FULMER RESEARCH INSTITUTE

By E. A. G. LIDDIARD
(Director)

THE opening of the Fulmer Research Institute at Stoke Poges, Bucks, by Sir Stafford Cripps (see p. 150) marks the beginning of a new experiment in industrial research, the progress of which should be followed by all who are interested in the organisation of research in Great Britain. Briefly, the object of the Fulmer Research Institute, Ltd., is to provide research facilities which can be used to carry out research privately for any sponsor, or group of sponsors, the results arising from the research remaining under the control of the people who pay for the work. Its closest parallel is in the Battelle Memorial Institute or the Mellon Institute in the United States.

The suggestion has often been made, both in the editorial columns of *Nature* and elsewhere, that there is room in Great Britain for this type of research institute. This opinion is not invariably accepted, particularly by strong supporters of the research association movement, on the erroneous assumption that such an institute would compete with research associations. At the moment, fundamental research work in Britain is mainly carried out at the universities, and industrial research work either by the private laboratories associated with the works of individual firms or by research associations. Research associations have been particularly successful in solving problems which are common to all sections, and in educating industry in the scientific methods of approach to their problems. They also provide an excellent pool for the exchange of technical information which benefits the industry as a whole. The research associations have the advantage that the cost of researches is borne by many subscribers whose individual contributions are small in relation to the cost of the researches, and much more work can therefore be done than would be possible if the research work was left to be financed by the individuals concerned. The Department of Scientific and Industrial Research grant and the freedom they enjoy from rates and taxes put the research associations in a favourable financial position.

The limitation of a research association, however, lies in the absence of any mechanism for developing really new, original and individualistic ideas. The most advanced firms in any industry are not often prepared to put forward their very brightest ideas for the research association to work upon for the benefit of the whole industry. Research programmes of research associations are usually arranged on democratic lines by committees representing the industry, which restricts the activities of the research associations to problems in which the majority of the industry is interested but which are either beyond the resources of an individual member or are not considered to be sufficiently urgent or important to take up the time of the research department of individual members.

What, then, is the position of a concern wishing to develop an original idea or a new process of manufacture to help it to compete successfully in the world's markets? In the absence of an institute where sponsored research is carried out confidentially, the choice lies between making the idea and the results of any research work on the idea generally known, when it becomes of equal value to competitors, or of collecting together the necessary specialized

staff and equipment to do the work in its own laboratories. This entails considerable capital outlay, and, when the work is completed, the profitable use of the staff and equipment may present a difficult problem.

There remained, therefore, an important gap in our organisation of research, and in filling that gap there is no question of competition between an institute for sponsored research and a research association.

In the situation in which Great Britain finds itself to-day, we are told that we must export. Some of the most important assets of the country are the brains and ideas of its scientific workers; these are at present mainly being used for the provision of knowledge which is available to the world at large. For pure scientific work this arrangement is ideal, but we are living in a competitive age, and it would seem to be common sense to do all we can to capitalize in the national interest our assets in the form of applied science. This can only be done effectively if the results of research remain in the hands of people capable of making full use of them. For example, a new process which may follow from research at a university becomes available equally all over the world, and is everybody's or nobody's property; in fact, research work done in Great Britain has often been applied abroad before it is used at home. But where the results of research work are owned by an individual sponsor, any process arising from them can be used to increase our exports or, if patentable or negotiable, can result in increased national income from royalties, etc.

The Fulmer Research Institute aims eventually at carrying out research in a wider field, but to begin with, will concentrate on metallurgical and allied problems. Equipment and staff will be available to tackle most forms of metallurgical research, and work may be placed there in the knowledge that the results will be treated confidentially and that they may be exploited by the sponsor for his sole benefit. Provision has been made whereby nominees of the people who sponsor a research can come to work in the laboratories on the development of new industrial processes and can go back to the sponsor when the work is completed, carrying with them the knowledge that they have gained in the laboratories.

The idea of such an Institute was conceived by Colonel W. C. Devereux, who, having studied the system of sponsored researches in operation in the United States at the Battelle and Mellon Institutes, became convinced that a similar institution is needed in Great Britain. The Fulmer Institute is non-profit-making, in the sense that there will be no distribution of dividends. Charges for research are based on cost of salaries and materials, plus a small margin which will be available for the future expansion and further equipping of the Institute. Work is not undertaken on one problem for more than one sponsor unless the original sponsor agrees to share both the cost and the results of the research. Publication of the research results will be at the discretion of the sponsor; but the Institute will advise publication wherever practicable, particularly where the results of the research can be covered by patents which, of course, become the property of the sponsor.

The size of the Institute can be assessed from the fact that the total floor area is approximately 20,000 sq. ft. Chemistry, corrosion, vacuum, engineering, physics and metallography sections are housed in the main building (a converted country

mansion), together with the library, offices and canteen. A new building contains the machine shop and the experimental casting and heat-treatment laboratories. Twelve out of a total staff of forty are graduates, and the staff includes chemists, physical chemists, physicists and engineers as well as metallurgists.

The most important researches at present in progress are in the development of new alloys for service at high temperatures; researches on aluminium base alloys (these are in charge of Dr. A. H. Sully); and on a process for refining impure aluminium by catalytic distillation based on the existence of monohalides of aluminium stable at low pressures and high temperature which can be formed by passing the normal trivalent halides over aluminium at high temperatures and low pressures. They decompose to the metal and the trivalent halide at lower temperatures. This work is being carried out by a team under the direction of Dr. P. Gross. The principle is likely to be applicable to other metals, and sponsorship for researches on the refining of other metals on this principle is sought.

Although the Institute is prepared to consider any type of research work, the staff and equipment are such that problems in physical metallurgy, corrosion and finishing, the development of new casting processes and in the application of thermodynamics to metallurgical problems are likely to be tackled most successfully.

A certain proportion of short-term work involving mechanical and analytical testing and advice and information on technical problems is also undertaken and constitutes an important but not a major part of the Institute's activities.

SURFACE TENSION IN LIQUIDS

By C. GURNEY

THERE is ample experimental evidence that the free surface of liquids is in a state of tensile stress, but this stress has never been satisfactorily explained in terms of the positions and motions of molecules. It is generally recognized that liquids cannot permanently withstand shear, and yet a two-dimensional tensile stress implies shear in all planes inclined to the plane of the tension. How is this possible? The most acceptable previous explanation is that due to Bakker¹, which has recently been discussed by R. C. Brown²; but the Bakker theory is not very satisfying, as it is an attempt to show that the surface of a liquid could be in a state of effective tensile stress without an associated shear stress. The failure to explain the tension stress in the surface of liquids has led many writers to regard it as unreal. Authors who have referred to the stress as a 'fiction' include Laplace, Rayleigh and N. K. Adam. Adam³ also writes, "The surface tension does not exist as a physical reality". J. Rice⁴, in his commentary on Gibbs' papers on surface phenomena, is at pains to absolve Gibbs from having the notion that the surfaces of liquids are in a state of tension stress.

By giving a molecular interpretation to the thermodynamics of surfaces as developed by Gibbs, I give below what seems to be a satisfying explanation of the tension stress in the planes of surfaces, and which appears to have some novel features. Gibbs introduced into thermodynamics a quantity (μ) which he

called the intrinsic potential of a substance. Subsequent authors have called this quantity partial molal free energy, chemical potential, etc. For equilibrium between phases and between each part of a heterogeneous phase, Gibbs showed that the intrinsic potential of the parts of each component substance must have the same value throughout the system. The intrinsic potential is a measure of the escaping tendency of molecules. Molecules tend to escape from regions of high μ and to migrate to regions of low μ . Equality of the intrinsic potentials ensures that just as many molecules of each species enter each region as leave it. This condition is therefore similar to the equation of continuity in fluid mechanics; but in thermodynamics we are dealing with random motion of molecules, whereas fluid mechanics deals with organised motion. At a given temperature, intrinsic potential depends on the arrangement and relative position of molecules. Molecules at a free surface or at an interface between two different substances have a different environment from interior molecules, and they would, therefore, be expected to have different intrinsic potentials, whereas for equilibrium they must have the same intrinsic potential as interior molecules. How then can equilibrium be achieved? At this stage it may be helpful to consider another case of thermal equilibrium.

Consider a pure substance, say lead, in equilibrium with its liquid. When stress-free, there is only one temperature at which this equilibrium can occur. At this temperature the intrinsic potentials of solid and liquid are equal. At room temperature, solid lead has the smaller μ , and in consequence the solid phase is stable. How could we have solid and liquid lead in equilibrium at room temperature? The answer is that stress must be applied to the solid or liquid or both, until their intrinsic potentials are equal. In principle at least we could apply pressure to the solid to increase its intrinsic potential to that of the stress-free liquid, or we could apply hydrostatic tension to the liquid to decrease its intrinsic potential to that of the stress-free solid. For two-phase equilibrium there is thus a relationship between stress and temperature. By making use of the relationships

$$\frac{\partial \mu}{\partial p T_n} = \bar{v} \text{ and } \frac{\partial \mu}{\partial T p_n} = -\bar{s}, \quad (1)$$

(where p , T , and n are pressure, temperature, and quantity of substance respectively and $\bar{v}$ and $\bar{s}$ are specific volume and specific entropy), the relationship between p and T for the case in which the liquid only is subjected to pressure is

$$\frac{dp}{dT} = \frac{L}{T\bar{v}}, \quad (2)$$

where L is the latent heat of the solid-liquid transition. The equilibrium pressure on the liquid thus increases with temperature; at low temperatures (below the stress-free melting point) the equilibrium pressure is negative. In principle, therefore, we could have solid and liquid lead in equilibrium at room temperature by applying a hydrostatic tension to the liquid.

It is now only a small step to the explanation of the tension in the free surface of a liquid. In the absence of stress, surface molecules have a higher μ than interior molecules. For equilibrium, stress must be applied to the surface or interior or both, to make the intrinsic potentials of surface and interior molecules equal. As the surface molecules have the higher μ , it is easy to see, by analogy with the solid-liquid equilibrium case, that the stress which must