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15 August 1954

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CLARENDON LABORATORY OPEN DAY

Recently the Clarendon Laboratory at Oxford, which is under the overall direction of Lord Cherwell, held an "open day", an event which occurs about once every five years. It included the exhibition of research apparatus currently in use and also demonstrations both technical and popular. The principal fields of investigation at the Clarendon Laboratory include nuclear physics, low temperature physics, radiofrequency and optical spectroscopy, and ionization phenomena in gases. There is also a group in theoretical physics.

The research underway in the field of low temperature physics includes the investigation of the properties of liquid helium including the so-called "creeping" film, investigation of electrical and heat conductivities at very low temperatures and also the mechanical properties and anomalous specific heats. The time effects occurring in the interaction between the electron spin system and the lattice of paramagnetic salts used in the magnetocaloric method of cooling are also being investigated. The phenomenon of nuclear paramagnetism is being studied particularly with the nuclear resonance method. One of the most recent lines of investigation at the Clarendon Laboratory is the nuclear alignment of radioactive nuclei at very low temperatures. The radiations from these aligned nuclei are investigated both in the simple angular distribution of say the gamma radiation with respect to the direction of alignment and also the effect of nuclear alignment on the angular correlation between successive radiations. The polarization of the emitted gamma radiation as a function of the angle with respect to the direction of alignment of the nuclei in the magnetic field is also being investigated at very low temperatures. The low temperature group is also engaged in the development of the process by which the magnetism of the

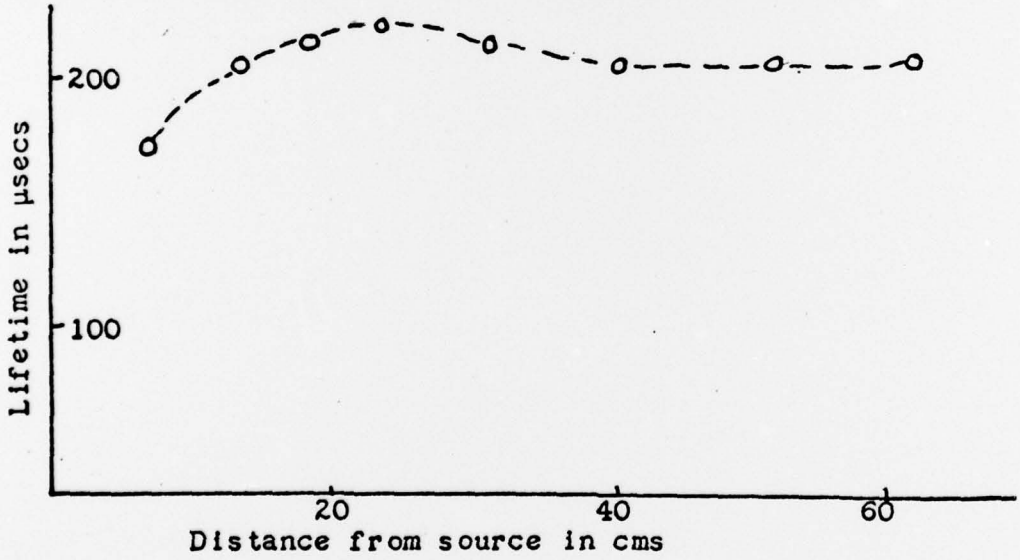
nuclei will be employed in the magnetocaloric effect to reach temperatures in the region of 0.0001°K. Magnetic fields of the order of 100,000 gauss are necessary and the power for these fields is supplied by a 2000 kw dc generator.

In the nuclear physics section the 125 Mev synchrotron was on display. This accelerator has been in reliable operation for about six months. It was constructed by the English Electric Company but was brought into operation by research workers at the Clarendon including Dr. J. Moffatt. The synchrotron operates on a power supply frequency of 50 cycles and employs a condenser bank for energy storage. The maximum magnetic field produced by the 16 ton electromagnet is 10,000 gauss and the equilibrium orbit has a radius of about 42 cm. The present yield of this accelerator is expressed in terms of the number of quanta of 125 Mev energy each that would have a total energy equal to that observed in the gamma ray beam. This number is 10^7 equivalent quanta per cm^2 per sec at a distance of 1 meter from the internal target of the synchrotron.

The present research program with the synchrotron involves two major problems. The first is the investigation of the photo disintegration of the deuteron in the range of 50 - 125 Mev. The angular distribution of the photo protons is being investigated as well as the excitation function for the reaction. The second proposed line of investigation is the measurement of the absorption of 125 Mev x rays in matter. The collimated x-ray beam is detected by a long liquid scintillator biased in such a way that it detects only events corresponding to pair production by gamma rays close to the full energy of 125 Mev. The most important part of this investigation will be the measurements of the absorption in a tube filled with liquid hydrogen of length 14 ft and $2\frac{1}{2}$ in diameter. It is hoped by these measurements to be able to obtain a value for the cross section for pair formation by 125 Mev gamma rays in the field of the electron since this should be an important part of the absorption in liquid hydrogen as contrasted with the absorption in other materials.

There are two Cockcroft-Walton cascade generators at the Clarendon Laboratory; one having an energy of 1 Mev and the other an energy of 0.5 Mev. Both of these accelerators have been converted to the use of selenium rectifiers

which apparently have so far proved to be quite trouble-free in operation. One experiment which is being done with the smaller accelerator is the measurement of the mean lifetime of thermal neutrons in water. This is being done by Drs. Collie, Meads, and England. The radiofrequency ion source of the cascade generator is pulsed every 1600μsec for a period of 100μsec. The modulated beam of deuterons obtained strikes a target of heavy ice producing a pulse of neutrons. This heavy ice target is situated below the surface of the water in a tank 8 ft x 4 ft x 4 ft so that the neutrons are slowed to thermal energies, diffused, and are finally captured by the protons in the water. The deuteron current during the pulse is 1 ma. Experiments similar to this have been done in Sweden and the United States, except that in this case the capture of the neutrons is actually detected through the subsequent emission of the 2.2 Mev gamma ray. This gamma ray is detected in a liquid scintillator at the end of a bent lucite rod which conducts the light pulse to a photomultiplier. The advantage of this method is that the liquid scintillator and lucite have neutron properties similar to the water so that they disturb the geometry to a negligible extent. The preliminary data obtained by these investigators takes the form of the following curve where the neutron lifetime is plotted as a function of the distance of the scintillation detector from the source of neutrons.



The data indicate a final flattening out of the lifetime as was to be hoped. These data will require corrections of a few per cent for such things as the presence of the heavy

ice target. It is hoped that the final results will be accurate to 1 per cent. From this result it will then be possible to obtain a more accurate value for the thermal neutron-proton capture cross section.

FREEZING OF WATER

Dr. A. W. Brewer and Mr. Houghton at the Clarendon Laboratory, Oxford, are studying the freezing of very pure water. An ingenious and simple technique is employed to produce the water in a capillary tube without impurity nuclei. Ordinary distilled water is boiled in a flask and the steam passed downward through a small clean glass tube. After a thorough flushing by the condensed vapor, the tube is quickly drawn to capillary size with a glass blower's torch and the bottom sealed off. In a few seconds enough water has condensed in the tube so that a section can be cut off by the torch producing a sealed capillary containing some water. Tubes from 0.1 to 0.5 mm internal diameter have been made up to 20 or 25 mm in length. Freezing is observed under a low power microscope.

Preliminary results indicate that the temperature at which the water freezes decreases as the equivalent spherical diameter of the cylindrical droplet decreases. Temperatures as low as -33°C have been reached. Each sample is frozen a number of times, with no systematic trend in the temperatures, and the average temperature is found to correlate fairly well with the equivalent diameter. Also the results seem independent of the rate of cooling as the freezing point is approached, within rates corresponding to temperature decreases of 0.5 to 0.05 degrees per minute. Further, the results are independent of capillary diameter within the limits indicated. Thus the experimenters believe that they are dealing with freezing initiated by statistical fluctuations in temperature rather than by foreign body nucleation, which appears to have been the dominant factor in most previous work. Apparently the technique of drawing the tube produces exceptionally clean glass surfaces, and the almost simultaneous sealing of fresh condensate within the tube insures a minimum of contamination.

SYMPOSIUM ON CREEP AND FRACTURE OF METALS AT HIGH TEMPERATURES

A Symposium on Creep and Fracture of Metals at High Temperatures was held at the National Physical Laboratory,

Teddington, on 31 May - 2 June. The participants, totaling about 150, came from Great Britain, most of the countries of Western Europe, the United States, and Soviet Russia. Half of the program was devoted to deformation processes in creep and the balance was concerned with tertiary creep and fracture. The papers presented along with their discussion are to be published by H. M. Stationery Office. A summary of some of the more interesting work discussed is given in Technical Report ONRL-52-54. Two of the significant contributions are reviewed in the following.

Interaction Between Crystal Slip and Grain Boundary Sliding During Creep

Mr. D. McLean (N.P.L.) has studied the deformation within the grains, the sliding at grain boundaries, and the interaction between these two factors. The creep experiments were conducted on 99.99% purity Al at temperatures in the range of 200° - 400°C. From theoretical considerations and the mechanism of crystal fragmentation, a relation was derived for the elongation due to crystal slip as a function of the angle of disorientation (θ) of the subgrains formed: $E^{\circ}/o_{slip} \cong 100\,\theta$. From optically measured values of θ, values of E°/o_{slip} were calculated. The amount of crystal deformation was determined separately by subtracting from the total elongation (E°/o total) that which was due to grain boundary sliding (E°/o_{gb}). The ratio

$$\frac{E^{\circ}/o \text{ total} - E^{\circ}/o_{gb}}{E^{\circ}/o_{slip}}$$

was shown to approximate unity proving that crystal deformation is due to slip.

Direct measurements of grain boundary sliding were made by observing the relative movements of markers astride grain boundaries. Results show that sliding occurs during the entire creep process from beginning to end although there are considerable differences in individual boundaries. Using average values, however, gives a linear plot of grain boundary displacement against total elongation, showing that the fractional contribution to extension made by boundary sliding is a constant throughout a given test. The linear relation holds over a wide range of conditions including a variation in grain size of 10:1, of about 3:1 in stress, and temperatures from 200° - 400°C.

This linear relation is due to an interaction between deformation of the grains and sliding at the grain boundaries. In support of the hypothesis (for the low temperatures involved) that the grain boundary sliding occurs to the extent necessary to accommodate the lattice bending during polygonization, McLean showed experimental agreement with the predicted relationship:

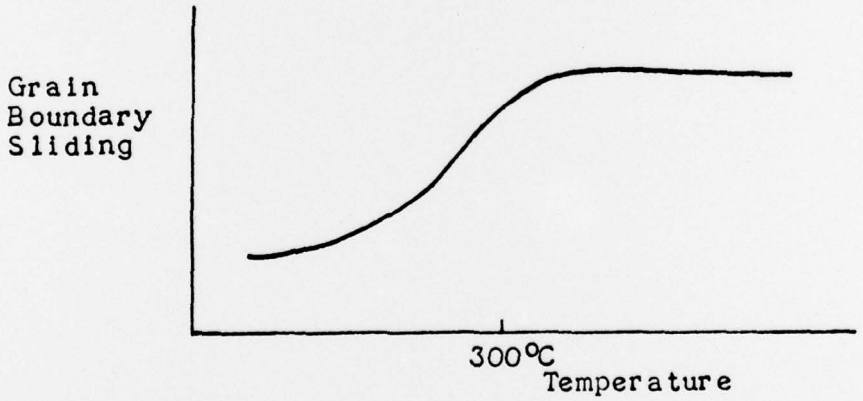
$$\frac{p}{E^{o}/_{o_{slip}}} = d$$

where p = the amount of grain boundary sliding

$E^{o}/_{o_{slip}}$ = elongation due to crystal slip

d = sub-grain diameter

Thus grain boundary sliding is the rate determining factor at low temperatures. But McLean believes that at high temperatures the grain boundaries slide readily and the process which controls the rate of creep is the deformation which occurs in the grains to accommodate this sliding. This argument was substantiated by experimental evidence for the creep of Al as shown in the following figure.



Above 300°C the grain boundary sliding is held to a constant value by virtue of the fact that it is limited by the accommodating deformation in the grains.

Creep and Aging Effects in Solid Solutions

Prof. A. H. Cottrell (Birmingham) presented an extremely interesting paper in which he applied some of

the theoretical concepts which he and others have recently developed to the problem of creep. He first distinguished between two kinds of recovery, both of which of course decrease the creep resistance:

1. High temperature recovery. This occurs at temperatures where self-diffusion is rapid, dislocations climb out of their slip planes and the density of vacancies is increased by creep itself.

2. Low temperature recovery. This can occur at lower temperatures if the metal is undergoing plastic flow. Some recent experiments on the stress-strain curves for aluminum single crystals at liquid air temperature followed by tensile test at 0°C showed a pronounced recovery effect. A marked recovery was obtained at 0°C (with stress applied) and to produce the same amount of recovery by annealing alone required warming to 100°C for 100 minutes. Thus Cottrell believes there is a low temperature recovery process which is due to the movement of dislocations through a forest of dislocations by the combined action of stress and thermal fluctuations.

The basic means of improving the creep strength is to inhibit the recovery process. Strain-age-hardening strongly inhibits recovery, as shown by the experiments of Dumbleton who observed a cessation of extension due to the strain-aging during creep of zinc containing nitrogen, the work of Fisher and McGregor on strain-aging carbon and nitrogen in iron, and also Dorn's research on solute atoms in aluminum.

There is a limit to how far a material can be strengthened by the strain-aging effect (i.e. solute atoms anchoring dislocations) and this limit is the point at which high temperature recovery sets in. Thus, the next problem in improving creep strength is to inhibit high temperature recovery. For this purpose it appears that precipitated particles are extremely effective inasmuch as they prevent the climb of dislocations. Further, from the work of Glen it is known that the precipitation of carbides during creep is better than the same material in which the carbide precipitated is formed before creep. Thus it appears advantageous to have two precipitates in an alloy in order to obtain a material with good strength throughout the creep history, the first precipitate to give high strength initially and the second to form during the creep process itself.

USE OF INTERFERENCE MICROSCOPES IN BIOLOGICAL RESEARCH

Interference microscopes are coming into increasing use in England. These microscopes, like phase-contrast microscopes, depend on phase changes produced by the specimen. However, in the interference microscope, the mutually interfering beams are generated by an interferometer system which is built into the microscope rather than by the specimen. Therefore, images are relatively free of halo effects and areas having only small phase gradients exhibit contrast.

One of the advantages of the interference microscope to biologists arises from the fact that if either the refractive index or thickness of an area be known the other can be calculated from the formula

$$\mu_o = \frac{\theta\lambda}{360t} + \mu_m$$

where μ_o is the refractive index of the object, θ is the phase difference in degrees, λ is the wave length of light in the same units as the thickness t, and μ_m is the refractive index of a reference medium (usually the surrounding immersion medium).

Another and perhaps greater advantage of the interference microscope is that it permits "weighing" microscopic amounts of material in intact cells or during histochemical procedures, (c.f. Nature 169, 366). Thus the amount of protein in a single cell can be measured, e.g. the average protein content of human erythrocytes was thus measured as 31.4×10^{-12} gm as against macroscopic direct analyses giving $27\text{-}32 \times 10^{-12}$ gm (ibid).

Prof. J. F. Danielli of the Department of Zoology, King's College, London, is applying this method to the measurement of enzymatic activities in cell inclusions as small as one micron in diameter. Using the Gomori method for localization of phosphatase activity the rate of development of pigment can be followed quantitatively.

The general principles of design of interference microscopes were reported in Technical Report ONRL-118-53. The specific details of commercial instruments and a guide to literature on the subject are available in brochures from the makers. Such microscopes are now commercially available from two manufacturers: C. Baker of Holborn, Ltd., 244 High Holborn, London, W.C.1; and Cooke, Troughton and Simms Ltd., Broadway Court, Westminster, London, S.W.1.

EXCITATION AND CONTRACTION OF MUSCLE

Important new findings regarding the processes of excitation and contraction of muscle are being made at University College, London. Two groups are primarily concerned: Prof. A. V. Hill in collaboration with Drs. L. Macpherson and R. Wilkie in the Department of Physiology; and Prof. B. Katz in collaboration with Dr. J. del Castillo in the Department of Biophysics.

del Castillo and Katz, using microelectrodes of the type first used by Ling and Gerard have applied acetyl choline to the exterior and interior of frog sartorius muscle fibers in the region of the motor end plate. The flow of acetyl choline from the pipets is controlled by applying a potential to the pipet so that diffusion of the acetyl choline cation out of the pipet is electrophoretically facilitated or hindered.

When acetyl choline is applied to the exterior of a muscle fiber in the region of an exposed end plate a large end plate potential appears which with large applications exceeds threshold and an action spike develops. When the pipet is inserted into the muscle fiber and acetyl choline liberated into the interior of the end plate it is without effect. These workers conclude that the acetyl choline receptors are located on the external (neural) surface of the end plate membrane.

Hill and Macpherson have been engaged in a study of the effects of various anions on contraction of frog sartorius muscle. Sodium bromide, nitrate, or iodide are substituted for sodium chloride in Ringer's solution. The effect of these anions is to increase (2 - 3 fold) the size or force of the twitch following a single stimulus. The twitch is also prolonged in duration. Prof. Hill feels that the greater force exerted in an isometric contraction (or the greater shortening in an isotonic contraction) is a function of the greater duration of the excited state.

The relative effectiveness of the anions is that to be predicted from the Hofmeister series. Their action appears to be on the outside of the muscle membrane, because the full effect of the ion is apparent in about one minute, whereas the penetration half-time for, say bromide, is of the order of 90 minutes. Also the effect disappears in about one minute when the muscle is returned to normal Ringer's solution, i.e. while the interior of the muscle still contains a high proportion of the unusual anion.

Wilkie is engaged in a study of elevated pressure (up to 600 atm) on the contraction of frog sartorius muscle. At 100 - 200 atm the size and duration of the twitch following a single stimulus are increased. In fact the curves obtained by Wilkie are remarkably similar to those recorded by Hill and Macpherson employing bromide, nitrate, and iodide. Wilkie finds no effect of pressure on the maximum force exerted during tetanic stimulation. Up to 200 atm the effects are instantaneously and completely reversible. Above 200 atm rigor develops and the muscle is irreversibly damaged.

MEETING OF THE ANATOMICAL SOCIETY

At a meeting of the Anatomical Society of Great Britain and Ireland, held at the University of Cambridge early in July, a number of interesting papers were delivered, of which three are summarized below:

Structural Changes Induced by Ischemia in the Kidney of the Rabbit

Dr. R. G. Burwell of the University of Leeds subjected rabbits to temporary renal ischemia by clamping the renal artery for periods of 1½ to 4 hours, and the resulting structural changes were studied after periods of reflow ranging from 6 hours to 4 weeks.

In some animals (31 per cent) structural changes were absent or minimal, but in 62 per cent of animals structural changes were distributed throughout the renal parenchyma and were maximal in the descending segment of the proximal tubule where, after 6 hours reflow, almost complete necrosis had occurred. In some tubules a few cells survived at the junction with the thin segment of Henle's loop. These surviving cells become actively phagocytic, ingest the adjacent necrotic debris and swell so as to occlude the lumen. Their cytoplasm is vacuolated and many of them show numerous hyaline droplets. Histochemical studies have suggested that there may be two distinct morphological manifestations of protein reabsorption by the cells, a conclusion which is in keeping with the findings of other workers.

These findings appear to shed light upon Selye's (Selye and Stone, J. Urol. 56, (1946); Selye, Trans. J. Macy Jr. Foundation, Jan. 8-9, (1948)) interpretation of "the endocrine kidney"; after subjecting rats to chronic partial renal ischemia, he found the development of active cellular

proliferation within the terminal portion of the proximal convolution and concluded that these cells were the source of the renal pressor substance. Burwell is inclined to the view that Selye was in fact describing cells which had undertaken an active phase of protein reabsorption, secondary to some tubular necrosis.

The Effect of Anoxia on the Bone Marrow

Drs. E. H. Batten, W. L. Gall, G. Halley, R. S. Harris, A. F. Rogers and J. M. Yoffey of the University of Bristol have made a quantitative study of the cellular changes in the bone marrow occurring during anoxia. Fifteen control experiments were performed in Berne, and 28 at the Hochalpine Forschungsstation, Jungfraujoch, at a height of just over 13,000 feet. It was found that the marrow responds to the anoxia by producing increased numbers of red cells, but there is a latent period of 3 - 5 days before these are discharged into the blood in sufficient numbers to increase the peripheral red cell count. Pooling the experiments done during the first five days at the Jungfrau and comparing them with the controls, the peripheral blood showed a mean reticulocyte increase from 80,000 to 163,000, the marrow erythroid cells rose from 190,000 to 345,000, and the marrow lymphocytes fell from 213,000 to 107,000. Furthermore, associated with the fall in the number of marrow lymphocytes there were interesting qualitative changes, including what appear to be numerous transitions between small lymphocytes and blast cells.

Observations on Vascular Perfusion and Fixation of the Lungs

Dr. Bernard Towers of the University of Cambridge has devised a perfusion technique which permits direct observations to be made on rat lungs maintained in a condition simulating full physiological expansion. A heart-lung preparation, with a perfusion cannula tied into the pulmonary trunk, is suspended from a tracheal cannula which passes through the lid of an air-tight transparent chamber. A controlled partial vacuum produces a standard degree of pulmonary expansion, and a preliminary saline perfusion is followed by either fixative, colored saline, or some other injection-medium. If either the saline wash-out or the subsequent perfusate is cold, the extent of tissue penetration is very variable. This is readily seen with a colored perfusate, when sometimes discrete patches of color 2 - 3 mm in diameter can be observed on the pleural surface, demarcating the areas of distribution of vessels supplying

secondary pulmonary lobules. Increase of intra-vascular pressure (within physiological limits) does not necessarily affect the extent of the penetration and even after 30 minutes' perfusion there may still be areas left uncolored by the dye. If, however, both the saline wash-out and the subsequent perfusate have been warmed in a water bath, immediate and complete penetration results at pressures less than 10 mm of mercury. The technique provides standard conditions for histological fixation and accurate measurements can therefore be made of various microscopic dimensions in the lungs of experimental animals.

FARADAY SOCIETY DISCUSSIONS IN 1955

Details of the General Discussions to be organized by the Faraday Society during 1955 have recently been announced. As usual, they promise to be of considerable interest to physical chemists, dealing with:

"Microwave and Radiowave Frequency Spectroscopy", Cambridge, 4 - 6 April 1955, and

"The Physical Chemistry of Enzymes", Oxford, 10 - 12 August 1955.

Full details will be available from the Society.

AUTOMATIC CONTROL AND COMPUTING AT THE NATIONAL PHYSICAL LABORATORY

The formation of a new Division for Control Mechanisms and Electronics has been announced at the National Physical Laboratory, Teddington. The field to be covered by the new Division, which has been formed by the amalgamation of two previously existing sections, is the automatic control of industrial, administrative and experimental operations, and the development of techniques and equipment for data processing and computation. Mr. R. H. Tizard of the Metrology Division of N.P.L. has been appointed as head of the new Division.

PERSONAL NEWS ITEMS

The membership of the Atomic Energy Authority, which was created under the recently passed Atomic Energy Authority Act of Great Britain, was recently announced in

Parliament. Chairman of the Authority is Sir Edward Plowden who has been serving as Advisor on Atomic Energy Organization to the Lord President of the Council. Full-time members are Sir Donald Perrott, who has been acting as Deputy Secretary to the Lord President of the Council; Sir John Cockcroft, Director of Harwell; Sir Christopher Hinton, Deputy Controller, the Division of Atomic Energy (Production); and Sir William Penney, who is in charge of work on atomic weapons. In addition, there are three part-time members of the board: Lord Cherwell of the Clarendon Laboratory, Oxford; Sir Luke Fawcett, general secretary of the Amalgamated Union of Building Trade Workers; and Sir Ivan Stedeford, chairman and managing director of Tube Investments, Ltd. It is expected that one additional member will be appointed shortly. The Atomic Energy Authority takes over responsibility for all atomic energy developments in Great Britain, effective the 1st of August.

Sir Frederick Brundrett is shortly to become Chief Scientific Adviser to the Minister of Defense, succeeding Sir John Cockcroft, to whom he is at present Deputy. The appointment is expected to take effect on 1 August (see above).

The Ministry of Supply has announced that Dr. C. H. Johnson, Chief Superintendent of the Explosives Research and Development Establishment, Waltham Abbey, has been appointed to succeed Mr. C. S. Bryant as Director of Materials and Explosives Research and Development, effective 1 July. Mr. Bryant is retiring from the public service on 30 June. Mr. L.T.D. Williams has been appointed to succeed Dr. Johnson as Chief Superintendent of the Explosives Research and Development Establishment.

Prof. J. Proudman of the Department of Oceanography, Liverpool University, is retiring this summer and Dr. K. F. Bowden, now at the National Institute of Oceanography, has been appointed to this Chair.

Prof. R. M. Barrer of Aberdeen has been elected to a Chair of Physical Chemistry at Imperial College of Science and Technology. He is to succeed Prof. H.V.A. Briscoe, who is retiring this summer. In addition, it is planned to appoint a Professor of Inorganic Chemistry at Imperial College. This, together with the previously announced appointments of Prof. A. R. Ubbelohde of Belfast to a Chair of Thermodynamics

and Dr. D. B. Spalding of Cambridge to a Readership in Heat, all form part of the plan to greatly expand and strengthen Imperial College.

Dr. R. S. Nyholm, Associate Professor of Inorganic Chemistry at New South Wales (Australia) University of Technology, has been appointed to a Chair of Chemistry at University College, London. This Chair was held by Prof. S. Sugden until his death several years ago.

Dr. G. Porter of the Physical Chemistry Department in Cambridge will join the British Rayon Research Association at Urmston, near Manchester, at the end of this summer. Dr. Porter plans to spend about 3 weeks in the United States in August and September and hopes to attend the American Chemical Society meetings in New York.

Dr. Charles Kemball of Cambridge University has been appointed to the Chair of Physical and Inorganic Chemistry at The Queen's University of Belfast, in succession to Prof. A. R. Ubbelohde.

Dr. C. Domb (Cambridge) has been appointed to the Chair of Theoretical Physics at King's College, University of London, in succession to Prof. H. C. Longuet-Higgins.

Nuclear Power Chief

The British Electricity Authority has announced the appointment of Mr. J. C. Duckworth, chief engineer of the Ferranti Laboratories, as nuclear power engineer. He will organize and lead a new branch of the chief engineer's department, which will be engaged on the design, construction, and operation of nuclear power stations.

NEW JOURNALS

Two new scientific journals have been announced from the Pergamon Press Ltd., London. The first issue of the Journal of Nuclear Energy will appear about 1 August and will be devoted to papers dealing with scientific, engineering, biological and economic aspects of nuclear energy and its by-products. The editors are J. V. Dunworth (Harwell),

J. Gueron (Paris) and G. Randers (Oslo), and the editorial advisory board includes such outstanding authorities as Sir John Cockcroft, Prof. Sir Francis Simon and P. Scherrer.

The Journal of Inorganic and Nuclear Chemistry will be edited by J. J. Katz (Argonne National Laboratory), H.A.C. McKay (Harwell) and others. It is planned to publish its first number towards the end of this year.

TECHNICAL REPORTS OF ONRL

The following reports have been forwarded to ONR, Washington. Copies may be obtained by addressing requests to the Commanding Officer, Office of Naval Research Branch Office, Navy No. 100, c/o Fleet Post Office, New York, N.Y.

ONRL-35-54 "Colloquium on Linear Equations" by W. D. Hayes

ONRL-46-54 "Meeting on High Temperature Chemistry" by G. J. Szasz

ONRL-47-54 "Colloquium on Fatigue of Metals" by E. Epremian

ONRL-48-54 "Laboratoires de Gif-Sur-Yvette" by T. K. Ruebush

ONRL-49-54 "Zoological Research at the Universities of Freiburg and Munich" by W. D. Neff

ONRL-51-54 "Tropical Medicine and Parasitology in France" by T. K. Ruebush

ONRL-52-54 "Symposium on Creep and Fracture of Metals at High Temperatures" by E. Epremian

ONRL-53-54 "Silwood Park Field Station of the Imperial College of Science and Technology" by T. K. Ruebush

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