METALLURGY DIVISION

OPEN DAY

17 JULY 1965

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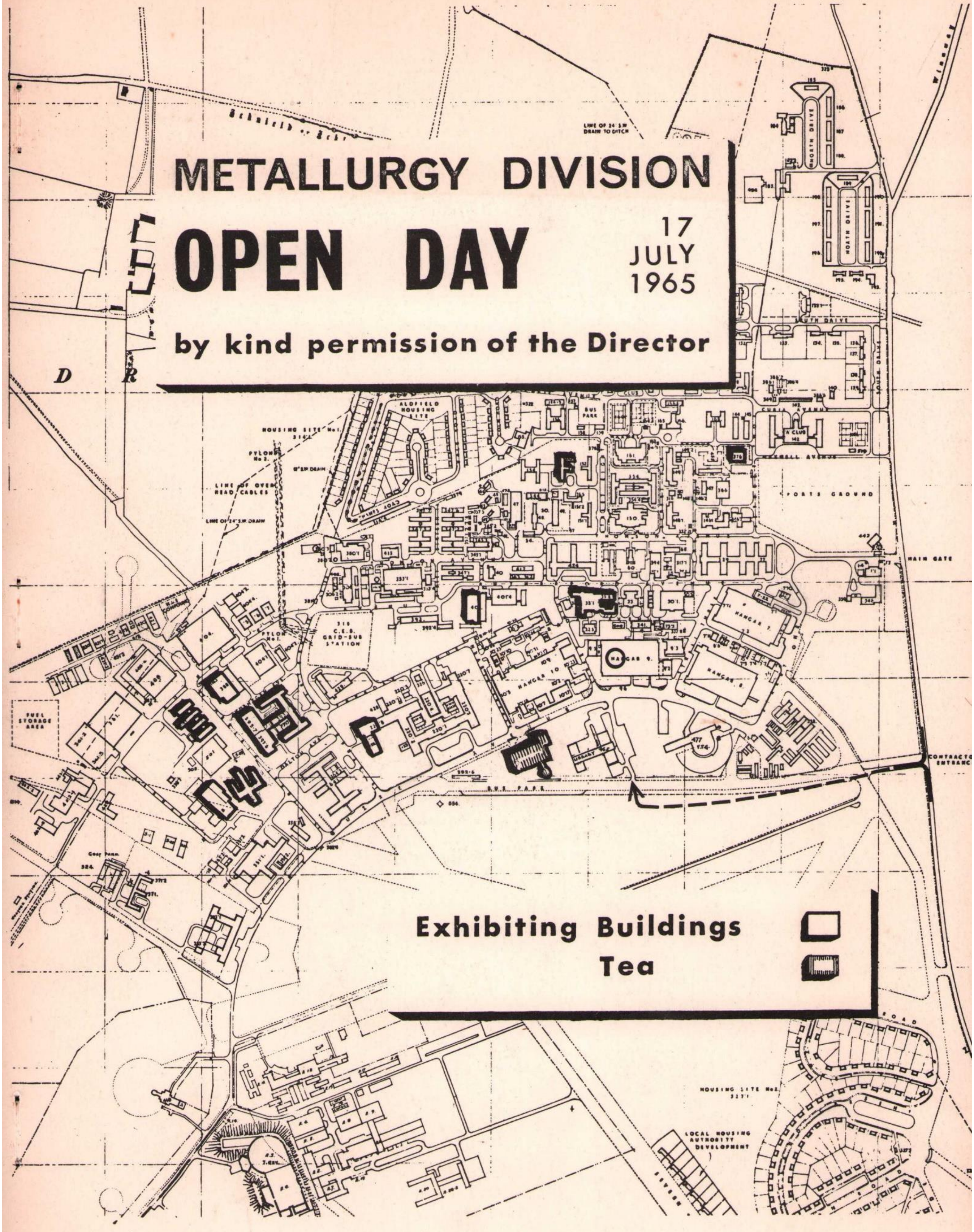

Exhibiting Buildings

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Head of Technical Secretariat	:	Dr. J. Thewlis
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The Staff of Metallurgy Division and I welcome you to an Open Day. We have not set out to impress you by elaborate preparation, for we feel sure that you would prefer to see us as you would on any normal working day. Such preparation as has been made is to ensure your safety, and to that end I ask you to keep out of roped off areas and not to handle specimens or equipment without approval.

The whole of the Division is open for your inspection except those areas into which it is impracticable to take visitors without protective clothing.

A continuous programme of films of the highlights of progress in Atomic Energy research, including a film of the Metallurgy Division will be shown from 2.30 p.m. until 4.00 p.m. in the Cockcroft Hall, and by the kind permission of the Head of Research Reactors Division you are invited to view BEPO (Air cooled, graphite moderated reactor) in Hangar 10, in which some of our irradiation testing is carried out.

My Staff and I hope you enjoy your visit, and that the weather will be kind to us.

Yours sincerely,

P. Murray

The Metallurgy Division

The name of this Division is to some extent a misnomer, for non-metallic and ceramic materials are investigated as well as metals. Indeed the function of the Metallurgy Division is to carry out objective and basic research on all of the materials of nuclear energy.

The research is concerned with the development of new materials as well as with the investigation of critical problems and determining the limits of behaviour of existing materials. One important feature in the programme is to forecast the trends in materials research in the nuclear energy field in advance of the needs of the Authority and the nuclear industry so that, when large scale development programmes are eventually started in the other organisations, we can be sure that we have played our vital role in seeing that the information is available on which reasonable scientific and technical judgments can be made. At the same time we have consistently maintained that the optimum method of making progress is via a combination of basic and applied research and this is particularly the case with the problems involved with materials. We therefore treat the definition of reactor materials in a liberal sense and, provided that the objectives are clearly seen and defined, an integration can be achieved which is a valuable feature of this dual approach. The investigations therefore cover the whole range from pure science to technology and make use of a wide range of the methods of physical and chemical science, so that the Division has need of physicists and chemists as well as metallurgists.

The materials of primary interest in nuclear energy are the fissile and fertile elements uranium, plutonium and thorium. Solid materials used as moderators include graphite and beryllia; magnesium, zirconium, niobium and special stainless steels are used to sheathe fissile material in fuel elements; boron, cadmium and to a lesser extent the rare earth metals, are important as control materials. In the past the Metallurgy Division has been interested in materials mainly as metals and has concerned itself with extraction and fabrication processes including advanced powder-metallurgical methods; the complex physical metallurgy of uranium and plutonium, with their several allotropic modifications, has also been investigated in detail. Present interest, however, is becoming concentrated on ceramic and cermet forms of the fuel materials because these are required for the higher temperatures of operation that will be used in future reactors. Owing to the transition from the alpha to the beta phase at 660 degrees C, uranium metal cannot be operated at temperatures much over 600 degrees C with surface temperatures of about

450 degrees C, whereas maximum temperatures in the uranium dioxide fuel up to 1600°C (can surface temperatures of 700 degrees C) are expected in advanced gas-cooled reactors and still higher temperatures in other systems.

But perhaps the most important characteristic of a nuclear fuel is its behaviour under irradiation. Fission results in the movement within the fuel of highly-energetic fission-product atoms; in natural uranium metal each fission causes about 25,000 atoms to be displaced by knock-on collisions, so that every atom in a bar of uranium is knocked out of place a few times in a year under irradiation in a reactor like BEPO. Furthermore, the fission products are chemically different and about 10 per cent of the new atoms are the rare gases krypton and xenon. Three broad effects therefore arise from fission: interstitial atoms and vacancies are formed; thermal spikes about 10^4 atoms long and of about 100 atoms radius are formed in which the material is melted; and inert gas atoms agglomerate into bubbles. The result in metals is gross distortion of various kinds, the relative importance of the different kinds depending on the temperature of irradiation.

Investigations over a number of years have resulted in a general understanding of radiation damage in fuel metals and its causes but much more work is needed before all the details, especially of the mechanisms by which the processes are initiated, are elucidated; recent work on the mechanism of swelling however marks a notable advance. Some extremely valuable basic work in this field is being carried out with non-fissile metals, radiation damage being produced by various means, including bombardment by heavy ions and by fission fragments from uranium. In experiments on extremely thin films of irradiated copper, dislocation loops are observed, under the electron microscope, having a diameter of about 10^{-6} cm, together with clusters of vacant atomic positions about a quarter of the size of the dislocation loops. Dislocation loops have subsequently been observed in thin films of uranium, of such types and so arranged as to suggest that they are responsible for radiation growth. In another set of experiments crystals have been bombarded with inert gas ions, having energies in the range 10-100 keV, and atomic collision cascades have been produced. The momentum distribution in these cascades has been deduced and evidence obtained of momentum focussing in sequences of collisions along close-packed directions.

The fact that certain effects of radiation damage are more marked, especially at high temperatures, in metal fuels than in ceramics is a major reason for interest in the latter. The first ceramic to engage attention was uranium dioxide, which is to be used in advanced gas-cooled reactors and in water-moderated reactors. A drawback to this material is that its thermal conductivity is low compared with metal; among other effects this fact leads to steep temperature gradients in fuel under irradiation and growth of oxide grains which may, in its turn, cause a higher fraction of fission-product gases to be released. These structural changes are being studied in irradiated and unirradiated material using novel experimental techniques.

An alternative ceramic is uranium carbide, which has the advantage of high thermal conductivity combined with high density of fissile atoms and high melting point; resistance to irradiation at high temperatures is also good. Research on this material is concerned with fabrication methods, by powder metallurgy, as well as with thermal and irradiation properties. Methods are also being studied for bonding carbide fuel and stainless steel, based on the use of metals that wet the carbide. Related research is being done on dispersions of uranium carbides in graphite, a type of fuel that is of interest for high-temperature gas-cooled reactors. Phase relationships in the fissile-carbide/graphite system are found to be more complex than expected and are under further investigation.

The brittleness of ceramics would be a drawback if they were used as fuel-element cans or structural materials and consequently a study is being made of the basic reasons for brittleness in these materials. In the initial work single crystals of magnesium dioxide are used and high ductility in this normally brittle material has been produced by removing microcracks by chemically polishing the surface. The role of microcracks, and of slip and the movement of dislocations in causing these microcracks to grow, is being studied at present.

Another considerable part of the metallurgy programme is concerned with the utilisation of plutonium. This is important because of the economic significance of the plutonium that will be produced as a by-product in large nuclear power stations. Current work is directed to plutonium ceramics. It includes methods of fabricating plutonium oxides and carbides and mixed oxides of plutonium and uranium. A major effort is devoted to investigating the behaviour under irradiation of these fuels.

Other work in the Division is concerned with the irradiation behaviour of steels and of control materials, the fabrication of materials for use in experiments on direct conversion of heat to electricity, and the properties of materials used in vessels in plasma physics experiments. The Division is also developing advanced methods of inspection for stainless steel based on ultrasonic interferometry, and has a programme of development work on non-destructive testing. It is equipped with the most modern apparatus, including powerful electron microscopes, the latest equipment for X-ray diffraction and X-ray fluorescence analysis, micro-beam analysers, electron-spin-resonance equipment, advanced neutron diffraction equipment, an ion accelerator, remote-handling facilities for the examination of radio-active materials at high levels of activity, apparatus for the accurate measurement of physical and mechanical properties, and modern equipment for testing materials in a variety of ways.

Building 393 (Divisional Headquarters)
Street Thirteen

Ground Floor

Centre: Basic Ceramics Group - Dr. F. J. P. Clarke

Ceramics are, in general, brittle materials; they possess poor resistance to thermal and mechanical shock and this limits their usefulness in many engineering and commercial applications. The basic Ceramics Group is doing long-term basic research into the causes of brittleness and into the factors affecting the strength and touchness of ceramics. Because of their ability to withstand high temperatures, ceramics are coming into increasing use in power producing nuclear reactors and the Basic Ceramics Group is also studying the damage produced by irradiation in such materials and its effect on their properties.

An understanding of the properties of most solid materials involves detailed studies, right down to an atomic scale, of the various flows or defects that can occur in the aggregates of tiny crystals of which such materials are composed. Defects in crystals can range in size from cracks visible to the naked eye down to individual atoms displaced from their normal positions in the regular crystals structure. A considerable part of the work of the Group is at present concerned with defects in magnesium oxide, beryllium oxide, aluminium oxide and graphite, although other materials are also under investigation.

<u>The Exhibits</u>

These include:-

1. Examples of single crystals of magnesium oxide produced by melting MgO powder (melting point 2,800°C), some with added impurities.

2. Optical and electron photo micrographs of defects in crystals including dislocations, defect clusters, impurity precipitates, and dislocation loops produced by neutron irradiation.

3. Apparatus for carrying out mechanical tests on materials and for optical and microwave spectroscopy.

4. Apparatus for sectioning and shaping hard ceramic materials into complex test shapes. Large, paper thin sections of concrete for microscopical examination will be on display together with machined rods of sapphire and ruby.

Electron Probe Microanalyser - D.M. Poole

This instrument can identify, in a non-destructive manner, the elements present in a volume of material approximately .002" (5 microns) across and determine their concentration with an accuracy comparable to that of conventional techniques requiring a much larger sample.

A finely focussed probe of electrons is directed onto the sample and the X-rays generated, which are characteristic of the elements present, are identified using one of two spectrometers; the intensities of these characteristic X-rays can then be related to the concentration of the particular element in the tiny volume under the probe. By moving the sample under the probe the distribution of selected elements in the sample can be studied.

Glassblowing - Mr. L. Birtwistle

Left: Carbides - Mr. H.J. Hedger

See Plutonium Ceramics Group. (Page 19)

Uranium Ceramics Group - Dr. D.T. Livey

Basic and applied research on high melting point ceramic components is carried out.

(a) to develop the understanding of the behaviour of powders used for fabrication purposes;

(b) to develop the fabrication technology of specific materials;

(c) to develop the basic understanding of certain phenomena related to high temperature behaviour - surface diffusion, creep, movement of gases, phase equilibria;

(d) to study gas release from irradiated non-fissile ceramics;

(e) the oxidation behaviour of UO_2.

Room G.11 - K.T. Scott, K.T. Harrison, C. Padget

Studies are in progress of the oxidation behaviour of irradiated uranium dioxide. The experimental technique employed is that of thermogravimetric analysis (TGA). An automatic electromicrobalance has been adapted so that active specimens can be loaded and unloaded remotely and also be heated according to a predetermined programme. The balance system can be evacuated or filled with various pressures of purified argon, oxygen, nitrogen or hydrogen. The changes in weight and temperature are displayed on a 2 pen recorder.

Room G.10 - K.T. Scott, L.L. Wassell

The diffusional release of tritium gas from irradiated beryllia on post-irradiation annealing is being examined. Specimens are heated in a molybdenum wound furnace tube with a flow of purified helium passing through it and carrying any tritium released into a gas ionisation chamber. The output of the electrometer amplifier attached to the counter is automatically displayed on a recorder.

Room G.13 - K.T. Scott, L.L. Wassell

Preliminary studies are being made of the diffusional release of helium from irradiated beryllia on post irradiation annealing. Specimens are placed in a vitreous carbon crucible mounted in a silica cell which is connected to a high vacuum system containing an MS 10 mass spectrometer. Induction heating is employed to raise the temperature and the helium release is measured quantitatively by the mass spectrometer. Temperatures are measured either by thermocouple or irradiation pyrometer.

Right: - Electron Microscopy - Mr. C.K. Jackson

Four electron microscopes in Metallurgy Division enable the structure of materials to be studied almost at atomic dimensions. Magnifications up to 160,000 times can be used, and photographs can be obtained at a quarter of a million times magnification. The full stop at the end of this sentence, when similarly magnified a quarter of a million times, would cover the full area of a football pitch, and a grain of sand on the pitch would then represent the smallest detail of the full stop which could be seen under the electron microscope.

A new electron microscope is due to be installed in July, which will further extend the limit, enabling detail half as small again to be visible at twice the magnification. This, in theory, could enable us to examine large atoms, but other difficulties make this impracticable.

Special treatments of the specimen during electron microscope observation are also possible with all our microscopes enabling us to tilt the specimen to look at it from a different angle, to heat it to red heat, to cool it to liquid nitrogen temperatures etc., thus extending our knowledge of the structure and behaviour of a wide variety of materials.

<u>C.T.R. Materials Section</u> - Mr. R.A. Dugdale

Plasma Materials Interaction - Phenomena such as arc initiation on metals and thermal pulse effects on glasses and ceramics will be demonstrated. In addition the application of the glow discharge to the heating and melting of refractory materials will be shown.

<u>Radiation Damage Processes Group</u> - Dr. M.W. Thompson

The aim is to understand what happens when solid materials are irradiated in a reactor. Many of them change their physical properties, for instance they may become brittle, or swell, or even disintegrate into powder. The underlying reason for these changes is that atoms are knocked out of place in the solid by the impact of nuclear radiation. They often find new places which are not ideal from the solid's point of view, and it is this that effects the external properties.

In many of our studies we use an ion accelerator, rather than a reactor, for producing the atomic particles with which we bombard small samples of solid material. One of our accelerators is on view in Room G.35, Building 393. The ions, which are simply atoms with a positive electric charge, are produced at the right hand end of the apparatus. A high positive voltage is connected to the ion source which accelerates the ions down the glass tube by the force of electrostatic repulsion. The target is in the cubic chamber to the left of the apparatus.

<u>First Floor</u>

Centre: <u>X-Ray Diffraction Section</u> - Mr. T.W. Baker

X-ray diffraction is the most powerful tool there is for investigating the fundamental structure of materials. In the X-ray Section, highly sophisticated apparatus, much of it designed and made at Harwell, enables us to apply diffraction techniques to the solving of basic problems.

For example the high temperature diffractometer enables us to examine specimens at temperatures up to 2500°C, and the precision single crystal automatic recording diffractometer allows us to follow changes in crystal lattice constants with say temperature, or irradiation to better than 1 part in 10 million.

Uranium Physical Metallurgy Section - Mr. B.R. Butcher

The Section is concerned with the properties of Uranium and its alloys before irradiation, for example, a study is made of the way that strength is affected by the internal structure of the metal and how these structures can be affected by heat treatment.

New materials such as mixtures of ceramic and metal, or fibre structures are also being studied.

Front: Damage Structure Group - Dr. M.J. Makin

Irradiation displaces atoms within solids and at ordinary temperatures these displaced atoms usually cluster together to form 'damage' which can be seen in the electron microscope. These clustered defects produce very large changes in the mechanical properties of metals, and one of the main activities of the Group is the study of the relationship between the clusters and the mechanical properties.

In fissile materials inert gas atoms are produced as well as defect clusters, and gas bubbles are formed. The behaviour of these bubbles and their interaction with the clusters is being studied by electron microscopy in uranium and UO_2.

Room 1.03 - The Preparation of Microscope Specimens from Large Crystals

Transmission electron microscopy techniques were initially applied to thin sheets of metal treated in a similar manner to large samples. Recently techniques have been developed for cutting thin sections from large samples and in this way the properties of the sample itself can be studied directly. Spark machining using a moving wire electrode is a suitable technique for cutting sections from large metal specimens. The damage layer introduced by the spark machining is a few hundred microns in thickness but provided the initial section is about a mm in thickness this layer can be removed by acid dissolution. Section cutting by spark machining has so far been applied to copper and aluminium specimens but recently sections from zirconium and uranium carbide rods have been prepared in this way.

The Structure of Irradiated Uranium Dioxide

Radiation damage and fission gas bubbles in uranium dioxide have been studied by transmission electron microscopy. Low dose irradiations at pile temperature produce dislocation loops which are formed from platelets of interstitial atoms. Higher doses produce a second set of loops thought to be formed from vacancies. On annealing material irradiated to doses greater than 2×10^{19} fissions cm^{-3} at temperatures greater than 1100°C for 1 hour, fission gas bubbles are precipitated.

Irradiation Damage in Uranium

The electron microscope has been used to study the two main problems associated with the irradiation behaviour of uranium in atomic reactors. These are growth when uranium metal undergoes large shape changes of the order of 100% without an increase in volume, and swelling, in which uranium metal can undergo an increase in volume of the same order of magnitude.

Growth occurs by the formation or removal of small discs of atoms which are displaced by the irradiating particles. Swelling is mainly caused by either voids growing at the crystal interfaces or by small bubbles ($\sim$ 200 Å) which form within the grains. The swelling is at least partly due to the collection of Xenon and Krypton gases, which are formed by nuclear transmutation within these two kinds of voids.

Left: Aqueous Corrosion Section - Mr. J. Wanklyn

This section studies the corrosion of reactor materials in water and steam at high temperatures and pressures. At present most of the work is concerned with stainless steels and alloys of zirconium, materials used in the steam Generating Heavy Water Reactor. Such metals protect themselves from corrosion by forming a thin layer of oxide on their surfaces and many of the experiments are designed, not merely to measure the amount of corrosion, but also to examine the properties of the layers of oxide - thickness, porosity, permeability, strength etc.

Exhibits

Room 1.51 - General Laboratory

Autoclaves for high pressure corrosion tests, glass apparatus for tests in steam at atmospheric pressure. Preparation of specimens for test by acid pickling and electroplating.

Room 1.47 - Balance and Microscope Room

Weighing of corroded specimens, examination of oxide films under the microscope, interference colours showing their thicknesses.

Room G.03 (Ground Floor)

Pumped autoclave for experiments in circulating water at high pressure. Spectrophotometer for quantitative measurement of oxide thickness, using the colours. Large single crystals of zirconium.

Right: Physical Metallurgy - Dr. D.M. Poole

The interests of the section cover a wide field and currently include:

1. A study of the constitution, metallurgy and properties of high field super-conductors such as Niobium-Titanium and Vanadium-Gallium alloys. These materials can carry enormous currents without resistance and, for example, enable high magnetic fields to be generated without the power dissipation problems of conventional magnets; much research remains to be done to enable the best performance to be obtained from these materials and to increase the extent to which super-conducting devices are used in research and industry.

2. An investigation into the factors controlling the performance of fibre-reinforced materials - initially using a simple model of tungsten wire in a copper matrix, but later to move to a more realistic combination. This class of material has shown very impressive strength properties at temperatures where the matrix would normally be extremely soft, but the exact mechanisms of the strengthening are as yet imperfectly understood; the particular aspect receiving attention at this time is the extent to which the fibre needs to be bonded to the matrix to obtain strengthening.

3. Other activities include the final stages of a study of the spreading of molten metal over solid metal (as in brazing) and an investigation of the surface energy of uranium carbide at elevated temperatures.

The basic equipment provides for alloy preparation, fabrication, heat treatment and metallographic examination; more specialised facilities are available, e.g. high temperature furnaces, and a rig for measuring the performance of superconductors at temperatures in the range 1.5 - 20^{o} above absolute zero; electron-probe microanalysis and electron-microscopy equipment are located elsewhere in the Building (Ground Floor).

Building 393.7 (Leading off centre ground floor wing of 393)

Petrology and Precision Ceramic Machining - Mr. Thorold G. Jones

Photographic Section - Mr. N. Last

A service to Metallurgy Division provided by Photographic Group.

Building 393.6 (at rear of 393)
& Building 388.1 (opposite north door 393.6)
Roentgen Avenue.

Irradiation Services - Mr. N. Hancock

This Group is responsible for arranging and performing all the in-reactor experiments needed by the Division. A wide variety of types of engineering structures (rigs) are required to cope with temperatures from 50°C to 2000°C and in-reactor times from seconds to years. Much effort must be spent on improving standards of reliability, in miniaturisation, and in the continuous improvement of the knowledge of temperature conditions inside rigs and cans. Removal of specimens from the rigs after irradiation is a highly specialised field in which careful and precise scientific work must be performed despite the difficulties imposed by thick radiation shielding.

Exhibits will be:

1. Irradiation rigs and capsules for use in DIDO, PLUTO, BEPO, D.F.R. (Dounreay) and BR.2 (Belgium).
2. Apparatus for determining temperature gradients in sodium filled cans.
3. Laboratory development of fission product gas pressure measurement.
4. Development of highly rated irradiation rig heaters of various types.
5. Helium purification apparatus.
6. Apparatus for determining the thermal conductivity of compacted powder insulants.

7. Laboratory experiments on high temperature heaters.

8. Determination of electrical resistance of ceramic insulants at high temperature.

9. Development of high temperature thermocouples.

10. Compatibility tests using high powered R.F. equipment.

11. Cable stripping by high intensity electrical power dissipation.

Building 393.6 - Post Irradiation Examination Laboratory

After irradiation in the experimental reactors specimens are removed from their rigs and sent to this laboratory so that the effects of irradiation may be determined.

The specimens will be radioactive, toxic and extremely reactive and are, therefore, handled under conditions of complete gas tight containment, inert atmosphere and shielding.

An alpha-gamma cell as used in this laboratory consists of an inner gas tight box of metal or plastic surrounded completely by lead or concrete shielding. The inner box contains an inert atmosphere, usually nitrogen or argon, which is automatically maintained at a pressure below atmospheric, so that any leakage takes place inwards and prevents the escape of radioactive particles.

Operations regularly carried out under these conditions include:

1. All types of machining.
2. Physical measurements i.e. dimensions, weight, density, mechanical properties.
3. Fission gas release studies at temperatures up to 2000°C.
4. Radiography and X-ray diffraction.
5. Heat treatment.
6. Optical Microscopy.
7. Electron Microscopy.

The whole range of lead cell components such as bricks, windows and cell units have been standardised at Harwell so that a cell may be built or modified with the minimum of design effort.

Building 338.4 (south of 388.1)

Street Fifteen

Ceramic Fuel Irradiation Group - Dr. B.R.T. Frost

The activities of this group, which are much wider than the name suggests, are divided between four sections:

The Advanced Fuels Irradiation Section - This Section is concerned with studies of the effects of reactor irradiation on carbide and cermet fuels when taken to high burn-ups. Of particular interest is the location and identification of fission products within these fuels and their effects of fuel properties.

A Basic Studies Section - This section forms a natural link with this more applied work by using the electron microscope to study radiation-induced defects and their effects on mechanical properties in carbides and in refractory metals.

The Direct Conversion and Surface Studies Section - This section has, until recently, been concerned with the materials problems involved in developing a nuclear diode, including high temperature compatibility between ceramic fuels, metals, electrical insulators and cesium vapour. Out of this work there has arisen a more general interest in the physics of surfaces as a result of which field ion microscopes and low energy electron diffraction equipment are being built at present.

The C.T.R. Materials Section - This section was originally set up to support the physics studies being conducted in the Culham Laboratory. The work has extended to a general study of plasma - material interactions and includes thermal shock and arcing phenomena. This work is being carried out in Building 393.

Exhibits

1. Irradiation Studies of Carbide and Cermet Fuels for Fast Reactor Application, including the use of a ruby laser and micro-manipulation techniques - (B. Bradbury).

2. Radiation Damage in Molybdenum and Uranium Carbide. High temperature furnaces ($\sim 2500^{\circ}C$). Thin film electron microscopy. Single crystals by electron beam zone refining. (B. Eyre).

3. Surface Studies. Ultra-high vacuum equipment. Work function studies. High temperature ($>2000^{\circ}C$) compatibility. Cesium vapour corrosion. (J. Adam).

Metal Fuel Irradiation Group - Mr. O.S. Plail

The work of the group can be divided into two main sections, under Mr. J.B. Sayers and Mr. R.G. Bellamy.

Mr. Sayers' section deals with work on high temperature fuel materials for advanced gas cooled reactors, e.g. uranium dioxide, the fuel of the Windscale AGR and uranium/thorium carbide, which in the form of small particles coated with carbon is dispersed in a matrix of graphite and used in the Dragon reactor at Winfrith. The work in this section has concentrated on understanding the mechanism and effects of irradiation damage during the lifetime of the fuel in the reactor, and special techniques have been developed to handle small particles of irradiated fuel of less than $^{1}/100"$ diameter, and to measure the thermal conductivity of fuel material while being irradiated.

The work of Mr. Bellamy's section is concerned with the irradiation effects in metallic uranium, such as is used in BEPO, Calder and C.E.G.B. Magnox type reactors. The work here consists of investigating the mechanisms causing dimensional changes in uranium during irradiation. In addition, work is also being undertaken in conjunction with Mr. Sayers' section on the effects of irradiation at high burn-ups of UO_2, and techniques are being developed for irradiation of very small cylinders of UO_2 $^{3}/100"$ diameter x 1".

In both sections a great deal of use is made of the electron microscope and very thin films of irradiated material are examined to reveal internal features, such as gas bubbles, at magnification up to 20,000.

Exhibits

1. Photograph showing irradiation effects on uranium metal.
2. Illustration of rig used for determining the creep of uranium under irradiation.
3. Photographs showing irradiation effects in UO_2.
4. Photographs showing the irradiation effects in coated particles.
5. Display of coated particles and their incorporation in a Dragon type fuel element.

Liquid Metals - Mr. B.W. Mott

Sodium containing the minimum of impurities can be obtained by distilling the impure metal under high vacuum in the plant shown. The difference in appearance between the impure and distilled materials can be seen from the samples on display. The surface tension of liquid metals of high melting point can be obtained from measurements of the shape of a molten drop formed by electron bombardment on the end of a wire sample. Examples of such drops and some of the difficulties encountered are given.

Building 459 (Behind New Ceramics Building)

Street Fifteen

Testing of Radioactive Materials - Dr. D.R. Harries
Mr. A.B. Ritchie

Equipment for examining and testing materials which are highly radioactive after irradiation in nuclear reactors are housed in a series of lead and concrete cells in Buildings 459.4 and 459.

The lead cells in Building 459.4 have four inch thick walls with eight inch thick leaded glass viewing windows and the equipment is operated remotely within these cells using tongs. Specimens can be transferred from a central storage cell to one of the other cells either by a chain driven conveyor or an air operated 'rabbit' system.

There are two concrete cell lines in Building 459 but only one - The Medium Activity Line - will be on display. This line comprises five cells each approximately 8 ft. wide by 10.5 ft. deep by 12 ft. high. The walls and the roofs of the cells are 4 ft. thick and each cell has a 4 ft. thick window with a 4 ft. by 3 ft. viewing area. The cells are designed to contain sources of up to 1000 Curies. The operations within the cells are performed using remotely controlled equipment such as cranes, power manipulators and master slave manipulators. Specimens may be transferred from the concrete cells in Building 459 to the lead cells in Building 459.4 by means of the air operated 'rabbit' system.

The examination and testing equipment in the lead and concrete cells include the following:

1. Tensile testing machines. These machines are fully automatic and are equipped with electrical furnaces so that tests can be made at temperatures up to 900°C. There is provision on some machines for the tests to be carried out either in vacuum or controlled atmosphere. Tests can be performed at initial strain rates ranging from 10^{-8} to 10^{-3} per second on a 0.835 in. gauge length specimen.

2. High temperature annealing furnaces. These furnaces are platinum wound and can be used for the heat-treatment of specimens at temperatures up to 1350°C in vacuum or a controlled atmosphere.

3. Ultrasonic Drilling Machine. This equipment is used for preparing 2.3 mm. diameter discs from 0.020 in. thick specimens; the discs are subsequently thinned, either chemically or electrolytically, to a thickness of about 2000 Å for examination by transmission in the electron microscope.

4. Polishing and etching equipment for the preparation of specimens for metallographic examination. The specimens are subsequently examined in an optical microscope which is operated remotely within a lead cell.

<u>Gas Corrosion Section</u> - Dr. J.E. Antill

The nuclear power produced at present in the U.K. is generated almost exclusively by reactors cooled by carbon dioxide gas. The coolant may corrode various components of the plant such as ducting moderator and fuel element materials (e.g. mild steel and stainless steels, graphite, uranium and uranium dioxide). Temperatures may be as high as 750°C and satisfactory behaviour has to be obtained with little or no maintenance for periods as long as 20-30 years in some instances. The Gas Corrosion Section studies the basic aspects of the various reactors and assists other Groups of the U.K.A.E.A. in the selection of suitable materials.

<u>Building 153</u>
Off Street Eight

<u>Graphite and Carbon Studies Group</u> - Mr. J.H.W. Simmons

The work in this building is concerned with the behaviour of Graphite in the cause of power reactors. Accelerated tests are conducted in the special materials testing reactors and measurements are made of resulting changes in dimensions and other physical properties at various stages. The work also includes microscopic and electron microscopic studies of the material.

Building 220.22 (Enter by Main Entrance to 220)

Plutonium Metallurgy Group - Dr. M.B. Waldron

Both the work of this Group and that of plutonium ceramics has to take full account of the radioactivity of plutonium and similar elements such as neptunium; all equipment has to be operated in gloveboxes or specially ventilated enclosures.

In this Group the properties and fabrication of metallic materials containing plutonium are studied. For example, in collaboration with Oxford University staff, measurements of physical properties are made at temperatures down to 10^{-272}°C to understand the structure of these actinide elements. On the other hand the fabrication of fuels using plutonium enrichment are developed up to the pilot plant stage in the laboratories.

Plutonium Ceramics Group - Dr. L.E. Russell

The main task of this Group is to develop new ceramic nuclear fuels in which the fissile atoms are plutonium. We are therefore involved in studies of the preparation of compounds usually as powders, of the fabrication of these powders into fuel pellets. In addition we have to determine those physical chemical and thermodynamic properties which are necessary to help us predict and explain the behaviour of these materials when they are used as fuels. Some of the early stages of the preparation and fabrication work and the development of the more elaborate techniques for property measurements are more conveniently performed on the corresponding uranium compounds. These aspects of the Group's work are illustrated by Exhibits in Labs. G.28 and G.05A in Building 393 and by a Main Exhibit in Building 220.

Many of the techniques which have been developed for the manufacture and study of nuclear fuel materials, particularly those where high purity atmospheres are used, are now being successfully applied to a wide variety of other materials such as the refractory metals and refractory carbides. In view of the high melting points of many of these materials we need to keep in the forefront of research into the production of high temperatures. In Lab. G.05 we are showing a new and simple form of high intensity heat source which can operate under less exacting conditions than are required in the operation of electron beam devices.

Building 35

Faraday Avenue

Fuel Element Technology Group - Mr. H. Lloyd

This Group is primarily engaged on the development of fuel elements for advanced nuclear reactors. The metals, ceramics, metallography, welding and canning sections comprise this Group.

The work includes investigations on all aspects of fuel fabrication, development of individual techniques and processes up to pilot plant operations to provide information leading to production plant installations in the Authority. The Group also provides specialist services to all divisions at A.E.R.E. engaged on fundamental studies of metals and ceramics.

Building 401

Rutherford Avenue

Non Destructive Testing - Mr. R.S. Sharpe

The quality of the components in a nuclear reactor has to be carefully controlled and sensitive inspection techniques are required to ensure that the highest standards are maintained.

The Non-Destructive Testing Section devises special methods which are used to examine, for example, the cladding materials which prevent radioactive substances leaking into the reactor coolant. Techniques illustrated show how stainless steel tubes may be checked for freedom from defects, dimensional accuracy and metallurgical structure.

Films showing in the Cockcroft Hall

2.30 p.m.	"Eye for Isotopes"
3. 0 p.m.	"Power from Plutonium"
3.30 p.m.	"Metals of the Nuclear Age"