The Fulmer Research Institute

Open Days 1966

The Fulmer Research Institute was originally formed in 1946 and recently celebrated its 20th anniversary with the opening, on 30 September 1966, by Sir Paul Chambers, the Chairman of ICI Ltd, of a new laboratory (figure 1), which adds about

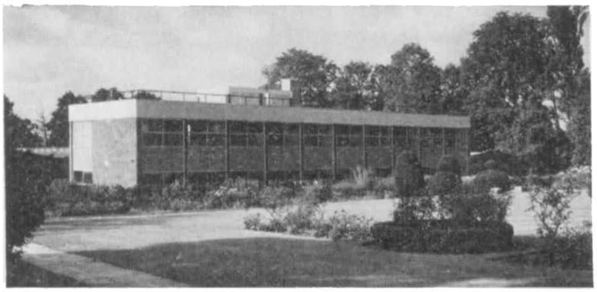

Figure 1. New laboratory.

6000 ft^2 to the 40 000 ft^2 that were available previously. Most members of The Institute of Physics and The Physical Society know that the Fulmer Research Institute is now wholly owned by the Institute and Society, and is the first—and probably still the only—contract research organization to be owned by a professional scientific body. However, not all will be aware that the instigator of this imaginative move was Sir James Taylor, then Honorary Treasurer and now President of the Institute and Society, and that the purchase was possible only as a result of the generous terms offered by Sir Paul Chambers and his colleagues on the board of ICI, one of the previous joint owners of the Fulmer Research Institute. It was, therefore, very appropriate that Sir Paul should have been invited to open this latest extension to the premises of the Fulmer Research Institute.

In introducing Sir Paul, Mr. Thomas Merton, the Chairman of the Fulmer Research Institute, observed that, in addition to ensuring the continuity of Fulmer, the action of Sir Paul and his colleagues in enabling The Institute of Physics and The Physical Society to purchase Fulmer had made possible the realization of a novel and highly interesting concept. He believed that this particular combination—of a contract-research organization and a professional society—had a unique potential for providing part of this country's needs in applied science. Mr. Merton went on to refer to the well-known advice that one could not be too careful in the choice of one's parents. He pointed out that Fulmer had always taken this advice very much to heart, having been the grandchild of ICI and the Aluminum Company of America, and having recently exchanged these grandparents for The Institute of Physics and The Physical Society, and noted with pleasure that both sets of parents had been legally united!

Sir Paul Chambers emphasized the need for still closer links between the universities, the learned societies and industry, and referred to the Fulmer Institute as an outstanding example of a successful link of this kind. He suggested that whilst British industry undoubtedly needs first-class scientists it has an even greater need for men, like Sir James Taylor, who are first-class scientists, good administrators and hard-headed, down-to-earth businessmen. Profit as a yardstick of success is just as important for industrial research as for any other industrial activity and Sir Paul referred to the Fulmer Institute's record in this respect as quite outstanding. It receives no gifts or grants and has increased its turnover from £25 000 in 1947 to £235 000 in 1965, the profit made in 1965 having been equal to the whole turnover in 1947. Sir Paul emphasized the advantages of the Fulmer Institute's research facilities, particularly for the smaller firm but for larger concerns also.

Thanking Sir Paul Chambers, Sir James Taylor then suggested that, with the enormous backing of science and technology in the parent organization, the Fulmer Research Institute ought to be able to show an example, not only to this country but to the whole world, on how to apply science in the form of technological research.

Mr. Liddiard, who has been Director of Research of the Fulmer Research Institute since its foundation, welcomed the guests and hoped that in future many more members of the Institute and Society would combine the roles of shareholders and sponsors, and would help the Institute by steering funds for research in its direction and also by giving it guidance to help it to function in the best interests of the parent body.

Facts and figures

Mr. Liddiard has recently described the Fulmer Research Institute and its work (*Bulletin*, May 1965) but, in the hope that members of the Institute and Society will be encouraged to take a greater interest in its activities, and perhaps to use its facilities, a little more information about the working of the Institute might be of interest.

Although the Fulmer Research Institute was formed by Almin Ltd in 1946 and was owned by that group until 1961, it has from the outset been an institute for the carrying out of sponsored research, and work for its parent group has never formed more than $2\frac{1}{2}\%$ of its turnover. 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 organization since it first opened. Its income is derived solely from payment

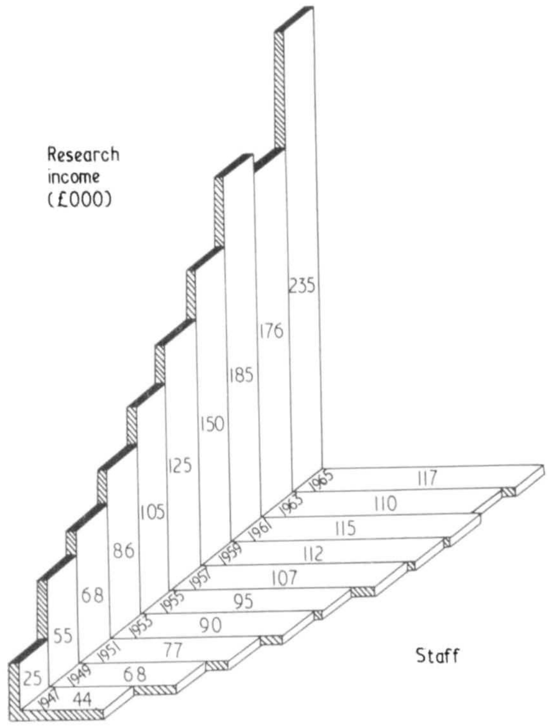

Figure 2. Growth of the Fulmer Research Institute since 1947.

for work done and, starting with an original capital of £40 000, its assets are now estimated at about £250 000. This growth is illustrated in figure 2. The proportion of the work sponsored by Government departments has, over the last ten years, been about 30% (figure 3) and work for the Atomic Energy

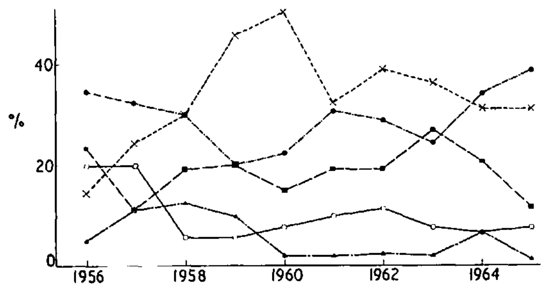

Figure 3. The proportion of the work of the Fulmer Research Institute sponsored in different ways. -- × -- U.K.A.E.A.; —· ● ·— Supply, Defence and Aviation Ministries; — ■ — Other U.K. sponsors; ○ U.S. Government agencies; -—▲-— other overseas sponsors.

Authority has averaged about 35%, although the proportion has fluctuated between 15 and 50% over the years. Over the same period work for overseas sponsors has averaged about 15%, of which more than 10% has been for U.S. Government agencies. Indeed, since its formation, the Fulmer Research Institute has earned more than one million dollars in work for the U.S.A. The remaining 20% represents work for individual industrial sponsors in this country, most of which, at present, is service work rather than research.

Obviously, the number and size of contracts in force varies from time to time but, to give an indication of the picture, in August of last year work was in progress on 48 contracts, the average total value being about £10 000 and the average annual value being about £5000. The distribution of contract size in August 1966 is shown in figure 4. As the Institute quotes the current cost of one graduate, together with a full-time junior assistant and a half-time research assistant, as £6300 p.a., it is clear that the average contract involves something less than the full-time services of one graduate. (The staff comprises 35 graduate scientists who between them were dealing with the 48 contracts.) In addition to these contracts, however, the Institute derives some £30 000–40 000 p.a. for short-term work: testing, analysis, enquiries, etc. Some testing work involves a fee of only one guinea and, in a year, the Institute does work of one kind or another for about 240 different sponsors. Provision is also made in the overheads for about 3% of the time of the staff to be devoted to projects

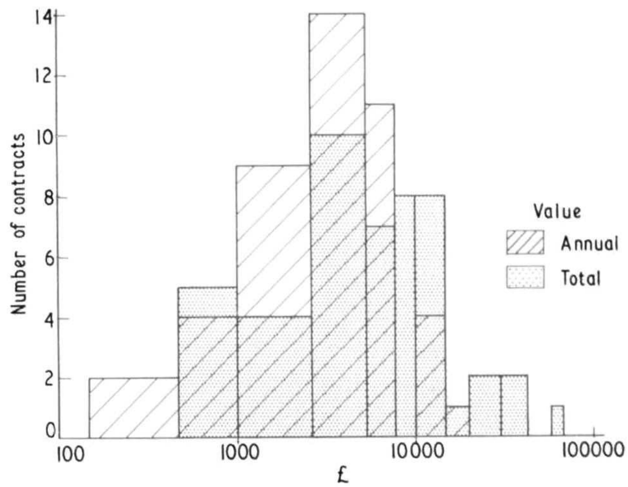

Figure 4. The distribution of contract size as at August 1966.

for which there is no immediate sponsor. This work is nearly always undertaken with a view to seeking a sponsor for its further development.

With most contracts, patents taken out as a result of the work become the property of the sponsor, but occasionally the contract allows for the Institute to take out patents, or patentable inventions are made as a result of work undertaken with the Institute's own resources. These patents are generally used to attract further sponsored work and have not usually been exploited by the Institute in the normal way. Thus, although these earn no direct income, they have been a valuable indirect source of income.

Routine work such as mechanical testing or chemical analysis is carried out for a fixed and agreed fee, but charges for other investigations are based on the time of the staff plus overheads at 110%. This overhead rate appears to be very low for a research organization; the figure is probably misleading because of the basis of calculation used. For comparative purposes a better figure is the total cost per graduate with an average of 1½ assistants which, at the Fulmer Research Institute, amounts to about £6300 p.a.—a figure which confirms the Institute's reputation as a good place to have research done cheaply.

A small development section is responsible for liaison with sponsors, for promotional work generally and for organizing replies to technical enquiries, but the main work of the Institute is organized in nine departments. Of course, research projects are often carried out in more than one department and weekly time sheets are used to control expenditure of time.

Previous work

Since 1946 some 176 papers have been published by the staff of the Fulmer Research Institute, based mainly on the work that has been undertaken for Government departments or the Atomic Energy Authority. About one-half of the published papers deal with physical metallurgy, and this is undoubtedly one of the fields in which the Institute's work is best known. The work of Sully and Hardy, in particular, from 1947 to 1956 on the metallurgical properties of aluminium alloys, is well known. Another development from that time is the Al–30% Sn bearing alloy which is now produced commercially.

The next largest group of papers (32) is on physical chemistry–process metallurgy. Prominent amongst the authors of these is Dr. P. Gross who is the Principal Scientist and, with Mr. Liddiard, a member of the Board of Directors. Many of these papers deal with the heats of formation of metallic halides (figure 5) and some of the work involved led to the development of the catalytic distillation process for primary aluminium production. A pilot plant is now operating in Canada and related processes have been worked out for the production of beryllium and titanium. Measurements have also been made of the emissivities of gases at temperatures up to 1000°c. Measurements were made of the total radiation from a flowing column of gas contained in a refractory tube open at both ends, the length of the gas column being defined by the use of exactly balanced opposing streams of argon to form gas barriers at each end of the tube. The emitted radiation was measured by a sensitive thermopile in conjunction with an optical system containing a concave mirror with a diaphragm close to its focal plane to exclude radiation from the furnace components surrounding the gas, the whole apparatus being mounted on a water-cooled optical bench (figure 6).

Since 1960 an appreciable amount of work on corrosion problems has been undertaken and 16 papers on this subject have so far been published. Stress corrosion (figure 7) and corrosion fatigue in light alloys have formed the bulk of the work, but the hydrogen embrittlement of high-tensile steels is now being studied and work has been started on the development of metal polishes which confer resistance to tarnishing.

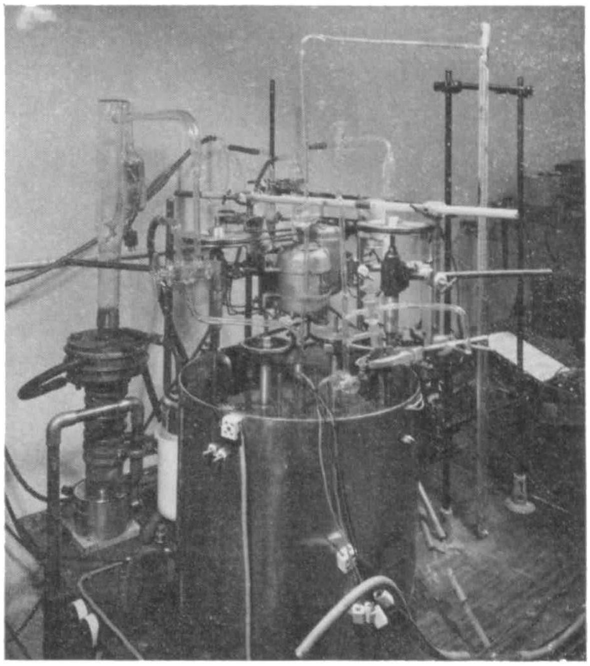

Figure 5. Calorimeter used for determining heats of formation of inorganic compounds. It consists of an inner calorimetric vessel containing the calorimetric fluid and the reaction bomb, and an outer constant-temperature bath controlled to within $\pm 0 \cdot 001$ degc. The interspace between the two vessels is maintained under high vacuum. The calorimetric fluid is usually water but other substances have been used for reactions which must be carried out at elevated temperatures (e.g. metal bromides). The amount of chemical energy liberated by the reaction is determined from the temperature rise of the calorimeter, which is measured by a semiconductor resistance thermometer having an accuracy to 2×10^{-4} degc.

The values obtained for the heats of formation of compounds vary from 20 kcal, for heats of alloying, to 500 kcal for heats of formation of metal fluorides. The overall uncertainty of a determination is usually less than $0 \cdot 1\%$.

The fact that the work has been of such a character as to lead to publishable papers and that permission has been given for their publication has undoubtedly contributed greatly to the success of the Institute. The Chairman might also have mentioned

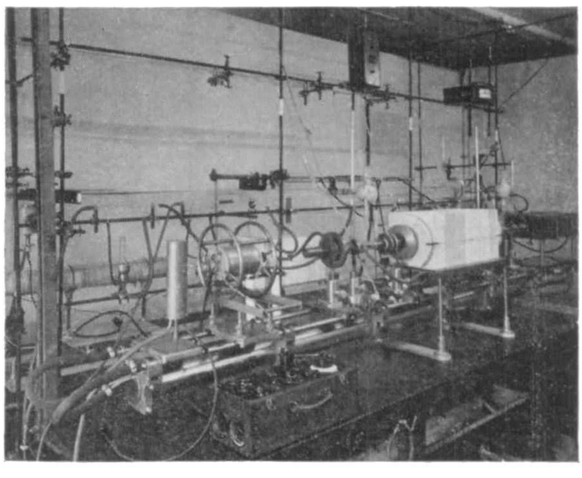

Figure 6. Apparatus for measuring the emissivities of gases at high temperatures.

the need for a sponsored research organization to choose its sponsors wisely; its published work, together with the exhibition of work on the Open Days held on the occasion of the official opening,

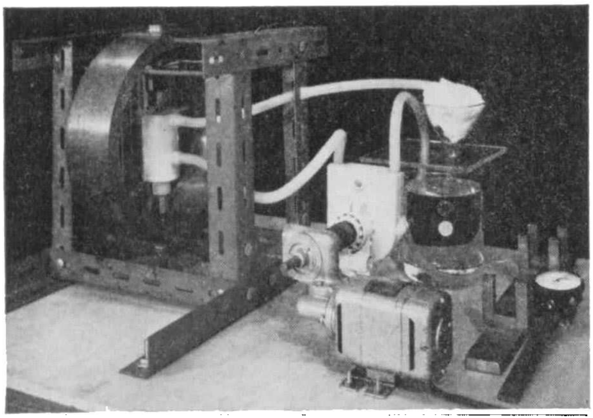

Figure 7. Apparatus for sustained axial load testing of ultra-high tensile steel in corrosive environments.

show that in this respect too the Fulmer Research Institute has chosen wisely. The Institute now hopes to broaden the scope of its activities and to increase the amount of work done for industry. Clearly great care will be needed in the choice of sponsors and in the way in which this is done if the Institute is to maintain its character and scientific reputation.

Current work

It is clearly impossible to describe or even to mention all of the current work of the Fulmer Research Institute, but attention might usefully be drawn to a few items of particular interest to physicists.

The Physics Department is responsible for about 20% of the income of the Institute. In the past much of its work has been on metallurgical problems, and the department is well equipped for work on x-ray and electron diffraction and for electron microscopy. It has been responsible for a number of improvements in the technique of x-ray analysis as well as contributions to the knowledge of alloy structures. One piece of work of particular interest is that on the structure of liquid metals and alloys using x-ray diffraction patterns which have been obtained by a surface diffraction technique. Diffraction patterns of simple liquids show a single main intensity peak at a position corresponding to the mean inter-atomic distance, but the patterns for more complex liquids show a subsidiary peak also and this is interpreted as being due to the occurrence of a special short inter-atomic distance. This distance is not normally resolved in the radial distribution functions obtained by the Fourier transformation of the diffraction patterns, but its value can be deduced by artificially removing the subsidiary peak from the intensity pattern and finding the position in the radial distribution curve where this produces most effect. In the case of mercury and tin it is found that these short distances correspond to those occurring in the low temperature allotropes of the crystalline solids. Thus liquid mercury, for example, is regarded as consisting of atoms which are capable of taking up either allotropic form and, at any instant, inter-atomic distances corresponding to the alpha and beta allotropes can be said to co-exist in the liquid.

Other aspects of liquid metals are also being studied. In certain circumstances molten sodium provides boundary lubrication, the lubricating action being attributed to the presence of surface compounds which form as a result of the chemical interaction of the sliding materials with the molten sodium environment. In an attempt to identify these compounds an x-ray camera has been constructed which allows samples to be heated in a sodium environment prior to x-ray diffraction examination.

The surface tensions of liquid metals are also being determined, the main object being to obtain the surface tension of liquid uranium, when saturated with carbon, over a range of temperatures. Bubbles of pure argon are formed at the orifice of a capillary tube immersed in the liquid metal and the pressure difference across the surface of the bubble is recorded. This pressure difference is made up of two components; a hydrostatic component and a surface tension component, depending on the surface tension of the liquid and the radius of the bubble. Maximum pressure occurs when the radius of the bubble is a minimum and this corresponds to the effective radius of the capillary orifice. A plot of maximum pressure against depth of immersion has an intercept on the pressure axis that corresponds to the surface tension component, and with a knowledge of the radius of the capillary the value of the surface tension can be calculated.

Currently the Physics Department is also working on the structures and properties of stable resistance alloys, thin metal films and superconducting materials, in particular on the problems associated with the production of high magnetic fields.

In the Process Metallurgy Department niobium–tin (Nb_3 Sn) flux concentrators up to 8 cm diameter and 15 cm long are being made for the production of magnetic fields in excess of 50 kg. This work is being done in collaboration with Drs. Smith and Spurway of the N.I.R.N.S. laboratory. A longitudinal slit is machined in a thick-walled cylinder of niobium–tin and is filled with stainless steel. Cones are machined from the ends to increase the current density near the centre and the concentrator is then wound with stainless-steel wire to prevent mechanical failure. Circulating currents are induced in the concentrator by placing it in a magnetic field above the transition temperature, cooling to below the transition temperature and then switching off the field. The large circulating currents near the centre of the concentrator then give rise to a high field in the hollow core.

The niobium–tin prepared by conventional powder metallurgy methods has a strength of 1·3 tons in^{-2}. Attempts to increase the strength, so as to resist the large forces produced when the magnetic field changes rapidly, have included impregnation with Araldite and impregnation with a metal by heating the sintered compact in a bath of the molten metal in an argon atmosphere containing a trace of chlorine. In these ways the strength has been increased from 1·3 to over 9 tons in^{-2}.

As already indicated, most of the work of the Fulmer Research Institute is of a metallurgical nature. Studies of uranium and its alloys have included the determination of the grain size of uranium in the beta phase at high temperature in a specially constructed x-ray camera, investigation of the solubility of aluminium and iron in the allotropes of uranium, the kinetics of transformation from the gamma phase and the structure and occurrence of the metastable monoclinic phase in uranium–molybdenum alloys, and the structure of a metastable gamma phase.

An electron beam zone-refinement process has been developed for the preparation of alumina with impurity levels of less than 1 part per million. The product takes the form of a thin rectangular sheet extensively cracked by thermal stresses, and an electron beam remelting process is now being developed for the preparation of crack-free stock from the purified alumina. Zone refining using induction heating has also been applied for the preparation of high-purity iron and nickel for use in high-purity stainless steels, and for the removal of oxygen from chromium. Impurity levels of 1–40 parts per million are achieved.

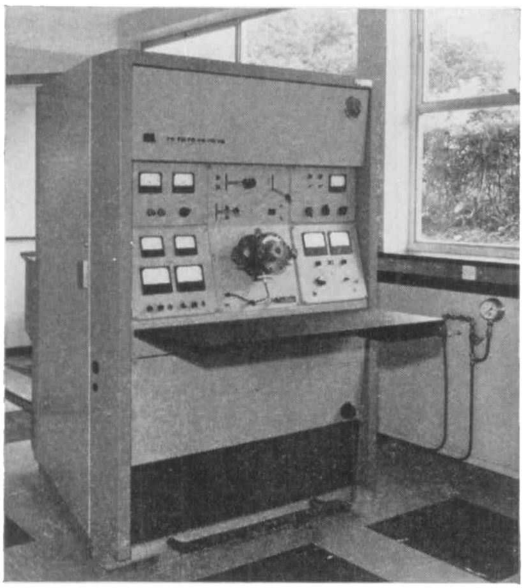

Figure 8. Mass spectrometer for inorganic analysis.

A mass spectrometer (figure 8) has recently been installed in order to provide a comprehensive and sensitive inorganic analytical service for scientists and industry. The instrument is capable of surveying all elements from lithium (atomic mass 7) to uranium (atomic mass 238) in one analysis and impurities can be detected in concentrations as low as 1 in 10^9. A complete analysis of one specimen will cost about £40.

A d.c. or r.f. discharge between electrodes of the material to be analysed provides the source of ions for analysis by the mass spectrometer, a spectrum rather similar in appearance to that produced by a conventional quartz spectrograph being recorded on a photographic plate. After development the photographic plate is measured by a densitometer and, after making allowance for multiply charged ions and the known isotopic abundance ratios of the elements, a quantitative analysis of all the elements in the sample can be obtained. When repeat exposures are made, the standard deviation of analyses of impurities is of the order of 20%.

A d.c. source is limited to the analysis of conducting samples, whereas with an r.f. source semiconductors and insulating solids can also be analysed. More ions are collected on the photographic plate from a d.c. source than from an r.f. source, partly because of the greater extraction efficiency resulting from the lower mean energy of the ions and partly because of the greater transmission efficiency arising from the narrower energy spread of the ions from the d.c. source. On the other hand, the d.c. source gives rise to a large proportion of multiply-charged ions so that each component of the sample contributes to several ion beams. It is of interest to note that approximately 10^7 atoms are consumed for each ion delivered to the photographic plate.

Another recent addition to the equipment at Fulmer is a third electron microscope, the latest instrument being equipped with an x-ray micro-analyser. This permits the quantitative analysis of elements from atomic number 12 onwards and quantities as small as 10^{-14} g can be detected. The combination of the analytical facility with simultaneous electron microscope observation of the area makes a powerful research tool.

These two new instruments are available, through the Fulmer Research Institute, to research workers or industry and make available these expensive facilities to those who cannot otherwise justify the cost or staff to provide such services. Together with the rest of the equipment at Fulmer—for x-ray work, mechanical testing, analysis, etc.—they provide specialized testing facilities covering a wide range of needs.

Acknowledgments

I am grateful to Mr. E. A. G. Liddiard, Director of Research of the Fulmer Research Institute, for assistance in compiling this article.

A. E. De Barr