The FULMER RESEARCH INSTITUTE

The First Ten Years
1947—1957

FRI

The

FULMER RESEARCH INSTITUTE

THE FULMER RESEARCH INSTITUTE LIMITED
STOKE POGES
BUCKINGHAMSHIRE

Main Building

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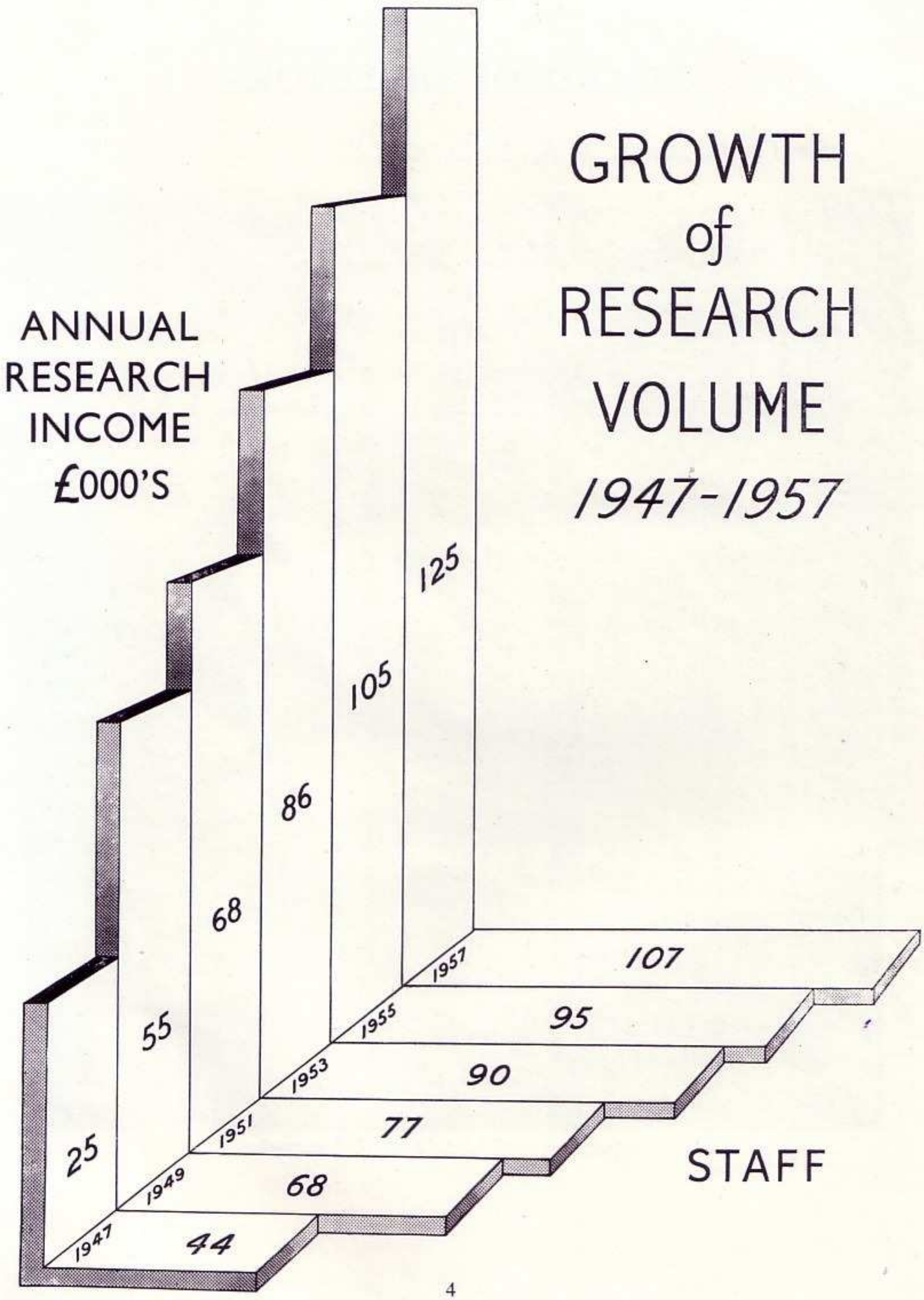
Engineering and Metallurgy Laboratories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STAFF

FOREWORD

THE tenth anniversary of the official opening of the Institute in 1947 offers an opportunity to review progress since its inception. The steady growth of the Institute's activities in staff and annual turnover is shown in the diagram opposite. This growth reflects the continued and expanding demand for the Institute's services, both from original and new sponsors. It has largely been made possible by the fact that the Parent Company, Almin Ltd., has ploughed back all profits. The investment in the form of new buildings and equipment has been doubled.

Although the Institute was founded as a service to British Industry, and sponsorship from this source has grown steadily throughout this period, particularly in the field of testing, analysis, and short-term investigations, industrial sponsors from Britain represent only about 25 per cent of the total. About half the Institute's work is for government departments and nationally owned undertakings. There has recently been a very marked increase in sponsorship from the United States both from Government and Industry. The present annual value of dollar contracts exceeds $120,000.

All results are normally confidential to sponsors but a large proportion of them have been published with the sponsors' permission in over 100 technical papers and articles. Some 80 patents, most of which are assignable to sponsors, have been granted. The greater proportion of the problems investigated are of a fundamental nature. This is particularly true of some work under sponsorship from the United States and the results of such work will be generally available with the sponsors' permission.

Despite the national shortage of scientific personnel, staff recruitment has not been a major problem, and it has been possible consistently to maintain a first-class team of highly qualified investigators, which is believed to be due mainly to the opportunities and interest offered by the problems under investigation.

There has been some increase in the number of sponsors' nominees working in the Institute's laboratories. This, together with the turnover in the Institute's own staff, has served to strengthen the ties between the Institute and its sponsors.

Developments in atomic energy have been reflected in the increased amount of work on uranium and on other metals which are of possible interest in this field. Titanium, zirconium, vanadium, niobium, and hafnium all figure prominently in the current programme. Work on aluminium and its alloys, although giving way to that on the "newer" metals, is still of outstanding importance.

To sum up, the record of the first ten years gives confidence in a future of continued success and expansion in the field of sponsored research.

ORGANISATION

THE Institute was founded in 1946 to carry out sponsored industrial research, the results arising therefrom, including patents, belonging solely to the sponsors.

Although the Institute is staffed and equipped primarily to deal with metallurgical problems of the type described in later pages, many investigations outside the metallurgical field, yet falling within the competence and experience of its staff, have been successfully undertaken.

The principal divisions within the Institute are:

(1) Physical Metallurgy.

(2) Foundry, Metal Working and Ceramics.

(3) Extractive Metallurgy, Physical Chemistry and Thermodynamics.

(4) Physics (including Electron Microscopy).

(5) Engineering and Mechanical Testing.

(6) Corrosion.

(7) Chemical and Spectrographic Analysis.

Ancillary services at the Institute include well equipped workshops (in which much of the Institute's specialized apparatus has been made) and an extensive library which receives more than 200 current technical publications. Information and advice based on published work can be supplied quickly to sponsors. A translation service is also maintained.

FUNCTIONS

The functions of the Institute include

(i) basic research work in such fields as the extraction of metals, the constitution and properties of alloys, materials for high temperature service, the corrosion of metals and alloys, creep and fatigue, thermochemistry;

(ii) the investigation of service failures and the development of materials or equipment for special purposes;

(iii) mechanical testing and chemical analysis (for which the Institute is A.I.D approved) for sponsors lacking the appropriate facilities.

CONDITIONS OF SPONSORSHIP

SERVICES PROVIDED AND COSTS

(i) Certain work, generally of a routine nature, such as mechanical testing or chemical analysis, can be undertaken for a fixed agreed fee.

(ii) Investigational work of short duration dealing with service failures, etc., is charged on the basis of the time devoted to the solution of the problem.

(iii) Other work is carried out on a contractual basis, a standard research contract being drawn up between the Institute and the sponsor after the terms of reference and the experimental programme have been agreed, and the costs of the programme estimated.

(iv) Results of experimental work (and patents arising therefrom) belong to the sponsor, and are treated as confidential, together with any information given to the Institute by the sponsor.

(v) The Institute does not carry out research on the same subject for more than one sponsor, except by agreement.

(vi) Nominees of sponsors may work in the Institute's laboratories, thus facilitating the development and application of research results in industry.

(vii) Publication of the results of an investigation is only made with the sponsor's permission.

Foundry, Metal Working and Machine Shop

EQUIPMENT AND SPECIALIZED TECHNIQUES IN CURRENT USE

X-Ray Crystallography

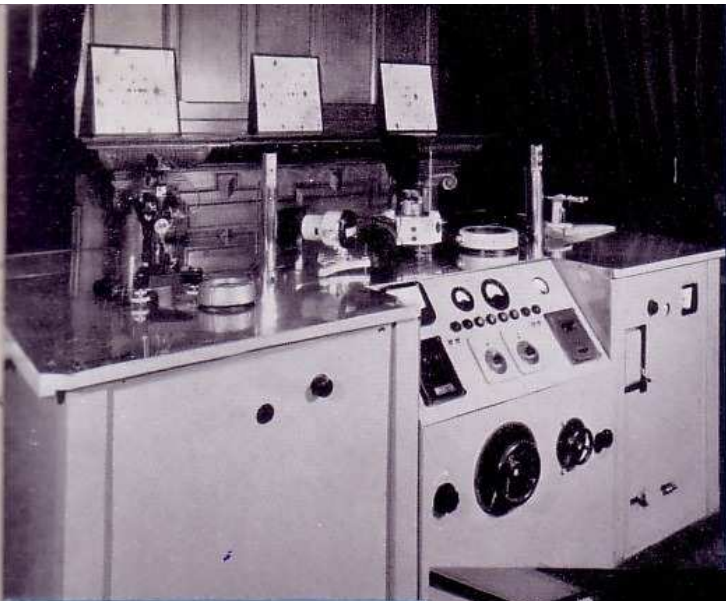
Five X-ray generators are in current use, and all the normal techniques of X-ray crystallography are available. Special techniques, involving the use of monochromatic radiation, have proved particularly useful in the study of age-hardening and similar phenomena. Some work has also been carried out using a reciprocal lattice camera. In addition to the normal high temperature camera, a special camera has been developed to enable X-ray studies to be made of highly reactive materials at temperatures up to 1000°C. This camera, which is of novel design, has proved vital in the examination of titanium and zirconium alloys. It can operate at temperature with a vacuum of 1×10^{-7} mm. of mercury. The study of the structure of liquid metals is made with a specially designed camera and a Geiger counter spectrometer.

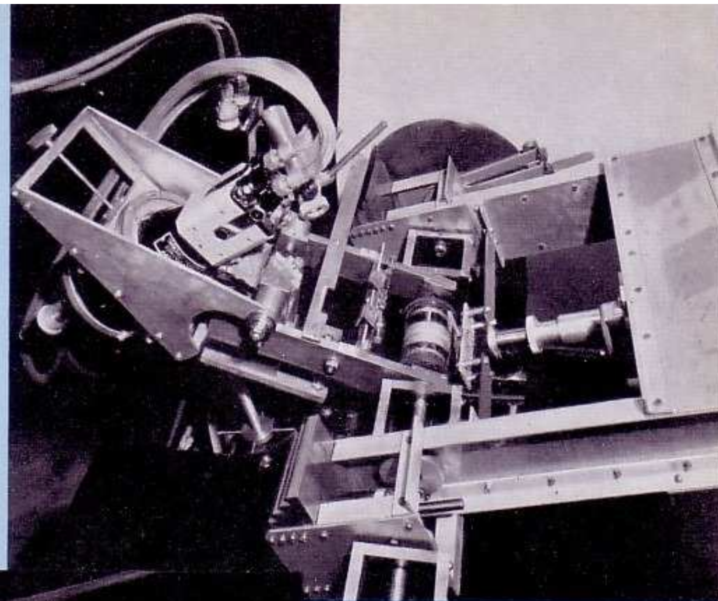
Electron Microscopy

The Metropolitan-Vickers EM3A electron microscope, together with ancillary equipment in the form of an evaporation unit for replica preparation, is in use and has proved useful, for example, in the investigation of the character of the oxide film formed on alloys, in a study of phase transformations, and in the examination of asbestos fibres, contaminated catalysts, and magnetic powders.

Metallography

In addition to the Bausch & Lomb Metallograph, and the Reichert Metallurgical Microscope, there are also several bench microscopes and a micro-hardness tester. An instantaneous specific heat apparatus is available for equilibrium diagram work. Special apparatus has been designed to give ultra-rapid quenching from vacuum or special atmosphere heat treatment. Considerable experience has been built up in the metallography of uranium and its alloys.





ABOVE

X-ray diffraction apparatus

ABOVE

Geiger counter spectrometer for liquid metal studies

LEFT

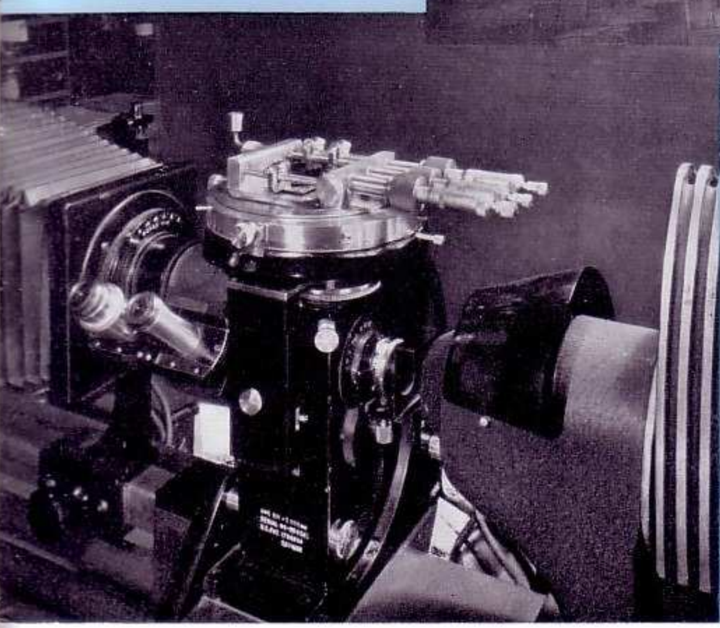
Electron Microscope and Evaporation unit

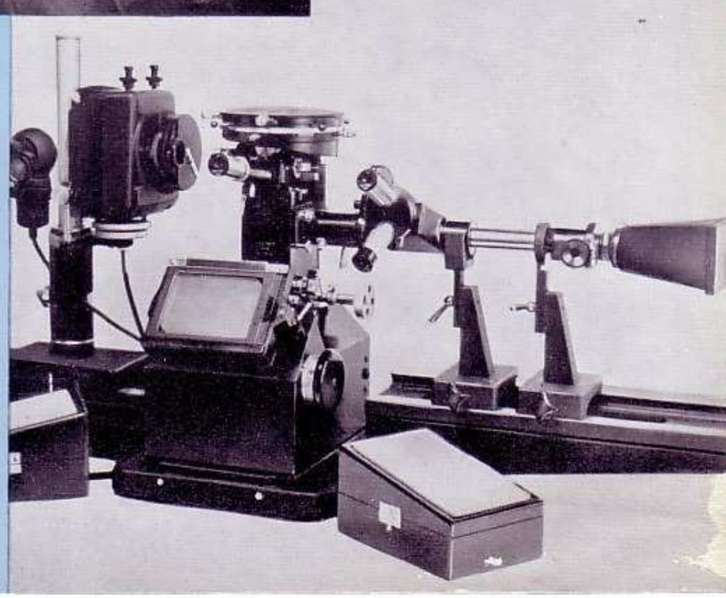
BELOW

Bausch & Lomb Metallograph

BELOW

Reichert Projection Microscope





Physical Chemistry

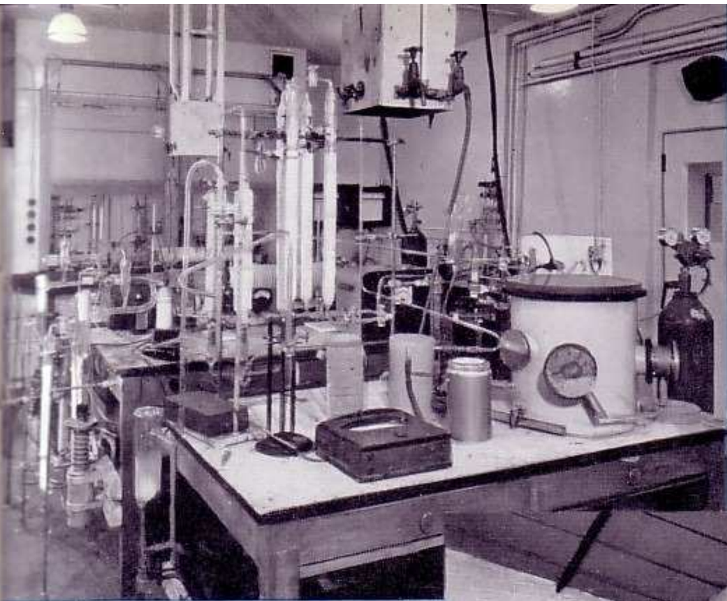
Specialized techniques in the field of physical chemistry include accurate measurements of vapour and reaction pressure, using the capillary vessel method developed in the Institute, in addition to all standard methods. These have been used to study the equilibria of important industrial reactions and to establish activity data for various metallic systems. Accurate calorimetry has established the heats of formation of various compounds, in particular metallic halides, and new values for the heats of formation of several of these important compounds have been established and published. The kinetics and equilibria of various reactions that might form the basis of new extractive methods have been studied in apparatus requiring highly efficient vacuum techniques.

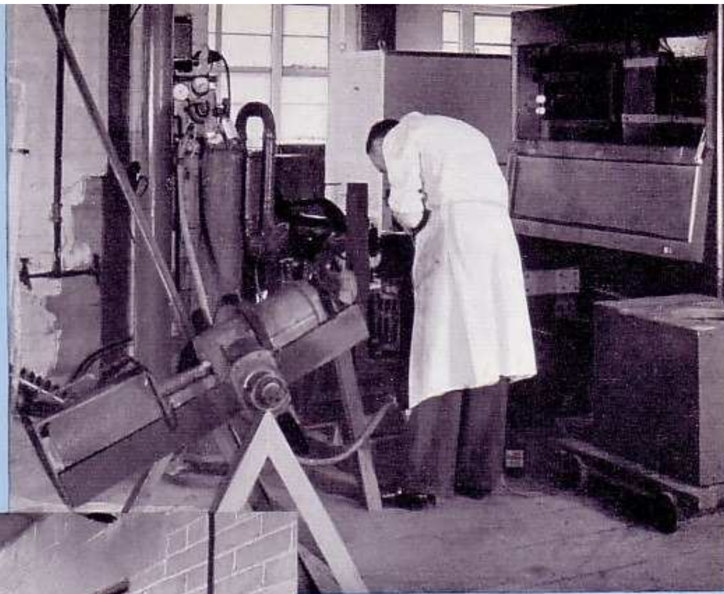
Vacuum Melting and Casting

Apart from the normal oil and gas fired furnaces for melting, induction furnaces have been adapted for melting and casting in special atmospheres or in vacuo and for zone refining, as well as for open melting. For highly reactive metals there are the vacuum arc melting furnaces in which small chill castings can be made, using water-cooled copper moulds. One of these is equipped with a retractable hearth, from which small billets suitable for extrusion can be made.

Metal Working

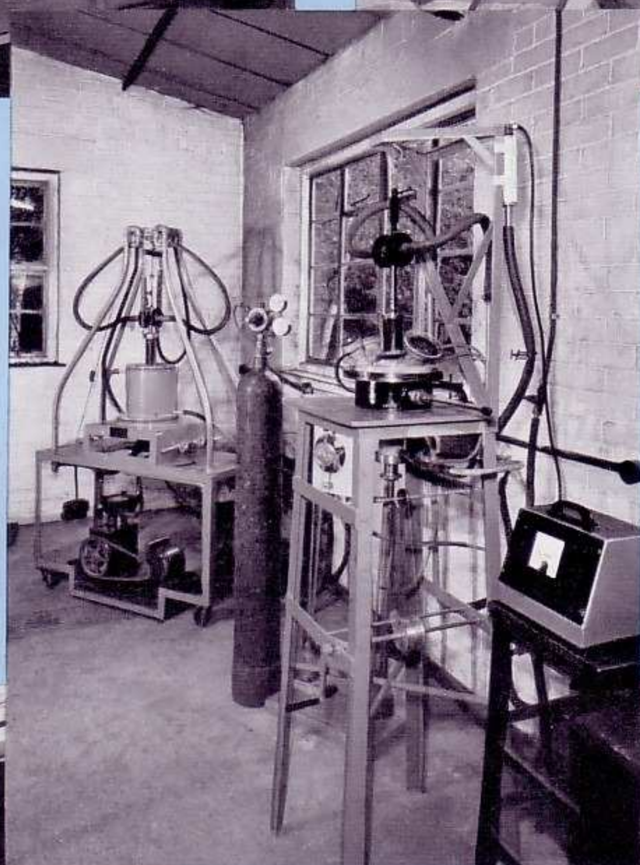
A forging hammer and a small rolling mill are available. From the latter either sheet or rod can be produced. There is also a 60-ton press for use with powder metallurgical techniques, and a miniature extrusion plant. Arrangements have been made outside the laboratories for the extrusion of highly reactive and refractory materials, some of which have been sheathed and extruded using glass lubrication. This technique has proved particularly valuable in the investigation of chromium and chromium-base alloys.





ABOVE
Physical Chemistry Laboratory

ABOVE
Induction Melting Unit



LEFT
Retractable Hearth, Argon Arc Melting Furnace

BELOW
Rolling Mill

BELOW
Forging Hammer

Refractories

Special techniques for the preparation of refractories for dealing with highly reactive metals have been developed. A kiln is available for firing refractories at temperatures up to 2000°C. Ball and roller mills allow the preparation of finely divided material for slip casting or spraying. A diamond cut-off wheel provides for accurate shaping and cutting of thin slices of hard brittle substances.

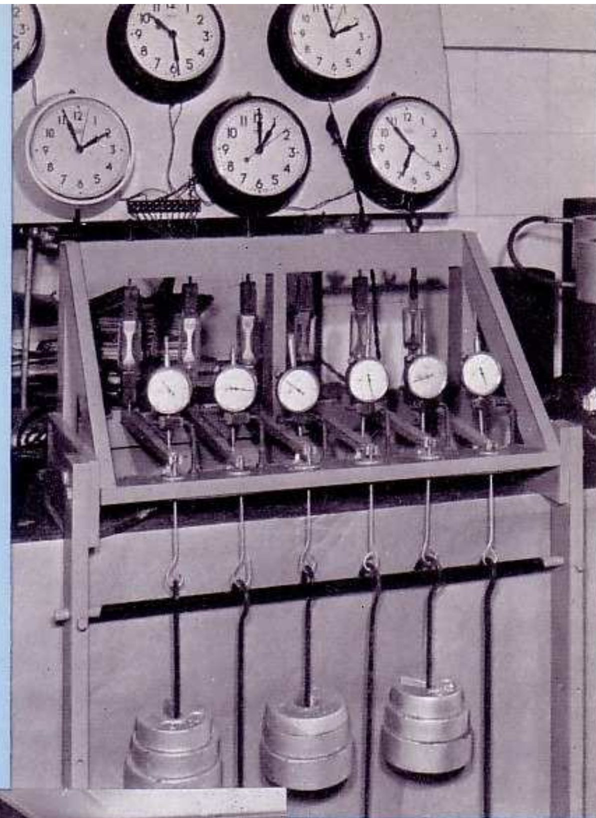
Mechanical Testing (including high temperature Creep and Fatigue)

The usual mechanical tests can be carried out at either very low or high temperatures and data have been produced for sponsors interested in designing for low temperature applications such as the transport of liquid methane. For high temperature design data, both creep and fatigue testing equipment are in use. Replica techniques are being used to study the progress of fatigue cracks, and a specially designed high temperature fatigue machine for testing sheet has proved particularly useful in studying the effect of various heat-resisting coatings on the high temperature fatigue properties of the basis metal. High temperature and corrosion fatigue studies are also being made using alternating tension and compression machines of the Haigh or "slipping clutch" type.

Conventional creep testing apparatus is supplemented by facilities for carrying out creep in compression and in special protective atmospheres. This has proved essential in studies of the compression creep of uranium and other highly reactive metals. Both static and dynamic strain gauge measurements have been made on structures under load. This work has been done in the field as well as in the laboratory.

Chemical and Spectrographic analysis

Conventional, polarographic, absorptiometric, microchemical and, particularly, spectrographic methods have been used for the solution of a wide variety of difficult problems. The co-ordinated effort in using a combination of appropriate techniques has enabled new methods to be developed for ore analysis, and for trace element determination in phosphors, pharmaceutical products, graphites, etc.



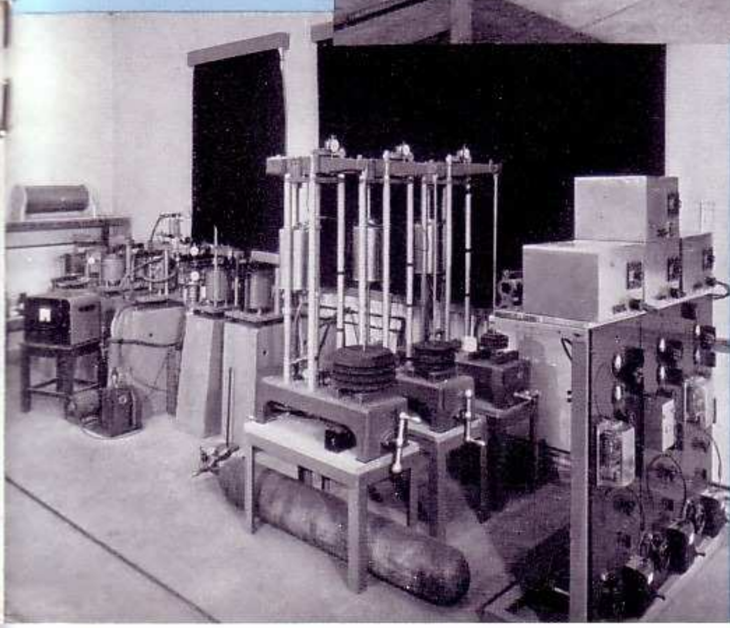
ABOVE
Tensile Creep Machines

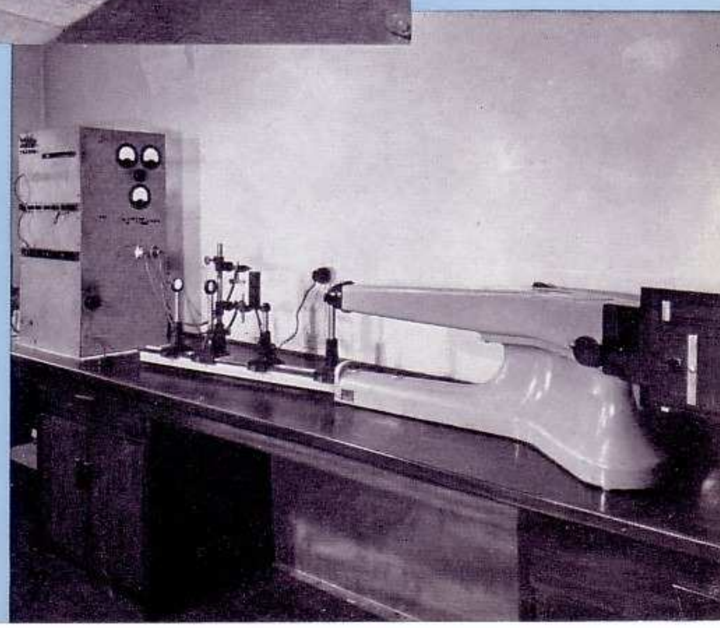
BELOW
Tensile and Compression Creep Machines

ABOVE
Laboratory Stress Corrosion Apparatus

LEFT
Mechanical Testing and Fatigue Laboratory

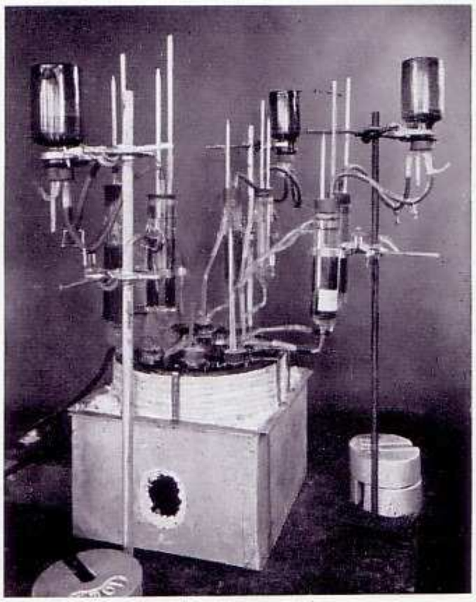
BELOW
Spectrograph





Corrosion

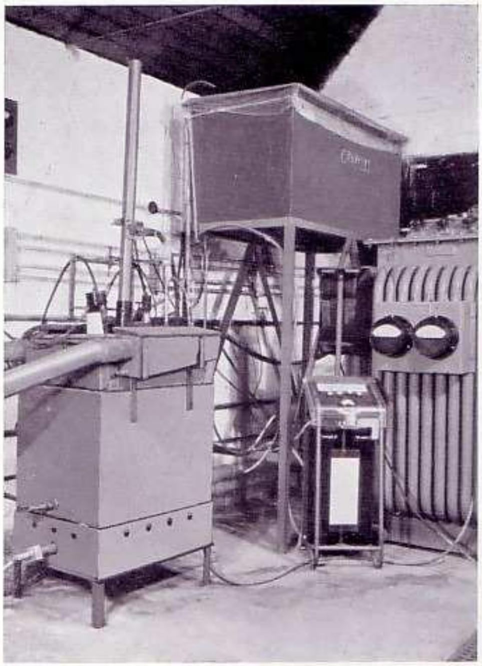
Accelerated laboratory tests and field tests at industrial, marine, and rural sites are used to assess corrosion behaviour. Salt spray cabinets and various types of stress corrosion apparatus are available. Current programmes are concerned, for example, with evaluating protective finishing schemes for structural steels, and with examining the corrosion and stress corrosion behaviour of the high strength aluminium alloys. Apparatus simulating a domestic water installation has been designed and used to determine the corrosion resistance of, and water contamination caused by, a potential new alloy for domestic boilers. Studies are being made of the oxidation of metals, including zirconium, at high temperatures.



Simulated Domestic Boiler Systems for Corrosion Testing

Electrodeposition

Four separate rectifiers deliver direct current supplies up to 250 amps at 60 volts, enabling experimental electrodeposition to be carried out on a scale ranging from beakers to full pilot plant. These facilities have been used extensively for the preparation of pure chromium, and work has been carried out on the electrodeposition of manganese, and on the anodizing and dyeing of aluminium and its alloys.



Electrodeposition Plant

Laboratory Workshops

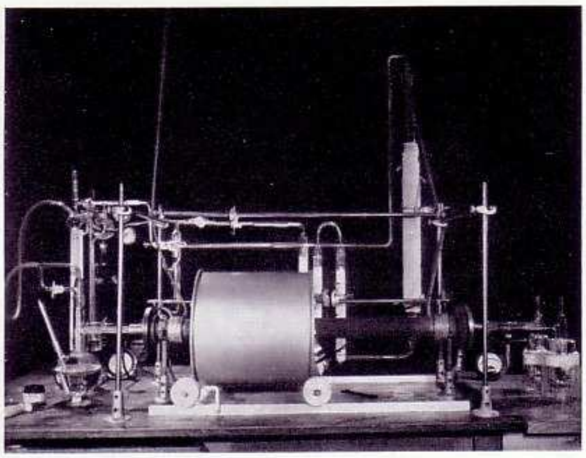
Much of the apparatus of the laboratory has been designed and made in the laboratory workshops, where the machine tools include precision lathes, a universal miller, a grinder, and an ultrasonic drill, as well as normal metal and wood working facilities. In the laboratory, glass blowing skills have been developed by several members of the staff and a glass-blowing lathe installed.

FIELDS OF INVESTIGATION

The following notes contain brief descriptions of work completed or in progress. In some cases only a brief outline of the work is given owing to the confidential nature of the problems.

EXTRACTIVE METALLURGY

The development by Dr. Gross in the Institute laboratories of a process for the catalytic distillation of aluminium is already well known. This process depends upon the reversible reaction between aluminium trichloride and an aluminium-bearing material to form a volatile monochloride, which subsequently decomposes into aluminium and aluminium trichloride. The reaction is applicable to the extraction of aluminium from alloys produced by direct thermal reduction of bauxite, or other suitable aluminium-bearing minerals, in an arc furnace, or to the purification of scrap. Aluminium of high purity has been produced by this method. Extensive development work is being carried out on a pilot plant scale, and supplementary laboratory work is continuing at the Institute.



Furnace Unit for Titanium Extraction

This method of approach to problems in extractive metallurgy has been followed by the study of related methods for the preparation of titanium, and a new process of titanium extraction, which has been covered by patents, has been developed on a laboratory scale, and is ready for extension to the pilot plant stage. Another related method is suitable for the purification of some other metals. Promising results have been obtained for beryllium.

The successful development of these purification and extraction methods was greatly assisted by the basic thermo-chemical work described in the previous section under the heading of "Physical Chemistry".

ATOMIC ENERGY

Various investigations connected with atomic energy are in progress. Some are concerned with the physical metallurgy of uranium and its alloys, and the study of liquid metals. Important work is also in hand on the measurement of thermodynamic activities in various binary uranium systems. High temperature creep studies are being made of low alloy steels to provide data for designers of nuclear power plant, and creep tests are being carried out in compression and in special atmospheres on uranium and its alloys. A brief survey of packaged reactors for isolated site operation has also been made.

Age Hardening

A study of the mechanism of precipitation hardening, with particular reference to light alloys, has always been a major item in the Institute's research programme. The results have been published in a series of papers with which Dr. Hardy's name is mainly associated. It was partly as a result of this work that Dr. Hardy was given a Beilby award, and later awarded the Rosenhain Medal of the Institute of Metals.

The X-ray techniques developed by the Institute's investigators for studying precipitation processes are well known internationally to specialists in the field. Trace elements have been shown to exercise a profound effect on ageing behaviour in some systems, and the influence of small quantities of cadmium in accelerating the ageing of aluminium-copper alloys has resulted in the development of the aluminium-copper-cadmium alloys, which, while free from room temperature ageing after solution treatment, can be aged at elevated temperatures to give properties approaching those of the duralumin-type alloys. More recently, the effects of radiation on precipitation and ageing behaviour have been shown to be important.

Aluminium Alloys

Apart from the age-hardening studies described above, work on new aluminium alloys includes the development of an aluminium-tin bearing alloy and of a structural alloy with improved corrosion resistance. The mechanism of layer corrosion and of stress corrosion in structural aluminium alloys is being studied. Attention is also being paid to anodic finishes for aluminium alloys, including an examination of the light fastness of dyed anodic sections, and to the development of a method of protecting light alloy forgings and extrusions.

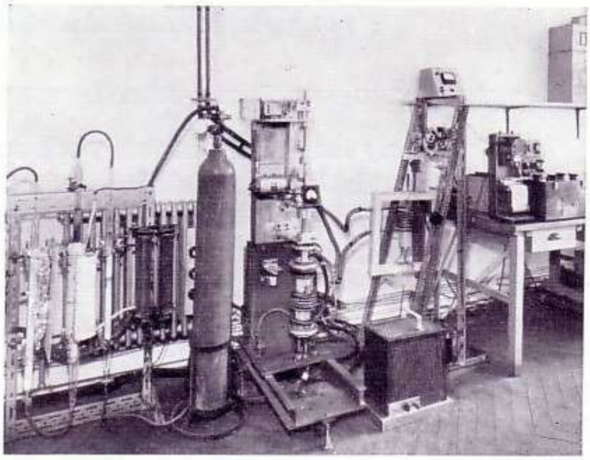
Chromium and Chromium-Base Alloys

Following a comprehensive investigation of the properties of certain binary and ternary chromium-base alloys, recent work has concentrated on high purity metal. Experimental and pilot plant work on electrolytic processes has been concerned with identifying and controlling commonly occurring impurities, and this has been coupled with an examination of the effects of these impurities on mechanical properties. Appreciable ductility has been achieved at room temperature in pure chromium, using metal produced in the laboratory by electrodeposition, and work is continuing on alloys.

Chromium Electrolytic Flake, Extruded Bar, Pressed Flake and Test Piece

SEMI-CONDUCTORS

Experimental work on the purification of silicon is in progress, and techniques for the production of large single crystals from super-pure silicon and the manufacture of devices therefrom are also being developed.



Apparatus for single crystal preparation

TITANIUM

A new process for titanium extraction has already been mentioned in the section above dealing with extractive metallurgy. Other investigations on titanium include a study of the effects of hydrogen, and of the formation and nature of the embrittling omega phase in binary titanium alloys.

FERROUS METALLURGY

In addition to the investigations on the creep and fatigue properties of protected low alloy steels, research and development work on oxidation-resistant alloys is in progress. Low alloy silicon-aluminium steels have been developed which in air in the temperature range 600°-950°C. exhibit oxidation rates comparable with 18/8 stainless steel. These steels are expected to find application in heat exchangers, electric furnaces, etc. Further metallographic work on the causes of failure of high speed steel tools has also been carried out. Work has also been done on nodular cast iron.

GLASS

The Institute is currently engaged in studying the fundamental structure of glass. Although in glasses the atoms are not arranged in the regular crystalline way characteristic of metals, the arrangement is not completely random. On this slight degree of regularity the explanation of the variation with heat treatment of the properties of glass is sought. The problem is closely linked with that of liquid metals and somewhat similar techniques of X-ray diffraction and refined interpretation are being used.

ANCILLARY SERVICES

Analysis, Testing and Short-Term Investigations

While relatively long-term research work accounts for the major proportion of the Institute's available effort, facilities exist for testing and analysis, for investigation of routine difficulties, and for related work of short duration. The Institute is A.I.D. approved for both mechanical testing and chemical analysis. Some of the more important of these investigations have been on problems outside the metallurgical field. For example, the mechanical and thermal properties of various insulating materials have been investigated, and methods of improving the specific modulus of plastics by reinforcement have been studied. The characteristics of certain types of oil filters have been determined by measurement of the pressure drop at various flow rates of liquids of varying viscosities.

Over 1700 short-term investigations have been completed. These have included the examination of service failures in a wide variety of materials and manufactured products, such as television aerials, dental and surgical equipment, gear cutters, automobile engine parts, addressing machines, cafeteria trays, bearings, food and other containers, switches and electrical components, aircraft accessories, etc. Corrosion and exposure tests on new manufactured products (for example, bicycle frames, domestic boilers, plastic penholders, etc.) and for the appraisal of various protective finishing schemes for structural work have also been conducted.

To assist the sponsors concerned, the literature has been reviewed on such subjects as orthopaedic materials, dyed finishes for anodised aluminium, and other topics.

Library and Information

The Institute's library contains approximately 3000 volumes and subscribes to some 200 technical periodicals. It maintains close contact with other technical libraries and the staff prepare reviews and bibliographies of particular subjects for sponsors, as well as for the investigators. Translations of foreign language articles of wide interest are available for loan or sale. Reprints of most of the published papers and technical articles written by the Institute's staff are available. Some Special Reports by the Institute are available for sale.

SOME RECENT SPONSORS

Addressograph-Multigraph Ltd.
Aero Controls Ltd.
Ajax Metal Shopfronts
Almin Ltd.
Aluminium Laboratories Ltd. (Canada)
Amalgamated Dental Eng. Industries Ltd.
Aron Electricity Meters
Aviation Development Ltd.

Belling & Lee Ltd.
Bells Asbestos & Engineering Ltd.
Bristol Aeroplane Co.
British Celanese Ltd.
British Industrial Solvents Ltd.
British Overseas Airways Corporation
British Welding Research Association
Burness, Corlett & Partners, Ltd.

Caltex Services Ltd.
C.A.V. Ltd.
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Cox & Co. (Watford) Ltd.

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Hemingway & Co. Ltd.

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Intermit Ltd.
International Alloys Ltd.
International Meehanite Metal Co. Ltd.
Intertype Ltd.

Jantar (Nigeria) Co. Ltd.

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Southern Forge Ltd.
Sperry Gyroscope Ltd.
St. Helens Cable & Rubber Co.
Sykes, W. E., Ltd.

Tin Research Institute
Trucast Ltd.
Tyresoles Ltd.

United Kingdom Atomic Energy Authority
United States Air Research & Development Command
United States Army
United States Navy

Warwick Production Co. Ltd.
Weatherfoil Ltd.
Whessoe Ltd.
Wiggins, Teape & Co. Ltd.
Wilkinson Sword Co. Ltd.
Williams & Williams Ltd.

STAFF

Just over 30 per cent of the staff have university degrees or equivalent qualifications and 40 per cent are research or laboratory assistants.

There is no fixed establishment or salary scale but opportunities for advancement exist both within the expanding Institute and from contact with important sponsors. Inevitably some of the staff have left to take up important posts elsewhere. Senior members of staff who have left include:

Dr. A. H. Sully - Director, British Steel Castings Research Association.

Dr. H. K. Hardy - Winner of Beilby Award, 1954, and Rosenhain Medal, 1956. Deputy Head of Laboratories, U.K.A.E.A., Springfields.

Mr. T. J. Heal - Research Manager, U.K.A.E.A., Culcheth.

The average staff turnover during the first ten years has, however, been less than 5 per cent per annum of graduates.

Junior laboratory staff are given facilities for attending evening classes. Two have won scholarships enabling them to attend full time at universities. One has gained an external Hons.B.Sc., another, graduate membership of the Institution of Mechanical Engineers, and four have been awarded Higher National Certificates. Approximately 90 per cent of the candidates have been successful in examinations.

Director of Research	E. A. G. Liddiard, M.A., F.I.M.
Principal Scientist	P. Gross, D.Phil.
Principal Physicist	E. A. Calnan, B.Sc., Ph.D., F.Inst.P.

SECTION LEADERS

E. A. Brandes, B.Sc., A.R.C.S., F.I.M.	Process Metallurgy
G. B. Brook, B.Met	Physical Metallurgy
C. S. Campbell, M.A.	Spectroscopy
H. K. Farmery, M.A., Ph.D.	Corrosion
D. L. Levi, M.A., B.Sc.	Physical Chemistry
K. W. Mitchell, B.Sc.(Eng.), Wh.Sch., A.M.I.Mech.E.	Engineering
H. H. Smith, A.R.I.C.	Analytical Chemistry
G. I. Williams, B.Sc., Ph.D.	Physics

INVESTIGATORS

B. S. Berry, B.Sc., M.Sc., Ph.D.	Metallurgist
L. Cartz, B.A., B.Sc., M.Sc., Ph.D.	Physicist
J. Cole, B.Sc.	Metallurgist
D. H. Desy, B.S., M.Met.E., Eng. Sc.D.	Metallurgist
Joan E. Fleming, B.A.	Physicist
B. Hatt, B.Sc.	Physicist
C. Hayman, M.A.	Physical Chemist
H. King, Assoc.M.C.T., A.M.I.Mech.E.	Engineer
Cynthia Knight, B.Sc.	Physicist
B. R. Orton, M.Sc.	Physicist
A. G. Provan, B.Sc., A.R.T.C., A.R.I.C.	Metallurgist
J. A. Roberts, B.Sc., Ph.D.	Physicist
Jeanne M. Silcock, B.Sc.	Metallurgist
Joan S. Steel, B.Sc.	Physicist
H. E. N. Stone, B.Sc., A.I.M.	Metallurgist
L. E. Webb, Ph.D., A.R.S.M., D.I.C.	Metallurgist
J. A. Whittaker, B.A.	Metallurgist
G. Wilson, B.A.	Physical Chemist

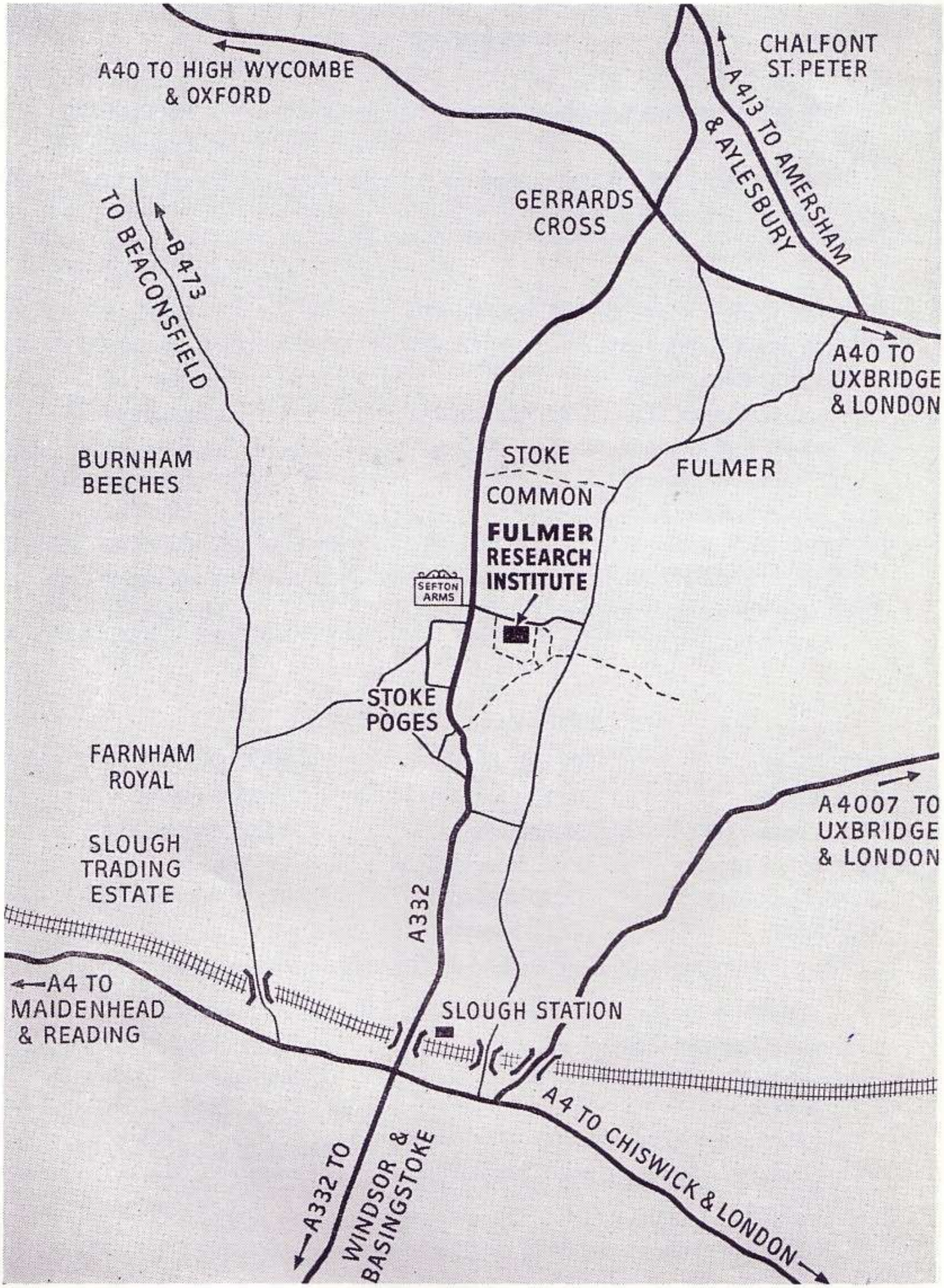
RESEARCH ASSISTANTS

A. H. Bowry	P. J. C. Kent	B. A. Shaw, L.I.M.*
F. A. Collins	R. H. Lewin*	P. J. Stevens*
E. F. Crosswell	J. A. McBain	M. C. Stuart
Patricia J. Cutler	J. C. Moore, A.I.M.	W. Warr
G. W. Goodwin*	D. Nicholas	K. D. Weller
J. B. Jubb	F. Pursehouse	

* Higher National Certificates in Chemistry or Engineering.

Development Officer	M. H. Davies, B.Sc.
Secretary	E. Sugars, A.M.C.I.A.
Librarian	R. F. Flint, A.L.A.
Workshop Superintendent	F. S. Palmer
Director's Secretary and Clerical Supervisor	Elizabeth S. Duckett
Cashier	R. Butler

In addition to the above, there are 55 laboratory assistants and other staff.



SCALE = 1 INCH PER MILE