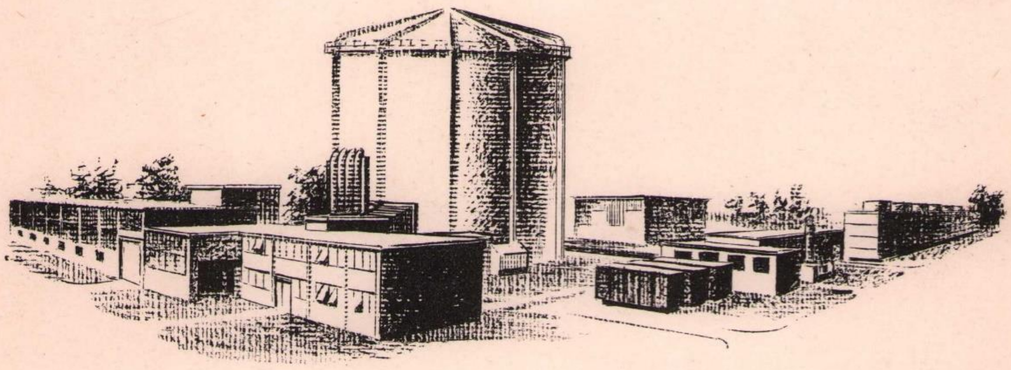
Research Reactors Division

ATOMIC ENERGY RESEARCH ESTABLISHMENT HARWELL

OPEN DAYS



6th & 7th APRIL 1962

GENERAL INFORMATION & GUIDE TO EXHIBITS

THE ATOMIC ENERGY RESEARCH ESTABLISHMENT

HARWELL

DIRECTOR: Dr. F. A. Vick, O.B.E.

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GENERAL INFORMATION

PROGRAMMES	The Open Day Programme must be produced to the Constable on arrival at the gate to the Establishment.
INTERNAL TRANSPORT	Extra buses will be provided between the Main Site and the Reactor Site during the whole of Friday, 6th April.
CARS	Visitors' cars will be allowed inside the Establishment. Visitors are asked to find approved parking spaces when visiting the various buildings. Parking spaces are shown on the plan on the back cover of this Programme.
CLOAKROOMS	Cloakrooms are available in all OPEN buildings.
OPEN BUILDINGS	Only the buildings detailed on the list of exhibits are open to visitors, and no attempt should be made to enter any other building.
RADIATION AND LABORATORY HAZARDS	The normal procedures for the control of radiation and laboratory hazards have been considerably modified for the convenience of visitors. Special precautions have been taken in laboratories and plants so that visitors can enter them with the minimum of restrictions. The few restrictions that are still necessary are indicated by warning notices, and it is essential that these notices should be strictly observed.
SECURITY	The Atomic Energy Research Establishment is a prohibited place and is subject to the conditions of the Official Secrets Act. In their own interest visitors are requested to observe the regulations in force. Visitors may not enter closed areas which are indicated by tapes and warning notices.

D I D O

(D'I'DO: D_2O is the formula of heavy water)

DIDO was the first high-power reactor at Harwell and was brought into operation in November 1956. It is used for making high-activity radioisotopes, for research into the effects of radiation on materials that are to be used to make nuclear power stations, and for a variety of research experiments carried out by other Divisions at Harwell - Chemistry, Metallurgy and Physics.

The core of the reactor consists of 25 2-foot long fuel elements suspended six inches apart each way in a tank containing heavy water. Altogether some 10 tons of heavy water is used, costing £20 per pound; a sample is on display.

Each fuel element consists of 10 plates of uranium alloy encased in a thin layer of aluminium. The uranium is enriched in the U^{235} isotope to be almost pure fissile material. Each fuel element contains 150 grams of uranium, so the total amount in the 25 elements is 3,750 grams (about 8 pounds). The fuel plates are arranged in such a way that a 2 inch hole is left up the middle of each element, into which an experiment can be inserted. A dummy fuel element is on display.

The heat produced in DIDO is 12,500 kW. This heat is swept away by a stream of heavy water forced up through the fuel elements by three pumps mounted in a shielded room below the reactor. Each second, half a ton of heavy water is forced through the reactor. As it returns to the pumps for recirculation, it is cooled down in a heat exchanger, where its heat is transferred to a stream of light water. The light water is pumped outside the building to a series of eight cooling towers, in which the heat is finally dissipated to the atmosphere.

The reactor power is controlled by 'signal arm' blades containing cadmium, a neutron absorber, which move up and down between the rows of fuel elements.

The aluminium tank of heavy water containing the core is surrounded by a steel tank (just in case the inner tank should leak) and by a thick shield of lead and concrete. This is to ensure that the radiation produced in the core does not escape and cause danger to the operating staff.

The neutron density in the reactor is measured by ionisation chambers and indicated on instruments in the control room. Here also are displayed all the instruments needed to control the reactor. The control room is open to visitors.

Fuel elements last about three months. When they have to be changed they have to be removed in a flask which has walls made of lead 12 inches thick to absorb the great residual radioactivity in the elements. These flasks weigh about 20 tons. Similarly, when an experiment has finished its useful life, or when its samples have to be changed, a shielded flask is needed to remove the containing rig. A fuel-element flask and a rig flask are both on display.

Over 60 holes are available in DIDO to be occupied by experimental apparatus, and 52 holes are currently in use.

RESEARCH REACTORS DIVISION

Reactors used for research are large, expensive, complicated tools, and require a lot of attention. In an establishment like A.E.R.E., where there have to be several, it is expedient to co-ordinate their organisation into the hands of a specialist group. This is the prime function of Research Reactors Division.

The Division runs the six Harwell reactors as a general irradiation service for the whole United Kingdom Atomic Energy Authority. The reactors provide facilities for such varied purposes as the production of radioisotopes for industry (marketed through the U.K.A.E.A.'s Radiochemical Centre at Amersham) to basic scientific research. Much ancillary work is also undertaken, and a great amount of specialised technical knowledge is entailed.

Research Reactors Division employs over 600 people, about 150 of Professional Grade - university graduates or equivalent. It is divided into four Groups.

The Operations and Plant Engineering Groups are together responsible for the daily running and upkeep of the reactors. Each reactor has a staff of highly qualified engineers and technicians, who work in a shift rota throughout the 24 hours. A responsible officer must always be on duty. The shift staff is backed by daywork teams.

The Design Group provides a complete engineering service, from inception to installation, to supply experimental apparatus or the often very complicated rigs in which the apparatus or samples are contained and maintained under the necessary environmental conditions. The rigs themselves become radioactive after irradiation in the reactor and have to have elaborate handling devices to install and remove them. Some of the major rigs, called "loops", simulate in miniature the conditions existing in a completely different type of reactor from that in which they are installed.

In addition, all the electrical control systems for the experiments are created in the Division.

The running of the reactors requires a complement of physicists to make measurements and calculations on the physics and some engineering aspects of the reactors, which are constantly changing with their use, and the effects on them of the presence of experimental equipment. In addition, the Physics Group performs experiments with the reactors themselves to further knowledge on such topics as reactor kinetics and measurement of neutron densities.

Providing a liaison between the Design Group and outside manufacturing contractors is the Supply Section. This deals with estimating and costing, progressing, programming, and inspection.

Finally, the Divisional Administration is responsible for all office services and the financial aspects of the Division's work.

The reactor is manned continuously, day and night; at all times a minimum of six men are on duty, working on a shift rota. These consist of a professional grade Engineer Control Officer, two qualified technicians (one for the reactor and one for the rigs, a Reactor Operator, who handles the controls, and two ancillary workers. There are six or seven E.C.O's, including trainees, under one officer, the Chief Pile Operator, responsible for the whole reactor and its safe operation. The shift crew are supported by day-work teams to cover maintenance, rig installation, radioactive handling, etc. Altogether about 100 men of all grades are employed full time. Similar arrangements exist on PLUTO.

PLUTO

(Pile for Loop 'U' Testing 'O')

PLUTO is the second high-power reactor to be built at Harwell, and started operating in October 1957. It is largely based on the design of the first, DIDO. Similar reactors are now in operation at Dounreay (Scotland) and in Denmark. It is designed for testing reactor materials and also provides facilities for neutron-beam work.

Completed at a cost of about £2,000,000, the annual running costs are about £1,000,000, the main charges being fuel costs and capital expenses on the reactor and heavy water. Staff concerned directly with the operation of the reactor number 90, drawn from Operations, Maintenance, and Reactor Physics Groups of Research Reactors Division, with supporting staff from Health Physics Division and Industrial Chemistry Group.

The heart of the reactor consists of a high purity aluminium tank 6 feet 7 inches in diameter and 10 feet 11 inches deep, containing about 5 tons of hea heavy water (moderator and reflector) and 26 fuel elements, spaced about 6 inches apart, the total amount of U^{235} (the fissile component) being 3 kilograms (about $6\frac{1}{2}$ pounds). Each fuel element consists of 10 plates of aluminium-clad uranium alloy. The heavy water is circulated over them by electrically driven pumps, and then leaves the tank and passes through heat exchangers, where the heat is removed in a light-water circuit to be dissipated in cooling towers. The heavy water surfaces in the tank and other parts of the system that do not run completely full are blanketted with helium to exclude air and atmospheric moisture, which would cause loss of purity of the heavy water. The aluminium tank is surrounded by a second reflector of 1-foot graphite blocks to increase the useful experimental volume, this in turn being bonded to a water-cooled lead shield surrounded by a 5-foot barytes concrete shield. The total amount of water in the whole reactor circuit is about 10 tons.

There are 14 vertical holes for experiments in the core and reflector of four or seven inches in diameter and up to 3 feet in effective length. In addition there are four 7-inch diameter holes passing right through the reactor close to the core, these being particularly suitable for large in-pile loop experiments, a high fast-neutron flux being available in these positions in addition to the thermal neutrons.

The reactor is contained in a $\frac{3}{4}$" thick mild-steel shell 70 feet in diameter and 70 feet high. The shell is kept at a pressure slightly below atmospheric and is fully air-conditioned with one air change per hour, the extract being filtered. Access to the shell is via two personnel air-locks, or a vehicle air-lock which admits trailers and handling equipment for the 24-ton flask used to remove fuel elements, and the flask used for transport of other active equipment and experiments. Mechanical and electrical supplies pass through the shell in specially designed leak-proof glands. The shell is the ultimate line of defence against the release of radioactivity into the atmosphere, should there be any leakage.

There are currently 25 experiments in the reactor, including the testing loop for fuel elements for the High Temperature Gas-Cooled Reactor DRAGON being built at Winfrith; this assembly runs at a maximum of 1,200°C. Other experiments are being conducted into damage and physical changes under irradiation in graphite and beryllium; irradiation effects on uranium, uranium carbide and oxide, and coated particles; carbon-dioxide/graphite reactions; and production of radioisotopes. Several holes are in use for fundamental studies into atomic studies into atomic structure and magnetic effects.

The reactor operates at a power of 10,000 kW on a 24-day cycle, after which it is shut down for four days for fuel changing, loading and unloading of experiments, and for maintenance.

A sectional model of the reactor permits a viewing of the inaccessible parts, and a closed-circuit television system used with the reactor is arranged to show the permanently radioactive heavy water plant room. Other demonstrations of particular interest are of the operation of the pneumatic grab of a carrying flask, and of leak detection by means of helium.

L I D O

("Swimming-Pool" Type Reactor)

LIDO is a low-power research reactor specially designed for neutron physics and shielding experiments. The reactor can be operated at any power between 5 watts and 100kW, and does not require any special means of heat removal. The core, of enriched uranium made up in elements similar to DIDO's and PLUTO's, is suspended in demineralised light water, acting as moderator, near the bottom of a reinforced concrete tank 28 feet long, 8 feet wide, and 24 feet deep. It hangs from a trolley which can be moved to place the core in any position within the tank. The concrete walls act as a shield to restrict radiation levels in the working areas, and are pierced at six irradiations positions. Three are aluminium panels 8 feet square and three are beam holes 12 inches in diameter.

The reactor is controlled by two cadmium absorbers which can be moved vertically within the core, and as a safety precaution two further absorbers are held above the core ready to fall into it if tripped either manually or through an automatic system. The reactor power is monitored by several ion chambers around the core, two of which feed recorders on the Control Panel. Others feed safety circuits and would shut the reactor down automatically when preset limiting conditions are reached.

LIDO is a very stable reactor and is easily controlled manually on the fine absorber rod by the Operator, who must always be on the trolley when the reactor is operating. He has one assistant, who is generally responsible for checking radiation levels and routine record-keeping.

The construction of this reactor readily permits the blue glow around the core to be seen when the reactor is 'at power'. This results from the interaction of the radiation given off with the surrounding water. The atomic collisions destroy the energy of the radiation (the normal moderating effect), part of which is converted into light. This known as the Cerenkov effect.

It has recently been possible to increase the loading of LIDO by the introduction of the movable trolley rail system. This permits one assembly to be worked on while another is being irradiated. A model shows its method of working.

DAPHNE

(DIDO's and PLUTO's Handmaiden for Nuclear Experiments)

Harwell's two high-power reactors DIDO and PLUTO have become increasingly used over the five or so years for which they have been operating; the demand for experimental space in them is so great that they are nearly fully loaded. Changes have already been made to increase the number of experiments which can be loaded (such as the replacement of the box-style Mark II fuel elements by the annular Mark III elements, which can each take an experimental rig in the middle of the fuel) and further modifications will be made in the future.

When any such change is made it affects the nuclear behaviour of the reactor. It is necessary to confirm the estimated effects of each change by careful measurements while the reactor is started up and then run at very low powers, before it can once again operate at its normal high power. In the past this meant an expensive loss of useful operating time.

DAPHNE has been designed and constructed for a total cost of only £100,000. It has only recently been completed, and started work last month. Operating at such low power that nothing in it becomes too radioactive to handle, it will permit the determination of how much reactivity experiments absorb, how best to arrange them so as to get the highest neutron density and how to modify the big reactors so as to improve their performance. In addition, it will be possible to find out, without risk, whether proposed changes will prejudice reactor safety. This reactor will also be used to test new fuel elements, control mechanisms and experimental rigs.

DAPHNE is a very low-power reactor, designed to operate with a heat output of no more than 100 watts. It is fuelled with DIDO or PLUTO-type fuel elements, composed of uranium highly enriched in the U^{235} isotope. These can be arranged so as to simulate the cores of either major reactor. Heavy water is used as moderator as with DIDO and PLUTO, but since DAPHNE runs at very low power, no artificial cooling means is required.

The core in which the reaction takes place is about 3 feet in diameter and 2 feet high. The containing tank is inside 4-foot thick concrete walls to shield staff from the radiations that are emitted when the reactor is operating. The 2-foot thick top shield may be moved when the reactor is shut down so that the core can be rearranged.

The reactor is remotely operated from a desk console in the control room. The power is varied either by altering the level of heavy water moderator in the reactor tank, or by moving a small rod of cadmium (the fine control rod) vertically in or out of the core. The heavy water is pumped into the reactor tank from the 'dump' tank below at a controlled speed through a small control valve. The fine control rod is suspended in the core on a cable and is wound in or out by a small motor worked from the desk.

Two banks of absorbers simulating the coarse control arms of DIDO and PLUTO may be preset before start-up. The positions of the control members and heavy water level are indicated on the control desk, the coarse control arm position and the water level being duplicated on two independent instruments.

The reactor power is measured by ion-chamber and pulse counting channels which not only indicate and record the reactor power, but are arranged to shut the reactor down if the power rises or falls too far or rises too fast. The automatic shut-down instrumentation is triplicated, and operates, if necessary, through two independent circuits to drop four safety rods into the reactor core and to dump the heavy water from the reactor tank quickly through two large pipes into the dump tank in the reactor pit.

Test and Commissioning - BUILDING 447

Exhibition of Rigs Used for Irradiating Materials in DIDO and PLUTO

A rig is a device used for the safe handling of materials in a reactor, and the maintenance of them under desired conditions.

On display are typical examples of the many rigs used for the development of better materials for future Nuclear Power Stations and the production of Medical and Industrial Isotopes.

Nuclear radiation produces widely different effects upon different materials. For instance, it produces more heat in some than in others; some materials disintegrate or change to a form having quite different physical properties; in others, gases are produced. Several types of rig are therefore necessary. In the simplest form, a rig may consist of tiers of containers arranged in 'cake-stand' fashion on a metal stalk which can be lowered into a hole in the reactor. On the other hand, some rigs (often referred to as loops) are complex pilot-plant-size installations.

A high standard of workmanship and rigorous inspection is necessary. Commercially available components and established manufacturing methods are used as much as possible, but almost every rig has novel features. The exhibits include specially developed components.

Safety and reliability are very important. Conditions inside the rigs are continuously measured and maintained at the required state by process-control instruments. If a fault occurs in the rig or instrumentation, the equipment is automatically brought to a safe state by special safety circuits. In some rigs the safety arrangements include automatic shutdown of the reactor.

Typical instrument panels are among the exhibits.

BUILDING 521

Drawing Office

The function of the Design Group of Research Reactors Division is to provide an engineering service to the Divisions at Harwell that require equipment for carrying out irradiation experiments in the reactors.

The service provided covers all aspects of the projects from initial discussions with scientific staff, through the various stages of design, safety assessment, manufacture, testing and commissioning, up to the handing over of the equipment for operational use.

These various stages are illustrated by a display in the Drawing Office, which is part of the Design Group. The finished articles are shown by the side of the engineering drawings used during their construction.

BUILDING 451/T

Supply Section Exhibition

The Supply Section provides a service to the other Groups in the Division and is divided into three departments:

Supply and Contract Liaison

Progress and Inspection

Estimating and Materials

The exhibition in Building 451/T demonstrates the work of the Section by using the project 'Neutron Crystallography Rig' as a typical example.

Exhibits will include a model of a collimator, materials used in the manufacturing processes, inspection techniques, and an indication of the procedures which are required to launch such a project from the initial idea to the final stage of operation in the reactor.

HANGAR 10

Physics Group Exhibits

Neutron Measurements

A knowledge of the neutron energy spectrum (the relative numbers of neutrons present travelling at different speeds) and of the neutron flux (the actual number of neutrons passing through a sample each second) is of vital importance to the experimenter irradiating materials in a reactor. The Physics Group of the Division makes the measurements of these quantities in all the Harwell reactors and is also developing new techniques to improve the accuracy and to extend the measurements into fields in which they have not in the past been possible.

Solid-state (semi-conductor) ionization counters have been applied to the measurement of neutron energies and are at present under development for the measurements of neutron spectra inside reactors. Some examples of this type of counter and the results obtained from them are demonstrated.

Neutron fluxes in reactor experiments are commonly measured by the radio-activation of small samples of suitable materials in the form of wires or thin foils. The method normally used in the Division is illustrated.

Reactor Calculations

Electronic computers are used extensively to perform calculations on reactor problems, most of which are too complex for practical solution by any other means. Examples are shown of calculations to predict the behaviour of a reactor (DAPHNE) when its conditions are changed, the neutron energy spectra in various reactor systems, and the intensity of the neutron flux in a proposed ultra-high-flux reactor.

Interaction of Neutrons and Radiation with Matter

The manner in which neutrons and other associated radiation interact with the materials of which reactors are built is of basic importance in the physics of reactor design. Demonstrations illustrating some of the more important properties are on view.

B E P O

(British Experimental Pile '0')

BEPO began operation in July 1948, and was Harwell's second reactor.

It is air-cooled, graphite-moderated, and fuelled with natural uranium, and is used for general purposes, including pile neutron research, radioactive isotope production, irradiation chemistry and metallurgy, and reactor engineering research. BEPO runs at a power of 6,000 kW.

The reactor comprises a graphite cube of 26 foot side, containing 850 tons of graphite and 40 tons of uranium fuel, surrounded by a 7 foot thick steel and concrete shield. The graphite is pierced by 1,760 horizontal channels at 7¼ inch intervals, the central 888 channels being designed to contain uranium fuel elements and so form the reactor core. This core is in effect a horizontal cylinder 20 feet in diameter and 20 feet long, surrounded on all sides by a graphite reflector 3 feet thick. Graphite columns through the shield from the top and experimental faces provide beams of neutrons for experimental purposes outside the pile. The graphite cube is also pierced by about 90 vertical and horizontal experimental holes in which can be placed individual experiments or from which beams of neutrons can also be drawn.

The uranium fuel is in the form of bars 0.9 inches diameter and 12 inches long enclosed in a finned aluminium can. The canned bar is called a fuel element, cartridge, or slug. Twenty of these bars are loaded in each channel, so a completely loaded core of 888 channels contains 17,760 fuel elements. The reactor is loaded by pushing in a row of fuel elements from the loading face, and unloaded by means of steel push rods which push the irradiated fuel out through the unloading face into a lead-shielded container, which is carried on a 12-ton hydraulic hoist extending the width of the reactor, and which can be positioned accurately at any hole. All holes through the shield are, of course, plugged to prevent the escape of radiation except when they are actually being unloaded. The reactor must be shut down while fuel is loaded or unloaded.

Cooling air is supplied to the uranium channels by three 1,400 H.P. centrifugal exhaust fans. The air is drawn through an inlet filter, along an underground duct, and thence through separate pipes and valves to each fuel channel. It is discharged through an underground duct to outlet filters and a heat exchanger, and thence to the exhausters which discharge up a 200 foot chimney stack to the atmosphere. This suction air-draught system is preferred to blown air draught as it establishes a slightly lower pressure in the reactor than atmospheric and so ensures that any leakage would be of fresh air into the reactor and not radioactive air or dust out of it.

The reactor power level is measured by a number of ionisation chambers placed in the graphite reflector, and the reactor is controlled by four boron neutron-absorbing rods running horizontally through the core about the centre line. These rods may be moved either by hand or automatically. Emergency shut-down is by 14 boron rods normally suspended in the top shield. These fall into the core under gravity after an initial downward push by compressed air and may be operated either by push buttons in the reactor area or automatically in the event of abnormal conditions arising within the reactor.

The majority of experiments using neutron beams from the reactor are located at the 'experimental' face, that is, the face at the opposite side from the control room, and in general the experiments are designed to provide fundamental physics data.

Two engineering loops (major rigs with a separate coolant circulation) have their control panels situated at the 'experimental' face. One of these, the PIPPA channel, is a test loop to study the chemical reaction between carbon dioxide and graphite. This has supplied information for the design of the present Calder Hall type reactors. The other loop provides design and operational experience of pressurised water systems.

The 'control' face of the reactor, from which the control rods operate, is used mainly for the Isotope Production Programme. Three belts of hinged graphite blocks containing samples for irradiation run out from the reactor core to loading and unloading devices attached to this face. Together, the irradiation belts can accommodate about 600 isotope samples.

There are in all 73 effective experimental 'holes' in BEPO, of which about 48 are currently in use.

Several rigs, some exhibiting their method of operation, will be on display, together with a demonstration apparatus showing the differing powers of penetration of the various forms of radiation existing inside a nuclear reactor. This brings home the reason for the thick concrete and lead shields to be seen everywhere there are radioactive materials.

G L E E P

(Graphite Low-Energy Experimental Pile)

GLEEP was commissioned on August 15th, 1947 and became the first nuclear reactor in Europe. The core, a 21 foot cube of graphite containing channels in which are rods of natural uranium in aluminium cans, is surrounded by a 5 foot concrete shield to provide protection from the nuclear radiation. The main function of GLEEP is the testing of materials to be used in the construction of nuclear power stations, in which small concentrations of certain impurities could seriously reduce the maximum electrical output.

The 'danger coefficient' train is to be seen oscillating a sample of impure reactor graphite; the effect of this on the reactor is compared with the effect produced by a pure sample, the difference being related to the amount of impurity in the impure graphite. It will be seen that the neutron flux (displayed on a recorder in the control room) falls as the impure graphite is inserted into the reactor core. Similar tests are carried out on aluminium, beryllium, magnesium, stainless steels, uranium, zirconium, plastics and ceramics.

In 1960, GLEEP was refuelled and fitted with new controls and partly transistorised instruments. It is now used in the training of future reactor personnel and for experiments in reactor physics, in addition to the routine material testing.

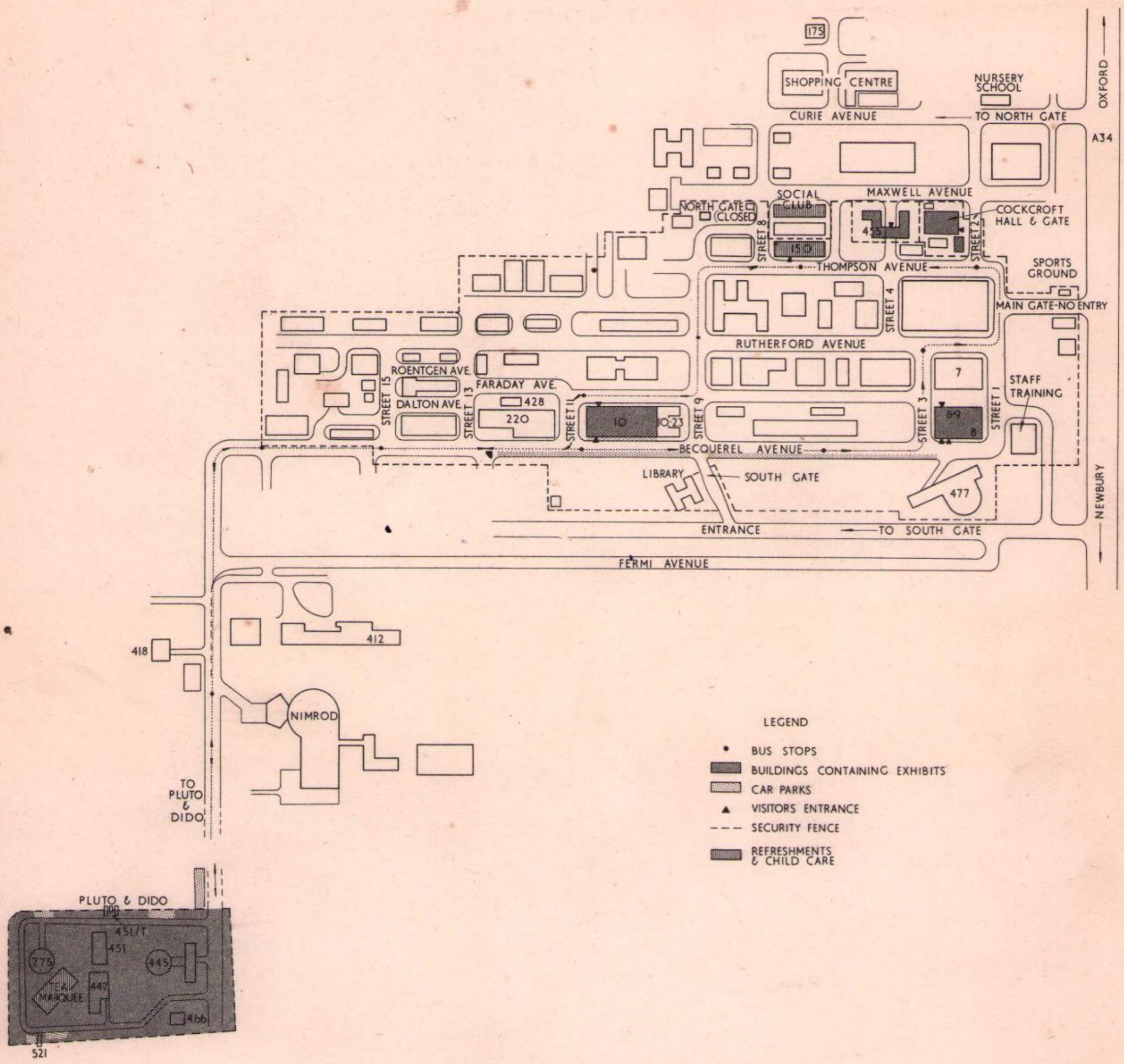
A recent unusual use of GLEEP was in the analysis of an ancient golden torc, or neckband, for Reading University. This was unearthed at Moulsford, Berkshire, and pronounced to be 3000 years old and worth £1,500. By making it slightly radioactive and measuring its radioactivity it was possible to determine its composition. A similar demonstration can be arranged to differentiate between the old silver and the modern cupro-nickel coins.

BUILDING 455

Harwell Reactor School

During the six years of its existence the Reactor School has been attended by some 2,600 students, 625 of them from overseas. The main rooms of the school will be open to visitors, and in the laboratory there will be displays and frequent demonstrations with the following apparatus.

NUCLEAR RADIATION DETECTORS	a selection of devices for the detection of alpha, beta, and gamma radiations, slow and fast neutrons.
SUB-CRITICAL REACTOR ASSEMBLIES	or 'exponential' piles of uranium in graphite and in water, with which some measurements of full-scale reactor data can be made.
REACTOR HEAT-TRANSFER RIGS	experiments which show some of the problems connected with the useful removal of heat from reactors.
REACTOR SIMULATORS	electro-mechanical devices which reproduce the performance of reactors of various types and power outputs.



SHOPPING CENTRE
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