impractical if judged by present concepts of what is vital and what is useful for an educated person to know. Even if an optimum solution could be found, it is fairly inevitable that the completion of some kind of specialized study course and the resultant feed-back of the individual's educational background into society would add one or two years to the present time-scale of formal education. But given the resources, is this such a great sacrifice in the long term in order to achieve a society which has a greater consciousness of its scope, together with a balanced perspective of specialist activity and its contribution to human progress ?

The idea is far from being new. Plato is quoted as saying the following in his famous *Republic* about the students of his equally famous Academy: "They will be offered all at one time the sciences which they have studied at random in their adolescence, so that they can get a broader view of the relationships between these sciences and by this means become acquainted with the true nature of reality".

In the fourth century B.C. it was, of course, possible to read the output of practically all the contemporary thinkers—a task which is beyond human capability to-day. Nevertheless, it would be ironic if, more than twenty-three centuries later, man has become so overwhelmed by the revelations of his own intellectual industry that he finally becomes the slave, rather than the master, of knowledge.

THE NATIONAL PHYSICAL LABORATORY, TEDDINGTON, MIDDLESEX

ON April 1, 1965, the National Physical Laboratory, together with most of the other stations of the former Department of Scientific and Industrial Research, became part of the new Ministry of Technology, and on the same day the National Chemical and National Physical Laboratories were amalgamated under one director. This year, therefore, for the first time, it was the combined Laboratories that were open for inspection during open days which were held on May 19–21, when 330 items were on display. Some 3,570 visitors attended during the first two days, while on the final day visits were made by more than 1,200 sixth-form pupils from 62 schools. No lectures were arranged, but two films were shown: one, *Ship Shape*, dealt with the work of Ship Division, and the other, *Precise Measurement in Engineering*, with the metrological work of Standards Division.

It is convenient to consider the various Divisions of the Laboratory as constituting a number of groups, each group having common interests. Thus there are two Divisions—Aerodynamics and Ship—concerned essentially with the movement of a solid body through gaseous or liquid media. Four others—Applied Physics, Chemical Standards, Light, and Standards—are interested in accurate measurement and standardization. Autonomics and Mathematics devote much of their effort to automation and computers, while Basic Physics and Metallurgy are concerned with the investigation of materials. The common interests between groups of Divisions were apparent from the items on display during the open days.

In Aerodynamics Division, research has been in progress for several years on base flows. This type of flow occurs behind wings or bodies, moving through the air, which are not shaped so as to converge to a sharp edge at the rear but are truncated earlier, leaving a bluff rearward-facing area or 'base'. Similar flows exist behind downstream-facing steps in a wall (the outer skin of an aircraft, for example) past which air is flowing. The problem is of considerable practical importance because the air pressure which acts on the rearward-facing area is usually low, making a contribution to the total drag of the aircraft or vehicle.

One of the Division's exhibits illustrated various methods which have been explored for reducing the drag arising in this way. One method at present being investigated consists of hollowing out the base, so that at the rear of the wing or body there is a thin-walled cavity with its opening facing downstream. The walls of the cavity are ventilated so as to allow air to bleed through into the cavity from the outer surface. This has the effect of alleviating the low pressures acting on the base. The preliminary results are encouraging, and further research on the method is in progress.

Two separate lines of research into methods of calculating the development of turbulent boundary layers are being pursued, with the ultimate objectives of improving estimates of the surface-friction drag of aircraft and ships, and predicting the undesirable phenomenon of separation of the flow from the surface. One method relies on an empirical correlation of nearly all existing data and should be more reliable than the more narrowly based existing methods; the second method uses the equation for the flow of turbulent kinetic energy to obtain a relation between the velocity and turbulent shear stress and their spatial derivatives, which is then solved simultaneously with the boundary-layer equation and the continuity equation on the *KDF*9 computer. This method requires a fairly small quantity of empirical information about the turbulence structure, which is being obtained as part of a wider experimental programme using a special wind tunnel. Experimental work is also being done on surface pressure fluctuations under turbulent boundary layers, which cause structural vibration, fatigue and noise.

The effort devoted to non-aeronautical aerodynamics is steadily increasing. One interesting investigation in this field concerns the collapse of cooling towers under wind loading conditions. This has been investigated using scale-models in the compressed air tunnel in which the increased air density raises the impact pressure of the airstream sufficiently to buckle specially prepared thin metal models (wall thickness 0·005–0·012 in.). Associated mathematical analyses have been made in the Mathematics Division. Work is also in progress on the aerodynamic stability of suspension bridges, with special reference to the Severn Bridge. Tall buildings, chimney-stacks and other tall, slender structures represent other examples where the natural wind can introduce loadings, particularly those of an oscillatory nature, for which no adequate provision is made in current *Standard Codes of Practice*. Wind-tunnel investigations have been undertaken to ensure that no unacceptable oscillations will occur on the General Post Office towers for London and Birmingham. Another interesting investigation, at present in progress, is that for the World Trade Center, a 1,350-ft. twin sky-scraper development for Manhattan, New York, which when built will be the world's tallest pair of buildings. On show also was a landscape model of a section of the Lancashire–Yorkshire motorway, on which wind-tunnel tests had been made in order to investigate the airflow with special reference to snow drifting in a deep cutting.

Another aspect of the problem of drag was illustrated by a hydroelastic model of a fully cavitating propeller in Ship Division.

The blade sections of fully cavitating propellers must have thin leading edges to avoid high cavitation drag with consequent loss of power and low efficiency. Despite the use of high-strength materials such as stainless steel, fully cavitating propellers with thin leading edges have failed structurally in service, and experiments are being made to determine the steady and unsteady stress levels in such propellers. Unsteady stresses occur mainly because a propeller has to operate in a non-uniform wake.

In order to predict full-scale steady-state stresses from a model propeller, the deformation under load of the model must be similar to that of the full-size screw. This condition may be closely simulated by making the model from a more flexible material; here this is an epoxy resin with a suitable filler added to adjust the elastic modulus to the required value.

The strains at selected positions on the blades are measured by means of very thin electrical strain-gauge rosettes attached to the blade surfaces. The energization of the strain-gauge bridges and the resulting output signals are controlled and measured from outside the tunnel by means of slip-rings and leads passing along the shaft into the propeller. Stress-levels in the blades are then calculated from these strain measurements.

The Division has recently also been investigating the potentialities of passive tank-type roll stabilizers to supplement the activated types at present commonly fitted to ships. Most encouraging results have been obtained. The passive ship roll stabilizer has certain advantages over the activated type. It requires no instrumentation, moving parts, or power supply, its action depending on the free motion of water from side to side in a rectangular tank.

The tank is incorporated in the ship structure as high as possible and usually extends from side to side using the maximum beam of the ship. The depth of water in the tank is such that at the resonant response frequency of the vessel the water moves from side to side with the same period of oscillation as the ship but lagging the ship motion by a 90° phase angle. The quantity of water transferred is such as to create large damping of the motion.

The design and development of the system are both simple and economic, and a scale model of the vessel to which it is to be fitted is used to prove the design. A demonstration of a typical installation in a ship model showed the principle of the stabilizer and the reduction in roll angles possible with such a system.

The Radiology Section of the Applied Physics Division which is concerned with the establishment of all types of standards in the field of radiation physics was able to exhibit this year the new 3-MV Van de Graaff positive ion accelerator. The acquisition of this machine considerably widens the range of the Section's activities. It will permit the establishment of standards of neutron flux density which are required for the calibration of neutron detectors and for the measurement of neutron reaction cross-sections. The machine accelerates beams of protons, deuterons or α-particles which may be directed along one of three drift tubes to bombard targets of suitable material. One such drift tube leads to a target situated in a low scatter environment in which the source of neutrons is at least 20 ft. away from all walls, ceiling and floor, the essential equipment being supported on a light open-mesh grating (Fig. 1). By suitable choice of particle, bombarding energy, target material and angle of detection, monoenergetic neutrons can be obtained at many energies from a few keV up to 20 MeV. A second drift tube, leading to another area of the accelerator hall, will enable a beam of deuterons to be rapidly oscillated between two targets situated in a large graphite moderator. At a point midway between these targets a well-thermalized neutron flux of about 10^7 n/cm^2 sec and having a very small gradient over a volume of about 100 cm^3 should be obtained. By this means it is hoped to establish a standard thermal neutron flux density standard which will be used to calibrate flux measuring foils; alternatively, a small beam of neutrons can be extracted from the moderator to calibrate neutron detectors for protection measurements.

Work in the Acoustics Section of the same Division lies largely in the field of psychoacoustics, and much interest was attracted by an exhibit showing the preliminary results from the latest in a series of subjective experiments designed to gain information on the relation between noise-levels and environmental factors on people's reactions to specific classes of noise, in this case aircraft noise. The tests were carried out at Farnborough during the SBAC Show in 1964. One object was to examine the validity of rating scale procedures for tests of this sort and to refine the techniques for subsequent use. One of the principal findings is that noisiness judgments depend not only on the noise-level received, but also on the listeners' inference about the noisiness at source. No significant difference was observed, however, between judgments of landing and take-off noise at corresponding sound-levels. The tests, for which 150 subjects took part, were spread over five afternoons. On the first afternoon the subjects were divided into four psychologically matched groups by means of their responses to 'annoyance' and 'semantic differential' questionnaires administered by the Applied Psychology Research Unit of the Medical Research Council. The aircraft noise tests occupied the remaining four afternoons during which the four groups were situated at indoor and outdoor locations variously sited with respect to the flight paths. The results accord closely with those of a smaller-scale experiment carried out at the time of the 1961 SBAC Show for the Wilson Committee on Noise, and their validity is now believed to be high as a result of the balanced-design cross-checks in the present series.

The new Chemical Standards Division, formerly the Division of Chemical Physics of the National Chemical Laboratory, illustrated work in chemical thermodynamics

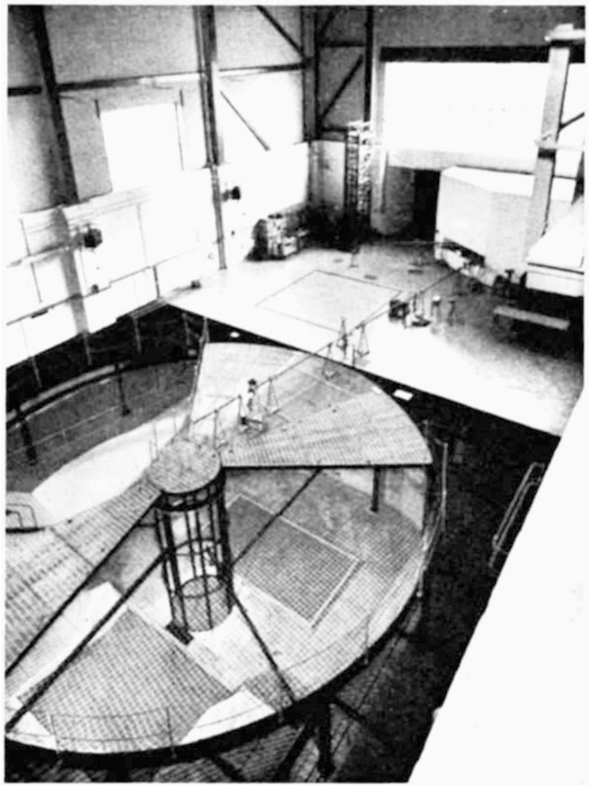

Fig. 1. General view of the Radiology Laboratory, showing a drift tube leading to the open-mesh grating forming the low scatter environment

and molecular spectroscopy, the two main items on its programme.

Thermal properties (heat capacities, heats of transition, heats of fusion, triple points) of substances are required in the chemical industry for the development of the best production methods. Heat capacities of 12°–473° K are being measured to a high degree of accuracy by adiabatic calorimetry. The apparatus exhibited has been largely automated. In each of the four sets of equipment, the temperature of a shield isolating the calorimeter is automatically maintained within a few thousandths of a degree of that of the calorimeter. Heat inputs to the calorimeter are calculated from voltage observations recorded automatically on paper tape. Temperature increases are measured to a thousandth of a degree by means of platinum resistance thermometers and an automatic a.c. resistance bridge, readings of which are also recorded on tape. All the observations are processed by digital computer.

Values of Gibbs energies and heat contents of substances are needed by chemical engineers engaged in plant design; values can sometimes be obtained by measurement of equilibrium constants over a temperature-range. Apparatus used for the determination of equilibrium constants for the gas-phase hydrogenation of three ketones and an aldehyde was shown; the vaporized compounds, mixed with hydrogen, were passed over a catalyst held at a known constant temperature and the products analysed by gas chromatography. The results confirmed the values of certain thermally derived thermodynamic quantities and data inaccessible by other methods were secured, for example, a value for the entropy at 298° K of *s*-butyl alcohol, which could not be derived from low-temperature calorimetric studies because the alcohol did not crystallize.

Important information concerning the vibrations of some molecules can be obtained from the study of their absorption spectra in the infra-red and far-infra-red regions. Examples of the use of infra-red, far-infra-red and Raman spectra to obtain fundamental frequencies were shown. The results are used to calculate thermodynamic values, for example, the heat capacity of industrially important compounds. These calculations are complementary to measurements of the same quantities and permit extension of the results to a wider temperature range.

Two of the most interesting items on display in Light Division were a colour temperature meter and thin film components for the visible and ultra-violet.

A very simple and convenient colour temperature meter has been developed which can detect differences of 1° K between incandescent tungsten filament lamps. This instrument can be used in the National Physical Laboratory and similar laboratories to inter-compare standard lamps.

The colour difference detector is a sector disk with yellow and blue filters revolving in front of a photocell. With incident light at a certain colour temperature, the a.c. output from the cell will be zero; but any slight change of colour temperature will produce an a.c. signal which can easily be greatly amplified for detection on a meter. If, as is probable, the light is not at the 'matching' colour temperature, it may be made so by sliding across a coloured wedge. The displacement of the wedge required for a null signal is then a measure of the colour temperature of the light, provided that the spectral distribution is similar to that of a full radiator.

Extensions of this principle could produce an extremely simple and sensitive colorimeter which could be used in industry to detect deviations from colour specifications in goods such as textiles, and hence, possibly, to control the process automatically.

Work is proceeding on the development of a very efficient polarizing beam-splitter which consists of a glass cube split on a diagonal, the interface bearing an interference filter comprising many alternate thin layers of magnesium fluoride and ceric oxide. This reflects only light of one direction of polarization, light of orthogonal polarization being transmitted. Samples made so far give an efficiency of separation of the two beams of more than 90 per cent.

Such beam-splitters find application in interferometry, where they can give efficiencies of four times those given by conventional beam splitters, and where the two beams being 'labelled' by their polarization can be manipulated separately without interference.

Thin film components for the vacuum ultra-violet are needed in space research, plasma physics and other spectroscopic applications. Most materials used in such components absorb strongly below 2000 Å, and work is in progress to determine the conditions necessary for efficient components.

Aluminium mirrors protected by thin layers of magnesium fluoride have given reflectivities of more than 80 per cent at 1216 Å, but deteriorate with time. It is hoped that further work will disclose the reason for this.

The application of lasers in the field of accurate measurement was illustrated by an exhibit in Standards Division.

For many years engineers' reference end bars have been measured accurately by means of wave-lengths of light, but such measurements have been limited to short bars by lack of complete purity in the colour of the light from the usual sources. The advent of separated isotopes, notably mercury-198 and krypton-86, permitted the production of purer radiations; but even then measurements could only be extended to 1 m with difficulty. The helium–neon laser, on the other hand, emits almost perfectly monochromatic light the wave-length of which has been measured at the National Physical Laboratory in terms of the krypton-86 radiation defining the metre. This practically removes the length limitation, and, in conjunction with other properties of laser radiation, extends the possibilities of measurement by light waves far beyond the usual measurement of end bars. A precise length-measuring machine using a laser has been designed and constructed using standard engineering techniques which will automatically measure the position errors of the lines on a scale with an accuracy in the region of 0·2 μm. Although there may be up to a thousand lines, their measurement takes only a few minutes; whereas by the classical methods a corresponding measurement used to occupy many hours. Moreover, the results are automatically recorded on paper tape and the subsequent analysis carried out by digital computer. Further developments will include application of the machine to metrological gratings and other types of scale, and refinement of its accuracy to better than 0·1 μm by closer control of ambient conditions.

Another exhibit which attracted attention in the same Division was an instrument designed for the easy and accurate measurement of distances up to one mile. This instrument known as *Mekometer II*, and believed to be the first of its kind in the world, can be regarded as a truly electronic tape-measure.

The device utilizes a light beam which is polarization-modulated in the ultra-high-frequency region. This measures the distance from the instrument to a reflector placed at the far end of the line. The modulation wave-length is conditioned by specially designed and constructed cavity resonators filled with dry air but allowed to acquire atmospheric temperature and pressure. By these means the velocity of light is excluded from the basic measuring equations and the results indicated by the device are scarcely affected by the state of the atmosphere. The accuracy is better than one part in one hundred thousand. Distance is indicated on dials directly in feet and the whole process takes but a few minutes whereas existing methods take hours. The first tests have been made using the National Physical Laboratory 300-m (984-ft.) base and the results obtained from *Mekometer II* differ from the true length by less than 0·005 ft. It is hoped to improve the difference to $\pm$ 0·002 ft. later in the year. A commercial licence to manufacture has been granted.

Considerable attention is being given in Autonomics Division to the possibilities of the automation of industrial processes, and visitors to the Division were able to see an automated small-scale distillation column in operation. The column, designed to separate a mixture of ethanol and water, is now coupled to a Ferranti *Hermes* digital computer, and direct digital control of top product composition has been achieved. The equipment is being used to investigate techniques for estimating the dynamic characteristics of the process, and for achieving adaptive and optimal control. The computer accepts signals from temperature, flow-rate and product composition transducers. The last of these is a newly developed instrument based on the use of very-high-frequency resonators immersed in the liquid. Control is exercised by the computer over input heater power and reflux rate. Alterations can be made in the feed composition.

A steady-state model, based on the materials balance equations for the column, has been programmed in the computer to provide predictive control of the process to an optimum steady state. A dynamic model is derived in the computer by applying to the control variables small, specially designed binary perturbations. By cross-correlation of the resulting signals from the column transducers with respect to the applied perturbations the computer derives estimates of parameters describing the dynamic behaviour of the column. These estimates are continually updated to keep pace with temporal changes in the dynamic behaviour and they therefore define an adaptive model for use in more sophisticated control techniques. Programming for full adaptive control is well advanced and will include investigations of hill-climbing methods and of techniques based on dynamic programming.

Another problem being investigated in the Division is that of information retrieval. The retrieval of scientific information is now a formidable, but important, task. It presents many challenging problems which, with the possibility of mechanizing many of the routine operations, are receiving much attention.

A mechanical system is being developed in which documents are indexed and enquiries are expressed in terms of descriptors. Each descriptor is a ground of associated key-words, the grouping being based on statistics of word co-occurrence in documents. During the retrieval process a comparison is made between the set of descriptors assigned to each document and the set used in formulating the request. Documents for which a perfect correspondence is found are retrieved, but it is also worth retrieving documents that have been assigned most, but not all, of the required descriptors. The retrieved items are therefore rank-ordered according to their degree of correspondence with the request.

The standard of retrieval which has already been achieved entirely by computer is illustrated by the following example. An enquiry for information on 'magnetostrictive band-pass filters' was made with reference to a collection of 12,000 abstracts covering electronics, computers and aspects of physics and geophysics pertinent to radio communication. The five abstracts which follow were at the top of the rank-ordered output:

(1) Electromechanical filters for use in telecommunication equipment. Includes descriptions of construction and performance of reed type magnetostrictive and piezoelectric filters.

(2) A practical electromechanical filter. Details of materials and fabrication techniques are given for narrow-band torsional filters.

(3) A theoretical analysis of the torsional electromechanical filters. The mechanical properties of a torsional system are expressed in terms of electrical equivalents. By introducing a transducer transfer ratio with the dimensions of charge a method is developed for the design of electromechanical filters based on equivalent electrical networks. Pass band ripple spurious modes and transducer matching are discussed.

(4) Surface magnetostatic modes and surface spin waves. The general existence of surface wave modes in the frequency region above the spin wave band is shown.

(5) Image parameter theory for mechanical quadripoles in compressional or torsional oscillation. The equivalence of the parameters of a mechanical system transmitting compressional or torsional oscillations and the parameters of an electrical transmission line is established. The design of mechanical filters is described and design formulae with response characteristics are given for the basic filter sections.

Much of the pioneer work in the design and application of computers was carried out in the Mathematics Division, which now has a *KDF*9 in addition to its older machines *Ace* and *Deuce*. For many years the Division has concentrated on developing techniques and programmes for facilitating the scientific applications of computers. These have been used not only on the Division's own research in numerical analysis, applied mathematics, theoretical physics and engineering problems but also on work for the Laboratory as a whole and for outside organizations. The attention of visitors was directed to a variety of such studies. These included the calculation of stresses in concrete cooling towers, which was associated with experimental work on show in the Aerodynamics Division, and work on the mathematical design and analysis of ship hulls.

For any shape and size of cooling tower, the stresses induced by the wind and by the tower's own weight can be computed by solving a set of rather complicated differential equations. For routine office work, however, it is more convenient to refer to data sheets or graphs which summarize the results relating to suitable skeleton sets of shape parameters. The design of cooling tower shells for the Central Electricity Generating Board is now based entirely on data sheets derived from the method developed at the National Physical Laboratory.

The problem of mathematical ship fairing has been successfully treated; mathematical surfaces are fitted to the detailed measurements of a ship's hull taken from the naval architect's design drawings, and these can be used to simplify the construction of the ship. In addition, improved hull forms have been estimated following a statistical analysis of model tests which has produced an empirical relationship between resistance and suitably chosen geometrical parameters of the hull shape.

The work in Metallurgy Division on high-field superconductors, besides constituting a field of research, is an illustration of the part the National Physical Laboratory can and does play in undertaking from time to time the technical direction of national projects financed by Government.

The technological importance of superconductors has been recognized by the formation of a national Superconductivity Advisory Committee of which Dr. N. P. Allen, superintendent of the Metallurgy Division, is the chairman. This Committee is responsible for co-ordinating the research and development effort throughout the country formerly on behalf of the Department of Scientific and Industrial Research, and now of the Ministry of Technology.

The area in this field in which the Metallurgy Division is itself engaged is concerned with endeavouring to elucidate the relation between the metallurgical properties of superconductors and the ability of certain of these materials to sustain large current-densities in high magnetic fields. To this end, niobium has been selected for investigation since it exhibits the required behaviour in relatively low magnetic fields, thus making the necessary experiments somewhat simpler to perform.

The relation between the deformation of single crystals of niobium and their superconducting properties has previously been investigated in the Division, and this work has now been extended to heavily deformed polycrystalline niobium. Cold-swaged niobium wire has been progressively annealed for fixed periods of time at temperatures of 200° C, 500° C, 700° C, 900° C and 1,100° C, and measurements of magnetization, critical current, and restoration of resistance taken from 4·2° K to 1·5° K after each heat treatment. A peak in the mechanical hardness for the 500° C treatment is matched by peaks in the various critical fields as defined by magnetic and resistance measurements, and it is believed that strain-ageing provides pinning centres which prevent the motion of magnetic flux through the material.

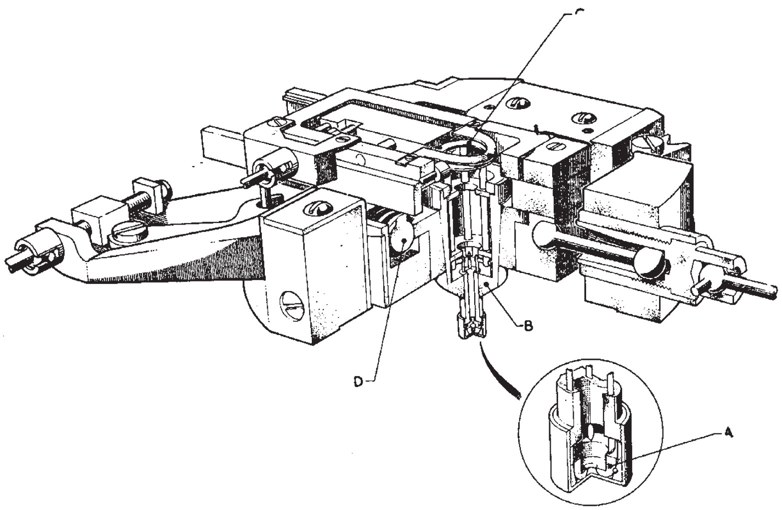

Fig. 3. The goniometer stage, adjustable over a wide range of angles, designed and built in the Laboratory

An additional piece of work involving the examination of the superconducting properties of sintered mixtures of copper and niobium was motivated by the present interest in adding large quantities of copper to superconducting wire to mitigate the effects of 'degradation' and 'flux jumping' when the wire is wound into coils. The properties of the resulting compacts are found to be strongly dependent on the distribution of the niobium particles in the sintered mixture, in addition to its density and composition.

Another interesting item on display in the Division was a goniometer stage adjustable over a wide range of angles, designed and built at the Laboratory for use in the *E.M.*6 electron microscope, together with examples of the much increased information it has been possible to obtain as a result.

When a metal deforms at normal temperature the stress increases continuously with the amount of deformation. This is the phenomenon of work hardening. The enforced change of shape is accommodated by blocks of metal sliding over each other on certain preferred atomic planes (slip planes), a process facilitated by movement along these planes of a particular type of atomic defect known as a dislocation. During deformation the number of dislocations may increase from 5×10^7/cm^2 to more than 1×10^{10}/cm^2, and as they move they interact with each other, tangling together to form an irregular cellular structure (Fig. 2). Moreover, the degree of strengthening produced during deformation is known to be proportional to the square root of the number of dislocations present. It is therefore necessary to obtain as much detail as possible about the dislocation tangles so as to find out which types of dislocation are interacting with each other and why strength should be dependent on their number.

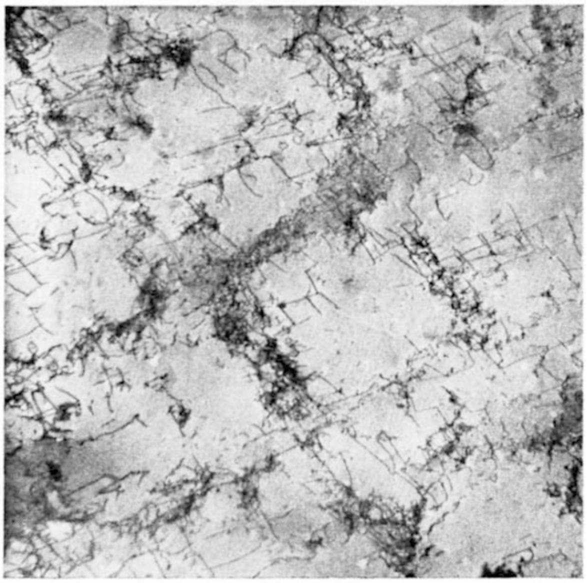

Fig. 2. A tangle of dislocations in iron (× *c.* 10,000)

The technique for distinguishing between the dislocations makes use of a result obtained from electron diffraction theory, that a dislocation produces no contrast, that is, its image can be made to disappear, when electron diffraction conditions are such that the diffracted beam lies normal to the displacement field of the dislocation. This displacement field characterizes the type of dislocation; it is called its Burgers vector, and hence by knowing the diffraction conditions when a dislocation disappears its type can be determined.

Until now a bright field technique has been used in which the specimen is viewed in the usual manner using the directly transmitted beam. Under this condition, however, in order that the disappearance condition shall be unambiguous the diffraction conditions have to be arranged so that apart from the transmitted beam only one other diffracted beam operates. This is normally difficult to achieve.

A considerable improvement has now been made by the use of a high-resolution dark-field technique in which the specimen is viewed using a chosen diffracted beam instead of the transmitted beam. Two beam conditions are no longer essential though it is necessary to be able to tilt the electron beam so that the desired diffraction spot may be brought to the centre of the microscope. This has been achieved by the use of a rotatable beam tilt device. To vary the diffraction conditions it is also necessary to tilt the specimen inside the electron microscope so that it can be made to lie at a variety of angles with respect to the electron beam. Since the commercial specimen tilt device only permitted this within an angular range of $\pm 5°$, the new goniometer was designed (Fig. 3). The specimen which is mounted between special grids, 2·3 mm in diameter, is placed in the hemispherical ball *A* which is tilted by the action of the three small push-rods housed in the cartridge *B*. The movement of the push rods is controlled by the swash plate *C* which is motor driven from outside the microscope. The specimen can also be rotated through 360° in its own plane by action of the worm and wheel *D*, so that, by a combination of rotation and tilt, the specimen can be accurately manipulated to lie in any plane within the angular range of $\pm 30°$ with respect to the electron beam. Some success has already been obtained with this goniometer in determining the

Burgers vectors of dislocations in iron and an iron alloy deformed over a range of temperatures.

At the open days last year, the Basic Physics Division released news of the discovery of a powerfully stimulated emission source in the sub-millimetre region at 0·34 mm wave-length. This year visitors were able to see the progress made in the development of this discovery into a practical laboratory source. The device is a gas discharge maser utilizing a rotational transition in the CN molecular radical, and has been given the name *Teratron* derived from the frequency of the radiation emitted. Discharge tubes only 3 ft. in length give useful amounts of power, and a commercial model with a portable power-pack is now being developed in co-operation with an industrial organization. Although the device is still at an early stage of development it is believed that great value is to be derived from making a powerful sub-millimetre source commercially available as soon as possible. At the Laboratory, the *Teratron* has already been used to measure errors in the lead screw of a lathe, and for dielectric measurements. The source promises also to be of value in teaching institutions because the wave-length is particularly suitable for demonstrating interference and diffraction phenomena.

A new field of research—Non-linear Optics—has recently been opened up in Basic Physics Division, and one of the items on display showed the results so far. The basic objective is to devise a modulator which will mix together optical and microwave signals in such a way that the output is a monochromatic signal the frequency of which equals the sum of the frequencies of the two incident waves. This follows work at low frequencies by Buhrer, Baird and Conwell[1]. Present experiments are aimed at producing an efficient mixer in which the microwave energy is used to the best advantage. The system uses a tunable resonant cavity in which a circularly polarized 10 Gc/s microwave field is set up, and it is expected to obtain complete frequency conversion with a microwave input of 10 W or less.

The High Temperature Group in Basic Physics Division is concerned with the behaviour of elements and compounds at elevated temperatures. Species, different in composition from those which exist at normal temperatures, often exist under these conditions and may be condensed to form new materials at normal temperatures. Gaseous reactants may be heated to 5,000°–20,000° K in the familiar d.c. discharge and radio frequency induction plasma torches which were exhibited. The RF plasma torch was used to demonstrate the oxidation of a mixture of metal halide vapours in oxygen plasma to form mixed oxides of small particle size and controlled stoichiometry. These devices are unsuitable, however, for reactions in which solid feed-materials must be used since heat transfer from plasma generated in these ways is generally only sufficient to melt the particles.

A rotating plasma furnace was also exhibited in which the plasma of a d.c. arc column is expanded by tangential bombardment from cool gas molecules to occupy a volume of approximately 2·5 l. Solid feed materials may be vaporized in this device. Although arc expansion by this principle has been demonstrated before with low-current ($\sim$10 amp) discharges, the device exhibited is the first to include an electrode configuration by which high-current ($\sim$400 amp) expanded discharges may be stabilized at atmospheric pressure for long periods of time. The power ($\sim$20 kW) dissipated in this device and the residence time of particles fed into the plasma are great enough to enable solid feed materials to be vaporized completely. It is intended to use this furnace in fundamental studies of vaporization in plasmas and for a variety of chemical syntheses which involve high-temperature species.

H. A. SLOMAN

[1] Buhrer, C. F., Baird, D., and Conwell, E. M., *App. Phys. Letters*, 1, 46 (1962).

OBITUARIES

Prof. Wilson Smith, F.R.S.

PROF. WILSON SMITH, emeritus professor of bacteriology in the University of London, died on July 10 at the age of sixty-eight. Wilson Smith's life-work in bacteriology may be considered as in three succeeding phases. His reputation was built on his early research, when he was a full-time worker under the Medical Research Council. Later, though by no means giving up his own investigations, he became an excellent teacher; and he finally devoted more and more time, as an elder statesman, to help in guiding scientific policy.

He was born on June 21, 1897, in Great Harwood, Lancashire, and always remained something of a Lancashire man. He went to school there at Accrington Grammar School and served with the 107th Field Ambulance during the First World War from 1915 until 1919. He then entered as a medical student at the University of Manchester, qualifying in 1923.

After a short while in general practice, he felt the call of bacteriology and took the course for the diploma in bacteriology at Manchester under Prof. Topley. He not only obtained the diploma but also married one of Topley's young demonstrators. He then came to London, joining the staff at the National Institute for Medical Research, then at Hampstead.

Those were days when filter-passing viruses, as we then called them, were first becoming a subject of serious study. Wilson Smith took part in the exciting developments in this field, working at first under S. R. Douglas on vaccinia virus. Then, in 1933, came his most important contribution to knowledge. He and I were making an all-out endeavour to find a virus in influenza: even as we planned, I fell sick with the disease and Smith carried on, inoculating my filtered throat washings into various laboratory animals. Guinea-pigs, rabbits and mice were injected, mostly intramuscularly or subcutaneously; and nothing happened. Then came the turn of ferrets, available because of their use by Laidlaw and Dunkin in current work on distemper. Somehow inspired, he this time put some of the washings up the ferrets' noses and two days later one developed nasal discharge and sneezing. This first step led on to an immense amount of work on the 'flu virus and subsequent developments kept him interested for the rest of his life. Discovery of the susceptibility of ferrets to 'flu entailed the building of a 'ferret hospital' with 32 isolation units at Mill Hill. Laidlaw, Smith and I made daily clinical rounds of our ferret 'patients' every morning for some years, working in the laboratory at Mill Hill in the morning and returning to the Institute at Hampstead for other work in the afternoons. It was duly revealed that mice as well as ferrets could be infected, that neutralizing and complement-fixing antibodies developed in the sera of both man and ferret, that our virus was related to that of Shope's swine influenza virus and that a formalin-inactivated vaccine could be used to immunize. All this came out of the team-work: particular contributions made by Wilson Smith himself were to show that the virus would grow in fertile hens' eggs and in tissue culture.

In 1939 Wilson Smith left Mill Hill to fill the chair of bacteriology in the University of Sheffield. With the outbreak of the Second World War it was a difficult time to begin a new kind of life. Besides his teaching duties, he was put in charge of local public-health bacteriology