The Physikalisch-Technische Reichsanstalt

Fifty Years of Progress

By a Correspondent

WHEN in the second half of last century the political and economic union of Germany had been effected, it was realized by far-seeing men that the new Reich could only maintain its position in the world, if the exact sciences, which had then reached a stage of development never before thought possible, were given adequate assistance by the State. In particular, there were many urgent physical problems, the solution of which was of the greatest importance for the general weal not only of Germany but also of the whole civilized world. This work could be undertaken only by a large State institute, in view of the considerable financial aid necessary to carry it out. For this reason, the Crown Prince Frederick, Werner v. Siemens, and Count Moltke took the matter up with the Government, and, in spite of much opposition, they obtained in 1886 the sanction of the Reichstag for the foundation of a "Physikalisch-Technischen Reichsanstalt" in Berlin-Charlottenburg. Hermann v. Helmholtz, the most famous physicist of his time, was appointed the first president of the new foundation, and took up his duties as director in 1887.

The institution was at that time unique, and had as its object primarily the development of the technique of accurate physical measurements, and the related establishment and control of the legal units of measurement, as well as the performance of tests submitted to it by industry. The uninitiated often regard measurements of precision as being opposed to the work of the discoverer, whose services they readily appreciate. Nevertheless, the successful activities of the discoverer would often have been frustrated but for the application of precision methods, as strikingly exemplified by Michelson's experiment, the discovery of the rare gases, the investigations on the effect of external fields on spectral lines, and the discovery of heavy hydrogen. Moreover, our belief in the trustworthiness of our conception of the atom is based essentially on the accuracy with which the fundamental constants involved have been determined by a variety of different methods.

The Reichsanstalt can look back with justifiable pride on having had on its staff men of science who, as a result of laborious and often inadequately acknowledged endeavour, have developed many important methods of measurement to an extraordinarily high level, or devised new ones. Of this we have ample testimony, for example, in the "Lehrbuch der praktischen Physik" of F. Kohlrausch, who was the second eminent president of the Reichsanstalt, which has been responsible for editing the book for many years, as well as in the "Elektrische Messtechnik" by that well-known investigator W. Jaeger. The Reichsanstalt has been responsible for the development of much of the standard equipment for measurements of precision which is used to-day throughout the civilized world. We need only mention here the Diesselhorst precision potentiometer, which is free from thermoelectric disturbances, the multiplex-interference spectroscope of Gehrcke and Lau, C. Müller's bolometer, and the Lummer and Brodhun photometer.

The precision methods of measurement were immediately applied to the establishment and control of the legal units in physics, which at the time of the foundation of the Reichsanstalt were subject to great uncertainty and lack of uniformity, a state of affairs equally intolerable to science and industry in all countries. The Reichsanstalt was concerned not only with the establishment of these units with the greatest possible accuracy, but also with their production in a form suitable for practical use. In other words, convenient secondary standards had to be derived from the primary standards. From among the relevant fundamental researches of the Reichsanstalt, which have extended over the whole field of physics, it will suffice if we direct attention here to only a few of them, such as the evaluation of the standard metre in terms of wave-lengths, the determination of the ohm and the related development of precision resistances of manganin, the researches on the standard cell (Weston cell), and those on the silver voltameter. Moreover, as a result of much laborious work, the temperature scale was fixed between the limits of $-259°$ and $+1773°$.

The precision methods devised for these purposes also opened up the way to the accurate determination of a number of fundamental constants that were not previously known with sufficient accuracy, such as the constants of radiation (Warburg, C. Müller), and the mechanical equivalent of heat (Jaeger and v. Steinwehr). We shall give only one example of the progressively increasing accuracy attained in measurements of this kind. Within the relatively short span of thirty years, it was possible to reduce the error in the measurement of the frequency of electro-magnetic waves from one per cent to one part in a hundred millions!

From the start, however, it was evident to German men of science that their work would have only a restricted value if they regarded it only as a service to their own nation and not as a cultural undertaking for the whole civilized world. For this reason they have always endeavoured to maintain a connexion with the advance of scientific work in other lands. Thus the Reichsanstalt has almost always been represented at the numerous international scientific conferences that have been held to fix and control physical and technical units of measurement, and its results have often had a decisive influence on the resolutions passed at these conferences. In particular, co-operation with the important foreign State institutes which have the same aims, for example, the National Physical Laboratory at Teddington, and the U.S. Bureau of Standards in Washington, has been so close that from time to time and also since the Great War representatives of the Reichsanstalt have worked in these other laboratories, and conversely. The importance of the guarantee of trustworthy international physical units is further exemplified by the fact that two presidents of the Reichsanstalt who were scientific men of world-wide repute, v. Helmholtz and Warburg, have taken part personally in international conferences dealing with these questions.

When we consider the enormous quantities of energy and material goods that are bought and sold in the world to-day, and that they are all measured in terms of these units, it is readily appreciated that this problem of units is of supreme importance not only from the scientific but also from the economic point of view. In these matters, insistence must be laid on the very accurate calibration of all measuring equipment. Thus it has been calculated that an error of only one per mille in the polarization apparatus used for the determination of the sugar content of beet would correspond at the present time, in Germany alone, to an annual market value of approximately one million Reichsmarks. Measuring equipment which has been tested at the Reichsanstalt in terms of its standards and by use of its precision methods is to be found all over the globe ; and in the work of scientific investigators and technologists for the welfare of humanity, which cannot be too highly apprized, it has been of inestimable value. The continuously increasing range of the work of the Reichsanstalt is illustrated by the growth in the number of tests which have to be carried out by that institution. The present income from fees for tests undertaken is about twenty times that of the year 1890, and much more than double that for the year 1913.

The progressive rise in the demand for accuracy of measurement which has resulted from the work of the Reichsanstalt has necessarily also brought in its train advances in industrial development. Thus, as soon as it has been certified that the permissible limits of error of a measuring instrument have been reduced, it is incumbent upon industry to strive after increased accuracy in the manufacture of the instrument. This has been especially noticeable in the work of the optical industry.

Since the economic importance of its work in carrying out tests was obvious even to those not directly concerned with physics, the Reichsanstalt has as a rule been granted the requisite funds and equipment by the particular Ministry concerned. On the other hand, the accommodation, equipment and staff necessary for the prosecution of exhaustive and extended investigations in pure science before 1933 were far from adequate. Thus it can readily be appreciated that the development of the Reichsanstalt was determined primarily by its obligations in the matter of testing instruments and the like, whereas the scope of its purely scientific activities lagged behind. It is a great tribute to the idealism and deep-seated scientific enthusiasm of many men who have worked at the Reichsanstalt that, in spite of the obstacles already mentioned, many excellent investigations of the greatest value to pure science have been carried out within its walls.

Included among about 1,500 publications from the Reichsanstalt, with a total of some 18,000 pages, which have appeared since its foundation, there is a large number devoted to problems of pure science. In particular, it should be mentioned here that the important problem of the spectral distribution of intensity of a black body was completely solved experimentally by Lummer and Pringsheim at the Reichsanstalt. The investigations of Hagen and Rubens on the connexion between the electrical conductivity of metals and their optical properties in the infra-red region of the spectrum are outstandingly brilliant in their formulation and execution. They confirmed the existence of the relation between the reflective power and the conductivity of metals, which results from Maxwell's theory. It was at the Reichsanstalt that Goldstein discovered canal rays, and Gehrcke and Reichenheim the anode rays ; here de Haas found experimentally the celebrated relation, fundamental in atomic theory, between mechanical and magnetic moments ; and here Geiger presented atomic physicists with the point-counter, so indispensable in modern research. The list could be extended by further examples, but we have confined ourselves here to those discoveries from which we are already sufficiently far removed in time to be able to estimate their great influence upon physics.

Although it is often difficult to determine immediately the value for our future knowledge of physics of an investigation in pure science, this applies in still greater measure when we consider its significance for applied science or in the field of economics. Here things are not always so simple as in the discovery by E. Gumlich, who has worked in the Reichsanstalt since its foundation, that certain iron-silicon alloys have an extraordinarily small electrical conductivity and excellent magnetic properties. He immediately recognized the great importance of the diminution of eddy current losses, which depend on the conductivity, in sheet, used for the construction of transformers and dynamos. Gumlich's alloy sheet has found world-wide application, and it has been calculated that in Germany alone, by the use of the alloy sheet, industry saves in iron and electrical energy the equivalent of about one hundred million Reichsmarks a year.

Speaking generally, one can say that the statement made by Werner v. Siemens in 1884, in a memorandum urging the foundation of the Reichsanstalt, still holds good : "Almost without exception it is the result of new scientific discoveries, often with no apparent significance, that such new paths are opened up and important branches of industry newly created or revivified. Whether or not the recognition of a new scientific fact has a practical application cannot as a rule be determined until that fact has been systematically and completely investigated, that is, often after an appreciable lapse of time. For this reason, *scientific progress must not be made dependent on material interests*."

The Reichsanstalt has never lost sight of this point of view, and its researches were never linked up only with considerations of time, for the high scientific value of its work of standardization is also bound up with its research work. In order to appreciate the spirit that has always been cultivated in the Reichsanstalt, it will suffice to mention the names of its presidents, in chronological order : H. v. Helmholtz, F. Kohlrausch, E. Warburg, W. Nernst, F. Paschen, and J. Stark. As already mentioned, the Reichsanstalt had not long been completed (in 1897) before great difficulties had to be faced as a result of the lack of accommodation and funds, and these reacted on its scientific development, in spite of the eminence of those in charge. Thus between 1897 and 1933 the effective area of its buildings increased only by about 35 per cent, mainly due to the construction of a heavy current laboratory (1913) and of a low-temperature laboratory (1927), and the funds available to the Reichsanstalt for its work lagged far behind those which would have corresponded to the enormous development of physics in the same period. But the new National-Socialist Minister Rust, who has been in office since 1933, began immediately to try to improve these conditions, and his Ministry has succeeded in augmenting the available accommodation almost to double its earlier area, partly by renting suitable buildings, and partly by the acquisition of funds for the erection of new buildings, so that the number of laboratories of the Physikalisch-Technischen Reichsanstalt is now seventy-seven. This process of development is still being actively pursued, and Prof. Stark believes that the leaders of the National-Socialist State, recognizing the importance of the Reichsanstalt, will see to it that adequate financial aid is placed at its disposal, for without this the Reichsanstalt cannot fully realize its aims.

Apatite, Nepheline, and Rare-Earth Mining in the Kola Peninsula

PARTICIPANTS in the northern excursion of the seventeenth International Geological Congress in Russia were afforded ample facilities for inspecting recent mining developments in the Kola Peninsula, and especially the unique apatite deposits at Kirovsk. The latter occur within the world's largest known massif of nepheline-rocks, the Khibine Tundra*.

The Khibine massif (Umptek in the Loparian language) has an area of 1385 sq. km. It is of roughly circular outline, with a diameter of about 40 km. The neighbouring Lovozero massif to the east is similarly shaped, with diameter 25 km. and area 485 sq. km. Still farther east there occur great intrusions of alkaline granites, which occupy an area of 3700 sq. km.

The Khibine massif is of annular structure and may be regarded as a lopolith, with steep contacts cutting across Archæan gneisses and the Proterozoic Imandra-Varzuga series. A broad peripheral ring and the central area consist of coarse-grained nepheline-syenites. Along the annular break between these rings a series of younger fine-grained nepheline-syenites, and rocks of the ijolite-urtite range have been injected (see accompanying map). The apatite-nepheline injections which are mined occur as intercalations within the ijolite-urtite series.

*The Lapp word *tundra* means the barren uplands above the limits of tree growth, and not the flat, frozen Arctic swamp lands ; hence the Khibine and Lovozero Tundras as names applied to mountain groups.