigate the magnetic characteristics of thin-film elements and devices.

The results of these fundamental investigations on materials and device structures stimulated the Department of Industry to provide substantial funding, in the late 1970s and early 1980s, to the Wolfson Centre under the Advanced Computer Technology Scheme. This funding was provided to enable the Centre, in collaboration with British industry, to develop magnetic recording heads and magnetic flux sensors based on thin-film technology. The main aim of the work was to develop magnetic heads and sensors for high-density magnetic recording systems.

It was however during this period that researchers within the Centre began to identify other applications for magnetoresistive sensors. These new applications were stimulated by the fact that they offer a number of technical advantages over other magnetic field sensors. The spatial resolution and maximum operating temperature of magnetoresistive sensors based on ferromagnetic films are higher than that of Hall effect devices. Like these devices they detect magnetic field H and not its time derivative dH/dt as is the case with inductive sensors. These factors make magnetoresistive sensors ideally suited for magnetic field sensing and high accuracy measurement of position and velocity of variable speed linear and rotating movements. In addition the characteristics of the sensor can be easily changed by controlling the composition of sensor material and by varying the dimensions of the sensor. Because the sensors are based on thin film technology, they can easily be integrated into a single package with the signal processing electronics to provide a complete sensing system. The application areas investigated included low-density, read-only heads for magnetic card and ticket readers, sensors for linear and rotary encoders, magnetic field and electric current sensing systems and sensor systems for non-destructive testing. For the latter, the Centre's staff developed and patented, in conjunction with the Industry Centre at University College, Cardiff, a novel coin-validating system.

In order to exploit these developments, M R Sensors Ltd was launched in April 1985 with the aid of the Industry Centre. Because of its strong research and development background, a major feature of the company is its ability to design and manufacture sensors and, where necessary, the associated electronic systems to match specific customers needs. This has resulted in the company's activities expanding into application areas for its sensors and systems which now include:

- ☐ Magnetic card readers for:
  - security access systems
  - teller terminals
  - retail terminals
  - EFT POS
  - transaction telephones
- ☐ Coin validation mechanisms
- ☐ Non-destructive testing
- ☐ Linear and rotary encoders
- ☐ Speed/position sensing for:
  - automobile engine management systems
  - anti-skid braking
  - video and audio cassette recorders
  - motor speed control
  - actuator position sensing
- ☐ Measurement of other physical parameters, such as current pressure, and force which can be translated into a magnetic field.

The company has now finalised a venture capital package with the Growth Fund Ltd, while the Wolfson Centre has received a further grant of £131,000 from the Wolfson Foundation to investigate new sensing systems and applications based on magnetoresistive sensors. These developments will be exploited commercially through M R Sensors Ltd. As the university remains a substantial equity holder within the company, it will benefit not only financially but from being associated with a commercial organisation.

Dr Collins, who is now the Managing Director of M R Sensors Ltd, believes that the increasing demand for sensors and associated systems, coupled with the company's sound research and development base and customising philosophy, will result in a substantial growth in the company's activities and turnover.

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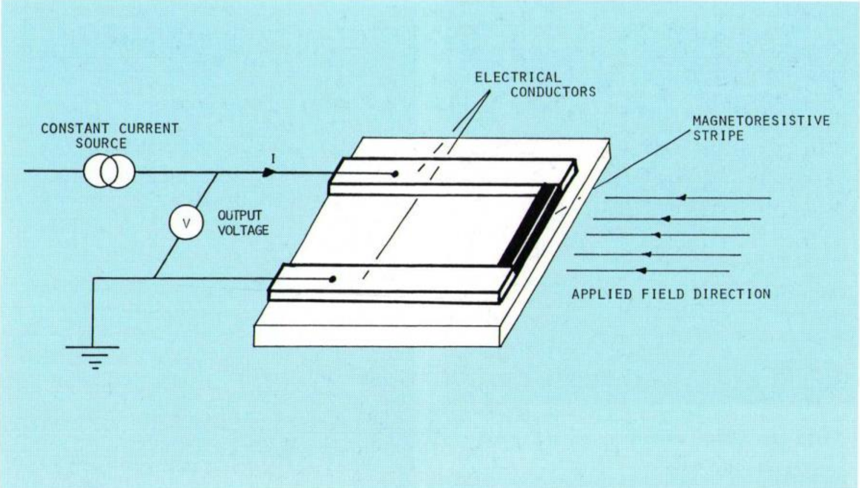
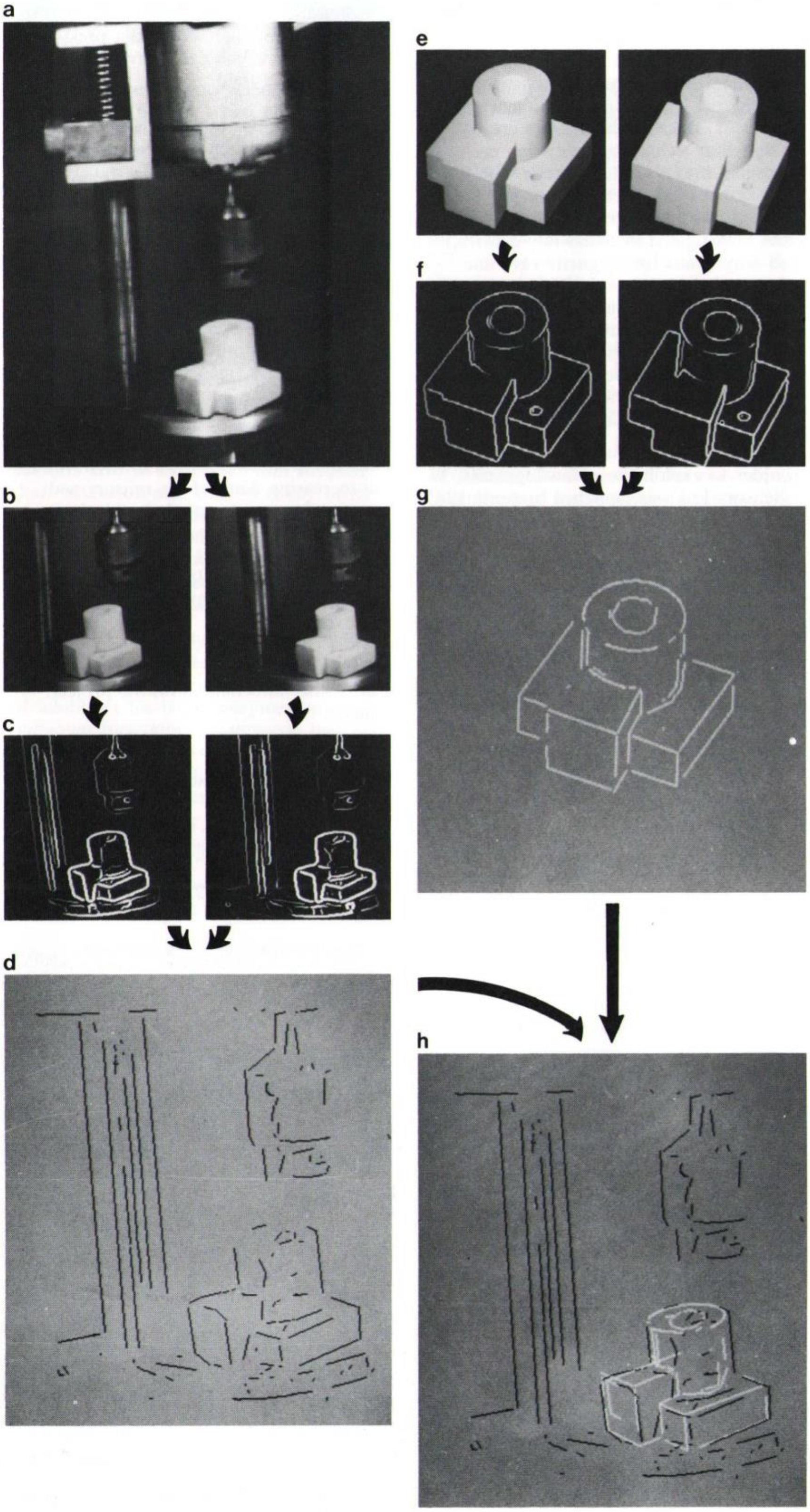
Basic magnetoresistive sensor



Alvey IKBS image interpretation

The overall objective of the image interpretation research at Sheffield University is to devise methods for deriving surface descriptions from multiple stereo images suitable for matching to three dimensional models, for the purposes of object recognition and vision verification. Target application domains are robot assembly workstations and autonomous vehicle control. The value of the research, the bulk of which should be complete by October 1987, will be demonstrated using realistic natural imagery in a way which will facilitate its speedy industrial take-up.



Stages in a prototype computer vision system developed at AIVRU/Sheffield University capable of finding an object in a cluttered industrial scene:

a. The task is for the computer vision system to guide a robot arm to pick up the object on the drilling platform. The drilling chuck and its support are here the 'visual clutter' within which the object has to be found. The fact that human vision finds this task easy is deceptive; it requires a large amount of computation and representations at many levels of visual processing if the solution is to be applicable to many types of scenes.

b. A pair of stereo images taken with TV cameras. The slight differences between images are a rich source of information about the depth structure of the scene - the differences can be used to find out how far away the object is, the shape of its surfaces and their edges in depth, and so on.

c. Edges found in each stereo image using a Canny edge operator. Bold lines represent strong contrast edges, and faint lines indicate weak edges.

d. Edge points from the two stereo images have been matched, grouped, and the resulting edge structures described as straight lines, curves, etc in three-dimensional space. The metrical details of these descriptions are not shown but are stored in the computer.

e. A pair of artificial stereo images of the object created by IBM's body modeller WINSOM.

f. Edges found in the artifical stereo pair using the low-level vision software used to find edges in the natural images.

g. Using the same process as above, the model is described as a structure of three-dimensional edges and curves, in this example incomplete and from a single view. Hence the same low level vision system is used both to acquire the model representation and to analyse natural images arising from the industrial scene.

h. The model representation (white) is matched correctly to the set of edges of the object derived from the natural images. The principle used here is to compute the rotation and translation which takes the geometry of the model representation into the viewpoint coordinate frame. The correct match is one which can account for the greatest number of image edges.

The object is now recognised, its location determined, and a suitable grasp point for the robot arm can be programmed, say to reposition the object under the drill, using additional stored knowledge about the object.

Alvey's Intelligent Knowledge Based Systems (IKBS) image interpretation research programme will cost about £2.4 million borne about equally between industry and the Alvey Directorate as part of its IKBS initiative. The programme, which is serving a valuable role in promoting industrial/academic collaboration, is organised under two industrial/academic consortia:

Spatio-temporal processing and optical flow for computer vision

The participants in this consortium are GEC Hirst Research Centre, BAeD Sowerby, PESR Romsey, Queen Mary College, London and the Institute of Cognitive and Information Sciences at Sussex University. Its goals are to develop methods for extracting accurate visual motion data from changes in image irradiance, interpreting those data in terms of 3-d surface descriptions with appropriate parameters for motion, and organising the surface descriptions into partial object representations.

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3D surface representations and 3D model matching from stereo

The participants in this second consortium are GEC, IBM (UK) Ltd Winchester, the AI Vision Research Unit at Sheffield University, and the Departments of Computer Science and Artificial Intelligence at Edinburgh University. Its goals are to create object model representations based on characteristic views of objects defined using CAD/CAM object modellers, and to find ways of matching those representations to surface descriptions derived from stereo range data. Work being done within this consortium in AIVRU/Sheffield is illustrated in the figure.

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Predicting preforms by computer

An ACME-supported research project to computerise the design process for forging preforms promises not only to eliminate the laborious calculations hitherto necessary, but also to avoid wasting expensive materials. A research team at Leeds University has been collaborating with the specialist manufacturer of aerospace forgings Daniel Doncaster and Sons.

The research team is led by Dr A Bramley, who holds a joint appointment in both Mechanical Engineering and Metallurgy Departments at Leeds. On the company side, Daniel Doncaster and Sons has made a considerable contribution to the cost of the work and has provided both materials and facilities for practical trials.

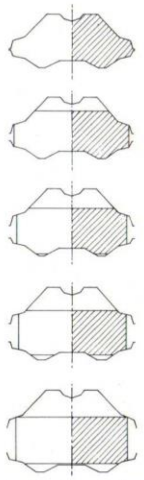
The forging industry is traditionally an area of empirical, some might say intuitive, design based upon extensive experience. The process, which derives originally from the working of iron by blacksmiths with hammers, has developed into more and more exotic materials with ever tighter tolerances. Control of the exact amount of energy required to deform a billet into a required shape demands much of the power press designer.

Depending upon the material, forging can be carried out with the workpiece cold, warm or hot. The required shape cannot normally be completed with one blow of the press and intermediate shapes produced are called preforms. Given the finished shape of the component which is to be produced, it is not easy to determine the exact shape of perhaps several preforms and hence of the tools needed to make them.

This is a serious problem for two reasons. First, the people who have the necessary knowledge are becoming increasingly rare and cannot readily apply their experience to new shapes. Secondly, even the best knowledge is not exact. The first attempt to produce a satisfactory preform for a new component is rarely successful and the procedure can involve a great deal of time and the waste of a lot of expensive material.

Daniel Doncaster and Sons is involved in producing a wide range of components for aero engines, such as turbine and compressor discs. Components have to be made to exacting standards for reasons of safety and must work reliably at high temperatures. Workpiece materials are expensive, components are large and forging specifications stringent in term of material flow and properties.

The preform design system developed at Leeds works back from the design of the finished forging through that of the intermediate preforms. The forging designer starts from an engineering drawing of the required shape and uses a digitiser board plus minimum keyboard input to feed the necessary shape definition data into a suite of computer programs. The forging process is then simulated in reverse, shown graphically on a VDU and suitable preform shapes selected. Further simulation enables an appropriate billet to be selected from a stock library. Finally, the analysis can be run in forward mode to produce a reasonably accurate simulation of the actual forging process.



Computer simulation (top to bottom) works backwards from finished forging to original billet configuration, through a series of intermediate preforms.

The computer simulation process is based upon the 'upper bound element technique' (UBET) which can predict forming loads and metal flow in closed die forging and extrusion type presses. Further associated research at Leeds will be aimed at producing a forging modeller with application to a much wider range of materials and shapes.

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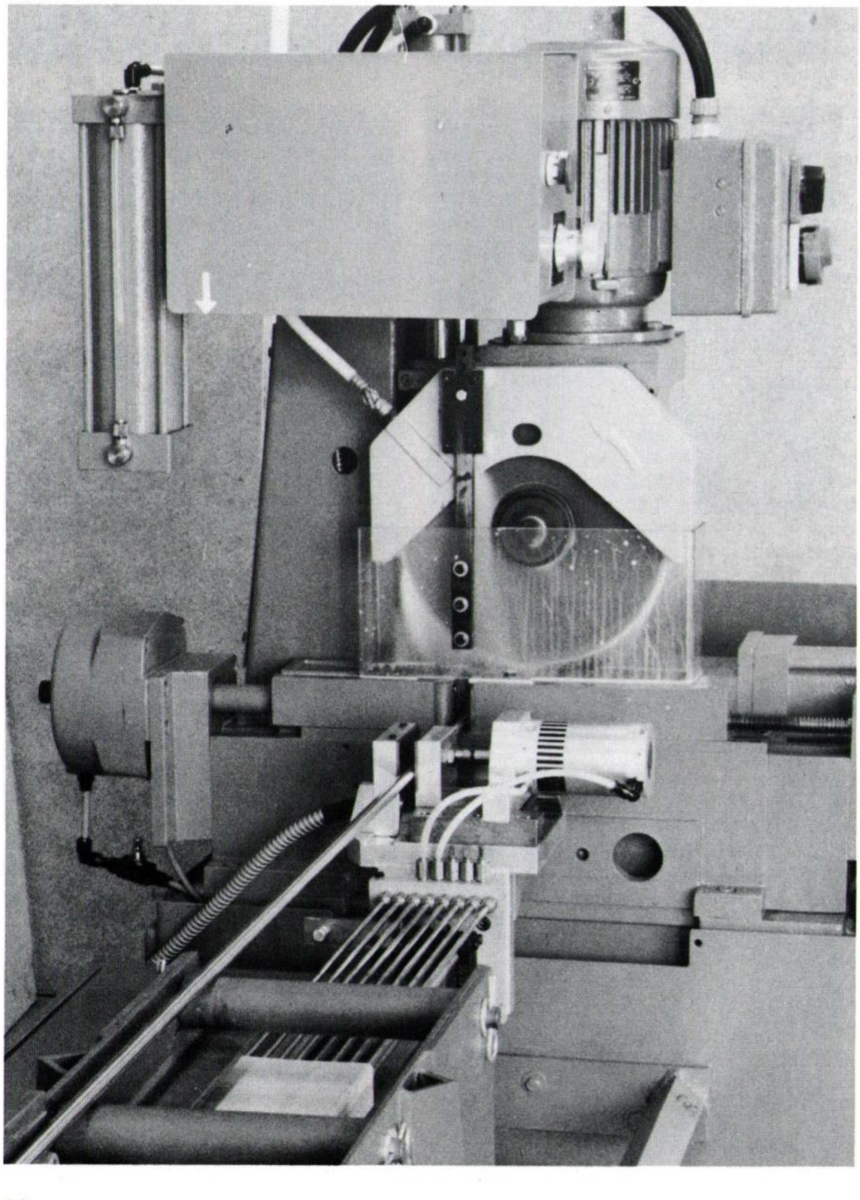
Research provides robotic building blocks

Collaboration between Martonair (UK) Limited and a team led by Dr R Weston in the Department of Production Engineering at Loughborough University has led to the development of a family of individually programmable, single-axis pneumatic actuator modules. Different modules can be combined in various ways to form single or multi-axis handling devices, either dedicated to a single task or reprogrammable within a specific operating envelope.

The basic module, based upon existing Martonair products, comprises a pneumatic cylinder with a five-port servo-actuated valve governing its air supply. However, the cylinder also has an accurate position sensor in the form of an incremental rotary encoder driven by a rubber belt attached to the cylinder slide. In addition, if a specific application requires positive positioning and enhanced rigidity, then the cylinder can also be fitted with an electropneumatic lock which clamps the slide once the particular positioning movement has been completed.



Each module incorporates an independent microprocessor which controls the five-port valve servo in relation to the required position of the slide, as sensed and fed back by the rotary encoder. The microprocessor also controls the operation of the electropneumatic lock, if fitted, and provides an interface to enable a supervisory computer to control complete handling systems made up from a number of actuator modules.

By means of a supervisory computer, the resulting handling system can be reprogrammed to position actuators to any point within their combined operating envelope; such a system is thus effectively a multi-axis robot.

Previously, pneumatically operated positioning units have only been applicable to locating and clamping specific objects of known dimensions - in other words dedicated to a single task or component. Based upon cylinders of fixed stroke and achieving position by means of mechanical end stops, they provide high accuracy and consistent repeatability but have little or no flexibility of positioning within their working stroke. This limits their use to relatively high volume manufacturing applications where successive objects being located or clamped do not vary dimensionally outside known manufacturing tolerances.

The major advantage of industrial robots is flexibility - the capability of rapid reprogramming of the robot controller to accommodate different objects or different positioning sequences. Before the Loughborough/Martonair developments, programmable positioning was achieved using relatively expensive electric or electrohydraulic servo drives. Three years' joint research and development work has provided a more cost-effective alternative.

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Saw with Martonair programmable positioning unit. Purpose built clamp attached to the Linear Modular Handling Unit carries the piston-rod billet forward to the saw and accurately positions it for the correct length to be cut. (Safety guard removed for photo).

Charge-coupled devices in high energy physics

Charge-coupled devices (CCDs), originally developed for detecting television images, are now being successfully used as sensitive detectors in a wide range of applications. This article outlines the current progress in three groups which are applying the devices to detect the presence of particles in high energy physics experiments.

The classical charge-coupled device (CCD) is essentially a silicon integrated circuit of the MOS type in which arrays of optically transparent electrodes overlay the silicon to form photosensitive regions. The electrodes can be connected in triplets (see figure 1) to form an analogue shift register which moves the charge packets created by incident light (or by charged particles) bodily through the silicon. In one arrangement, the electrodes would lie horizontally across the imaging area (typically a few millimetres square) shown schematically in figure 2, and after exposure the image would be moved in the direction of the arrows first into a storage area and then via an output register into storage or display circuitry.

High precision detectors

As a result of a collaboration between Rutherford Appleton Laboratory, Brunel University and GEC Hirst Research Centre, CCDs have been successfully used to track high energy particles with very high precision (5 microns) in an experiment at CERN. Because high energy particles typically produce signals of only 1000 electrons in the device, it was necessary to develop a fast read-out system with very low noise. Using a GEC P8600 CCD and suitable electronics, noise levels of 40 electrons at a readout rate of 3 MHz have been achieved at a working temperature of 180 K.

The same collaboration is now working on developing CCD mosaics for use in the Stanford Linear Accelerator Center in California. Mosaics are required in order to cover most of the solid angle into which particle tracks are produced. Moreover the detector elements need to be as thin as possible. Figure 3 shows an early prototype with one CCD mounted on to a ceramic motherboard and connections are made to the CCD using thick film techniques. This board will contain three CCDs in all, which will be driven in parallel.

This work has potential in other areas: for example, low level light imaging, X-ray detection in the 2-15 keV range and electron microscopy. The development of mosaics is necessary in order to make large area detectors. It is technically difficult to make CCDs larger than about 1 cm^2.

Figure 1: A charge-coupled device register, showing a section through the silicon surface.

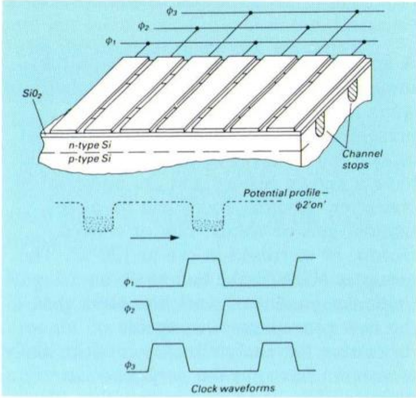


Figure 2: A CCD area array of the frame transfer type.

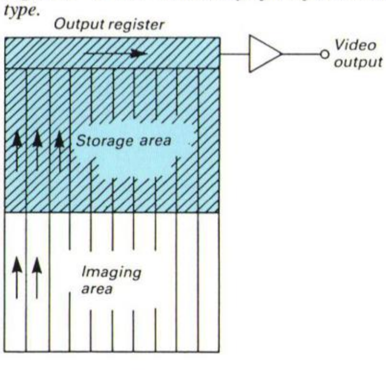
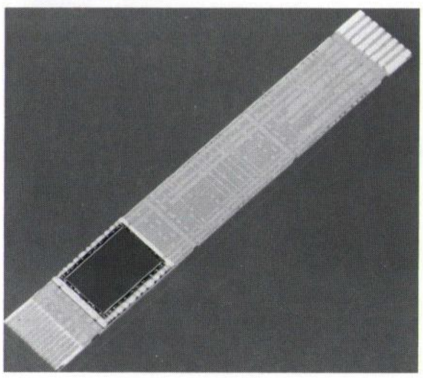


Figure 3: An early prototype CCD mosaic of dimensions 12 mm by 84 mm. Just one out of the three CCDs is mounted on to the ceramic motherboard. Thick-film techniques are used for electrical connections.



Multi-fibre detector

A Cambridge University high energy physics group has been working on an application of CCDs for the UA2 project at the antiproton-proton collider at CERN. A large cylindrical detector of charged particles is being built out of many 1 mm diameter scintillating fibres packed into an annular region 2 m long, 80 cm in diameter, and about 5 cm thick. It comprises about 60,000 fibres, grouped at one end into 30 bundles, each of which is pressed on to the front of a chain of three image intensifiers having a total photon gain of about 15,000.

The passage of a high energy particle through a single fibre produces up to five photo-electrons at the photocathode of the first image intensifier. The image of each fibre of a bundle appears at the output of the chain, to which a Thomson TH7852 CCD (144x208 pixels) is optically coupled. The role of the CCD is to read out the image of the bundle, identify each fibre that brightens by means of the group of CCD pixels (typically 10) viewing it, and produce in digital form a measure of the quantity of light from each fibre.

The use of image intensifiers with CCD read-out has applications to digital imaging devices in the areas of medical diagnostics and industrial radiology.

Single photon detector

A group at Bristol University has developed an optical imaging technique capable of finding the positions of single photons. It has been used to detect vacuum ultraviolet photons in a gas mixture of argon and triethylamine which is held in a chamber with suitable electric fields set up between conducting meshes transparent to photons and electrons. In the first gap, next to the entry into the chamber, conversion of photons to electrons by the photoelectric effect on the triethylamine can take place. In later gaps a single electron can be multiplied in the gas mixture if the electric field is high enough. The single electron becomes an avalanche of photons and electrons and at the exit window the photons are viewed by a combination of image intensifiers and a silicon array of photosensitive pixels, such as a CCD. This has involved collaboration with Instrument Technology Ltd.

The positions of single photons have been detected by this technique to an accuracy of 100 microns.

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Immunoassays for food analysis

A Cooperative Research Grant from the SERC Biotechnology Directorate has resulted in the launch of the world's first commercial immunoassay (IA) kits specifically designed and tested for food analysis. The grant of £105,000, to Dr John Allen, Dean of Research and Innovation at the North East Wales Institute of Higher Education (NEWI), was more than matched by the contribution from the collaborating body, Grand Metropolitan Biotechnology. The initial promise of the results has led to the formation of a new company, Biokits Ltd, to manufacture and market the IA kits. These take the form of convenient packages containing all the materials, buffers and solutions for the assay, ready-standardised and pre-calibrated; although this is quite typical of kits destined for use in clinical diagnosis, the whole concept is entirely novel to food analysis.

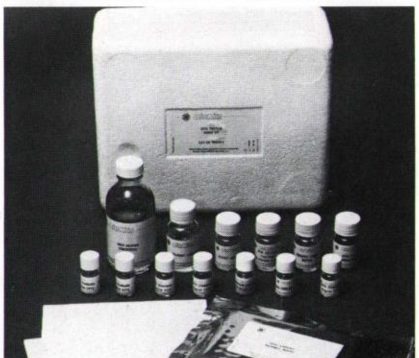
The present kits are designed for quantitative analysis, and are based on enzyme-linked immunosorbent assay (ELISA) systems, using conventional microtitre plates. Biokits' first product, launched in 1985, is an ELISA for the detection of soya protein in meat products. Other kits are now on the way, including systems for meat species detection, determination of other protein contaminants in meat products such as casein, type of species present, and for fungal toxins.

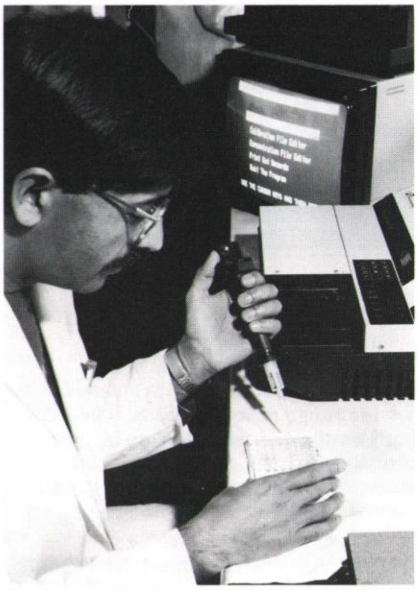
Many of the research and development problems are common to both food analysis and clinical diagnosis. For instance, the common prerequisite is a 'good' antibody. It must bind avidly and specifically to the analyte, and not cross-react with anything else present; also, enough stocks must be produced to maintain standardisation between production runs over an extended period of time.

Purification of antibodies by affinity chromatography.

A specific difficulty associated with the immunoassay of foods is the multiplicity of ways in which the analyte can be presented. Clinical samples are usually of blood, urine, saliva or cerebrospinal fluid, have a known history and are universal in character, whereas foods can be pastes, liquids, gels or solids, raw or cooked, frozen, or sterilised-in-can at 120°C. The group at NEWI have had to do an immense amount of work to ensure that the new procedures are capable of measuring the analyte in any product likely to contain it; or, at the very least, to define the limits of its applicability. The problem turns out to be by no means insuperable. As an example, soya protein can be incorporated into food formulations in a variety of forms: as isolates, full-fat flours, defatted flours, concentrates and texturates. In order to reduce the soya protein into a comparable state for ELISA, the Biokits assay demands that samples be homogenised, extracted into urea/dithiothreitol at 100°C and finally 'renatured' before the immunoassay itself. Results from a range of meat products containing known amounts of different types of soya protein (between 1% to 3% wet weight) are consistently good, with values between 94% to 107% of those expected.

Biokits' new ELISA kit for soya protein meat products. Developed in collaboration with the research team at the North East Wales Institute, it represents the first commercial immunoassay kit specifically designed and developed for food analysis. It is now in use throughout the UK.





Immunoassay development at the North East Wales Institute. The Institute team developed its own software for data analysis direct from the plate reader.

It is also important to check thoroughly that the antibody used does not cross-react with any other component present in the sample. For example, the anti-soy protein serum was found, surprisingly, to cross-react at a low level with denatured bovine casein but not with native casein. The cross-reacting antibodies are removed by affinity chromatography.

It was anticipated that monoclonal antibodies, which are highly specific and pure, would be better for the food ELISA systems. Indeed, current research at NEWI shows great promise in this area. However, monoclonals are more susceptible to degradation and are also expensive; it was thus considered that conventional antibodies, provided they were rigorously purified, would be more appropriate for initial commercialisation.

Dr Allen at NEWI states that the joint SERC grant with Grand Metropolitan Biotechnology came at just the right time to put their ideas into practice. The SERC funding was essential to get things moving and the Newtech Innovation Centre at NEWI provided a suitable mechanism to get ideas out of the research laboratory and into commercial production as quickly as possible.

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Partnership enhances protein production

Teaching Company Programmes can have considerable benefits for the academic as well as the industrial partner. In the example which follows, the implications of scaling up process plant are having a significant effect upon the subjects of research projects. Some five or six chemical engineering projects for university undergraduates have been developed as a result of 'real' industrial problems. The Programme has also provided some good teaching examples and the basis for several realistic examination questions. In time, the research findings could mature into a specialist course. Already some existing course content relating to control systems has been modified in the light of experience.

Bio-Isolates' Programme with the Department of Chemical Engineering at the University College of Swansea is well into its third year. The four Teaching Company Associates involved to date, coordinated and advised by Professor John Howell, have been mainly concerned with commissioning a plant at Mitchelstown, near Cork, and with the design, construction and commissioning of a new plant recently completed in Le Sueur, Minnesota, USA.

Professor Howell believes that the Programme has provided a commercial perspective which fosters greater understanding of the interdisciplinary pressures within a process engineering environment. The logical, step-by-step academic research approach may simply take too long; out in the field several critical activities may have to be identified quickly and developed simultaneously.

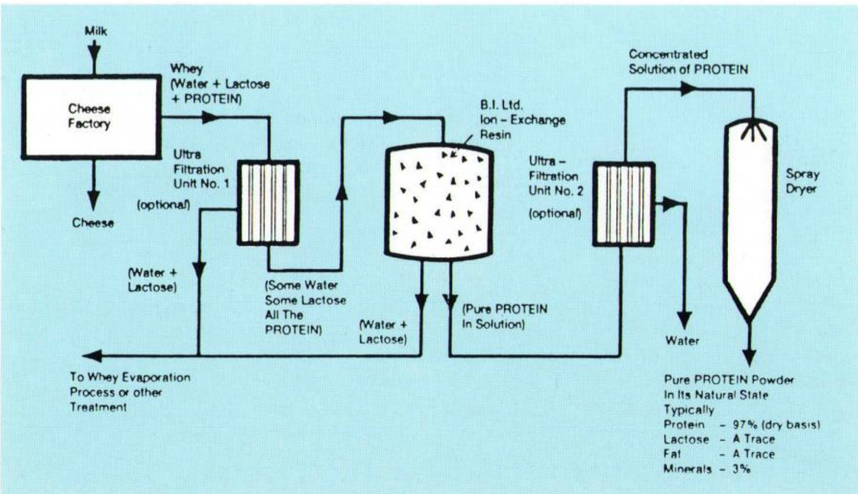
The business of Bio-Isolates plc is largely concerned with the recovery of by-products of primary processes. The most significant of these is Bipro, a pure protein recovered from whey.

The Mitchelstown plant was designed to produce commercial quantities of Bipro and has been scaled up some ten times from the original plant at Carmarthen, although subsequent modifications to the latter have increased its capacity as well. The product itself is 95 per cent protein on a dry basis, which places it in a unique position in the protein market-place. Purity and functional properties are important since Bipro is widely used in the food industry.

Regular production at Mitchelstown started in May 1984 and the plant was gradually brought up to design capacity over the succeeding months. There were some unforeseen teething troubles and problems which, although planned for, could only be solved at full-scale.

The difficulties experienced with the process control system at Mitchelstown led to an analysis at the university of the overall control strategy required for the second large-scale plant at Le Sueur, Minnesota. It was decided that, instead of purchasing a programmed control system, in view of continuous process improvements being implemented, it would be better to install a versatile control system which could be programmed by the Associates.

Protein extraction process at Bio-Isolates plc, Swansea



Professor Howell and two of the Associates went on a training course to learn about the operating system and the control language to be used. They then wrote the control software and spent six weeks carrying out a simulation exercise in which the Le Sueur program was tested and modified until satisfactory.

Another Associate was trained in ultrafiltration (UF) equipment. The fouling of UF membranes is a well known problem in dairy applications and Professor Howell is an international authority in this field. Cleaning, pretreatment and process control procedures have been modified, resulting in fewer problems with the unit at Mitchelstown and no problems at all at Minnesota.

Every Associate involved in the Programme has been caught up in the long hours of commissioning work, with periods of relatively low activity alternating with periods of near panic. The experience gained is considered by all to be first-rate preparation for a process engineering career.

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Seabed sampling and testing system

The application of vibro-impact techniques to offshore site investigation has been the subject of research at Aberdeen University since 1981, when a project funded by SERC's Marine Technology Directorate began. Vibration alone has been used since the early 1930s as a means of driving coring tubes and piles into the ground. It exploits the fact that high frequency vibrations cause a temporary reduction in the resistance of soil, thereby facilitating its penetration. This influence of vibrations on soil properties is, however, generally restricted, to cohesionless soils. The combination of vibration with impact overcomes this restriction, permitting penetration of a wide range of soil types. But development of vibro-impact generating machines has been hindered by the lack of a detailed understanding of the complex machine-soil interaction involved in the process. The work at Aberdeen has established a theoretical simulation of this process enabling development of a successful commercial vibro-impact machine.

Principle of operation

An idealised vibro-impact system is shown in figure 1. In loose, cohesionless soils the machine provides vibration alone. When materials of a higher penetration resistance are encountered, the displacement amplitude of the vibrating mass increases and the machine automatically begins to impact, to maintain penetration. As the machine has the potential for self-adjustment to match the soil conditions, disturbance to the recovered sample is minimised and a measure of soil resistance may be obtained.

Research work

The research work at Aberdeen has involved the development of a computer simulation of the process and a concurrent experimental testing programme at model and full-scale level. Figure 2 shows the large-scale model rig employed in the work which has been used to drive instrumented coring tubes of up to 127 mm diameter into a bed of Aberdeen beach sand. After the project began, further finance for the work was obtained from offshore site investigation contractor Alluvial Mining Ltd. This assistance allowed the University to construct prototype machines which have been tested in a wide range of soil conditions both on and offshore. A design procedure has evolved from this work from which the optimum parameters for coring and soil resistance measurement may be derived.

Exploitation

Commercial exploitation of the system has been undertaken through the British Technology Group who have licensed Alluvial Mining Ltd to operate the system. The current commercial version employs a vibro-impact convertor unit (VIC) which, when coupled to a conventional pure vibration corer, permits the generation of vibro-impact motion. This approach has the benefit of allowing existing vibrator units and associated hardware to be used.

In its first year of commercial use, as a corer alone, the system has seen widespread use and has proved effective in difficult soil conditions. Fast production rates have also been achieved. On one site, for example, the use of the VIC permitted coring rates of more than 65 metres in a 12-hour period to be attained with in excess of ten locations being cored in any one day.

The project has produced a prototype remotely controlled system with the potential for rapid and simultaneous sampling and testing of the seabed. Future research will widen the system's applications and establish a firm relationship between results obtained and those from more standard penetration testing systems.

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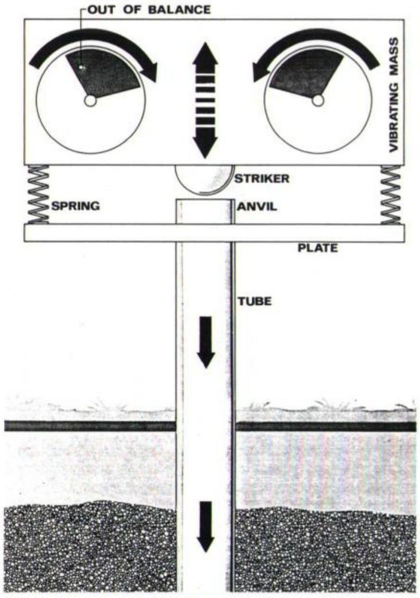

Figure 1: An idealised vibro-impact system.

Figure 2 (right): A large-scale model vibro-impact rig.

Tolerances for externally pressurised bearings

Two of the advantages usually claimed for hydrostatic bearings are zero wear-rate and high quality of precision implying precise axis of movement and freedom from vibration. When deciding whether to employ hydrostatic as opposed to aerostatic bearings, the designer will wish to satisfy himself that true accuracy and reliability are achievable.

In the past, many researchers have found that, when they investigated the performance of externally pressurised bearings, the theoretical predictions differed from their experimental results, and this has often been explained by experimental inaccuracy; but this may not have been the case.

A team at Coventry (Lanchester) Polytechnic has made major study of the effect of errors of size and geometry on the performance of hydrostatic bearings, to lay down a basis for objective tolerancing of components. This investigation was funded by SERC grants.

To ensure that these bearings operate successfully and according to design it is necessary to consider the acceptable manufacturing tolerances for the operating parts of the bearing. The application of the correct tolerances will ensure that the bearings achieve:

- ☐ The maximum load capacity and optimum stiffness of the fluid film bearings;
- ☐ A low flowrate, reducing pumping-induced heat into the hydrostatic bearings, or excessive cooling in the case of aerostatic bearings;
- ☐ Minimum variation between individual bearings within a machine system.

When designing fluid film bearings it is important to specify accurately:

- ☐ The bearing fluid film clearance;
- ☐ The position of the inlets (or inlet recess);
- ☐ The dimensions of the inlet restrictor;
- ☐ The general form of the bearing members.

Variations in any of these four factors will affect the performance of the bearing. For example, variations in bearing clearance, position of the inlets and dimensions of the inlet restrictor will cause a modification to the entry pressure into the bearing clearance, which will affect load capacity flow rate and stiffness. Also, when form errors are encountered, the inlet pressures remain unchanged but the pressure profile within the bearing is modified, affecting load capacity and stiffness but yielding a more marginal variation on fluid flow through the clearances.

It is possible to calculate the effects of variations in any of these by modifying the appropriate terms in the Reynolds equations contained within the computer programs for bearing analysis.

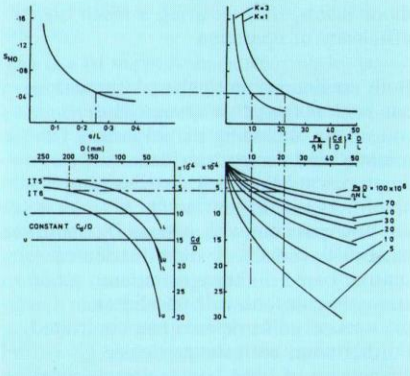

Figure 1: Design chart relating clearance limits and pressures.

From the modified analysis, it was possible to calculate the effects of the variations of load capacity and stiffness from the design condition. As a consequence of this work, limiting tolerances for the various critical features were established to provide guidance for manufacturers.

Figures 1 and 2 show what has been achieved. Figure 1 is a design chart for hydrostatic bearings which enables all critical dimensions of a hybrid hydrostatic bearing to be established at the same time keeping the total power consumed in the system to a minimum. Figure 2 presents theory and experiment for an externally pressurised gas bearing, showing the experimental values falling within the load/eccentricity tolerance envelope calculated for the bearing.

To summarise, it has been possible to define tolerances for hydrostatic/ aerostatic and hybrid bearings. The analysis and subsequent design procedures developed have been used to design a number of machine bearing systems including machines for the Admiralty Compass, Cranfield Unit of Precision Engineering, Astron Ltd, the National Engineering Laboratory and the National Physical Laboratory.

These procedures are currently being used to design bearing systems in the US.

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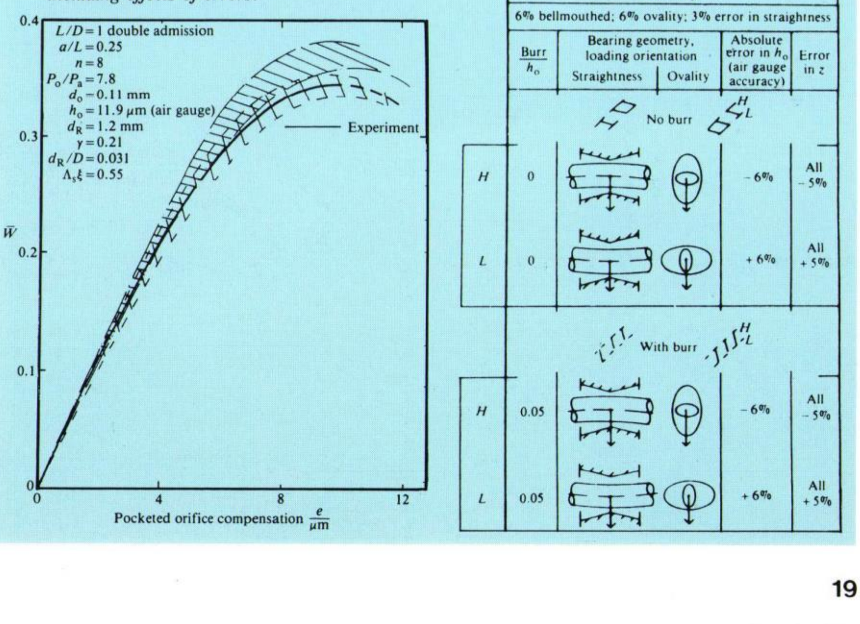
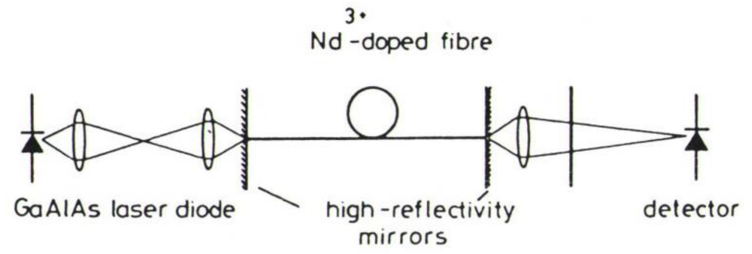
Figure 2: Comparison between experimental and theoretical load capacity including effects of errors.



Rare-earth doped fibre lasers



Experimental arrangement for diode-pumped fibre Fabry-Perot cavity laser.

For many years, the Optical Fibre Group at Southampton University has maintained an innovative lead in the fiercely competitive field of fibre optic technology. In the past, the Group has forged strong links with industry which have been reinforced in recent times through the Joint Opto-Electronic Research Scheme (JOERS) supported by SERC and the Department of Trade and Industry. The Group is currently actively involved in five JOERS-funded programmes, collaborating with the industrial partners on a wide variety of research topics ranging from the study of fundamental properties of fibres to active fibre devices.

One of the major success stories of this programme has been the developement of rare-earth doped single-mode optical fibres. Normally such materials cause large optical losses but it has been found that the new fibres possess transparent windows where the transmission is just as good as in conventional telecommunications fibres. This remarkable fact has allowed for the invention of a totally new class of lasers, amplifiers and active fibre devices.

Conventional lasers must be optically straight, rigid and have accurately-configured mirrors of special design, solidly aligned to each end. They are easily affected by dust, vibration and other environmental conditions, may require large expensive power supplies and have a limited operating life.

In contrast, single-mode fibre lasers are made with the rare-earth ions in the core of the fibre, thus overcoming most of these problems. They are flexible (for example, they can be wound around the operators finger without affecting their operation), they do not require separate mirrors, contamination has no effect because they are totally enclosed in solid glass and of course, being almost as thin as a human hair, they can be coiled into a very small space. They can be pumped longitudinally by cheap, conventional semiconductor diode lasers, thus ensuring a much higher efficiency of operation.

Both continuous and pulsed laser action has been obtained on several laser transitions, including the important 1.5 micron band for optical fibre communications. Long distributed optical amplifiers to compensate for fibre losses are now possible with potentially enormous bandwidth. Small, flexible distributed sensors based on changes in laser action and gain-compensated, non-linear picosecond pulse devices can be created. Furthermore, with the particular advantages of fibre lasers, namely axial pumping, high light intensity in the core and long lengths, it is now possible to obtain laser action with new materials.

These fibre lasers are fully compatible with other single-mode fibre devices such as polarisers, couplers and optical filters. It is anticipated that the fibre lasers will have many important applications and could revolutionise the design of many types of laser. They will have many uses in addition to those mentioned. Already many new results have been achieved and a whole new sector of laser technology has been generated.

Considerable interest has been shown in fibre lasers and amplifiers by the industrial JOERS collaborators (Plessey, GEC, STC and British Telecom) as well as by a large number of companies both at home and abroad. Negotiations are currently underway for further research contracts and technology transfer to industry.

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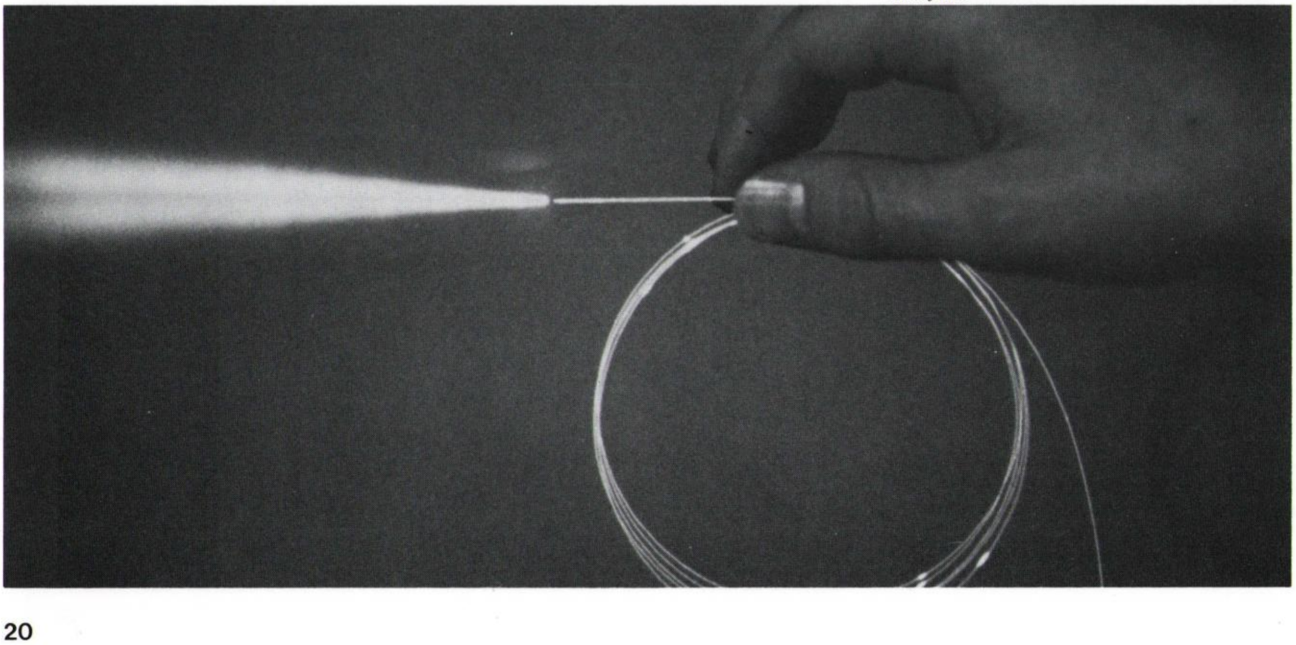
Visible fluorescence from a Tb^{3+}-doped single-mode fibre.



Coatings technology research at Cranfield

The Coating Technology Unit at Cranfield was established in 1981 with funding from SERC to develop a new multisource ion plating system capable of depositing graded coatings for high temperature service. Use of a multi-source system enables alloying to take place in the vapour phase and, with correct control, allows variable compositions to be programmed into the growing coating.

A design specification for such a system was produced by the Cranfield team and Electrotech, a UK vacuum equipment manufacturer, produced the system, based on extensive modification to one of their existing evaporators. SERC provided the funds for manufacture of the coater and Electrotech provided a specialised computer control system. This advanced evaporator system (figure 1) was installed late in 1983 and has the following unique combination of capabilities:

- ☐ Radiofrequency (RF) sputter cleaning of components to be coated;
- ☐ Substrate heating, rotation and the capability of applying bias to ensure uniform coverage and optimisation of coating structures;
- ☐ Co-evaporation from up to three electron beam sources to permit the deposition of alloys from the vapour phase using simple single component or binary source materials;
- ☐ RF ion plating of evaporant to ensure good adhesion;
- ☐ Reactive deposition from up to four gases, should it prove necessary to incorporate oxide species in the coatings or for the deposition of thermal barrier coatings.

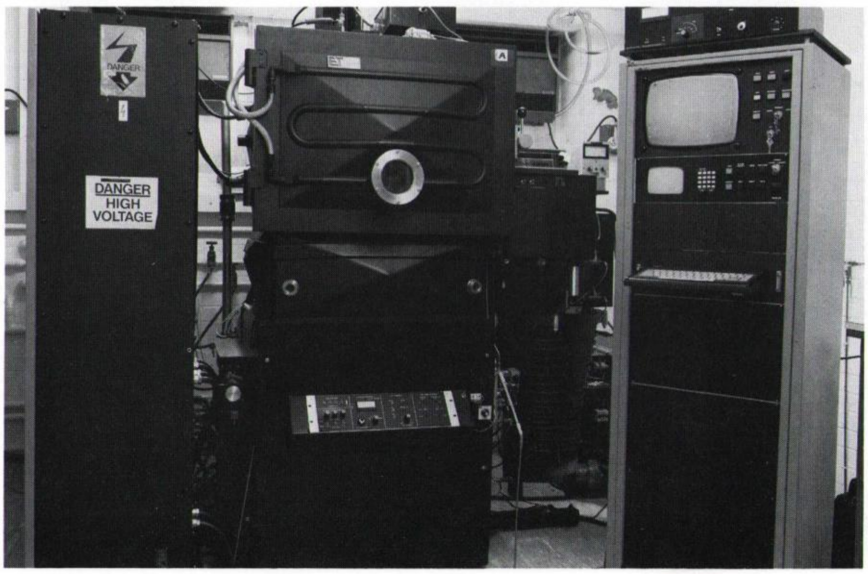
Computer control of the main items - the three electron beam sources, RF power supply, substrate heating, specimen rotation and gas inlet pressure - permits the design of reproducible, complex multilayered or variable composition coating and automatic deposition of these coatings. Figure 2 shows evaporation from the multihearth in the presence of an RF glow discharge; this procedure is used to develop surface coatings.

Since commissioning, further funding from SERC and from the EEC has permitted the development of new high temperature corrosion-resistant coating compositions. Coating adhesion and diffusion stability are being studied to produce stable graded coatings.

The use of vapour-phase alloying by co-evaporation from all three sources is currently being used as the prime route to deposit graded high temperature, corrosion-resistant coatings. In this phase of the programme, close collaboration with Rolls-Royce Ltd and RAE Pyestock ensures that the research is of direct relevance to industry. Rolls-Royce also provides the casting capability for the source materials used in this programme and will be closely involved in future burner rig assessments of the most promising coatings.

The initial SERC support allowed the coatings group at Cranfield to start up and the expertise developed has attracted further EEC funding to provide clean-room facilities, support services and advanced analytical equipment including a quadrapole mass spectrometer and thin-film analysis software for use on the department's scanning electron microscope.

Figure 1: Electrotech's computer-controlled evaporator source at Cranfield.



From this beginning, the capability of the coatings unit has expanded with the addition of a second electron beam evaporator system, two resistive heated evaporators and a magnetron sputtering system. Research activities are currently under way in the following areas:

- ☐ The development of high temperature corrosion resistant coatings by multisource evaporation
- ☐ The deposition of Si_3N_4 TiN and Al_2O_3 wear-resistant coatings;
- ☐ Metallising plastics;
- ☐ The development of a crack growth sensor by thin film deposition;
- ☐ The development of solid state ion selective electrodes;
- ☐ The deposition of indium-tin-oxide optical coatings;
- ☐ The deposition of polymer films by RF sputtering;
- ☐ The development of a metallic film solar-thermal collector;
- ☐ The use of multi-source sputter deposition to produce new fine grained ceramics as coatings.

In addition to these research activities, the unit currently runs industrial short courses on coating technology aimed at updating the industry on a wide range of coating processes.

The SERC grant, given in 1981, was directly responsible for this development which has benefited both British industry and the many students who have worked on the above programmes.

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Figure 2: Evaporation from the multihearth in the presence of radiofrequency glow discharge.

Developments in in gamma-ray detection

Nuclear structure experiments using gamma-ray detection techniques have led to significant developments in detector technology. These advances include the use of the dense scintillator bismuth germanate (BGO) in large crystals and of large-volume, n-type hyperpure germanium detectors. These developments have led to many industrial applications.

When gamma-radiation interacts with a scintillator, the crystal has to be large enough to absorb most of its energy. Until recently, sodium iodide (NaI) was the most commonly used scintillator, but large crystals (say 100 mm diameter and 150 mm long) were needed and detectors did not like extreme environments. Nuclear structure research experiments demanded a new, denser scintillator which could absorb the gamma-radiation in much smaller crystals. The answer was BGO which, before recent developments, was only available in small pieces (typically 25 mm). The table contrasts the properties of BGO and NaI, the density difference implying that 75 mm-diameter crystals would be large enough for most nuclear structure experiments. The technolgical difficulties were overcome and BGO crystal are now available in large pieces.

The nuclear structure experiments based at Daresbury Laboratory carried out by groups from Liverpool and Manchester Universities were among the first uses of such BGO detectors. This new technology has since been applied in other fields. BGO detectors are particularly useful in neutron activation analysis involving high energy gamma-rays as, unlike NaI, they are relatively insensitive to neutrons. Very small BGO crystals can be used to absorb 511 keV annihilation radiation and thus give better position resolution in positron tomography. BGO detectors are more robust than NaI detectors and can be used in extreme environments, such as checking underwater pipelines.

Scintillation detectors are efficient but have low resolution, typically 10 to 20%. Both nuclear structure experiments and environmentalists require high-resolution, large-volume detectors for cases where gamma-ray identification is required. Semiconductor germanium detectors are used for such purposes. The best quality gamma spectra in nuclear structure experiments are obtained using n-type hyperpure germanium crystals. These are relatively insensitive to the neutrons produced in nuclear reactions and have very thin ion-implanted external contacts (see figure 1).

The small dead layers lead to an improved detector response which is vital in the experiments - a feature that also has an application in the environmental field. The thin external dead layer extends the useful detection range (typically 5 keV-2 MeV) to lower gamma-ray energy, which allows a greater range of radioisotopes to be detected in one measurement; this is particularly significant as the gamma-decay of ^{239}Pu (plutonium) includes a 13 keV gamma-ray. This method of detecting plutonium (as well as any other gamma-emitting species) has many potential applications.

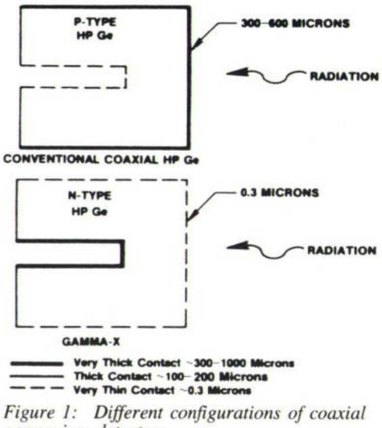

Figure 1: Different configurations of coaxial germanium detectors.

Comparison of BGO and NaI properties

	BGO	NaI
Density (g cm^{-1})	7.13	3.67
Hardness (mho)	5	2
Chemical stability	good	poor
Solubility in water	none	very hygroscopic
Refractive index	2.13	1.85
Wavelength of maximum emission (nm)	480	420
Relative neutron cross section	0.25	1

The work on improving detectors for gamma-ray spectroscopy experiments involves both elements described here and has produced high quality, escape-suppressed gamma-ray spectrometers. The work at Daresbury Laboratory and Liverpool University in this area leads the world. Advances in detector technology are only possible by close cooperation with the relevant manufacturers: John Caunt Scientific Ltd are the UK agents for Harshaw/Filitrol who developed the BGO detectors in use at Daresbury, and E G and G Instruments Ltd supplied the n-type germanium detectors which were manufactured by E G and G Ortec.

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Telephone 051-709 6022

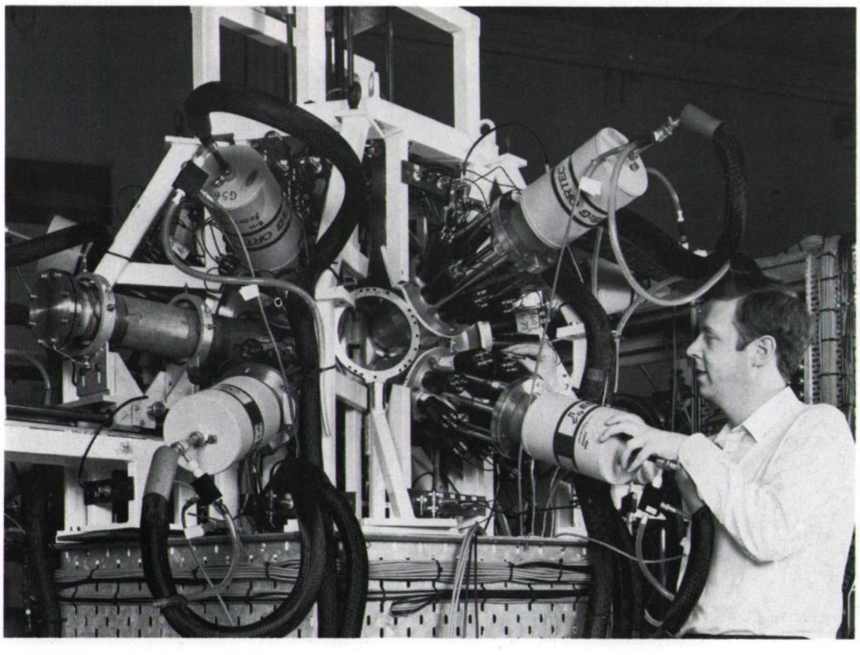


Figure 2: Dr Paul Nolan working on the Total Energy Suppression Shield Array at Daresbury Laboratory. The apparatus is used for experiments that require detection of all the gamma-radiation produced following a collision of a heavy ion with a target nucleus. Exciting results have been obtained on the manner in which the properties of nuclei are disrupted by the rapid rotation produced by the collision.

SERC and industry

SERC's role is to encourage and support research and advanced training in UK universities and polytechnics in all the basic areas of science and engineering. The fields of interest include astronomy, space science, geophysics, nuclear physics, the biological sciences, chemistry, mathematics, physics, engineering and applied science. A major priority is to encourage collaboration between academic institutions and industry in areas of national importance.

SERC's policy in recent years has been to place increasing emphasis on engineering and 'small' science (eg physics and chemistry); and in a tight economic climate this has meant reducing expenditure on the 'big' sciences of nuclear physics, astronomy, space and radio. As a result, SERC's funding of 'big' science has dropped from 60% to below 40% over the past ten years.

Selected research areas

Since 1975 SERC has developed a policy of identifying and supporting coordinated programmes of research in specific subject areas with the aim of providing industry with the knowledge required to sustain innovation and introduce advanced technology. Six 'directed' programmes have been launched so far in the following areas:

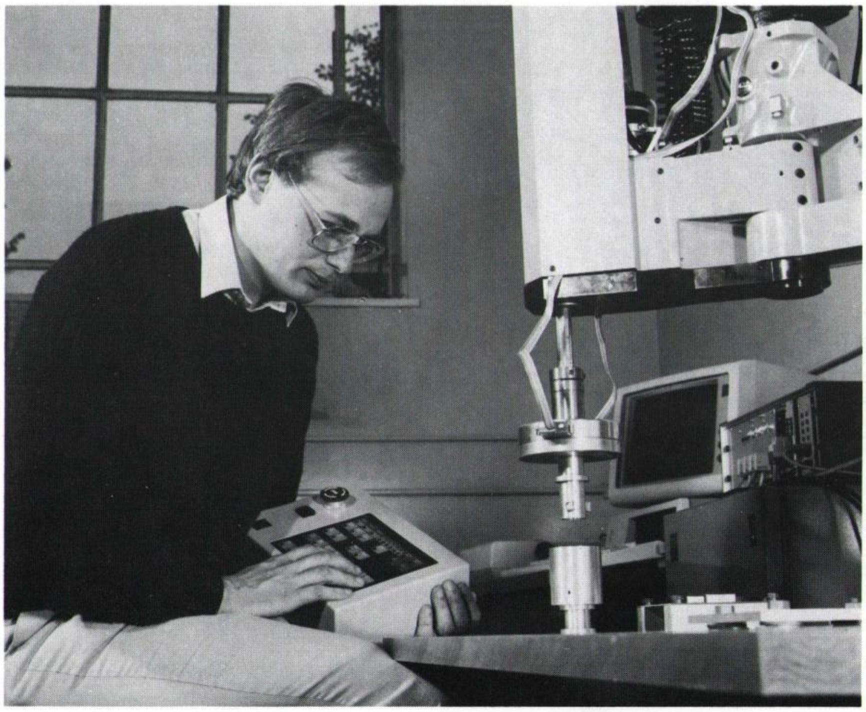
Application of Computers to Manufacturing Engineering
Biotechnology
Information Technology
Marine Technology
Polymer Engineering
Teaching Company Scheme

Directorates have a limited lifetime and, after a period of pump-priming wholly from public funds, they move into a more industrial environment where a proportion of the costs are provided by industry. The Polymer Engineering and Marine Technology Directorates have both moved into this second phase.

On a smaller scale, there are specially promoted programmes and special initiatives which operate in a similar manner. Current programmes include:

Civil Engineering
Construction Management
Design of High Speed Machinery
Electroactive Polymers
Medical Engineering
Particulate Technology
Chemical Sensors
Low Dimensional Structures
Protein Engineering

SERC wishes to encourage the close collaboration of industry in all these programmes to ensure that research relevant to industry is undertaken and to create the opportunity for exploitation of the results.



Testing an accurate positioning device for use with automatic assembly techniques, at the University of Wales Institute of Science and Technology.

So what about industry?

SERC is keen to encourage collaboration between academic institutions and industry in both research and postgraduate education. In addition to jointly-funded arrangements with certain public bodies and large companies on specific research programmes, SERC has established five generally applicable schemes whose common objective is the promotion of communication and collaboration between industry and the academic community. These are:

Teaching Company Scheme (a joint scheme with the Department of Trade and Industry)
Cooperative Research Grants Scheme
Industrial Fellowships Scheme (a joint scheme with the Royal Society)
Cooperative Awards in Science and Engineering (CASE) Scheme
Industrial Studentships Scheme

Common features of the five schemes:

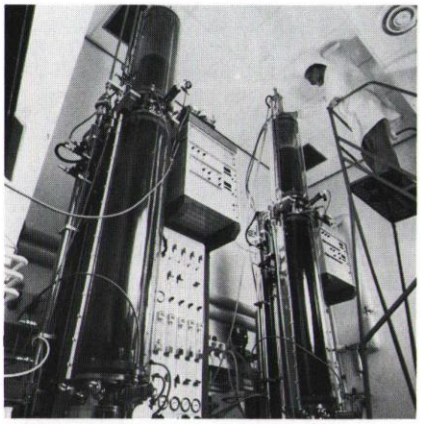
All of the schemes:

- ☐ offer a company partnership with an academic department which possesses expertise in an area relevant to the company's technological needs;
- ☐ provide funding for work on a problem of commercial interest to the company;
- ☐ seek benefit also for the academic department and for the individuals (such as the teaching company associates or the industrial fellows) involved;
- ☐ require some contribution from the company;
- ☐ recognise the company's natural concern for any resulting industrial property rights;
- ☐ provide for some kind of personnel transfer which, while normally full-time, could be on a part-time basis.

Teaching Company Scheme

The Teaching Company Scheme, mainly funded by SERC and DTI operates through teaching company programmes. In these programmes, a university or polytechnic team takes part in a company plan intended to achieve a substantial and comprehensive change in the company's techniques and procedures. From the company's point of view, the aims of the scheme are twofold:

- ☐ to raise the industrial performance by the use of academic expertise and the introduction of advanced technology;
- ☐ to develop and retrain existing company staff and to encourage able graduates to train for careers in industry.

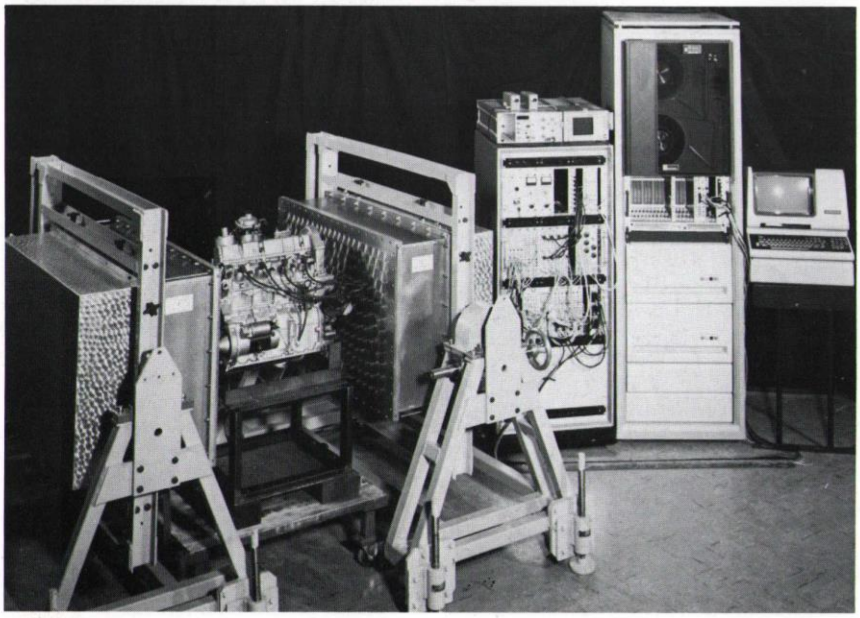


Bulk production of monoclonal antibodies at Celltech, a major UK biotechnology company collaborating actively with a number of universities and with SERC's Biotechnology Directorate.

The permanent academic staff contributing to each programme are assisted by high calibre graduates, recruited in consultation with the company for two-year academic appointments as Teaching Company Associates. The Associates, normally based full-time in the company, work in collaboration with company and academic staff on tasks within the programme. In addition, the university/polytechnic arranges induction, tuition and so on according to personal and programme needs. Associate appointments may lead to higher degrees but more importantly they invariably lead to posts in industry often with substantial responsibility and reward, either at the participating company or elsewhere.

SERC makes a grant towards the basic salaries of the Associates and academic support costs, normally complemented by an average contribution of one-third from the company. There are currently some 200 teaching company programmes in operation. These are mainly concerned with batch manufacture in the mechanical and electrical engineering industries, but the scheme is being widened to include other industries and functions other than manufacturing.

High-resolution positron camera developed by a collaboration between Birmingham University, Rolls-Royce Ltd, Burmah Castrol and Rutherford Appleton Laboratory.



Cooperative Research Grants

This scheme supports academic research work in partnership with industry. It aims to encourage research which both advances understanding and leads to results that can be exploited by the industrial partner.

An academic institution and a company together put forward a proposal for a collaborative research project that meets these objectives. SERC then considers funding the academic side of the programme, seeking a matching commitment from the industrial partner. As a minimum, the company's direct support must be one-third as much as the resources that SERC puts into the programme.

Any intellectual property rights, for example patentable results arising from the work, are vested in the company (subject to certain conditions, including the company's agreement to pay royalties).

About 100 cooperative grants, costing SERC on average about £55,000 each, are made each year.

Industrial Fellowships

Introduced in 1980, the objective of the Royal Society/SERC Industrial Fellowships scheme is to improve communication between industry and the academic community. Fellowships are provided to allow scientists, engineers and mathematicians who are in permanent academic or industrial employment, to move from a university or polytechnic into industry (or vice versa) for a period of between six months and two years. Awards can also be held on a part-time basis.

During that time, Fellows work on a project which is seen as important by both sides. Typically this may be some significant part of the industrial partner's engineering or scientific programme, although design-oriented projects are also encouraged.

In recognition of the industrial partner's concern about any industrial property rights that may arise from the fellowship project, SERC and the Royal Society are prepared to waive their own rights, subject to agreement being reached between the industrial partner and the Fellow. On average, seven or eight fellowships have been awarded each year since the inception of the scheme, with about 60% of the Fellows coming from the academic sector.

Cooperative Awards in Science and Engineering (CASE)

The CASE scheme is a variation of the standard SERC research studentship. The CASE project undertaken by the postgraduate student is devised and supervised jointly by representatives of the academic and industrial partners and lets a graduate work on a project of commercial significance to the company. This project may be in any area of research, design, manufacture, and so on. SERC is again prepared to waive its claims to any industrial property rights that may stem from the project, provided that satisfactory terms can be agreed between all parties.

The project can last between one and three years, and the scheme requires that the student spend part of the time working at the industrial partner's establishment. For a three-year studentship this period must be at least three months. The company benefits from a studentship not only by obtaining an economic way of solving a problem of commercial significance, but also by having the opportunity to assess and build a relationship with a potentially valuable recruit. In return the company must:

- ☐ pay the student's travelling and out-of-pocket expenses while he is working at the company's establishment;
- ☐ make a contribution to the academic partner's costs. For 1986-87 this must be at least £540.

The company is also encouraged to supplement the normal grant which SERC pays to the student.

About 900 CASE studentship are offered each year.

Industrial Studentships

To keep up-to-date with advances in scientific knowledge and technological developments, companies often find it necessary to supplement the training of their graduate employees. An industrial studentship is an arrangement where a SERC studentship is supplemented by a British employer.

A typical computer-aided design workstation (graphics terminal, data tablet and colour plotter), crucial to the exploitation of Very Large-Scale Integration circuits.

It is intended to help eligible candidates in employment to obtain postgraduate training without undue financial hardship. To qualify for the conversion of a standard studentship to an industrial studentship, a candidate must have completed at least one year's approved postgraduate employment immediately before taking up the award. Under the scheme the student remains in employment receiving normal salary, and making the normal national insurance and superannuation contributions. SERC pays a flat rate contribution to the employer and approved fees to the academic institution.

About 50 industrial studentships are awarded each year.

The benefits to the employer are:

- ☐ the scheme provides an economic way to arrange for selected employees to have further training at postgraduate level;
- ☐ SERC is prepared to waive its claim to any industrial property rights stemming from the studentship.

Where do you go from here?

With any of the five schemes a company must, at an early stage, find an academic partner. Your company may already have the necessary contacts with the universities and polytechnics but, if not, SERC may be able to help.

In any case, the first step is to obtain further details of the scheme in which you are interested. These are available from the following people:

Teaching Company Scheme	Martin Rees (ext 2335)
Cooperative Research Grants Scheme	John Davis (ext 2445)
Industrial Fellowships Scheme	Alan Harrison (ext 2206)
CASE Scheme	Michael Parker (ext 2465)
Industrial Studentships Scheme	David Harman (ext 2144)

They are all located at SERC's Central Office
Polaris House
North Star Avenue
SWINDON SN2 1ET
Telephone: Swindon (0793) 26222

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.

Establishments of the Science and Engineering Research Council

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Daresbury, Warrington
Cheshire WA4 4AD
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Royal Greenwich Observatory
Herstmonceux Castle
Hailsham, East Sussex BN27 1RP
Director Professor A Boksenberg FRS
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Royal Observatory, Edinburgh
Blackford Hill, Edinburgh EH9 3HJ
Astronomer Royal for Scotland and
Director Professor M S Longair
Telephone 031-667 3321

SERC's ***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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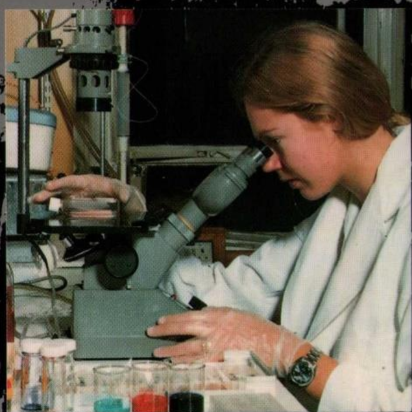
Back cover pictures (from the top)

SERC-supported students on North Staffordshire Polytechnic's MSc course in computing science.

ROVER, an untethered submersible developed at the Heriot-Watt Centre for Marine Technology to solve problems of communications and control at depth.

A research student in the Zoology Department at University College London engaged in immunological studies.

Background picture: A process module at the Mossmorran natural gas plant. (Photo: Shell UK Ltd. See page 5)



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