SCIENTIFIC INSTRUMENTS FOR RESEARCH AND INDUSTRY

PHYSICAL SOCIETY'S EXHIBITION 1951

THE thirty-fifth annual exhibition of scientific instruments and apparatus, organized by the Physical Society, was held at the Imperial College, London, during Friday, April 6, to Wednesday, April 11 (Sunday excepted). As in the previous year, it was again found advisable to spread the period of the exhibition over five days and, by a special system of issue of tickets, to limit the numbers attending any particular session. In addition to this restriction in the issue of tickets, the exhibition was expanded into the Huxley Building in Exhibition Road—thus providing more space both for the exhibitors and the visitors. The arrangements proved in the main very satisfactory, but of course there was a certain disadvantage in dividing the exhibition into two rather widely separated parts; fortunately, the weather at the time had improved, and the inconvenience of crossing from the Imperial College to the Huxley Building was not so serious as it might have been. During the five days in which the exhibition was open, a total of approximately 17,000 visited the exhibition—of these at least 80 per cent crossed over to the Huxley Building. This number of visitors represents an increase of 3,500 on the previous year.

The president of the Physical Society, Prof. L. F. Bates, in his two formal openings of the exhibition—the first at 10 a.m., April 6, for Fellows of the Society and the Press, and the second at 2 p.m. on the same day for the general public—made a brief reference to the main objects of the Physical Society and to the manner in which the exhibition furthered these objects in bringing together annually the manufacturers of scientific instruments and the research workers and teachers who make use of them. He also made special reference to the extension of the area of the exhibition to the Huxley Building, and to the exhibits from three research departments of the French Government. He paid a tribute to the excellence of the scientific instruments on view and to the great achievements of the British scientific instrument industry.

During the exhibition, four discourses were given by eminent authorities in different branches of physics. The first of these was by Dr. G. E. R. Deacon, director of the National Institute of Oceanography (at present housed at the Admiralty Research Laboratory, Teddington). His subject was "Electric Currents in the Sea". He first referred to the earlier work on this subject by Admiralty and other scientific workers, notably the researches of Young, Jevons and Gerrard, which had demonstrated the existence of diurnal variations of electric current due to tidal flow of a conducting medium (the sea) cutting the lines of the earth's magnetic field. It was realized that it should be possible to obtain quantitative information about tidal streams and other water movements by recording horizontal potential gradients induced by these water movements. If a pair of stationary electrodes is spaced on a line transverse to the stream, the potential difference between them will depend on (a) the earth's vertical field, the stream

velocity and the distance between the electrodes, and (b) the degree to which the sea bed short-circuits the induced E.M.F. In the absence of precise information about the conductivity of the sea-bed, it is necessary to calibrate the measurements by measuring the stream velocity. If the electrodes are connected by a wire to a voltmeter and the whole system is allowed to drift with the stream, an E.M.F. will be induced in the wire equal to that which is induced in the water, and the voltmeter will register only a voltage which corresponds to the flow of electricity between the electrodes. It depends on the electrical conductivity of the water path between the electrodes and the conductivity of the return path through the sea-bed or through stationary ocean water over which the stream flows. Dr. Deacon referred to the work of Barber and Longuet-Higgins on this subject, directing attention also to the magnetic effects produced by earth currents of all kinds.

The second discourse, on Monday, April 9, was given by Dr. D. McKie (University College, London) on "The Age of Newton". His lecture covered the following subjects: the foundation of the Royal Society of London and the Paris Academy of Sciences; the publication of the *Philosophical Transactions* and the *Journal des Savants*; Newton's early life and studies; Cambridge and the Royal Society; the great discoveries on gravitation and light, and the invention of the calculus; Newton and his contemporaries; his character; Halley and the "Principia"; Newton and Hooke; Newton as president of the Royal Society; his last years and his influence on the science of his times and on his successors.

On April 10, Dr. F. P. Bowden's discourse dealt with "The Friction of Metals and Non-metals and the Influence of Surface Films". In introducing his subject he quoted from the writings of Leonardo da Vinci in the fifteenth century. Leonardo expounded the laws of friction and referred to the interposition of thin films or layers between surfaces to "lighten the load". Dr. Bowden then described recent experimental studies in Cambridge of the friction of clean metals and the influence of adsorbed films on the friction, adhesion and surface damage. Clean de-oxidized surfaces of metals in a vacuum weld together when brought into contact. The effect of hydrogen, oxygen, water, chlorine and sulphur has been investigated and it is found that both chemisorption and a reversible van der Waals adsorption are important. Analogous experiments have been made with non-metals, particularly with outgassed surfaces of diamond, carbon and graphite. Here also the adsorbed films have a profound influence. Further study has been made of the high temperatures developed at the rubbing points of contact between non-conductors, and measurements have been made of the rise and fall of the 'hot spot' temperature with non-metals. The effect of temperature on the orientation and disorientation of boundary films of lubricants were described, and the relation between the intermetallic adhesion and the structure of the boundary film was discussed. Dr. Bowden showed

some simple, but very striking, experiments on the reduction of friction between metallic surfaces by the use of the fluorine compounds 'Teflon' and 'Fluon'. A toy motor with metal wheels ran up a steel slope without hesitation, but a similar motor with its wheels coated with 'Teflon' or 'Fluon' refused to climb beyond the foot of the slope. Similarly, a coating of indium on steel resulted in a drop in the friction coefficient. In this case also the friction decreased with increase of temperature up to a critical limit. Molybdenum sulphide evaporated on to sintered copper, or better still formed on a surface of sintered molybdenum, resulted in a spectacular fall in the friction coefficient (to about 0.02). Experiments to demonstrate this were made with a pair of similar heavy pendulums in (a) molybdenum sulphide bearings (heated by a gas flame) and (b) steel bearings lubricated by 3 in 1 oil. Both pendulums were set to swing at the same initial amplitude, but the molybdenum sulphide pendulum continued to swing with a considerable amplitude long after the steel pendulum had stopped. Similar striking demonstrations were made by sliding small weights coated with various films down an inclined plane.

Dr. L. A. Sayce, superintendent of the Light Division, National Physical Laboratory, gave the fourth discourse, on April 11, his subject being the activities of the Laboratory's Light Division. His object was to show how it maintains and administers the national standards of illumination and radiation and to discuss some of its past and present researches. His lecture dealt with the two themes: (a) light as a form of energy measured in physical units of energy; and (b) light as a stimulus of the sense of sight, the motive power of the eye, measured in units of sensation. The Radiation Section of the Light Division is concerned with radiation extending from a wave-length 0.2μ , where quartz begins to be transparent, and ends at 15μ , where rock salt begins to be opaque. Sources of radiation in this range vary from the hydrogen lamp in the ultra-violet to the bare radiator in the infra-red. Standards of energy measurement are based on the Callendar type standard (using the Peltier effect in a thermocouple) and the Guild type standard (which equates the Joule heating effect with the radiation heating). Sub-standard radiation receivers are thermopiles of the Moll type calibrated from the Guild standard. The Radiation Section is also concerned with measuring the spectral sensitivity of photocells. At this point in his discourse Dr. Sayce referred to the eye as a photocell. The eye is comparatively useless as a measuring instrument; but it is excellent as a means of comparing stimuli both as regards brightness and colour. It is, of course, decidedly selective in its spectral response and varies from person to person. But the National Physical Laboratory has deduced, from tests of a large number of eyes, what is called a 'standard observer'. This hypothetical person has an eye which has a maximum sensitivity at $\lambda = 0.5550\mu$. Another responsibility of the Light Division is the fundamental unit of photometry, the candle power or candela. After describing the historical development of candle power standards, Dr. Sayce referred to the modern unit, which is defined in terms of a black body at the temperature of a freezing platinum surface.

Dr. Sayce next dealt with the measurement of colour, a subject with which his colleague, Mr. J. Guild, has long been identified, referring to the various

'colour triangles', Guild's colorimeter, and Donaldson's '3-primary' and '6-primary' colorimeters and their method of use. In conclusion, he referred to an interesting line of research which is at present under way at the National Physical Laboratory. This is based on a new method of ruling diffraction gratings suggested by Sir Thomas Merton. The general idea is to rule the gratings as a helix upon a cylinder and then open it out on a flat surface by means of a replica process. The experiments were started by copying flat gratings by the use of suitable plastics, and stripping and re-mounting methods. Having developed the replica copying process, attempts were next made to 'rule' accurate helical gratings of 15,000 lines per inch on cylinders. The periodic errors which inevitably arise in screw-cut threads were entirely removed by a simple method devised by Sir Thomas Merton, known now as the 'Merton nut' method. This has resulted in the production of plane gratings of a very useful quality, and it is hoped that good gratings will no longer be the rare and expensive things which they have been in the past.

This year, one hundred and thirty-seven firms and research organizations displayed their scientific instruments and apparatus. To avoid certain incongruities in the method of display, so noticeable in earlier exhibitions, the name-plates and stand numbers on this occasion were standardized. The improvement in the general appearance of the stands was quite marked. A list of exhibitors and a description of the exhibits are given in the Handbook of Scientific Instruments and Apparatus 1951 (35th Exhibition), published by the Physical Society (price 5s.), pp. xi+244+A72. This is a very useful reference book, well produced on art paper and containing a plentiful supply of illustrations (half-tone and diagrammatic). As usual, all branches of physics are well represented in the exhibits, and most of the 17,000 visitors, whatever their special interest, must have found something novel to attract attention.

As the president mentioned in his opening address, a noteworthy feature of the exhibition this year was the exhibits of three research organizations of the French Government. The first of these, Centre National de la Recherche Scientifique, was showing various optical devices, notably phase-contrast oculars for the microscopic study of transparent and reflecting objects, a device for increasing the numerical aperture of microscope objectives and an attachment for converting an ordinary microscope into a variable-phase contrast microscope. In addition to these optical devices, a high-tension electrostatic machine was shown which develops a power of 50 watts at 500 kV. The second French government organization, Commissariat à l'Énergie Atomique, exhibited a number of devices used in atomic energy investigations, namely, survey equipment, (a) 'gamma-phone', for audible detection of gamma-radiation, and (b) portable beta-gamma survey ratemeter; scaler of 1,000, pocket dosimeter, coincidence amplifier and four-channel pulse-amplitude analyser; also a three-stage oil diffusion pump having a speed of 5,000 litre/sec.—first made to evacuate a cyclotron. The third organization, Office National d'Études et de Recherches Aeronautiques, showed an infra-red gas analyser which could estimate an absorbing gas mixed with a non-absorbing gas down to 0.0001 per

cent; a rogascopes—an electromagnetic apparatus for the detection of cracks or variations of diameter of wire threads, whether insulated or not, of non-magnetic metals, in particular molybdenum and tungsten (the use of this device results in considerable economies to manufacturers of valves, etc., where it is important to have reliable filaments). This organization also showed an oersted meter (range from tenths of a millioersted up to 1 oersted), a remanometer, magnesium electrode batteries, and miniature permanent magnet motors, 'Microtax' and 'Birotax' types. These small motors have extremely low inertia, and this allows almost instantaneous starting and stopping. The weight of the rotor in the 'Microtax' is only 5 gm. and in the 'Birotax' 16 gm., the respective powers being 0.5 watt and 5 watt.

It is difficult to make a representative selection of exhibits to which to refer in a brief article of this nature, and the following are chosen almost at random. An interesting development in laboratory balances was shown. This has a capacity of 10 kgm. and is designed for automatic loading of weights and charge from a remote-control unit. Weight loading and beam release are operated by geared slave motors. A small electric truck, which is also controlled from the operating unit, can be driven on to the pan. An automatic micro-pipette was shown which delivers a measured volume of liquid from a surplus in the pipette, and dispenses only the amount to which the device has been set; the error due to drainage is eliminated as the tube is not completely emptied. The Cavendish Laboratory and Birkbeck College research staffs showed their pendulum inclinometer for the measurement of glacier flow. The velocity distribution in a vertical profile through the glacier is obtained from measurements of the lateral displacement of the ice at various depths. Developments in planimeters illustrating the progress from the early form of this instrument were shown—the continuous chart planimeter, rule-form planimeters for non-uniform charts, integrators and harmonic analysers. An interesting variety of thickness meters was on view. In one of these a 'pocket-sized' magnetic gauge was used for the measurement of non-ferrous layers or films on ferrous bases (in ranges of 0 to 5, 0 to 10, or 0 to 30 thousandths of an inch). Another type used the radiation from radioactive thallium-204 and was capable of measuring 0.0005–0.10 in. of paper or equivalent weights of other materials. A radioactive β -ray source was used in a thickness or weight gauge—for materials such as paper, board, plastic sheet, metal foil, etc.—during the manufacturing process or in the course of subsequent inspection. The range of this gauge is 0–150 mgm./cm.²—equivalent to 0–0.06 in. of paper or 0–0.025 in. of aluminium foil. Another entirely different type of thickness gauge enables the thickness of a slab of non-metallic material to be measured in terms of its dielectric properties. Thicknesses up to $\frac{1}{2}$ in. can be measured with an accuracy of 0.2 per cent. An interesting exhibit demonstrated a twist test for wire, giving data which can be correlated to its coiling properties. The wire under test is twisted on its own axis while under tension, and the change in length and number of turns are measured. A precision mining aneroid was shown which is fitted with a micrometer dial. The instrument covers a range from 24 in. to 38 in. pressure of mercury, the dial being subdivided into 0.1-in. divisions, and

micrometer dial readings are obtainable to 0.001 in. A hand-operated adjustment is provided to set the micrometer dial to zero.

The Admiralty Research Laboratory (Teddington) showed an interesting piezo-electric pressure recorder, designed to give a continuous record on paper tape of sea waves. It is provided with a time mark coding device, and enough tape is supplied for a continuous record over a period of seven days, without attention. A correlation meter was also shown which automatically prepares cross- or auto-correlograms from black-and-white records on the same time-scale. Corresponding amplitudes are measured photoelectrically and their sum squared electronically. A twelve-channel galvanometer recorder developed for field-use where compactness, simplicity and ruggedness are important was also demonstrated; it operated from bonded resistance strain-gauges without amplification of the signals. The Admiralty Experiment Works (Haslar) staged an exhibit illustrating research on the steering qualities of ships. Prescribed manoeuvres are executed by a ship model and the turning path is plotted from photographic records. Force and torque on the rudder stock are recorded electronically, and the distribution of pressure on the rudder is recorded by manometers. The Meteorological Office exhibited a method of measuring the vertical depth (or height) of a fog layer. The method makes use of photocells on tethered hydrogen balloons to detect light scattering of fog particles. There appears to be an increasing interest in rheometers and viscometers, and a number of varieties of these were shown. Zirconium metal is now available in moderate quantities; sheets down to 0.005 in. in thickness, 6–7 in. in width, and 2–3 ft. in length are now available, swaged rod down to 2 mm. diameter can be supplied, and methods for production of zirconium wire are being developed. This metal has excellent resistance to corrosion which, in addition to its peculiar property of attaching itself to surrounding flesh, makes it of considerable value in surgery. Tantalum and molybdenum sheet are also available now. On the electrical side, vibrating reed electrometers are gaining popularity. One of these, designed by the Atomic Energy Research Establishment, Harwell, measures currents as low as 10^{-16} amp. The commercial form is provided with full-scale readings of 1 mV., 10 mV. and 100 mV.; the input resistance of the vibrating reed unit is greater than 10^{16} ohm. The vibrating reed electrometer provides an alternative to most forms of valve electrometer, having a greatly improved zero stability, and is designed primarily for measurement of ionization currents. It is used at Harwell in the determination of α -particle energies.

A large variety of gas analysis equipment was shown. These instruments indicate, or record electrically, water vapour in coal gas, air-gas ratio, organic vapours, dissolved hydrogen in boiler condensates, oxygen, etc. A fascinating demonstration showed the piercing of a diamond by an electric spark. The technique is particularly suitable for producing diamond dies of small bore, and holes of 0.0002 in. diameter have been produced in this way. The growth of sizeable quartz crystals by a hydrothermal process was shown, the crystals being suitable for telecommunication purposes. Germanium diodes and triodes, and barium titanate resonator elements were shown. High-vacuum equipment included not only the latest forms of pumps but also ionization gauges of various kinds, a palladium ionization gauge

leak detector, and evaporation plants for metallizing surfaces.

The Science Museum (South Kensington) exhibited apparatus devised or used by Sir Charles Wheatstone (1802–75), namely, the original rheostat and Wheatstone bridge described in 1843, apparatus which he used in 1834 to measure the speed of electricity in a wire, his telegraphic thermometer and his cryptograph.

The Admiralty Signal and Radar Establishment (Haslemere) showed a nice collection of metallized-glass microwave components and resistors. The metal used is nichrome, its resistance being measured during evaporation in a vacuum. It is used as wave-guide attenuator vanes and coaxial terminations in the 3-cm. and 10-cm. wave-bands. An unusual type of electrolytic condenser having a capacity of 55 μ f. at a working voltage of 80 V. d.c. using tantalum as the electrode metal and sulphuric acid electrolyte was shown. This miniature condenser, not much larger than a shilling, has satisfactory characteristics of capacity and power factor at 60 c/s. through the temperature range -70° C. to $+200^{\circ}$ C. The research department of the same firm also showed a soft magnetic core material, 'Caslam', with a finely laminated structure, for use at frequencies up to 10 kc./sec. It has a ring permeability of the order of 1,000 and is composed of flake iron particles pressed compactly in such a way as to produce innumerable thin magnetic layers aligned in the plane of the flux. In another exhibit a series of high-voltage generators using the radio-frequency method of voltage transformation was shown. Use was made of voltage multiplier circuits, and any voltage up to 100 kV. at 0.5 m.amp. could be provided in a very small bulk. Accurate automatic recording of the polar diagrams of centimetric antennae mounted on the roof of a rotatable trailer can be made while the receivers are illuminated by a fixed transmitter. The amplitude of the receiver signal is plotted continuously against the angular traverse of the trailer and test antenna. A scintillation counter using an E.M.I. photo-multiplier tube is used with the crystal exposed for radioiodine work on the thyroid, etc., and various types of radiation monitors for β -, γ - and X-rays were on view. A series of diagrams was shown explaining the principle of the travelling-wave linear accelerator developed at the Telecommunications Research Establishment, Malvern, and the Atomic Energy Research Establishment, Harwell. Details were given of the 3.5-MeV. machine installed at Harwell. The machine has a corrugated wave-guide 2 metres long, the radio-frequency pulses being derived from a 10-cm. magnetron and modulator. The manner in which the principle is now being applied to the production of high-voltage X-rays for the treatment of cancer was also shown. Another exhibit showed the latest form of mass spectrometer, of the 90° sector type designed primarily for the determination of abundance ratios of stable isotopes in the range 1–70. On the same stand was shown an electron diffraction camera, with automatic focusing, to give maximum beam-intensity compatible with small spot size; a stable high-frequency d.c. set giving 25, 50, 75 and 100 kV. also forms part of the instrument.

Reduction of surface reflexion by 'blooming' has now been achieved by the Telecommunications Research Establishment in the 8–9 mm. wave-length band. The reflexion coefficient of a dielectric is reduced from 20 to 2 per cent by correct grooving

of its surface. In the realm of optics, the Colour Group of the Physical Society made a striking display illustrative of the history of colour vision from the time of Boyle and Newton to the present day. A new series of photocells, made by Schwarz, was exhibited. They are of cadmium sulphide (and/or selenide) having sensitive areas approximating in size to that of a linear thermopile for spectroscopic use. Synthetic mica may now be used for windows of ultra-violet lamps, as it has appreciably higher transmission in that region of wave-lengths than any of the natural micas. It has the additional advantage that it can readily be fused to glass to form windows. The Armament Research Establishment exhibited a repetitive Kerr cell camera which takes a sequence of 80 photographs at a rate of 400,000/sec.; each picture is exposed for 0.1 μ sec. The Light Division of the National Physical Laboratory demonstrated new developments in the cathodic sputtering of non-metallic films—films of oxides or sulphides of metals such as cadmium or zinc. Argon is added to the vacuum gas (oxygen or hydrogen sulphide) to increase the rate of sputtering. These films are interesting for their optical and electrical properties.

In acoustics, new developments in acoustic strain-gauges were illustrated, and an automatic high-speed level-recorder (of the Neumann type) was shown. The latter records response characteristics on a logarithmic scale. An acoustic controller of the feed-rate in a steel ball mill was exhibited. The noise of the mill is a criterion of the state of grinding of the balls and controls the feed-rate automatically. An ultrasonic scanner for flaw detection had novel features. The ultrasonic beam scans the material to be tested while an electron beam of an oscilloscope is deflected in a television type raster, in such a way that an image of the flaw is generated. In the thermal field, an interesting exhibit illustrated the use of glass fabric—metal wire bands and mantles for heating pipes, flasks, etc., in the laboratory. Another exhibit illustrated the Golay pneumatic infra-red detector; in this a membrane absorbs the radiation passing through a potassium bromide window and in turn heats the gas in contact with it; the pressure is thereby increased and is indicated by a simple optical system. A simple device for measuring heat flow consists of a 12-mm. disk of tellurium alloy faced on either side with copper elements. Heat flow through the sandwich generates an E.M.F. proportional to the heat-current density. The device has many useful applications.

As in previous exhibitions, an important feature was the craftsmanship competition. A splendid display of glass-blowing, instrument-making, designing and draughtsmanship was on view. The judges must find it a very difficult task to allot the prizes when so much excellent work is shown. In the case of glass-blowing, the first and second prizes were awarded to two excellent examples of the art of glass-blowing, of no utilitarian value. Other very praiseworthy efforts, resulting in less spectacular but more useful articles, received only 'special mention' prizes. This gives the impression that the competitors are not altogether clear as to what is required of them.

The exhibition, like its predecessors, was a great success and much credit is due to the Physical Society for organizing it, and to the scientific instrument industry for providing such a wonderful display of high-class workmanship.

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