NATIONAL PHYSICAL LABORATORY, TEDDINGTON

ANNUAL INSPECTION AND OPEN DAYS

On May 23, the National Physical Laboratory was inspected by members of its General Board, and a series of 'open days' began which continued until May 29. More than six thousand visitors took advantage of the first opportunity since May 1949 of seeing the widely varied work being carried on. In January of last year the 'N.P.L.' was fifty years old, and this, with the wider celebrations of the Festival of Britain, gave special significance to the 'open days' and the two-day symposium on standards which preceded them. The weather was good, and bright sunshine made the Laboratory and its gardens particularly attractive. There were three hundred and eighty-two exhibits altogether, of which it is possible to mention here only a few.

In the High Speed Laboratory of the Aerodynamics Division, a new tunnel was shown which has a working section 18 in. × 14 in. and can be run at subsonic speeds and at supersonic speeds up to 1·6 times that of sound. The pressure can be varied between one and three atmospheres absolute, so that investigations can be carried out into the effects of using reduced-scale models.

Three exhibits showed the methods of investigation which the Laboratory used in its work on behalf of the Ministry of Transport on the proposed Severn Suspension Bridge: a series of sectional models showed how the latest top-deck design with four separate roadways evolved from the suggested mid-deck forms. The methods of measuring the wind forces on a part model were demonstrated, and a complete flexible model bridge was shown which had been tested in a specially designed wind tunnel at Thurleigh (Beds.) to confirm the results of tests on the sectional models.

There was an alarming 'chamber of horrors' in the Engineering Division, in the form of a display of failures in service which had been sent to the Division from time to time for investigation. Almost invariably, the firms had suggested that the material had been at fault, only to be told by the Division of some defect in construction, such as sharp corners in a keyway or a poor surface finish, which had, in fact, caused the failure.

The Engineering Division as such will cease to exist this summer, when much of the equipment and work is to be transferred to the Mechanical Engineering Research Laboratory at East Kilbride, near Glasgow. There was particular interest, therefore, in a historical exhibit which traced the development of the Division and showed how it had taken the lead in various items of research work, such as road and hydraulics research, which had since developed to the extent that entirely new divisions of the Laboratory and stations of the Department of Scientific and Industrial Research had been formed to further them. The study of fatigue has always been one of the Division's responsibilities, and a repeated-impact testing machine dating from about 1905 was on display. As a contrast, the multiple-unit direct stress-fatigue testing machine recently designed in the Division was also shown. This subjects twenty-four miniature test pieces simultaneously to repeated tensile loading at 3,000 cycles a minute.

The Electricity Division is now testing electrical instruments up to 30 kc./s. by comparison with standard electrostatic instruments. Power of the order of a milliwatt is generated by a stable oscillator and amplified up to 200 watts by two amplifiers. By the use of considerable feedback in the amplifiers, the power output is made extremely stable. Measurement errors are liable to arise principally from capacitance currents. The quadrant and voltage-dividing resistances are wound with fine wire in such a way as to make the residual inductances and capacitances as small as practicable. Shunt capacitance circuits are provided so that the capacitance currents taken by the electrostatic instruments do not pass through the resistances and cause errors.

Two more amplifiers are at present under construction designed to increase the total available output to 400 watts.

In the basement of Bushy House, the Division showed the equipment by which the standard frequencies transmitted daily from the General Post Office station at Rugby are automatically compared with the National Physical Laboratory frequency standard and recorded. A twin-channel electronic switching unit designed and made at the Laboratory allows up to eight different frequencies to be compared in one cycle of operation lasting three minutes; the unit is switched automatically to the next position at the end of each. A record of frequency differences is obtained on a chart recorder, and variations of less than 1×10^{-9} can be detected.

In the Electronics Section, the pilot model of the Laboratory's electronic digital computer (ACE) was shown, operating at the rate of 30,000 additions or 500 multiplications per second. Another item demonstrated, by relays and signal lights, that the error-producing effects of noise in a communication channel can be reduced by including a suitably coded redundancy of information in the transmitted message. By means of lights representing the binary digits 0 and 1, a relay-operated working model showed the sequences of 6-digit patterns that arise when various prescribed functional relations exist between the value of a given digit and the preceding values of two digits of the set.

Water occurs in great quantities in the surface layers of the earth as fresh or sea water, or as moisture in soil, thereby playing a large part in the determination of the characteristics of ground-reflected waves. It also occurs as rain in the atmosphere, and so affects the performance of centimetre-wave radar equipment, because of the absorption and scattering of radiation to which it gives rise at wave-lengths less than about 10 cm. A knowledge of the dielectric properties of water is thus clearly of importance in the study of radio wave propagation. The Radio Division demonstrated the measurement of the dielectric properties of water, salt solutions and methyl and ethyl alcohols at centimetre and millimetre wave-lengths, at frequencies in the range 10,000–50,000 Mc./s.

Another exhibit was an automatic atmospherics wave-form recorder which was built to determine what accuracy may be obtained in the location of thunderstorms by distance measurements made from echo-type wave-forms. For purposes of comparison, the recorder is linked with the Meteorological Office network of direction finders. The wave-form technique may possibly enable thunderstorms to be located from a single station and so lead to an economy in staff.

A new exhibit from the Light Division was a photoelectric colorimeter. A spectroscope is used to spread the colour into a spectrum, and a variable template placed in the plane of the spectrum is adjusted to make the response of the combined spectroscope and photocell match that of the average human eye. Colours are thus measured as they would be with an ordinary trichromatic colorimeter and a human observer, but with more accuracy and precision.

In the original model a single spectroscope was used. To eliminate the error caused by stray light, a commercial instrument of the same type has employed a double spectroscope. In the instrument at the National Physical Laboratory, the light beam has been reversed so that the same dispersing prism is used over again to purify the light. This device, in addition to avoiding the need for two prisms, produces an extra image of the spectrum which allows the use of an exploring slit and so makes the setting and checking of the template easier.

A recently developed process for producing diffraction gratings was also demonstrated in the Light Division. It consists of cutting a very fine screw thread on a cylinder and then 'opening out' the helix upon a flat surface by a plastic replica process. These threads of very fine pitch are cut by a diamond on cylinders of good surface finish, by means of additional reduction gearing to a small screw-cutting lathe. This part of the work is carried out in the workshop of the Metrology Division, and threads as fine as 15,000 per inch have been produced. The inevitable periodic errors in the fine screw threads are then removed by applying the 'Merton nut', a nut lined with a resilient material such as cork, by means of which, on the opposite end of the cylinder, a second thread is cut of extreme regularity. This second, corrected, helix can then be made into a plane grating by a replica process which, when applied to existing plane gratings, has been found to have a fidelity approaching the Rayleigh limit.

The Metrology Division demonstrated a method of autographic testing which provides a continuous record of the errors of precision lead-screws, rather than a series of measurements taken at discrete points along the helix. The test is made in the Laboratory's standard lead-screw lathe, on which the screw is mounted so that it is supported and driven between centres, with the feed of the lathe saddle set to correspond with the nominal pitch of the screw. A small stylus wheel mounted on the lathe saddle engages with the thread of the screw, and errors in the helix of the screw are revealed by axial displacements of the wheel. These are detected by an electromagnetic measuring head and, after electronic amplification, are recorded at a magnification of 1,000. In this way a continuous autographic record of the errors of the screw is obtained along its complete length. The method has the additional advantage that the test can be performed quickly.

Commercially-produced discharge lamps were on show which emit monochromatic rays suitable for high-precision measurements of length by optical interferometry. These lamps contain a small quantity (1 mgm. or less) of a mercury isotope, prepared by irradiating gold in one of the atomic piles at Harwell; usually a little argon gas is added to give stability to the discharge. Comparisons of samples of the lamps show that the wave-lengths of the rays emitted are reproducible to 1 part in 100 million, provided that the pressure of the argon is the same. Direct measurements of length up to nearly 50 cm. (18 in.) are possible, and it has been suggested that the wave-length of the green ray could serve as the ultimate standard of length.

Experiments are also in progress on the application of radio waves to the measurement of length or of the velocity of propagation of electromagnetic radiation or light by interferometry. Waves of length 1·25 cm., generated from a stabilized klystron oscillator, when directed into a suitable interferometer display characteristic interference phenomena similar to those of light waves. As the radio wave-length is about 20,000 times longer than the average wave-length of visible light, the interferometric procedure for measuring lengths of several metres is much simpler with radio waves than with optical waves.

The Division has for a long time collected information on the stability under good atmospheric conditions of analytical weights of various materials, and has now exposed a selection of 100-gm. weights to accelerated corrosion and stability tests in five representative chemical laboratories. For stability of mass, there is apparently little to choose between weights of austenitic stainless steel (25 per cent chromium, 20 per cent nickel), non-magnetic nickel–chromium (80 per cent nickel, 20 per cent chromium), and good rhodium-, platinum- and chromium-plated weights having a nominal thickness of plating of about 0·015 mm. (0·0006 in.) or more. Chromium-plated weights retained their appearance better than any, except perhaps those of highly-polished stainless steel and nickel–chromium, but they are open to the objection that the underlying nickel is slightly magnetic. No kind of weight appeared to be much more suited to one laboratory than to another. An incidental outcome of the tests is a clear indication that lead ought never to be used for the adjustment of screw-knob weights, whether they are likely to be exposed in corrosive atmospheres or not.

Exhibits in the Metallurgy Division showed the extreme similarity in the tensile properties of various copper alloys of which the composition had been adjusted to give equal electron-atom ratios. Others demonstrated the properties of iron alloys of very high purity and brought out particularly the great influence exercised on mechanical properties by small amounts of elements which dissolve interstitially. Photographs illustrated the microstructure of polished aluminium specimens during the process of creep, and an analysis of the various types of displacement had been carried out by means of the phase-contrast microscope and the interference microscope.

Tests in waves were in progress in the No. 1 Tank in the Ship Division on a wax model of a proposed new passenger ship, and in the No. 2 Tank measurements were being carried out on the friction drag of a plane glass surface 7 ft. long. There was also on view a 50-ft. plank, the resistance of which had been measured by the momentum-loss method using a large bank of pitot tubes, four lines of twenty-five tubes each, just behind the trailing edge.

The carriage of No. 2 Tank has been completely overhauled mechanically and electrically since the last 'open days' in 1949, and a storage pond for the wax models has been built. A new model-cutting machine has also been installed.

A new exhibit in the Photometry Section of the Light Division was the apparatus used for the primary standard of light. This standard is a Planckian radiator at the temperature of solidification of platinum. The actual radiator used is a small thin-walled hollow cylinder of thoria immersed in an ingot of platinum contained in a crucible of the same refractory material. The ingot is heated by eddy currents generated in it by means of a high-frequency induction heater. Tungsten filament sub-standard lamps are calibrated by comparing them with the radiator during the time the platinum is solidifying. While this process is taking place, the ingot and therefore the radiator are at a constant known temperature, and hence the latter has a definite and readily reproducible luminous intensity per unit area. This standard was adopted internationally in 1948 as the Primary Standard of Luminous Intensity, and the corresponding unit of luminous intensity, the 'candela', is the intensity of one-sixtieth of a square centimetre of the interior of the radiating cavity. It differs from the earlier unit, the International Candle, by less than 2 per cent.

The 'equal-loudness' contours, which relate the intensities of pure tones at different frequencies when the sounds are judged equally loud, are fundamental to the acoustics of hearing, but considerable discrepancies exist between the classical determinations. The National Physical Laboratory has undertaken a new determination, to help to resolve these discrepancies and in the hope that the data will assist in providing a basis for an internationally accepted set of curves. This investigation, in which a 'free-field' method is being adopted with a variety of improvements in technique, is now under way in the Physics Division.

An adiabatic calorimeter for the measurement of the specific and total heats of metals up to high temperatures, about 1,600° C., was also shown in the Physics Division. The sample is placed in a pot of pure sintered alumina which is surrounded by radiation screens of platinum and by an outside enclosure kept electrically at a temperature as close as possible to that of the sample. The rise in temperature of the sample when known amounts of heat are added is measured by thermocouples. The whole apparatus is mounted in a vacuum tank. From work carried out with this equipment it will be possible, for example, to calculate the best cooling cycle for a steel ingot by which it may be brought to working temperature without internal strain. For a large ingot, hours and even days may be saved by such knowledge.

Two types of precision measurements of elastic constants at ultrasonic frequencies were shown. In the first, a short pulse of shear or compression waves at perhaps 5 Mc./s. is timed through the specimen; a precision in timing of $\pm 0\cdot002$ microsecond is often possible, so that useful accuracy may be obtained from quite short specimens. In the second, the resonant frequencies of a cylindrical specimen are precisely identified; a magnetostrictive drive and detector are employed. The two methods are complementary and are being used to study the variation of elastic constants with composition of alloys.

Industrial visitors particularly found a good deal to interest them in the Test House, where they watched the routine testing of clinical and meteorological thermometers, barometers, viscometers, volumetric glassware, hydrometers and engineers' small tools.

Short talks on various aspects of the Laboratory's work and on particular items of research were given each afternoon in the recently equipped lecture hall.

EXTRACELLULAR PHOTOSYNTHETIC REACTIONS

By Prof. DANIEL I. ARNON

Division of Plant Nutrition, University of California, Berkeley

ONE of the widely accepted tenets of plant physiology is that photosynthesis is intimately associated with the integrity of green cells. Disruption or even injury to the intact cell leads to the cessation of the process. This view has been based on the failure, for almost three-quarters of a century, of the many attempts to reproduce photosynthesis outside the living cell. The early experiments have often sought to attain an objective which has been aptly characterized as alchemistic in the light of modern knowledge: the performance by broken or dead cells or even by chlorophyll solutions of the process of photosynthesis *in toto*, that is, the utilization of light energy for the reduction of carbon dioxide and the simultaneous evolution of oxygen. However, these early attempts were not wholly negative. Although complete photosynthesis was never reproduced *in vitro*, some of the early experiments of Haberlandt[1], Ewart[2] and Molisch[3] indicated that certain cell preparations retain a limited capacity for oxygen evolution under the influence of light. The full significance of these observations did not become apparent until Hill[4] showed by independent biochemical methods that chloroplasts removed from living cells retain for an appreciable period of time that part of the photosynthetic apparatus which is responsible for the evolution of oxygen under the influence of light in accordance with the general equation:

$$A + H_2O \xrightarrow[\text{chloroplasts}]{\text{light}} H_2A + \tfrac{1}{2}O_2, \qquad (1)$$

in which A represents a hydrogen acceptor other than carbon dioxide.

The photolysis of water by isolated chloroplasts with the concomitant evolution of oxygen, known as the 'Hill reaction', falls short of being a complete photosynthetic reaction in that carbon dioxide cannot serve as the hydrogen acceptor A in reaction 1. The non-participation of carbon dioxide was confirmed by Brown and Franck[5] and Aronoff[6] with the sensitive tracer technique using carbon-14 dioxide. The hydrogen acceptors which have been found effective were substances such as ferricyanide and quinone, which are generally considered foreign to the metabolism of the cell.

These facts were rather puzzling. The Hill reaction has demonstrated the extracellular viability of not only that part of the photosynthetic apparatus which is responsible for the use of light energy for the splitting of water, but also of the cellular components involved in the initial transfer of hydrogen to a suitable acceptor. Why did the hydrogen transfer by isolated chloroplasts fail to accomplish the reduction of carbon dioxide? To answer this question it was postulated that the isolated chloroplasts lack either the appropriate hydrogen carriers or enzymes, or both, required for the reduction of carbon dioxide by the hydrogen derived from the photolysis of water, and that in the intact cell these factors are found chiefly or wholly outside the chloroplasts.