NATURE

No. 4064 SATURDAY, SEPTEMBER 20, 1947 Vol. 160

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Editorial and Publishing Offices
MACMILLAN & CO., LTD.,
ST. MARTIN'S STREET, LONDON, W.C.2.
Telephone Number : Whitehall 8831
Telegrams : Phusis Lesquare London
Advertisements should be addressed to
T. G. Scott & Son, Ltd., Talbot House, 9 Arundel Street, London, W.C.2
Telephone : Temple Bar 1942
The annual subscription rate is £4 10 0, payable in advance, Inland or Abroad

GOVERNMENT RESEARCH AND DEVELOPMENT IN GREAT BRITAIN

THE question of incentives for the research worker and manager has rarely received in the past the attention it merits. In this respect, the valuable report on expenditure on research and development which has recently come from the Select Committee on Estimates for the Session 1946–47* is exceptional. This important report reviews the total estimated expenditure for 1947–48 in Government research and development, amounting to more than £69 millions. It does not consider the technical problems involved in the detailed planning and conduct of this work. The Committee is concerned rather to inquire whether in drawing up the programme the Government has provided itself with the best scientific advice available in the country, and has secured that this advice can be brought to bear on the formulation and execution of Government policy ; whether the administrative organisation has been so planned as to secure the right relationship between the scientific worker and the executive and to obtain the most fruitful results from the money spent ; and, above all, whether the scope and balance of the programme is such as will direct the application of scientific knowledge and effort into those fields where it is most likely to yield returns of permanent value to the nation and in such a way as will make the most efficient use of the limited resources of both money and man-power.

These are the right questions, and while a very much longer report would have been necessary to do justice to all the factors, there can be no doubt that the Committee has done its work thoroughly and provided a reassuring and encouraging answer to most of the questions. Moreover, an admirable and lucid review of the whole organisation of Government research is supported by a note on the composition and functions of the Defence Research Policy Committee and of the Advisory Council on Scientific Policy, and a series of departmental memoranda which add not a little to the information already published about the work of the Department of Scientific and Industrial Research, the Medical Research Council, the Ministry of Transport and the Board of Trade, in spite of the fact that no detailed information could be given on the work done at the research establishments of the Service Departments. That aspect of the problem is, however, to be dealt with in greater detail in a later report.

On the first of these questions the Committee welcomes the appointment both of the Advisory Council on Scientific Policy and of the Defence Research Policy Committee. Neither body has yet completed its first year of work, and it is too early to say how far these developments will succeed in securing the most efficient direction of the nation's scientific resources. On the administrative question, the distribution of functions and responsibilities among departments and other bodies appears to be illogical, and possibilities of overlapping and waste

* Report of the Select Committee on Estimates for the Session 1946–47. Pp. 132. (London : H.M. Stationery Office, 1947.) 1*s.* 6*d.* net.

of effort exist. The Committee takes the view that within limits a certain amount of overlapping can be a healthy stimulus; but it urges that the danger is best avoided by a first-class system of liaison at all levels and the freest interchange of information on projects as well as on results. Generally, the Committee appears to be satisfied that improvements in the existing organisation are being made as weak spots are revealed, and it agrees with Sir Edward Appleton's opinion that it is too early to decide what the ideal Government organisation for research should be. The organisation for fostering scientific research must remain for many years in a state of active development.

The point about free interchange of information comes up again in observations on the third question, where the Committee is both more reserved and more critical. Pointing out that in determining whether the nation's money is being well laid out within the limits of the policy implied in the Estimates, the Committee observes that the scope and balance of the programme are of great importance; money has been, and can still be, wasted by undertaking applied researches without securing that sufficient provision has been made for research into fundamental principles. In particular, it is suggested that the control of pests and the prevention of plant and animal disease might be more rapidly advanced by greater stimulus to fundamental researches in certain aspects of biology and in the specialized problems presented by viruses. Again, appropriate investigations in the social sciences might lead to lower administrative charges and to large monetary savings to the community as a whole.

These matters are commended to the attention of the Advisory Council on Scientific Policy, and at the same time the Committee stresses the value of regular, non-technical, readable, balanced and sober statements of the Government's research activities, in order to prevent undue expectations of greater and more rapid results than can be justified. It welcomes Sir Henry Tizard's indication that he hopes to publish an annual report, but, rather surprisingly, it makes no comment as to the desirability of the Department of Scientific and Industrial Research and the research councils resuming as speedily as possible the practice of issuing annual reports which was interrupted during the War. A publication policy of this type is, however, an essential element in securing the favourable political climate for research on which Dr. R. P. Russell, president of the Standard Oil Development Co., laid such stress in his recent lecture to the Industrial Research Committee of the Federation of British Industries; and in particular, the suggestion made by the Committee that Parliament should be provided periodically with comprehensive 'progress reports', setting out the range, aims and progress of Government research activities, is very much to the point.

Before discussing further the question of relations between the scientific worker and the executive, the Committee proceeds to discuss that of the scope and balance of the programme. The two questions are not, however, entirely separate, for evidence presented to the Committee showed that the pursuit of profitable new lines of research at the present time is impeded not so much by lack of money as by shortage of men and accommodation. It is clear from the way in which the Committee refers to such matters as reasonable housing accommodation for staff and to the new salary scales for the Scientific Civil Service that it is fully cognizant of those other factors in securing appropriate staff and in encouraging creative work. Specifically, it directs attention to the danger of excessive rigidity. The strict application of a code to certain types of research work, it rightly observes, may cause considerable waste of money and effort and may jeopardize the success of a costly project, besides creating an atmosphere alien to the conduct of first-class research. Moreover, not only is elasticity important in securing the right man for the right job; it is equally important in the financial control of research projects. For some projects a reasonable flexibility in the detail of expenditure is essential to the success of the research and to the most economical use of the money. Scientific workers will note with appreciation that the Committee is impressed with the economies that can accrue in such expenditure from allowing the greatest freedom compatible with safety, and it is to be hoped that the Committee's recommendation that existing arrangements should be reviewed to secure that such freedom and flexibility are more uniformly the practice will receive appropriate action.

The question of scientific staff is considered more fully in a later section of the report which comments particularly on the recommendations of the Barlow Committee on scientific man-power. Shortage of accommodation and difficulties in erecting new buildings are already hampering university expansion, and the Select Committee observes that the provision of sufficient staff and accommodation for teaching and for fundamental research at the universities should be the basis of the Government's research programme. It considers, however, that the substantially increased grants administered by the University Grants Committee should be sufficient to cover the expansion which can be undertaken in the current year. In view of recent discussions on technical colleges, it is worth noting that the Committee favours bringing more of these institutions within the university framework; but it recommends that other sources of recruitment such as engineering and other apprentices in Service establishments or in industry who receive part-time training in applied science should also be brought in, and in particular immediate action on a resolution of the British Commonwealth Scientific Official Conference regarding scholarships, studentships and maintenance grants is urged.

What most disturbs the Select Committee, however, is evidence that conditions of Government service do not always create an atmosphere attractive to research workers or conducive to scientific progress; and it refers to a number of the difficulties which were considered by the Barlow Committee on scientific staff. It attaches particular weight to eliminating the danger of isolation from active outside work in his field that may afflict the scientific

worker in departmental employment. Men of science could scarcely wish for a more pointed reference to the need for appropriate action to remedy this defect, and the Select Committee's view that attendance at the appropriate meetings of learned societies and other organisations where the all-important personal contacts can be made should be regarded as part of the duty of those in Government employment rather than as an occasion for which leave is grudgingly given, gives the individual scientific worker and his professional association all the backing that he could expect where further representations may be required.

It seems clear from such passages that much has yet to be done to implement the recommendations of the report of the Barlow Committee on scientific staff and to bring the conditions of service into line with those which Dr. Russell claimed in the lecture referred to above are most fruitful. None the less, this authoritative support for the idea of freedom in outside contacts and for the principle of a sabbatical year should go far to impress upon departmental heads the need for action along these lines, and to secure the removal of the barrier to movement between the universities and Government service which pension rights continue to offer.

Turning now to the question of the balance of the Government's research programme, the Select Committee distinguishes four aspects which require consideration: whether the sum granted for fundamental research bears a reasonable relation to that allocated to the conduct of applied research and development; whether the sum spent on directed fundamental and applied research is distributed in the best proportions between the several main lines of civil and military research; whether sufficient is being done to enable the universities to improve the quality and quantity of their human output, and whether the inducements offered are such as will attract a fair share of this output into the Government's scientific service. The views of the Select Committee on these last two aspects have already been indicated, and while on the first the Committee is reserved, holding it is a matter for experts fully informed of the amount and distribution of endowments and able to consider how far those endowments need supplementing, it is at least doubtful whether the allotment to pure research and to scientific teaching is sufficient to secure the twin objects of gaining natural knowledge which provides the foundation for the whole structure of applied science, and of providing the required output of trained research workers. Equally, it is for consideration whether the expenditure of nearly two thirds of the total sum of £76·5 millions on defence research represents an equitable distribution between civil and military needs. The relatively insignificant sum of £500,000 allocated for Colonial research is also stressed, and there are other weaknesses revealed in this admirable survey.

The Select Committee is not satisfied that the Admiralty is sufficiently flexible in its attitude to matters of common interest, and the Committee expresses the opinion that the research links between the Admiralty and the Ministry of Transport do not yet provide sufficiently for the application of scientific knowledge to improve the comfort, health and safety of the men and the proper equipment of the ships of the Merchant Navy. Here and elsewhere, the Medical Research Council is not always consulted on matters where its advice and work might be of great value. One of the weakest points in the Government organisation appears to be the absence of sufficient provision for the identification of scientific problems in day-to-day administration. This requires, as the Select Committee points out, men with wide scientific knowledge who are in daily contact with the work of their Departments, who know where the best advice can be sought or the research done, who can interpret the answer received and can advise on its special application to the administration and policy of their Departments.

That, however, is only another way of saying that scientific men are required as administrators, and that it is essential that the administrator in general should by training have acquired at least some ability to appreciate the scientific method and the scientific and technical factors in a situation or problem. That, as Dr. Russell, too, brought out, is an essential condition in the effective management of research.

A statement which has since been issued by the Association of Scientific Workers is much more critical of the organisation of Government research than is the Select Committee on Estimates, and proposes the immediate addition to the Advisory Planning Board to the Cabinet of three scientific and three technical members. In urging this, however, the Association appears to be less concerned with the balance of effort in the past than with its re-orientation to secure the immediate and effective utilization of science and technology in industry and agriculture in accordance with a plan prepared by the Advisory Council on Scientific Policy. The Association recommends, indeed, the diversion of at least a third of the scientific man-power, of laboratories and equipment of the defence services of Great Britain to civil production, challenging the present distribution of research effort between the defence services and civil production even apart from the present crisis. Similarly, it recommends steps to pool scientific research and development work in the essential industries, and to provide opportunities for scientific workers and equipment in non-essential industry to be used for more important work. The formation of regional research councils linked with the central organisation of production and research and the specific representation on production committees of scientific and technical workers are also urged in this statement, the main emphasis of which lies in the mobilization of scientific resources to improve production rather than in criticism of the organisation for co-ordination already established.

The utilization of science in connexion with the present state of emergency in Britain and elsewhere was also discussed vigorously at the Dundee meeting of the British Association, and a committee was appointed to examine the question as a matter of national urgency.

It is unfortunate that the comments by the Select Committee on Estimates on expenditure upon research into the use of atomic energy have attracted popular attention somewhat to the exclusion of the many other important matters covered by its report. No such comprehensive and detailed survey of the whole organisation of Government research in Great Britain has appeared before, and no other document brings together so conveniently quite the same range of information. Naturally, many questions require consideration in greater detail; but in the main the right questions are asked and some indication is given of the direction in which answers should be sought before the country is committed to any great or unbalanced increase of expenditure on research, whether it be for the Services, under the Department of Scientific and Industrial Research, or in any other field.

HELIUM

Helium

By Prof. W. H. Keesom. Pp. xx + 494. (Amsterdam, London and New York: Elsevier Publishing Co., 1942.) n.p.

MONOGRAPHS on the properties of a single substance are mostly rather tedious, though often useful, affairs. Helium has, however, been for many years of special interest, as the substance of lowest boiling point, and therefore an essential tool in all techniques for the production of temperatures near the absolute zero. Now, also, helium has emerged as itself the subject of intensive investigation, being the representative—actually the only terrestrial representative—of a phenomenon which might best be termed 'liquid degeneracy' and which manifests itself in a number of most striking effects occurring in the last few degrees above absolute zero.

If helium behaved as a normal substance, it would not exist as a liquid in this region, but would solidify somewhere between 2° and 3° K. Kamerlingh Onnes soon found, however, after his first liquefaction of helium, that it would not solidify under its own vapour pressure even at the lowest temperatures he could reach—about 1·5° K. At that time, curiously enough, this fact—though very useful to the low-temperature physicist—did not arouse unusual interest, nor did the equally strange fact that helium had an abnormally high volume, nearly four times that which would be predicted from the data of gas kinetics. We now know that this is due to the zero-point energy, the effect of which on physical properties becomes more marked for the low-boiling point substances. In helium it counteracts about three-quarters of the energy of attraction between atoms, 'blows it up' to its abnormal volume and prevents it from settling down to what is normally the state of lowest energy, the crystalline state. Thus as it approaches absolute zero, helium is unable to lose entropy in the ordinary way, that is, by arranging its atoms in the geometrical order of the crystal. It is true that helium can be solidified by pushing it by sheer force into a very small volume, but under its own vapour pressure helium remains liquid—and a very liquid liquid—down to the lowest temperatures.

However, although helium remains liquid, it must lose entropy if it is not to conflict with the Third Law of Thermodynamics. Many a low-temperature physicist probably hoped secretly that this law of the unattainability of absolute zero did not apply to liquids, so that by some process involving the use of liquid helium that final goal might be reached. These hopes were soon shattered, however, when in 1932 the author of the book under review discovered the so-called 'lambda' phenomenon. From this it became evident that helium changed from a more or less normal liquid into one of vanishing entropy by a transition of higher order. It was shown that helium lost its entropy rapidly below the 'lambda' point (2·18°), and that by about 1° K. the entropy had already reached an exceedingly low value. By the middle of the 1930's most of the thermodynamic data had been collected for helium in this low-temperature state, or helium II as it was termed.

In the latter part of the 1930's, chiefly as a result of developments in the technique for liquefying helium, more laboratories entered the low-temperature field and joined in the investigation of the properties of liquid helium. This was especially true of Great Britain, the United States and the U.S.S.R. There followed in quick succession a series of startling discoveries in the field of the dynamic properties of liquid helium: in 1935 the anomalous heat conductivity was discovered, in 1936 the phenomenon of the creeping film, and in 1938 the 'fountain' effect and the anomalous viscosity.

Theoretical workers soon became interested in these manifestations of what were obviously quantum effects on a macroscopic scale, and by 1939 this field had become one of leading scientific interest. The War at once interrupted developments in Britain and in the United States, and shortly afterwards in Holland and the U.S.S.R. Prof. Keesom has used this period of enforced experimental inactivity to write his book, which appeared in 1942 but only reached Great Britain late in 1945.

All known properties of helium are treated, as can be seen from the headings of the nine chapters, which are: (1) discovery, occurrence, production, commercial uses; (2) helium gas; (3) liquid and solid helium; (4) the diagram of state of helium; (5) transformations of higher orders; (6) the liquid condition; (7) the solid condition; (8) the helium atom; (9) the helium nucleus. The first three chapters, and particularly Chapter 3, will be of great value to everyone interested in low-temperature experimental techniques. The main interest is, however, in Chapters 4–7, where all the properties of helium in the liquid and solid states are discussed, with special emphasis on the newly discovered anomalous properties. At first sight the last two chapters might seem somewhat out of place, but one may be grateful for the collection of data from which the interatomic forces can be calculated, and also for the data given in Chapter 9 on the occurrence of He^3, which—as it follows a different set of statistics—may play an important part in the elucidation of the properties of this 'quantum liquid'.

One must admire in the book the very great objectivity with which every piece of work is discussed, a degree of objectivity which is greater than one could reasonably expect from one who has himself contributed so much to this field. Notwithstanding the author's detached view, the book is far more than a complete enumeration of the work done in the field; each paper has been discussed in its proper context and in relation to other work; furthermore, the author has not restricted himself to the discussion of experimental data, but has tried to make the reader