NATIONAL PHYSICAL LABORATORY, TEDDINGTON

OPEN DAY

AN open day was held at the National Physical Laboratory, Teddington, on Friday, May 15. In addition to the Laboratory's General Board, which held its annual meeting in the afternoon, the guests included some twelve hundred representatives from universities, government departments and industry. Of the two hundred exhibits, more than ninety had not been shown previously; the following notes describe briefly some of the items which most interested the visitors.

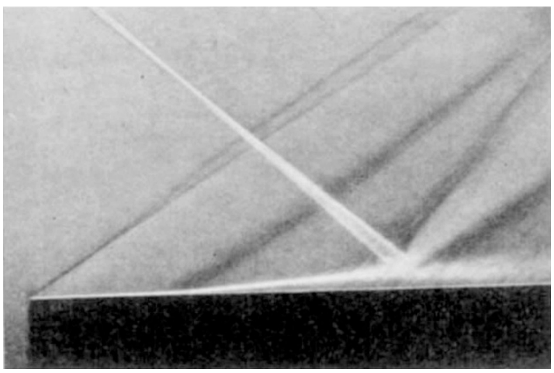
The Collins' helium cryostat, which was demonstrated by the Physics Division, had only recently been installed, but was already producing liquid helium in quantity. This cryostat is manufactured by an American firm and the equipment at Teddington, obtained through the funds of ECA, is the first to be installed in Britain. The great merit of the helium cryostat is that it avoids the use of hydrogen, and the risk of fire and explosion is therefore eliminated. The low-temperature plant at the National Physical Laboratory will be used in the standardization of thermometers and in the study of the crystalline properties of metals such as steel. Work has already been done, using the new apparatus, on the state of internal strain of metal specimens; but the main application, to begin with, will be for the measurement of the entropy of pure chemicals.

The Physics Division also demonstrated methods of measuring radioactive isotopes. Artificial radioactive isotopes are now widely used for medical and industrial purposes, and for certain applications in medical, biological and physical research the highest possible accuracy is desirable. The National Physical Laboratory is collaborating with other laboratories in Britain and with those in the United States and Canada in order to establish national and international standard methods of measurement and standard specimens of radioactive isotopes, particularly for the clinically important isotopes of sodium, phosphorus, cobalt, iodine and gold. As already announced in *Nature*, a service for the supply of standard solutions of radioactive iodine-131 has already been established by the Laboratory, and this service will later be extended to include other important radioactive isotopes. The best accuracy attainable (about $\pm$ 2 per cent) in the measurement of the active constituent is less than that traditionally thought of in connexion with other physical measurements; still wider limits are quoted for the more complex isotopes.

Some of the older tunnels in the Aerodynamics Division of the Laboratory have already been closed down and the building in which they were housed has been modified to provide a small lecture hall and to accommodate the Mathematics Division. The up-to-date requirements of aerodynamics research are being met by the provision of new tunnels to augment the existing high- and low-speed tunnels. Two new tunnels, with working sections 36 in. $\times$ 14 in. and 25 in. $\times$ 20 in. respectively, are nearing completion and will provide the larger-scale facilities required for some of the high-speed work. Both tunnels have a range of Mach number from 0 to 1·8 and are of the induced-flow type. A special strain-gauge balance has been developed for measuring three components of the aerodynamic force (namely, normal force, pitching moment and longitudinal force) acting on a model in a supersonic tunnel. The model is attached to a special form of support, the members of which are stressed by the forces acting on the model, and resistance strain-gauges cemented to the members convert each of the three component forces into electric signals which operate chart recorders. It is possible to alter the incidence of the model to the airstream while the tunnel is running, and the whole equipment can be remotely controlled.

The phenomena which occur when a shock wave interacts with the boundary layer on the surface of a body are of fundamental importance in most problems of high-speed flow. Experimental studies of the interaction have been in progress at the Laboratory for many years and, as a result of recent experimental and theoretical work, the major features of the problem are now understood. Most of the recent experiments, the results of which were on show, have been made in a specially constructed wind tunnel which enables the Mach number (which determines the effects of the compressibility of the air) and the Reynolds number (which determines the effects of the viscosity of the air) to be varied independently over a large range. An interesting film has been prepared demonstrating the interaction between a shock wave and the boundary layer (see photograph).

The increased use of high-speed wind tunnels has stimulated the demand for small metal aerofoils made to precise limits of form and size. There is a particular demand for 'three-dimensional' aerofoils of the delta-wing type, where the section diminishes progressively from root to tip. It is possible to make such models to any degree of accuracy by cutting a large enough number of tangential planes enveloping the form required. The Metrology Division of the Laboratory has evolved a method of manufacture using an accurately set milling cutter to generate the required tangential planes on the blank, which can be precisely rotated and tilted. The models are made in mild steel or brass and a limited number of planes are cut so as to leave 0·000 5 in. excess metal at the intersection of adjacent planes. The excess



Photograph showing the separation of a laminar boundary layer upstream of a shock wave metal is removed with fine emery, and after final hand-finishing the surface is accurate to within 0·001 in. of the required form. The Metrology Division has also developed a simple microscope method of checking the dimensions of the models and relating measurements made on one side of the model to those made on the other.

The Division has recently acquired a special lathe for producing diffraction gratings by the Merton process. The lathe, which will cut accurately spaced threads ranging in pitch from 100 to 30,000 threads per inch, will be used also to produce the surface of the cylinders on which the master threads are ruled. When scribing 30,000 threads per inch, the tool slide, which carries the diamond and which weighs more than 50 lb., travels quite smoothly at the rate of about 1/16 in. per hr. For every inch of travel of the slide, the diamond cuts a groove more than a mile long.

Apparatus for the measurement of the dielectric constants of pure liquids for use as standards for physico-chemical work was demonstrated by the Electricity Division. Standards are required in the range of dielectric constant from two to approximately thirty, and the Division has so far made determinations for benzene, nitrobenzene, ethylene dichloride and *cyclo*hexane. Benzene from four different sources of supply has been used, and the agreement between the results obtained after two distillations and a drying process is very satisfactory. The value obtained in each case, 2·283 at 20° C., is also in close agreement with the less accurate determinations of the dielectric constant of benzene made at the Laboratory in 1926. Ethylene dichloride, which contains impurities affecting the dielectric constant and making its precise determination extremely difficult, has a value at 20° C. of about 10. Nitrobenzene, which suffers from the same drawback, has a dielectric constant of about 35 at the same temperature. *Cyclo*hexane, unlike benzene, is not hygroscopic, and determinations of its dielectric constant give the same value for the 'as received' condition as is obtained after the double distillation and drying process. Unfortunately, there is no standard grade for *cyclo*hexane of high purity.

The Control Mechanisms Section of the Metrology Division has developed a method of storing and tabulating information, using first a magnetic tape for recording the information at high speed. This information is later tabulated by a slow-speed printing device such as an automatic typewriter. In the system used, digits and signals for typewriter operations are stored on single-channel tape as 20-millisecond pulses of one, two, three or four fixed frequencies. Letters can also be stored if two additional frequencies are used. The recording is decoded using frequency-selective filters setting a relay system corresponding to the typewriter operation to be carried out, for example, typing a digit, spacing or carriage return. The standard electric typewriter used has been fitted with solenoids so that it can be operated automatically. The maximum typing speed is about eight strokes per second.

The Mathematics Division showed a card-operated typewriter which has been adapted for use with the ACE pilot model. The results from the latter are obtained on punched cards, and in order to print them a commercial punched card unit has been modified to operate a commercial electric typewriter at a printing rate of eight characters a second. The ACE pilot model itself, the Laboratory's prototype high-speed electronic digital computer, has been working satisfactorily for about eighteen months and has dealt with problems concerned with mathematical physics, linear algebra, ray tracing, flutter in aircraft, etc.

The crystalline appearance of fracture in mild steel when it breaks in the manner usually referred to as 'brittle fracture' is caused by the fracture occurring across the cleavage plane of the individual crystals. An understanding of the mechanism of this type of failure obviously requires a knowledge of the cleavage strength of iron crystals, and the most straightforward manner of determining this strength is by the use of single crystals, so that no interference from grain boundaries will be experienced if the crystal is broken in tension. At ordinary temperatures, a plain single crystal of iron cannot be broken along the cleavage plane by plain tension, as the crystal yields by slip at a much lower stress than the cleavage strength. At lower temperatures (about − 200° C.), the cleavage strength may be less than the yield stress, and if so the crystal will break with a cleavage fracture without appreciable deformation.

For experiments carried out by the Metallurgy Division, small tensile test pieces consisting of single crystals are made by a strain-and-anneal method, the final dimension over the test length being obtained by electrolytic machining, leaving the surface of the crystal in a highly polished condition. The orientation of each crystal is determined by an X-ray method, and the test-pieces are broken in a micro-testing tensile machine, the test-pieces being cooled to a low temperature in specially designed Dewar flasks. Results obtained so far indicate that over a wide range of orientation single crystals of iron are still completely ductile at − 196° C., but a change to completely brittle behaviour may occur if the orientation is such that a 100 cleavage plane is inclined to the stress axis at angles not less than about 80°.

The highly reactive nature of titanium makes the determination of its melting point extremely difficult. The Metallurgy Division has, however, devised a technique which reduces to a minimum the possibility of contamination while the melting point is determined under black-body conditions. The specimen, a small cylinder about $\frac{3}{4}$ in. long and $\frac{1}{4}$ in. diameter, rests in a zirconia crucible provided with a lid with a sighting hole. A recess in the base of the specimen ensures that only a small area of metal is in contact with the crucible. During an observation, the filament of an optical pyrometer is focused on the base of a small axial hole drilled in the specimen. The specimen is slowly heated in a furnace consisting essentially of a tungsten spiral surrounded by radiation shields made of tantalum and molybdenum foil. The spiral, shields and electrodes are enclosed in a water-cooled evacuated cylinder. When melting begins, molten metal fills up the hole in the specimen and disturbs the black-body conditions. The furnace is then shut down before the specimen collapses and reacts with the crucible.

The melting points of nickel and iron as determined in this apparatus are within 3° C., and that of platinum within 10° C., of the accepted melting points of these metals. The melting point observations obtained for titanium are reproducible to within

3° C., and a mean value 1,660° C. is considered to be accurate within ± 10° C., which is the estimated accuracy of the pyrometer.

To commemorate the centenary of the date when Kew Observatory first undertook the accurate calibration of barometers, the Laboratory had arranged a small exhibition of historical records and apparatus in the hall of Bushy House. The exhibits included two standard barometers of 1854 and 1858; when it was formed in 1900, the Laboratory took over with the Kew Observatory much of the work on the standardization of instruments which until then had been the responsibility of the Observatory.

NEW MAGNETIC MATERIALS OF HIGH COERCIVITY

By Prof. L. F. BATES, F.R.S.

DURING the past five to ten years, considerable strides have been made in our understanding of the theory underlying the production of materials of high coercivity. According to the domain concept of ferromagnetism[1], we picture a ferromagnetic metal as made up of a very large number of small regions or domains. Each of these is magnetized, more or less to the complete degree of saturation appropriate to the temperature of the material, with the direction of magnetization parallel to one of the directions of easy magnetization, these being the edges of the crystal cube in the case of iron. We think that the initial permeability of a material is determined by the ease with which boundary movements between adjacent domains can take place, so that any domain in which the direction of magnetization is more nearly aligned with respect to an applied magnetic field may grow in volume, at the expense of neighbours the magnetizations of which are less well aligned, simply by boundary displacement.

But let us suppose we are dealing with particles which are so small that they are, in effect, single domain particles with no domain boundaries inside them. It then follows that it may be difficult to change the direction of magnetization of such a particle, particularly if it possesses marked magnetic anisotropy, that is, if a crystal of the substance is much more easily magnetized along certain directions than along others—or if the particle is of a special shape, so that large demagnetization fields may arise if it is magnetized along certain axes of shape. Consequently, it should be possible to prepare permanent magnets from materials which formerly were regarded as quite unsuitable for such purposes, such as pure iron. At the Physical Society Exhibition this year, the Salford Electrical Co., Ltd., exhibited 'Gecalloy Micropowder Magnets' made from finely powdered iron. The powder is given an insulating coating and mixed in a conventional dough mixer with heat supplied from below. It is then prepared in a variety of shapes by the use of special press tools and powder presses. The new products are important because of their lightness—since they are about half as dense as ordinary permanent magnets—and because of their insulating properties. Incidentally, soft iron pole pieces are sintered as an integral unit with sintered alcomax alloys ('Sincomax') by Messrs. Murex, Ltd., who thus make many sintered permanent magnets of intricate shape.

The behaviour of permanent magnets made of 'Alnico' has been explained by Stoner and Wohlfarth[2] on the assumption that the material consists of finely divided particles, shaped as prolate spheroids, embedded in a weakly magnetic matrix. Now, we know that such iron – nickel – cobalt – aluminium – copper alloys are given exceptionally valuable properties by exposing them to a magnetic field while they are being cooled from a high temperature. The permanent magnetization parallel to the direction of the applied field is, of course, obtained at the expense of the permanent magnetization perpendicular thereto. We also know that if we take a single hexagonal crystal of cobalt it is comparatively easy to magnetize the crystal parallel to its axis, while it is much more difficult to magnetize it in the basal plane. Hence, the possibility arises of producing important magnetic materials which may be easily magnetized in one direction, if we can arrange that the axes of the constituent crystals are aligned in a preferred direction.

This problem has been tackled in two ways. Thus, Swift Levick and Sons, Ltd., have produced the commercially available 'Columax', which is an improved grade of 'Alcomax III', in which the equiaxed crystals of the normal alloy are replaced by long columnar crystals in a preferred direction parallel to the direction of magnetization determined during heat treatment in an applied field. The new magnets must always be in the form of simple solid cylinders or rectangular blocks, and cannot be provided with cored or drilled holes; but, of course, this does not preclude their use in many assemblies and iron circuits. Their maximum remanence is about 13,000 gauss and their coercivity between 700 and 740 oersteds. The quantity $(BH)_{max.}$, which is a criterion of suitability as a permanent magnet material, is of the order $6 \cdot 8 \times 10^6$ gauss-oersteds.

A second way consists in making magnets of compressed manganese bismuthide powder[3] (MnBi). Single crystals of manganese bismuthide are hexagonal and have properties resembling those of hexagonal cobalt, but the material has very high magnetic anisotropy and so possesses a very high coercivity; in fact, values of coercivity measured from an I,H curve as high as 12,000 oersteds have been recorded, which would mean that the coercivity as measured from a B,H curve, as normally specified by a manufacturer of permanent magnets, might be of the order of 7,000 oersteds. It would be surprising, however, if stable permanent magnets of a material as brittle as manganese bismuthide, with a Curie point around 350° C., could be prepared as conveniently as those described earlier.

In addition to the above materials, we also have on the market a material of high coercivity which is virtually a Heusler alloy in which the copper in the well-known aluminium–copper–manganese alloy is replaced by silver. Another important new development[4] in powder metallurgy is the production of the materials known under the trade name of 'Ferroxdure', which consist of blocks of compressed oxides of iron and barium. These have coercivities of the order 1,450 oersteds with a value of $(BH)_{max.}$ of about $0 \cdot 85 \times 10^6$ gauss-oersteds.

Naturally, all such materials are of considerable interest because of the special uses to which they may be put by persons of ingenuity.

[1] Bates, L. F., "Modern Magnetism", 443 (Cambridge, 1951).
[2] Stoner, E. C., and Wohlfarth, E. P., *Phil. Trans. Roy. Soc.*, A, **240**, 599 (1948).
[3] Adam, E., *Rev. Mod. Phys.*, **25**, 306 (1953).
[4] Went, J. J., *et al.*, *Philips Tech. Rev.*, **13**, 194 (1952).