Fulmer

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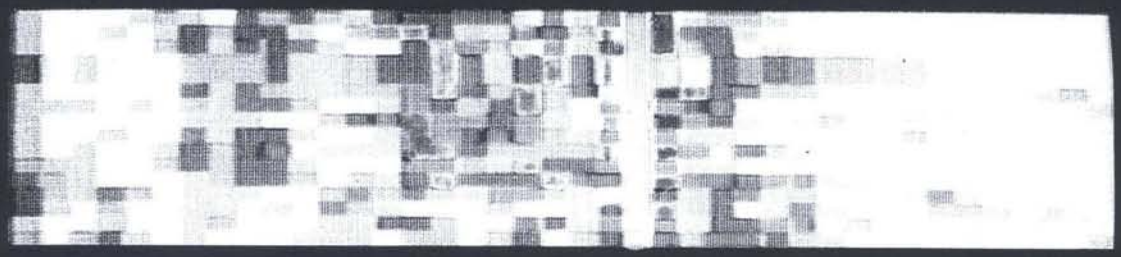
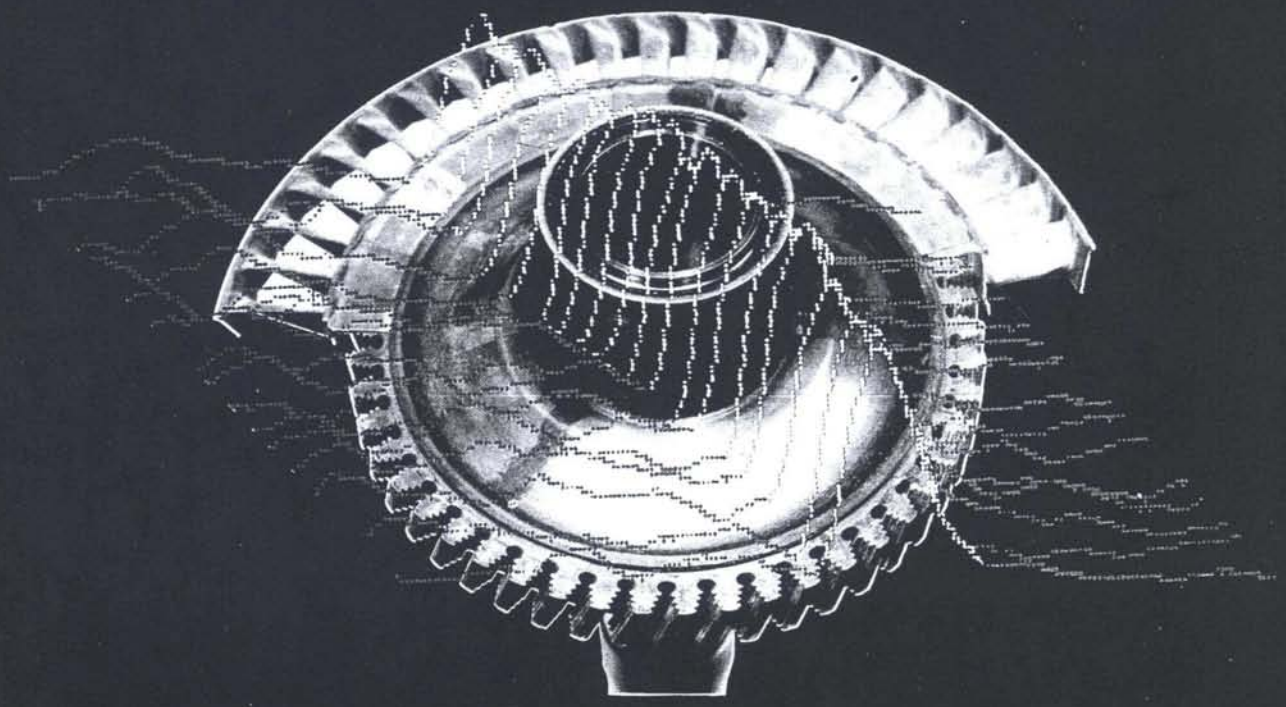




review 1982

CHAIRMAN'S FOREWORD

In the present difficult economic atmosphere it is most gratifying to report that income growth of 10%, to a record level of £3.223M, was achieved during the year. Profit increased 32% to £145,000. We were also able to increase staffing levels by 3%. The Company thus returned to the path of continuous growth, from which it had temporarily strayed in 1981.

While remaining firmly established as a major international centre of research and expertise in materials technology, Fulmer is extending its credibility and track record in product and process research, design and development covering a wide range of industrial applications. The semi-solid metal injection casting process is now attracting worldwide interest, and we have commenced commercial manufacture of polyvinylidene fluoride film for piezoelectric and pyroelectric operations. Our magnetic tape abrasivity monitor is now being purchased as a standard quality control instrument, and a major development of the technology into oil abrasivity monitoring is being supported by the Department of Industry and the British Technology Group.

We have had major successes with our hot isostatic pressing technology, including the development for production purposes of the depleted uranium targets required for the spallation neutron source of the SERC Rutherford Appleton Laboratory.

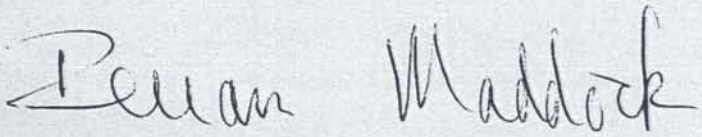
Our joint project with the Shanghai Research Institute for Materials has produced novel high temperature and drill materials. We have completed a major UNIDO contract with the Marmara Scientific and Industrial Research Institute in Turkey. Our other work with over thirty countries has earned us more than £800,000 as our contribution to Britain's invisible exports, an increase of 26% over the previous year.

We have established a laboratory in Singapore and won an important contract in Hong Kong to study technology transfer in the metals industries. The requirements of confidentiality inhibit the mention of many other notable successes during the year.

Both Fulmer Research Institute and Yarsley Technical Centre are NATLAS laboratories listed under registration numbers 0050 and 0036 respectively. In addition to our high reputation for testing work in manufacturing industry we are becoming increasingly recognised for our expertise in testing building products and investigating building failures and defects.

As a participant in AICRO, Fulmer played its part in the launching of the Cogent Development Company, which we anticipate will make a major contribution to industrial innovation in the UK.

With the increasing requirements of many of our major clients for our participation in their products and process development and innovation we look forward with confidence to further growth in 1983.



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

CONTENTS

The cover picture shows a partially assembled disc and blade set from a gas turbine engine. The detection of defects in these highly stressed components is critical. Such components are inspected using ultrasonic techniques. Limitations are placed on these inspection techniques by the nature of the superalloy metals used in blade and disc manufacture. Signal processing work at Fulmer has successfully enhanced the performance of conventional methods of ultrasonic flaw detection.

Two representations of a flaw indication are shown. The upper two illustrations show a colour representation of a defect before and after signal processing (upper and lower illustration respectively). The yellow area indicates a region of high amplitude reflection from a defect. The unprocessed data in the uppermost picture show several other regions which could indicate a defect. Processing smooths out unwanted noise and the defect signal is displayed unambiguously in the second illustration.

The lower overlaid picture shows a set of processed time versus amplitude signals from an ultrasonic test on a turbine disc. The prominent peaks are the reflections from a defect. Other unwanted signals from surrounding material have been suppressed by computer processing.

The photograph of the disc and blade assembly is reproduced by courtesy of Rolls-Royce Ltd, Leavesden.

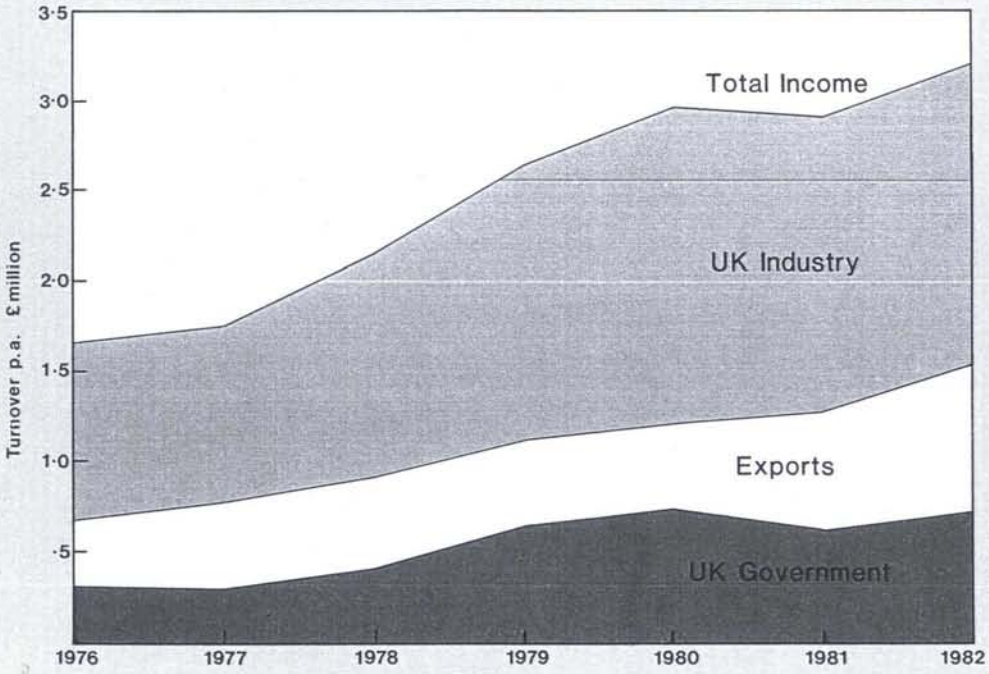
Facts on Fulmer

Fulmer Research Institute is an independent contract research, design and development organisation mainly concerned with the science and technology of engineering materials, processes for their manufacture, and products and components making the optimum use of material properties.

Most current projects are confidential to clients but they range from the development of new processes for the shaping of metals and polymers, the manufacture of new materials such as PVdF piezoelectric and pyroelectric film, the development and testing of building materials for internal and external use, the development and testing of new process and quality control equipment, the development and testing of new energy conversion and storage systems, of new materials for electronic applications, of new types of coatings and means of application and of many new instruments, devices and components of wide application in the engineering and chemical industries.

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 was founded in 1946 and since 1965 has been owned by the Institute of Physics. The Company and its subsidiaries employ about 230 people including 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 graphical presentation below, Fulmer has doubled its total income and its exports since 1976, while the income from Government contracts has remained an approximately constant 25%.



GROUP TRADING REPORT

	Turnover, £		Profit (Loss), £	
	1981	1982	1981	1982
Fulmer Research Laboratories Ltd. (including Fulmer Technical Services)	1,648,000	1,845,000	63,000	176,000
Yarsley Research Laboratories Ltd.	350,000	369,000	—	(55,000)
Yarsley Technical Centre Ltd.	794,000	883,000	44,000	38,000
Fulmer Components Ltd.	208,000	206,000	8,000	(5,000)
Reform Manufacturing Co. Ltd.	22,000	21,000	(5,000)	(8,000)
GROUP TOTAL (less Inter-Company Trading)	2,922,000	3,223,000	110,000	145,000

SEMI-SOLID METAL INJECTION CASTING

Semi-solid metal injection casting is a new process for making precision die castings which overcomes the defects associated with conventional pressure die castings cast from superheated liquid metal.

Semi-solid casting has been used to make components in existing steel dies designed for liquid aluminium alloys. The advantages of the semi-solid process include:

freedom from internal porosity. Thus the castings can be heat-treated to improve strength.

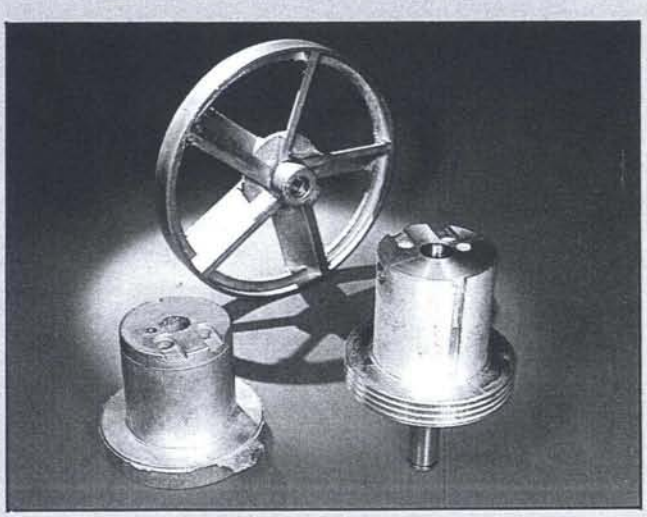
freedom from surface folds and cold shuts. A high quality surface is produced with a finish limited only by that of the die.

simpler die designs can be used because there is no need to incorporate the weir to prevent liquid metal entering the die prematurely.

lower latent heat retention and injection into the die cavity in a non-turbulent manner reduces thermal fatigue and increases die life.

With the support of the Materials and Chemicals Requirements Board of the Department of Industry and three industrial partners, a pilot plant for continuously casting the aluminium alloy with the required thixotropic structure has been established. Billets cut from this bar are then heated to the semi-solid state with 40-50% liquid phase and are transferred as a rigid material to the shot sleeve of a pressure die casting machine modified to accept the billet. The material is then sheared as it is injected into the die and flows as a viscous liquid through the runners and gates to fill the die cavity in a non-turbulent manner.

A variety of components have been made and these exhibit high quality, very low porosity, good dimensional accuracy and surface finish, and have passed industrial inspection. Several components made by this route are now in commercial use.



Components made by semi-solid casting.
Background: finished component.
Foreground: (left) as cast, (right) finished component

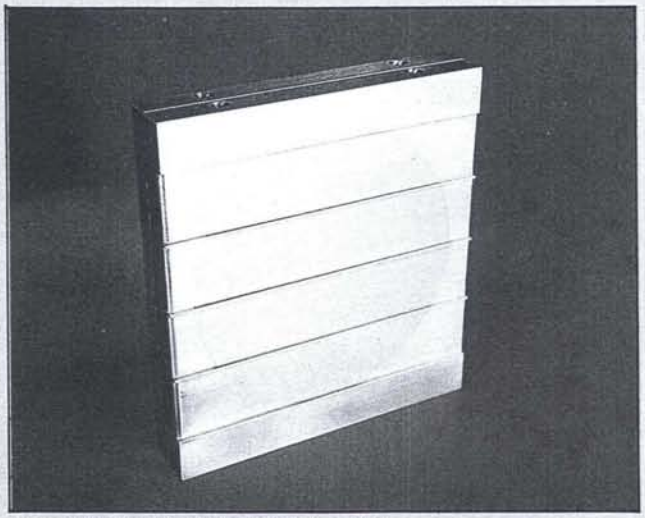
The process lends itself to automation and is suitable for making die castings from heat-treatable alloys and for shaping components not normally made by the die casting route.

The project has recently been renewed for a further two years with the support of additional industrial partners to enable the process to be transferred to industry and be evaluated under factory conditions.

HOT ISOSTATIC PRESSING

Fulmer has used hot isostatic pressing (HIP) for several years as a powder metallurgical processing tool and in 1980 installed its own laboratory-scale facility, capable of hot isostatically pressing a wide variety of materials and products at temperatures of up to 2000°C and pressure of 200 MPa (30,000 lbf/in^2).

The process comprises the simultaneous application of temperature and high inert gas pressure. It can be used to densify powder bodies (ceramic and metallic), heal porosity in castings and to diffusion bond different materials in complicated joint configurations. The use of research-scale equipment has enabled Fulmer's clients to benefit from cost-effective research programmes designed to consolidate new materials and establish feasibility on a small scale before embarking on a production-scale operation. The metallurgical response of materials is not particularly size-sensitive in HIP.



Two elements of the SNS Target Assembly

Current work is being carried out on the removal of shrinkage porosity in hot-section turbine components to improve the creep behaviour of castings in service.

The process is also being applied in the densification of refractory oxides, carbides and nitrides. Here the ability to apply very high temperatures and pressures extends both the range and properties of new and existing structural ceramics. This has involved Fulmer in developing the containment systems necessary to process these materials whilst retaining the correct shapes in components which otherwise would be difficult to machine.

Other current projects using HIP as a diffusion bonding technique include the manufacture of components for the nuclear industry. Because of the isostatic nature of the applied pressure, HIP has advantages over the conventional uniaxial technique in that complex joints with re-entrant faces and bonding surfaces at right angles can be made.

A good example of this has been the development at Fulmer of the target components used in the SERC Spallation Neutron Source currently under construction at the Rutherford Appleton Laboratory. The target 'stack' consists of an array of uranium 238 discs completely clad in zirconium alloy (Zircaloy-2). Some discs contain fine passages for thermocouples in wells lined with Zircaloy-2. Because of the need to remove the heat generated in the uranium targets through the wall of Zircaloy-2; a sound, thermally conducting bond is required between the uranium and Zircaloy-2; HIP has proved to be the only feasible way of achieving this.

Diffusion bonding combined with powder densification is also the subject of another investigation into the development of wear-resistant surfaces on less expensive substrates for the automobile industry.

cess Development

PIEZOELECTRIC AND PYROELECTRIC POLYVINYLIDENE FLUORIDE (PVdF) FILMS

For some years there has been considerable interest in piezoelectric and pyroelectric polyvinylidene fluoride (PVdF) film for advanced electronic devices. Commercial introduction of such devices and R & D in this field has been hampered because of the limited availability of the film.

Yarsley Research Laboratories, with its expertise in polymer film technology, undertook a project to develop processes for the manufacture of PVdF film and so create an indigenous U.K. source of the material available at a reasonable price. The project was sponsored by a consortium comprising major U.K. electronics companies, government departments and state-owned industry, all of which wished to use PVdF film.

As a result of this project, and following extensive trial manufacture, production facilities have been set up for the manufacture of piezoelectric and pyroelectric electroded PVdF films. Unpoled, unmetallised films are also available. These uniaxially oriented films exhibit excellent piezoelectric and pyroelectric properties and are physically robust. Ageing characteristics are believed to be superior to all commercial PVdF films previously available.

APPLICATIONS

Polyvinylidene fluoride is a thermoplastic fluorocarbon resin which, when mechanically stretched and then polarised in an electric field, is rendered both piezoelectric and pyroelectric. The mechanism for piezoelectricity is thought to be a ferro-electric-like response based on net alignment, through polar-isation of the highly polar carbon-flouride bonds in one of the crystalline forms of PVdF.

Since PVdF can be prepared as a flexible thin film which may be of large area, it can be used to construct novel types of transducer and other devices not previously possible using conventional single crystal and ceramic materials. It is also tough and chemically inert. Its high dielectric strength and thus high input capability for electrical power results in maximum electrical power per unit volume approximately five times greater than PZT ceramics in pulsed applications. In receiving trans-ducers, even greater advantages are possible (up to about 20 times, depending upon geometry and mode of operation).

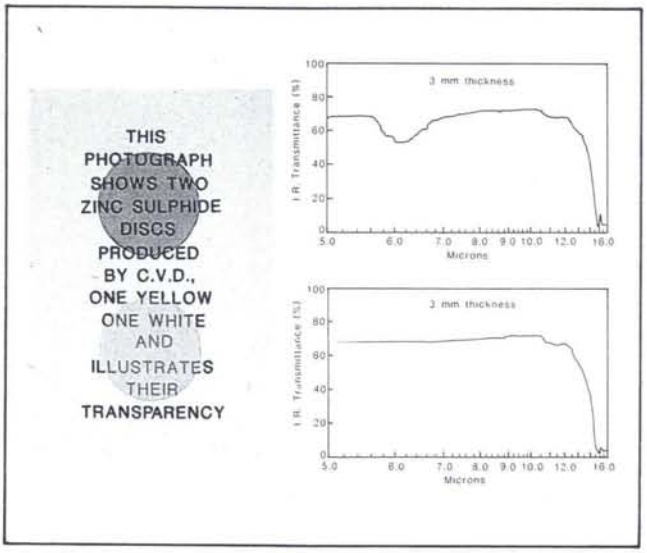
Components made by Plessey Limited using PVdF film. From right to left; noise cancelling microphone, transducer element, hydrophone, air crew headphone, ultrasonic microphone, telephone microphone. Photo: Courtesy Plessey Limited

These and other properties, including low mechanical and acoustic impedance, thermal stability and moisture resistance, give rise to a range of applications which includes the following:

- Electroacoustic transducers (stereophonic equipment)
- Underwater transducers
- Microphones and headphones
- Acoustic emission sensors (non-destructive testing)
- Biomedical sensors
- Infra-red sensors (fire alarms, intruder detection)
- Impact measuring devices
- Pressure sensing devices (e.g. safety systems)
- Traffic sensing devices
- Voltage-generating pressure switches
- Strain gauges
- Ultrasonic imaging
- Thermal imaging and laser beam profiling
- Accelerometers

Evaluation samples and further information on piezoelectric and pyroelectric PVdF films, which are now available on a commercial basis, can be obtained from Yarsley Technical Centre Ltd.

INFRA-RED TRANSMITTING WINDOWS



Fulmer Research Laboratory's specialised knowledge in chemical vapour deposition technology is currently being applied to the fabrication of zinc sulphide windows with high transmission in the infra-red.

The components are produced by reactive deposition on a heated mandrel. Flat or domed windows may be obtained by variation of mandrel shape.

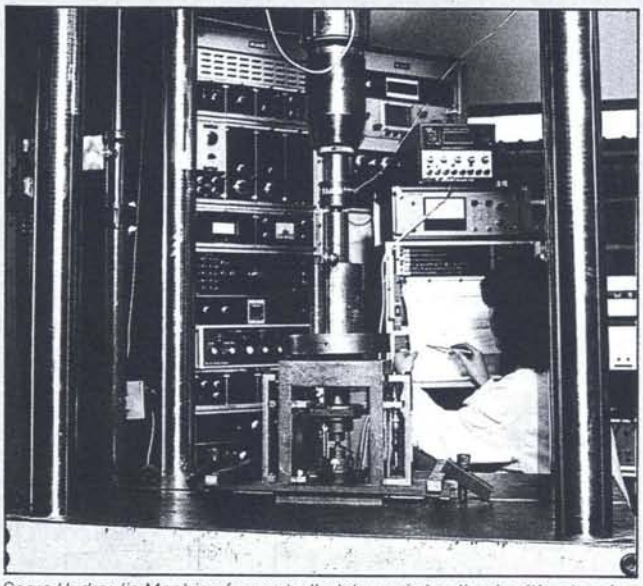
Two types of zinc sulphide are being produced - a white type and a yellow type. Both transmit in the 1-11 μm region of the infra-red, but the yellow has a narrow absorption band around 6.0 μm. The two types also differ in other physical properties, particularly mechanical. Limited amounts of the materials will soon be available for evaluation.

FULMER TECHNICAL SERVICES

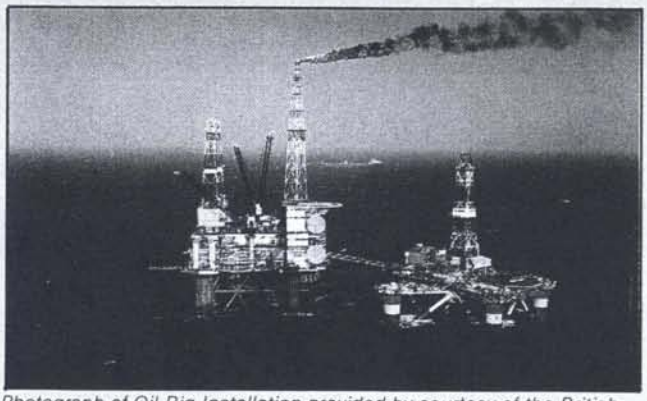
Fulmer Technical Services is a Ministry of Defence approved test-house and uses the staff and facilities of Fulmer Research Laboratories, listed under NATLAS Registration No. 0050.

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.



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



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

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. 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.

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.

HIGH RESOLUTION ULTRASONIC EXAMINATION

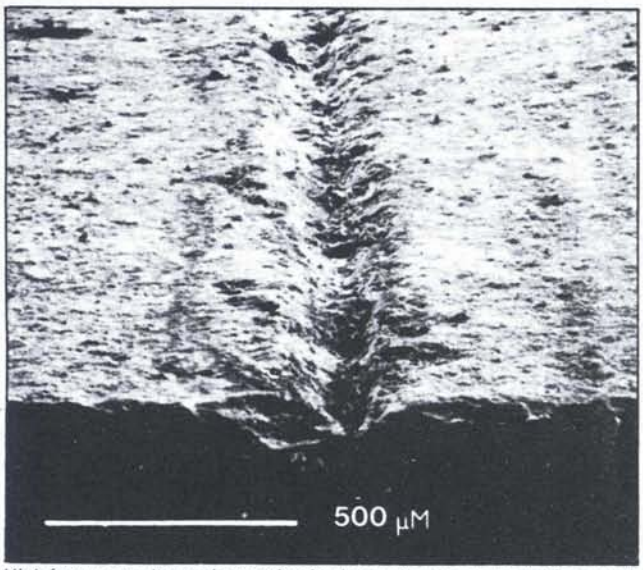
For several years Fulmer has been involved in research and development in the field of non-destructive examination. This work has revealed the need for a method of examining specimens, and features within specimens, which are small by normal non-destructive examination standards. Consequently, a facility using unconventionally high ultrasonic frequencies is under development at Fulmer.

Standard ultrasonic examination methods operate in the 0.5MHz to 20MHz frequency range. Even the upper limit of this range does not provide sufficient spatial resolution for many applications and consequently equipment operating at 30MHz and 50MHz has been assembled.

Two types of operation are available; a manual mode using a 50MHz hand-held contact transducer and a scanning immersion mode using 30MHz focussed transducers.

The contact transducer produces sound pulses of approximately 60ns duration. It will detect features as small as approximately 0.5mm diameter and 0.2mm below the specimen surface. This system has been used extensively to examine the diffusion bond between a metallic cladding and a substrate; the cladding is 0.25mm thick. Failures in the bondline are readily revealed and examination of the shape of reflected waveforms enables sound bonds to be characterised, for instance for the presence of intermetallic compounds.

The 30 MHz and 50 MHz focussed transducers have focal spot diameters of 0.15mm and 0.1mm respectively. These transducers will detect extremely small features (by normal examination standards). This capability is particularly valuable for structural ceramics, an increasingly important class of material. In one study at Fulmer, irregularly shaped inclusions of 0.075mm dia and cracks and scratches of 0.05mm depth



High frequency ultrasonic examination located and measured this scratch on the bore of a 2mm wall-thickness ceramic tube.

were identified in a ceramic tube of 2mm wall thickness. The photograph shows one of the scratches so identified, which could not have been found by any other ultrasonic system.

The very high spatial resolution of these facilities coupled with computer control and data storage provide a hitherto unavailable service to industry. Important successes in bond examination and ceramic quality control have already been demonstrated. These techniques will, with continuing development and growing experience, reduce many 'uninspectable' requirements to routine procedures.

Testing and Consultancy

YARSLEY TECHNICAL CENTRE

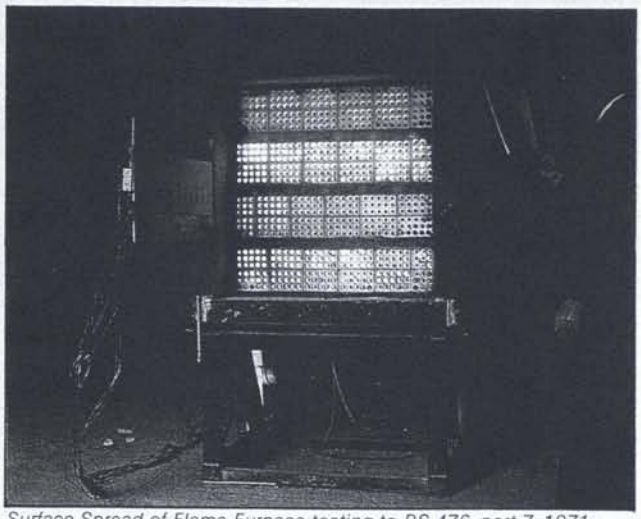
The testing laboratories of Yarsley Technical Centre are listed under NATLAS Registration No. 0036 and are also fully approved by a number of other Agencies including the British Calibration Service and Civil Aviation Authority.

SERVICE PERFORMANCE OF NON-METALLIC MATERIALS

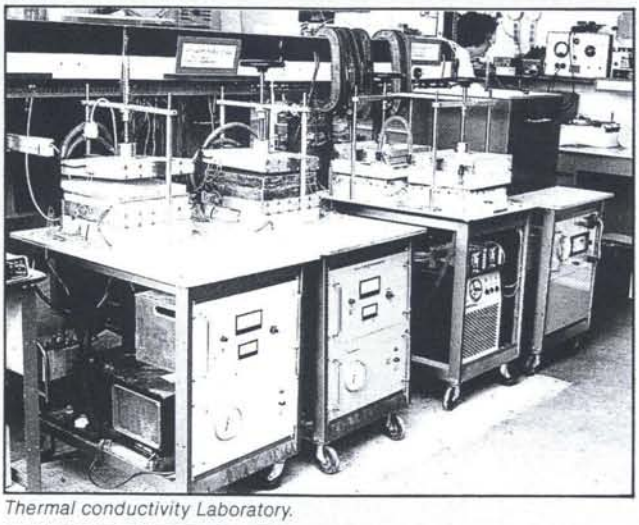
Yarsley specialise in standard and non-standard testing of all types of non-metallic materials, and the products and components manufactured from them. A wide range of facilities is available for mechanical testing, chemical analysis, wear and corrosion testing and for testing under conditions of controlled 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 Yarsley offer a comprehensive service for the design, development and testing of moulds, including the use of computer-aided design techniques. Yarsley 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

Yarsley 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 Yarsley'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. Yarsley is ideally placed to assist the building industry to realise the full potential of plastics.

FIRE AND THERMAL PROPERTIES OF MATERIALS

Yarsley 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 funiture, 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:

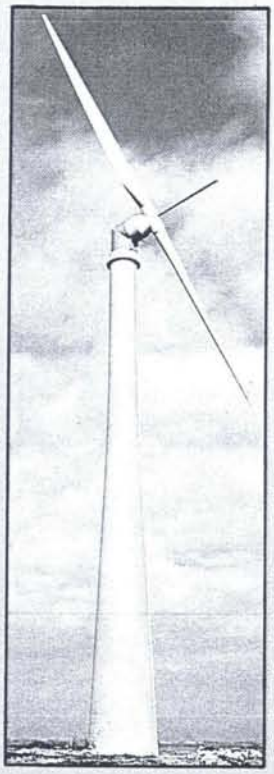
the installation of a precision rolling facility for metal foil,
the design, procurement and installation of an automated injection mould for a toy manufacturer,
the setting up of an injection moulding factory for housewares in Saudi Arabia.

Energy Studies

MATERIALS FOR AEROGENERATORS

In recent years interest in the generation of electricity from renewable energy sources has resulted in the development of technology to harness energy economically from wind. Known as aerogenerators, highly advanced windmills, such as the one shown below, can generate several megawatts of electricity at windy sites. Arrays of several tens or hundreds of these machines have the potential to provide a significant amount of cheap, clean energy. Fulmer has recently carried out a survey of materials suitable for use in the construction of MW sized aerogenerators.

Cost-effective generation of electricity from wind requires aerogenerators which are capable of producing power in excess of 1 MW in favourable wind conditions, and which can operate reliably for thirty years. Such aerogenerators have blades which may exceed 50m in length, and the materials problems which arise are exacerbated by a marine environment if the aerogenerators are to be sited off-shore, as is likely to be the case in the UK.



The Fulmer study revealed that there is no fundamental reason why aerogenerators constructed from currently available materials should not operate reliably for thirty years, provided that fabrication and maintenance are carried out to the highest possible standards. However, several gaps in existing materials information were identified, particularly regarding materials for the blades, and further research in these areas would enable more confident use of materials and more cost-effective design.

The blades of an aerogenerator are subjected to wind, gravity and inertia loading and thus need to be able to withstand high wind speeds, cyclic stresses, and start-up and shut-down loads. Blades made of steel, wood or glass-fibre reinforced polymer (GFRP) can be designed to meet these considerable requirements, but some uncertainties in materials behaviour remain. These include:

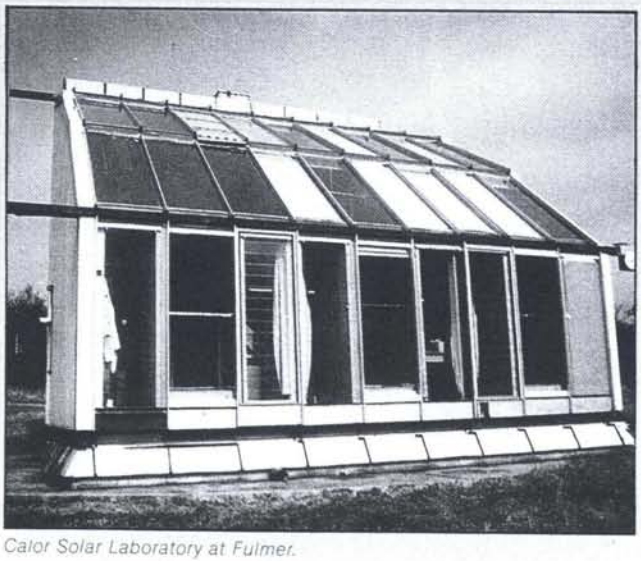
- The effect of a salt spray environment on fatigue of welded steel;
- the behaviour of GFRP at cyclic strains greater than conventional design limits;
- the safe operating limits for advanced wood composite constructions.

Components other than the blades of aerogenerators, such as the components of the drive train, generating equipment and supporting tower, can be constructed from conventional materials by conventional engineering methods, and it has been found that the requirements for materials research are relatively minor. Throughout the study, however, the Fulmer team have found examples of failures caused by insufficient attention to engineering detail. Critical engineering aspects which have been identified as requiring further investigation include vibrational responses and resonances of components and machines, controlled flexibility and damping provided by electrical means, and reliability of hydraulic control mechanisms.

It is believed that the results of the Fulmer survey, the first of its kind, will serve as a useful guide to those involved in planning and constructing large aerogenerators. The survey has fulfilled an important function in identifying materials problems which are likely to arise, and has brought the possibility of useful electricity generation from the abundant and clean resource of wind one step closer. The findings of this survey have been published in the British Wind Energy Association Conference, March 1983.

PASSIVE SOLAR HEATING

The current trend in house building to produce low energy houses has been clearly demonstrated at the UK Home World Exhibition (May 1981) at Milton Keynes. A particular feature with many designs was the use of glazed apertures, with patent glazing systems. These glazed apertures demonstrated the desire of architects to increase the passive solar gain of housing as well as adding to the architectural features.



Calor Solar Laboratory at Fulmer.

The solar gain achieved by using these designs can, however, be significantly increased if a solar blind is used to prevent the escape of energy (the thermal diode or intelligent window principle). Estimates of the amount of energy saved vary according to the design of the house and the operation of the thermal diode.

A further saving in energy can be provided by adding thermal storage materials to the glazed roof aperture. A phase change material (PCM) store can be positioned directly in a glazed aperture for new house construction or as a retrofit package to existing houses. Materials with a phase change temperature close to the desired temperature can provide 10 days complete heat in a superinsulated building and 4-5 days partial heat in a standard building. The use of PCM in this application however is for purely passive heating without fan assistance to circulate the air. By using fan assistance higher temperature PCM stores can be used more efficiently when combined with a solar blind.

A Fulmer solar test laboratory used for the development of active solar heating systems for Calor Gas has now been converted to carry out a programme on passive solar heating for the EEC.

Technology Transfer

A HELPING HAND ACROSS THE SEA - TECHNICAL ASSISTANCE TO TURKISH RESEARCH INSTITUTE

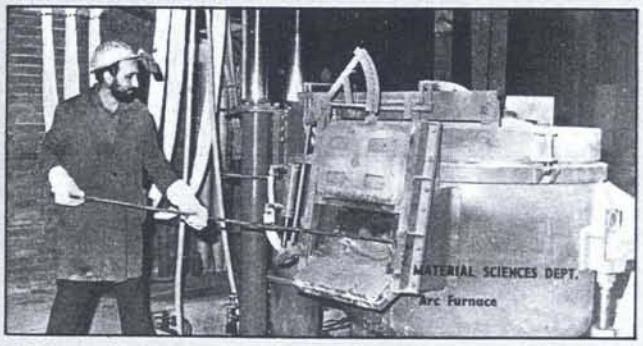
Fulmer Research Laboratories have completed successfully another assignment for the United Nations Industrial Development Organisation (UNIDO). This time technical training was provided for the Marmara Scientific and Industrial Research Institute (MSIRI) near Istanbul in Turkey.

MSIRI was established at its present location on the coast of the Sea of Marmara in 1972 to accommodate small units previously operating at various Universities. The Scientific and Technical Research Council of Turkey (TUBITAK) has gradually expanded the complex so that there are now over 32,000 square metres of laboratory area and a staff of more than 500.

The fields of activity at the Marmara Institute are very extensive. The eight departments include such topics as Applied Mathematics, Operational Research, Electronics, Nutrition and Food Technology and, of particular interest to Fulmer, Materials Sciences.

Over the last ten years UNIDO have provided assistance to MSIRI in three ways:

- Purchase of laboratory equipment
- Visiting consultants for in-house training.
- Travelling Fellowships for overseas training.



500 kg Arc Furnace at MSIRI

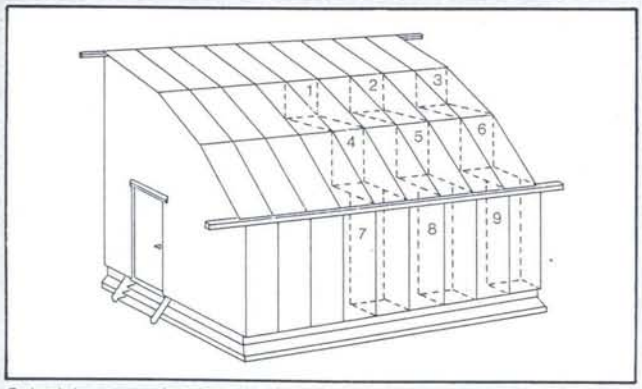
The laboratories are now generally very well equipped and manned by an enthusiastic staff. Several areas had been identified where additional training was needed to enable MSIRI to provide a better service to Turkish industry. UNIDO therefore engaged Fulmer to provide a specialist programme of assistance to the Materials Sciences Department of MSIRI.

Fulmer's brief covered a number of areas:

- Melting and casting of alloy steels.
- Rolling and extrusion theory and practice.
- Manufacture of rolls.
- Setting up a shell moulding facility using the Croning process.
- Manufacture of electrical steels.
- Electron microscopy and metallographic techniques.
- Texture analysis by X-ray diffraction.
- Setting up a corrosion laboratory and technical advisory service.

The overall programme entailed twelve man months of visits to Turkey by a team of ten specialists, and twenty-five man months training in the U.K. for twelve members of MSIRI staff. This whole operation was fairly complex as it was necessary to ensure that visits to Turkey did not coincide with U.K. training programmes for relevant people and that National Holidays and the summer closure at MSIRI did not interrupt the programmes.

During their visits to Turkey the team members provided training in the form of demonstrations and seminars in addition to more personal man-to-man discussions. Opportunity was also taken to visit industrial establishments for on-the-spot advice and trouble shooting and to demonstrate to MSIRI staff the importance of maintaining close links with industry. The Fellowship's training programmes encompassed laboratory training and demonstrations as well as tutorials and work visits.



Solar laboratory showing position of individual test cells.

The programme will combine the use of a solar blind with a PCM store in a glazed roof space to determine the benefits likely to be achieved. The aims of the project are to determine:

1. The total usable energy gain with:
   (a) a closed glazed roof-space collector.
   (b) a closed glazed roof-space collector with a PCM store and an automatic roller blind.
   (c) a closed glazed roof-space collector with PCM store but without roller blind.
2. The effect of roof pitch using the above test conditions.
3. The effect of using a vertical glazed conservatory window and the above test conditions.

ENERGY EFFICIENCY IN PRODUCTION

Fulmer has carried out a comparison of the energy efficiency of conventional and novel routes for the production of engineering components for the Department of Energy.

The use of energy in the manufacture of metallic components by novel processes involving the processing of semi-solid slurries has been estimated for materials produced by both melting and powder routes. These have been compared with estimates of energy usage made for competing conventional processes, e.g. diecasting, forging and powder metallurgy.

The estimates are dominated by the energy used in melting processes and in the efficiency of material usage. Diecasting or forging of semi-solid billets can provide energy savings of about one-third and produce fully dense alloys. This is competitive with pressed and sintered alloys of greater porosity and lower density.

The advantages of semi-solid processing of steel are less clear because of lack of practical exploitation of the route.

Processes which involve attrition melting like mechanical alloying or chopping and grinding of swarf to make powder for reconstitution as solid material are not attractive from the point of view of energy savings as such. However, in the case of swarf treatment, there may be overall benefits by the compensating effect of improving material utilisation. Melting and atomising the swarf could provide a more attractive route from the point of view of energy savings provided that it could be integrated with the production route.

The adoption of the semi-solid processing route in the aluminium component industry could lead to substantial savings in energy.