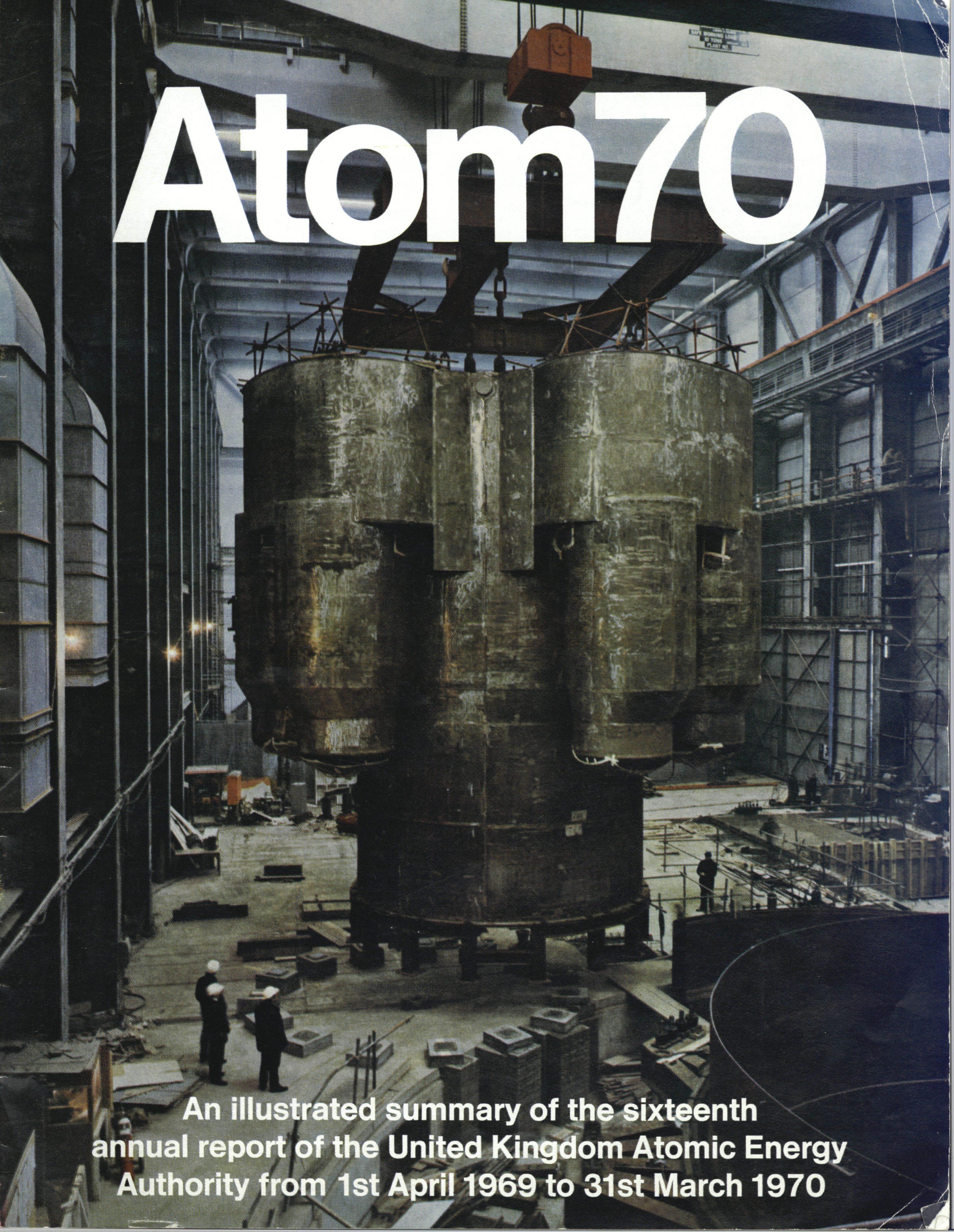
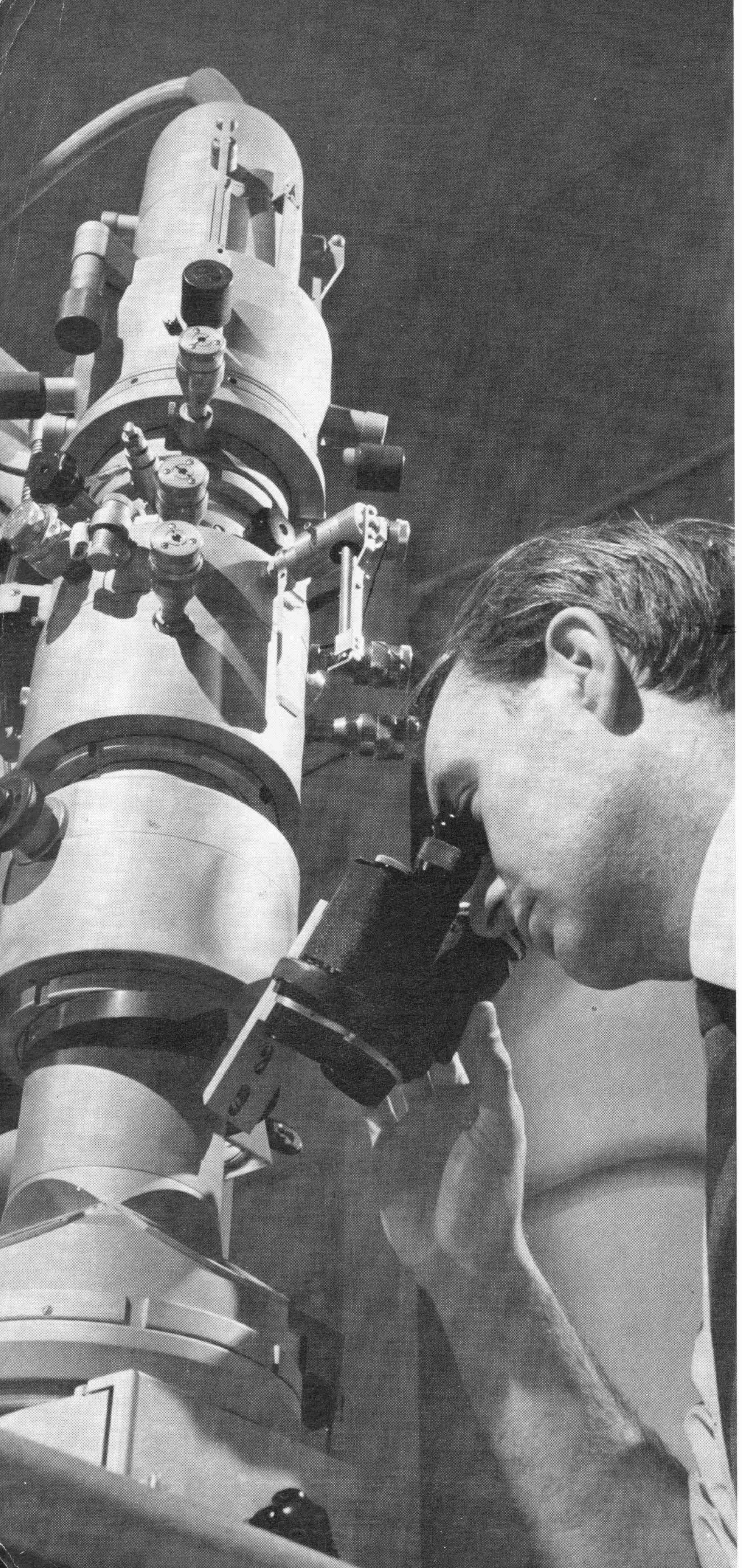
Atom 70



An illustrated summary of the sixteenth annual report of the United Kingdom Atomic Energy Authority from 1st April 1969 to 31st March 1970



THE R&D PATTERN 1970

Three categories of research and development are separately described in this report: nuclear power (reactors); industrial applications of nuclear techniques; and a variety of "non-nuclear" techniques and applications. It should be stressed, however, that, in practice, neither the men nor the facilities concerned exist in "water-tight compartments". The three categories of project are kept distinct in management arrangements, but in many cases individual scientists and engineers are contributing to more than one category of activity.

In the Authority there is a continuous interflow of information and experience not only between basic disciplines, but between teams concerned with different—though technologically related—applications.

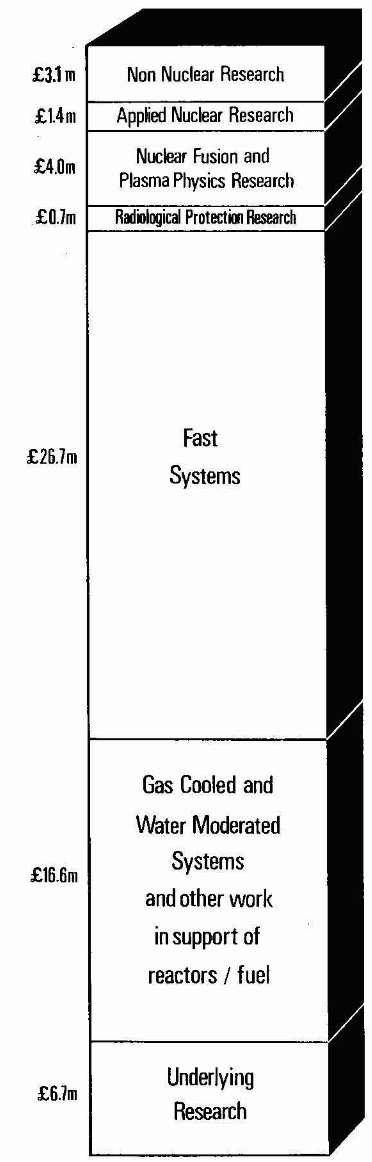
This is true not merely in an individual Establishment, but on an Authority-wide basis, so that a multiplicity of skills and facilities can be deployed for the solution of any specific problem, regardless of its "entry-point" into the organisation.

Although the Authority's work in new fields and, in particular, work in the non-nuclear field naturally attracted a high proportion of public interest during the year, by far the largest component in the Authority's civil R & D programme continued to be the work in support of power reactor development Expenditure on this programme totalled £43·3 million: 62 per cent for the fast reactor; 18 per cent for the Mk. II and III gas-cooled reactors; and 20 per cent for the water-moderated and other systems. The operating costs for all other types of civil R & D (nuclear and non-nuclear) totalled £16 million —of which the non-nuclear element was £3 million.

Left:
REACTOR DEVELOPMENT LABORATORIES, WINDSCALE:
Transmission Electron Microscope.

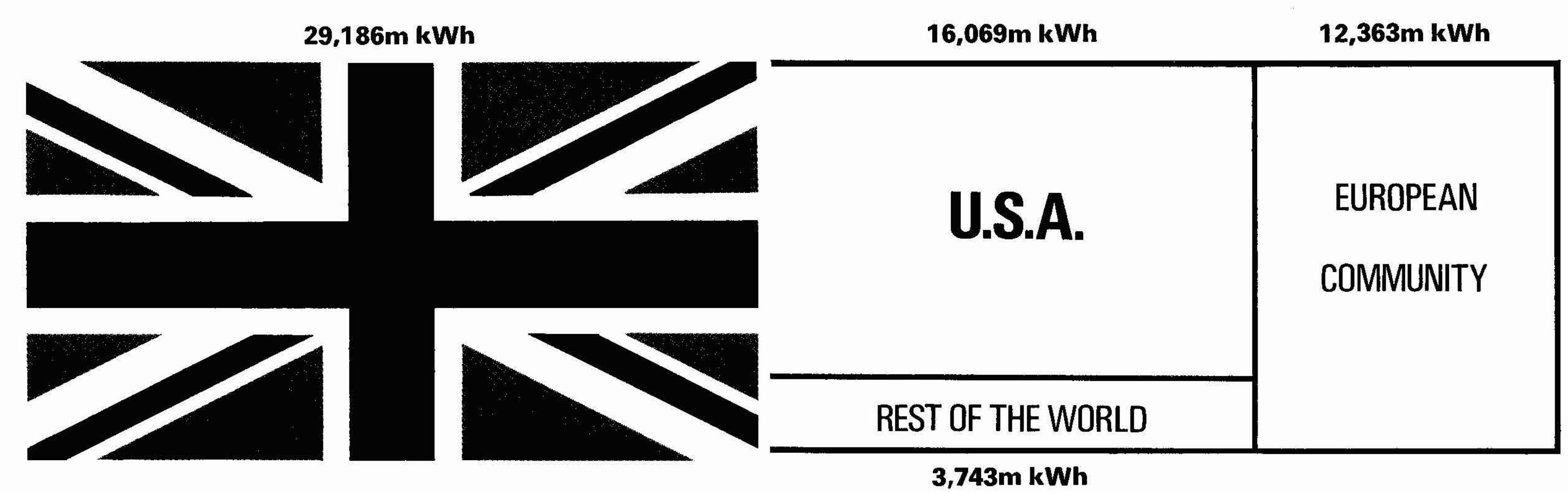
Front Cover:
PROTOTYPE FAST REACTOR under construction at Dounreay (November, 1969).

OPERATING COSTS OF CIVIL RESEARCH AND DEVELOPMENT 1969-70



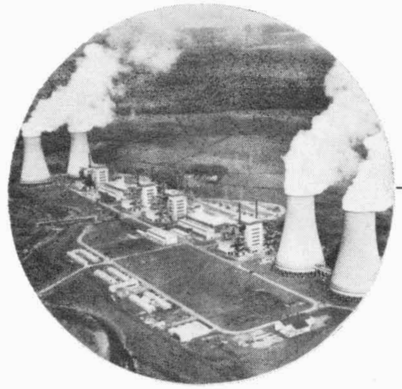
Civil research and development

	Operating Costs £ million					Qualified Scientists and Engineers	
	1965/66	1966/67	1967/68	1968/69	1969/70	31.3.69	31.3.70
Reactor Research and Development Programme							
(i) Major Development:							
(a) Gas-Cooled Systems Mk. II	14·8	13·9	9·8	7·3	4·7	305	225
(b) Gas-Cooled Systems Mk. III	—	—	0·7	1·7	3·3	135	235
(c) Water-Moderated Systems	12·7	15·6	11·3	10·2	7·1	355	235
(d) Fast Systems	16·4	14·8	17·8	20·8	26·7	690	670
(ii) Other work in support of power reactors and their fuel	7·0	7·6	2·4	1·3	1·5	65	75
	50·9	51·9	42·0	41·3	43·3	1550	1440
Other Research							
(a) Applied Nuclear Research			2·0	2·1	1·4	120	95
(b) Underlying Research	11·7	12·3	8·9	7·4	6·7	290	275
(c) Radiological Protection Research			0·6	0·7	0·7	50	40
(d) Nuclear Fusion and Plasma Physics Research	4·2	4·6	4·4	4·2	4·0	175	155
(e) Non-Nuclear Research	0·4	0·9	1·5	2·7	3·0	195	220
Grants to International Projects	1·2	0·9	0·8	1·7	0·3		
	68·4	70·6	60·2	60·1	59·4	2380	2225
Total Cash Expenditure on Civil Nuclear R & D	48·0	50·5	46·0	45·0	47·0		
Total Cash Expenditure on Civil Non-Nuclear R & D	0·3	0·8	1·4	2·6	3·1		

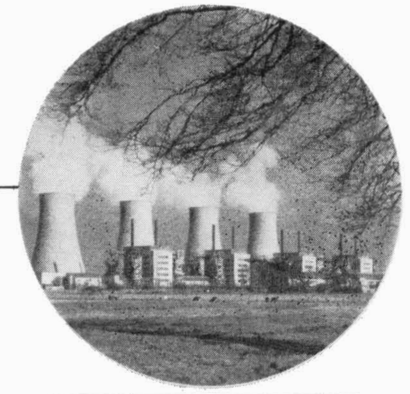


ELECTRICITY GENERATED BY NUCLEAR POWER 1969

THE BRITISH NUCLEAR POWER PROGRAMME

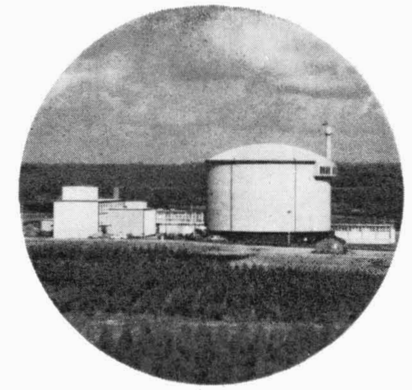


Calder Hall
on load 1956 200 MW



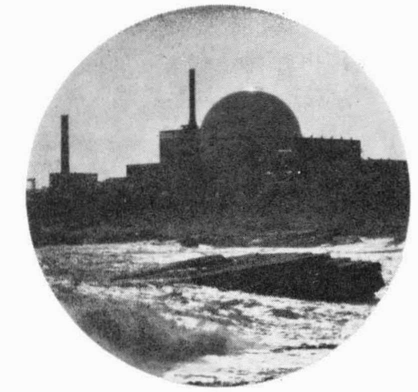
Chapelcross
on load 1958 200 MW

A.G.R. Windscale
on load 1962 33 MW

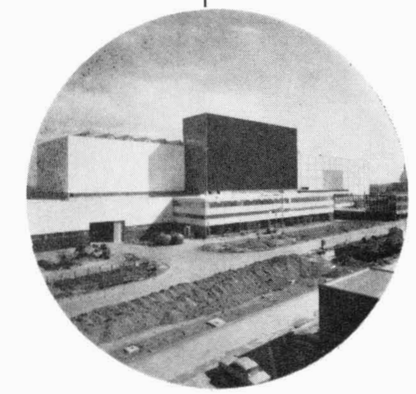


H.T.G.R. (Dragon)

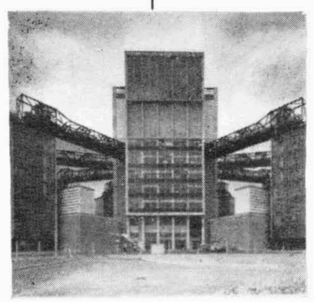
S.G.H.W.R.
on load 1967 100 MW



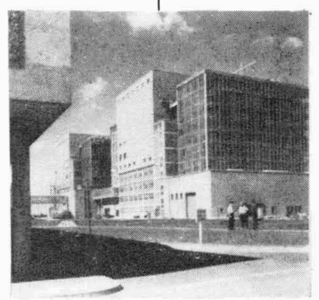
D.F.R.
on load 1959 14 MW



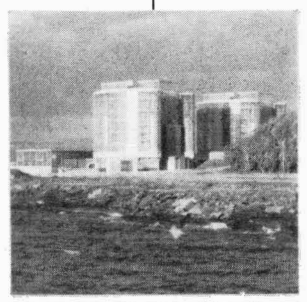
P.F.R.
on load 1972 250 MW



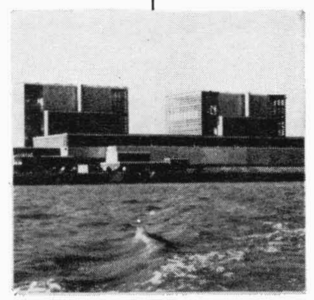
Berkeley (CEGB)
on load 1962 275 MW



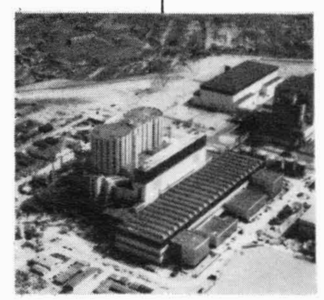
Bradwell (CEGB)
on load 1962 300 MW



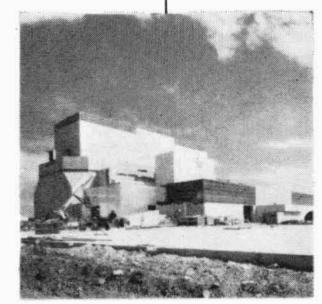
Hunterston 'A' (SSEB)
on load 1964 320 MW



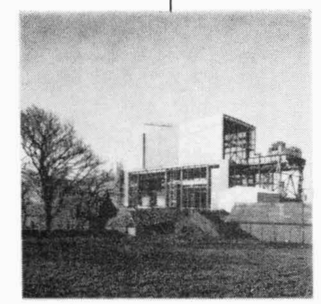
Hinkley Point 'A' (CEGB)
on load 1965 500 MW



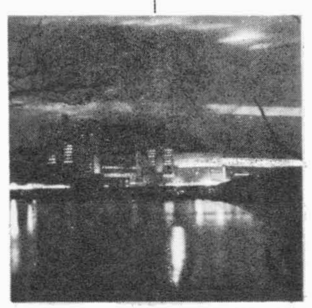
Dungeness 'B' (CEGB)
on load 1974 1200 MW



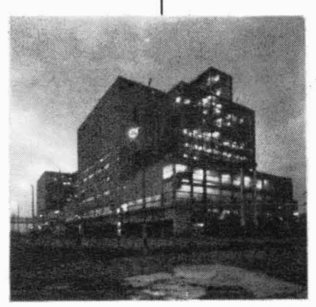
Hinkley Point 'B' (CEGB)
on load 1972 1250 MW



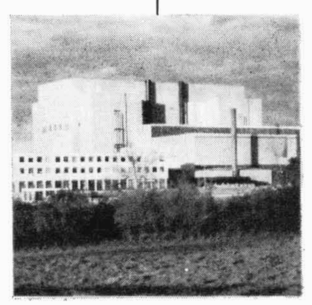
Hunterston 'B' (SSEB)
on load 1973 1250 MW



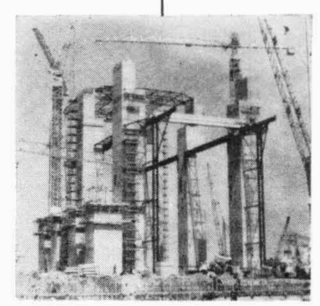
Trawsfynydd (CEGB)
on load 1965 500 MW



Dungeness 'A' (CEGB)
on load 1965 550 MW



Sizewell 'A' (CEGB)
on load 1966 580 MW



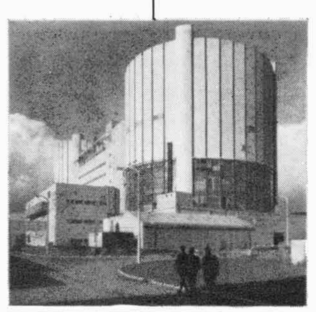
Hartlepool (CEGB)
on load 1974-5 1250 MW

Announced October 1969

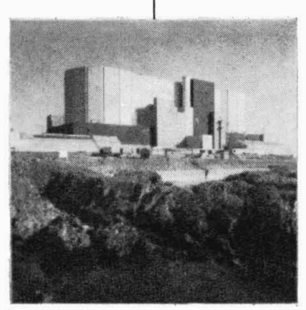
Heysham (CEGB)
on load 1974-5 1250 MW

Announced October 1969

Sizewell 'B' (CEGB)
on load 1976 2640 MW



Oldbury (CEGB)
on load 1967 600 MW



Wylfa (CEGB)
on load 1970 1180 MW

The first line of reactors—at the top of the chart—consists of those built by the United Kingdom Atomic Energy Authority (or, in the case of "Dragon", by the Authority in co-operation with other members of the European Nuclear Energy Agency) to establish the viability of a particular reactor system.

The two blocks of reactors on the lower part of the chart (left and right) are those built from the basis of AEA designs by British industry for the Generating Boards as part of the commercial electricity supply to the national grid.

There is close collaboration between the Authority and the UK nuclear power industry at all levels on the reactor systems under development—Mk. II and Mk. III gas-cooled reactors, SGHWR and Fast Reactors.

In addition to close and detailed consideration with the Central Electricity Generating Board and the South of Scotland Electricity Board of the nuclear stations being built and planned for their networks, the Authority have discussed the suitability of nuclear power plants for the Aberdeen area with the North of Scotland Hydro-Electric Board and are studying the introduction of nuclear power to Northern Ireland jointly with the Northern Ireland Joint Electricity Authority.

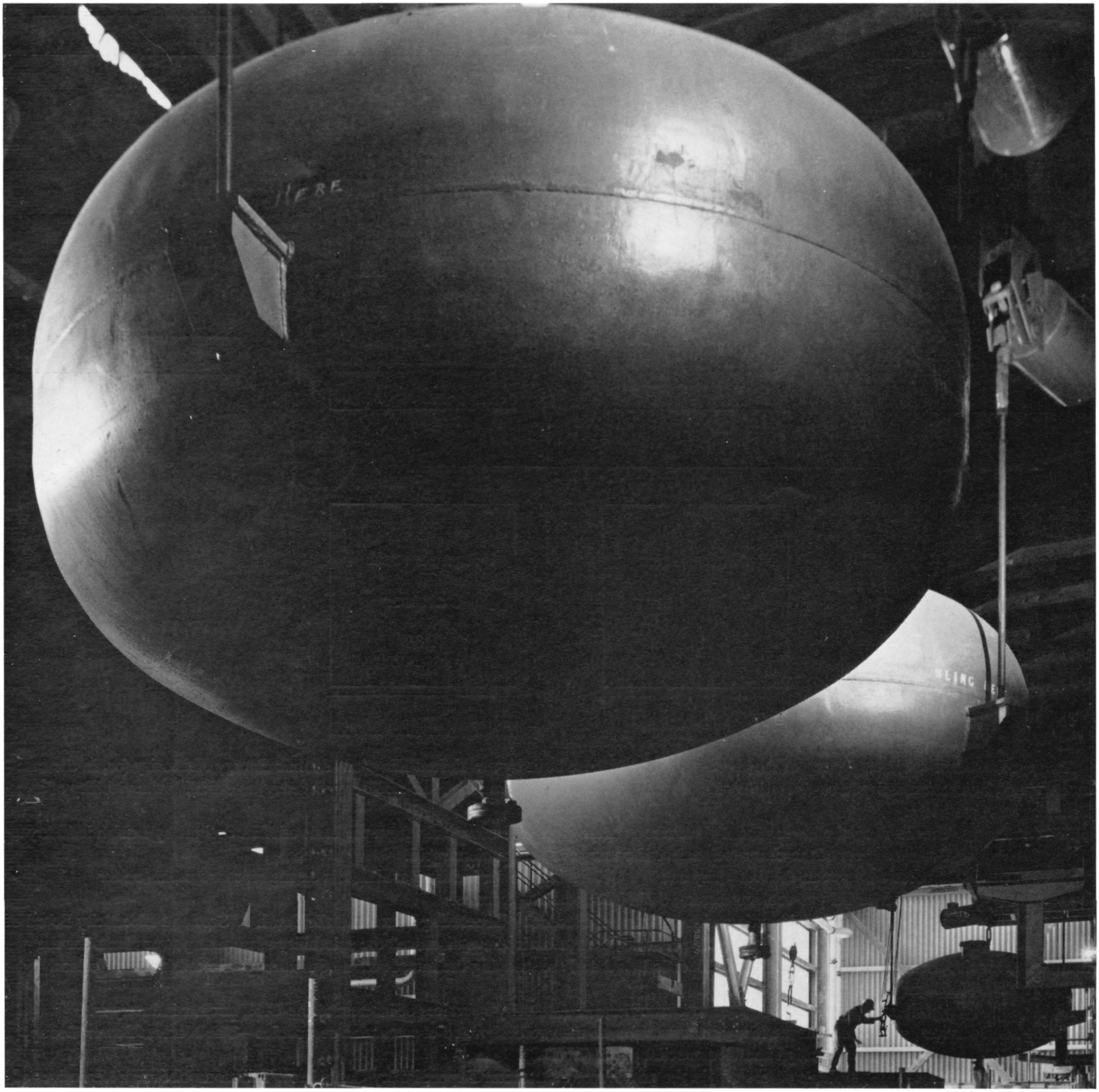
Throughout 1969/70 increasing effort was given to identifying the Authority's services of interest to the U.K. nuclear industry and providing such services, particularly in the hire of test facilities, to the two design and construction companies—The Nuclear Power Group, Ltd. (TNPG) and British Nuclear Design and Construction, Ltd. (BNDC).

Overseas promotion of these systems comes within the purview of the Reactor Export Policy Committee. This comprises representatives of the two nuclear design and construction companies (one of which provided the chairman for the year) and the Authority. Observers attend on behalf of the British Nuclear Forum, the Export Credit Guarantees Department and other Government Departments.

POWER REACTOR R&D

DURING 1969/70 Government approval was given for the construction by the Central Electricity Generating Board of two further nuclear power stations, both using Mk. II gas-cooled reactors (Advanced Gas-Cooled Reactors). The stations will be at Heysham, Lancashire, and Sizewell, Suffolk. The total planned output of Mk. II stations, either under construction or granted Government approval, now stands at 7500 MW(E).

The main emphasis in the Authority's work in support of the second nuclear power programme was on the testing and improvement of Mk. II gas-cooled reactor fuel and checks on reactor materials. The aim of fuel development work is to improve the performance of fuel in the conditions obtaining in Mk. II reactor stations, especially the ability to withstand power changes encountered in normal operation and to meet future changes in the operating role



EFFLUENT SYSTEMS on each of the PFR secondary circuits allow sodium/water reaction products to be safely vented to atmosphere, should a leak occur. Within these effluent systems there are conventional separators which remove the solid reaction products from the gases.

of the stations when load following will result in increased power cycling.

FAST REACTORS

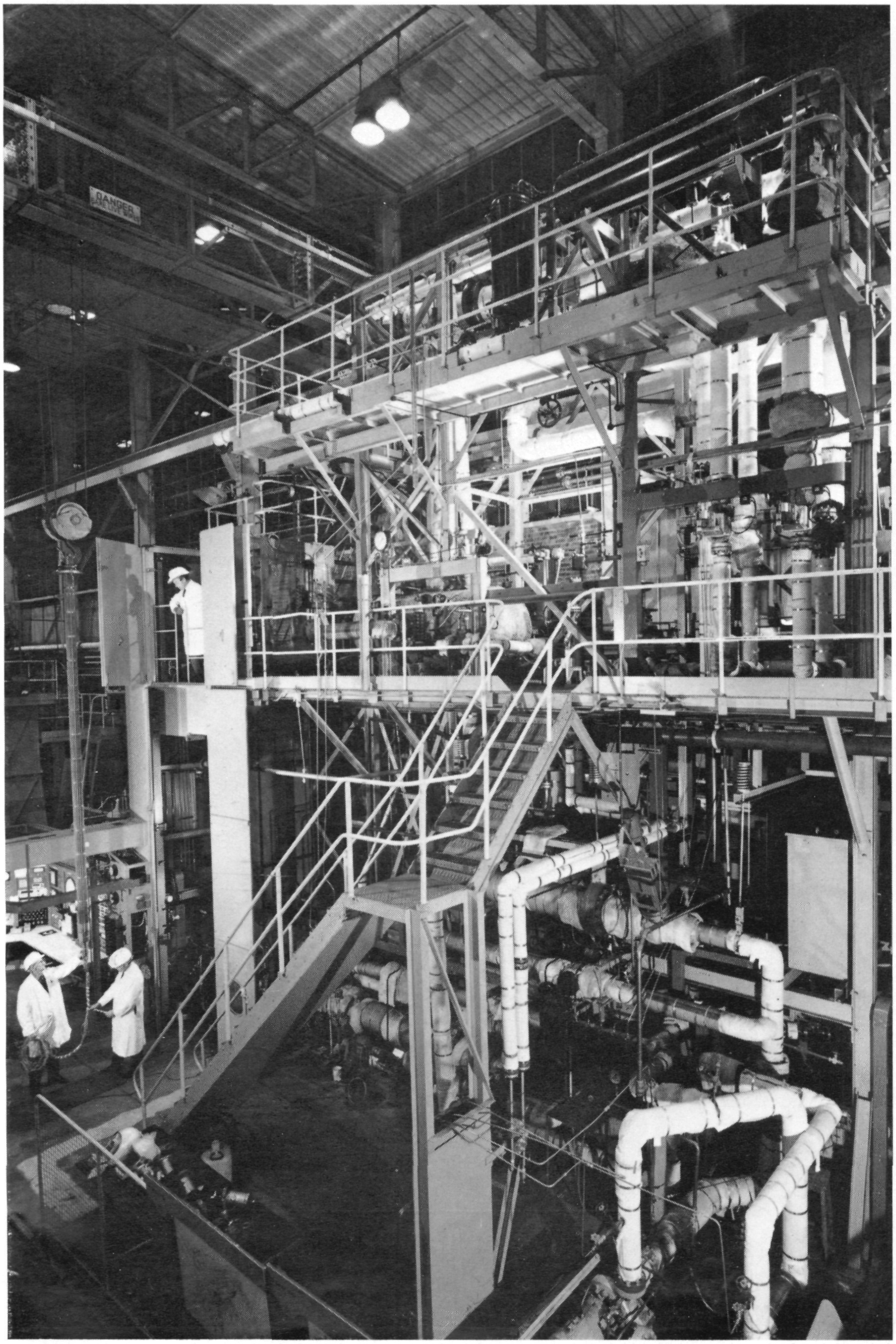
The larger part of the reactor development work as a whole, however, was concerned with the fast reactor, which produces plutonium fuel as well as consuming it. It is envisaged that this will be the dominant reactor type installed in the 1980's and onwards.

The fast reactor project is centred on the construction of the 250 megawatt (electrical) sodium-cooled fast reactor—the Prototype Fast Reactor or PFR—at Dounreay.

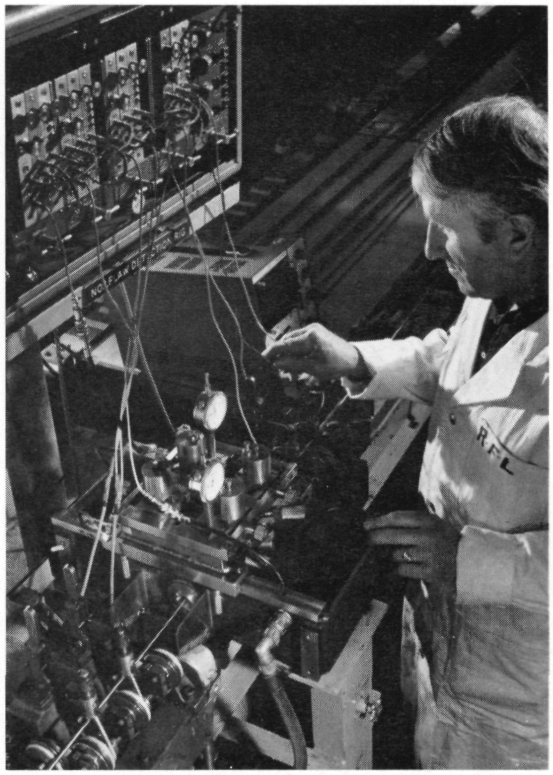
Construction of the PFR progressed well following the previous year's set-back, caused by welding difficulties with the biological shield roof. The roof was delivered to site and assembly began. At the end of the period under review the building and civil engineering works for the reactor were nearing completion and the administration block was being occupied by the reactor operating team. Commissioning of the first fuel charge, including experimental fuel, began.

The Central Electricity Generating Board, in association with the Authority and the Design and Construction companies, is considering the future programme for the introduction of commercial fast reactors. Design studies for such reactors continued, attention being concentrated on those of 1250 MW(E) output. Development of fuel for commercial fast reactors proceeded and included irradiation trials in the Dounreay Fast Reactor.

The DFR will continue to be an important irradiation facility for some years to come and its reliability has been thoroughly examined.



9 MW RIG. This rig at Winfrith is used for thermal performance studies on full-scale simulated water-cooled reactor fuel elements.



NDT. Nondestructive testing modular equipment (designed at Harwell) being used at Springfields to detect very small defects in reactor fuel cans to standards unattainable by commercially available equipment.

PFR. Fuel element carriers being fitted to the diagrid of the PFR at Fairey Engineering's Stockport Works.

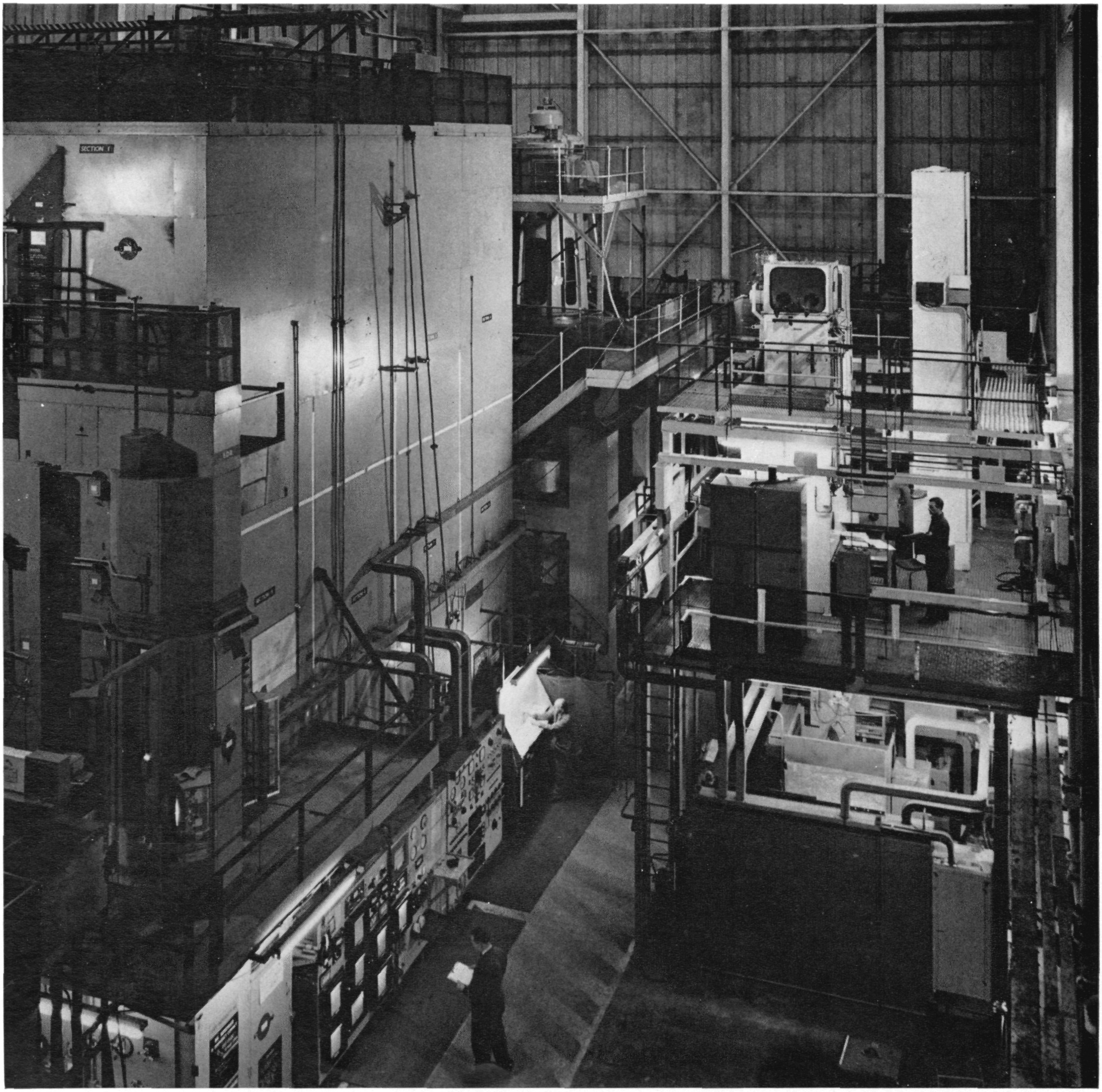
A number of modifications aimed at increasing its reliability, availability and ease of operation are being put into effect.

However, even though fast reactors are likely to be ordered within the next few years, thermal reactors will continue to be built for some years concurrently with fast reactors, to provide plutonium fuel for the increasing fast reactor installation. Work is proceeding on two concepts of advanced thermal reactor to fill this role.

SGHWR

A water moderated reactor, the steam generating heavy water moderated reactor (SGHWR) has been developed by the Authority. The Authority's 100 MW(E) SGHWR at Winfrith, which has operated since the beginning of 1968, is being used to confirm features of existing commercial designs for outputs of 450 and 600 MW(E) which have been made available to the Design and Construction Companies for commercial exploitation. The fuel and fuel channels of the commercial designs are identical to those of the Winfrith reactor which is thus an adequate facility for proving design features and for undertaking large scale fuel tests.

The SGHWR system is being offered by both British design and construction companies (TNPG and BNDC) for Australia's first nuclear power project at Jervis Bay. The Authority have maintained contact with the team of Australian scientists and engineers who



SODIUM LABORATORY. Part of the sodium laboratories of the Risley Engineering and Materials Laboratory, which play an essential role in the development of fast reactors. Sodium laboratories at Dounreay occupy a further 15,000 square feet.

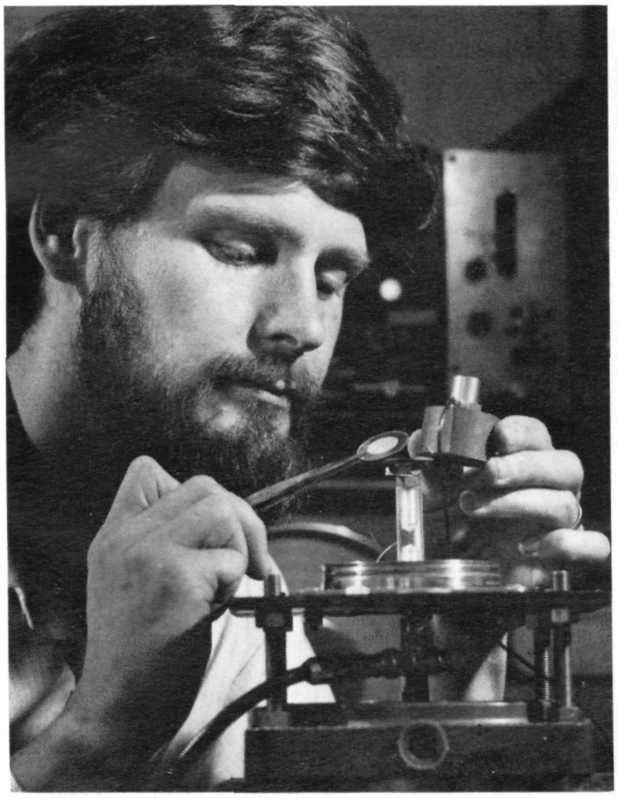
worked on the SGHWR at Winfrith.

Two staff of the South African Atomic Energy Board were attached to the SGHWR design team at Winfrith during the year under review.

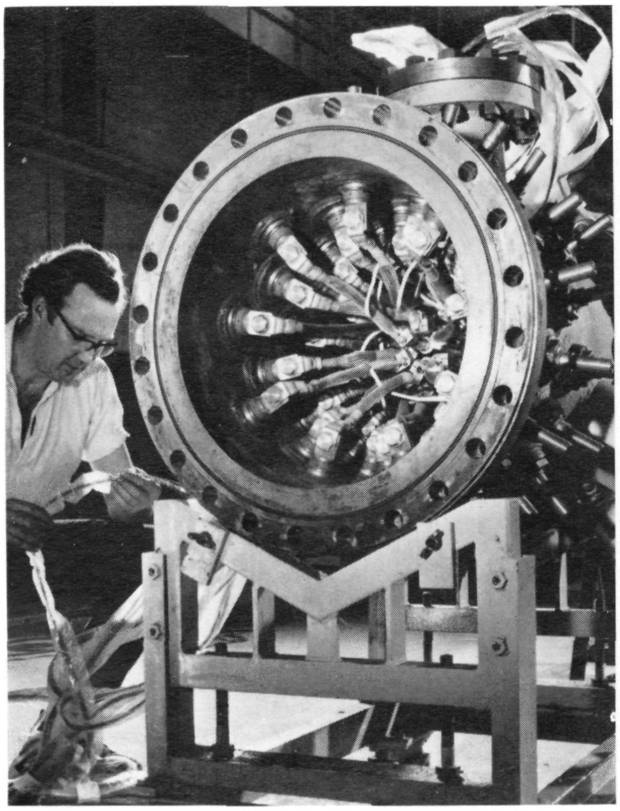
MARK III GAS-COOLED

The other advanced thermal reactor is moderated with graphite and is a further development of the Mk. I and Mk. II gas-cooled reactors installed and being built for the Generating Boards. This Mk. III gas-cooled reactor draws on the UK experience of gas-cooled reactors and some of the technology developed by the international Dragon project, including the use of helium instead of carbon dioxide as coolant. Designs are being evolved by the Design and Construction Companies, who, together with the Generating Boards, are playing an increasing part in formulating the development programme to support the system, most of which is being undertaken in Authority establishments.

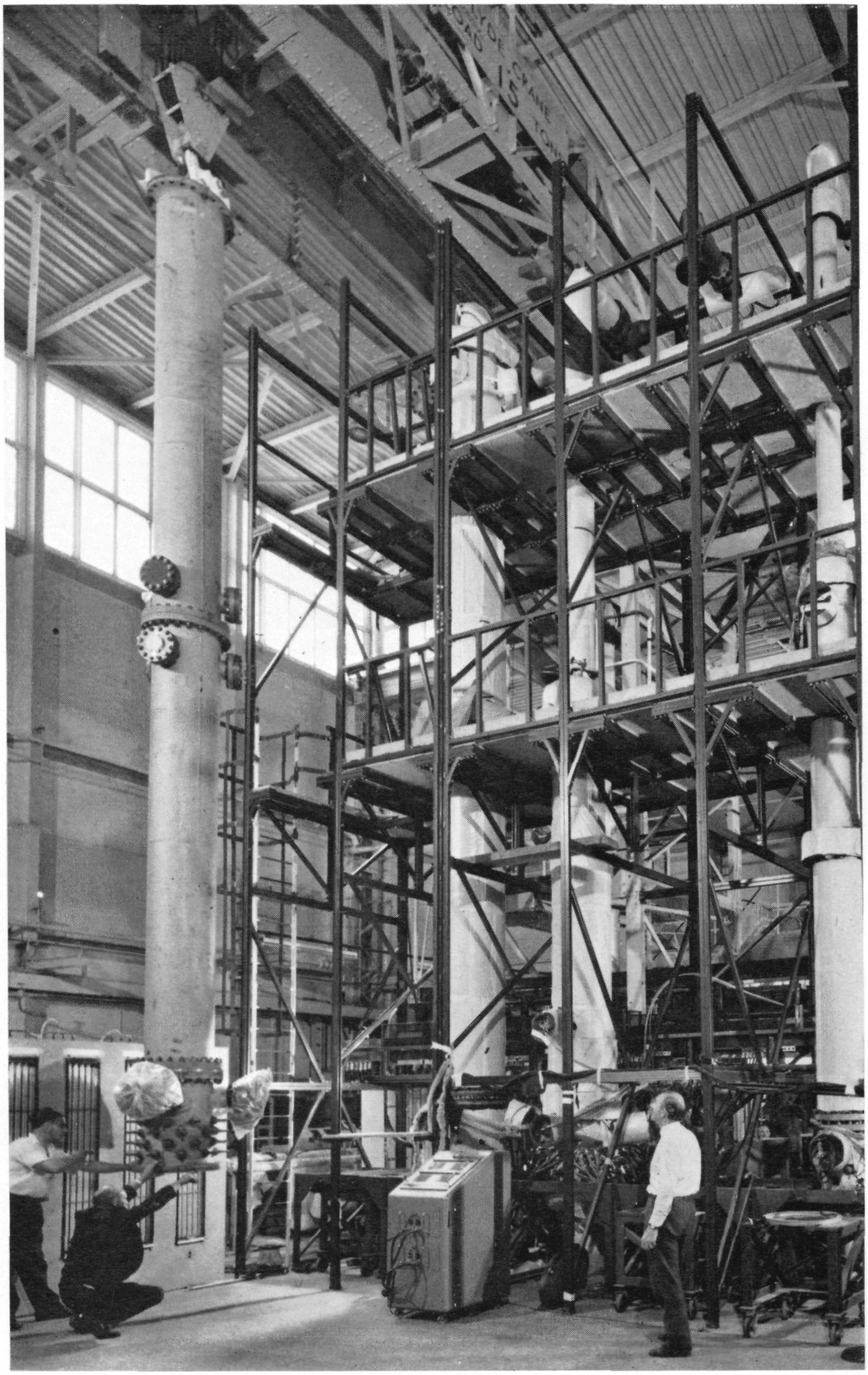
The Authority's programme concentrates on the technology of the system—fuel, reactor physics, coolant, moderator—while the engineering aspects are largely the responsibility of the CEGB and the Design and Construction Companies. In addition the Authority are co-ordinating the views of the industrial organisations on the development programme and the work undertaken in the various laboratories.



INSTRUMENTS. Winfrith is one of the establishments where specialised work is carried out on the control and instrumentation of reactors.



HEAT TRANSFER. AGR fuel element for Hinkley "B" being tested at the Reactor Development Laboratories, Windscale.



GAS LOOP. A pressure vessel being loaded into one of the five bays of the high pressure gas-loop used for heat transfer and pressure drop experiments on reactor fuel elements at RDL, Windscale.

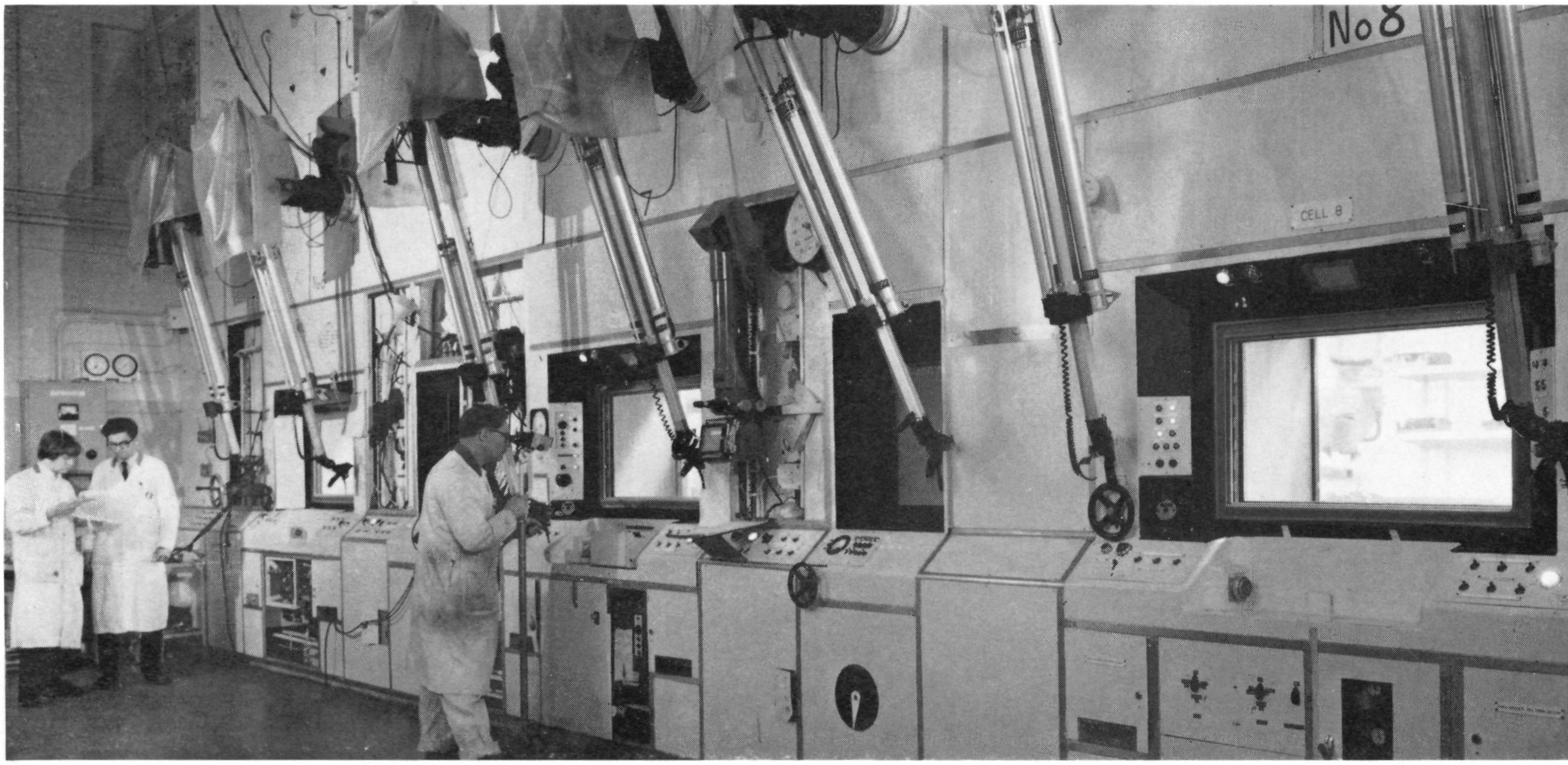
SERVICES TO THE NUCLEAR INDUSTRY

The provision of services to the two nuclear design and construction companies continued, particularly in the hire of testing facilities. The Authority own two gas circulating loops which together can reproduce the gas flow conditions and geometrical features of the fuel channels of the various commercial Mk. II gas-cooled reactors; the rig at Windscale is designed to simulate conditions during the whole of the refuel operation and that at Springfields can change the simulated core geometry of the flow distribution through it while the rig is operating. Both loops and the associated staff are working under contract to the design companies.

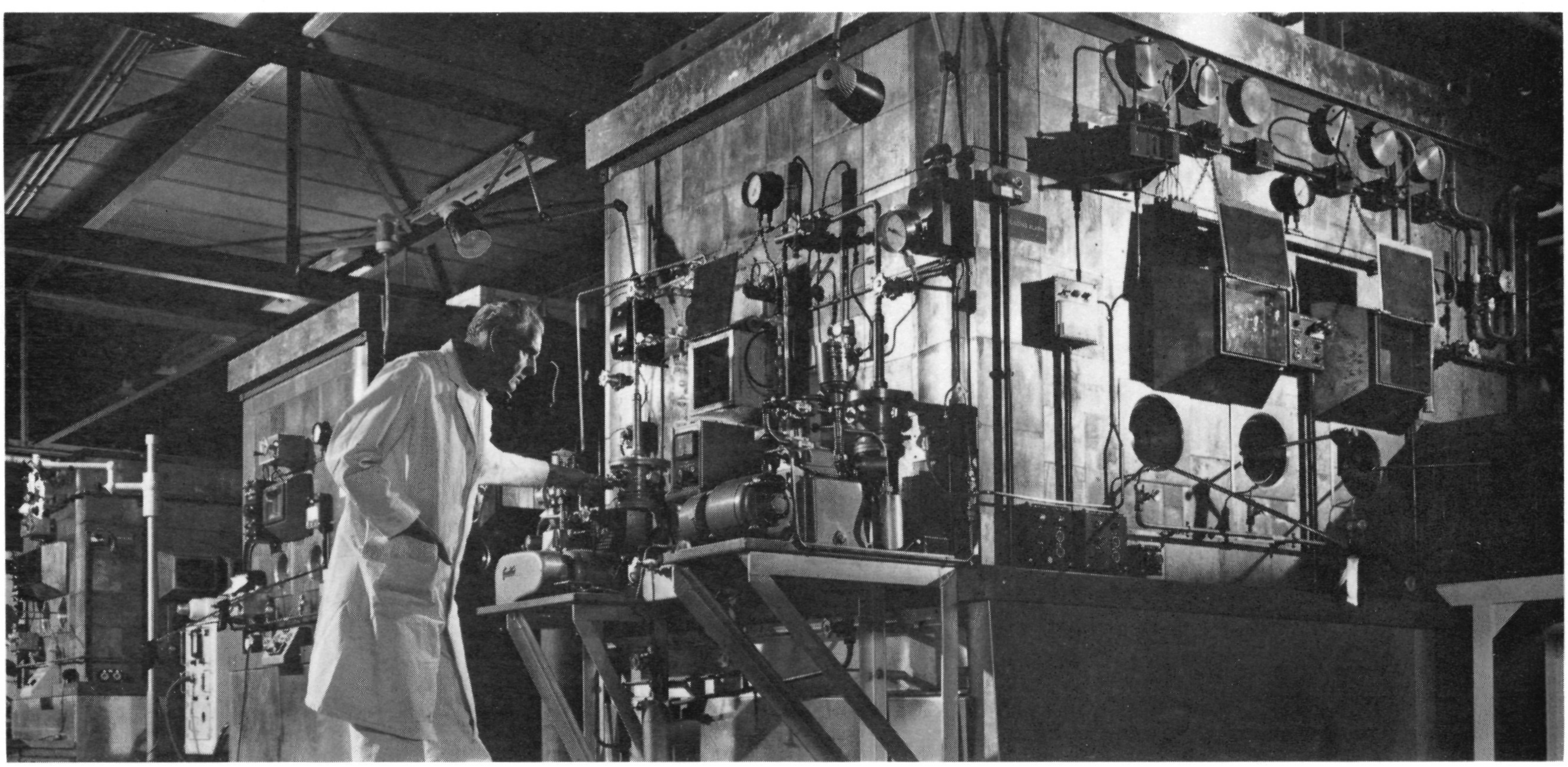
NEW SYSTEMS

The Authority maintain a small effort on the assessment of new reactor systems and new applications of existing systems, backed in selected cases by limited experimental work. During the year an examination of long-term possibilities, in relation to likely future power generation and other requirements, has been started with the assistance of the electricity industry and the Programmes Analysis Unit.

A small amount of experimental work is being undertaken to resolve feasibility questions of fused salt and gas-cooled fast reactor concepts.

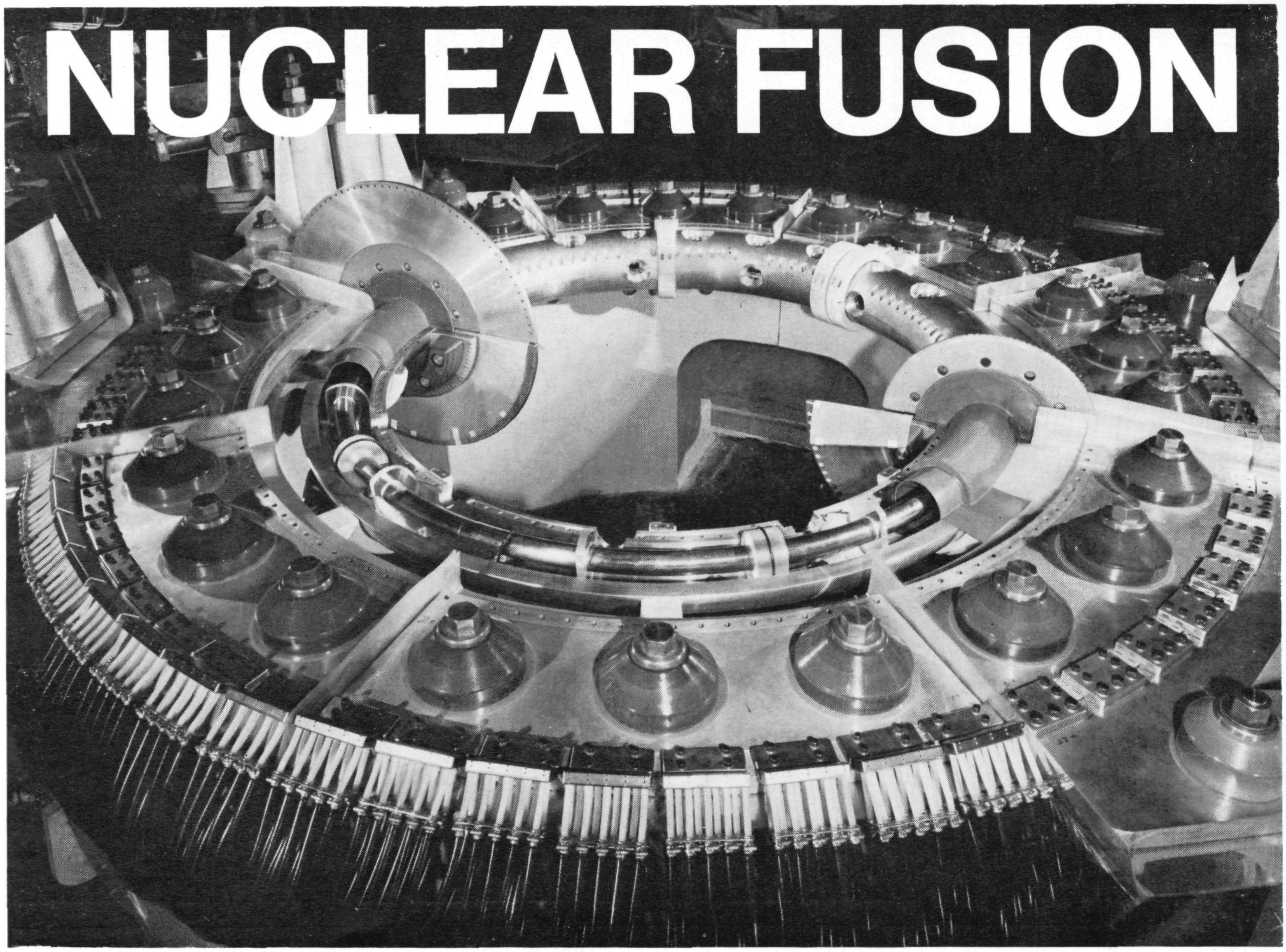


CAVES. The Winfrith "caves" cater for the post-irradiation examination of large fuel elements. A cave 10½ metres long is equipped for handling and dismantling SGHWR fuel clusters (over 3½ metres long).



HARWELL. The post-irradiation examination laboratory at Harwell conducts detailed examination of highly radioactive materials (such as fuel elements and cladding) to determine the changes induced by irradiation in a reactor.

NUCLEAR FUSION



HBTX. Culham has built the High Beta Toroidal Pinch experiment to continue the successful programme of investigation that started with Zeta. The photograph shows this apparatus as it was nearing completion. (For the purpose of electrical testing a copper ring was used to simulate the plasma.) Its aim is to produce and investigate the confinement of plasma with densities of 10^{16} nuclei/cm^3 and temperatures of one million degrees Centigrade. The torus is 2 metres in diameter; the overall diameter of the apparatus shown is $3\frac{1}{2}$ metres.

THE AUTHORITY'S research and development programme on controlled nuclear fusion is aimed at establishing a practical method of releasing controlled nuclear energy from the joining (fusion) of light elements (in contrast to present-day nuclear power reactors which are based on the fission of heavy elements).

Considerable advances towards bringing about the basic process are being made—not only in the United Kingdom but in a number of other countries (including the USSR, the USA, France, Japan and the Federal Republic of Germany). But many major problems still remain to be overcome before the fusion principle can be developed into a power generator; and it is, therefore, too early to forecast with any precision the nature, cost or timing of the development programme that would be justified once the main lines for advance towards a commercial fusion reactor can be determined.

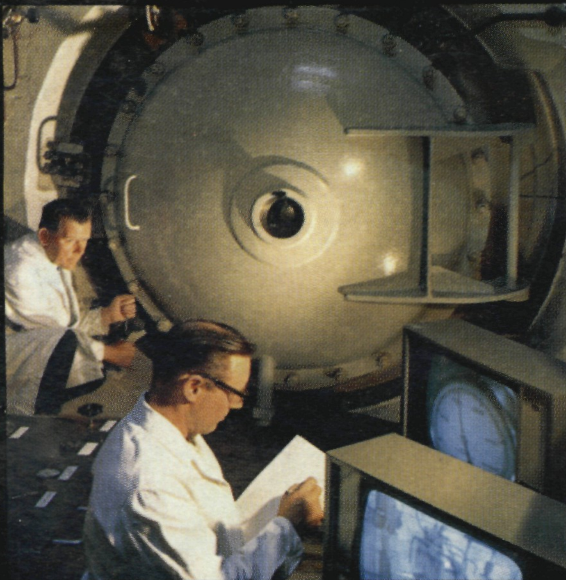
The method generally envisaged is that of generating controlled thermonuclear reactions in a very hot gas (a "plasma") which has to be confined and thermally insulated from normal surroundings by means of a magnetic field.

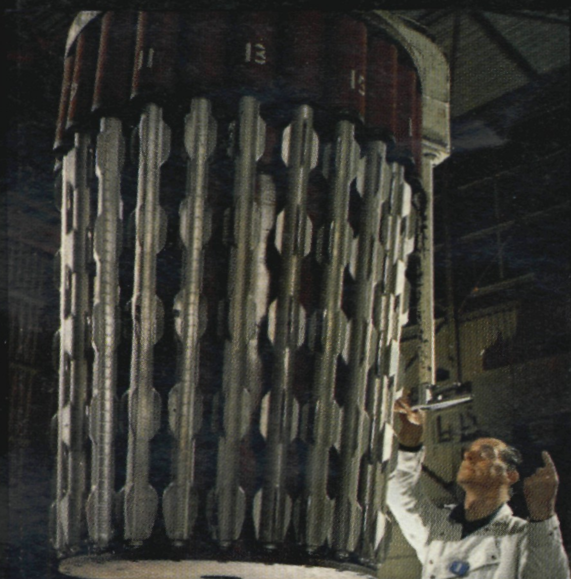
Because of the many calls on the resources of men and money, the Authority's programme of research in this field continues to be reduced in accordance with decisions made some years ago. Nevertheless the quality of the experimental and theoretical work at the Culham Laboratory of the Research Group continues to be of such a standard that the team enjoys a high reputation internationally. The progress made fully justifies, in the opinion of the Authority, the maintenance of a strong and viable programme in the United Kingdom.

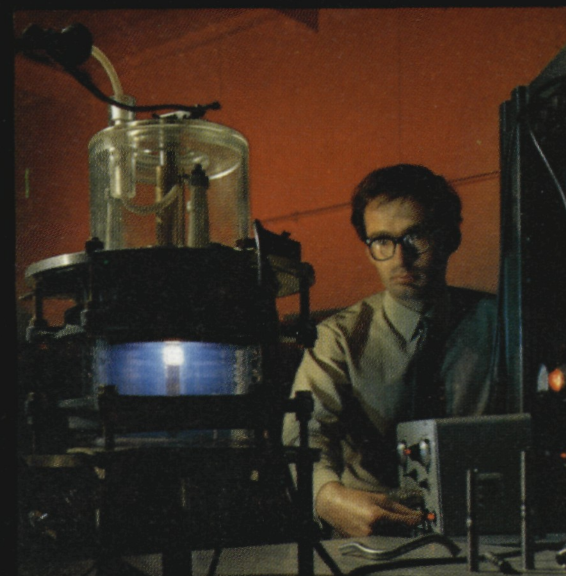
To achieve the fastest practicable rate of progress, the Authority continue to promote international collaboration in this area. Among the more striking examples of experiments carried out during the year was an Anglo-Russian collaborative investigation which, together with other experiments, reinforces the prospects for closed-line (toroidal) systems as potential reactors.

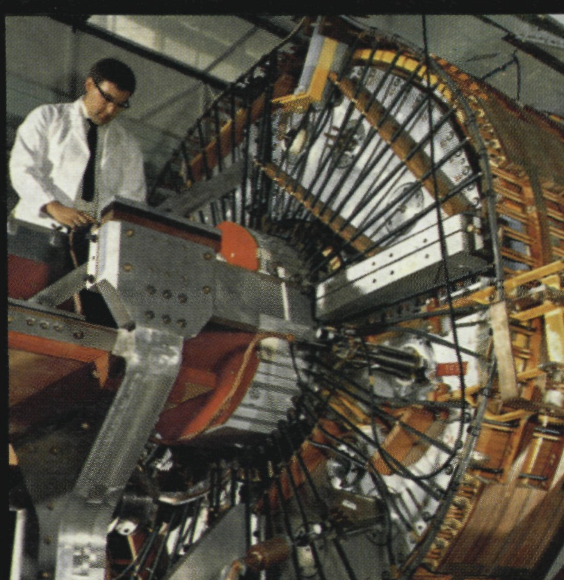
A conference on the engineering and technology of fusion reactors—the first on this subject—was held at Culham in September, sponsored by the British Nuclear Energy Society. The delegates represented a wide spectrum of engineers and scientists from 18 different countries. The first half of the proceedings covered the whole range of possible reactor systems while the second reported on specific technological problems common to most systems. Economic and environmental considerations were also covered.

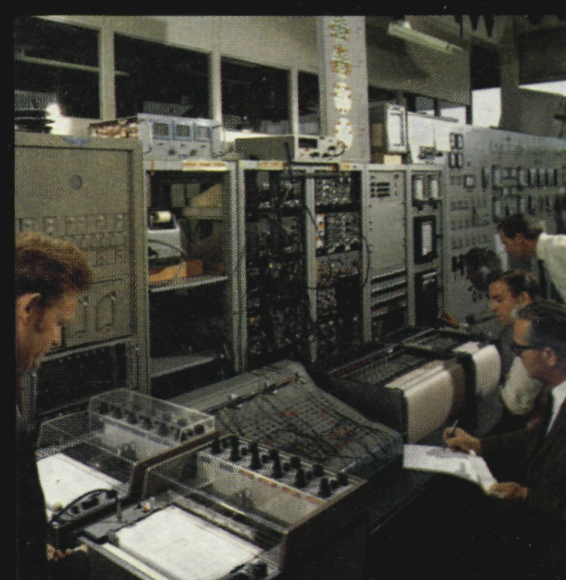
Since the conference, studies at Culham on the High Beta Toroidal Pinch system have shown that it may be feasible to design a pulsed reactor with a convenient unit size, e.g. 1000 MW(E), and that such a system may not need the large superconducting magnet which is the major cost factor in other system studies.











ABOVE (READING DOWNWARDS)

PRESSURE VESSEL TEST observed on closed circuit television (Harwell Pressure Testing Laboratory).

HERRINGBONE fuel elements being loaded into a "fuel basket" on the charge floor of one of the Calder Hall reactors.

TRIBOLOGY. The National Centre for Tribology at Risley provides a consultative service for industry and undertakes R & D on specific problems. Apparatus shown tests fibre-reinforced cages for rolling element bearings.

ABOVE (READING DOWNWARDS)

VIBRATION MEASUREMENTS of large panels to be used in the Prototype Fast Reactor (Risley Engineering and Materials Laboratory).

PILE-CAP CHECK on the Advanced Gas-Cooled Reactor at Windscale. The Mark II gas-cooled reactors of the Nuclear Power Programme are based on this design.

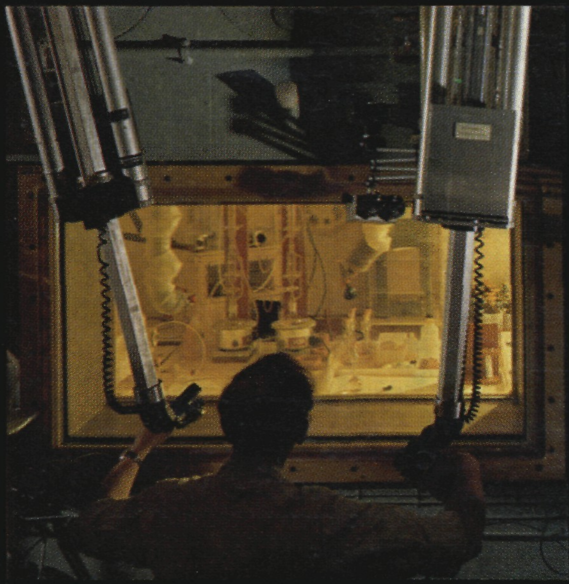
PLASMA PHYSICS and fusion research is carried out at the Culham Laboratory. Picture shows a diagnostic probe being adjusted on a toroidal multipole experiment.

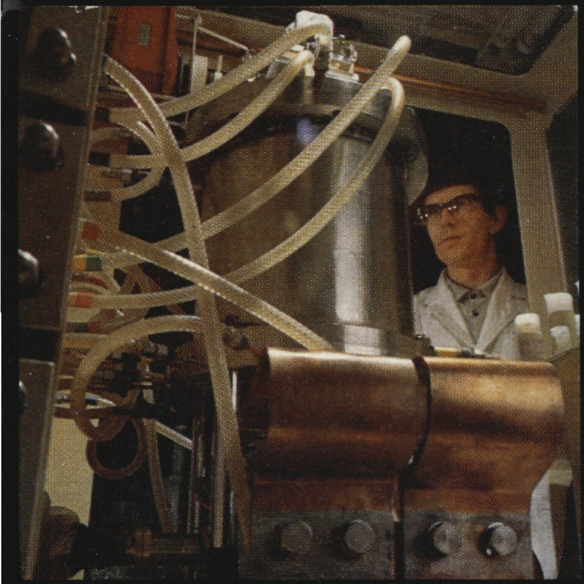
ABOVE (READING DOWNWARDS)

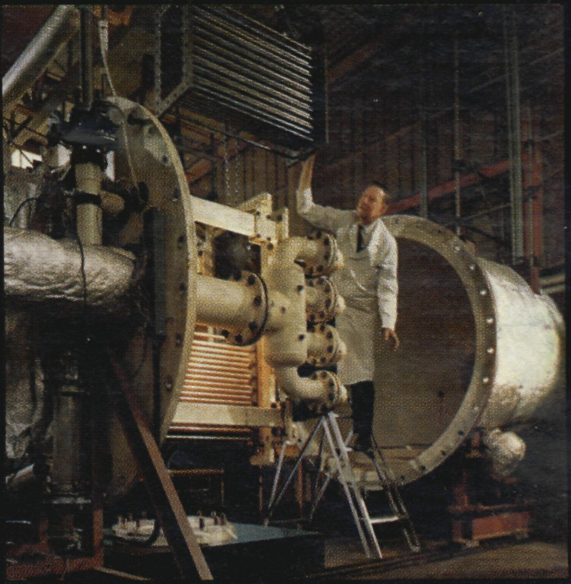
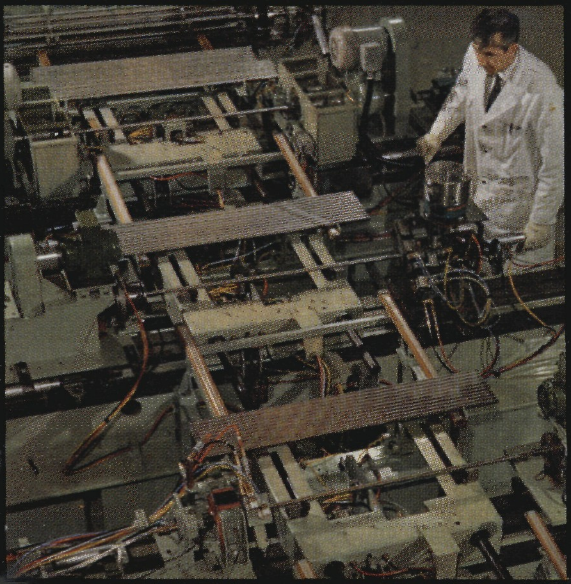
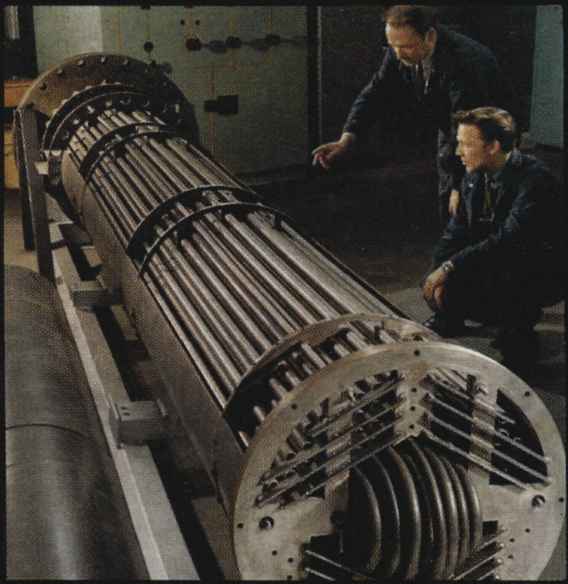
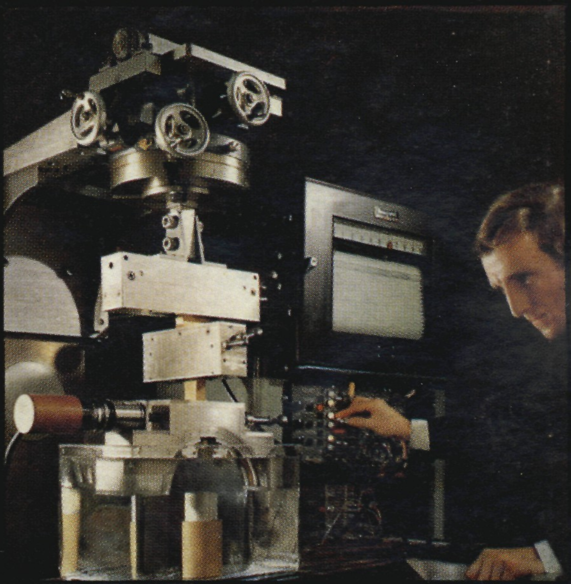
APPRENTICES under instruction in the workshops at Chapelcross (which has four "magnox" reactors similar to those at Calder Hall).

CERAMICS. Experimental "one-shot" glow discharge electron beam tube welder at the Harwell Ceramics Centre, which has a research programme geared to the needs of industry.

WATER REACTOR. The loop control room of the Steam Generating Heavy Water Reactor, at Winfrith, which is used to confirm the features of commercial designs of 450 and 600 MW(E).



ABOVE (READING DOWNWARDS)

2MV ELECTROSTATIC GENERATOR designed at Aldermaston. This model is for the Space Research Department of Birmingham University. A licence for marketing the generator has been granted to a commercial firm.

THERMAL DIFFUSIVITY. A high-temperature rig at Windscale. The operator has loaded a ceramic sample into a furnace which will heat it to 1000–2000 °C. A laser technique is used to measure conductivity.

FUEL for the Mark II Gas-Cooled Reactor (AGR). Automatic trimming and welding of fuel pins at Springfields.

ABOVE (READING DOWNWARDS)

ACTIVATION ANALYSIS. Experience of this technique acquired during reactor fuel development is now more widely available on a commercial basis through Harwell's Analytical Research and Development Unit.

URANIUM arrives at the Authority's Springfields factory in the form of "concentrate"—crude uranium oxide which has had the mined impurities removed.

FAST REACTORS. Model of an evaporator unit (for the Prototype Fast Reactor) being prepared for test in a sodium/water reaction rig at Dounreay.

ABOVE (READING DOWNWARDS)

CARBON-14. Carbohydrates labelled with Carbon-14 are prepared by photosynthesis at the Radiochemical Centre, Amersham, which received the Queen's Award for its innovations in this field.

DESALINATION. The Authority co-ordinate desalination R & D (by industry and others) on a national basis. Picture shows a condenser test rig at Winfrith.

NDT Since it was set up in 1967 the Non-Destructive Testing Centre at Harwell has carried out sponsored R & D for many industrial organisations. A wide range of equipment includes the automated ultrasonic goniometer shown here.

Applied nuclear R&D

A VALUABLE PROGRAMME of nuclear research and development (i.e. other than that in support of reactors) is being maintained. Of special interest at a time when environmental problems are undergoing some scrutiny, is the further exploitation of radioactive tracer techniques to study the movement of ground- and surface-water and the deposit of silt at the mouths of estuaries.

The aim of the hydrological tracer and coastal sediment project at Harwell is to make radioactive tracer techniques available to industry and public bodies for measuring the movement of silt and of ground and surface water, and for determining the age of ground water bodies. Measurements for studying water movement were carried out under contract from the Natural Environment Research Council and the Water Resources Board. Several enquiries were received and quotations given for coastal water pollution and siltation studies, including one major operation overseas.

New uses of radioactive tracer techniques and radioisotope instruments in industry are constantly arising. Such instruments are usually compact and well-suited for field and laboratory use and for on-line measuring systems.

Recent developments include improved coal-ash monitors; one, designed in conjunction with the National Coal Board, accepts a top-size of only one-sixteenth of an inch and is to be installed at Lynemouth Colliery to control blending of coal supplies for the new ALCAN aluminium smelter. Another instrument measures the thickness of solder on brass-strip in the manufacture of car radiators.

In contrast to these applications of minute quantities of radioisotopes are the large "irradiation sources" which are used industrially for the sterilisation of surgical and similar products. Firms licensed to use Authority designs for equipment of this kind are currently constructing three new plants: one for Gammarad, SA, Bologna, Italy; one for Gamma Radiation Services, Ltd., Reading; and one for a pharmaceutical firm in the South of England. These bring the total of British-built plants to 15—seven of them overseas.

Industrial interest is growing in the process for producing composites by impregnating natural wood (or wood products) with a monomer which is polymerised *in situ* by high energy irradiation. The resulting products, harder and less likely to warp than ordinary wood, are being used for knife-handles, hairbrush-backs, etc., and are already on sale in the UK and North America. Tests are being carried out on veneers and wood-flooring prepared in this way and R & D is being extended to fibre boards, paper and concrete.

The curing of paints by electron-beam irradiation promises technical advantages over curing by heat because of its speed; progress has been made in the commercial exploitation of this technique.

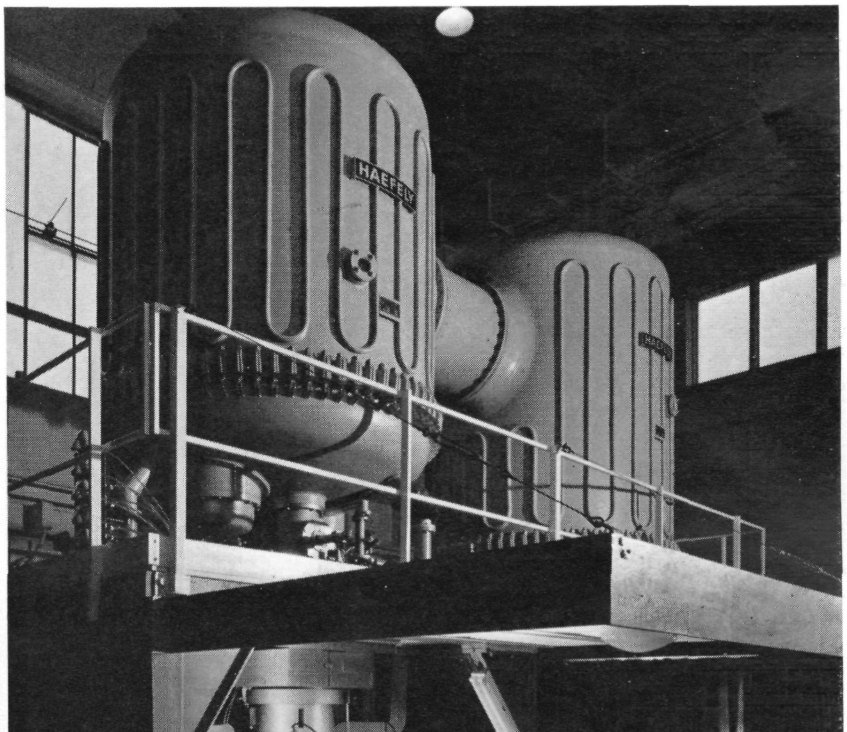
One new Harwell project (NUTMAQ) has as its objective the application of nuclear instrumentation in the mining and quarrying industry to help in locating and developing new sources of minerals. Some of the electronic instruments and techniques developed for uranium prospecting have already been adapted for application in other fields. Borehole probes developed under contract from Consolidated Goldfields, Ltd., for use in tin-mines, are to be manufactured under licence by Ekco Electronics, Ltd., and the first commercial prototype equipment will soon be available.

PACEMAKER. Harwell scientists have developed an isotope-powered thermoelectric battery which will power a heart pacemaker for 10 years (as compared with the 2-year life of the normal machine). Two successful implants were made in patients at the National Heart Hospital, London, in July, 1970.

Development of the battery took place at Harwell and its integration into a pacemaker involved collaboration with Aldermaston, Devices Implants, Ltd., the Institute of Cardiology and the Dept. of Health and Social Security. Seen above is Dr. Michael Poole, head of the Applied Physics Group at Harwell and Dr. John Myatt who played a large part in the development work.

CHINA CLAY. Isotope tracers being used aboard MV "Margareta B" during experiments off Dodman Point to determine a possible position for a pipeline that could carry away waste from the Cornish china clay pits.

THE VARIABLE GEOMETRY ISOTOPE SEPARATOR developed at Harwell is now being manufactured under licence by Lintott Engineering, Ltd. Several models have been sold, including one to the USA.



MILLION VOLT ELECTRON MICROSCOPE. The first of three such machines to be built by GEC-AEI (Electronics) Ltd. was delivered to Harwell early in 1970. Harwell and the other customers (NPL and SRC) were actively involved in its design.

Non-nuclear R&D

THE AUTHORITY have co-operated with private industry in developing many technologies and products. This partnership began, naturally, in the nuclear power sector, but Authority staff have, over the years, come to understand how their skills may help firms over a wider front. This is a result of the many applications the Authority have helped to devise and introduce, either for instruments incorporating radioisotopes or for large irradiation sources.

Since the Science and Technology Act of 1965 the Authority have been able to extend this co-operation. They are now authorised to make available, to industry in general, the skills which—though originally acquired as part of research and development with specifically nuclear objectives—have obviously useful applications in a variety of other directions.

A typical example of this evolutionary process is the Authority's participation in desalination development (their first major "non-nuclear" project). Their work on the design of the first Steam Generating Heavy Water Reactor gave them a valuable insight into problems associated with heat-transfer and the two-phase flow of liquids, knowledge which is equally applicable to flash distillation plants for the de-salting of sea-water. They were therefore given, by Ministerial direction, the task of co-ordinating all desalination research, by industry and others, on a national basis. Although the major effort is at present concentrated on the two techniques that are currently of most commercial interest—flash-distillation and electrodialysis—much significant work is being done on more novel processes such as freezing and reverse osmosis. The last of these has a considerable potential for other purposes such as the purification of polluted water.

Other major projects are the Ceramics Centre and the Non-Destructive Testing Centre. Both of these are based at Harwell and each has a programme which is planned by an advisory committee representing industry, research associations and other interested organisations. Both committees have endorsed the value of the work and recommended its continuance.

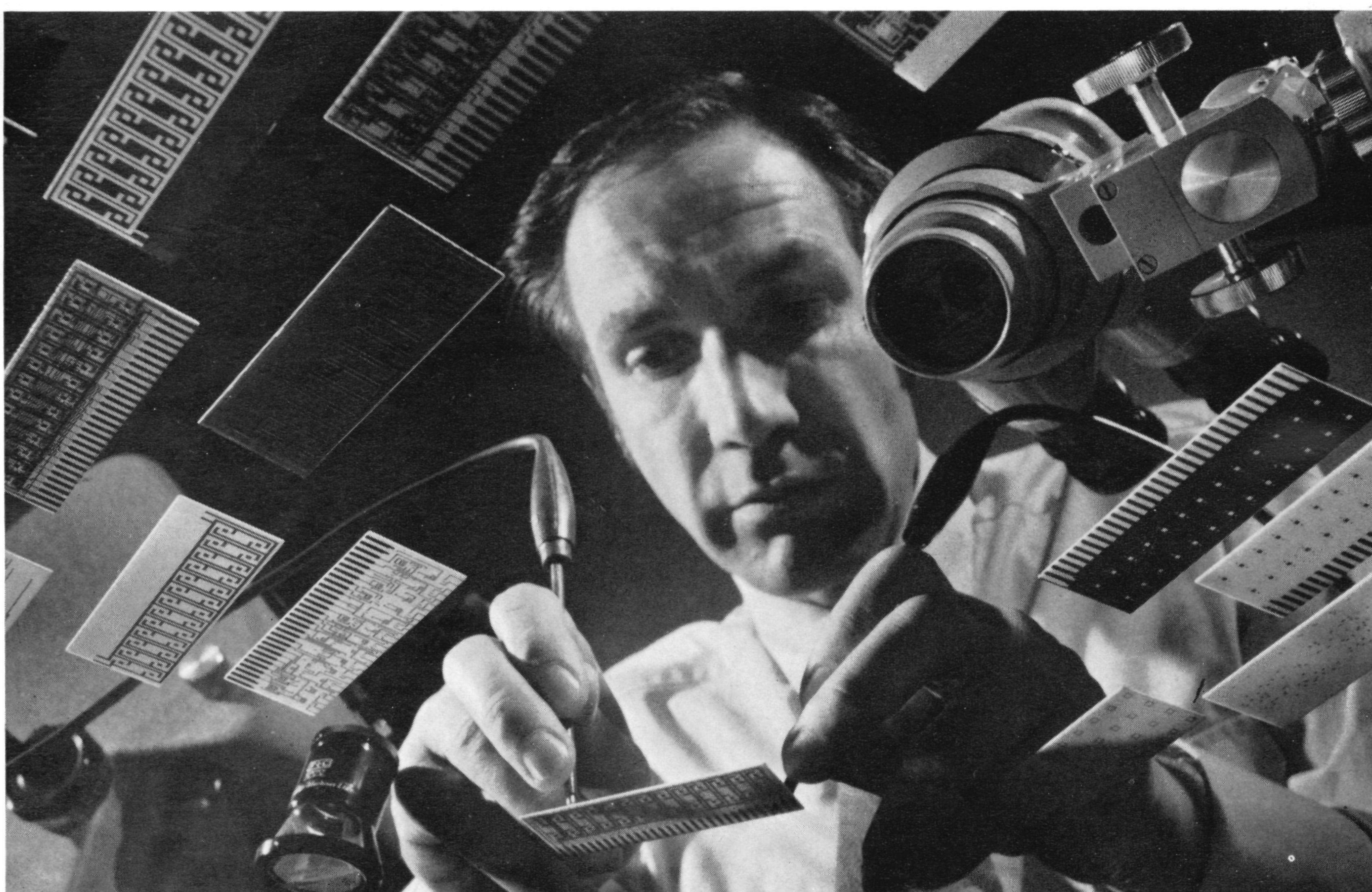
In the last five years the percentage of the Authority's scientists and engineers engaged on these and similar projects has increased from 1·5 to 12·7. Activities deserving particular mention are those of the Tribology Centre at Risley, which has signed nearly 100 contracts with industry, and the work at Aldermaston in the medical field, to develop—for example—materials for artificial kidneys or surgical implants.

In 1969/70, fifteen new projects under existing Ministerial requirements were approved; five under Electro-Technology; four under Quality Control; two each under Improved Utilisation of Steels and Marine Technology; and single projects under Atmospheric Pollution and Ceramics.

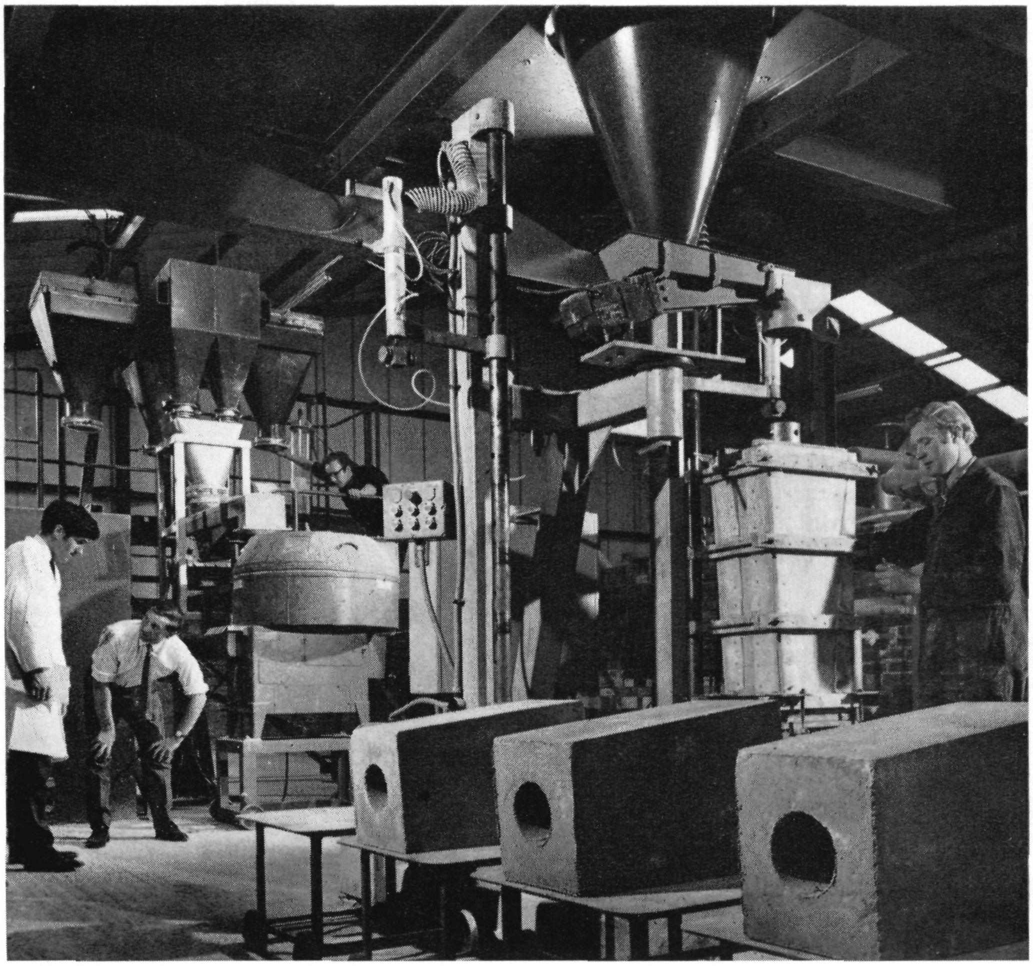
The Authority's non-nuclear programmes are of three broad types: centres and multi-purpose projects equipped to serve numbers of clients on advisory, repayment or collaborative terms; specific projects, concentrating upon particular industrial or other objectives; and work under contract mainly for Government departments (principally at AWRE Aldermaston).

An interesting example of the transfer of a technique from the nuclear to the non-nuclear field is that of "laser anemometry". Originally designed to study heat-transfer in nuclear reactors, it is now being developed at Harwell for ground-based measurement of wind-velocity to assist the safe landing of large aircraft.

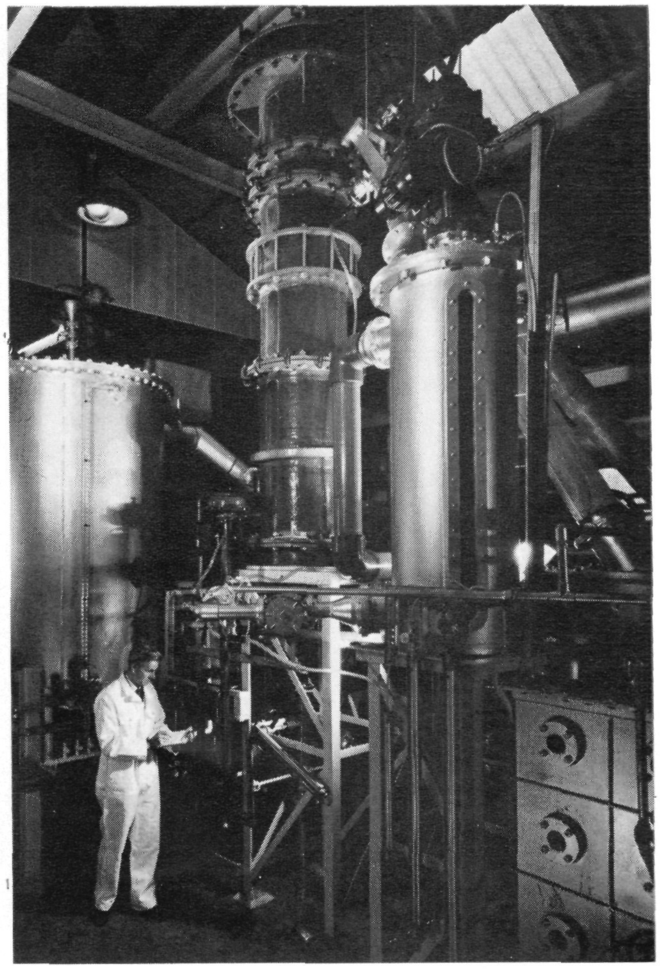
This work is financed in various ways (which reflect the objectives of the sponsors). A single project may comprise a technological research element; advisory and consultative work; and short term jobs on direct repayment; as well as the primary task of collaborating with industry upon advanced technological developments from which the Authority may receive royalties over a period of years.



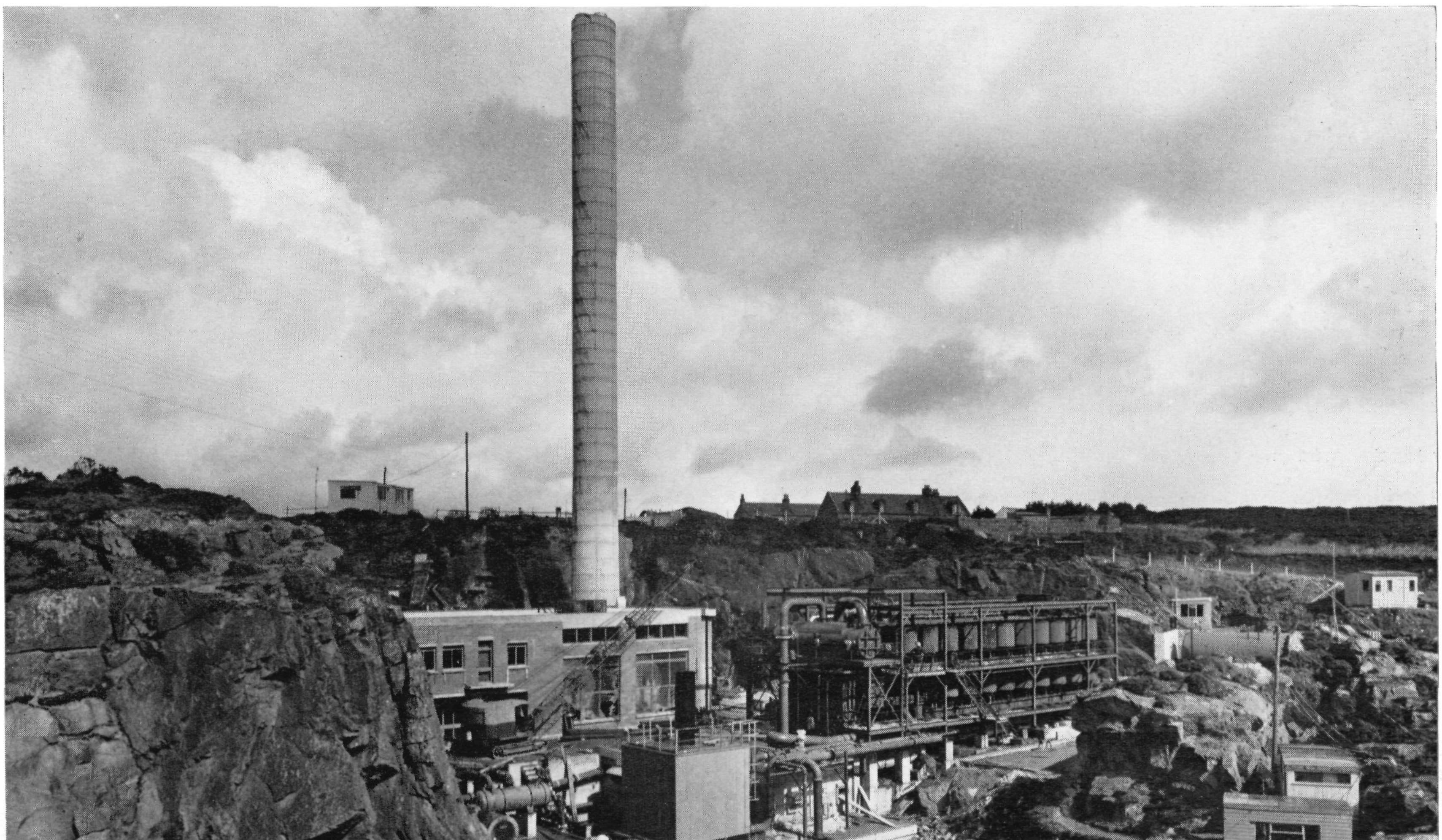
MINIATURISED COMPUTER CIRCUITS. Aldermaston have produced circuits with nine layers containing 200 through-connects between layers and 1000 crossovers. A research and development scheme is being worked out with the Ministry of Technology and industry.



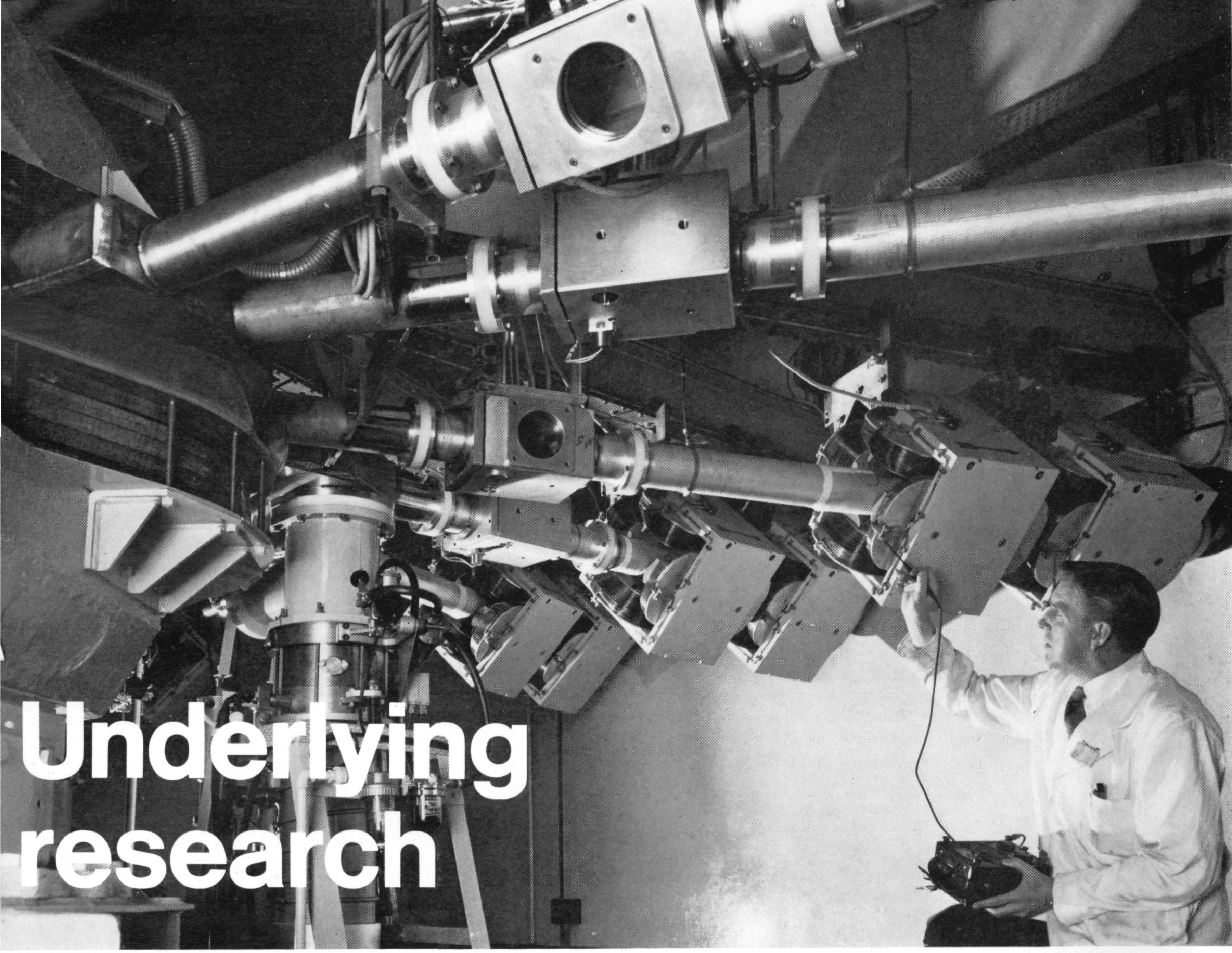
CERAMICS. This prototype vibro-compaction plant has been installed at the Worksop Works of GR-Stein Refractories, Ltd., under a collaborative agreement with the Harwell Ceramics Centre. This Centre was one of the earliest of Harwell's "diversification" projects.



FREEZING. This 10,000-gallons-per-day pilot desalination plant has been built at Simon Carves Ltd. (Stockport). Work continues with the earlier 700 g.p.d. plant at Harwell.



THE 1,500,000 GALLON a day desalination plant built for the Jersey New Waterworks Co. by Weir Westgarth Ltd. The plant, shown here nearing completion, contains design features resulting from the joint AEA/industry R & D programme on desalination.



Underlying research

THE AUTHORITY's reactor development and other applied programmes are supported on the one hand by underlying research, and on the other by an extensive range of major research facilities, including materials testing reactors, particle accelerators, post-irradiation examination cells, radiochemical laboratories and computers.

A balanced programme of underlying research in the relevant scientific disciplines is essential to the proper development of the reactor, applied nuclear and non-nuclear research programmes. The ability to mount good quality applied programmes, sometimes at short notice, also owes much to the broad interests and technical skills of the workers associated with this type of research.

The Authority are concentrating on research into lines associated with known fields of application, tempered by the need to maintain research of high quality in a wide range of scientific disciplines. Above all, the purpose of the underlying programme is to ensure that there is the ability to meet those applied problems which require the multi-disciplinary approach—an approach which is so hard to achieve in a normal industrial laboratory. It is also essential to maintain that ability over the period when technological evolutions based on today's science will need skilled and rapid exploitation.

The major research facilities were built up over many years to further the reactor and nuclear R & D programmes. Their use also by universities, industry and other organisations is steadily increasing, and the Authority now derive a significant income from these sources. The use of the particle accelerators for nuclear physics experiments and of research reactors for neutron beam work by Universities (under an agreement with the Science Research Council) continues to grow.

Commercial services are also being offered to the nuclear industry at home and abroad (e.g. by the use of loops and other testing facilities, irradiation space, especially in DFR—for which there is a high demand from overseas—and post-irradiation examination cells). Some computer facilities are being made available, e.g. with access through GPO Datel lines, to industrial firms associated with reactor development or with applied nuclear and non-nuclear projects.

The practical value of this type of experimental work can be illustrated by the following example. Materials subjected to ion-beams from the Variable Energy Cyclotron at Harwell can receive *in two weeks* the equivalent of a 30-year "irradiation dose" in a fast reactor.

THE VARIABLE ENERGY CYCLOTRON at Harwell is one of the most versatile instruments of its kind in the world. Its programme continues to expand and about 60 different extracted beams can now be offered.

Advances in the scientific understanding of the structure of nuclei and the way they interact with nuclear particles, and improvements in the technology of nuclear measurements have a strong bearing on the determination of nuclear data for reactors. Such nuclear studies are carried out almost entirely on the particle accelerators at Harwell which is the best-equipped laboratory in the country for this subject.

A research reactor (of the HERALD type, used at Aldermaston), together with associated equipment, is being supplied by Fairey Engineering, Ltd., for installation by the Chilean Nuclear Energy Commission at their new nuclear centre in Santiago and a training programme for some of the Commission's engineers and technicians was arranged which included work on the Aldermaston HERALD and on the HELEN assembly at Winfrith.

THE RADIOCHEMICAL CENTRE

THE RADIOCHEMICAL CENTRE at Amersham had a busy and extremely successful year. Sales of radioactive products increased by over 22 per cent to £4 million, of which £2·4 million (60 per cent) was exported. The Centre's achievements were marked at the end of the year by the grant—for the second time in four years—of the Queen's award to Industry. This was made in recognition of the Centre's technological innovation in the production of the important radioisotope carbon-14 and its compounds.

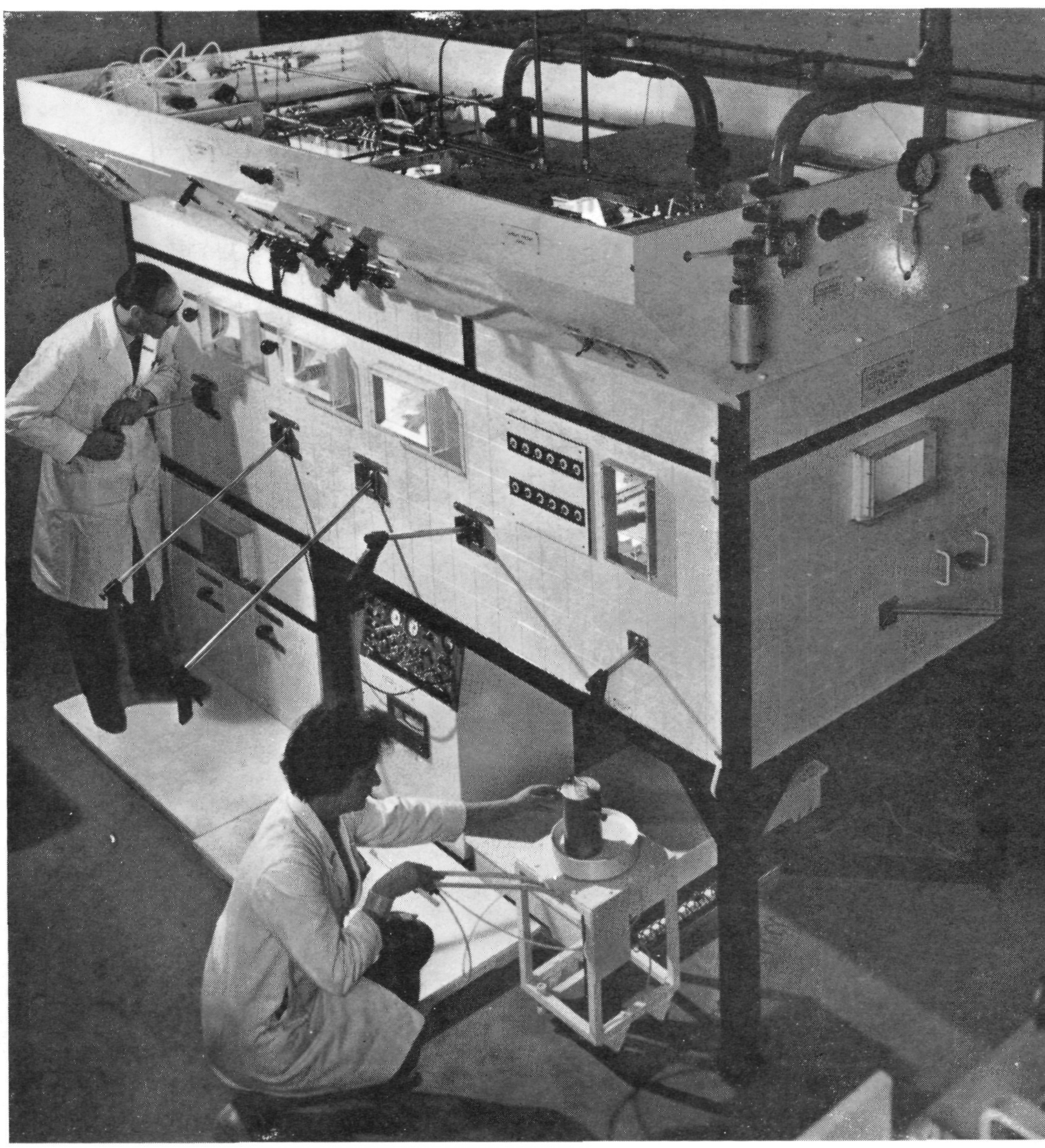
Selling prices were held steady throughout the year, and so the rise in sales value represented a real increase in volume of business, as was indicated also by a growth of 25 per cent in the number of consignments of products from the Centre which totalled 105,000 in the year.

The growth of sales was well spread over the main product groups of chemicals and labelled compounds, radiopharmaceuticals, and radiation sources. Useful progress was made in several territories, particularly in West Germany; and the Amersham/Searle Corporation consolidated its position in the American markets.

By using the heavy water reactors DIDO and PLUTO at Harwell, it was possible for the first time to supply the whole of the teletherapy requirements for high quality cobalt-60 in the National Health Service. At the same time, over one million curies of industrial cobalt-60 were delivered to users from the Isotope Production Unit at Harwell.

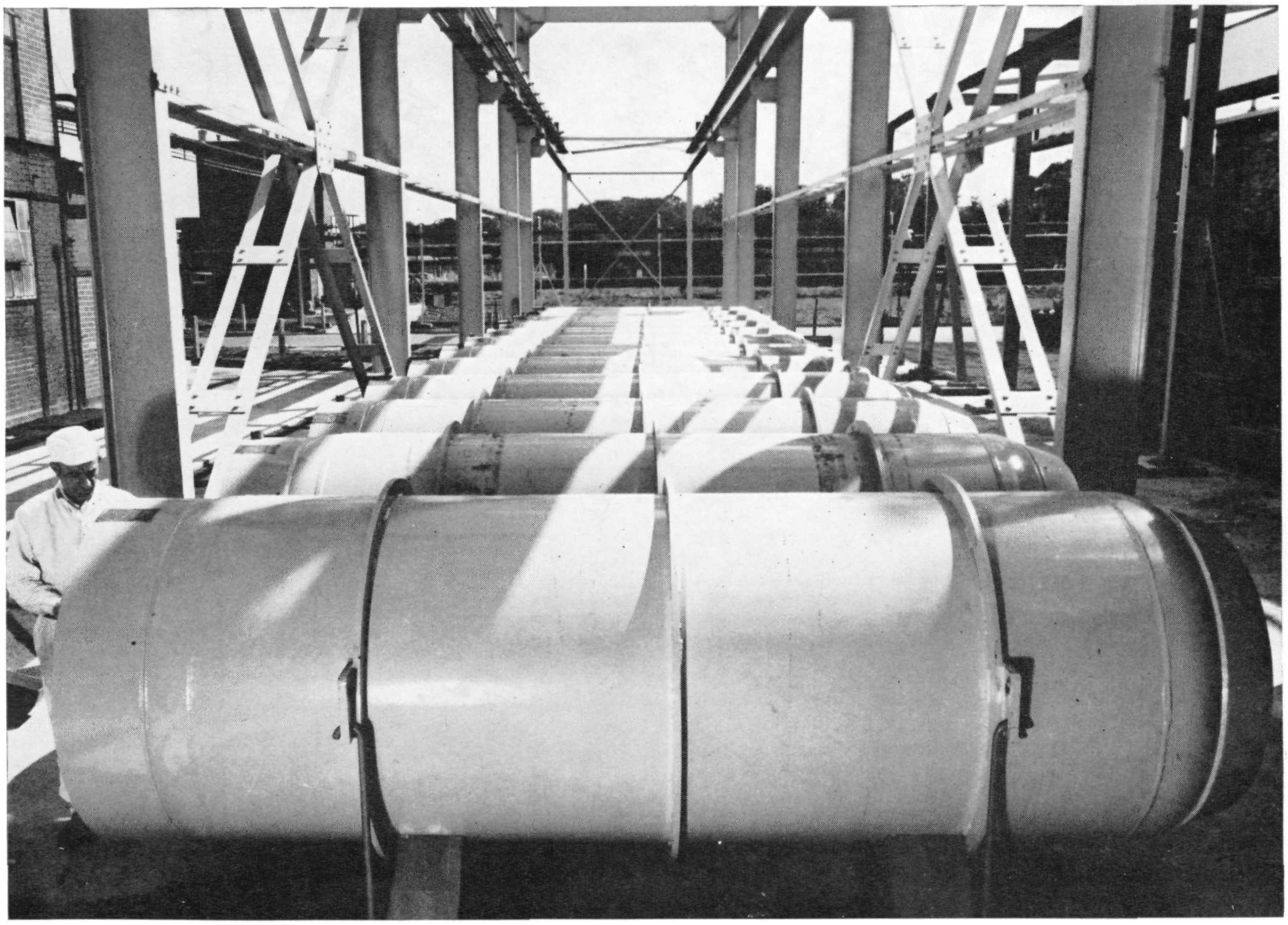
DR. W. P. GROVE (Director) holding aloft the Queen's Award for Industry, which the Radiochemical Centre, Amersham, has been granted twice in four years. Also in the photograph (left to right) are: The Lord Lieutenant of Buckinghamshire, Major J. D. Young; Sir John Hill, Chairman of the Authority; and Sir Charles Cunningham, Deputy Chairman.

IRRADIATION. Magnesium alloy capsules being loaded with cobalt chloride pellets prior to neutron irradiation.

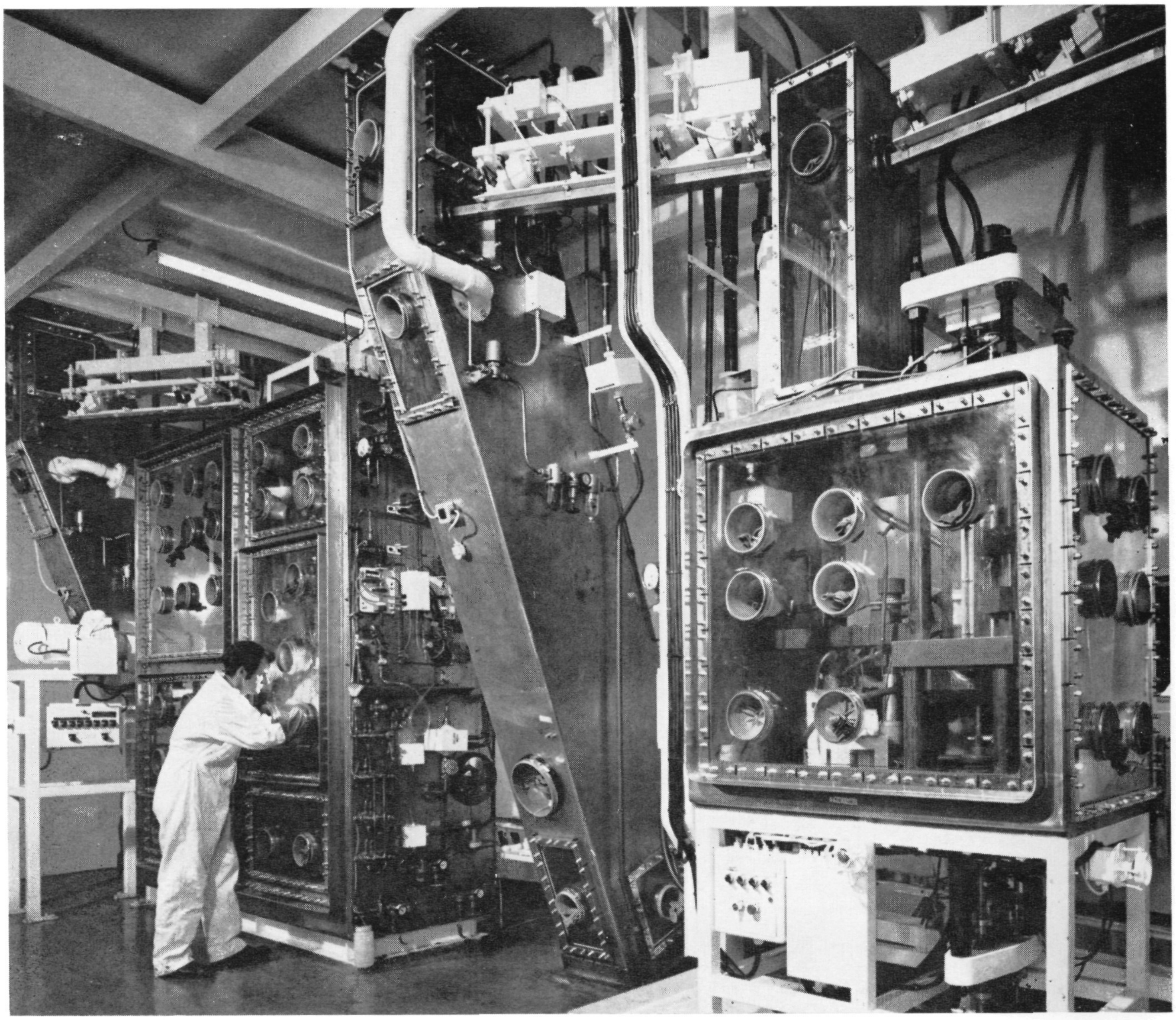


PHARMACEUTICAL DEPARTMENT. Processing iodine-125 inside a shielded cell. Improved recruitment of scientists during 1968/9 has enabled a large programme of development to be carried out in all departments.

Nuclear fuel

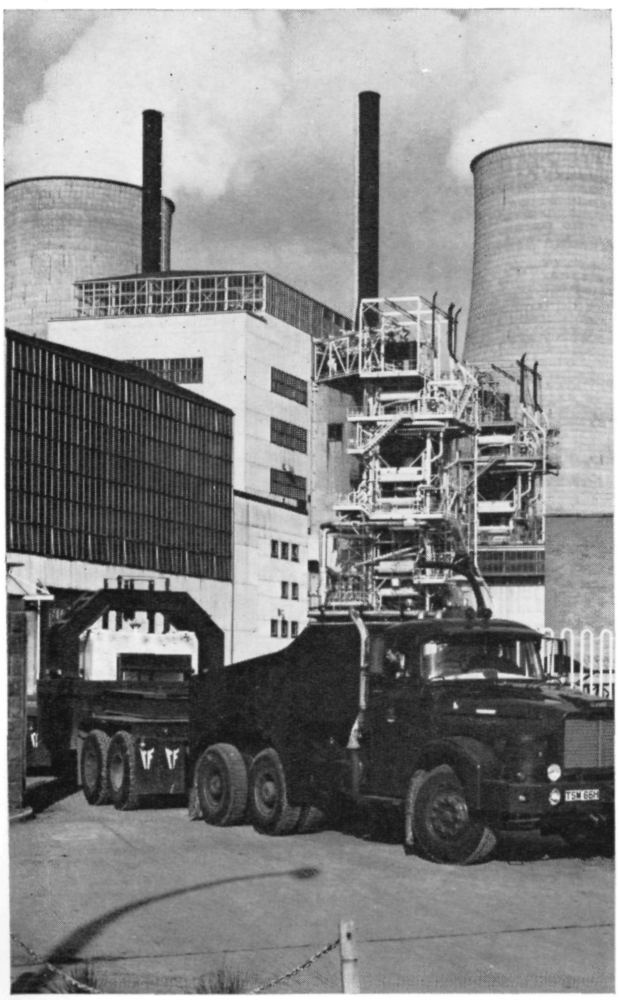


HEX. Uranium hexafluoride cylinders at the Springfields plant. Each has a capacity of 12 tonnes.



FAST REACTORS. Part of the plant at Windscale being used for the manufacture of fuel for the Prototype Fast Reactor at Dounreay.

FOR THE U.S.A. Part of a consignment of 222 tonnes of uranium hexafluoride, from Springfields, on its way to a United States diffusion plant, being loaded at Liverpool.



TRANSPORT. Spent fuel leaving Chapelcross Nuclear Power Station in Dumfriesshire on its way to Windscale in Cumberland for re-processing.

New facilities

New facilities, which had been introduced in 1968/69 for fuel cycle services for enriched uranium oxide fuel, were brought into full operation at Springfields during 1969/70 with a consequential change in emphasis in the production pattern. Requirements of magnox fuel for replacement purposes will be substantial but the manufacturer of enriched uranium fuel for Mk. II gas-cooled reactors (the second nuclear power programme) has become the major technical task.

The reduction in work load resulting from the completion of the initial charges for magnox stations, was more than compensated by the increased requirements for enriched uranium from Capenhurst and for oxide fuel from Springfields involving processes of considerably increased complexity. In spite of this, there was a slight reduction in the total manpower employed in Production Group during the course of the year. The upward trend in productivity has continued with the use of improved equipment and the extension of incentive bonus schemes.

PFR fuel

At Springfields, production began of breeder fuel for the Prototype Fast Reactor (PFR). At Capenhurst, recommissioning of re-constructed plant for the production of enriched uranium by the diffusion process was completed. There was a 15 per cent rise in throughput of irradiated fuel at the Windscale reprocessing plants.

Production reactors at Calder Hall and Chapelcross continued to operate at full power and at load factors above 90 per cent with the exception of Chapelcross No. 2 reactor which was brought back into operation after a two-year shutdown.

Export activities

The value of export sales completed during the year was £4·4 million and the total value of new export contracts signed and letters of intent received was £7·1 million. At the end of the year, outstanding export business covered either by long- or short-term contracts was valued at approximately £20 million.

Sales were made to Australia, Belgium, Canada, Denmark, Finland, Holland, India, Italy, Japan, New Zealand, South Africa, Spain, Sweden, Switzerland, USA and West Germany.

New contracts won included three for the fabrication of plutonium fuel, for PNC Japan, GFK West Germany, and EIR Switzerland, and two for the transport and reprocessing of irradiated oxide fuel, from the Zorita reactor in Spain and Oskarshamn Reactor No. 1 in Sweden. Despite keener competition, the volume of business for conversion of uranium ore concentrate to uranium hexafluoride increased considerably during the year, in particular on behalf of customers in West Germany.

Combustibili Nucleari, the company in Italy owned jointly by the Authority and Società Minerali Radioattivi Energia Nucleare, completed commissioning of the magnox fuel plant at Rotondella, and an appreciable quantity of replacement fuel for the Latina reactor was manufactured.

An agreement was signed with Gulf General Atomic for technical collaboration with a view to establishing a joint company to supply light water reactor fuel to the United States market. In later years, it is envisaged that a fuel fabrication plant will be built in the USA in which the Authority will be a minority shareholder, but in the meantime the facilities at Springfields will be used to meet orders secured by the joint enterprise.

Centrifuge

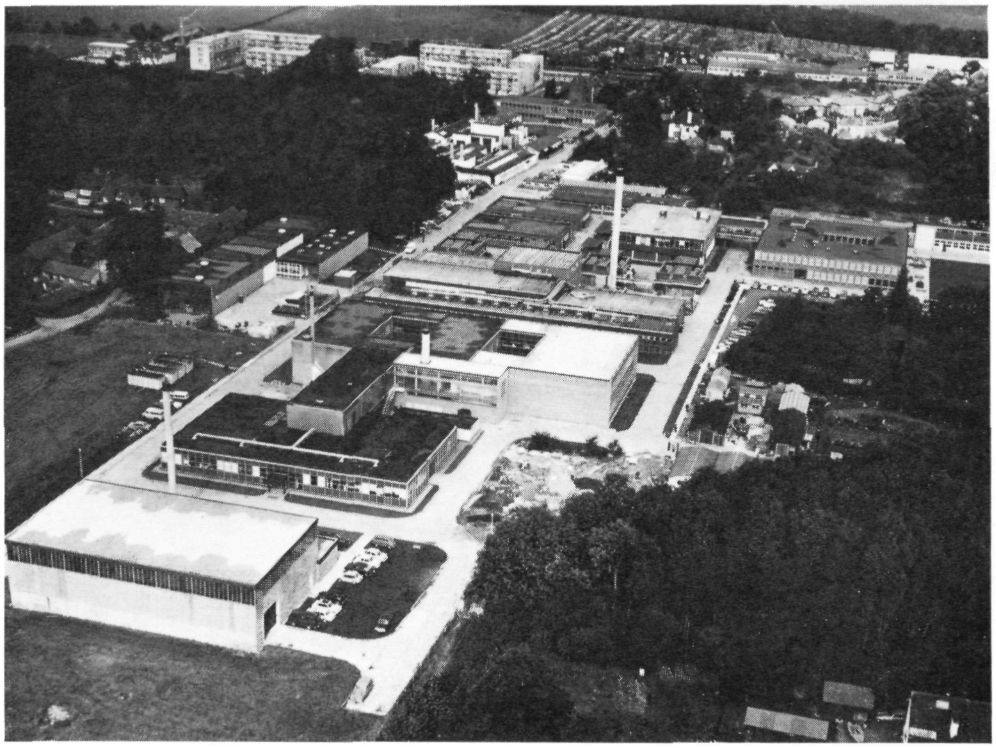
The negotiations between the British, German and Dutch Governments resulted in the signature at Almelo in Holland on 4th March of an "Agreement on Collaboration in the Development and Exploitation of the Gas Centrifuge Process for Producing Enriched Uranium". This agreement provides for the establishment and operation of joint industrial enterprises to build and operate gas centrifuge plants. Shareholdings in these joint enterprises will be divided between industrial interests in the three countries. The initial UK shareholder will be the Atomic Energy Authority, which will transfer its shareholding to British Nuclear Fuels, Ltd., if and when that company is established. At the end of the year under review, detailed negotiations were proceeding between the industrial interests concerning the establishment of the two industrial enterprises, and the drafting of Articles of Association.

The three Governments agreed that centrifuge plants should be constructed at Almelo and Capenhurst and that they should be owned by the joint enterprise (though possibly operated on its behalf by the Dutch and British shareholders respectively). It is expected that the first stage of the initial centrifuge plant at Capenhurst will be commissioned in 1972 and that the eventual capacity of the fully completed plant will be 40–50 tonnes separative work a year.

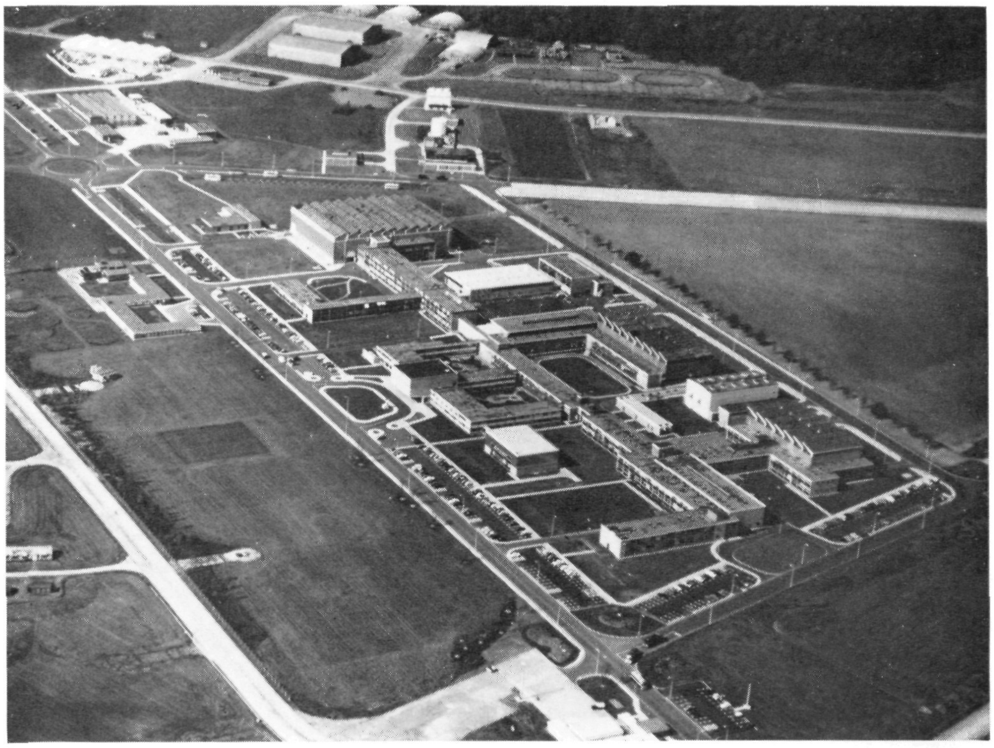
UKAEA REACTORS

1 GLEEP	*Harwell*	Routine testing of the quality of graphite and uranium. Research with oscillator. Biological irradiations.
2 LIDO	*Harwell*	Thermal reactor studies including shielding and neutron spectra measurements.
3 DIDO	*Harwell*	Studies of nuclear reactor materials. Isotope production. Neutron and solid state physics. Radiation chemistry.
4 PLUTO	*Harwell*	Studies of nuclear reactor materials. Isotope production. Neutron and solid state physics. Radiation chemistry.
5 HORACE	*Aldermaston*	To obtain basic nuclear information for HERALD.
6 FAST REACTOR (D.F.R.)	*Dounreay*	Fast neutron irradiation testing of advanced fuels, structural materials, etc. Development of fast reactor technology.
7 ZENITH	*Winfrith*	Reactor physics investigations for advanced graphite-moderated reactors.
8 HERALD	*Aldermaston*	Studies in neutron physics, radiochemistry and nuclear reactor materials, including work with universities and CEGB.
9 VERA	*Aldermaston*	Experimental studies of fast reactor systems.
10 NESTOR	*Winfrith*	Source of neutrons for sub-critical assemblies giving thermal fluxes of 10^8 in the assemblies.
11 DIMPLE	*Winfrith*	Testing a wide range of lattices at uniform temperatures up to about 80°C.
12 DAPHNE	*Harwell*	To simulate DIDO or PLUTO; to provide basic physics information in support of these reactors.
13 ZEBRA	*Winfrith*	Reactor physics studies of the P.F.R. and other large fast reactors.
14 HECTOR	*Winfrith*	Oscillator reactor reactivity measurements on materials and fuel elements. Temperature coefficient measurements of samples of reactor lattices.
15 JUNO	*Winfrith*	Testing a wide range of liquid-moderated lattices.
16 VIPER	*Aldermaston*	Pulsed reactor; experimental studies of the effects of intense, transient bursts of neutrons and gamma radiation.
17 ADVANCED GAS-COOLED REACTOR (A.G.R.)	*Windscale*	To study the advanced gas-cooled power reactor system and to test fuel elements for commercial A.G.R.s.
18 STEAM-GENERATING HEAVY WATER REACTOR (S.G.H.W.R.)	*Winfrith*	To obtain experience with the S.G.H.W.R. concept and to test fuel for commercial S.G.H.W.R.s.
19 PROTOTYPE FAST REACTOR (P.F.R.) (under construction)	*Dounreay*	To obtain the information necessary for the design of high power, commercial fast reactors.
20-23 CALDER HALL (Four reactors)	*Calderbridge*	Power and plutonium production; process steam supplied to Windscale site services.
24-27 CHAPELCROSS (Four reactors)	*Annan*	Power and plutonium production; experimental work in aid of the U.K. power programme.

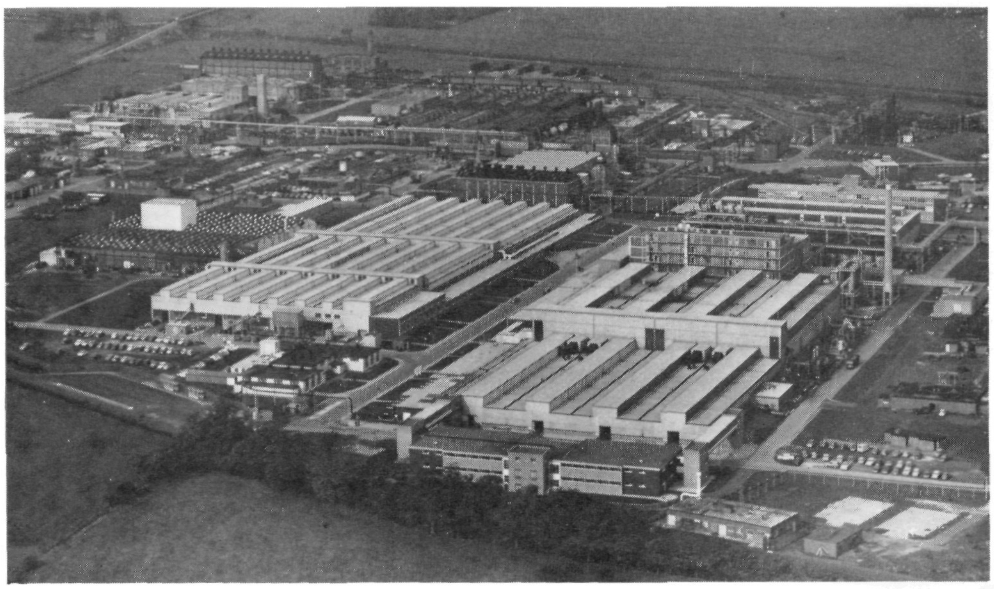
NOTE: ZEUS was dismantled in 1957, ZEPHYR and HAZEL in 1958, and NEPTUNE in 1959. NERO and DIMPLE were dismantled at Harwell and re-erected at Winfrith in 1960 and 1961 respectively. NERO was dismantled in 1963, and rebuilt as JUNO. BEPO and HERO were closed in 1968. D.M.T.R. was closed down on 12th May, 1969, under a programme of reorganisation of materials testing facilities.



AMERSHAM



CULHAM



SPRINGFIELDS

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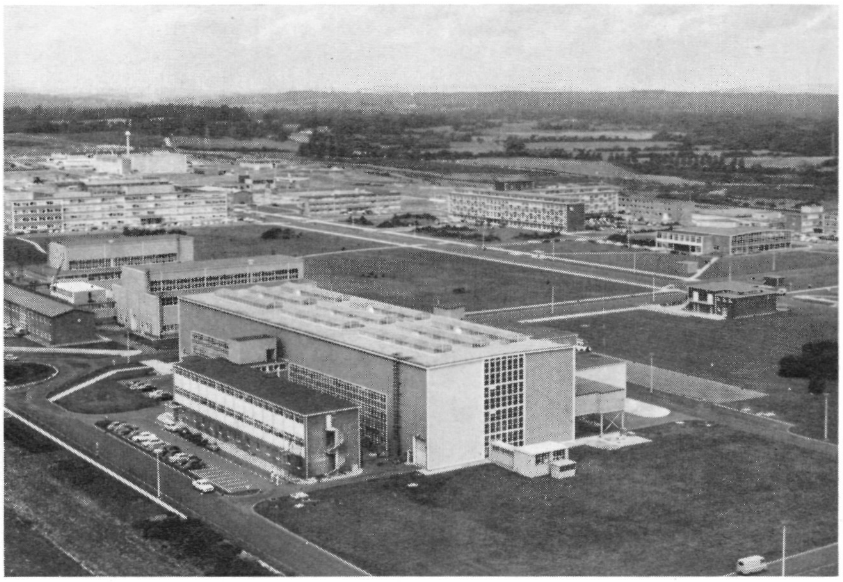
UKAEA RIGS AND SPECIAL FACILITIES

This list is not complete but indicates the wide range of facilities available.

Sodium Rigs	Several large rigs, involving ton quantities of sodium, for studying the behaviour of components and materials; smaller rigs for studying friction and wear behaviour, calibration and corrosion testing.	**Risley and Culcheth**
	Six loops and rigs for testing reactor components, and sub-assemblies in sodium and for PFR studies, e.g. primary circuits; hydrogen detection, examining movement, deposition and effects of fission products and fuel on b.c.d. equipment. Tests of cold traps, boiling noise studies, large scale sodium/water reaction tests for steam generators.	**Dounreay**
Remote Handling Laboratories	Examination of plutonium and highly enriched uranium rigs, and sub-assemblies, after irradiation in DFR, up to 0·5 million curies. Interconnected cells with inert gas facility, for rig radiography and mensuration. Smaller cells for metallography and mechanical tests of rig specimens. Neutron radiography of inactive fuel.	**Dounreay**
	Caves and other shielded facilities for handling and examination of highly radioactive fuel elements from gas- and water-cooled reactors and other alpha, beta and gamma emitters. Full range of facilities including microprobe analysers, stereo-scan and electron microscope, metrology and radiography. Design and manufacture of in-pile rigs etc.	**Windscale, Harwell and Winfrith**
Accelerators	Cockcroft-Walton generator, 3 MV pulsed Van de Graaff, 5 MV Van de Graaff, 14 MV Tandem Generator, Synchrocyclotron electron linear accelerator, variable energy cyclotron. These are used for studying ion implantation, reactor physics work, nuclear spectroscopy, radiation damage, chemical studies, detector development, basic physics, fast reactor research and liquids research.	**Harwell**
	6 MV Van de Graaff generator.	**Aldermaston**
Experimental Fuels	Authority centre for development and fabrication of fast reactor fuels.	**Windscale**
	Fabrication of plutonium-containing fuels.	**Winfrith**
	PFR prototype fuel plant for experiments into full-scale manufacture of sub-assemblies.	**Aldermaston**
	Fuel design and manufacture facilities for uranium and its alloys, ceramics, cermet fuels, etc. including melting and sintering equipment.	**Springfields**
Physics Equipment	High voltage electron microscope for examining thick specimens of uranium, carbon fibres, ceramics and studying radiation damage. Electromagnetic separator for high purity stable isotopes and ion bombardment.	**Harwell**
	Gas and water facilities for scale models of PFR components, study pressure drops and stability in flow and for hydraulic development. Sound and vibration spectrum analysis, acoustic coupling and vibration of components in liquids at temperature and under irradiation.	**Risley**
	Seaspray rig etc., for desalination flashing and other process studies.	**Winfrith**
	Out-of-pile rigs for testing AGR fuel.	**Windscale**
Heat Transfer	6 and 9 megawatt, Freon and smaller rigs, for studying full-scale simulated and actual water reactor fuel elements at high pressures, also for once-through boiler experiments. Also condenser tests, e.g. for desalination. Instruments developed for this work.	**Winfrith**
	Heat transfer and fluid flow service.	**Harwell**
	Gas-cooled flow studies using nitrogen, helium or carbon dioxide, at pressure for fuel elements, with advanced instrumentation.	**Windscale**
Metals Testing, etc.	Crack arrest test machines; brittle fracture studies and pressure vessel research.	**Culcheth**
	Hydrostatic extrusion with very large machine for use with difficult and tough alloys.	**Springfields**
	Creep and fatigue testing rigs.	**Springfields and Harwell**
Quality Control	Extensive NDT equipment for X, gamma and neutron radiography, ultrasonic tests, etc.	**Springfields, Harwell and Windscale**
Subcritical Assemblies	HELEN and other subcritical assemblies for research in water and gas-cooled reactors.	**Winfrith**
	FIFI and EAGLE for gas-cooled reactor fine structure measurements at elevated temperatures.	**Windscale**
Reactor Loops	The WAGR and SGHWR have loops for testing fuel under special conditions. The Materials Testing Reactors at Harwell have high pressure water, gas and liquid nitrogen loops as well as a cold neutron source.	**Windscale Winfrith Harwell**
Tribology	Friction and wear characteristics of materials.	**Risley**

RISLEY



WINFRITH

On the back cover (top to bottom): Dounreay, Harwell, Windscale and Calder, Capenhurst