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Fulmer Research Institute

1968

OWNED BY: THE INSTITUTE OF PHYSICS AND THE PHYSICAL SOCIETY

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DIRECTION

As the owner of the Fulmer Research Institute, the Institute of Physics and The Physical Society is responsible for the appointment of directors.

The present board of directors consists of:

W. R. Merton, M.A., F.Inst.P. (*Chairman*)

*E. A. G. Liddiard, M.A., F.Inst.P., F.I.M.

M. R. Gavin, C.B.E., D.Sc., F.I.E.E., F.Inst.P.

Sir Gordon B. B. M. Sutherland, Sc.D., LL.D., F.Inst.P., F.R.S.

Sir James Taylor, M.B.E., D.Sc., F.Inst.P., F.I.R.C.

SCOPE AND FUNCTIONS OF THE INSTITUTE

THE Fulmer Research Institute is wholly owned by the Institute of Physics and the Physical Society. It was founded in 1946 to carry out contract research and was originally associated with Almin Ltd. and passed to Imperial Aluminium Company Ltd. when Almin was acquired by them. It was acquired by the Institute of Physics and the Physical Society in 1965 and it is the first sponsored research organisation to be owned by a professional scientific institution.

The Fulmer Research Institute is run on strictly commercial lines and has received no endowment, subsidy or grant from any outside source or from the parent organisation since it first opened. Its income derives solely from payment for work done. The growth of the organisation (shown opposite) has been achieved by ploughing back profit and the present value of the capital assets is estimated at about £300,000 which has built up from an original capital of £40,000.

The main fields of activity are metallurgy, physical, inorganic and analytical chemistry, and solid state physics, but there are no prescribed limits to the type of work undertaken. Patents arising from major investigations which are the subject of the Institute's standard contract belong to the sponsor, and all results are confidential and are divulged or published only with the sponsor's permission.

A large part of the research work is for Government departments and the U.K.A.E.A., and a substantial proportion of the Institute's income is from overseas. Nevertheless, there is increasing use of the Institute by industry. Larger firms, with their own laboratories, find it economical to sponsor work in fields where the Institute has specialised experience and equipment. Smaller firms can call upon the Institute for far more extensive research facilities than they have available internally, without being involved in capital outlay on expensive items of equipment and the employment of specialised staff.

Both large and small firms make extensive use of the facilities for mechanical testing, chemical analysis and consulting services, and short term investigations are undertaken to solve specific production difficulties. This short-term work represents about 25% of the Institute's total income.

* Executive director until the 1st June, 1969, when Dr. W. E. Duckworth, M.A., Ph.D., F.I.M., F.I.S., takes over chief executive duties. Mr. Liddiard will remain a member of the board.

EQUIPMENT AND SPECIALISED TECHNIQUES

X-ray Facilities

Phase transformations in metals and atomic and molecular structures generally are studied by X-rays in the Physics laboratory where there are seven generators. Special equipment includes a diffractometer for studying the structure of liquid metals, high vacuum high temperature X-ray cameras for structure and grain size measurements of reactive materials and a miniature camera used in conjunction with a high powered source of X-rays for obtaining rapid exposures to record metastable structures. Materials can be examined at low temperatures over a continuous range down to that of liquid helium using a diffractometer and cryostat constructed for that purpose.

Highly sensitive single crystal techniques using monochromatic radiation have been used in studying precipitates in aluminium alloys, uranium alloys and orientations relationships between oxides films and their substrates. Structural changes occurring in rare earth alloys are being followed by measurements of lattice parameters of polycrystalline specimens.

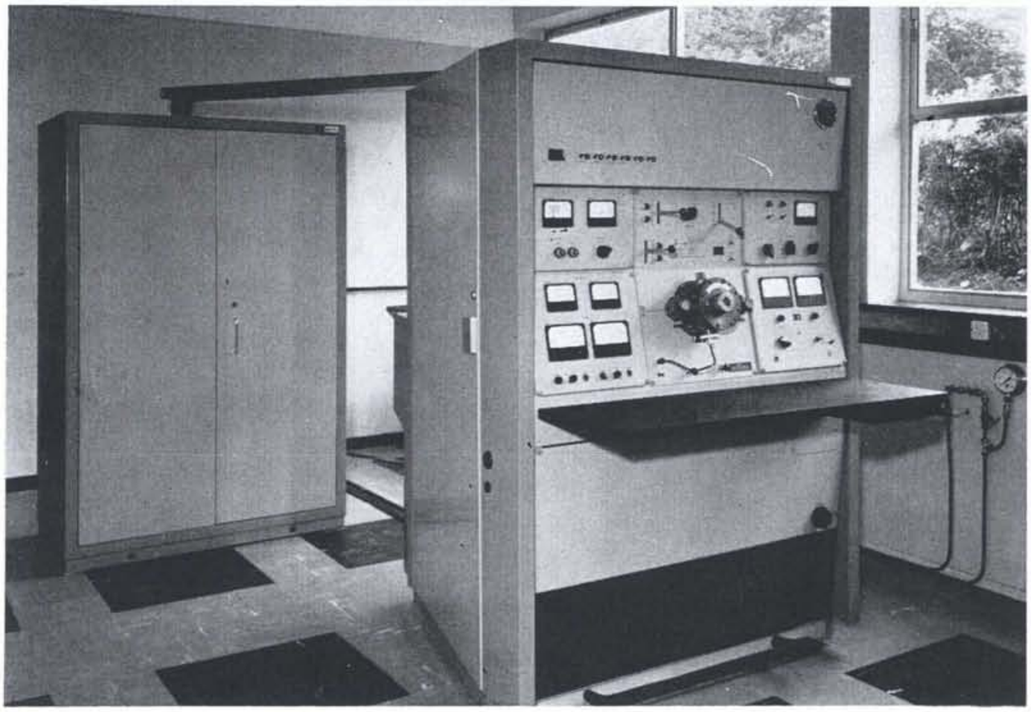
An X-ray fluorescent spectrometer has been acquired to augment other analytical facilities at the Institute.

Electron Microscopy

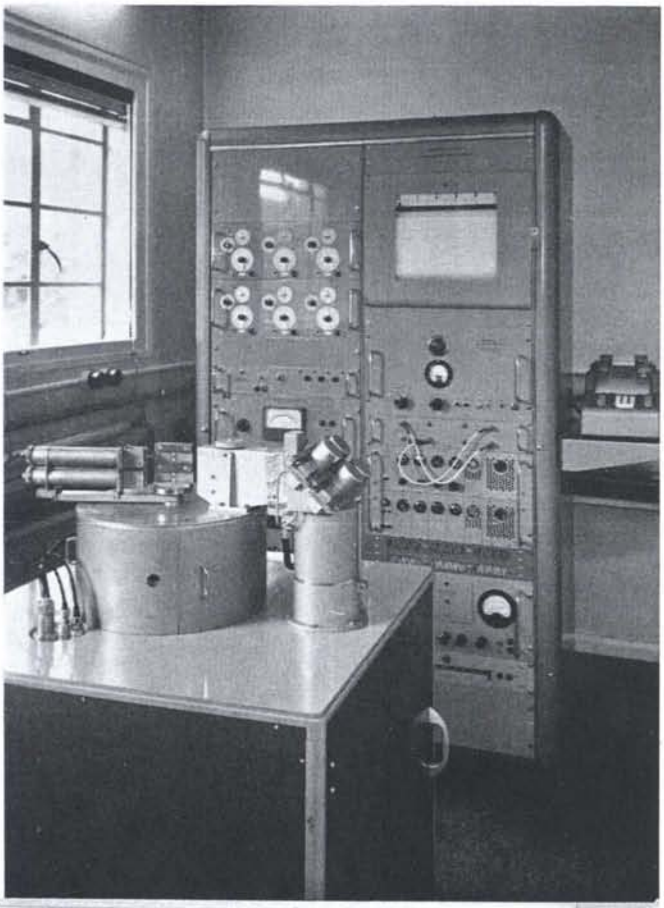
The latest version of the Cambridge Instrument Co. Stereoscan scanning electron microscope (S.E.M.) has recently been installed. The important feature of this instrument is its very large depth of focus, 300-1,000 times that of an optical microscope, combined with high resolution which is normally 200-500Å. In addition very little specimen preparation is required and most materials can be examined directly. These features make the S.E.M. a versatile tool for the examination of many different types of materials including metals (particularly fractures and worn or corroded surfaces), composite materials, ceramics, cermets, paints, plastics and biological specimens. An electron micro-probe analysis facility will shortly be available for the Stereoscan and this, together with the AEI EM6 and Siemens Elmiskop 1A high resolution transmission electron microscopes, will mean that the Institute possesses all the modern techniques of electron microscopy, electron diffraction and micro-probe analysis.

All these instruments are available for hire on a rental basis, when the sponsor may be present during the examination, and are also extensively and increasingly applied in long term research contracts. Recent or current investigations include, studies of the effect of microstructural features (inclusions, precipitates and dislocations) on the fracture toughness of medium-high strength steels, the development of new and improved aluminium and cobalt-base alloys, the relationship between microstructure and magnetic permeability of aluminium bronze alloys and the distribution of boron and helium in stainless steels before and after irradiation. In addition, electron microscopy continues to be used in a variety of short term investigations including the examination of welding failures, the structures of evaporated or sputtered thin films, particle size determinations, wear and abrasion of metals and the structure of catalysts.

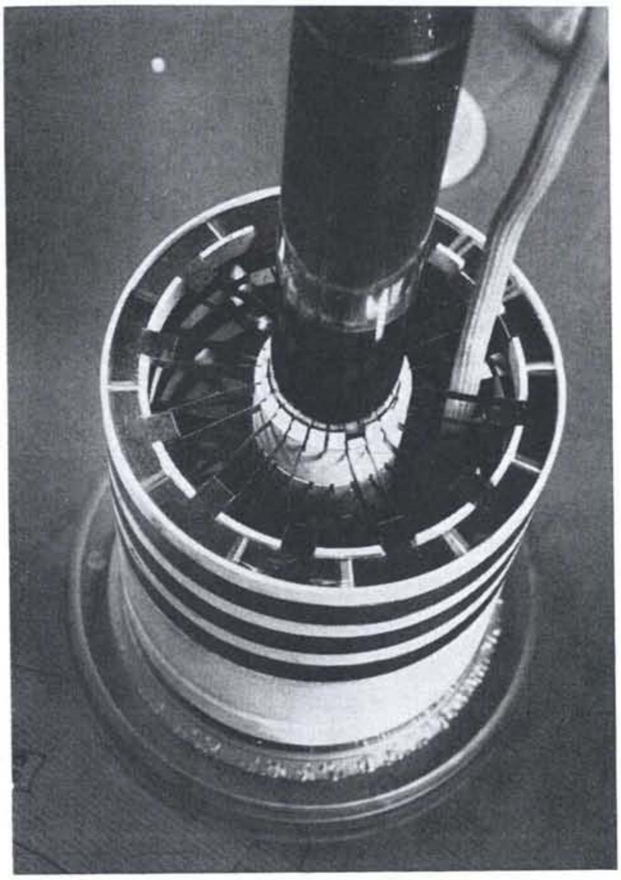
A.E.I. MS702 Mass Spectrometer



X-ray Fluorescent Analyser



New Cambridge Instrument Co. Stereoscan Mk. IIA Scanning Electron Microscope.



High Temperature Calorimeter (partly assembled): in central block (right) showing holes into which thermopile assemblies (left) are fitted.

Mass Spectrometry

An A.E.I. MS702 mass spectrometer is available as an inorganic analytical service or for contract research. The instrument is able to make a complete survey of all elements in the range ^{7}Li to ^{238}U in one analysis and to detect impurities down to one part in 10^9 under favourable conditions. Specimens analysed include laser materials, semi-conductors, corrosion products and paint pigments.

Metallography and Physical Metallurgy

A Bausch & Lomb metallograph, a Reichert MeF metallurgical microscope, a Watson stereoscopic zoom microscope and several bench microscopes (one of which is equipped for phase contrast microscopy and micro-hardness testing) are available for metallography. Various specialised pieces of equipment have been developed for studying phase changes, particularly in reactive alloys. These include a hot hardness tester that will operate at temperatures up to 1000°C. in a vacuum of 10^{-5} mm. Hg and a dilatometer. The latter utilizes a transducer capable of detecting displacements of 2.5×10^{-6} in., and is used for studying isothermal and martensitic transformations in alloys as well as for the accurate determination of coefficients of thermal expansion of materials. There is also a sensitive stress-strain machine of Polanyi type for studying yield point phenomena and machines for examining the effect of strain rate changes during slow creep. A simple torsional pendulum has been constructed for investigations of the diffusion and precipitation of interstitial elements such as nitrogen in the b.c.c. metals iron and chromium by measurements of internal friction.

Physical Chemistry

Special techniques are available for physical chemical studies up to 2300°C. Gas equilibria and thermodynamic activities have been determined at high temperatures. Thermochemical measurements of high precision and on reactions which proceed only at elevated temperatures (up to 800°C) have been made. Equilibrium measurements have been applied to determine the stability of various compounds (Al_4C_3, $TiCl_2$ (gas), $TiCl_3$ (gas)), of normally non-existing radicals (AlCl, AlBr, AlF, BF) and the activities of various constituents of many alloys. The gas transference method has been used at total pressures of about 1 atmosphere, and the effusion method for pressures below about .01 mm mercury; for the latter a vacuum micro-balance and a torsion cell are available. The "capillary vessel" method has been developed in the Institute for measurements in the intermediate pressure range.

For thermochemical determinations, calorimeters of various design, resistance thermometers for different temperature ranges and ancillary equipment for calibration of calorimeters and thermometers are available.

Halogen bomb calorimetry in which substances are combusted in fluorine, chlorine and also bromine in glass vessels at pressures up to 8 atmospheres has been developed in the Institute. Flow type calorimeter vessels made from various materials for reaction with the halogens and other gases, in instances at 700°C, and equipment for determining the heat of the interaction between solids (including metals) at temperatures below 800°C, are also available. Reaction with the halogens constitutes a new development in the determination of the heats of formation of a wide range of inorganic compounds (oxides, nitrides, phosphides, borides, etc.).

The heats of formation of many refractory oxide compounds and glasses cannot be determined by the usual calorimeter methods, e.g. dissolution in solvents at room temperature. For such compounds a special high temperature calorimeter has been built in which the oxides are dissolved at 800°C in molten glass contained in a gold crucible. The change in temperature produced on dissolution results in a flow of heat along conductors between the crucible and a large metal block surrounding it. The magnitude of the heat flow is determined electronically by means of a series of thermo-electric junctions at the ends of the heat-flow paths.

Measurements of the kinetics of chemical reactions have been made. The radiation of gases at high temperature has been measured. Equipment constructed for these and more conventional investigations is available.

Chemical and Spectrographic Analysis

In addition to the mass spectrometer described earlier, the Institute is equipped for inorganic and metallurgical analysis and the analytical staff have extensive experience of working with alloys and compounds. The equipment includes large and medium quartz emission spectrographs, a Wild-Barfield vacuum fusion apparatus, a cathode ray polarograph, a U.V. spectrometer and, as a recent addition, a E.I.L.-S.C.W. "Titracarb" semi-automatic equipment for the rapid determination of carbon for combustion from $<0.01\%$ C by weight to over 3%.

Ceramics

The laboratories are equipped for the fabrication of ceramics by processes such as pressing and sintering, slip casting and hot pressing, as well as reaction sintering in an inert atmosphere.

A process for making crucibles and ceramic shapes by reaction bonding has been developed in this laboratory.

Ceramic vessels have been prepared from the melt by an electron beam technique and oxide single crystals can be made by floating-zone melting. An important new technique is the purification of alumina by electron beam zone refining. This has yielded alumina comparable in purity with the best available.

Ceramic coatings can be made by rod or powder flame spraying or by enamelling and the viscosity and other properties of molten glass or glasses can be measured.

Melting and Casting

The experimental foundry is equipped with conventional oil, gas and electric furnaces for melting. More specialised equipment includes induction furnaces for melting and casting, with or without special atmospheres, or in vacuo. Reactive alloys are prepared in small argon arc furnaces. A consumable electrode argon arc furnace, capable of melting ingots 4 in. or less in diameter is available. Apparatus is available for electron bombardment melting and is also used for zone refining and growing single crystals of both metallic and ceramic materials. Development work on continuous casting is undertaken.

Metal Working

Metal working equipment includes a forging hammer, a rolling mill with plain and grooved rolls for hot and cold work, and small jewellers' rolls. Metals and alloys can be fabricated into sheet, rod and large diameter wire forms. There is also a 60-ton press, used for hot pressing metal powders, and a small laboratory extrusion press. A salt bath heated by means of the electrical resistance of the molten salt is available for pre-heating and heat treatments up to a temperature of 1350°C. Small batches of high purity stainless steel sheet can also be prepared.

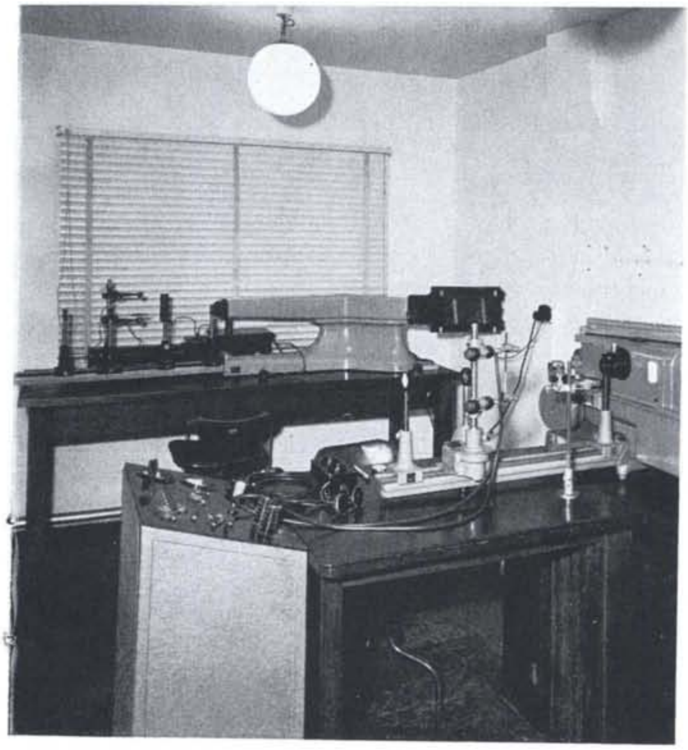
Corrosion

The corrosion section can offer a wide range of facilities to assist in the solutions both of specific production problems and of long term fundamental investigations. Testing of protective schemes can be carried out to all major Government specifications, and a wide range of simulated environments for testing—e.g. salt spray, sulphur dioxide and high humidity atmospheres—can be provided. Exposure sites in rural, industrial and marine locations are available. Electroplating and anodising problems can be investigated with the aid of potentiostatic and coulometric techniques, and high-output rectifiers can be used to simulate plating shop conditions. Work on corrosion reactions at high temperatures and pressures can be carried out in the Department's autoclave facilities. Rapid identification of corrosion products can be achieved using the X-ray micro analysis attachment for the Elmiskop Ia electron microscope (see page 6).

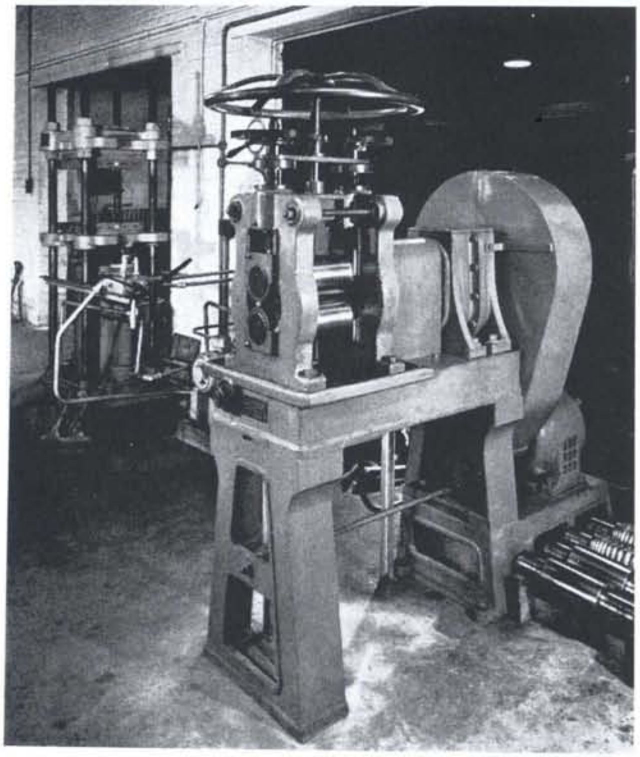
The section is also responsible for work of a chemical engineering nature; facilities are available for pressure testing of hoses and couplings, for determining flow characteristics of high capacity filters and for pilot plant production. Work is at present being carried out to investigate movement of swarf particles in lubricant streams.

Engineering and Mechanical Testing

The Engineering Laboratory is equipped to carry out all normal mechanical tests to British and International specifications. The design and construction of apparatus for non-standard testing is also undertaken. Equipment available includes impact and hardness machines, a Dennison 50-ton universal testing machine with ancillary equipment for high and low temperature testing, and a recently delivered 10,000Kg Instron tensile testing machine with accessories for torsional and compression loading

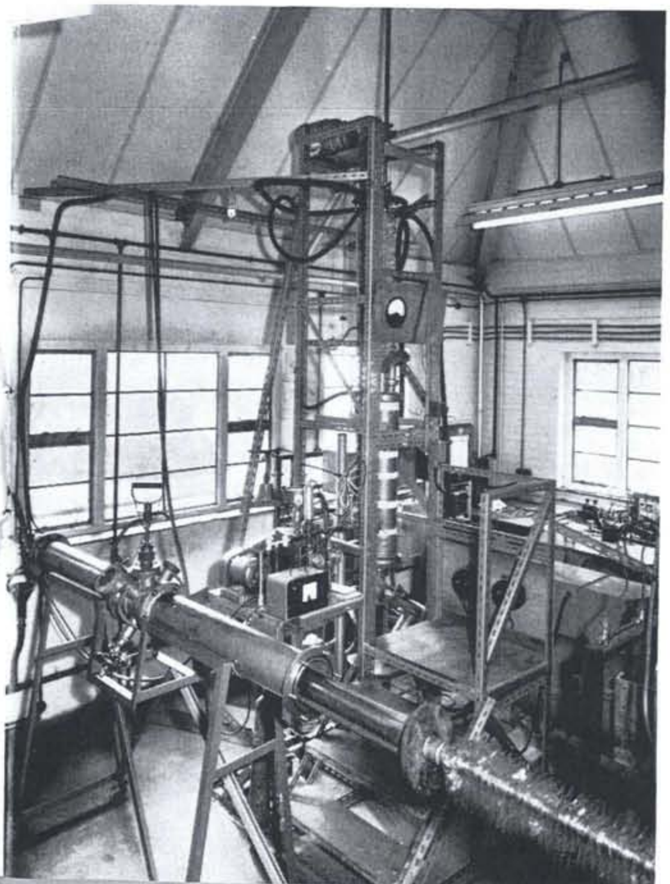


Large and Medium Quartz Spectrographs

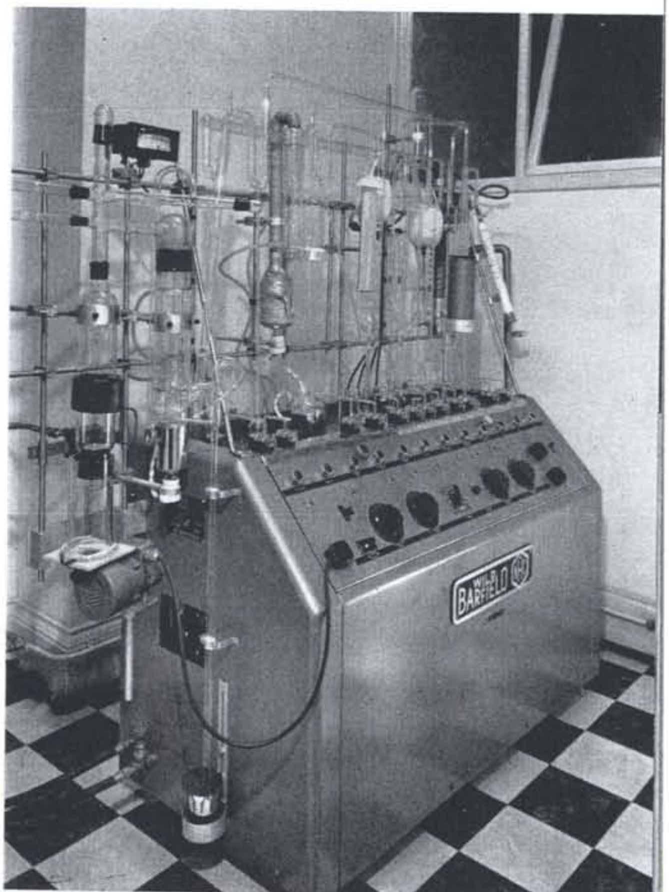


Rolling Mill

Consumable Electrode Argon Arc Furnace



Apparatus for Vacuum Fusion Analysis



Fatigue test equipment comprises axial load, reverse bend and rotating ben cantilever machines which can be adapted for hot or cold testing and for corrosio fatigue studies. The majority of this equipment has been designed and built to me our own special requirements and recent additions include low cycle corrosio fatigue machines to give square or impulse loading for hydrogen embrittlemer studies on maraging steels.

Several N.P.L. type axial load fatigue machines have been supplied to oth research laboratories and universities and now a low cycle reversed bend fatigu machine designed by the N.P.L. and modified by ourselves is being sold under licen in increasing numbers particularly in the U.S.A. This machine applies a maximu surface strain of 2½% at temperatures up to 1000°C for thermal fatigue studies.

Besides acting as consultants we also design specialised test apparatus. A rece patent arising from this branch of our activities has been the "Fulmer Tensio Meter" for accurate measurement of loads in steel or wire ropes.

Facilities are available for conventional creep testing and also for compressio creep testing; the compression machines have been used with special atmospheres.

Static and dynamic strain gauge measurements have been made on structur under load, both in the field and in the laboratory.

In collaboration with the Aluminium Window Association facilities have bee provided for the environmental testing of windows for resistance to air and wat penetration.

Studies are being made involving theoretical and experimental solutions e countered in the economical use of brittle materials for structural components.

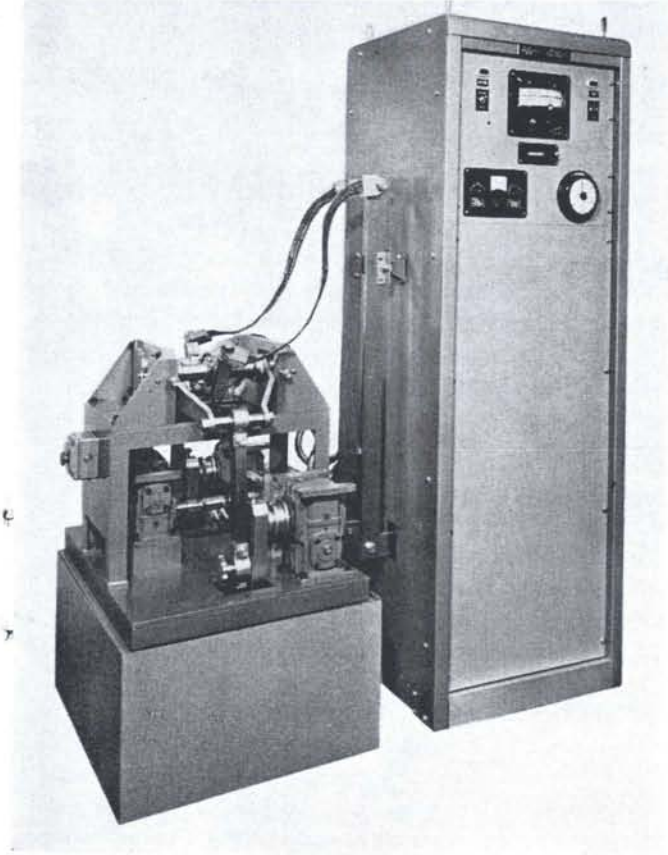
Fracture Toughness Testing

The increasing use of higher strength materials, in which inherent structur defects may play a critical role in determining the behaviour of components in servic is causing designers to take more account of the fracture toughness of materi Fracture toughness measurements, unlike impact energy tests, are independent component geometry. If they are made at the lowest expected service temperatur they allow calculation of the maximum size of material flaw which can be tolerat to avoid fracture of the component below the general yield stress during service.

The Fulmer Research Institute is currently engaged on a number of projects which the fracture toughness, and the metallurgical factors which affect it, is bei measured for many different ferrous and non-ferrous alloys. The Institute is no proposing to make these facilities available to any organisation which has an intere in this important advance in materials testing. Tests can be undertaken on a wi variety of materials on a unit cost basis as for normal test house procedure. Altern tively work can be arranged on a contractual arrangement, when all the extensi facilities of the Institute are available to assist in the investigation.

Laboratory Workshops

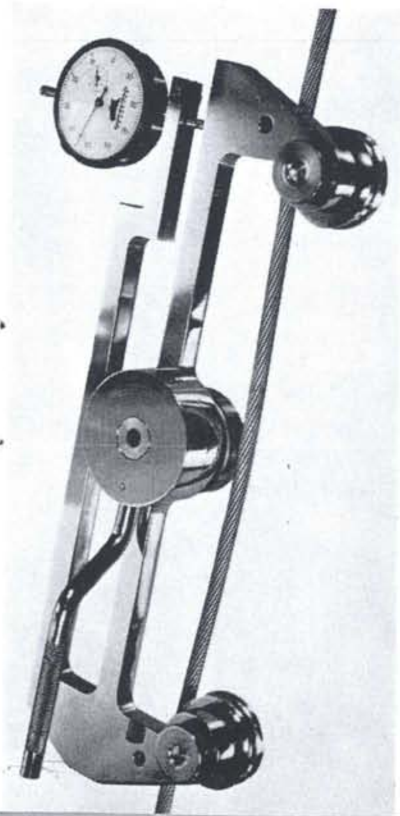
A large proportion of the laboratory apparatus is designed by the research st and constructed in the Institute's workshops. The workshop equipment compris precision lathes, universal millers, grinders and an ultrasonic drill as well as norm metal and wood working facilities. Members of the staff are encouraged to acqu glass blowing skills and a glass blowing lathe is available.



Thermal Fatigue Machine

10,000 *Kg. Instron tensile testing machine with accessories for torsional and compression loading.*

Fulmer tension meter for accurate measurement of loads in steel or wire ropes.



Rig for environmental testing of windows for resistance to air and water penetration.

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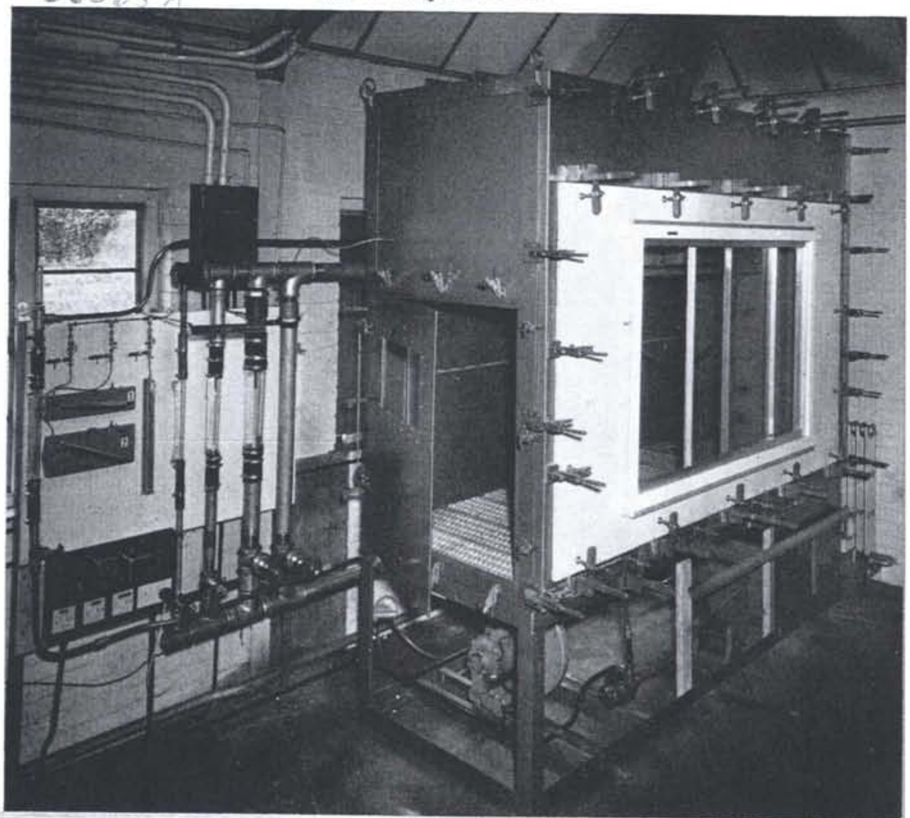


FIELDS OF INVESTIGATION

The following notes contain brief descriptions of some of the work completed or in progress. Work is confidential to the sponsor and the account given is confined to those investigations which have been published or otherwise made available with the permission of the sponsor.

Chemical Thermodynamics

A knowledge of chemical thermodynamic data (heats of formation, free energies of formation and thermodynamic activities) of compounds is necessary for calculating the equilibria of chemical reactions in which they participate. These equilibria comprise those occurring in metallurgical extraction and refining processes, including the precipitation of metals by gas phase reactions for coating purposes and the preparation of thin layers of intermetallic compounds, for instance those needed for superconductors. The preparation and purification of elements and compounds, particularly semiconductor compounds, by "chemical transport" also involves reversible chemical equilibria, a knowledge of which is essential for the understanding of the processes and for selecting optimum conditions of operation. Chemical equilibria, very often involving species which are unstable at lower temperature, occur also in high temperature flames and thermodynamic data are necessary to predict reaction of flame products with solid high temperature materials with which they are in contact. Thermodynamic data relating to alloy constituents are of interest in physical metallurgy because they determine the stability of the various phases. Similarly, a thermochemical study of the compounds in the system sodium—oxygen—iron in the presence of liquid sodium has been made with a view to elucidating the mechanism of the attack on iron by liquid sodium containing oxygen; an analogous study in the system sodium—oxygen—chromium has recently been completed.

For the evaluation of "sophisticated" rocket propellants which involve the combustion of light elements in fluorine or oxygen, the heats of formation of the oxides, fluorides and other compounds of the light elements are of primary importance. The heats of formation constitute a very essential part of themodynamic data and can, at present, be only determined experimentally with sufficient accuracy. The heats of formation of the following compounds have been determined calorimetrically:

By combustion in fluorine: BF_3, BN, BP, GeF_4, $Ge0_2$(hex), $Ge0_2$(tetr), PF_5, SF_6, TiF_4, UF_3, UF_4, UF_6.

By combustion in chlorine: $AlCl_3$, $BeCl_2$, α- and β-Be_3N_2, $HfCl_4$, $NbCl_5$, $SiCl_4$, $TaCl_5$, $TiCl_4$, VCl_4, $ZrCl_4$.

By combustion in bromine: $NbBr_5$, $TaBr_5$.

By reaction of solids with gases other than halogens: α-Be_3N_2, $LiBF_4$, KBF_4, $NaBF_4$, UN, $UN_{1 \cdot 5}$.

By solution calorimetry, in bromine: $TiBr_4$; in hydrochloric acid: $Fe0.2Na_20$ in hot hydrofluoric acid: $Al_20_3.3H_20$, $B_20_3.2Al_20_3$, $2B_20_3.9Al_20_3$, $Li_20.Al_20_3$, $B_20_3.3Be0$, $Li_20.2Be0$, Al_4C_3, Be_2C.

By reacting the components of powder mixtures with each other: AlF_3, BeF_2, Li_3AlF_6, Na_3AlF_6, $LiBeF_3$, Li_2BeF_4, USi_3, USi_2, USi, U_3Si_2, SmAs.

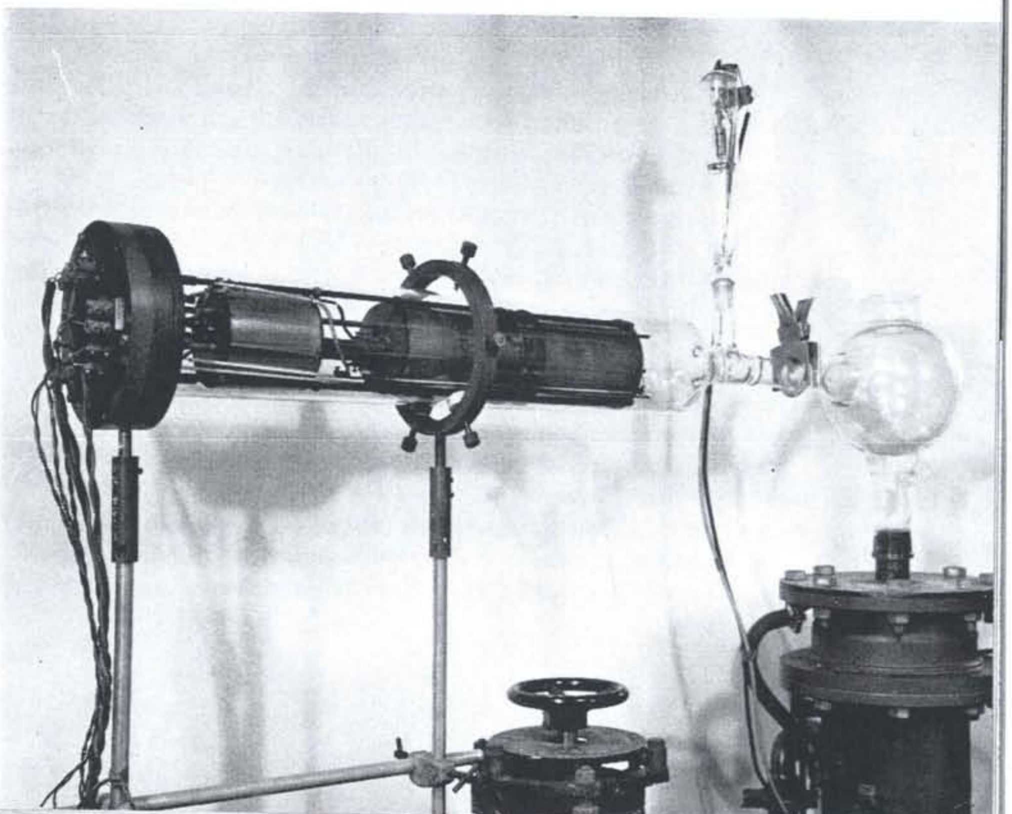
The free energies of formation of the compounds Al_4C_3 (solid), $TiCl_2$ (gas), $TiCl_3$ (gas), and of the unstable radicals AlF (gas), AlCl (gas), AlBr (gas) and BF (gas) have been determined.

The activities of various constituents in the following alloy systems have been measured: aluminium-manganese, aluminium-iron, aluminium-iron-silicon arc furnace alloys, bismuth-uranium, bismuth-thorium, chromium-iron-carbon. For all these determinations each system requires a special approach and novel techniques have been developed, for example, in the preparation and handling of highly reactive materials or in overcoming problems arising from the difficult experimental conditions frequently encountered.

High Temperature Equilibrium Apparatus

At high temperatures elements form compounds in which they have a lower than their normal valency; for instance, the halide vapour MeX_2 of the divalent element Me will, particularly at low pressure, react with further Me (solid) to form the "radical" MeX [according to the equation: $MeX_2(vapour) + Me(condensed) = 2MeX(Vapour)$].

The photograph shows the apparatus for the study of an equilibrium of this kind. In the evacuated glass envelope can be seen (from left to right): furnaces for the MeX_2 evaporator, for the reaction cell (containing Me), and for the condenser on which the reaction is reversed by absorption of Me.



Deposition from the Vapour Phase

The deposition of metals and of intermetallic compounds from the vapour phase is of increasing technological importance. The Institute has facilities for these processes.

Tungsten, molybdenum and rhenium have been deposited by reduction of their fluorides by hydrogen, tantalum and niobium by reduction of the chlorides. Methods for producing tungsten hexafluoride in commercial quantities more economically and procedures for its separation from the effluent gases of deposition are currently being studied.

The conditions necessary for the preparation of sound coatings of tungsten, and their physical behaviour, have been studied extensively; deposits varying in thicknes from less than one thousandth to more than one eighth of an inch have been produced Graphite rocket nozzles have been coated with tungsten and have shown gooc performances in actual firing tests. Tungsten vessels have been made by coating formers.

Coatings of oxidation resistant molybdenum disilicide on molybdenum have beer made by forming the compounds on the surface of molybdenum by keeping it a elevated temperatures in an atmosphere containing the normally non-stable silicoi dichloride. Boron has been incorporated into such coatings in a similar way. Th coatings obtained have excellent high temperature oxidation resistance under botl static and cycling conditions.

The co-deposition of metals from their halide vapours by hydrogen reduction ca be accomplished under conditions which can be estimated from the thermodynamic of the chemical processes involved. Thin layers of a super-conducting intermetalli compound have been deposited on various substrates (metals and inert oxides) b this method.

Extraction Metallurgy

The "catalytic" aluminium distillation process (invented by Dr. P. Gross) i thought likely to be competitive with the conventional extraction process. Aluminiu trichloride is passed over an aluminium alloy obtained by arc smelting of bauxit Aluminium monochloride is thereby formed and subsequently converted into pu aluminium and aluminium trichloride which is recirculated. The process can also b used for aluminium refining. Extensive laboratory and development work was carrie out at the Institute.

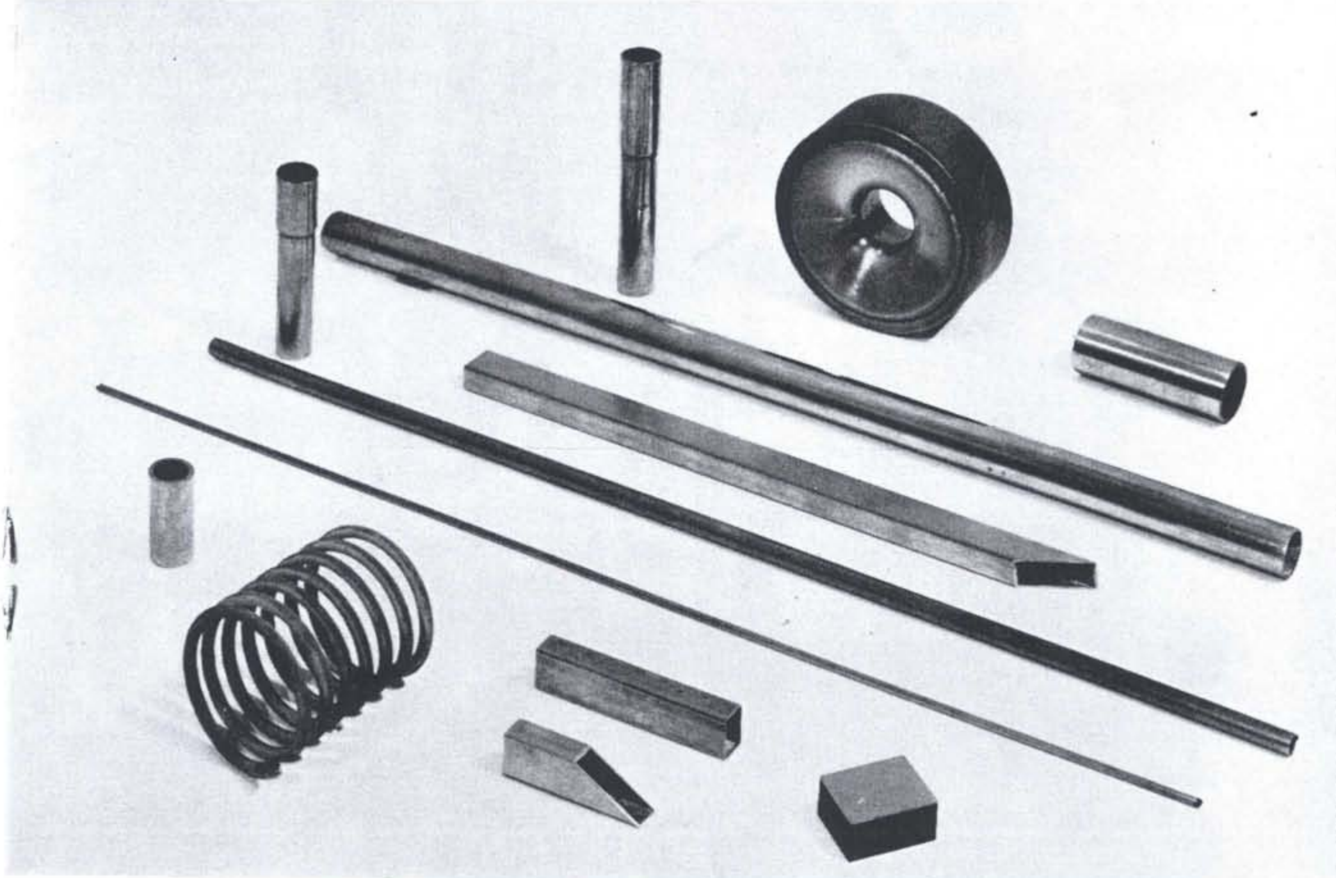
A somewhat similar process involving titanium tetrachloride and its lower chlorid has also been developed for the extraction of pure titanium from commercial ferr titanium alloy and has been developed on a laboratory scale and could be extend to the pilot plant stage.

A related method has been applied to the purification of beryllium with goc results.

A study of the thermal reduction of alumina by carbon to the various intermedia products—aluminium oxy-carbides and aluminium carbide—and finally aluminiu at temperatures up to 2300°C has been made.

Aluminium and its Alloys

The Institute's work on the effect of trace elements on precipitation hardening h been reviewed in F.R.I. Special Report No. 3. More recent work has been concern with the stability of precipitates on prolonged ageing at elevated temperatures, a



VAPOUR DEPOSITION OF REFRACTORY METALS

Coatings of refractory metals (e.g. Ta, Mo, W and Re) from less than 0.001 *to* 0.125*inch thickness are made on a variety of substrates by hydrogen reduction of the gaseous halides. By removal of the substrate after deposition, articles of varying shapes can be made.*

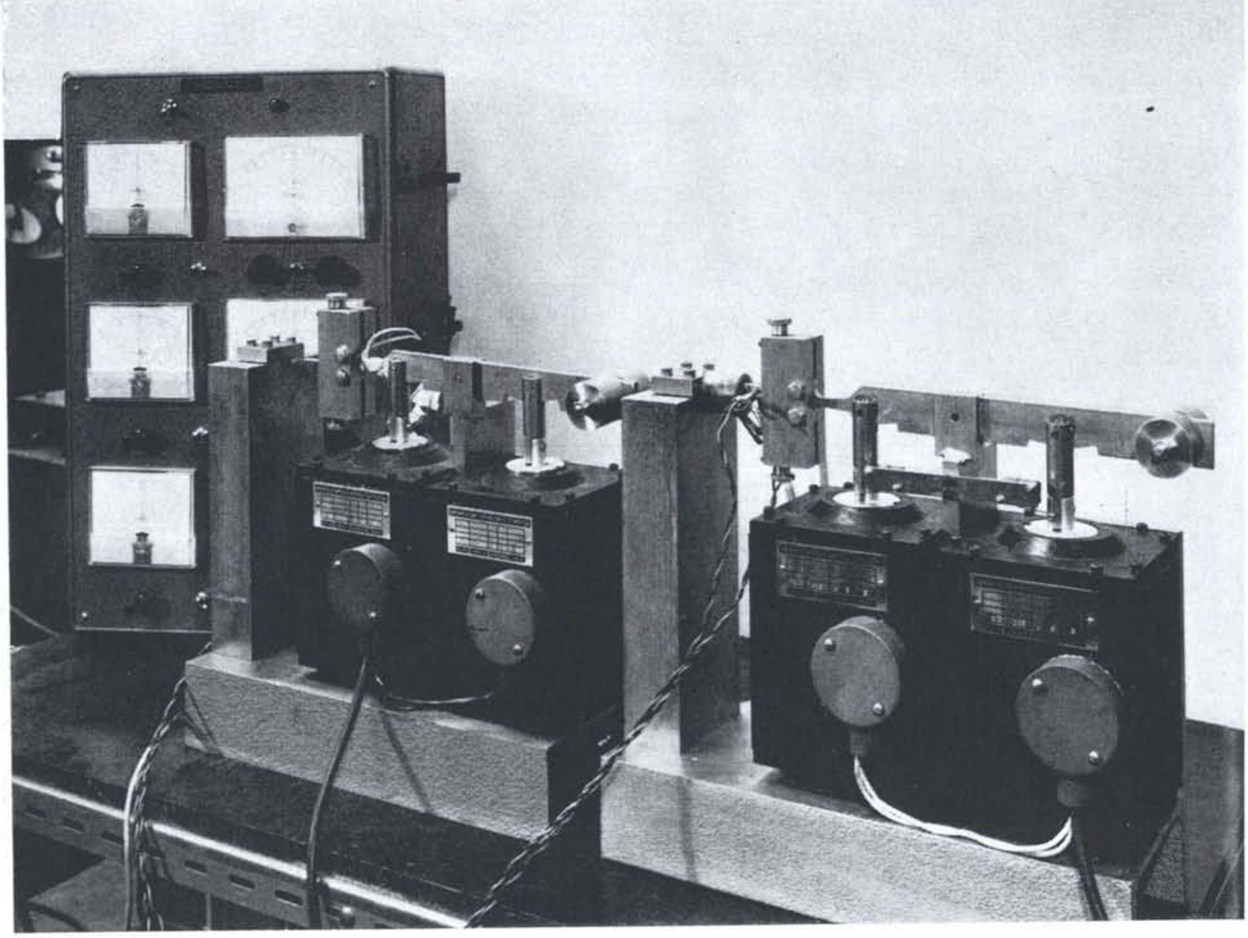
The photograph shows a tungsten coated graphite rocket nozzle together with a number of tungsten tubes and crucibles.

it has been shown that in aluminium-copper alloys, trace elements such as cadmium, indium, and tin, can inhibit precipitate coarsening and so influence creep behaviour. This research has led to the discovery of specific nucleation by combined additions of magnesium plus silicon, and of magnesium plus germanium. This produces alloys of high strength with excellent creep resistance which are the subject of patent applications.

Investigations have shown that an A1-Cu-Cd alloy developed by the F.R.I. has very much superior resistance to exfoliation corrosion and stress corrosion than conventional A1-Cu base alloys such as H.E.15, particularly in the welded condition.

Extensive work has been carried out on anodised aluminium alloys and exposure tests in marine, rural and severe industrial environments to study the effect of anodised film thickness on corrosion resistance have been completed, and the results are being evaluated.

Following the successful use in automotive engineering of the aluminium-30% tin



SLOW CYCLE CORROSION—FATIGUE TEST APPARATUS

The slow cycle fatigue machines are constructed so as to be capable of impartin either square-wave, impulse or sinusoidal stress wave forms to the specimens, and ar currently being used to investigate the effect of fatigue cycling curve shape on the hy drogen embrittlement of ultra-high strength steels.

alloy previously developed with the Tin Research Institute, F.R.I. is taking part i the development for an industrial sponsor of an aluminium-lead bearing containin a comparatively high proportion of lead.

Copper-base Alloys

The nucleation and propagation of cracks in complex aluminium bronzes are bein studied. Cracks are nucleated after very small amounts of deformation at coarse I particles or in regions of retained β, but these do not propagate in wrought materia where these structural features are usually isolated.

The metallurgical factors influencing the fracture toughness of copper-base allo such as aluminium bronze are being correlated with the microstructure. To satisf a demand for a weldable and corrosion resistant copper-base casting alloy with goo fracture toughness, alloys based on the copper-nickel-manganese system are beir studied. The strength of these alloys can be varied by a simple heat treatment to alt the degree of order of the coherent precipitate, which forms quite readily on coolin e.g. after casting. In the disordered state, the precipitate offers little resistance t dislocation movement but by ordering the structure of the precipitate considerab strengthening can be induced by a single heat treatment.

The relationship between microstructure and magnetic permeability of aluminium bronze alloys is also under investigation. These alloys contain approximately 1% iron and the permeability is controlled by the type and distribution of intermetallic compounds formed between iron and other alloying elements such as silicon and nickel.

Work is being carried out on a novel form of dispersion hardened copper, using a laminar structure of aluminium oxide electrolytically deposited. Such materials have markedly directional properties, and should be of interest to the electrical industry.

Chromium and its Alloys

Work is being restarted on chromium base alloys, with the objective of developing alloys with good high temperature properties combined with some room temperature ductility.

Beryllium Base Alloys

An answer to the problem of brittle fracture in beryllium is being sought by grain refinement of sheet by alloying so that the β/α transformation can be utilised and by thermomechanical treatment of sheet. Attempts are being made to purify the material by adding reactive metals to scavenge the carbon, nitrogen and oxygen from the alloy.

Uranium Alloys

Uranium undergoes two allotropic transformations, the characteristics of which can be controlled by addition of elements such as molybdenum, niobium and zirconium. These transformations can be used to produce materials with very interesting properties, e.g. an alloy with a yield stress of over 100 tons f/in^2 combined with high damping capacity. Other compositions can be obtained which undergo up to 12% pseudo-elastic deformation before deforming as a normal high modulus material.

The similarities between uranium alloys and steels form the basis of current research in which thermo-mechanical treatments of the type devised for steels are being applied to uranium alloys in order to produce material with a better combination of strength and toughness.

Special Alloy and Metal Services

Special Alloy Manufacture

The Institute is currently engaged in providing a service for the manufacture of casts to specified analyses as either vacuum or air crucible melts. The material is available as small sand or die castings, as ingots or as a wrought product. Stainless steel, bronzes, aluminium alloys and chromium base alloys are examples of materials frequently produced.

Metal Spraying

In addition a service is also available by which metal spraying either from wire or powder can be undertaken. For special purposes sprayed coatings of the following metals and materials have been made:— Mg, Ge, Ta, Ti, Rh, Pt, Ru, Fe, Mn, Mo and $RbCl_2$. Ceramics may also be flame sprayed.

Wire Drawing

A wire drawing vertical bull block has recently been installed so that experimental quantities of wires can be prepared and supplied in a wide range of diameters.

STAFF

(as at 1st November, 1968)

***Director of Research**	E. A. G. Liddiard, M.A., F.I.M., F.Inst.P.
***Director designate**	W. E. Duckworth, M.A., Ph.D., F.I.M., F.I.S.
Consultant	P. Gross, D.Phil., Hon. Professor Univ. Vienna.
Development Officer	J. A. Coiley, M.A., Ph.D.
Assistant Development Officer	M. W. H. Gillham, A.I.M.
Company Secretary	E. Sugars, A.M.C.I.A.
Librarian	R. F. Flint, A.L.A.
Workshop Superintendent	T. Summers
Director's Secretary and Clerical Supervisor	Elizabeth S. Duckett
Cashier	R. Butler
Assistant Cashier	V. C. Edwards
Photographer	W. Collis

RESEARCH STAFF

(Section leaders are in italics)

Analytical Chemistry	*H. H. Smith*, A.R.I.C.
	J. A. McBain
Corrosion and Electrochemistry	†*I. G. Rose*, B.Sc.
	†*G. Sanderson*, B.Sc., Ph.D.
	J. Hutchings, B.Sc.
	G. W. Russell*
	Miss L. M. Dalling, B.Sc.
Electron Microscopy	*M. A. P. Dewey*, A.I.M.
	D. A. C. Williams*
	I. A. Baird, M.S.R., S.R.
Engineering	*K. W. Mitchell*, B.Sc.(Eng.), Wh.Sch., C.Eng., F.I.Mech.E.
	H. King, Assoc.M.C.T., C.Eng., M.I.Mech.E.
	P. J. Stevens*
Physical Chemistry	*C. Hayman*, M.A.
	G. C. Curme, B.Sc.
	P. J. C. Kent
	R. H. Lewin, L.R.I.C.
	M. C. Stuart
	A. H. Bowry

*Dr. Duckworth will take over from Mr. Liddiard on 1st June, 1969, as Director of Research but Mr. Liddiard will remain a member of the board.

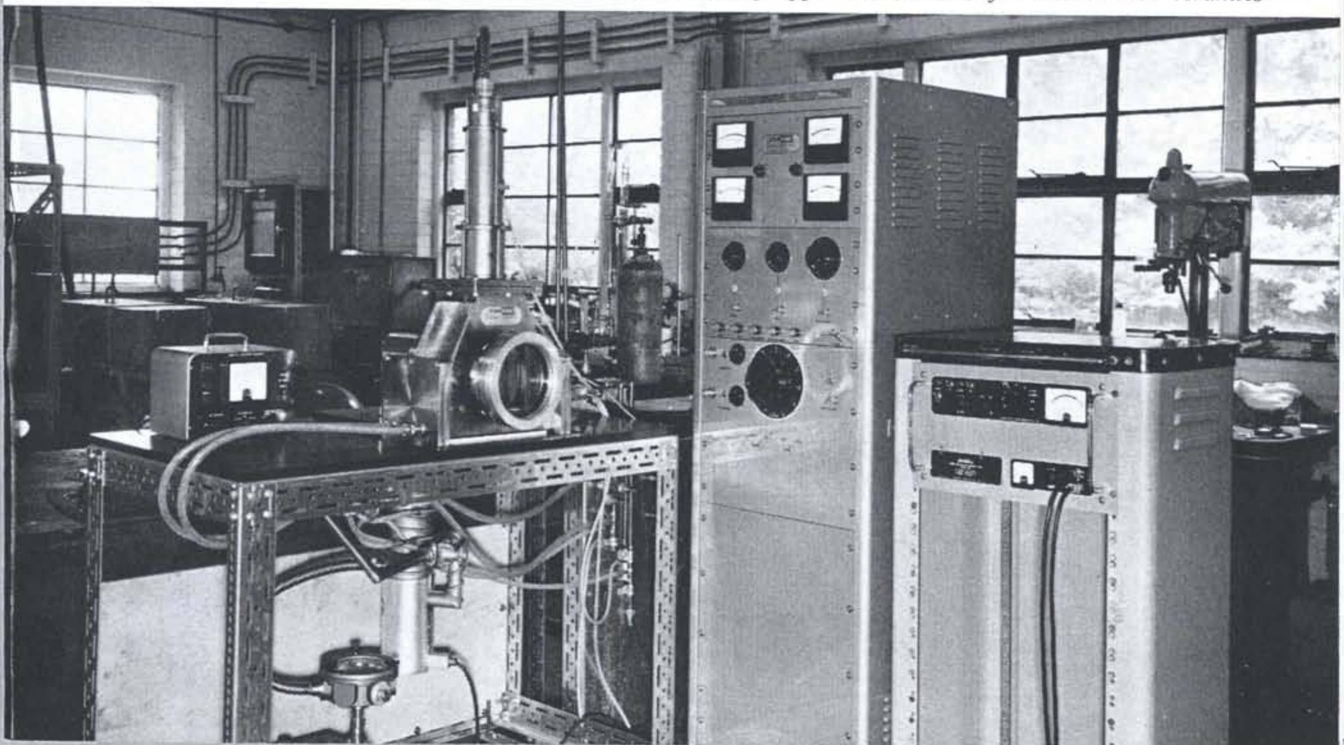
*H.N.C. †Joint section heads

Physical Metallurgy	*G. B. Brooks*, B.Met., A.I.M.
	M. Deighton, B.Sc., Ph.D., A.I.M.
	J. M. G. Crompton, M.Met.
	R. F. Iles, B.Tech.
Physics	*G. I. Williams*, B.Sc., Ph.D., F.Inst.P.
	B. A. Hatt, M.Sc., A.Inst.P.
	W. A. Gutteridge, M.Sc., A.Inst.P.
	V. G. Rivlin, M.A., D.Phil., A.Inst.P.
	R. M. Waghorne, B.Sc., D.I.C.
	R. F. A. Freeman, B.Sc., Grad.Inst.P.
	N. J. Helbren, B.Sc., Grad.Inst.P.
	J. K. R. Page, B.A., Grad.Inst.P.
	D. Stewart, L.Inst.P.
Process Metallurgy	*E. A. Brandes*, B.Sc., A.R.C.S., F.I.M.
	A. G. Provan, B.Sc., A.R.T.C., A.R.I.C.
	D. G. S. Davies, B.A.
	B. D. Goldthorpe, M.Met., L.I.M.
	B. Smith, B.Sc.
	R. E. Ayling
	F. A. Collins
	M. J. Flynn
	M. B. Pithouse*
Spectroscopy	*D. Nicholas*, L.Inst.P.
	Mrs. P. Lord, B.Sc., Grad.Inst.P.
	W. Warr

* H.N.C.

In addition to the above there are 60 laboratory assistants and other staff.

Scanning electron beam zone refining apparatus suitable for metals and ceramics



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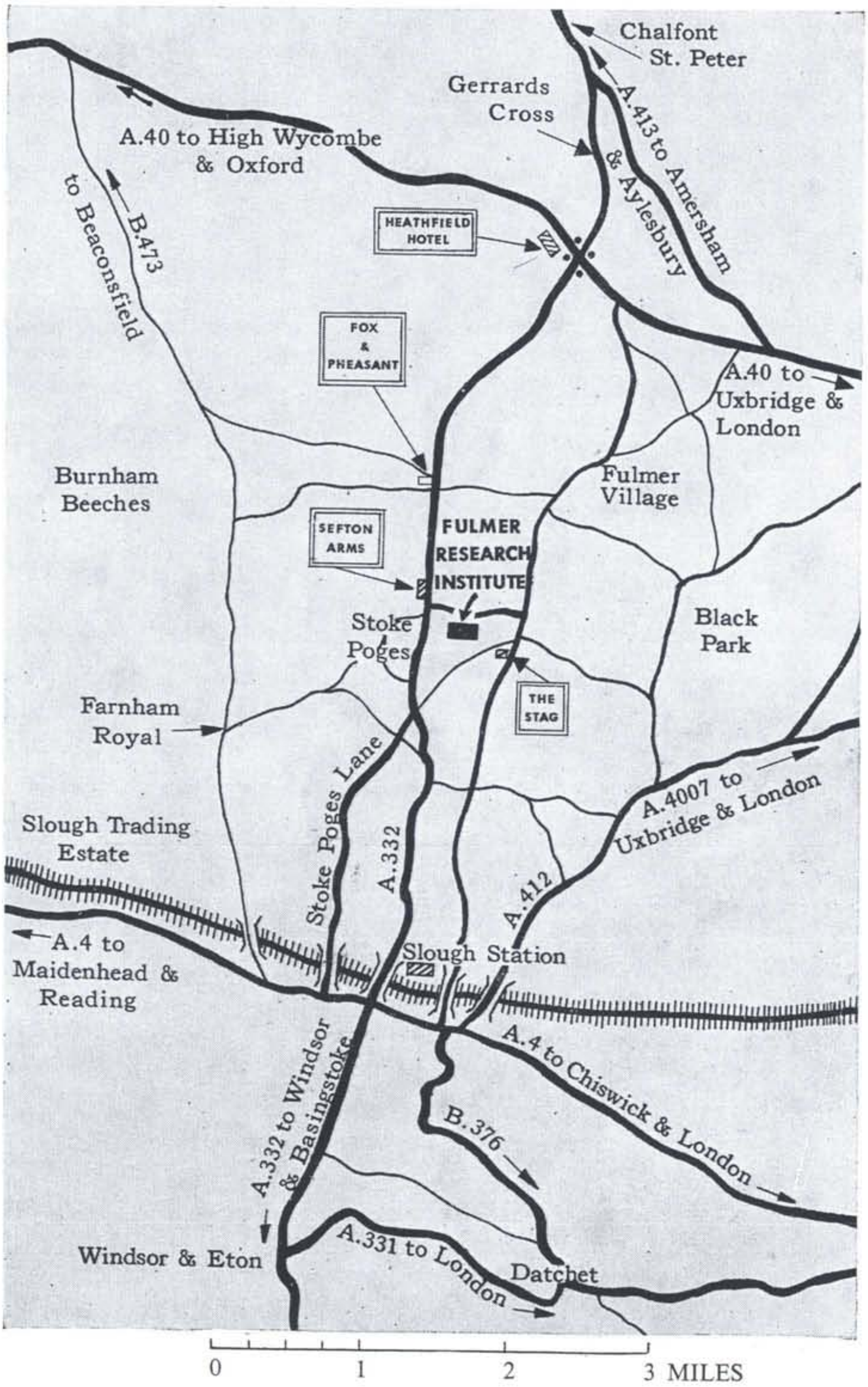

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