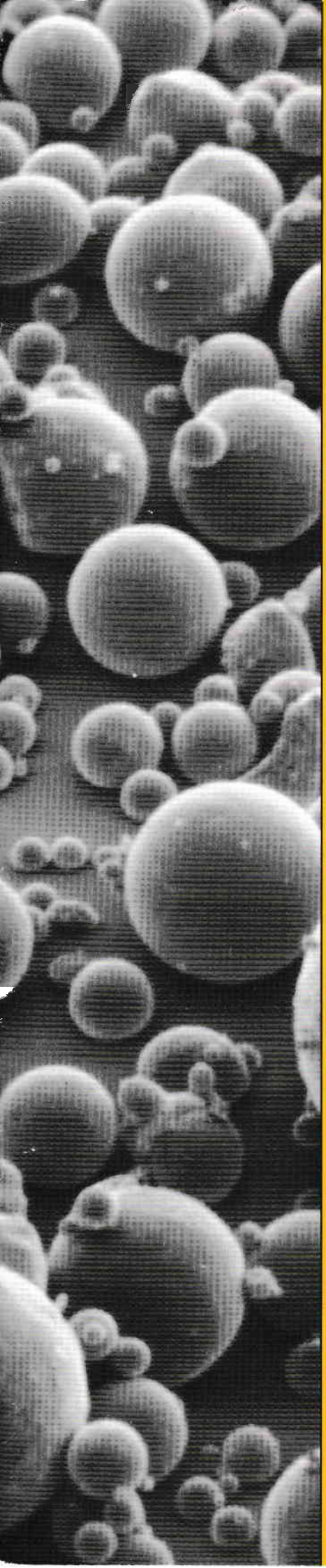


BNF-Fulmer

The Materials Centre

BNF Fulmer

BNF-*Fulmer*

Wantage Business Park, Wantage, Oxfordshire* OX12 9BJ, *England
Telephone: 0235 772992 Fax: 0235 771144 Telex 837166 BNFMTCG

The Company

BNF-Fulmer, Fulmer Systems and Fulmer CVD are trading names of businesses owned by BNF Metals Technology Centre, and were formed when BNF Metals Technology Centre, Fulmer Research Ltd, Fulmer Systems Ltd and Fulmer CVD Ltd combined in the second half of 1990.

The new businesses combine the majority of the previous activities of the two organisations.

The Businesses

BNF-*Fulmer* - is an independent Contract Research and Development company serving the materials industry worldwide.

In addition, it provides testing, consultancy, and litigation services for a wide range of industrial and commercial activities.

***Fulmer* Systems** - combines the former activities of Fulmer Systems Ltd, and other manufacturing operations.

It produces for sale a number of products resulting from research and development projects which have been developed commercially.

***Fulmer* CVD** - continues the former activities of Fulmer CVD Ltd, providing commercial CVD manufacturing facilities at its site in Slough.

Markets Served

The company provides research, development, engineering, consultancy and technical services in the following areas:-

Advanced Robotics
Aerospace materials
Analysis (metallurgical)
Battery technology
Ceramics
Chemical vapour deposition (CVD)
Coatings development
Combustion control in fossil fuel furnaces
Composites (MMC, CMC, CC)
Continuous casting
Electronic materials
Energy targeting and monitoring
Environmental monitoring and protection
Failure analysis
Foundry technology
High temperature materials
Instrumentation
Litigation
Magnetic media
Materials selection
Mathematical modelling
Mechanical testing
Metal working
Microfabrication
Non-destructive testing (NDT)
Non-ferrous foundry technology
Optical and electron microscopy
Powder metallurgy
Quality assurance
Sensor development
Specialised software development

Membership

Companies and other enterprises having appropriate interests are eligible to become subscribing members of BNF-Fulmer, this status providing a number of benefits.

At present over 200 companies and organisations worldwide make up the membership, their interests being spread across a wide range of industrial activities, from base metal producers, through metal semis fabricators and foundries, to end users such as aerospace, engineering and electronics.

The major proportion of the subscription income is allocated to research and development work aimed at being of direct benefit to members, and these programmes of work are overseen and guided by committees drawn from the member companies.

The results of the work funded in this way are confidential to members.

Client base and confidentiality

The company undertakes work funded by single clients, and by consortia of companies having a common interest ("multi-client"), in addition to the membership subscription funded programme.

Work is also undertaken for Government, through its various agencies (DTI, MoD, DoE, ETSU, etc). This can take the form of 100% funding for specific work or as part-support for industrially sponsored projects.

The company also participates in projects part-funded by the European Community, under the various schemes supported from Brussels, e.g. BRITE/EURAM, EUREKA, etc.funding for specific work or as part-support for industrially sponsored projects.

In all cases, the results of the work are strictly confidential to the companies providing the financial support.

The company is an active member of the Association of Independent Research and Technology Organisations (AIRTO) and is becoming increasingly involved in the European Association of Contract Research Organisations (EACRO) as part of its commitment to achieving a strong liaison with the European Community.

Company structure and management

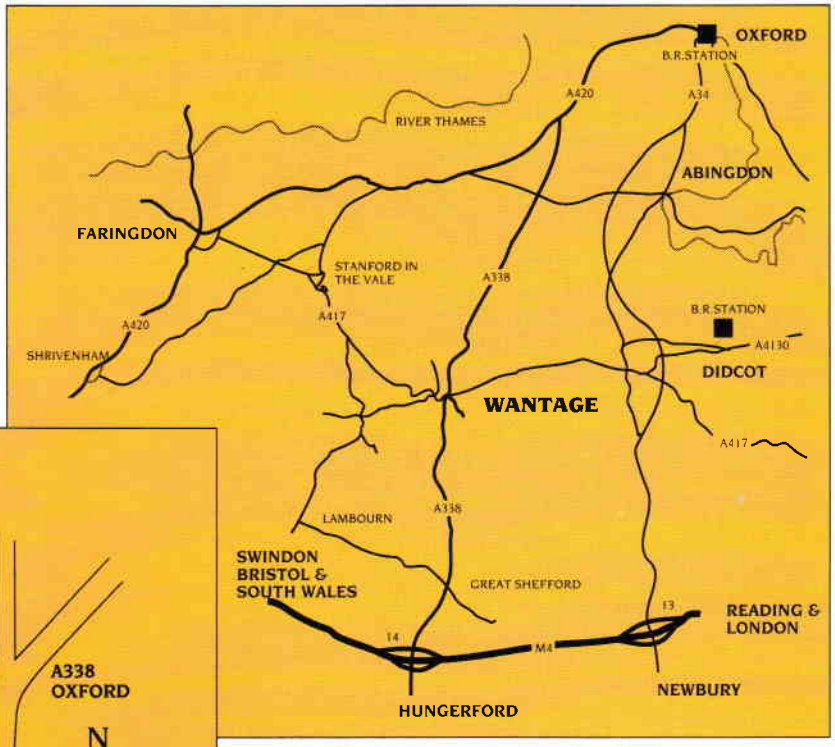
BNF Metals Technology Centre, the holding company, is a company limited by guarantee, and is not permitted to distribute profits to its members, any surpluses being re-invested in the business. It is controlled by a Council consisting of representatives of the membership plus other invited members drawn from industry, commerce and academia.

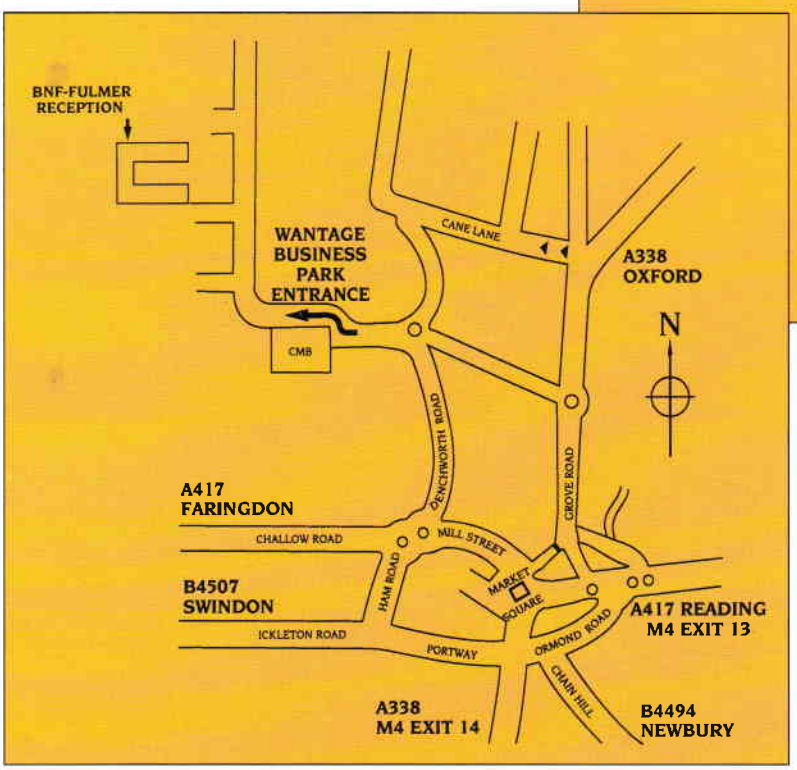
Principal Executives

Chairman - M I M Watson
Chief Executive - Dr W H Bowyer
Finance and Company Secretary - P R Frances

The size of the businesses

The present staff complement is 120, of which eleven are at the Slough site, the remainder being at Wantage.





Instrumentation and Sensors

Manager - P D Wilson

The Division provides a wide range of R & D, testing and consultancy services covering sensor and transducer technology, microfabrication, NDT systems, and related instrumentation.

Sensors

BNF-Fulmer has extensive experience in developing novel sensors for many market sectors. Examples of developments include:

Wear sensors - based on thin, resistive metallic films, monitor wear debris in fluids, magnetic tape, paper and floppy disk abrasivity.

Piezoelectric and Pyroelectric Transducers - these sensors utilise the electroactive polymer PVdF and include ultrasonic transducers, medical sensors, and hydrophones

Optical Beam Gas Sensors - intrinsically safe and based on the absorption of infra-red, generated by light emitting diodes.

Silicon Pressure Sensors - in-house microfabrication capabilities have been used to exploit the mechanical properties of silicon to produce new silicon capacitive pressure sensors - high performance, low cost sensors amenable to mass production.

Microfabrication

The Division has employed techniques developed for the production of semiconductor electronic components to produce a variety of precision three dimensional mechanical structures on a micrometre scale. This technology is at present being employed primarily to develop new silicon based sensors although other products and materials have been developed and utilised, for example TaC field emitters.

Instrumentation

The Division has developed instrumentation to fully exploit the performance and capabilities of its own and commercially available sensors and transducers.

Specialist skills include:

- Sensor interfaces and signal conditioning
- Analogue and digital system interfacing, data capture and control
- High speed digital and analogue designs
- Hardware and software computer implementations
- Engineering and integration of electrical, mechanical and software components
- Instrumentation for the metals industry

Non-destructive Testing

The Division has a particularly strong expertise in high frequency ultrasonic inspection and eddy current inspection.

This expertise has been applied to various specialist developments including many difficult non-routine requirements.

Consultancy, design, development and testing services are offered. Also:

High Resolution Inspection and Imaging of:

- Bonds - adhesive, brazed or diffusion
- Coatings
- Advanced materials - including metal matrix and ceramic matrix composites
- Electronic components and devices

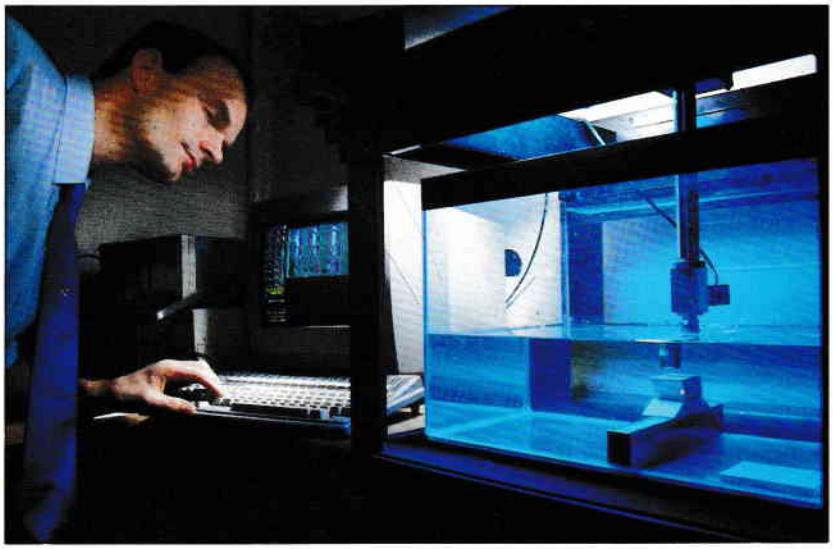
The Division also offers services in:

- Radiation effects on materials and devices
- Acoustic Emission
- Physical Vapour Deposition - Sputtering, Electron Beam andResistive Evaporation - under clean room conditions

Top right
Microfabrication is carried out in clean room facilities.

Top Left
Capacitative pressure sensor device

Below
High frequency ultrasonic inspection.



Chemical Metallurgy

Manager - D W Davies

The Division's activities can conveniently be divided into three main areas:

Chemical Metallurgy

Activities are concerned with the environment, predominently effluents, solid waste, and potable water.

Typical projects are:

- Biosorption processes to reduce the heavy metals content of aqueous effluents and potable waters
- The development of freely-machinable lead-free copper alloys for the manufacture of fittings used in pipework systems conveying potable water
- Cleaning or treatment of used foundry sand to reduce heavy metal and organic contamination to an acceptable level

Top
PC driven rig for battery plate alloy performance assessment

Below
Offshore applications impose particularly arduous service conditions on all materials

Battery Technology

The storage of electrical power is costly and, for traction applications, has an associated weight penalty. While batteries have been used for over a century, developments are still continuing.

Current development work includes:

- Improvements in efficiency and reliability of high capacity lead acid batteries used in traction applications
- Causes of premature capacity loss during deep discharge cycling of antimony-free lead acid batteries
- Development of reinforced lead grids for lead acid batteries, to reduce weight
- Development of specific corrosion inhibitors to extend the useful life of aluminium battery anodes
- Assessing the performance of conducting polymers for use as coatings in electrowinning anodes, and in battery applications

Corrosion and Surface Engineering

The Division has an international reputation for the excellence of its work in:

- the determination of the fundamental mechanisms of corrosion - in the atmosphere, fresh water, sea water, and other media
- the development of testing methods to determine corrosion susceptibility
- the development of surface treatments or coatings to modify the behaviour of components in service, either to prevent corrosion or improve other performance characteristics

Particular areas of expertise are:

- The performance of copper and copper alloys in both fresh water and sea water systems
- The development of rapid test techniques to assess materials' performance in corrosive conditions
- The development of long-life coatings to enhance the performance of condenser and heat exchanger tubes
- Improvements to zinc galvanised coatings

Composites and CVD

Manager - D P Bashford

Composites

BNF-Fulmer has many years of experience in the production of composites having either a metal matrix (MMC), ceramic matrix (CMC), or inorganic matrix, e.g. carbon-carbon (C-C).

Methods of manufacture for which equipment and expertise are available are:

- Melt infiltration by aluminium or magnesium matrix alloys:
  - of wound continuous fibre preforms, using the BNF-Fulmer patented Vacuum Infiltration Gas Pressurisation (VIGP) process
  - of pre-placed short fibre preforms
  - of continuous linear fibres or tows to produce unbroken lengths of shaped section (pultrusions)
- Casting of near net shaped components from particulate reinforced aluminium alloy:
  - by gravity diecasting
  - by investment casting
- Compaction and sintering, or hot isostatic pressing (HIP), of:
  - metal powder plus particulate reinforcement
  - ceramic powder plus short ceramic fibre reinforcement
  - powder, particulate or short fibres of reinforcement coated with matrix by chemical vapour deposition (CVD)
- Hot extrusion of HIP'd powder mix billets
- Continuous cold extrusion of powder mixes by the CONFORM process
- Chemical vapour infiltration (CVI) of partially densified ceramic fibre preforms

Chemical Vapour Deposition (CVD)

Chemical Vapour Deposition (CVD) may be defined as the deposition of solid material from the vapour phase brought about by a thermally induced chemical reaction.

When applied to a solid substrate, a coating on the surface is produced. When applied to a partially densified powder or fibre compact, deposition will take place in the interstices, until ultimately a solid, fully densified shape results. This is termed Chemical Vapour Infiltration (CVI).

Rates of deposition are often sufficiently high to permit the growth of relatively thick coatings as intermediates in the fabrication of free standing shapes.

BNF-Fulmer has both research and production facilities. Research programmmes are based at Wantage, production is based at the Slough site of Fulmer CVD.

Facilities

The Division has a comprehensive range of deposition facilities, totalling ten in all, based on low pressure CVD (LPCVD) up to 2100°C. These allow the following to be achieved in refractory metals and ceramics:

- Protective, high temperature coatings
- Overlay coatings
- Diffusion coatings
- Infiltration of ceramic matrix composities
- Free standing components
- Coated powders, particulates and fibres

MAIN MATERIALS DEPOSITED BY CVD
Graphite (PG)
Boron Nitride (PBN)
Tungsten (W)
Tantalum (Ta)
Silicon Nitride(Si_3N_4)
Silicon Carbide (SiC)
Aluminium Nitride (AlN)
Silicon Carbide-Silicon Carbide composites (SiC-SiC)

CVD *Development rigs*

Materials Processing

Manager - G P Yiasemides

The Division incorporates the metal working and powder metallurgy facilities of the company, and also has some specialised manufacturing capabilities.

The equipment available is representative of plant used in industry for commercial production. Results achieved are therefore directly translatable by clients into their own production environment, without the need for a "scaling up" exercise, which can be lengthy and expensive.

Plant available for research/development includes:

Metal Working

- 750 tonne instrumented hot extrusion press
- cold drawbench
- bull blocks
- 'CONFORM' continuous cold extrusion machine
- small rolling mills for flats or sections

Powder Metallurgy

- Water atomising powder manufacturing rig
- High energy inert gas atomising powder manufacturing rig
- powder conditioning and processing equipment
- hot and cold isostatic presses
- Mechanical attritors
- Horizontal screw, plastic injection moulding machine

Specialised Manufacture

- Vacuum melting and casting furnace
- Electron beam welding unit
- Investment casting equipment
- Equipment for the manufacture of solid electrolyte cells for oxygen measurement in molten metals

Typical project work undertaken:

- Extrusion dies:
  - design
  - coatings/surface treatment to improve surface finish of aluminium extrusions
  - bridge dies for producing hollow copper and copper alloy extrusions
  - development of electro-machinable ceramics
- CONFORM:
  - production of copper sections
  - production of copper tube
  - production of brass wire
  - production of high strength aluminium sections from mechanically alloyed powder
- Powder metallurgy:
  - development of high strength copper and aluminium alloys by mechanical alloying
  - development of novel alloys by rapid solidification
  - manufacturing technology of intermetallics
  - production of net shaped components by metal injection moulding (MIM)
  - consolidation and shaping of ceramics
- Joining:
  - production of high integrity assemblies by diffusion bonding

Top left
High energy inert gas powder atomiser

Top right
750 tonne extrusion press

Bottom
Hot isostatic pressing

Casting and Computer Modelling

Manager - D W Townsend

Pioneering work on alloy development, melt quality control, running, gating and feeder placement has earned the Division the reputation of being the "Centre of Excellence" for non-ferrous foundry work in the U.K and has led to the extensive application of BNF-Fulmer technology to industry in the UK and overseas.

Shape Casting

The division is able to manufacture shaped castings by virtually all the casting process routes including sand, investment, gravity, low pressure and high pressure processes on industrial scale equipment.

Continuous Casting

BNF-Fulmer has been pre-eminent for the past quarter of a century in the development of continuous casting techniques for casting non-ferrous alloys.

Three industrial scale continuous casting machines are available on site for experimental and development work.

Metals cast on this equipment include alloys of copper, zinc, aluminium, lead and magnesium.

Additionally the Division designs, and supplies commercially, mould systems and associated instrumentation, for retrofitting to existing continuous casting machines. Also, in conjunction with a machine supplier, new continuous casting plants are supplied, incorporating BNF-Fulmer high efficiency mould equipment.

Mathematical Modelling

Casting

Comprehensive on-site modelling facilities have recently been installed. The object of this activity is to increase the cost effectiveness of the processes by the use of computer predictions to cut down on expensive 'trial and error' experimentation.

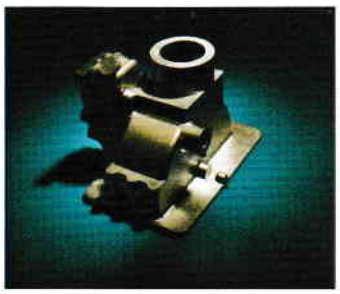
Other processes

Modelling techniques are currently being applied to:

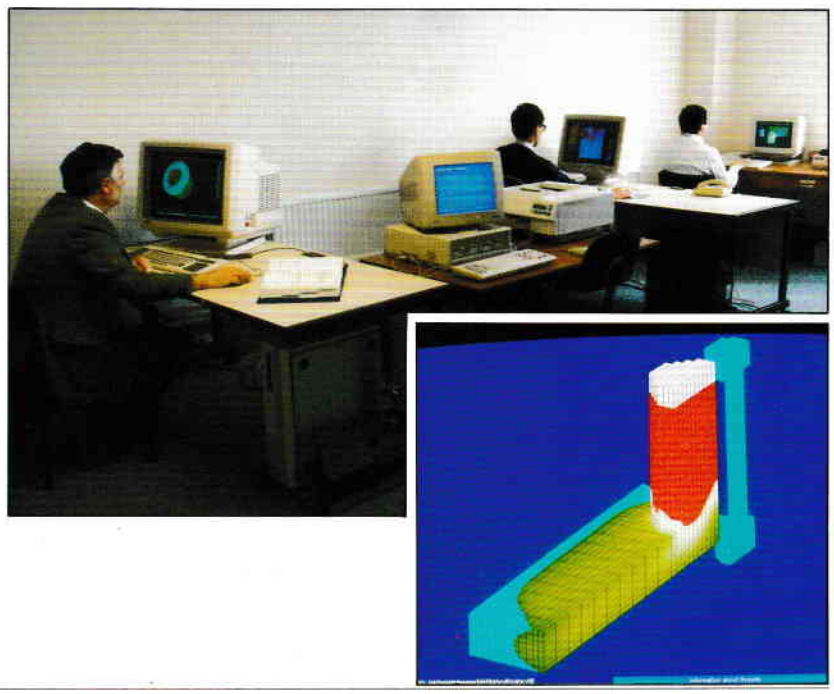
- the development and use of computer codes to describe metal flow and wear on dies in the extrusion process
- the development and use of a computer code to describe the rod straightening process
- the use and testing of codes to describe water flow in pumps.

Other activities of the Division

- Environmental monitoring of worker exposure, workplace and stack emissions
- Energy saving - automatic control systems have been designed, supplied, installed and commissioned for combustion control in fuel fired furnaces.
- Energy monitoring and targeting - energy audits of metallurgical operations are undertaken, targets set, and management programmes introduced to ensure these targets are achieved.
- Process monitoring and control - machines and processes have been monitored and control systems introduced to ensure reproducible production conditions



Top
Particulate reinforced aluminium MMC investment casting



Bottom
Mathematical modelling laboratory

Robotics and Engineering

Manager - Dr P A Finlay

This Division trades as Fulmer Systems and is engaged in its own programmes of research and development, and in addition manufactures for sale items of equipment and instrumentation which have been developed by other Divisions within the company.

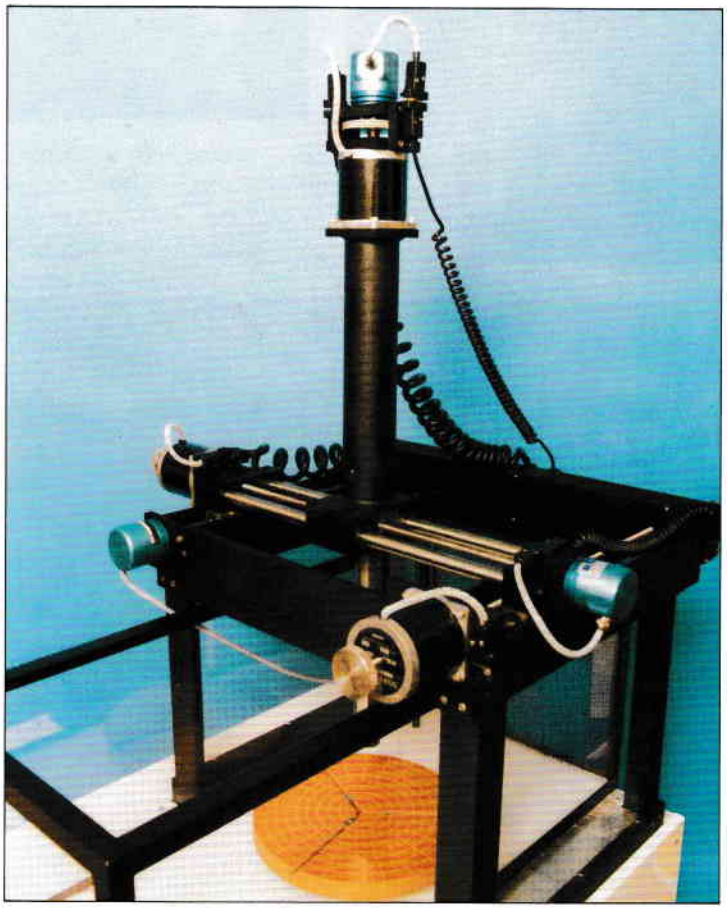
Measurement and Control

The Division has experience of developing equipment for on-line metrology and quality assurance equipment, including dimension gauging, non-destructive inspection and surface defect detection in the non-ferrous metal industries and elsewhere. Measurement equipment can be interfaced to a central computing facility for QA records, or to the production process controller for alteration of conditions.

Top
Robotic paint spraying

Centre
Acoustic emission rig for detecting cracks in structural members

Bottom
Scanning Acoustic Microscope -SAM- manufactured by the Division



Materials Handling Equipment

The design and manufacture of special purpose machines for transferring, handling or processing equipment is undertaken using BNF-Fulmer computer aided design work stations and in-house manufacturing facilities.

Automated Inspection

The Division manufactures for sale the Scanning Acoustic Microscope. Its main field of application is for precision NDT (Non destructive testing). This system produces ultrasonic images of engineering components and has a step size of 7.5 microns.

Special purpose systems for inspecting mass produced components and work pieces of unusual size are designed and manufactured to order.

Factory Automation and Robotics

The robotics and engineering division has experience of factory automation projects ranging in size from special purpose robot cells for work piece processing and assembly, through to fully integrated production and warehouse automation.

Mathematical Modelling

The Division undertakes advanced modelling tasks based on finite element analysis. A current project involves modelling the human spine as an aid to the diagnosis and treatment of skeletal disorders. Modelling of anistropic materials such as polymer based composites has also been successfully undertaken.

Advanced Robotics

The Division has been active in the development of advanced third generation robots designed to work in hazardous and unstructured environments. Each of these projects is the subject of collaboration being undertaken by a number of companies and universities under the leadership of Fulmer Systems, which is Project Manager for the Medical Sector of the DTI Advanced Robotics Initiative.

Applied Materials

Manager - Dr R I Saunderson

This division is divided into two groups, providing services in Materials Diagnostics and Data Storage respectively.

Materials Diagnostics

The Materials Diagnostics Group is a team of highly experienced materials engineers selected specificially to provide a unique service in materials failure diagnosis and consultancy. This group offers an integrated package of services designed to tackle materials problems on a broad front encompassing failure prevention, failure analysis and support for litigation.

The key services offered are:

- Failure diagnosis
- Mechanical testing
- Chemical analysis
- X-ray analysis
- Corrosion studies
- Optical and electron-optical examination
- Support for litigation

The laboratory is NAMAS accredited, routinely carrying out work for UK government bodies and many leading plc's. The group has particularly strong links with the petrochemical, marine and general engineering industries, as well as the aerospace, transport and local government sectors. Wherever materials or component failures arise, the group can offer effective, professional technical support.

Data Storage Media

The Data Storage Group draws on a wealth of experience in the data storage media industry. Activities fall into three broad areas- media science and technology, test and measurement and consultancy and training.

Science and Technology

Work in this area includes all forms of particulate and thin film magnetic media, optical media, substrates, head/media interfaces, and security magnetics e.g. credit cards, data security, etc.

Projects undertaken in this area include:-

- studies of the archival properties of recording tape
- the use of DAT in data recording
- the development of improved security or bank cards

Test and Measurement

The testing and evaluation of data storage products is a central feature of the activities. As part of a completely independent laboratory, the Group is ideally suited to carrying out unbiased product evaluation or comparative product testing.

Consultancy and Training

These services include troubleshooting, market analysis, and the establishing of test laboratories or other facilities. In addition, technology transfer assignments are undertaken involving training by seminar or 'on-the-job' teaching.

Top
Mechanical testing of tape

Centre
Magnetic Media come in many forms

Bottom
Mechanical testing laboratory

Computer Applications Unit

Manager - A J Willemsen

The Unit has four areas of specialist expertise:

- In the area of information managment, software products have been developed, notably including:
  - STRIDE, one of the most flexible and powerful thesaurus management systems available
  - SPEED, a powerful yet simple screen-based system for entering text data into databases

  BNF-Fulmer, under contract to Harwell Computer Power, provides support to all users of STATUS, the leading text database package, running on PRIME computers.
- Production Management software. Systems can be configured to meet specific user requirements and a complete hardware and software turnkey service is available.
- BNF-Fulmer's RPD system the most flexible and powerful method available for planning and managing projects involving uncertainty, such as R & D projects.
- Other services based on expertise in uncertainty include data analysis and uncertainty modelling using the Fulmer AUQ method.

Working with the materials specialists in BNF-Fulmer, the Unit also develops software solutions to specific client problems and opportunities.

Membership Services

Manager - R Avery

The Division covers membership by industrial organisations which manufacture or use the wide range of materials with which BNF-Fulmer is concerned. It is the main point of contact for all matters, both administrative and technical.

Membership gives companies exclusive access to the results of all the membership subscription funded researches conducted over previous years, up to current projects still in progress.

In addition, the Division coordinates the range of free services, to which every member is entitled.

The opportunity to participate in the guidance of the individual projects within the portfolio funded by subscriptions is a further benefit of membership. Suggestions from members regarding the content of the programme are always welcomed.

Reference Standards

Reference Materials

Manager - R Avery

Using the expertise and foundry equipment of the Research Divisions, plus the comprehensive analytical facilities of the test laboratory, a range of copper-based and lead-based reference materials are produced for sale.

These are certified by BNF-Fulmer using various analytical techniques - optical emission, X-ray fluorescence, atomic absorption, and classical wet chemistry.

These materials are supplied in the form of solid round discs or squares, and are intended for use in calibrating optical emission and X-ray fluorescence spectrometers.

In addition to the alloys produced and certified by BNF-Fulmer, a range of nickel-based reference materials, produced and certified by INCO Alloy Products Ltd, are available for sale.

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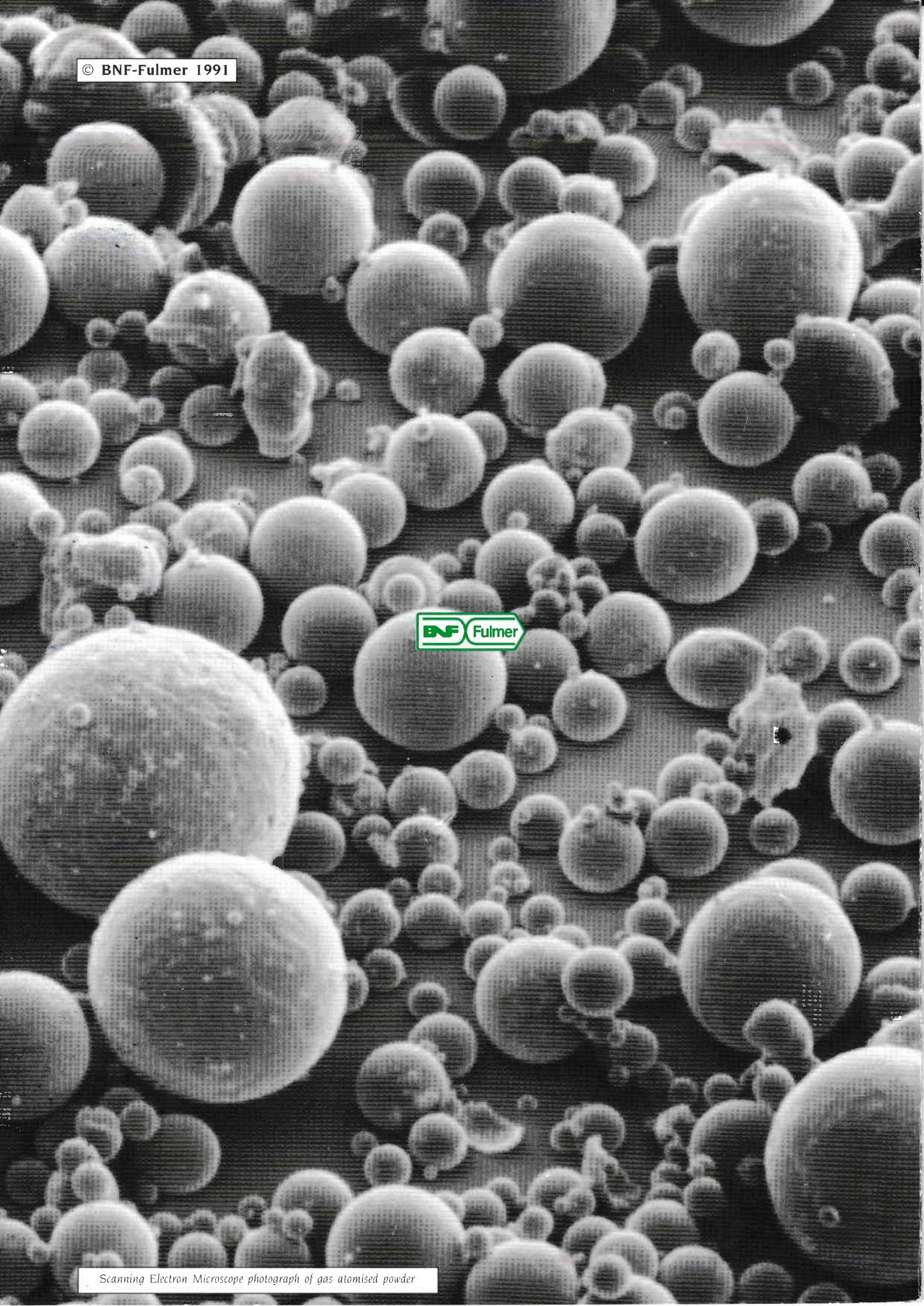

Scanning Electron Microscope photograph of gas atomised powder