Fulmer

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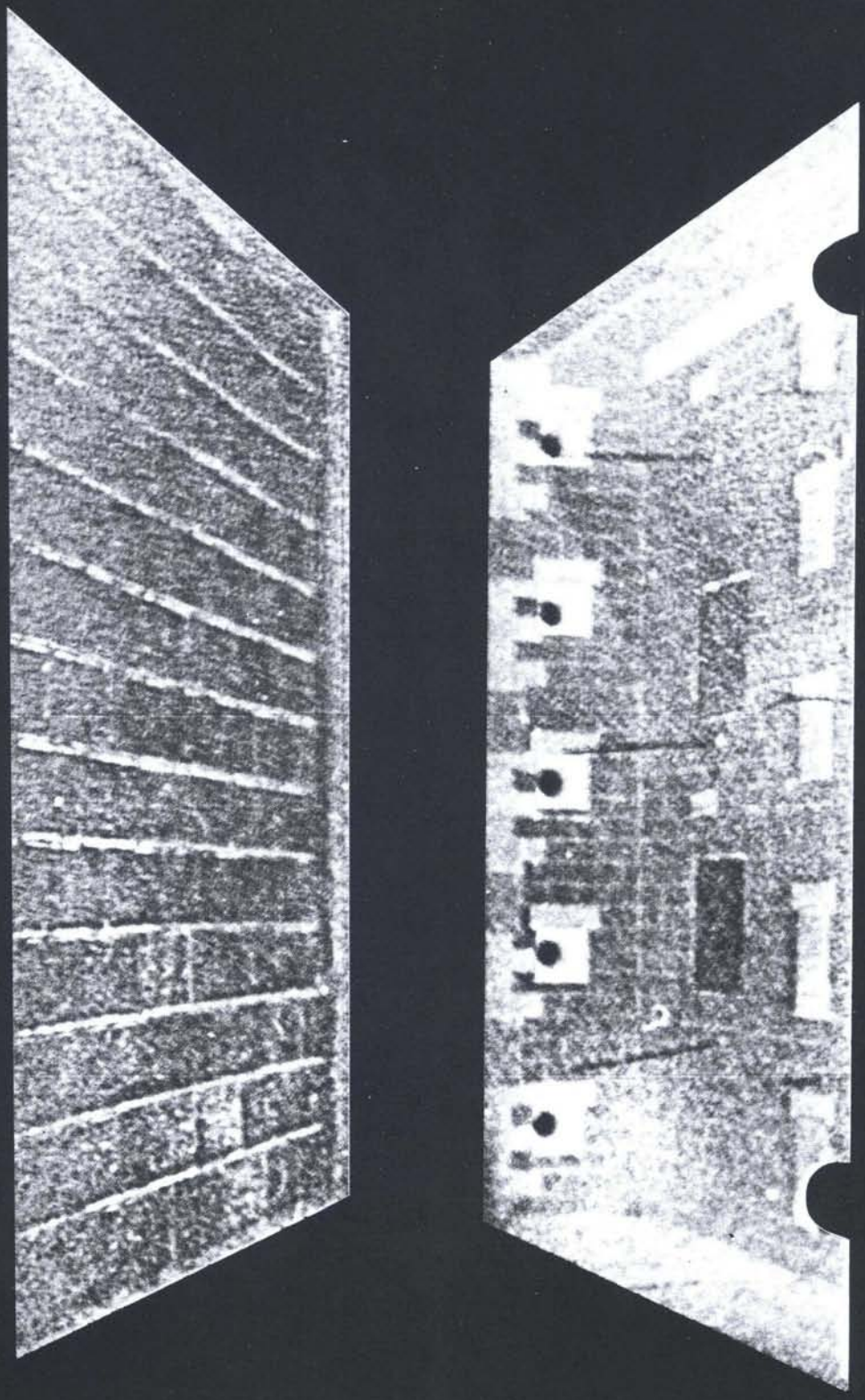
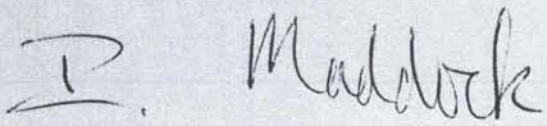


review 1980

Chairman's Foreword

Despite the severe economic recession which developed during 1980, I am pleased to be able to report that Fulmer has had another successful year. Total income continues to increase and the £3M earned in 1980 represents a 13% increase over the previous year. In common with most British companies profit declined, to £98,000. Research contracts earned £1.4M; testing, consultancy and information services £1.3M; and manufacturing £0.3M. £467,000 was earned overseas, mainly from the USA, Australia, Japan, India, Pakistan and the EEC countries.

We look forward confidently to the challenges which will be placed on us during 1981, not only by the external economic difficulties, but also by our clients in their search for even more efficient processes, or improved performance from their products. Our strength lies in the skill, expertise and ingenuity of our staff, to whom we are once again grateful for their unstinting efforts.



SIR IEUAN MADDOCK, C.B., O.B.E., F.Eng., F.R.S.

Contents

In this review we show how Fulmer's expertise is based on 35 years' experience of undertaking product-oriented research and development, and provide examples of the successful application of this expertise.

Chinese Contract

One of the highlights of the year occurred on Saturday, 11th October, when two years of discussions with various Chinese organisations culminated in the signing in Peking of the first Chinese contract to be awarded to Fulmer.

The contract provides for two engineers from the Shanghai Research Institute for Materials to spend one year at Fulmer Research Laboratories working on advanced powder metallurgical techniques. It is hoped that this contract will be the precursor of many similar arrangements whereby the Shanghai Research Institute and Fulmer can co-operate on advanced technology to the mutual benefit of both countries.

During the year considerable effort was made to develop other export business and senior Fulmer staff made frequent overseas visits.

South Africa

Fulmer has had long associations with South African companies and these were consolidated during an extended tour undertaken by Dr. W. E. Duckworth. The South African economy is now the fastest growing of all developed countries. Over the next few years South African industry will be moving up-market by producing more finished components from its indigenous raw materials. This generates a need for technological development because production plants in South Africa operate under environments different from those in their usual country of origin.

The Far East

Yarsley Research Laboratories have continued to develop their information services for Japanese companies and a regular clientele now subscribes to the Current Awareness Service.

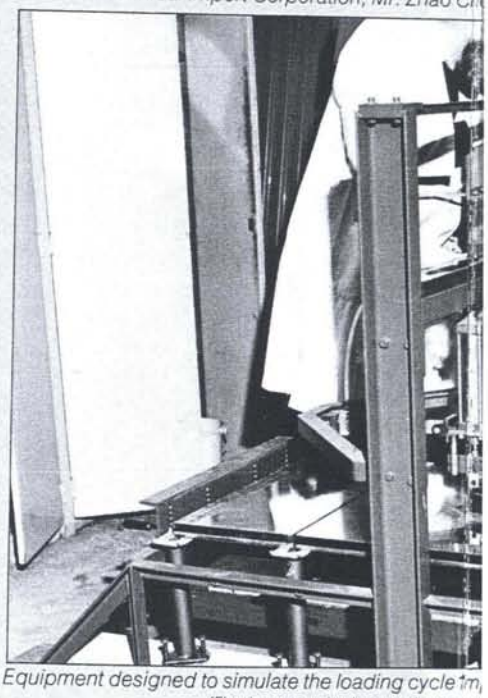
The demand for the technological training and work experience programmes offered by the Yarsley Technical Centre is increasing, particularly from countries in the Far East. Programmes involving mould and die design, polymer processing and polymer product testing are currently available from YTEC.

New Facilities Installed

A new Hot Isostatic Press capable of pressures up to 30,000 psi and temperatures of 2,200°C has been installed at Fulmer Research Laboratories. The press will be used for powder metallurgical developments on superalloys and hard metals, diffusion bonding components and pore closure in castings. Fulmer also recently commissioned a new 150 tonne diecasting machine for studies involving metallic slurries. Unique facilities are also being developed for non-destructive testing involving ultrasonic flaw detection.

Yarsley Research Laboratories have extended their facilities by the installation of a coating/laminating machine. This very versatile machine has a maximum operating width of 12" and will be used for a wide range of coating and laminating requirements, including the application of hot-melt compositions. Electrostatic spray equipment for powder coating has also been installed.

Fulmer's Managing Director, Dr. W. E. Duckwort
Technical Import Corporation, Mr. Zhao Ch



Equipment designed to simulate the loading cycle in
(Flooring system in photograph was su

Group Trading Report

	Tu
	1979
Fulmer Research Laboratories Ltd. (including Fulmer Technical Services)	1,393,000
Yarsley Research Laboratories Ltd.	290,000
Yarsley Technical Centre Ltd.	750,000
Fulmer Components Ltd.	178,000
Reform Manufacturing Co. Ltd.	28,000
Group Total	2,639,000

Cover Photograph: Fire Resistance Furnace for tests to BS 476, Part 8, installed at Yarsley Technical Centre, Redhill.

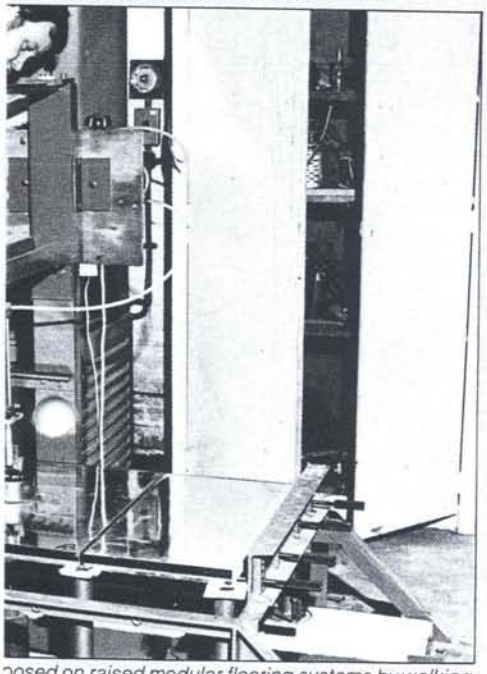
ghlights

', and the General Manager of the China National ng-Yen, exchange copies of the contract.

Fulmer Materials Optimizer

Following the success of the first edition of the Optimizer (over 400 copies were sold to companies and organisations throughout the world), the information contained in the system was completely revised and up-dated prior to the launching of the second edition in May 1980. The Optimizer corresponds to the distillation of the equivalent of over 50 man years' experience in the use of engineering materials by Fulmer's staff and associated consultants.

The system contains readily assimilated information on the performance, current costs and related component manufacturing processes of metals, plastics and ceramics; plus an unbiased method of selecting the optimum material for a given application. In the current industrial economic climate of rising materials and manufacturing costs, the Optimizer is an invaluable aid to company profitability.



posed on raised modular flooring systems by walking. plied by J. A. Hewetson and Co. Ltd.)

New Contracts

The many important contracts won by Fulmer during the year included a major project from the Commission of the European Communities to contribute to the energy research and development programme. The objective of the work is to evaluate the potential of hydrogen produced from excess nuclear electricity generating capacity or nuclear power plant heat.

Another contract, won against strong competition from several major European concerns, was placed by the European Space Agency for a study of spacecraft materials. The purpose of the contract is to survey the properties of advanced materials that are of interest for the fabrication of spacecraft structures, and to compile a series of design guides on specific materials and/or processing methods.

Yarsley Research Laboratories started a major contract, initially sponsored by the Department of Industry and the Ministry of Defence aimed at developing new anti-corrosive coatings which can be applied to steel under wet conditions (or even under water). The two main areas of application envisaged are for marine finishes and maintenance coatings.

During the year Yarsley Technical Centre completed a large testing programme for the Property Services Agency, which was concerned with developing performance and purchase specifications for raised modular flooring systems such as are used in computer rooms. A major Turnkey project was also undertaken to install a hot runner injection moulding and component handling system for a moulding company in Sweden. Yarsley Technical Centre also licensed Lucas Logic Ltd., a subsidiary of Lucas Industries, to market the YTEC system for hot runner injection moulding.

Among the major manufacturing orders awarded to Fulmer Components Ltd. was a contract to build a number of solar water and space heating controllers developed by Fulmer Research Laboratories for the Calor Group.

rnover, £	Profit (Loss), £	
1980	1979	1980
1,568,000	100,000	36,000
304,000	16,000	(4,000)
919,000	84,000	46,000
210,000	10,000	21,000
23,000	8,000	(1,000)
3,024,000	218,000	98,000

Facts on Fulmer

Fulmer is a contract research and engineering company concerned with the science and technology of materials. We provide research, development, design, consulting, testing and production engineering services to industry, commerce and government. Our aim is to assist clients to manufacture products and operate processes more profitably through the application of our deep understanding of the behaviour of materials, both as they are fabricated and in service.

Our activities involve all engineering materials, including metals, plastics, polymers, ceramics, fibres, composites, refractories, glasses and adhesives. The development of new and improved products and components is undertaken, often leading to Turnkey projects for the establishment of manufacturing operations. Other projects range from the development of new materials and new ways of processing materials to the evaluation of properties of materials under real or simulated service conditions, using existing, or specially developed, testing techniques.

Consultancy and technical service assignments include routine testing and analytical services, materials selection, failure diagnosis, technical advice relating to patent and other forms of litigation, technical/economic studies and market surveys.

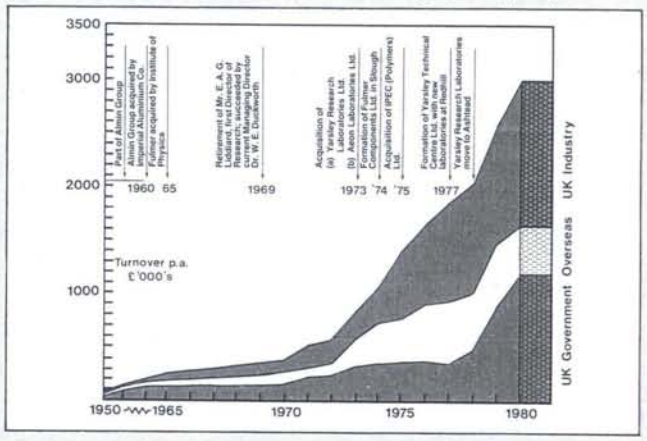
Fulmer is thus able to assist with a project from its initial conception through research and development to full-scale manufacture. All work is carried out under strict conditions of commercial security.

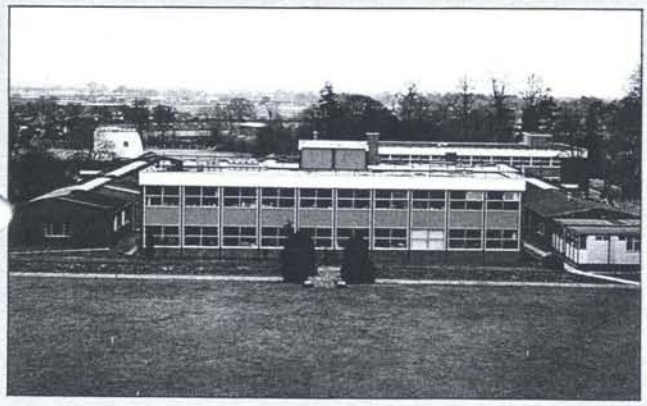
Equipment for testing materials is also developed and manufactured, and assistance provided for the setting up of quality control or R & D laboratories.

Fulmer was founded in 1946 and since 1965 has been owned by the Institute of Physics. The company and its subsidiaries employ about 240 people, including over 100 professionally qualified scientists, technologists and engineers. Fulmer is fully self-supporting financially and the operating surplus is used to finance further development. Ownership by the Institute of Physics guarantees that Fulmer is completely independent of any commercial or industrial affiliation.

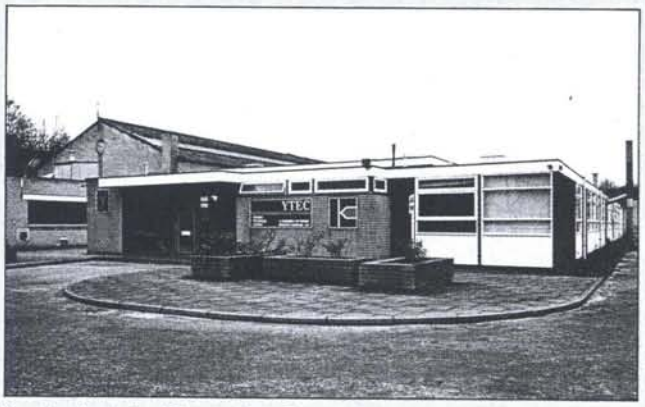
As shown in the graph, Fulmer has achieved a virtually unbroken record of growth, with the current income of £3M being obtained from three main sources of sponsorship — UK Government Agencies; British industry and commerce; companies and organisations based outside the UK.

The company operates on four sites, whose particular expertise is summarised on the back of this review.

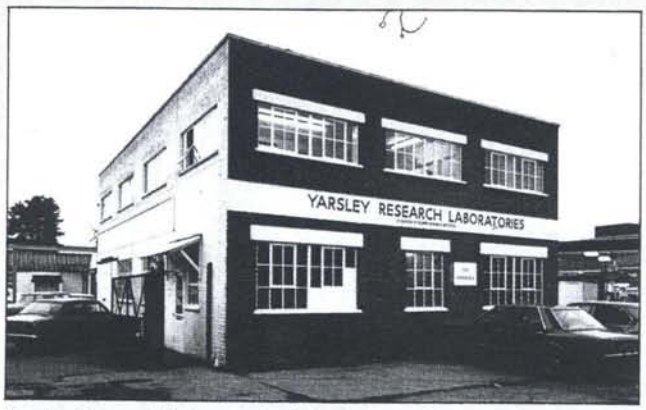




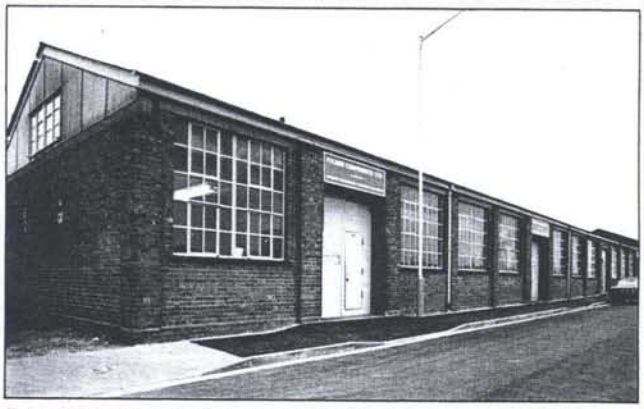
Fulmer Research Laboratories Ltd., Stoke Poges, Buckinghamshire.



Yarsley Technical Centre Ltd., Redhill, Surrey.



Yarsley Research Laboratories Ltd., Ashtead, Surrey.



Fulmer Components Ltd., Slough, Berkshire.

Materials and Process Development

Composites Technology

Fulmer and its Yarsley subsidiaries have been involved for many years in the development of composite materials and structures, the evaluation and development of fabrication techniques and fitness-for-purpose testing. The expertise available includes:

- Resin Chemistry
- Materials Development
- Process Development
- Product Design and Development
- Non-destructive Testing
- Performance Evaluation
- Failure Analysis
- Quality Assurance and Control

Military Applications

Much of the R & D work on composite materials at Fulmer has been sponsored by the Ministry of Defence, to support the introduction of these materials into defence hardware. For example, Fulmer have been involved in the programme to build a class of mine counter measures vessels with glass fibre reinforced plastic (GRP) hulls. The activities included determination of the basic toughness parameters of the woven roving GRP selected as the main hull construction material, study of different hull constructions yielding improved performance, investigations into the bond strength of secondary structures laminated on to the hull, and fire testing of selected laminate and stiffener configurations. This work is continuing and current studies are investigating improved lamination and attachment methods for the stiffener frames inside the hull, which in the current construction method are reinforced with through-bolts.

HMS Brecon.
(Photograph by courtesy of Vosper Thorneycroft (UK) Ltd.)

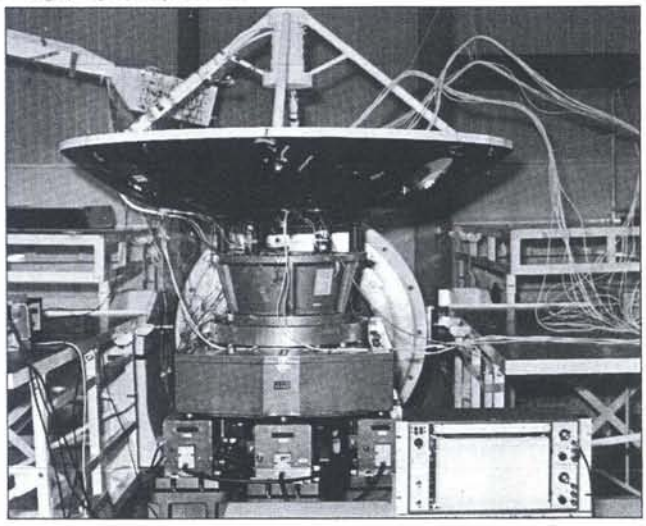
This work on GRP has now expanded to cover work on composites reinforced with carbon and Kevlar fibres and glass/carbon fibre hybrid mixtures. Kevlar fibre composites have been investigated on behalf of the Ministry of Defence for ballistic protection applications. The fundamental interactions between fibres, and between fibres and matrices are being studied in an effort to improve the design of current products whose construction has evolved by largely empirical methods. Other studies have included the development of improved efficiency filament wound CFRP pressure vessels and an assessment of the applicability of fibre reinforced composites to the rapid repair of pressure pipes.

Glass/carbon fibre hybrid materials have been developed for applications such as emergency repair systems for damaged aircraft. The use of a selected hybrid makes possible the matching of both absolute and specific stiffness of the composite and the parent metal, so that a true load-bearing repair can be made with no weight penalty. It was found that a properly prepared composite repair performs as well as, and in some cases better than, the equivalent riveted repair.

Spacecraft

CFRP is in common use in spacecraft for the construction of stiff, dimensionally stable, lightweight structures such as antennae. Honeycomb cored sandwich structures using very thin CFRP skins are a frequently used construction method, and work at Fulmer has investigated the effects of manufacturing defects on the properties of these sandwiches, and non-destructive methods for their detection. Methods for monitoring the spread of damage during pre-flight qualification testing have also been developed. This work has been sponsored by the European Space Agency.

CFRP-skinned antenna dish monitored by Fulmer during vibration testing at the European Space Technology Centre.
(Photograph by courtesy of ESTEC.)



Building Applications

The virtues of GRP are now being recognised by the building industry, for example in the manufacture of roofing and cladding panels. Extensive performance testing has been carried out by the Yarsley Technical Centre on panels for a number of different buildings, including the new Covent Garden Flower Market and Mondial House, the location of the new International Telephone Exchange in London.

Mondial House.

Plastics and Polymeric Materials

Adhesive Bonding

Yarsley Research Laboratories has been active in adhesion technology for many years and has experience in the formulation and application of all types of adhesive. A particularly interesting example of YRL's expertise was the development of a special adhesive system for repairing the Clifton suspension bridge. A survey of the bridge had revealed considerable wear of the original wrought iron bolts and the strap links and cleats to a point where it was considered necessary for repairs to be carried out.

Because of the construction and siting of the bridge (over the Avon Gorge) conventional repair methods of replacing corroded metal parts, etc., were considered impracticable. Through Howard Humphreys and Partners, engineering consultants to the Bridge Trust, YRL were approached to conduct a feasibility study to determine the possibility of developing a plastic-metal load bearing adhesive system which could be used to make in situ repairs and provide new bearing surfaces for the badly corroded and irregular existing surfaces.

A basic adhesive system was developed and thoroughly tested, improved, and again tested. The system was put on test on the bridge in the repair of two suspension rod units at either end of the bridge. These were monitored by strain gauges, etc., for performance over two years prior to consideration of complete repair of the bridge.

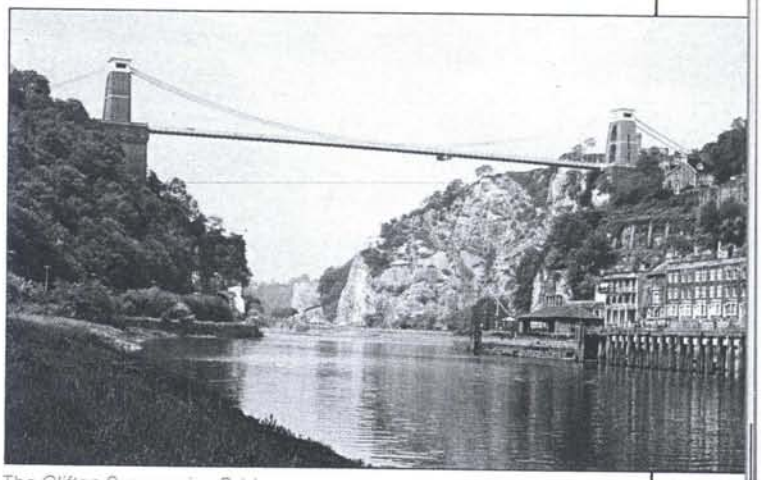
All the bearings on the bridge that were hitherto badly corroded involving the strap link and cleat bearings supporting the bolts at either end of a strap link, have now been replaced using the system prepared from the composition developed at YRL.

In more recent years, with the growing concern over the hazards of toxicity and flammability associated with the use of solvents, in addition to their ever-increasing cost, attention is turning to adhesives which do not contain solvents. In some cases it is possible to formulate a water-based adhesive to replace a solvent-based composition and YRL have undertaken several projects of this nature.

Solventless hot-melt adhesives are particularly important in this context, as they can be formulated to meet almost any set of application conditions, have high bonding strength and set very rapidly. Such adhesives, as the name implies, are applied in the molten state and set simply by cooling, with no chemical reaction involved.

YRL have built up a particularly strong background of experience in the hot-melt field. Projects successfully undertaken include:

Development of an iron-on coating composition.
Development of trouser waist-band non-slip composition.
Hot-melt adhesives for high-speed packaging.
Reformulation of hot-melts to replace toxic polychlorinated biphenyls (PCB).
Development of cigarette pack adhesives.
Adhesives for record sleeves.
Hot-melt adhesives for crown cork lining.
Encapsulation of pyrophoric chemicals.



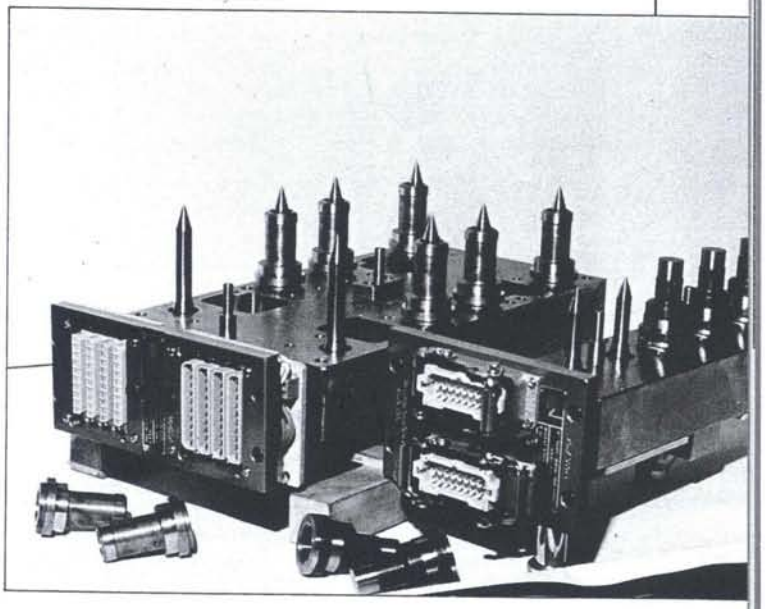
The Clifton Suspension Bridge
(Photograph by courtesy of the City of Bristol.)

Injection Moulding

Injection moulding is the most widely used process for the mass production of high quality products and components in polymeric materials. The Yarsley Technical Centre has always worked extensively with this process and has first class facilities for moulding all types of materials, both thermoplastics and thermosets. A particular speciality of YTEC is Hot Runner Injection Moulding, which is more material-efficient and easier to automate than conventional moulding. For many years YTEC engineers have been producing systems that work reliably and consistently. The secret is attention to detail: at the design stage, during construction and during final proving trials; coupled with good temperature control.

YTEC have now used this experience to design and develop a totally new Hot Runner System. The YTEC POLYMER TRANSFER SYSTEM is simple and thermally balanced. It is based upon well established principles to transfer the polymer from the injection machine nozzle to the mould cavity. In addition, the YTEC system incorporates specific features to assist both Mouldmaker and Moulder. All moulds designed by YTEC using the Polymer Transfer System are fully tested and de-bugged under full operational conditions before delivery to the customer.

The YTEC Hot Runner System.



Product Design a

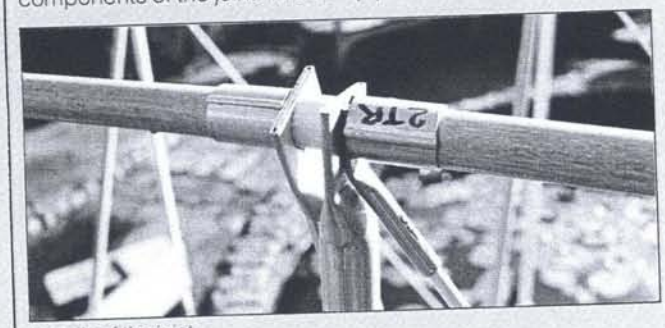
The materials of construction are the means whereby the performance functions of a product or component are translated into a physical form. Selection of the optimum materials and processes of manufacture is therefore essential to the development of products that can be produced profitably and whose performance will meet the service requirements. Fulmer's expertise in materials and design is extensively used by manufacturing industry to assist in the development of new products or to improve existing ones. A few examples are given here.

Bonded Fitments for FRP Sections

Fibre reinforced plastics are commercially available in a range of pultruded profiles eminently suitable for bearing the predominantly axial loads encountered in the elements of space frame structures. Pultrusions have transverse and shear strengths that are poor in comparison with their axial properties. This feature makes the use of many conventional attachment techniques, such as threading and mechanical fasteners, inappropriate. Unfortunately, this difficulty in making structural connections to aligned fibre composites has led to inelegant, bulky and heavy fittings. These fittings have negated much of the potential weight-saving that could accrue from the substitution of pultruded for metal elements in space frames.

Fulmer have developed lightweight, low cost, end fittings made from standard, commercially available, light alloy tubing, which offer great potential for assembling structures from both GRP and CFRP sections and tube. These fittings are manufactured by crimping the alloy tube on to the pultruded section with a structural paste adhesive between the components of the joint. The crimp profile is arranged to achieve a thin bond line around most of the joint circumference. Only low crimping forces are used so that hollow pultruded sections may have fittings mounted on them without crushing.

Demonstration bridge assembled from pultruded sections using jointing system developed at Fulmer, designed and constructed in co-operation with BTR Permali RP Ltd., the manufacturers of the sections.



Details of the joint.

Fittings have been developed using both medium and high strength light alloy tubing for use on carbon fibre reinforced plastic (CFRP) tube made by both pultrusion and table rolling, and pultruded glass fibre reinforced plastic (GRP) rod and tube. Fittings suitable for use on 8mm, 15mm and 25mm diameter composite elements have been manufactured and no scale effects have been observed. The fitting design has been developed such that when tested in tension the composite element fails remote from the fitting. An excellent performance following accelerated hostile environmental conditioning has also been demonstrated. Patent protection for the fitting design is pending.

Portable Work Bench

The award winning Black and Decker Workmate is a portable work-bench designed for the D-I-Y enthusiast. There are a number of plastic components in the Workmate, including the feet and swivel grips. Initially, Yarsley Technical Centre were retained by Black and Decker to investigate the scope for reducing the cost of these components. With the swivel grip, for example, it was found possible to achieve very significant savings by:

1. Changing the material from acetal to ABS.
2. Re-designing the component to reduce the weight of material required, allowing more impressions per mould.
3. Re-designing the tools and changing the moulding process from conventional injection moulding to hot runner or runnerless moulding, which avoids the need for secondary operations to remove the runner from the moulding and then re-grind this material.

Black and Decker Workmate.

Similar savings were achieved with the foot and an overall saving of 15% was made by producing only black components instead of the usual four colours. Together these savings amounted to some 55%, which amply justified the cost of making new hot runner tools.

Having completed this cost reduction exercise YTEC were then commissioned by Black and Decker to set up a complete new moulding shop for producing the plastic components. At a cost of £150,000 it was YTEC's task to design the factory unit, and select, procure and install all of the plant and equipment necessary to put the moulding shop into production within 12 months. The economics of this moulding shop were subsequently found to be so favourable that swivel grips could then be exported to Black and Decker's Canadian plant.

nd Development

Permanent Wear Soft Contact Lenses

Hard contact lenses and acrylic polymer implant lenses have been in use for many years and Yarsley Research Laboratories have developed improved lens moulding procedures where high quality mouldings are of the utmost importance. Major programmes have recently been carried out in which novel homopolymer and copolymer systems were developed specifically for soft contact lens preparations. In such development projects the 'tailor made' polymer system was devised to exhibit a high degree of water containment in the swollen state and yet be sufficiently stable to form a precision lens to an individual prescription. A large number of candidate combinations of various monomers were examined and a process was developed and taken up to a full production scale on a commercial basis. At the appropriate stage in the development programme Yarsley gave the clients full assistance with commissioning the new process on their own premises.

Engineering Design in Brittle Materials

Through research carried out on engineering ceramics such as silicon nitride and alumina, Fulmer has made considerable advances in understanding the problem of extreme brittleness as it affects the engineering designer.

Offered a choice, no engineer will use materials which are completely brittle. However, in some situations, where extremes of temperature, corrosive or erosive environments are involved, no ductile materials have adequate life and ceramics or other brittle solids must be used.

The mechanical properties of brittle materials are inherently variable and this variability causes four problems for the designer. Firstly, the material cannot easily be characterized and published data must be treated with great caution. Secondly, safety factors must be large and, where possible, proof loading must be used to achieve adequate levels of reliability. The third consequence of brittleness is that large components tend to be weaker than small ones — they are more likely to contain large defects. Finally, it is not sufficient for a designer to consider only the most highly stressed points in a component; failure may be initiated in less highly stressed regions.

Typical components made from reaction bonded silicon nitride.
(Photograph by courtesy of Advanced Materials Engineering Ltd., Ruabon.)

Fulmer's research in Weibull analysis and related statistical techniques has helped the designer to understand and overcome these problems.

Fulmer Tension Meter

The safety of items ranging from lifts to radio and TV masts depends upon maintaining the correct tension in the steel cables. Fulmer have developed a simple, reliable and accurate instrument for doing this. Known as the Fulmer Tension Meter, the instrument is now available through Fulmer Components.

The tension load is measured by engaging the meter on the loaded item by a half turn of the handle. This causes the eccentrically mounted centre wheel to deflect the item between the two outer wheels or shoes.

The reaction to the deflecting force acts upon the frame, causing it to bend to an extent which is proportional to the tension applied. This is read out on a dial indicator.

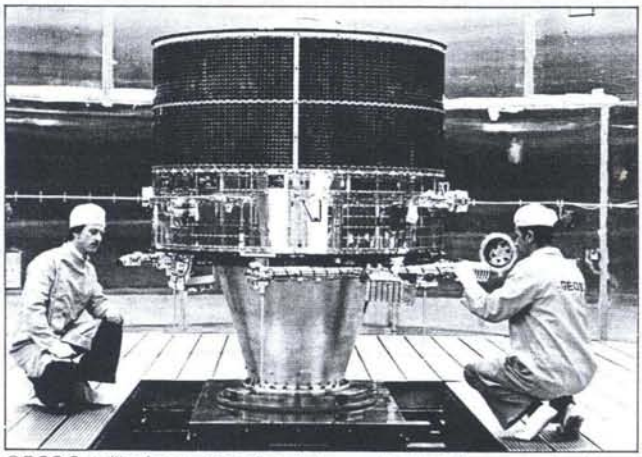
The actual load in the cable or wire is read from the calibration chart, after ascertaining the extent of deflection shown on the meter and relating this reading to the appropriate load curve.

A calibrated scale can be supplied to provide direct reading of the actual load, where the instrument is to be used on only one size of tensioned items.

Design Guides for Composite Structures

Fulmer has compiled a number of design and fabrication guides over the last five years covering the use of advanced materials in engineering. This work reached its logical conclusion in the compilation of the Fulmer Materials Optimizer, a comprehensive materials selection system for the engineering designer. However, in some cases, the end-user requirement is so specialised that a conventional design guide is not adequate. An example where specialised requirements dominate materials selection occurs in spacecraft, and the European Space Agency have contracted Fulmer to prepare a series of design and fabrication guides.

Where state-of-the-art technology is being employed, as is usually the case in spacecraft, suitably comprehensive materials data for design purposes is frequently not available. The work being carried out by Fulmer is intended to fill this gap by providing designers with guidelines for the use of advanced materials and processes, rather than definitive design data. It will be emphasised that structural design and material selection may have to be carried out co-operatively. It is expected that the provision of data on fibre-reinforced composite materials will be the major emphasis of this work.



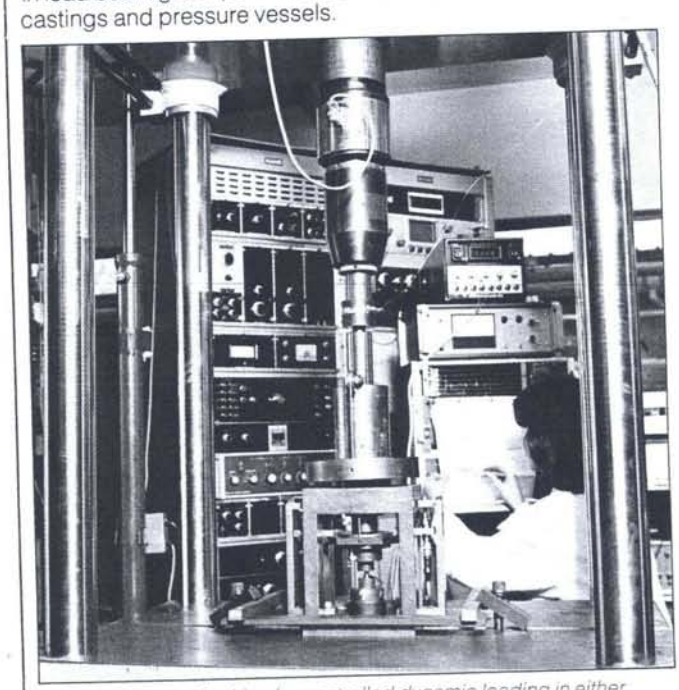
GEOS Satellite for studies of particles and fields in the magnetosphere.
(Photograph by courtesy of British Aerospace Public Ltd. Co.)

FULMER TECHNICAL SERVICES

Fulmer Technical Services is a Ministry of Defence approved test-house and uses the staff and facilities of Fulmer Research Laboratories.

Service Performance of Metallic Materials

FTS undertakes a large variety of failure diagnoses and consultancy assignments. These investigations are generally industrial problems which require rapid provision of results and reports. They range from failures in soldered joints in multi-way connectors or malfunctions in flame failure devices, to fractures in load bearing components, e.g. rotating shafts, welded joints, castings and pressure vessels.



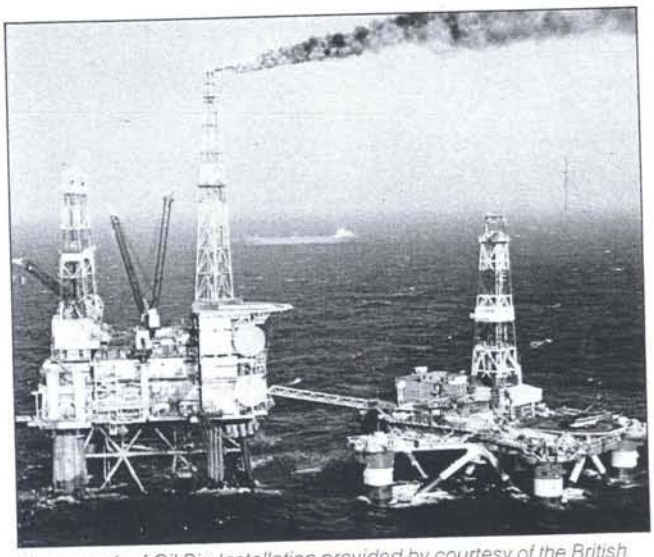
Servo Hydraulic Machine for controlled dynamic loading in either tension or compression.

A number of specialised services are available. For example, the effects of radiation on high-technology materials are usually so complex that every test of a new device or material raises new physics research problems. Fulmer offers routine radiation test and engineering support services and also carries out research projects aimed at a better understanding of why materials degrade under irradiation.

Radiation Effects in Space and Nuclear Systems

Fulmer's 'Radiation Effects Engineering Handbook', prepared for the European Space Agency in 1978, had a wide success amongst designers of space vehicle electronics. This success led to a request from Euratom's Joint European Torus (JET) Undertaking, to prepare similar guidelines for the layout of electronics for the JET nuclear fusion experiment. A guideline report was delivered in September 1980, and consulting on design continues.

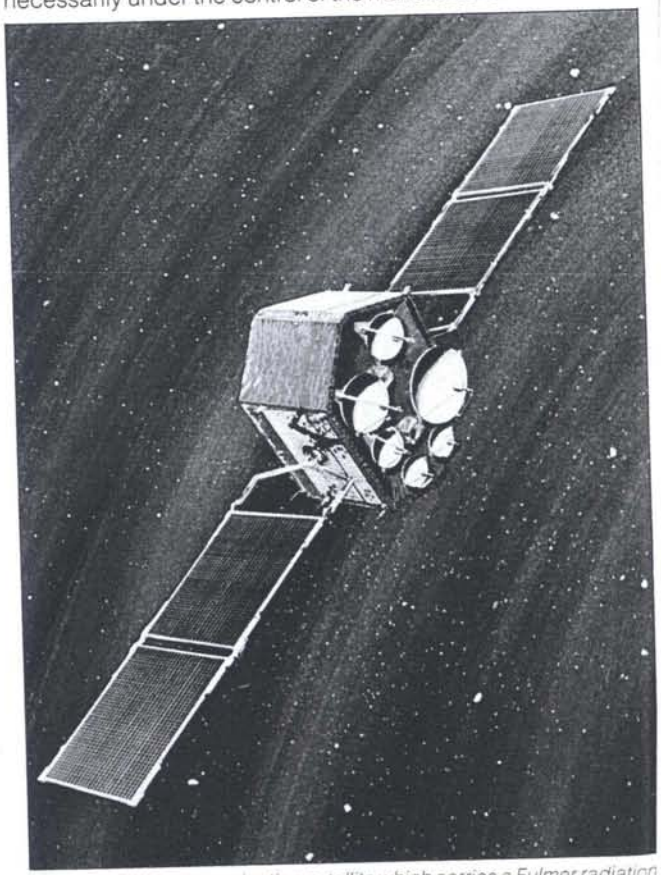
By means of the Fulmer/ESTEC Radiation Monitoring Unit, Fulmer keeps in direct touch with satellites which are being bombarded by radiation in space. Units are carried on the OTS-2 communication satellite and GEOS-2 scientific satellite and have sent back data for the last 2½ years. Improved units are being prepared for a new satellite project.



Photograph of Oil Rig Installation provided by courtesy of the British National Oil Corporation (Development) Ltd.

A wide range of mechanical tests can be carried out by Fulmer Technical Services to establish tensile, impact, fatigue, compression, creep rupture and fracture toughness properties in materials. Work of a routine quality control nature is undertaken together with the assessment of the behaviour of materials in simulated service conditions.

Much of the product assessment work is also concerned with defining the performance with abnormal service loads not necessarily under the control of the manufacturer.



Europe's OTS communication satellite which carries a Fulmer radiation monitor of new design. (Photograph by courtesy of British Aerospace Public Ltd. Co

ting and Consultancy

YARSLEY TECHNICAL CENTRE

The testing laboratories of Yarsley Technical Centre are fully approved by a number of Agencies, including Ministry of Defence, Department of the Environment Supervisory Scheme for Fire Test Laboratories, and Civil Aviation Authority.

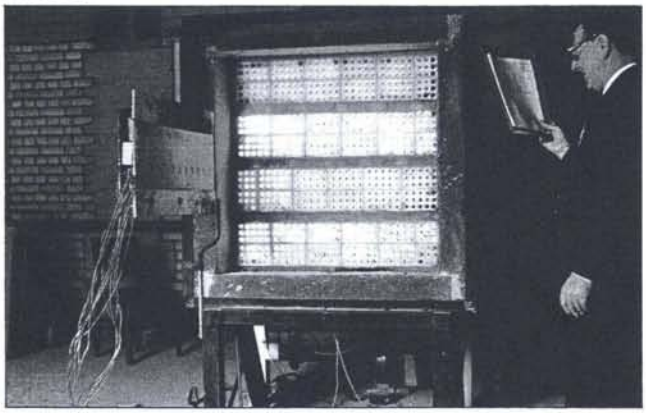
Service Performance of Non-metallic Materials

YTEC specialise in standard and non-standard testing of all types of non-metallic materials, and the products and components manufactured from them. A wide range of facilities is available for mechanical testing, chemical analysis, wear and corrosion testing and for testing under conditions of controlled humidity and temperature. Special test rigs can be designed and built for reproducing in-service conditions.

Mould Design and Development

As experts in injection moulding YTEC offer a comprehensive service for the design, development and testing of moulds. YTEC staff have particular expertise in hot runner injection moulding, an advanced process which is finding wide application due to the improved efficiency of materials utilisation and its ability to be automated.

Surface Spread of Flame Furnace, testing to BS 476, part 7, 1971, section 2.



Thermal Conductivity Laboratory

Services to the Building Industry

YTEC provide comprehensive testing, on-site investigation and consultancy services to the different sectors of the building industry, including architects and designers, civil engineering organisations, construction companies, and the producers of building materials and components. Much of YTEC's work involves the use of plastics and related materials which are relatively new to the building industry, and are now playing an increasingly important role, not only in the manufacture of building components, but also as structural materials. One factor which will accelerate the structural uses of plastics in buildings is the greater energy efficiency of GRP compared with steel. But there are a number of drawbacks to the more widespread use of plastics as structural units, for example, fire problems, and the lack of formal standards. Despite this it is now widely predicted that the inherent advantages of plastics — weathering resistance, lightness, design flexibility and energy efficiency — will ensure their increasing application in building systems. YTEC is ideally placed to assist the building industry to realise the full potential of plastics.

Fire and Thermal Properties of Materials

YTEC has the most comprehensively equipped laboratories in the UK for the determination of the fire and thermal properties of all types of materials and products. Both standard and non-standard testing is carried out on building components and materials, furnishings and furniture, and industrial hardware.

Turnkey Projects

Fulmer/Yarsley engineers are frequently retained to advise on, or manage, the establishment of a manufacturing facility on a Turnkey basis. Typical projects include:

the installation of a precision rolling facility for metal foil,
the design, procurement and installation of an automated injection mould for a toy manufacturer,
the setting up of an injection moulding factory for housewares in Saudi Arabia.

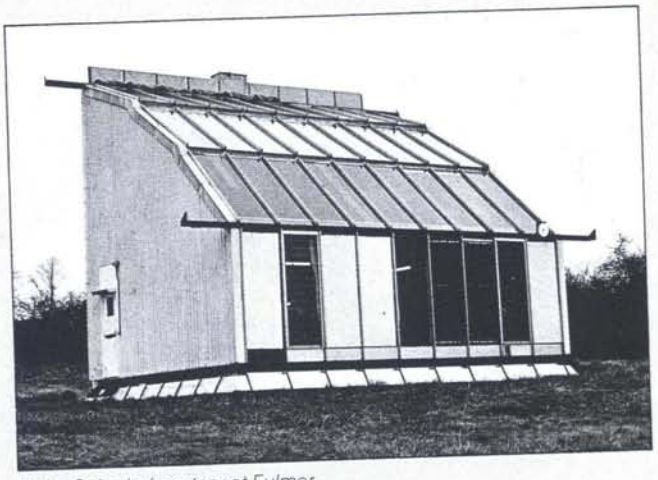
Devices and Systems

Solar Energy Systems

Fulmer has been working for many years in conjunction with the Calor Group on the development of solar energy systems for domestic water heating. The initial project concentrated upon individual components of solar energy systems, such as solar collectors, and then expanded to include the complete systems design for a typical house of approximately 1,200 sq. ft. in area. These systems have now been exhaustively tested in the solar laboratory at Fulmer.

Following the testing programme in the laboratory, prototype designs of combined water and space heating solar systems have been built and installed by the Calor Group in houses in Edinburgh and Milton Keynes.

The solar system performance will be monitored by equipment designed, built and installed by Fulmer to measure the total energy consumed and the contribution made by the solar input. The fuel savings that can be expected when the houses are occupied will then be assessed.



Calor Solar Laboratory at Fulmer.

Houses built by Miller Homes under construction in Edinburgh.

Interactive Training Aids

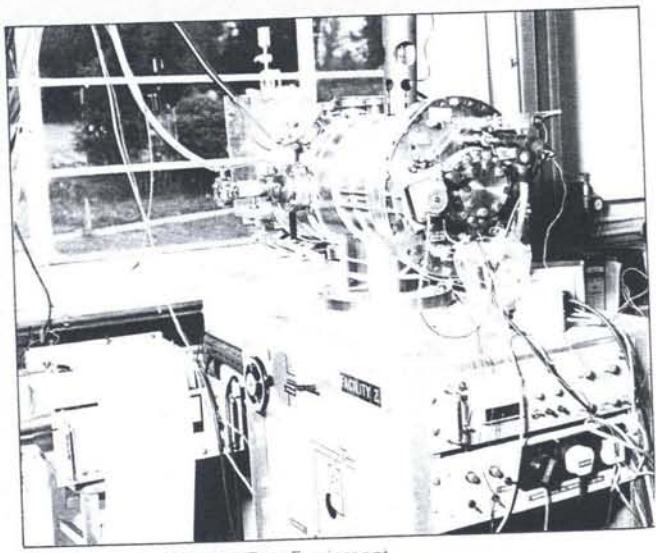
Fulmer has co-operated with Australasian Training Aids Pty. Ltd. over several years to develop the Superdart marksmanship training system. The system is designed to reduce the time and cost involved in training rifle marksmen. It works by providing the trainee with instant feedback on his hit position and details of the way in which he supported and fired his rifle. This enables the required remedial action to be identified and implemented immediately.

The hit position is determined mathematically from measurements of the time of arrival of the shock wave from the bullet at a number of fixed sensors. These, as well as sensors attached to the rifle to measure holding pressure, and the mathematical procedure for the determination of hit position, were all designed at Fulmer. The data presentation is on a VDU situated close to the trainees and/or on a master training console which handles data from several trainees simultaneously. Patents on the system have been granted in the UK, USA, and many other countries. The first major order has been delivered and many enquiries relating to further orders have been received.

Novel Propulsion Systems

Communication satellites require periodic orbital adjustments to maintain an accurate station. Chemical rocket motors are unsuitable for these minor manoeuvres which call only for small power outputs over extended periods of time. Ion field emission thrusters are under development for this purpose and Fulmer has been working for many years to test the new form of spacecraft propulsion in which a liquid metal such as caesium or gallium is fed to a point array where it is then extracted by a high electric field and accelerated to produce a beam of liquid metal ions. The reaction thrust on the device enables it to be used for periodically adjusting the orbit of a satellite. The reliable operation of the system depends to a great extent on the flow characteristics of the liquid metal, its oxidation behaviour and compatability with other structural materials.

The advantage of the field emission thruster concept lies in its inherent simplicity: no high temperatures are required for ion production, no vapourisers are needed, and very low voltages are required. This leads to a high beam current density, high overall efficiency, simplicity of feeding and very simple switch on/switch off.



Field Emission Thruster Test Equipment.

Development and Engineering

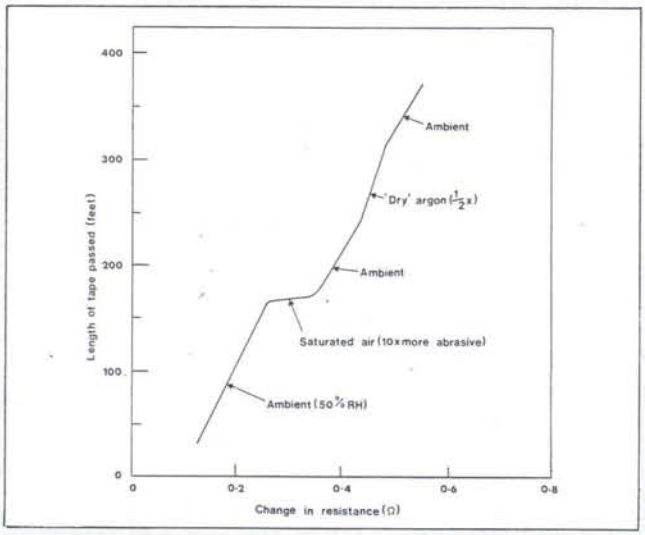
Magnetic Tape Abrasivity Monitor

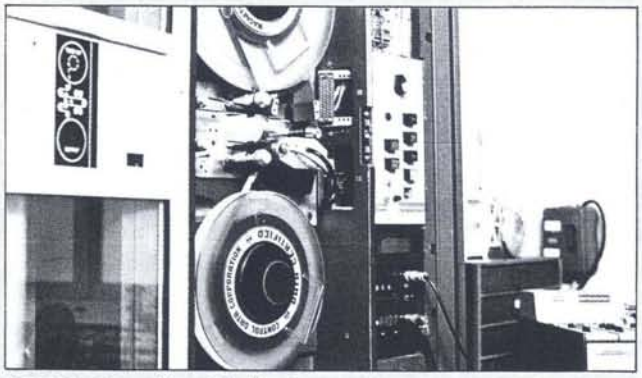
An 'early-warning' method has been developed for measuring tape abrasiveness. The sensor consists of a thin metal film deposited on to a highly polished ceramic cylinder. When the film is abraded by a magnetic tape its thickness, and hence its conductance, is diminished.

On-line monitoring of the sensor resistance is performed using a bridge arrangement with chart recorder output of the out-of-balance voltage. Meaningful results are obtained from test runs on as little as 100 ft of tape. A typical plot is shown of the wear caused under conditions of different humidities.

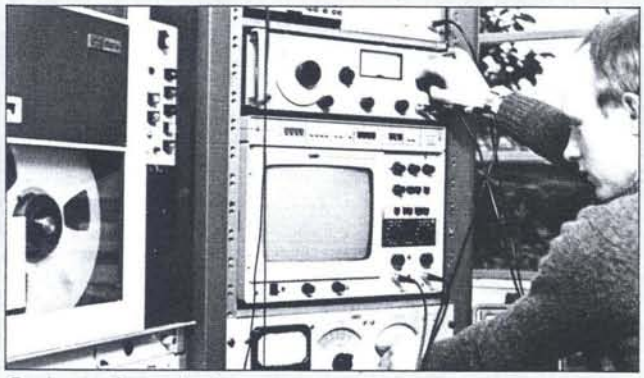
The test appears to have no deleterious effect on the tape and is therefore suitable for use in quality assurance procedures. By including suitable rollers, fitted with strain gauges, it is possible to derive tape tension at the head and the friction at the tape/head interface.

A further development employs a microprocessor to simplify the testing. This is marketed through Fulmer Components. It is intended for use in product assessment, both by tape manufacturers and tape users.

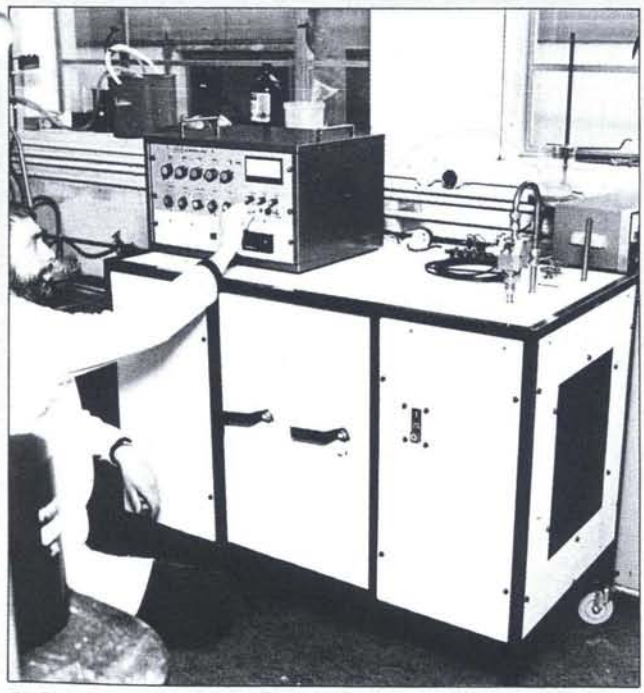




Magnetic Tape Abrasivity Monitor.



Equipment for monitoring magnetic and electrical properties of recording tape.



Oil Condition Monitoring Equipment.

Oil Condition Monitor

A novel type of sensor for detecting the presence of wear particles in fluids is under development. The sensor consists of a thin resistive metal film deposited on to a ceramic substrate. When a fluid containing foreign particles is directed at the sensor, the thin film is abraded and so its electrical resistance is increased. This allows the debris present in, say, lubricating oils to be detected and thereby provides a means for following the rate of wear of oil-washed machinery.

The size of sensor currently available is 10 x 5 x 1 mm, which is sufficiently small to allow it to be used 'on-line' in many systems. The sensor is compensated for temperature variations which may occur in the fluid. Resistance is measured using a simple bridge circuit, with the out-of-balance voltage fed direct to a chart recorder. Typical sensitivities, obtained in laboratory loops running at 100 psi are better than 3 ppm with 9 micrometre alumina; 3 ppm with carbonyl iron size range 0-38 micrometres; 5 ppm with iron oxide as used in magnetic recording where the particle size is about 1 micrometre.

The sensor is patented world-wide. Potential applications include:

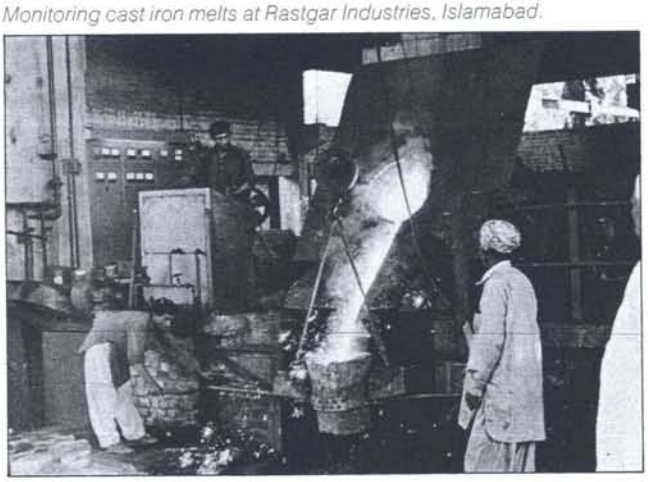
- Monitoring of wear in gear boxes to prevent catastrophic failure.
- Studying the running-in characteristics of engines.
- Determining the presence of harmful impurities in hydraulic systems.
- Checking efficacy of filters.

Technology Tra

Technology cannot be transferred effectively from one individual to another or from country to country by reports or other forms of documentation only. Personal contact is essential. Fulmer's activities in technology transfer are based on this premise, which is founded on many years' experience of transmitting the results of R & D projects to sponsors, who require to incorporate these results quickly and efficiently in their business. Fulmer's specialism is in the provision of programmes tailor-made for the individual requirements of specific clients, rather than formal training courses. Of particular importance is Fulmer's flexibility in being able to accept trainees into laboratory-based development, testing and consultancy programmes, whilst at the same time providing in-situ technical assistance on the client's premises. Training programmes can be provided for the staff of manufacturing companies, and national and international Agencies, in the following areas of materials technology and engineering, particularly involving metals and plastics:

Materials processing
Laboratory management
Project management
Product development
Materials testing
Quality control procedures
Technical services and consultancy
Information services

Monitoring cast iron melts at Rastgar Industries, Islamabad.



Project Planning and Control

For the past eight years Fulmer has been running a successful series of seminars on Project Planning and Control for Research Managers, based on the RPD system developed at Fulmer.

RPD (originally an acronym for Reseach Planning Diagrams) was developed about ten years ago in response to Fulmer's own project planning needs, particularly the need to present project plans clearly to potential clients.

Project Network Analysis techniques such as CPM and PERT, despite their success in planning well-defined engineering projects, were found to be inadequate in R & D. They do not make provision for uncertainty of outcome and, although they can be generalised to do so, the resulting complex notations are confusing; as an aid to communication they are self-defeating.

It was soon realised that a clear notation for R & D project planning must emphasise the contingencies that can arise and the alternative courses of action which may be needed. RPD notation was therefore based on computer programming flow charts, with their natural emphasis on the logic of alternatives.

Quantitative analysis of RPD plans is also different from that of conventional networks. Traditional network concepts such as that of the critical path are retained but the main feature of RPD analyses is that answers to questions of project cost, benefit and duration are all given in probabilistic terms.

The Seminars

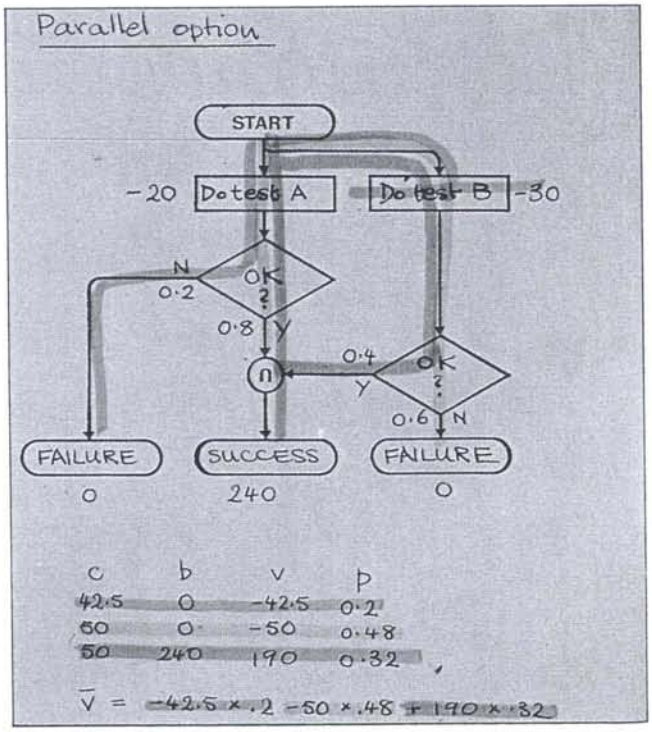
The RPD seminars each take the form of an interactive discussion group of between 10 and 25 participants. RPD methods are explained in the context of network analysis and their applications in R & D management are discussed. About 70 seminars have been held over the last eight years.

Metals Advisory Service

In 1975 the United Nations Industrial Development Organisation (UNIDO) appointed Fulmer Research Institute to set up a Metals Advisory Service (MAS) in Lahore. The aims and objectives of the project were defined as:

— To provide technical assistance to the metals industry in Pakistan with respect to improving productivity, profitability and quality of product.
— To provide information on new techniques where these are suitable for application to Pakistan.
— To examine and assess indigenous sands and clays for use in foundries.
— To establish chemical and metallurgical analysis facilities at the MAS laboratories to assist Pakistani companies lacking these facilities.

The project is administered by the Pakistan Ministry of Industries, which is responsible for the provision of buildings, and the local counterpart staff who will eventually manage MAS on their own. UNIDO provides aid in the form of specialised capital equipment (analytical and test apparatus, furnaces, etc.) the provision of external consultants (Fulmer) and the overseas training of local staff (mainly at Fulmer's laboratories).



An example of an RPD decision analysis diagram in which a plan for parallel testing is evaluated.

sfer and Training

Schools/Industry Education

At the time when James Callaghan made his now famous speech in October 1977, inviting educationalists to involve themselves closer to the world of industry, Fulmer had already taken the initiative to make links with schools and universities.

Because of the close association of Fulmer staff with the engineering profession and their background in higher and further education, the need to attract a better standard of student into the engineering profession was well understood.

Our work began in 1970 when a party of 6th formers from the Scientific Society of Merchant Taylors' visited Fulmer. Much of the work they saw demonstrated the link between the classical mathematics and science taught in school and how this could be applied to real products.

Over the next four years our activities extended into lectures and workshops for university students through to primary school children; we also invited pre-university students to experience a year's work in the laboratory and workshop environment prior to starting their degree course.

Our work attracted the attention of the Industry Education Unit of the Department of Industry and in 1978 we were awarded a grant to assist in the extension and intensification of our work in secondary schools. During this first phase of our work seminars and workshops were developed to introduce students to the qualities and skills needed by technologists and engineers. As part of this study we investigated the constraints to introducing technology into schools and making sound links with industry.

The present work which has developed out of the original studies has extended into the area of the primary school where technological awareness has to be introduced. Other facets of the project encompass technology for gifted children and the special topic of microprocessor awareness in middle and secondary schools.

A group of ten-year-old Primary School children (a) discovering the principles of bridge design, (b) testing their designs for paper gliders.

Training and Work Experience Programmes

In response to the requirements of technologists and engineers from developing countries, Fulmer has developed a series of courses which involve periods of intensive training in Fulmer's laboratories and workshops, coupled with industrial work experience through secondment to appropriate manufacturing companies. The content of the programme, and the relative length of the periods of intensive training and work experience, are varied to suit the specific requirements of each individual trainee. Examples of such courses are:

Analytical procedures for quality control.
Metallurgical investigation of component failures.
Foundry practice.
Powder metallurgy.
Injection mould design.
Polymer processing.
Product testing.

Information Services

Fulmer/Yarsley have an established reputation for undertaking confidential, high level information searches, technical surveys, market reviews, investment appraisals, etc. In addition, a number of publications are generally available, including:

Fulmer Materials Optimizer

The Fulmer Materials Optimizer is an information system for the selection and specification of engineering materials. The system consists of four volumes of readily assimilated information on the performance and current costs of all commercially available production engineering materials and related component manufacturing processes.

Superplasticity

A review of current materials, processes, applications, patent information, and commercial data which is updated annually.

Fulmer Special Reports

Surveys of specific areas of technology, the most recent being:
Asbestos — Characteristics, Applications and Alternatives

Current Awareness Service

Yarsley Research Laboratories also operate a confidential Current Awareness Service, the purpose of which is to make clients aware of developments, possibly in fields outside their own areas, which could have an impact upon their business; for example, new processes or products which might compete with the client's business or which he might usefully apply, opportunities to license new processes or products, etc.

Manufactu

Fulmer Components Ltd. provides a manufacturing facility for the production of electronic equipment, electromechanical instruments and associated components. The policy of Fulmer Components is to provide the finest components for the designers of precision electronic and electromechanical equipment. The Company has made and is continuing to make exclusive agreements with leading companies throughout the world to make available a selective range of high quality products for the benefit of British industry.

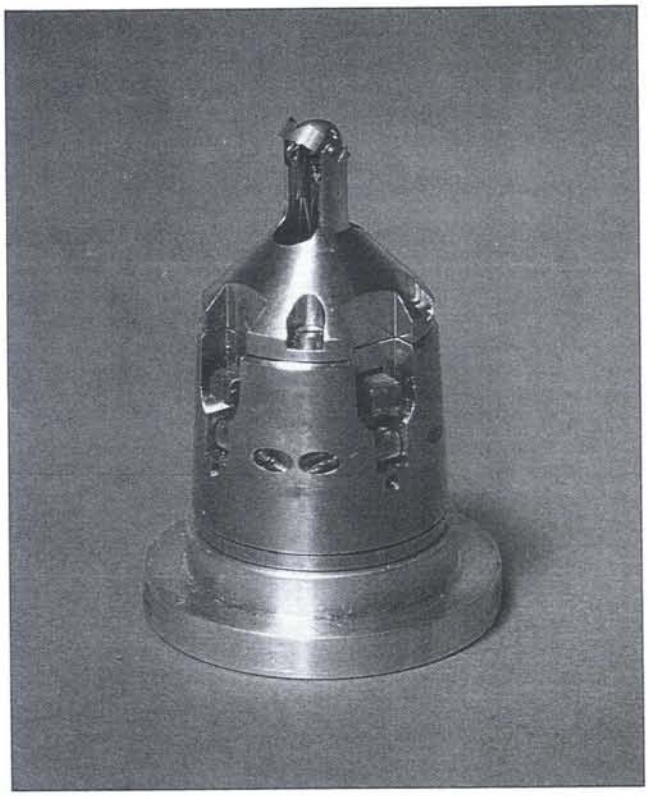
FCL Mechanical

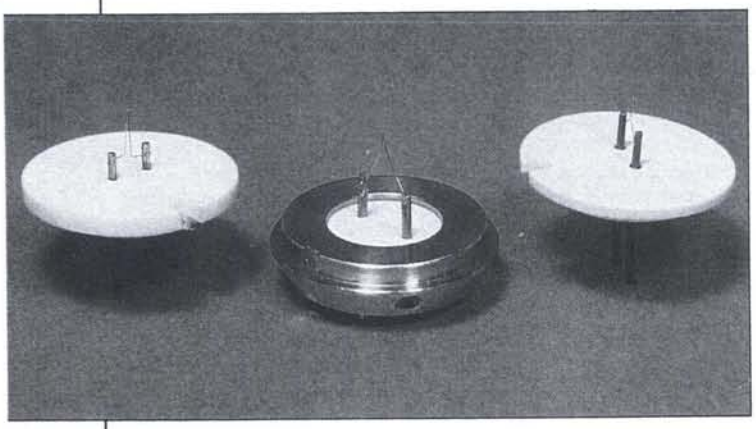
Accessories for Electron Microscopy

The main items are double tilt specimen cartridges with replacement loading fixtures, pulling wires and springs, etc.

Fulmer Tension Meter

A simple, reliable and accurate instrument for measuring the tension in steel cables





Electron Beam Filaments

The supply of pointed and loop type filaments for almost any electron beam device.

Automated Spray Unit

An automated Spray Unit has been designed and developed by the Paint Research Association for the application of uniform films of paint to test panels maintaining a constant thickness in any number of repeat operations.

Loop Filament Rebuilding Service

The service includes reconditioning of the base, insertion of a new filament loop, vacuum normalising and pre-centering and inspection.

ng Services

FCL Electronics

Delay Units

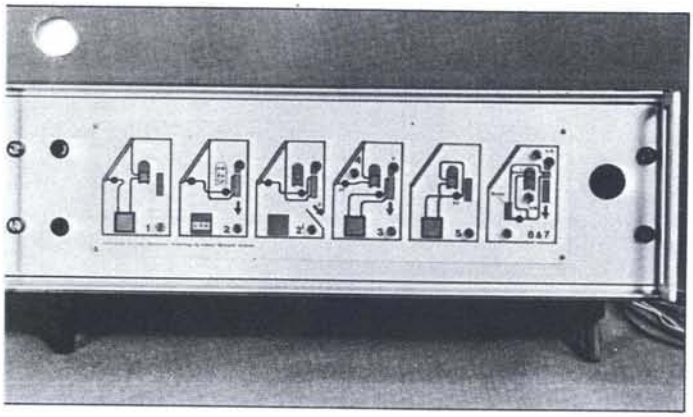
Dual in-line Delay Units with lumped constants giving delays from 10 to 100 ns (taps provided to give increments of delay) have been developed for use in computers and electronic data processing.

Delay Cables

Delay Cables with a magnetic core are suitably calibrated and terminated to MoD (Navy) specification. Terminations can be either by amphenol plugs and sockets or injection moulded polypropylene designed for connection direct to printed circuit boards. Delay time is in the order of microseconds.

Tapered Thermocouples

Developed at Fulmer Research Laboratories under contract to the European Space Agency, approximately 100 tapered thermocouples monitor temperatures at various points on the spacecraft surface whilst undergoing simulation trials.



Solar House Electronics Unit

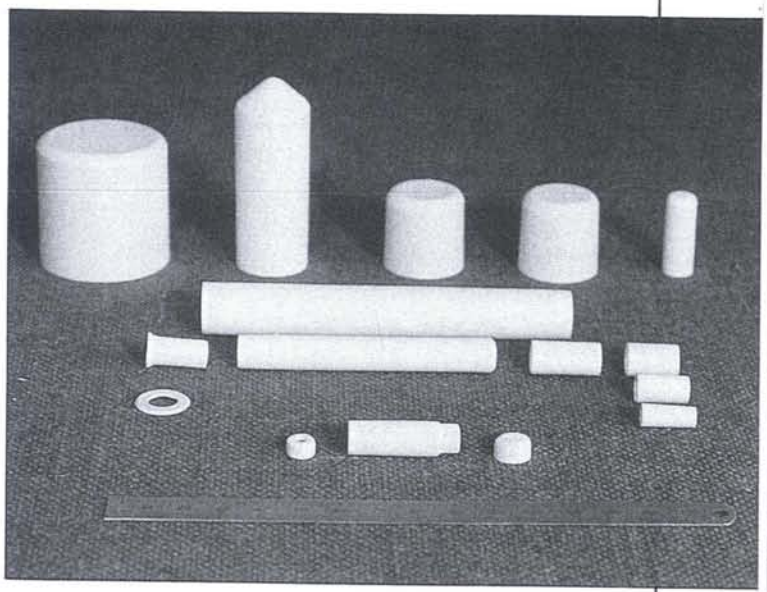
An electronic controller which selects and operates various water loops (used in a solar house) permitting the system to operate at maximum efficiency. Energy from the solar collectors is directed automatically either for domestic hot water, space heating or into storage, according to demand and ambient conditions prevailing at the time. This unit was developed for the Calor Group Ltd.

FCL Chemical

Pyrolytic Boron Nitride

Pyrolytic boron nitride is a high temperature material with exceptional resistance to thermal shock. Several shapes such as crucibles, dishes, tubes and flat plate can be formed by chemical vapour deposition.

Fulmer Components will consider the manufacture of any special component in pyrolytic boron nitride. The PBN is deposited on to a graphite mould. After release, this produces a free-standing article having a high degree of crystal orientation. The hexagonal layer lattice of the material is always parallel to the surface of the mould, and consequently the thermal conductivity around the walls is up to 40 times greater than through them. This is ideal for crucibles and dishes as it gives rise to very uniform heating within them.



Synthesis of Fine Chemicals

Yarsley Research Laboratories are actively involved in the synthesis of fine organic chemicals, particularly organofluorine compounds, in batches ranging from a few grammes to tens of kilogrammes. Examples of some compounds recently prepared are:

hexafluorobenzene
pentafluorophenol
pentafluorobenzoic acid
4-trifluoromethylphenol
4-aminobenzotrifluoride
4-bromobenzotrifluoride

Equipment and Facilities

Fulmer and its Yarsley subsidiaries have comprehensive facilities for processing and testing materials and products. The major items are listed below:

FULMER RESEARCH LABORATORIES LTD./FULMER TECHNICAL SERVICES

Metal casting including continuous casting equipment: 150 tonne diecasting machine; 650 kg aluminium melting unit; 100 kg steel melting unit; 100 kg holding furnace; 10 kg vacuum induction melting and casting furnace; electro-slag refining equipment for ingots 1½'' to 4'' diameter.

Metal processing, including laboratory facilities for forging, wire drawing, rolling, powder metallurgy processing and manufacture of fibre reinforced composites. Air, inert atmosphere and vacuum heat treatment furnaces. Hot isostatic press.

Chemical Vapour Deposition of a wide range of metals and compounds including:
the manufacture of plate, rod, tube and crucibles in pyrolytic boron nitride,
the production of wear and corrosion resistant coatings in hard metal compounds

Measurement of mechanical properties, including tensile, impact, fatigue, compression, creep rupture and fracture toughness.

Routine and investigational chemical analysis, including emission spectroscopy; mass spectrometry of solids and gases; UV spectrometry; polarography; gas analysis by fusion; atomic absorption.

Surface analysis, by scanning electron microscopy with microprobe analysis and X-ray photo-electron spectroscopy (XPS).

Metallographic investigation, including optical microscopy, transmission electron microscopy, scanning electron microscopy, with quantitative image analysis.

Non-destructive testing, including acoustic emission; ultrasonic attenuation and resonance; ultrasonic testing using solid, liquid and air coupling; X-radiography; thermography.

X-ray diffraction analysis of solids, powders, fibres and liquids.

Corrosion investigation of structural materials and coatings, including accelerated and stress corrosion; corrosion-fatigue; controlled environments; impingement testing.

Physical property research, including surface tension; electrical resistivity — thermal conductivity; specific heat; calorimetry and high temperature thermodynamics of inorganic compounds.

Differential thermal analysis; thermogravimetric analysis; dilatometry; damping capacity; fire testing under load.

Ballistic testing of metals, polymers and composites.

YARSLEY RESEARCH LABORATORIES LTD.

Pilot plants for chemical synthesis, resin preparations, suspension and emulsion polymerisations, compounding of adhesives and other products.

Electrochemical fluorination cell

Thermal analysis, including instruments for DTA, TGA, DSC and TMA

Wet spraying booth

Flat bed film casting unit

Laboratory spray dryer

Pressure polymerisation equipment

Temperature, humidity — and dust-controlled laboratories

Powder coating electrostatic spray equipment

Coating/laminating machine, widths up to 12''

YARSLEY TECHNICAL CENTRE LTD.

Polymer processing including injection, transfer and compression moulding, extrusion; mixing, blending and compounding.

Routine and investigational chemical analysis, including High Performance Size Exclusion Chromatography; Miran portable infra-red spectrophotometer for on-site analysis of vapours and gases.

Fire testing and fire investigation, including furnaces for surface spread of flame, fire resistance, roof tests; smoke density and toxicity.

Thermal conductivity testing of all insulating materials and metals over the temperature range −200°C to +1100°C.

Measurement of mechanical properties including tensile, impact, flexural shear properties, compression and fracture resistance. Controlled atmosphere test rooms.

Physical property measurements, including electrical properties; specific heat; rheometry; optical properties; permeability to vapours and gases; energy absorption; light fastness; light transmission.

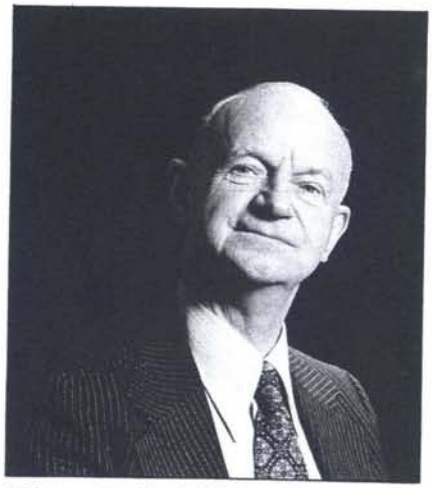
Wear and corrosion testing.

Special test rigs for reproducing in-service conditions, which are designed and constructed in our own workshops.

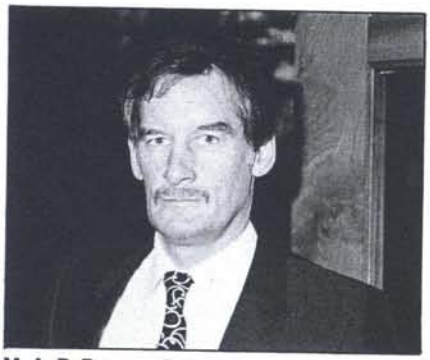
Pollution investigation and the control of environmental hazards, including a mobile laboratory.

Senior **Fulmer** Staff

W. E. Duckworth, *M.A., Ph.D., F.Eng., F.I.M., F.I.S., F.Inst.P., Managing Director, Fulmer Research Institute Ltd.*

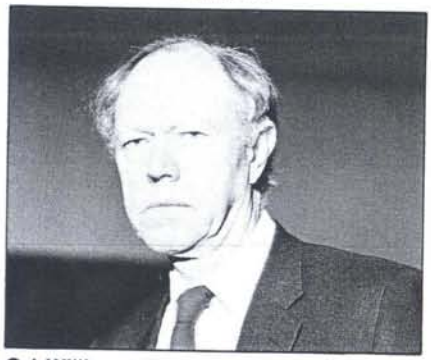


Sir Ieuan Maddock, *C.B., O.B.E., D.Sc., F.Inst.P., F.Eng., F.R.S., Chairman*

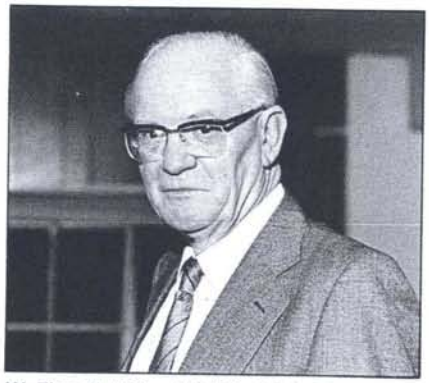


M. A. P. Dewey, *C.Eng., F.I.M., Financial & Marketing Director, Fulmer Research Institute Ltd., Managing Director, Yarsley Technical Centre Ltd.*

G. B. Brook, *B.Met., C.Eng., F.I.M., Director, Fulmer Research Laboratories Ltd.*



G. I. Williams, *B.Sc., Ph.D., F.Inst.P., Director, Fulmer Research Laboratories Ltd., Managing Director, Fulmer Components Ltd.*



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W. H. Bowyer, *B.Sc., Ph.D., C.Eng., General Manager, Fulmer Research Laboratories Ltd.*

D. G. S. Davies, *M.A., Principal Administration Manager, Fulmer Research Institute Ltd.*

E. Sugars, *A.S.C.A., Company Secretary, Fulmer Research Institute Ltd. and subsidiary companies*

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