SCIENCE AND INDUSTRY, WITH SPECIAL REFERENCE TO THE WORK OF THE NATIONAL PHYSICAL LABORATORY.[1]

AFTER a reference to the work of the Privy Council Committee, the speaker pointed out that, in the words of their first report, "the object of the scheme is to bring scientific knowledge to bear practically upon our everyday industrial and commercial life." He continued :—In this process, as we shall see, and as has been well pointed out by various recent writers—see Dr. Rosenhain's paper before the West of Scotland Iron and Steel Institute, "The National Physical Laboratory: its Work and Aims," and Dr. Mees's pamphlet on "Science and Industry," issued by the Advisory Committee of the Privy Council—three distinct stages may be observed. We need :—

(1) The work of the man of science in his research laboratory.

(2) Investigations which go on in an industrial research laboratory, developing new processes or introducing new products.

(3) The works laboratory proper, controlling the quality of raw materials, finished products, and processes.

Let us note then, in the first place, we must have scientific knowledge. That point I need not labour, but note also that to be successful that knowledge must be pursued for its own sake. Each of the modern practical applications of science had its foundations in purely scientific work, and, to quote Prof. Gregory, in his recent book, "Discovery; or, The Spirit and Service of Science," "was not the result of deliberate intention to make something of service to humanity." It is scarcely necessary to illustrate this; let me, however, give one classical example. The discovery of the laws of electromagnetic induction is due to Faraday, and is described in his first three series of "Experimental Researches," published in 1831–33. Oersted, Ampère, and Arago had investigated some of the phenomena connected with the magnetic force produced by an electric current, and to Faraday it appeared clear that, conversely, it should be possible to produce electricity from magnetism, as he put it. It is difficult to picture, the world to-day without electric power, and yet the whole development of electrical machinery, as we know it, rests on the laws described in these brief scientific papers. Each advance of knowledge brings its benefits to mankind, and in a general way Faraday may have hoped to be a benefactor to his race by widening the sphere of knowledge, but it was the desire to know the truth which led him on and to which we owe such tremendous consequences.

We must have the student of pure research, the genius who goes on his way discovering new truths, irrespective of consequences, laying bare more and more of Nature's secrets and unravelling her mysteries.

In England we have never lacked such men; our roll of great discoverers has been a glorious one. Too frequently their lives have been hard and difficult, prophets without honour they have lived; to-night it is not my task to speak of them beyond urging the importance of giving every encouragement to such men by supporting, in the most generous spirit, any among you here in your University or elsewhere who are advancing the bounds of knowledge, searching for truth in some of its difficult byways. The endowment of pure science is essential; without it the attempt to apply science to industry fails.

This, however, is not my subject to-night; let us turn for a short time to the third need among those enumerated above—the works laboratory proper. My audience will appreciate perhaps more fully than I can the need for this.

It is necessary, if for no other reason, to maintain the standard of the output, to secure that the proper grade of material is supplied to the works, to check the instruments in use, and to test the product in its various stages of manufacture. The days are gone when successful manufacture could be carried on entirely by rule of thumb, trusting to the skill of some trained workman for the success of each delicate operation, when the hereditary instinct, passed down from father to son, was sufficient to produce each year practically the same results. New processes come, which appear likely to improve production or to reduce its cost; the works laboratory serves to test these. New products are suggested, which may or may not have the advantages claimed for them; this can be investigated in the works laboratory, and all these investigations and tests must go on in the works themselves under the eyes of men familiar with the process of manufacture in its every stage. The works laboratory must extend, and others are more competent than I to outline the direction of extension and to guide its growth.

Now between these two—the man of science researching in his university or college, and the works chemist toiling in his shop—there is a gap. Some means are needed to make the discoveries of science available to the manufacturer, to secure to him the advantages which come from the growth of knowledge to keep him in the forefront of his trade. This, if I grasp the problem aright, is the function of a laboratory of industrial research, and among such laboratories the National Physical Laboratory should hold a prominent place. The National Physical Laboratory has another function to fulfil—it is a great standardising and testing institution. I will recur again to that aspect of its work; for the present let us consider what is required in a laboratory for industrial research and see how far these requisites are supplied at Teddington. Quoting again from Dr. Mees's paper, already referred to, "This kind of research work," he says, "involves a laboratory very different from the usual works laboratory, and also investigations of a different type from those employed in a purely industrial laboratory. It means a large, elaborately equipped and heavily staffed laboratory engaged largely on work which for many years will be unremunerative, and which for a considerable time after its foundation will obtain no results which can be applied by the manufacturer."

This work clearly needs a special home; it cannot be done in the laboratory of a technical institute. The main work in a laboratory such as that of a technical institute must be educational. The object of the professor is to educate his pupils so that each may apply his knowledge to his lifework in the future. For this he will teach them to research. They will help him in his own investigations, and these may well have a bearing on the industry of the district. They may commence to solve for themselves simple problems akin to those they will meet with in their future work, but their power and opportunity to apply the new discoveries of science to the manifold problems of industry must be limited. For such work training is required, and full and elaborate equipment; the plant of a technical school laboratory must be designed to serve many purposes, all aimed at educating the pupils to apply science, and at teaching them the methods to follow. It is not their work, while still at college, to solve the conundrums of the manufacturer. The research laboratory is necessary if progress is to be made. Abbe realised somewhere about 1876 that British optical in-

[1] Abridged from an address delivered to the Birmingham and Midland Institute, on December 4, by Dr. R. T. Glazebrook, C.B., F.R.S.

struments had reached the highest possible development unless a radical change could be produced in the optical properties of glass, and the researches of Schott and himself, aided by subsidies from the Bavarian Government, lasted a number of years before the first catalogue of Jena glass was produced. Synthetic indigo was discovered by von Baeyer about the year 1880; it was not until some twenty years later that it was put commercially on the market, and in that time it is reported that no less than 1,000,000*l.* was spent by the Badische Anilin- & Soda-Fabrik before this desired end was reached.

Standardisation in all its branches is an important function of such a laboratory, and this involves research. The methods of measurement, the materials in which the standards can best be expressed, the accuracy of reproduction, and the conditions of use, all need investigation.

One other aspect of the matter remains to be considered, though very briefly. If we are to have a National Industrial Research Laboratory, who is to pay for it, who is to support it? The obvious answer is, the nation, but this in some quarters at once raises a difficulty. It is claimed that the results of any successful research bring profits, in the first instance, to some particular class, and that class ought to pay. For example, the discovery of some new and valuable alloy would profit, in the first instance, the manufacturer of the alloy and the persons employing it in their special trade. Before, therefore, you undertake an investigation you must secure, so it is said, the co-operation and financial support of a limited class who will presumably benefit by the success of the investigation. And no doubt, as a general rule, in cases in which it can be applied, this principle is a sound one, but such cases are limited. If a manufacturer comes with a conundrum, which he desires to have answered for his own private benefit, he must pay; but if a competent committee controlling an industrial research laboratory concludes that a research is of importance and likely to lead to knowledge of benefit to the whole industry with which it is concerned, I would plead that the cost of such a research should be met out of national funds. It is very difficult to say what individual will profit most in the end. An improvement in an industrial process leading to more employment and to a cheaper method of manufacture benefits a wide circle beyond the man who introduces the process. Germany—not merely Messrs. Schott and Zeiss—has profited by the labours of Abbe and his co-workers at Jena, labours rendered possible in the first instance by State help. No doubt there are cases where the co-operation of an industry can, and should, be secured; sometimes, too, it will be in the public interest to protect a discovery by a patent, if only to prevent action by a private firm restricting the free use of the discovery, but, in my opinion, it is not well to hamper those who control the laboratory by conditions aimed at securing support from industry before any special research is commenced.

The needs of the nation at the present time are too serious, the danger of delay too pressing, and the State may well devote large sums to industrial research without minute inquiry as to whether the research is going to benefit Messrs. A. B. specially, and what share, therefore, of the expense Messrs. A. B. must be asked to guarantee. In America the Bureau of Standards, in Germany the Reichsanstalt and the Material-Prüfungs-Amt, work thus for the national good, and this should be the task of our English industrial research laboratory.

And here let us note the importance of keeping the test work a live thing by the aid of research. Instruments are tested to see, among other objects, if they come up to standard, but the standard of to-day is too low some years hence; the tests must be so regulated as to tend to a gradual improvement in the product, and this can be done only by accompanying the tests with continuous research—research into methods of construction, into the materials most suitable for use, into the scheme of tests most helpful towards forming a correct opinion of the value of the instrument. Research must go hand in hand with testing. Without such close co-operation routine tests grow obsolete and cease to be of value; worked thus they prove an important aid to the manufacturer and a most desirable check on his production.

I trust I have convinced you—probably you did not need convincing—that laboratories of industrial research are necessary.

There must be more than one; in many cases an industry can be best served by a laboratory near its principal centre. Large firms, again, may each prefer to have their own; trade secrets and trade jealousies may interfere with full co-operation—this must be so to some extent—but a private laboratory on a really sufficient scale is expensive; too often it becomes little more than what I have called a works laboratory for testing the products of the factory, and for the smaller firms, at least, the only way to secure the full advantage of scientific advance is by co-operation—co-operation in the laboratory, co-operation, with specialisation in production, in the works themselves.

There is much for us all to do, and I ask your active support to make the National Physical Laboratory more efficient, more worthy of its name.

Increased funds must be provided, and it is only through the aid of the manufacturers, and of those who from experience have profited by the work of the laboratory, that the authorities can be induced to do all that is needed to establish the laboratory in a secure position.

On Friday, December 1, in the hall of the Institution of Civil Engineers, some of us listened to an address by Lord Crewe, President of the Privy Council Committee, on the subject of industrial research. It was in reply to a deputation from the Joint Board of Scientific Societies. Sir J. J. Thomson, president of the Royal Society, had spoken eloquently on the claims of pure science, Sir Maurice Fitzmaurice dealt with engineering, and Prof. Baker with industrial chemistry.

Lord Crewe announced that a large sum—the exact figure was not mentioned—is to be at the disposal of the committee during the next five years, and outlined the scheme for its expenditure. Associations are to be formed representing various trades or industries; the representatives of these will discuss with members of the Advisory Committee and other experts questions needing scientific investigation, and when these are determined the grant, supplemented in most cases by funds raised privately or contributed by the industry, is to be used to carry them out. Such work needs laboratories, and it is here, it seems to me, that the future of the National Physical Laboratory lies. Lord Crewe spoke in generous terms of the work of the laboratory in the past; its many friends who heard him were grateful for his cordial recognition of our labours, and he indicated a sphere of wider usefulness under less difficult conditions in the future. Let me picture to you what I trust that sphere may be.

In many cases, no doubt, the researches contemplated must go on in special laboratories arranged and equipped for the purpose—laboratories closely connected with the industry it is desired to help, situated at the great manufacturing centres; but there are many other researches of wide interest and great importance for which a central laboratory is the proper home, a laboratory fitted and equipped in an ample manner, with a trained and competent staff animated, like those, my colleagues, who have built up the National Physical Laboratory, with a love for science, and yet withal with a keen appreciation of the practical side of the question discussed and a real desire to help our country by the application of science to industry.

The body controlling industrial science research must have access to a laboratory in which may be studied the many problems which do not require for their elucidation appliances of the more specialised "works" character, or opportunities only to be found in particular localities; where a staff is available, able and experienced, ready to attack under the advice of men skilled in industry the technical difficulties met in applying new discoveries on a manufacturing scale or to develop ideas which promise future success.

Such a *rôle* the National Physical Laboratory should be prepared to play; such is the future which I trust may be in store for it.

COAL AND FUEL ECONOMY.

It may be hoped that nowadays no one needs to be reminded about the importance of the economical use of coal. We require all, and more than all, of the power and by-products which can be obtained from it, and are beginning to realise the value of the thousands of tons poured annually into our atmosphere with none but deleterious effects.

A committee of no fewer than forty-six members appointed by the British Association at the 1915 meeting, and containing representatives qualified to speak on the various aspects of the problem, presented its first report at the Newcastle meeting last September, when it was the subject of a joint discussion between the Chemical and the Engineering Sections.

At the same meeting there was also a discussion by the geologists and the chemists on the chemical and microscopical characters of different varieties of coal with a view to their more effective utilisation as fuel and to the extraction of by-products. The two discussions, though at the meeting quite distinct, may well be considered together, since they deal with different aspects of the same question. It is not proposed here to deal with the many papers seriatim, but rather to review the general lines of the discussion.

When chemists, geologists, and engineers meet to consider the coal question, three different views are ever present. The chemist regards coal as *the* valuable source of raw material for the manufacture of synthetic drugs, dyes, and certain high explosives and ammonium sulphate, and would have us carbonise all our coal in by-product recovery plants so as to waste none of these precious substances. Though these substances represent only a small percentage by weight of the coal, their value to chemical industry is such that he cannot sit idly by and see them burnt away, particularly as the consumption of the resulting coke would help to diminish the smoke nuisance. The geologist looks upon coal as a rock of varying physical properties and chemical composition, and, feeling that his duty is to find coal by mapping outcrops or stratigraphical evidence, regrets, in his endeavours to extend our coalfields, that the chemist does not come to his assistance in assigning a particular value to the coal in each seam. The chemist investigates a sample of coal for some specific purpose, benzol or ammonia content, for example, but the geologist would like him to come forward with a definite classification, saying which coals were best for steam or domestic purposes, etc. He feels that both ultimate and ordinary commercial analyses should be carried out, and that the chemist should know the nature of the roof and floor of the seam from which his sample was taken. The palæobotanist might be of great value in association with chemistry, for, as it is known that coal consists of an assemblage of the remains of very many kinds of plants, if it could be shown that particular by-products resulted from particular plants or parts thereof, palæobotanical investigation would show the commercial value of coal from any one seam.

There are, however, certain difficulties. Though much has been discovered by the action of solvents, chlorine, etc., on coal as regards the cellulose and resinic constituents, so many secondary changes may have taken place in the history of a seam that to associate them with individual plants or parts of plants may not be justified, for the decomposition of the original vegetable constituents might prove to be more important than the constituents themselves.

The engineer would have us turn our coal into cheap power, preferably electrical, on account of the ease of distribution. Just as there are trunk lines of railway, so there should be trunk lines of electric power generated from the largest and most economical machines in stations situated in the best localities for the needs of any district where land is cheap and coal and water plentiful. But just as the branches from a trunk railway enable the towns at their termini to develop in a way impossible without the trunk line, so trunk power mains would enable collieries to use their friable coal unfit for transport by turning it into electrical energy, at the same time extracting the by-products, for they would have a means for distributing their power which at present they do not possess.

It would really seem that for industrial purposes this is the line for advance, having in view economy, and the North-East Coast power system may be taken as an example in this country of the theory put into successful practice. It goes a long way to satisfy the chemist in his reasonable desire for by-products, and the efficiency of the conversion of coal into electricity is great if properly developed.

Economy in the domestic consumption of coal is more difficult. Gas is acceptable for cooking purposes, but the Englishman has a strong preference for warming himself by the direct radiation from a fire instead of the far more economical stoves so common in other countries. People must be educated in this matter, and no doubt the Domestic Fuel Sub-Committee of the General Committee mentioned at the commencement of these remarks will see to it that this is attempted. Manufacturers realise that smoke pouring from their chimneys implies bad stoking, and this means waste, and is consequently avoided so far as possible, but smoke from a domestic chimney conjures up visions of the crackling fire and genial warmth within the house.

The two discussions at Newcastle, if not producing any very new points, helped greatly in showing how we stand in relation to this most important question, and it is to be hoped that the committee will be in a position to present much valuable information in their next report. A *rapprochement* between chemists and engineers seems to be coming about, but the chemist and the geologist look as though they would continue grubbing for some time yet in a coal-seam on individual purposes intent. The satisfactory solution of the problem will require all three to work hand in hand, and now is the time, when co-operation is on everyone's lips, to achieve this happy result in the interest of the nation.