THE NATIONAL PHYSICAL LABORATORY

THE National Physical Laboratory held its annual open week during May 25–29, and 175 items were on display in the nine Divisions of the Laboratory. Some 3,000 visitors attended during the two main open days, while on the final day visits were made by more than 1,000 sixth-form pupils from more than fifty schools. No lectures were given this year but two new films were shown to visitors: one, "Ship Shape", dealt with the work of the Ship Division; and the other, "Precise Measurement in Engineering", dealt with the work of the Standards Division.

The visitors were able to inspect for the first time two new buildings in which have been rehoused the two newest Divisions, Autonomics and Basic Physics, which previously were scattered in a number of small, often temporary, buildings within the grounds of the Laboratory.

An exhibit which attracted much interest in the Basic Physics Division concerned the behaviour of solid carbon dioxide when subjected to very high pressure. Some time ago the group working on the behaviour of materials when subjected to very high pressures discovered that carbonyl sulphide can, like carbon disulphide, be transformed into a black, stable, semi-conducting polymer at high pressures. As a preliminary to an attempt to produce this polymer from solid carbon dioxide and carbon disulphide it was decided to investigate the behaviour of solid carbon dioxide under high pressure. It was then found that above a certain pressure, in the neighbourhood of 35 kilobars, the carbon dioxide underwent a change of phase and its specific resistance dropped by several orders of magnitude. The exact values of the pressure at which this change takes place have yet to be determined and little is yet known about the properties of the resulting substance. This high-pressure form, however, is not stable, and when the pressure is removed the carbon dioxide reverts to its normal state. Subsequent experiments with carbon disulphide at lower temperatures than those used to produce the stable polymer have shown that a change to an unstable conducting phase can be produced by high pressures.

The Basic Physics Division was also exhibiting the results of its latest work on sub-millimetre stimulated emission sources. The apparatus used for this work consists essentially of a 50-kV, 2·5-μsec pulsed gas discharge between two plane mirrors, and power is extracted by a dielectric film (thin compared with the wave-length of the emission) set at 45° to the optical axis of the mirror system. This arrangement provides a resonator of reasonably high 'Q' and a Fabry–Perot interferometer of high resolving power; the addition of a third mirror provides a Michelson interferometer of lower resolving power for wide-band spectroscopy.

Strong, narrow lines with peak powers of the order of watts and wave-lengths 20–120μ were observed to be emitted by laser action when water vapour was introduced into the resonant cavity provided by the mirror system of the interferometer. The introduction of vapour containing the cyanide radical CN (from hydrogen cyanide, methyl cyanide or ethyl cyanide) gave rise to a strong stimulated emission at 336·5μ with a peak power of the order of 10 W.

This discovery has interesting possibilities for the long-standing problem of generating sub-millimetre waves of reasonable power. A possible practical importance arises from the closeness of the new line to the most favourable wave-length in the sub-millimetre range to minimize absorption attenuation due to atmospheric water vapour, which is in the region of 345μ.

In the Autonomics Division building, visitors were able to see work on character recognition, which is concentrating on two main problems. One is the recognition of poorly printed numerals, such as may be produced by typewriters or cash registers, and the other is the recognition of printed text.

The systems of character recognition being investigated are based on the premise that characters consist of a limited number of features (for example, straight lines, curves, intersections and line endings) grouped and joined together in various spatial arrangements to form the characters of a set. Two-dimensional autocorrelation techniques are used to deduce the orientation and relative positions of these features and groups of features, and these in turn determine the identity of the characters.

For the recognition of numerals the output from a conventional flying-spot scanner is fed to three serially connected delay lines, and tapping points along the delay lines are used to sample the stored wave-forms. The output of a multiplier associated with each group of sampling points is integrated; the outputs from the integrators indicate the extent to which each feature is contained in the scanned character, which is then identified by a likelihood comparison with similar sets of characters using a linear decision network. The apparatus demonstrated is the result of a two-year design investigation which has shown the feasibility of constructing a practical system of character reading. Its main advantages are a high reading rate—more than 1,000 characters per second—and tolerance of a wide range of print quality and of the orientation of the character within the field being scanned. Its print quality tolerance is largely due to the use of analogue signals.

The recognition of text presents additional problems, one of the most important being the difficulty of segmenting words into individual characters, particularly if the quality of the printing is poor. An experimental system for the reading of text without prior segmentation, at present restricted to the ten most frequent letters of the alphabet (e t a o n r i s h d) in one size and style, but with variations in the quality of printing, is being simulated on the *ACE* computer. This system is shown schematically in Fig. 1. A line of text is scanned and stored in the form of a binary pattern, on which are then performed auto-correlation transformations similar to those made in the character reading described above. However, in this case the output is not integrated but the positional information is retained in two-dimensional form. This information about the position of features is then, by means of further auto-correlation transformations, searched for the presence of groups describing the familiar alphabetic characters. This results in a sequence of probability scores which are then scanned by a decision aperture to produce a sequence of identifications.

Another new building on view contains the mechanical working laboratory of the Metallurgy Division. The object of this laboratory is to facilitate metallurgical work for the expected requirements of engineering developments during the next twenty years, and to this end work will be directed towards three primary objectives. The first of these is the examination of the large group of body-centred cubic metals in Groups IV, V and VI. These include vanadium, niobium and tantalum, chromium, molybdenum and tungsten, and the body-centred cubic forms of titanium, zirconium and hafnium. They are all of high melting-point and easily contaminated, and special equipment has therefore had to be installed for their proper handling.

The second objective is to exploit the new knowledge of the structure of metals which is arising from the direct observation of dislocations. Earlier work in the Division on the dislocation patterns in iron, and their relation to mechanical behaviour, showed that these patterns may be controlled partly through the purity of the material and partly through the working operations applied during

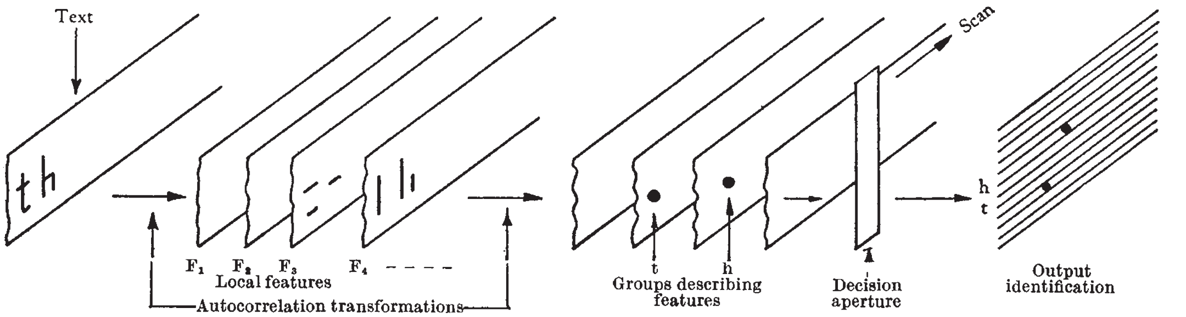

Fig. 1. Schematic diagram of processing and recognition of text

the course of manufacture, and that the patterns will control many of the more subtle mechanical characteristics. It is therefore planned to examine these effects in more detail using iron and its simpler alloys, since iron and steel seem likely to remain the basis of engineering practice.

The third type of work for which the laboratory is suitable, and which it may be desirable to do in the future, is the preparation and study of bodies composed of mixtures of metallic and non-metallic phases. Important developments have taken place in the production of powders in which the non-metallic phase is uniformly coated by the metallic phase, and these considerably simplify the making of the desired composites.

The equipment on view consists of two rolling mills, a 700-ton extrusion press (Fig. 2), swaging machines, a forging hammer, a wire-drawing bench, together with saws, slitting wheels and similar ancillary equipment. There are two vacuum furnaces of novel design. The larger of these enables a billet for extrusion to be heated to temperatures up to 1,700° C and quickly removed from the furnace without breaking the vacuum in the heating chamber. Small specimens can be heated to temperatures up to 2,400° C in the smaller furnace and quenched into water, again without breaking the vacuum.

Also to be seen in the Metallurgy Division was a universal electron probe microanalyser. The electron probe microanalyser has many applications in metallography since it can be used to explore fluctuations of composition in inhomogeneous specimens and to reveal the differences in composition of phases seen in the microstructure. As developed by Castaing some years ago, it cannot detect elements with atomic numbers below 12 because there are no crystals capable of diffracting the long-wave X-rays characteristic of the lighter elements. Metallurgically important constituents found in industrial alloys (such as oxides, carbides or nitrides) therefore fall outside the range of the analyser.

The foregoing limitation may be overcome by the use of optical line gratings to analyse the radiations from the light elements, but hitherto the diffraction efficiency of these gratings for X-rays has been low because of imperfections in the grating surface produced by the action of the ruling tool. A joint programme of research between the Light and Metallurgy Divisions has produced a development of the Siegbahn-type grating which consists of an optically worked surface interrupted by grooves. The National Physical Laboratory gratings, which have 7,500 lines per in., are manufactured by a process involving the replication and etching of a ruled grating and have a very high diffraction efficiency. They have been used in microprobe analyses and all elements down to lithium have been detected by attaching a grating spectrometer to a commercial microprobe analyser. In addition to metallurgical applications, the new X-ray gratings should be of value for the precise measurement of X-ray wave-lengths, the examination of solar and stellar X-ray emissions observed in outer space, and the elucidation of processes taking place in thermo-nuclear devices.

The Aerodynamics Division had an exhibit dealing with the maintenance of laminar boundary layers in order to reduce the drag of an aircraft, a subject which has for many years been investigated at the Laboratory within the Reynolds number limitation of its low-speed wind-tunnels.

One problem associated with swept-back leading edges is that wedges of turbulent flow originating at the wing root, or from insects accidentally impacted on the leading edge, may cause unlimited span-wise contamination of the outboard laminar boundary layer. Results were shown of a recent Laboratory experiment which has established roughness criteria for this occurrence for comparison with the existing two-dimensional criteria. Ways of limiting such span-wise contamination, and of raising the Reynolds number at which it occurs, have been found and are jointly being investigated at the Laboratory and the College of Aeronautics. The latter work forms part of a flight-research programme, sponsored by the Ministry of Aviation, on a swept fin in which boundary-layer suction is applied through a slitted surface, and aimed at possible applications to the next generation of high-speed swept-wing transport aircraft.

A long-term application of boundary layer control, to a supersonic aircraft of slender planform, could be seen in the 13 ft. × 9 ft. wind-tunnel. A delta wing, with leading edge swept back 76° and with a wholly porous upper surface of sintered steel, is being tested at low wind

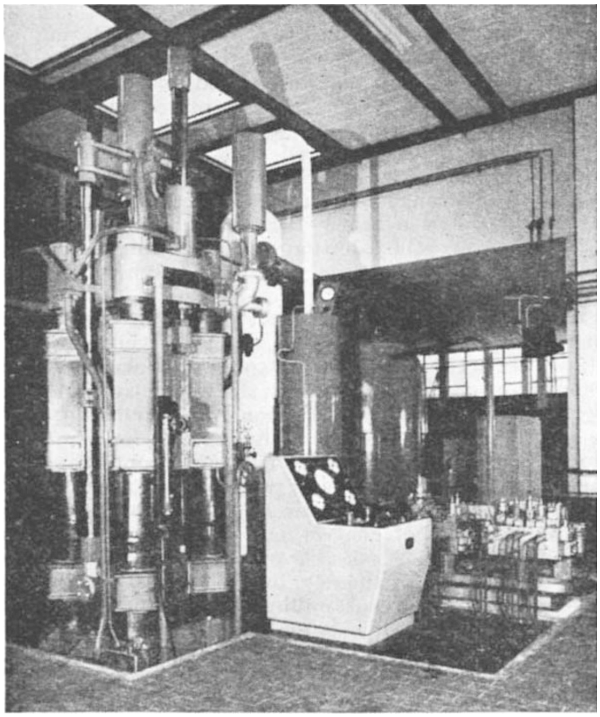

Fig. 2. Extrusion press in the new mechanical working laboratory. The press is of modern design, with a fast top speed to facilitate the extrusion of high-melting-point materials

speeds in order to determine the distributed suction needed to maintain laminar boundary layers over the upper surface in the presence of the three-dimensional flow associated with the very high leading-edge sweep. The interior of the wing is divided into six compartments, and the flow through the surface over each compartment can be controlled independently. The work includes the examination both of attached flow at the leading edge and the leading-edge vortex type of flow which produces a swept attachment line inboard of the leading edge in the vicinity of the highly turbulent vortex. Distributed suction is expected to affect the position of the vortices by eliminating secondary separation.

An interesting exhibit in the Ship Division illustrated the effect of a contaminant on turbulent boundary layers in water. In the apparatus used for this demonstration two identical revolving flanged disks were immersed in identical cylindrical casings, containing equal volumes of water, and the torque exerted by the water on each casing was shown. The addition to one casing of a small quantity of 'Polyox', sufficient to give a concentration of about 30 parts per million by weight, reduced the torque by about 30 per cent. Another contaminant which causes the same effect is guar gum.

Investigations have shown that this reduction in torque is not associated with any delay in transition from laminar to turbulent flow, but the thickness of the turbulent boundary layer is appreciably reduced by the addition of the contaminant. The exact mechanism producing this change has yet to be determined, but it is thought that it is possibly associated with a weakening of the larger eddies in the boundary layer. This effect may explain some anomalous results which have been obtained from time to time in ship hydrodynamic tests, the supposition being that certain algae in the water can act in a similar manner to 'Polyox' or guar gum. These additives can be used to reduce the power required to pump liquids over long distances.

The Ship Division also showed, in its larger water-tunnel, an impressive demonstration of the flow from a fully cavitating propeller (Fig. 3). The conventional marine propeller is designed to minimize the amount of cavitation that occurs at high forward speeds. However, propellers in high-speed craft often cavitate heavily, and under such conditions the mode of operation of the propeller is different from that of the non-cavitating propeller. The growth of large cavities in the wake restricts the mass of water that can effectively be accelerated astern and, in consequence, the thrust and torque of the fully cavitating propeller are reduced in comparison with the equivalent non-cavitating propeller.

Existing design methods developed for propellers which operate with cavities completely covering the suction side of the blade surfaces are now recognized to be inadequate, and attempts are being made to produce an improved design procedure. This improved design method requires, at least, knowledge of the size and shapes of the cavities in the wake downstream from the propeller and attempts are being made to obtain such information from experiments with fully cavitating propellers. It is hoped to be able to correlate this experimental information with a simple theory which will allow future predictions of cavity dimensions to be made. Further progress is thus dependent on the results of experiments, such as that demonstrated, with models designed using approximate estimates for some of the essential factors. In this experiment, the circumferential thickness of the cavities in the wake is measured by using a number of probes spaced in the radial direction and held by a stationary strut in the wake of the propeller.

One of the exhibits in the Radiology Group of the Applied Physics Division was a solid-state spectrometer for α- and β-rays. The requirements of a spectrometer for detecting and measuring the energy of charged particles are: good resolution, that is, the ability to distinguish

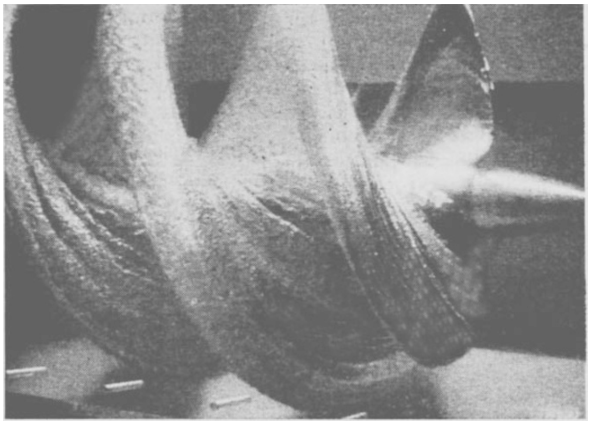

Fig. 3. A fully cavitating propeller in the National Physical Laboratory 44-in. diameter water-tunnel

between particles of closely similar energies; an output proportional to the energy deposited in the detector and independent of the nature of the radiation; a rapid response, allowing high counting rates; compactness; and simplicity. Gas-filled ionization chambers are simple, have good resolution and a linear output; scintillation counters are compact and possess a rapid response. However, solid-state devices possess all the required properties and are replacing ionization chambers and scintillation counters in many applications.

The signal from a solid-state detector is a quantity of charge produced by ionization and collected by an applied field. To obtain a realistic signal-to-noise ratio combined with rapid collection, the solid must be a semi-conductor. The straightforward 'homogeneous' detector suffers from disadvantages associated with the difficulty of obtaining material of sufficient purity. Junction detectors, which make use of the rectifying junction between *p*- and *n*-type material, are therefore preferred. These are operated with a reverse bias which determines the width of the depletion layer, the sensitive volume of the detector. Junction detectors give good energy resolution, about one order of magnitude better than scintillation counters; very fast response, collection times of the order of 1 nanosecond; and a very thin dead layer.

In the experiment demonstrated a silicon surface-barrier junction detector was being used to measure the α-radiation from a source of americium-241. A similar detector with a wider depletion layer can be used for measurements of β-ray spectra. Future developments that can be foreseen are a fast $4\pi\beta$–γ coincidence system, utilizing solid-state detectors for the β-rays and inorganic scintillators for the γ-rays, and identification of γ-rays from measurements of the photoelectrons ejected from a suitable converter foil.

Exhibits in the Light and Standards Divisions illustrated the Laboratory's responsibilities in the field of standards.

The present primary standard of light is a black-body radiator held at the freezing-point of platinum. While in theory this standard leaves nothing to be desired in accuracy, in practice there has been great difficulty in realizing precisely the theoretical conditions and in achieving good repetition. An alternative approach proposed by the National Physical Laboratory involves the use of a black radiation thermopile, observing all wavelengths equally, behind a filter which transmits in varying proportions at different wave-lengths in accordance with the spectral sensitivity of the eye. For this measure to be absolute, and hence photometry become a logical branch of radiometry, it is necessary that the filter transmission should be amenable to calibration and that the thermopile be calibrated in terms of known intensities of incident radiation.

As a result of this proposal, the Consultative Committee on Photometry of the Bureau International des Poids et Mesures requested the National Physical Laboratory to organize an international comparison of radiometric scales, as a first step in assessing the possibilities of the proposed method as an internationally agreed substitute for the material primary standard of light. Standards laboratories in seven other countries are participating in this work. Lamps calibrated at the Laboratory for total radiation intensity are being sent to these laboratories for comparison and the results will be reported to the Consultative Committee at its meeting in 1965.

In the Standards Division work is being carried out on the realization of the thermodynamic temperature scale above 175° C, using a method based on the Planck law of radiation. The International Practical Scale of Temperature (IPST) was first defined in 1927 to conform as closely as possible with the thermodynamic Celsius scale as then known. However, recent determinations of thermodynamic temperature above 100° C by gas thermometry have given temperatures higher than those of the IPST, the difference steadily increasing with temperature until it reaches about 1·5° C at the gold point (1,063° C). It is therefore urgently necessary to revise the IPST, or at least to make an authoritative statement of the differences between it and the thermodynamic temperature scale. The Advisory Committee on Thermometry of the International Committee of Weights and Measures is dealing with this problem and the work demonstrated in the Standards Division stems from this Committee's activities.

The apparatus used in measuring temperatures up to the gold point consists essentially of a double monochromator using a prism, followed by a grating, in order to produce a narrow wave-length band at a mean wavelength λ, which can be set accurately. Energy radiated at this wave-length by two furnaces at temperatures T_1 and T_2 is detected by a cooled lead–telluride cell, and the energy ratio R is determined by adjusting the area of the aperture in front of the detector so that equal signals are received from the two furnaces. The energy ratio is then given by:

$$R = \frac{\exp\left(\frac{C_2}{\lambda T_1}\right) - 1}{\exp\left(\frac{C2}{\gamma T_2}\right) - 1}$$

where C_2 is the second constant of radiation in the Planck formula. Since λ is known, T_2 can be determined in terms of T_1. When the most recent assessment of the value of C_2 from atomic constants is used (that is, 0·014 388 4 m deg) the thermodynamic temperatures measured in the experiments are proving to be in agreement with those given by gas thermometry up to 800° C, but somewhat lower above this temperature.

The realization of the temperature scale above 1,063° C is normally based on the use of a visual optical pyrometer. By using a rotating sectored disk to achieve known energy ratios and a photomultiplier cell as a detector the Laboratory is aiming to achieve a ten-fold improvement in accuracy over the visual method. The apparatus on show used at its lower temperature source radiation from a graphite black-body cavity held at 1,063° C and the higher temperatures were produced by special black-body lamps, developed jointly by the Laboratory and the Hirst Research Centre.

Another type of work done by the National Physical Laboratory was also illustrated in the Standards Division, where visitors were able to see new force-measuring columns for 50 tonf and 500 tonf maxima which satisfy the requirements of Grade I proving devices of British Standards 1610 : 1964 for loads ranging from their maximum to less than one-fifth maximum, respectively. These instruments, developed in the Division, have the advantages of being robust, simple in design and accordingly of relatively low manufacturing cost. They may be used for the verification of all types of compression testing machines. The Standards Division also showed an exhibit dealing with the re-definition of the yard and pound as a result of the new Weights and Measures Act which came into force on January 31, 1964. Under this Act the yard is defined as 0·9144 international metre and the pound as 0·453 592 37 international kilogramme.

Open days provide a valuable opportunity for National Physical Laboratory staff to demonstrate the results of their latest work to other scientists and industrial users and at the same time for the staff to widen the already extensive contacts that they have with such people. Visitors are given a cordial welcome and it is hoped that even greater numbers will be able to come to Teddington in 1965 when the open days will take place in the week beginning May 17. Requests for invitations should be addressed to the Director, National Physical Laboratory, Teddington, Middlesex.

A. CHINNECK

NATIONAL LABORATORIES IN INDIA*

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THE post-war period saw a rapid growth of scientific research in India. The Council of Scientific and Industrial Research which was set up in the early 'forties set up a chain of thirty-one laboratories during the period 1946–63. These laboratories were committed to the task of solving industrial and other national problems through research and development, by way of assessing correctly the quality of raw materials available in the country and improvising their proper use. Since industrial research always faces crucial problems in basic science, proper stress was also given to basic research. An investigation has been made by the Survey and Planning of Scientific Research Unit to take a stock of the development of these laboratories by making a statistical appraisal of the research inputs, namely, expenditure, scientific personnel, scientific equipments, personnel and the research outputs in different laboratories.

Expenditure

The total expenditure of the Council of Scientific and Industrial Research increased about sixteen times during the period 1946–62 from Rs. 5·2 millions in 1946–47 to Rs. 81·2 millions in 1961–62. In 1961–62 the recurring expenditure formed 64 per cent of the total expenditure, which again was 17 per cent of the total Government expenditure on scientific research in India (Rs. 469 millions)†.

A detailed statistical investigation has been carried out for the period 1954–62. During this period the

* A comprehensive monograph will be published shortly.

† "A Study of Government Expenditure on Scientific Research", *J. Sci. Indust. Res.*, 22, 479 (1963).