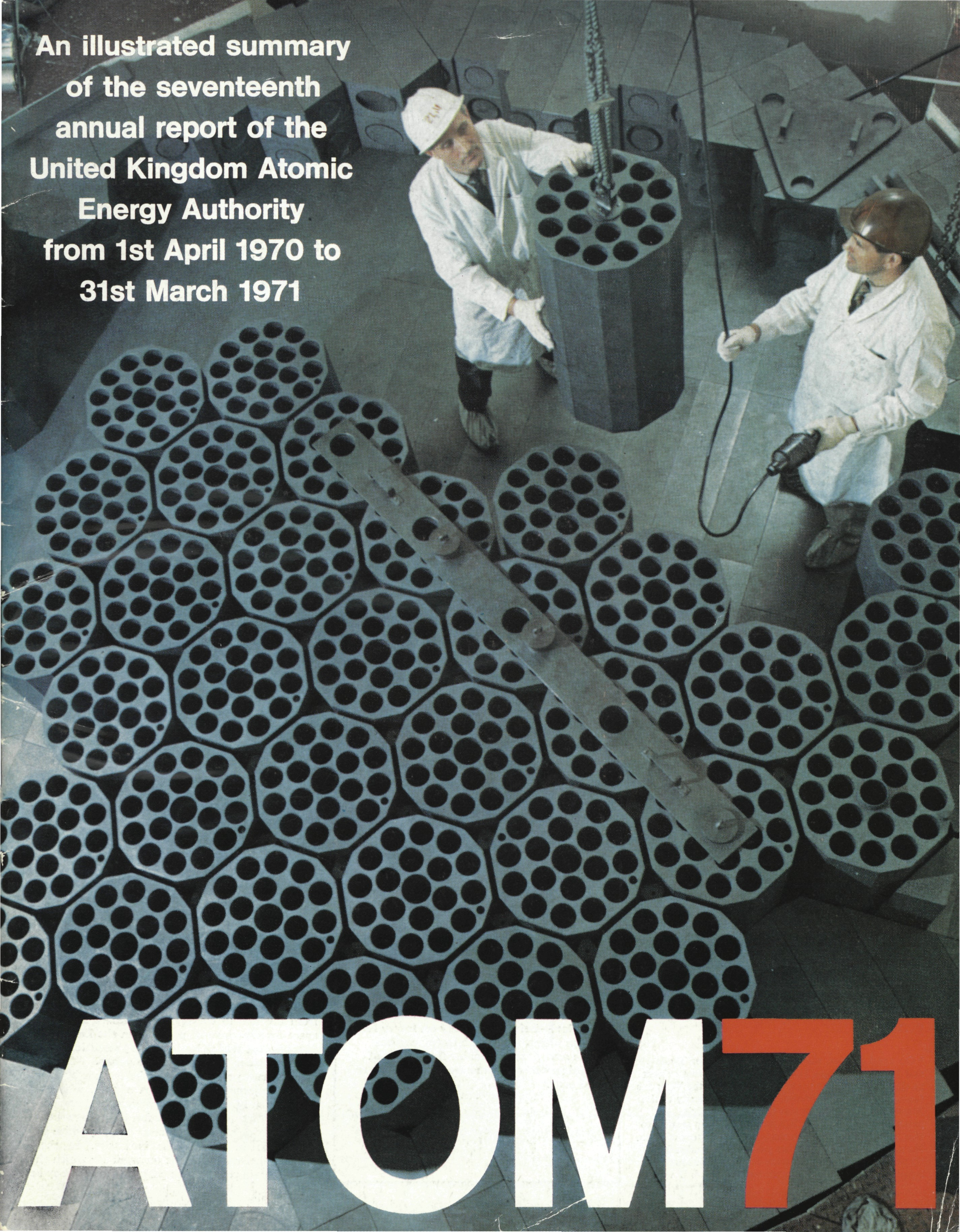
An illustrated summary of the seventeenth annual report of the United Kingdom Atomic Energy Authority from 1st April 1970 to 31st March 1971



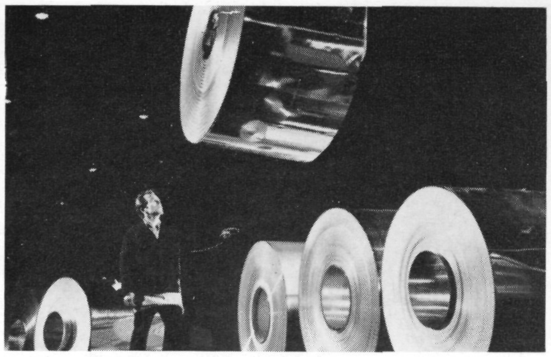
# ATOM 71

# THE UNITED KINGDOM ATOMIC ENERGY AUTHORITY 1970-71

Major decisions affecting the Authority were taken in the year 1970/71. The Atomic Energy Authority Act 1971, received the Royal Assent on 16th March 1971, and 1st April 1971 was the day on which the activities of the Authority's Trading Fund (effectively, the Production Group and the Radio-chemical Centre) were transferred to British Nuclear Fuels Ltd., and The Radiochemical Centre Ltd., respectively. 1970/71 also saw organisational changes in the Health and Safety field.

Since it was created by the Atomic Energy Authority Act 1954, the Authority have been responsible for a wide range of activities including those which are now the responsibility of the two companies. The major continuing functions of the Authority are the further development of nuclear energy for the generation of electricity, the development and manufacture of nuclear weapons*, and the continuation of the underlying work necessary to support these activities. The Authority also have played a significant role in using the skills and facilities built up to discharge its main functions to assist both the nuclear industry and industry in general.

* On 22nd August, the Secretary of State for Trade and Industry told the House of Commons that subject to the passage of the necessary legislation, the Weapons Group would be transferred from the Authority to the Ministry of Defence. It was the Government's intention to introduce a Bill in the following session so that the transfer could be made in the summer of 1972. He added—concerning other parts of the Authority: "The Government foresees the need for a substantial long-term programme of important civil R & D work."



Isotopes in Industry (page 16)

Tribology, Risley (page 18)

## Nuclear power

The significance of the Authority's work on the further development of nuclear energy for the generation of electricity—on which expenditure of over £40 million has been incurred and nearly 1500 qualified scientists and engineers employed in 1970/71 —can be gauged from the fact that it is estimated that, **in only thirty years from now, over three-quarters of all electricity in the United Kingdom will be generated from nuclear power and that more than half of this nuclear generation will stem from fast breeder reactors** (to the development of which almost half of the effort on the Authority's reactor programme is currently geared).

A further component of the Authority's R & D programme, of a longer-term character, is Culham's work towards the evolution of nuclear fusion (as distinct from fission) reactors.

The furthering of nuclear power development and generation entails close and continuing co-operation between the various bodies, governmental and industrial, concerned. The industrial interests are all represented on the Reactor Policy Committee which, with its supporting Committees, ensures a consistent approach on major issues of policy and maintains a close collaboration between the various sectors of the industry. In conformity with the conclusions on reactor policy reached by this Committee, the Authority undertake power reactor development up to the prototype stage, including, as an important part of this, the research and development on nuclear fuels up to the stage where the basic design of fuel for a reactor system has been satisfactorily formulated and proved.

The type of reactor currently under construction by industry for the UK generating boards is the Advanced (or Mk. II) Gas-Cooled Reactor. During the year under review there was started a detailed examination of all the factors bearing on the future policy for development and installation of thermal reactors in the UK. This examination involves the Department of Trade and Industry, the Generating Boards and the design and construction companies, as well as the Authority. No conclusions had been reached at the end of the period covered by this report. The Authority's future development programme in the thermal reactor field will, of course, be vitally influenced by the decisions which emerge from this review.

The Authority co-operated with the Generating Boards and the design and construction companies in a review of the programme for the development and introduction of commercial fast reactors. **It was decided that, for planning purposes, it should be envisaged that construction of the first commercial fast reactor would begin in 1974.**

**"Nuclear energy, with its very low fuel cost—even if at the moment at a relatively high capital cost and complexity—is firmly destined to be the major fuel of the future. Personally, I think that in an era of constantly expanding demand for power, the ecology of the world demands it—we cannot for ever continue to burn fossil fuels on the increasing scale required. The economies of this young technology will, in my view, point the same way. Nuclear energy is already cheaper, overall, for base load use than is coal-fired generation in this country and within striking distance of bearing comparison with untaxed oil at present prices; furthermore the comparison is likely to become more favourable as time passes.**

**"The ability of the fast reactor to produce more fissile material than it consumes is likely to be a very important aspect of fuel economy in the longer term.**

**"As time goes by, therefore, an increasing part of our basic fuel needs will be filled by nuclear energy, with fossil fuels—coal, oil or gas (according to price)—being used only on lower load factor plant, for which lower capital costs and perhaps easier flexibility of running will compensate for the higher fuel cost."**

SIR STANLEY BROWN, Chairman of the Central Electricity Generating Board, speaking on "The Next 25 Years in the Electricity Supply Industry". to the Institution of Electrical and Electronics Technician Engineers, November, 1970.

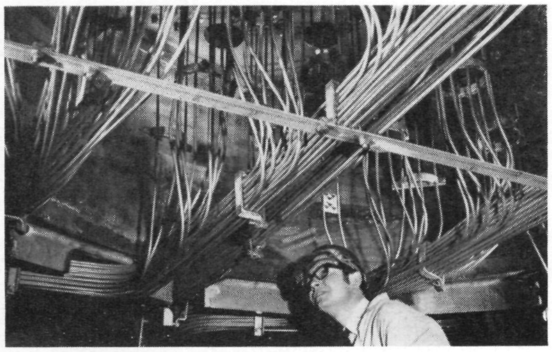
## Services to industry

Atomic energy development in the United Kingdom has now a history of about a quarter of a century. Over that time the constituent parts of the Authority have, in implementing the nuclear programmes, acquired **many skills and facilities which can be of benefit to a wide range of industries** and which, to an increasing extent, yield commercial returns to the Authority.

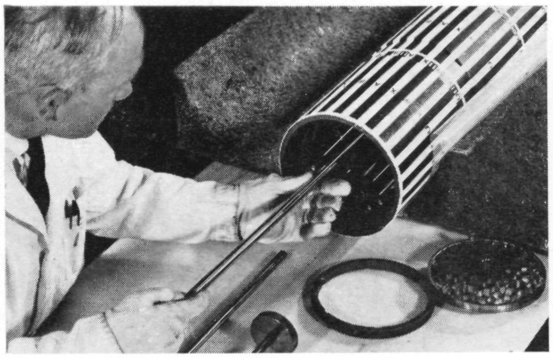
On the reactor side, the Authority play an increasing role in supporting the nuclear industry by fulfilling contract work on repayment. The two design and construction companies use a number of Authority facilities (such as the fuel handling rig at Windscale) for achieving refinements of design in the commercial reactors for which they are responsible: active handling "caves" at the Authority's Winfrith establishment are to be used by the Generating Board for the examination of fuel which has been irradiated in their own reactors.

A notably high level of income has been obtained from the sale to overseas countries of irradiation space for experimental purposes in **the Dounreay fast reactor which has earned £3 million from these sources in the last five years.**

Significant progress has also been made by many of the projects in another area of the Authority's work which has a strong commercial connotation—the provision and exploitation of "know-how" (acquired originally in a nuclear context) which has application in non-nuclear industries. In these projects the main stress is on work for which the customer will pay. In such cases the sponsor may be



Fast Reactors, Dounreay (pages 8–9)



AGR Fuel Tests, Windscale (page 6)

Reactor Instrumentation, Winfrith (pages 10–11)

either a private firm or a group of firms or—where appropriate—a Government Department. Where industry is directly involved as the sponsor, payment may either be for services performed or include an undertaking to pay royalties on the subsequent exploitation of ideas developed in, and with the assistance of, the Authority.

A major programme of work in this area is that which the Authority have been doing for desalination, that is the improvement of salt or brackish water so that it can be used for drinking or for industry. The Authority's Research Group initiated this work and the Reactor Group has joined with the Research Group in its development in close collaboration with industry. **On 17th March the Secretary of State for the Environment announced that he had approved the construction of a million-gallons-a-day pilot plant near Ipswich.** This plant would use the freezing desalination process developed by the Authority and Simon Engineering Ltd. The Water Resources Board and the Authority have been authorised to spend £2 million on the construction and operation of the plant.

## Weapons Group

The Authority continued to meet the requirements placed upon them by the Ministry of Defence. This work is concentrated in the Weapons Group and amounts to about three-quarters of the Group's overall programme, which covers both nuclear and non-nuclear defence work. The programme also includes work relating to research on verification in the field of arms control and the detection of nuclear explosions including those underground. The Authority also provide advice to the Government on the operation of safeguards under the Non-Proliferation Treaty and on problems relevant to the peaceful use of nuclear explosions.

### Radiological protection and plant safety

A further measure of reorganisation carried out during the year concerned the protection of workers in the industry and of the general public. Under the Radiological Protection Act 1970, a National Radiological Protection Board has been set up. The Board's activities include those previously carried out by the Radiological Protection Division of the Authority's Health and Safety Branch. Twenty-nine Authority staff who have been engaged on this work have joined the staff of the new Board. The Board will take over some activities of the Authority concerned with the effect of radiation hazards on health and safety, but the responsibility of Authority staff for the safety of operations under their control remains unchanged. The Safeguards Division which (like the Radiological Protection Division) previously formed part of the Authority's Health and Safety Branch has been retitled the "Authority Safety and Reliability Directorate". Its functions are to advise the Authority on the formulation of their safety and reliability policy, to apply this policy to the assessment and inspection of Authority reactors and plants, to provide advice and services to government departments and others on request and to provide a reference point for the Authority's external relations in this field.

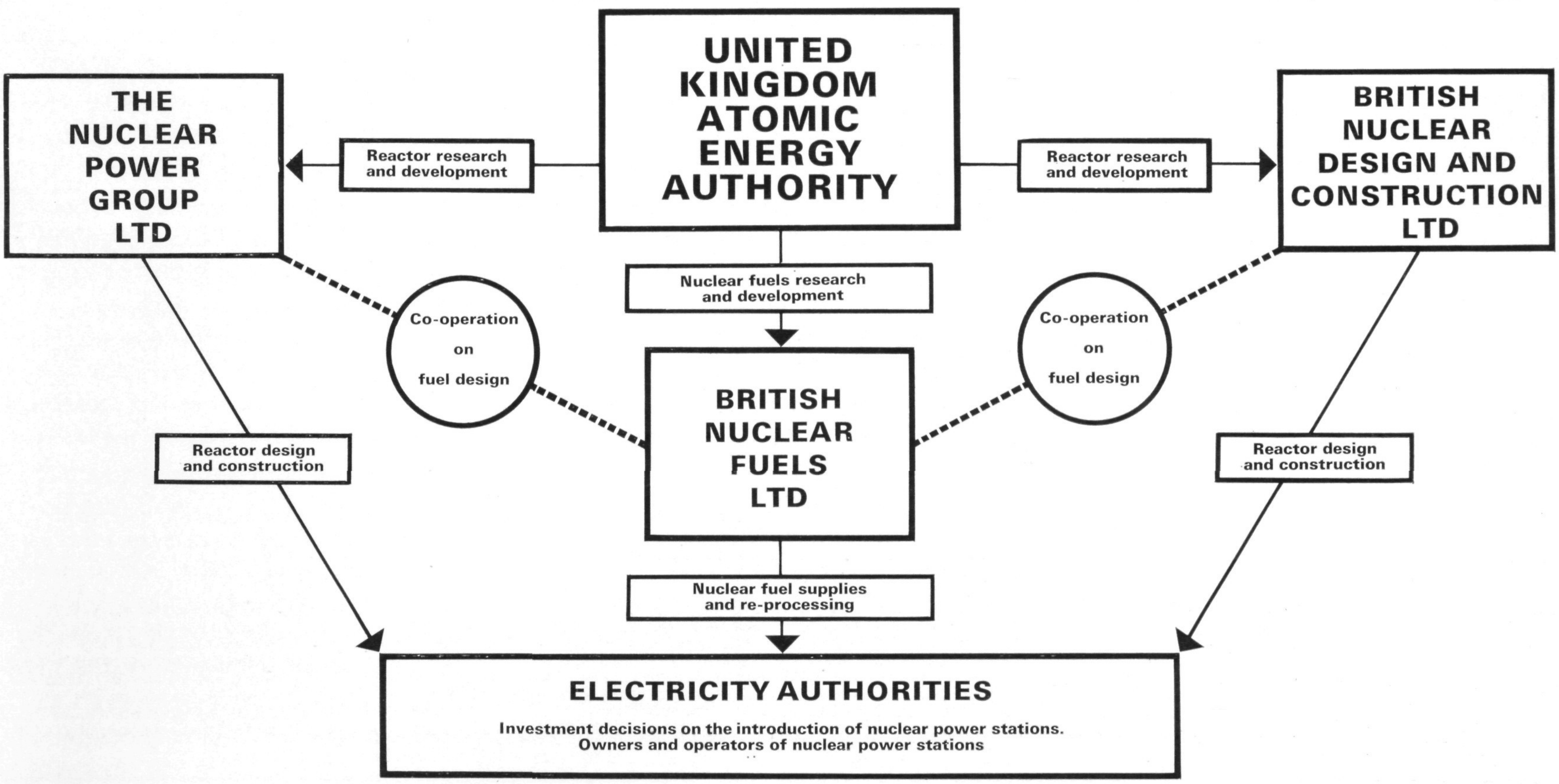
### Overseas collaboration

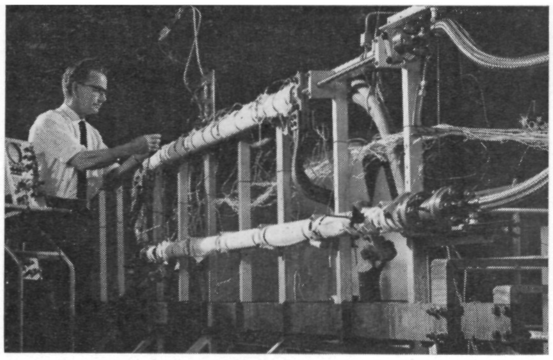
The Authority's continuing work in the field of international relations involves contacts with many organisations and countries. Development of particular importance in the year under review concern the development of plans for international collaboration in the field of uranium enrichment and reprocessing. On the former, tripartite discussions continued with representatives of the German and Dutch industrial organisations nominated by their governments for collaboration in the development and exploitation of the gas centrifuge process for producing enriched uranium. It was agreed with Gesellschaft für nukleare Verfahrenstechnik (GnV) and Ultra-Centrifuge Nederland (UCN) that the prime contracting organisation was to be set up as a limited company under German law, to be known as CENTEC Gesellschaft für Centrifugentechnik mbH. The headquarters will be in Bensberg, West Germany. Parallel discussions with Uran-Isotopentrennungsgesellschaft (URANIT) and UCN reached agreement on the setting up of the Enrichment Organisation, to be known as URENCO Ltd., as a company under British company law.

Good progress was made with the legal, financial and organisational matters relating to the two companies which are a necessary preliminary to their incorporation.

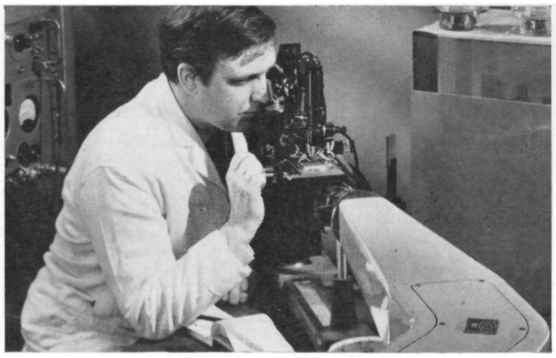
A study in 1969 by Foratom (the international union of fifteen European industrial organisations)

**Nuclear power organisation in the United Kingdom**





Heat Transfer Service, Harwell (pages 17–19)



Fuel Laboratory, Windscale (page 22)

Radiochemicals (page 23)

on the European reprocessing industry strongly recommended co-ordination in the use of existing reprocessing plants and in the planning of future plant investments as the only means of developing a viable European reprocessing industry. Negotiations proceeded during the course of the year between the Authority, the French CEA and a German group of industrialists with this aim in view. A draft Memorandum of Understanding was prepared defining the main principles for the formation of a joint organisation, specifying the scope of its activities and providing a basis for future plant investment and utilisation. United Kingdom policy is to aim at wide commercial collaboration in the reprocessing industry in Europe and negotiations are continuing with this in view.

## Finance and staff

The Authority's net expenditure for 1970/71 was £37·1 million, some £1 million less than originally forecast. Gross expenditure was, in fact, £1·5 million above the original estimate, owing to pay awards; but this was more than offset by additional receipts of £2·5 million.

The estimate for 1971/72 amounts to £41·968 million net (£91·516 million gross).

Expenditure on the Authority's civil research and development programme during the year was £58·5 million and 2,185 qualified scientists and engineers were engaged on this work at the end of the year. Details of the deployment of these qualified staff are shown in the table below. In addition, 375 qualified staff were employed on civil nuclear and non-nuclear work for other organisations on full repayment.

Consequent upon the establishment of British Nuclear Fuels Ltd., and The Radiochemical Centre Ltd., on 1st April 1971, and the transfer of the work of the Radiological Protection Division of the Authority Health and Safety Branch at Harwell to the National Radiological Protection Board on the same date, the total strength of the Authority was due to fall at the end of the year under review from 29,427 to 19,802.

## Commercial activities

Income, from sales of electricity to the UK generating boards and of nuclear fuel services and radioisotopes (at home and abroad) totalled £76·0 million with a net surplus of £4·6 million. Exports of fuel services rose by over 22 per cent to £5·4 million and of radioisotopes by 16 per cent to £2·8 million. At the end of the year, outstanding export contracts were valued at £21·4 million.

## Authority members

The Authority record with the greatest regret the death in September 1970, of Dr. Hans Kronberger, CBE, FRS, who had been Member for Reactor Development since 1st January 1969.

On 1st July 1971, Mr. Frank Doggett, CB, was appointed Deputy Chairman of the Authority in succession to Sir Charles Cunningham.

Mr. R. V. Moore, GC, CBE, was appointed a full-time Member of the Authority from 1st March 1971: he continues as Managing Director of the Reactor Group. Mr. Arnold Allen was appointed a full-time Member on 1st July 1971.

Mr. Leslie Williams, CBE, Staff Side Secretary-General of the Civil Service National Whitley Council, was appointed a part-time Member from 1st July 1970, and Professor Sir Brian Flowers, FRS, Chairman of the Science Research Council, as a part-time Member from 1st March 1971.

Dr. N. L. Franklin, OBE, relinquished his position as Member for Production at the end of the year on becoming Managing Director and Chief Executive of British Nuclear Fuels Ltd., Dr. Franklin becomes a part-time Member of the Authority. Mr. J. C. Duckworth retired from his part-time membership of the Authority on 14th February 1971.

## CIVIL RESEARCH AND DEVELOPMENT

| | EXPENDITURE (£ million) | | | | | Staff Deployment[2] | |
|---|---|---|---|---|---|---|---|
| | 1966/67 | 1967/68 | 1968/69 | 1969/70 | 1970/71 | 31.3.70[3] | 31.3.71 |
| **Reactor Research and Development Programme** | | | | | | | |
| (i) Major Development[1] | | | | | | | |
| (a) Gas-Cooled Systems Mk. II | 13·9 | 9·8 | 7·3 | 4·7 | 3·2 | 225 | 180 |
| (b) Gas-Cooled Systems Mk. III | — | 0·7 | 1·7 | 3·3 | 5·2 | 275 | 305 |
| (c) Water-Moderated Systems | 15·6 | 11·3 | 10·2 | 7·1 | 5·5 | 245 | 165 |
| (d) Fast Systems | 14·8 | 17·8 | 20·8 | 26·7 | 26·3 | 735 | 700 |
| (ii) Other work in support of power reactors and their fuel | 7·6 | 2·4 | 1·3 | 1·5 | 1·7 | 100 | 100 |
| | 51·9 | 42·0 | 41·3 | 43·3 | 41·9 | 1580 | 1450 |
| **Other Research** | | | | | | | |
| (a) Applied Nuclear Research | | 2·0 | 2·1 | 1·4 | 1·6 | 95 | 85 |
| (b) Underlying Research | 12·3 | 8·9 | 7·4 | 6·7 | 5·8 | 275 | 245 |
| (c) Radiological Protection Research | | 0·6 | 0·7 | 0·7 | 0·5 | 45 | 30 |
| (d) Nuclear Fusion and Plasma Physics Research | 4·6 | 4·4 | 4·2 | 4·0 | 4·1 | 155 | 140 |
| **Non-Nuclear Research** | 0·9 | 1·5 | 2·7 | 3·0 | 3·6 | 220 | 235 |
| **Grants to International Projects** | 0·9 | 0·8 | 1·7 | 0·3 | 1·0 | — | — |
| | 70·6 | 60·2 | 60·1 | 59·4 | 58·5 | 2370 | 2185 |

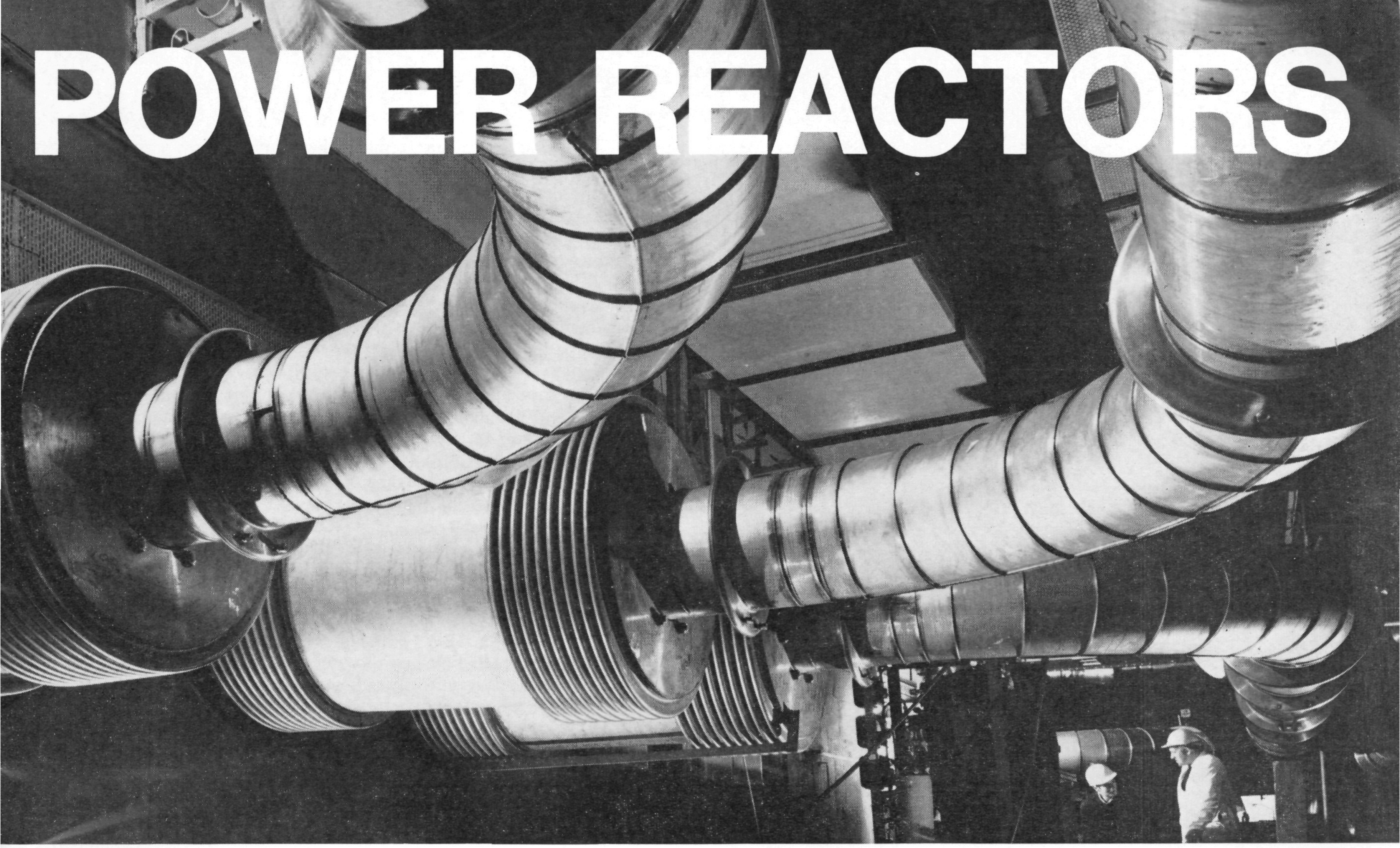
**NOTES**

1 The cumulative expenditure on the individual Major Projects is: Magnox systems (including £10·9 million related to the development of fuel) £20·6 million, gas-cooled systems Mk. II £114 million, gas-cooled systems Mk. III £10·9 million, Water-moderated systems £77·9 million, and Fast systems £149·4 million.

2 The staff deployment figures relate to qualified scientists and engineers engaged on programmes which are primarily financed by Parliamentary Grant. A proportion of the work, however, attracts cash receipts from other organisations. In addition, 375 qualified staff were employed at 31st March 1971 (310 at 31st March 1970) on other civil research and development projects, the full cost of which was met by other organisations. Of the 140 qualified staff involved, approximately 100 are attributable to Reactor Group and 40 to Research Group.

3 The figures at 31st March 1970, have been revised since the 16th A.R. to include staff of the Engineering Division of the Reactor Group and the Authority Health and Safety Branch who provide supporting services to the Civil R. and D. programmes.

# POWER REACTORS



**PFR.** The Prototype Fast Reactor under construction at Dounreay will pave the way for the larger commercial fast reactors of the future. Photograph shows the main sodium pipes and penetration bellows (July, 1971).

**DURING THE YEAR under review the arrangements for joint formulation of reactor development programmes by the Authority, the CEGB and the design and construction companies were extended to include the Fast Reactor and the Steam Generating Heavy Water Reactor as well as the Gas-cooled Reactors, Mark II (Advanced Gas-cooled Reactor - A.G.R.) and Mark III (High Temperature Reactor - HTR).**

Thus, following the reorganisation of the British nuclear industry the Authority's development programmes for all reactor systems are now fully integrated with the requirements of the industry; design responsibility for commercial Fast Reactors and SGHWR's has similarly passed to the design and construction companies. The British nuclear industry is making increasing use of the Authority's experimental facilities on commercial terms for work in connection with the established systems.

In addition the Authority continue to make capacity available in appropriate circumstances to overseas organisations on a commercial basis. There has been increasing collaboration with European development organisations to ensure uniformity of approach in areas such as reactor safety, and to reduce the cost of programmes by sharing test facilities and avoiding duplication of activities.

High priority continues to be given to work in support of the UK Generating Boards' extensive installation programme of Mk. II gas-cooled reactors, and in longer term development of their fuel. Arrangements have been made to irradiate in the Boards' reactors promising improved fuels, selected after successful proving trials in the Authority's facilities, thus ensuring a coherent and rapid development progression from laboratory to commercial exploitation.

**As in previous years, the biggest item in the Authority's reactor development programme has been work on the fast reactor, which continues to promise substantially lower generating costs when adopted. In the course of the year a strategic plan for the installation of commercial fast reactors in the UK was agreed for planning purposes between the parties concerned, viz. the Generating Boards, the design and construction companies and the Authority.** ***The plan, which will be reviewed annually, envisages the invitation of tenders for the first station in 1974.***

The Authority have continued the development of the two reactor systems, the helium-cooled Mk. III gas-cooled reactor and the Steam Generating Heavy Water Reactor, to complement or succeed the Mk. II gas-cooled reactors. The development programme for Mk. III gas-cooled reactors represents an extension of the UK experience of gas-cooled reactors; while being based on the low-enriched uranium/plutonium fuel cycle, it incorporates appropriate technology developed by the international Dragon Project, in which the Authority are a participant, and makes use of project facilities, particularly the Dragon reactor. The development of the SGHWR in support of the design and construction companies' commercial exploitation of the system is based on the operation of the 100 MW(E) prototype reactor at Winfrith and extensive supporting facilities.

***The Authority and Generating Boards are represented on a Working Party, under the Chairmanship of a senior official of the Department of Trade and Industry, which is considering the future policy for development and installation of thermal reactor systems in the U.K.***

# Gas-cooled reactors

Development work, particularly on fuel, has continued in support of the programme of Mk. II gas-cooled reactor stations (AGR) being built by the design and construction companies for the CEGB and the SSEB. So far five stations are being built with a total capacity of over 6000 MW(E), ten reactors in all. Manufacture of fuel for one of these stations has been completed; the programme of work to confirm specific features of fuel element designs for the later stations under construction is nearing completion.

The major objectives of the fuel development programme are to provide the Generating Boards with information on the operating procedures required for maximum fuel endurance and to establish an improved fuel capable of withstanding power cycling. An important part of the work this year will be aimed at extending and refining the information already available on operating procedures using the Windscale AGR to confirm the irradiation behaviour of fuel designs typical of the first commercial stations under the best simulated operating conditions.

The work on improved fuel, capable of operating at intermediate loads and withstanding step changes in output which occur in varying degrees even in base-load operation, is expected to establish a design which will enable the reactors to be employed increasingly on load-following duties arising later in the lives of the stations. Such improved fuel will be demonstrated first in Authority facilities. The Authority have during this year prepared designs for and begun to build independently-cooled loops which will be installed in the Windscale AGR, and which will be capable of operating at much higher coolant pressures than exist in the main core of the reactor, so as to achieve comparability with, or enhancement of the pressures of the commercial stations.

The Generating Boards have agreed that, after such sorting tests, the most promising designs will be given trials in their reactors.

The Windscale AGR itself operated satisfactorily throughout the year, engaged principally as a test bed for Mk. II gas-cooled reactor fuel and graphite, and continued to demonstrate the high reliability of this reactor concept. The reactor has now completed more than eight years operation; its overall availability during that period was 85 per cent and its overall load-factor 75 per cent.

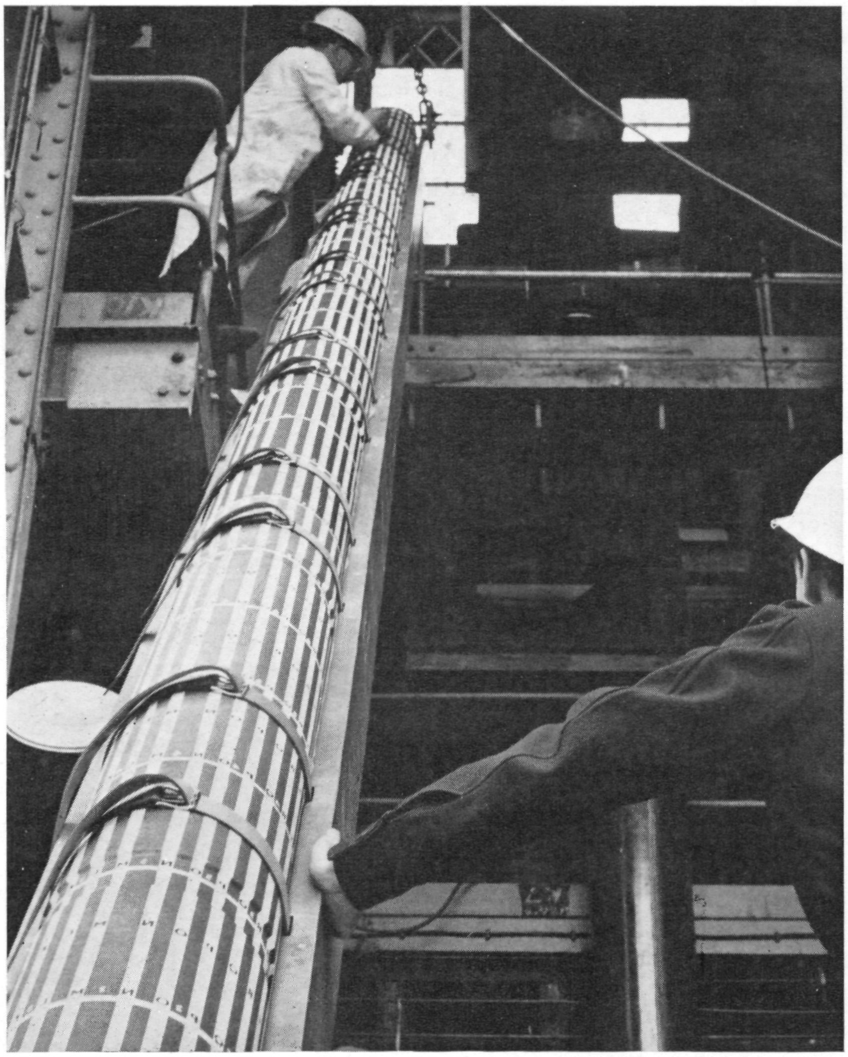
Progress with the Authority's programme for the development of the Mk. III gas-cooled reactor (HTR) was generally satisfactory. This reactor maintains certain features of the Mk. II reactor, including concrete pressure vessels, on-load refuelling and conventional steam turbines, but uses helium as coolant and a matrix of low-enriched uranium oxide graphite-coated particle fuel in separate tubes supported in removable moderator blocks.

A prototype plant for the manufacture of coated particles and fuel compacts (coated particles bound into a graphite matrix) is in operation at Springfields and several tens of thousand compacts have now been made for zero energy experiments at Winfrith and for a variety of irradiation experiments and out-of-pile testing at Harwell and Springfields and in the Dragon reactor. Operation of the prototype plant has provided experience on plant reliability and statistical information on product quality and has guided the specification and design of equipment for commercial plants.

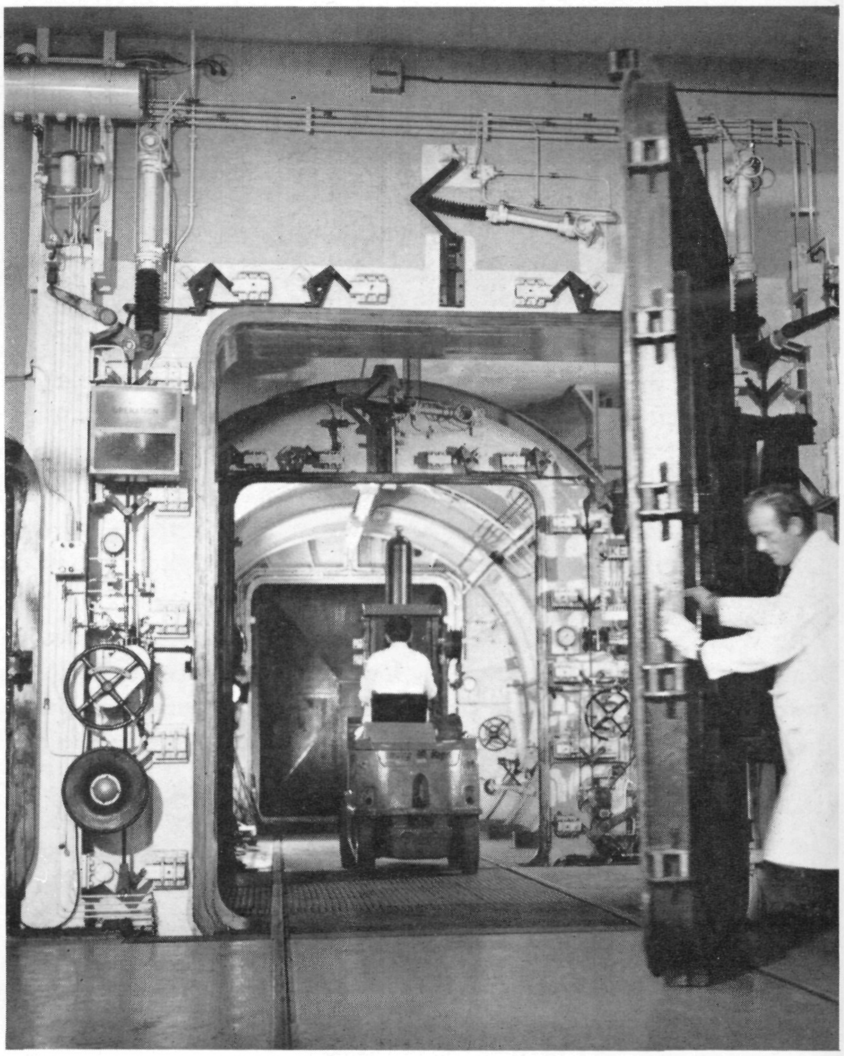
The selection of suitable materials and detailed conditions of service for the reactor circuit received considerable attention during the year by REML and at Harwell.

Reactor physics measurements at Winfrith using coated particle fuels have confirmed the basic physics parameters of the Mk. III gas-cooled reactor concept. The zero energy high temperature reactor ZENITH was taken to criticality again on 14th June 1970 for the start of the second phase of the experimental reactor physics programme for Mk. III gas-cooled reactors. The construction of a new large zero energy critical facility known as ZENITH-II is well advanced. ZENITH-II will be used to study specific design characteristics of Mk. III gas-cooled reactors.

Contact with work in this field overseas has been maintained through the Dragon Project and in addition the Authority's programmes have been discussed with various organisations in other countries.



**CAGR.** A "stringer" of fuel elements for commercial advanced gas-cooled reactors being lifted to the vertical position in a test rig at the Reactor Development Laboratories, Windscale.



**"DRAGON".** Vehicle air-lock entry to the "Dragon" (High-Temperature) reactor at Winfrith. The UK is a partner in this joint undertaking of the European Nuclear Energy Agency.

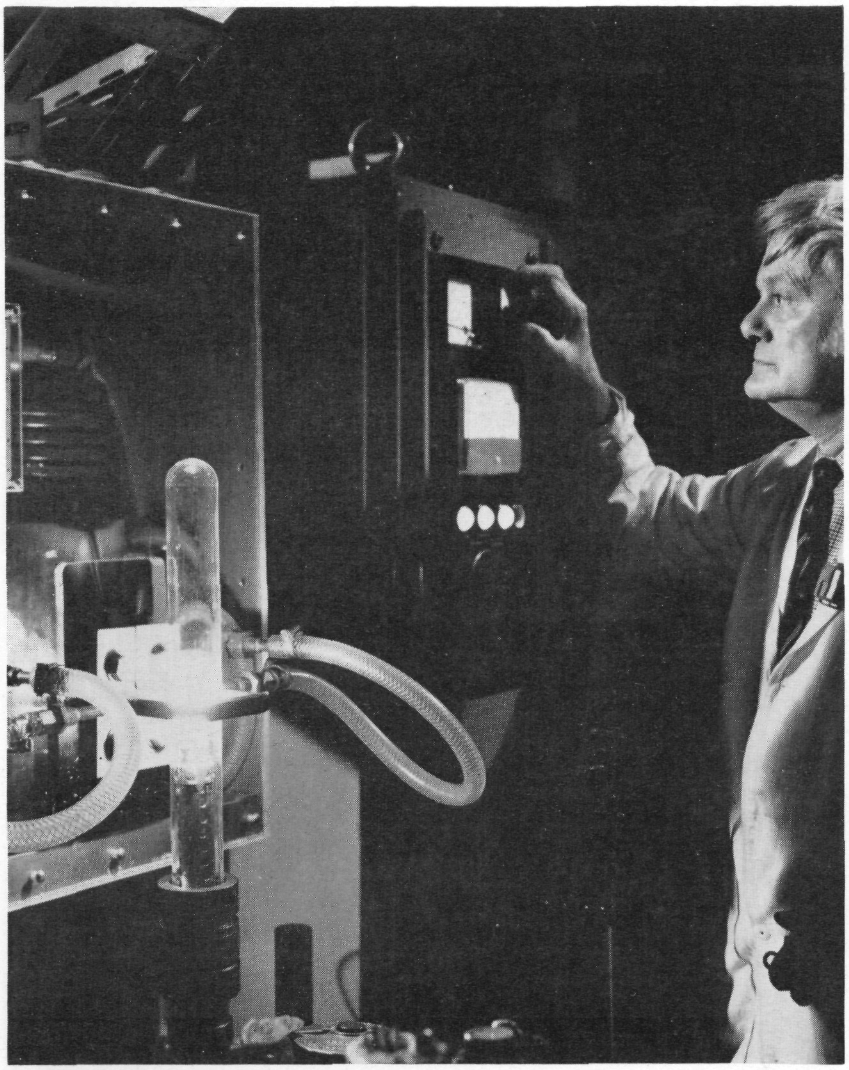
# SGHWR

The Authority have continued to devote development to the Steam Generating Heavy Water Reactor system to support the design and construction companies in its exploitation. In addition, longer term improvements to the system have been reviewed. Formal agreement was concluded between the Authority and the two companies on the licensing of the Authority's information, and close contact has been maintained with them, both on their individual commercial offers and on future programmes of development work.

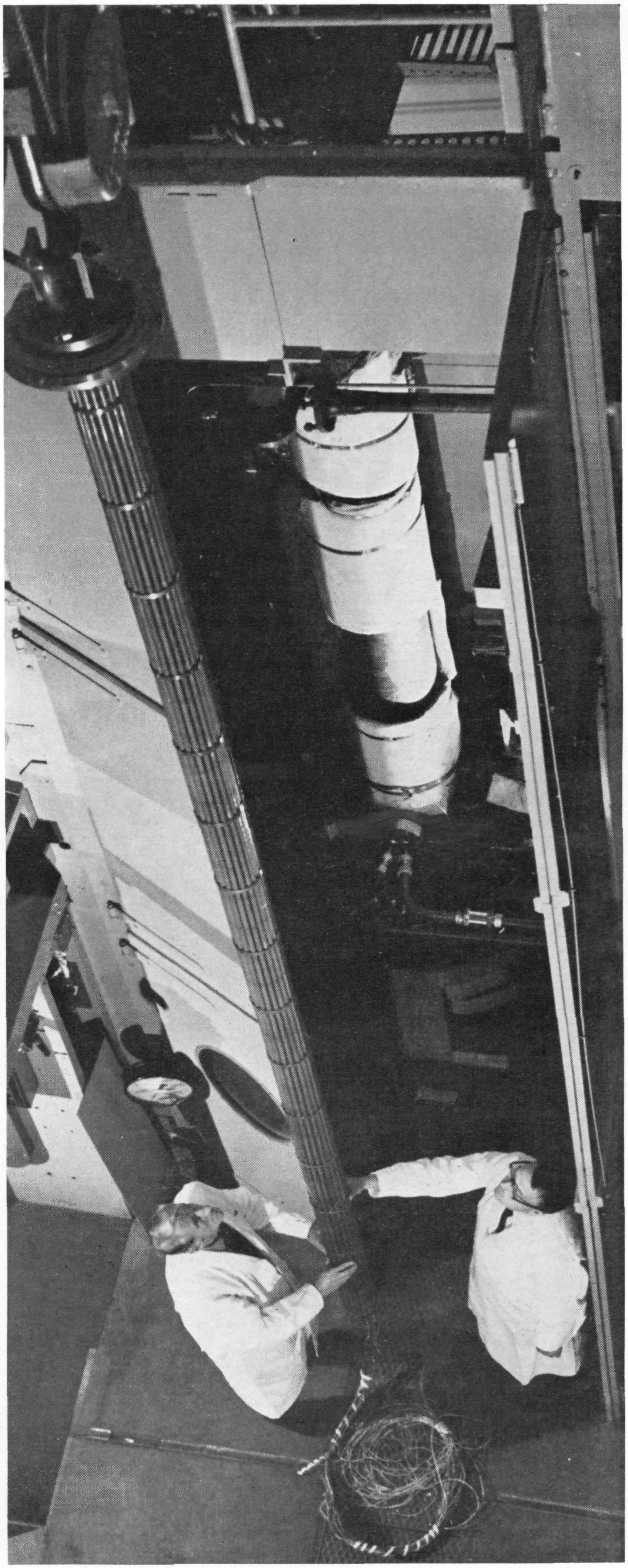
The principal item in the Authority's programme has been the operation of the Winfrith prototype, which has worked satisfactorily as a demonstration of the system as a power producer. There was no recurrence of the early teething troubles with the fuel which arose from faults in the coolant treatment plant, now remedied. It was notable that although there were some leaking fuel elements present, these did not give rise to radioactivity release levels which could affect the operational programme. The turbine was inspected during the autumn 1970 shutdown and found to be in generally good condition. It was, however, necessary to return the rotor to the manufacturer's works for modifications to the shrouding and subsequent rebalancing. The radioactivity levels were such that no difficulties were encountered in this remedial work.

As an experimental plant, the most significant feature of the year's work on the prototype has been the satisfactory experience with power cycling and frequency-following conditions. The reactor had undergone more than 120 large power cycles by the end of the year without adverse effect, and underwent tests using a coupled control system, in which reactor power is coupled to grid frequency—a necessary characteristic of frequency-following power plant and of commercial designs of the SGHWR. These tests showed the plant was stable with this form of control and seemed eminently suitable for working under both sets of conditions.

Development information is being used to advance further the commercial reactor designs offered by the design and construction companies.



**REACTOR CONTROL.** The Control and Instrumentation Division at Winfrith carries out R & D on instruments for the control of nuclear reactors. Picture shows work on development of neutron detectors.



**WATER REACTORS.** One of Winfrith's concerns is the prediction of water heat transfer performance in reactors. A simulated SGHWR fuel cluster being loaded into the pressure vessel of the 9 MW rig.

# Fast reactors

A co-operative study and assessment of commercial fast reactor designs by the Generating Boards, the design and construction companies and the Authority was completed and resulted *inter alia* in the formulation of a "strategic plan" for the introduction of fast reactors to the CEGB network.

This assumes that construction of a first commercial station will start in 1974 as a "lead" station, following operation of the Prototype Fast Reactor. This would be followed by other stations after an interval of perhaps two years. This plan assumes that the technical and economic results from the development programme confirm present expectations; it will be reviewed each year in the light of progress achieved. It is further assumed in this plan that all the early commercial stations will have reactors of 1320 MW(E) size, so as to limit the number of step changes in design.

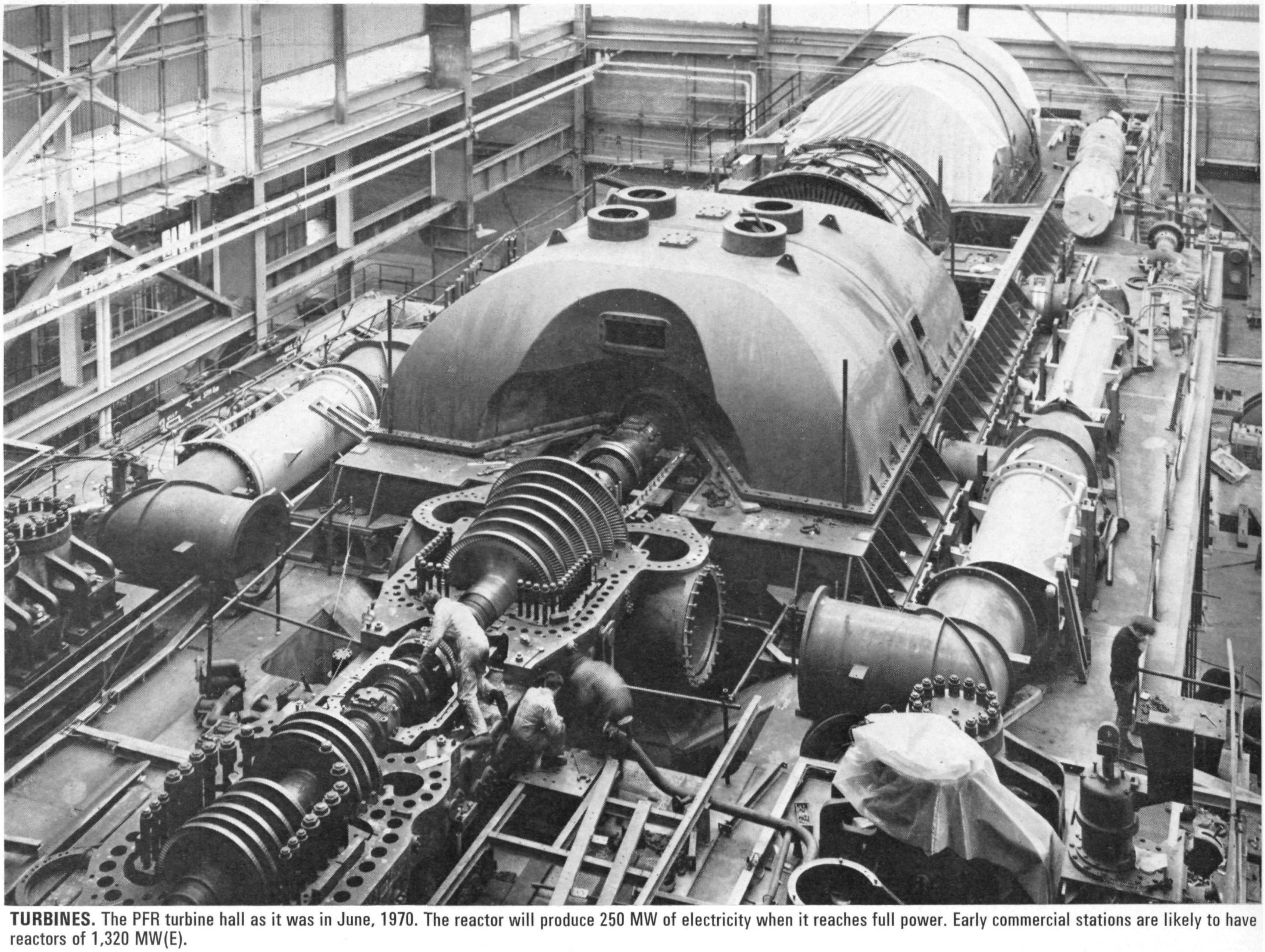
The construction and operation of the 250 MW(E) Prototype Fast Reactor at Dounreay is a key item in the plan. Whilst the highest priority in the development programme is accordingly being given to the early achievement of reliable full power operation of the PFR, substantial effort is being deployed in parallel to aid the design and further development of commercial stations.

Steady progress was made during the year in the construction of the PFR. Most of the major plant items have been delivered to site and installed. Construction of the secondary sodium circuits and the steam plant is well advanced; the main turbine generator has been erected, the temporary steam supply installed and accordingly commissioning of the turbine generator will start in 1971. Of the reactor internals, the drive mechanisms of the control and shut-off rods have been assembled and a large test structure has been completed to facilitate the installation of the fuel handling equipment and associated electrical supplies.

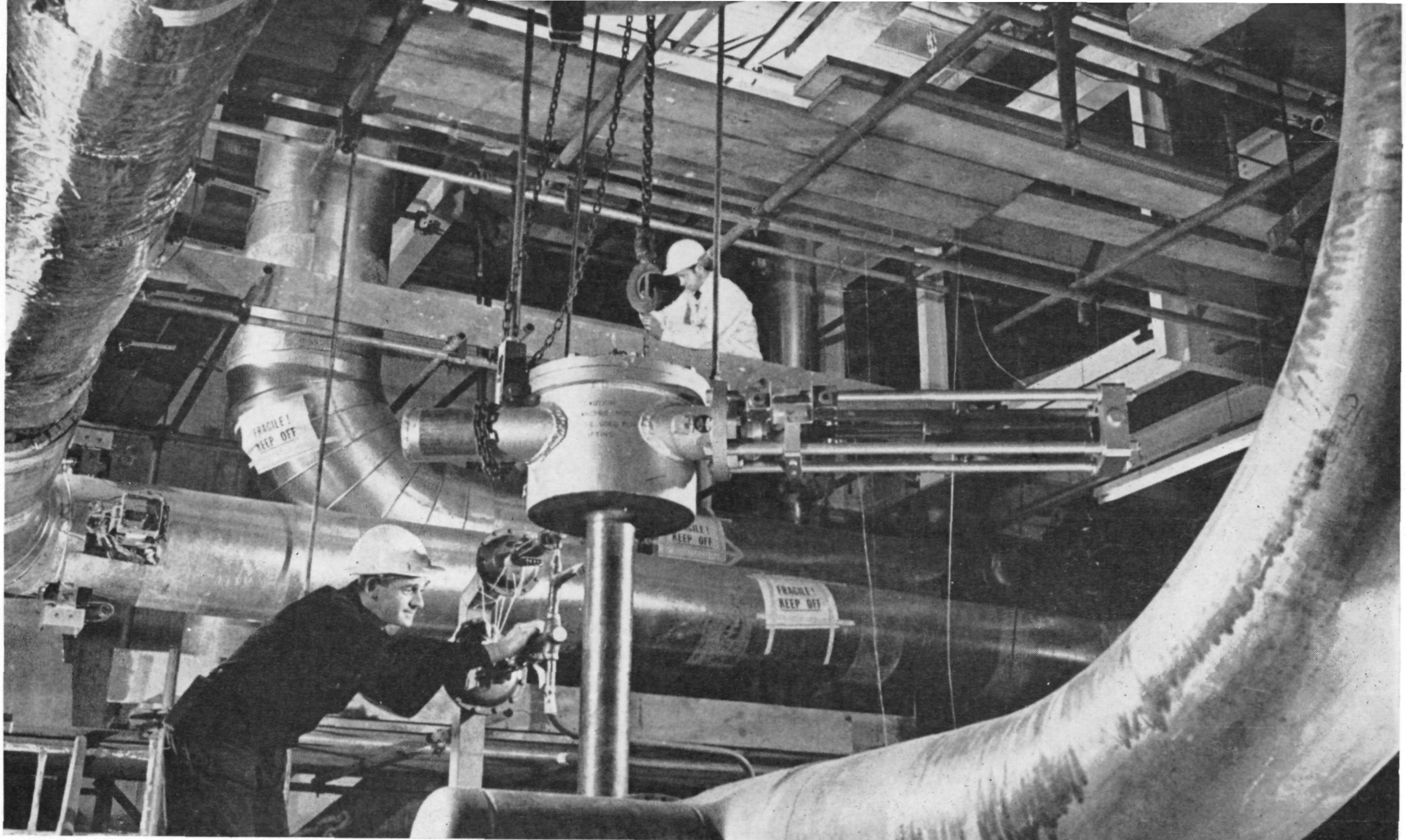
The Authority's reactor operations staff have been engaged on a programme of plant familiarisation, operator training, preparations for commissioning and operation and progressive take-over of plant on completion of construction. About 1000 tons of the sodium for the primary and secondary circuits has been delivered and has been purified to the required standard prior to loading at a later stage in the programme.

Examination of substantially different advanced fuel element designs has concentrated on carbide fuels. In principle, carbide fuels offer scope for improved fuel cycle costs through improved thermal conductivity (making for larger pins and cheaper manufacture) and higher density (giving improved plutonium breeding). The programme of exploration of concepts is progressing satisfactorily, with larger loadings of promising concepts being undertaken in DFR. The culmination of this programme will be substantial loadings of the selected design concept in PFR.

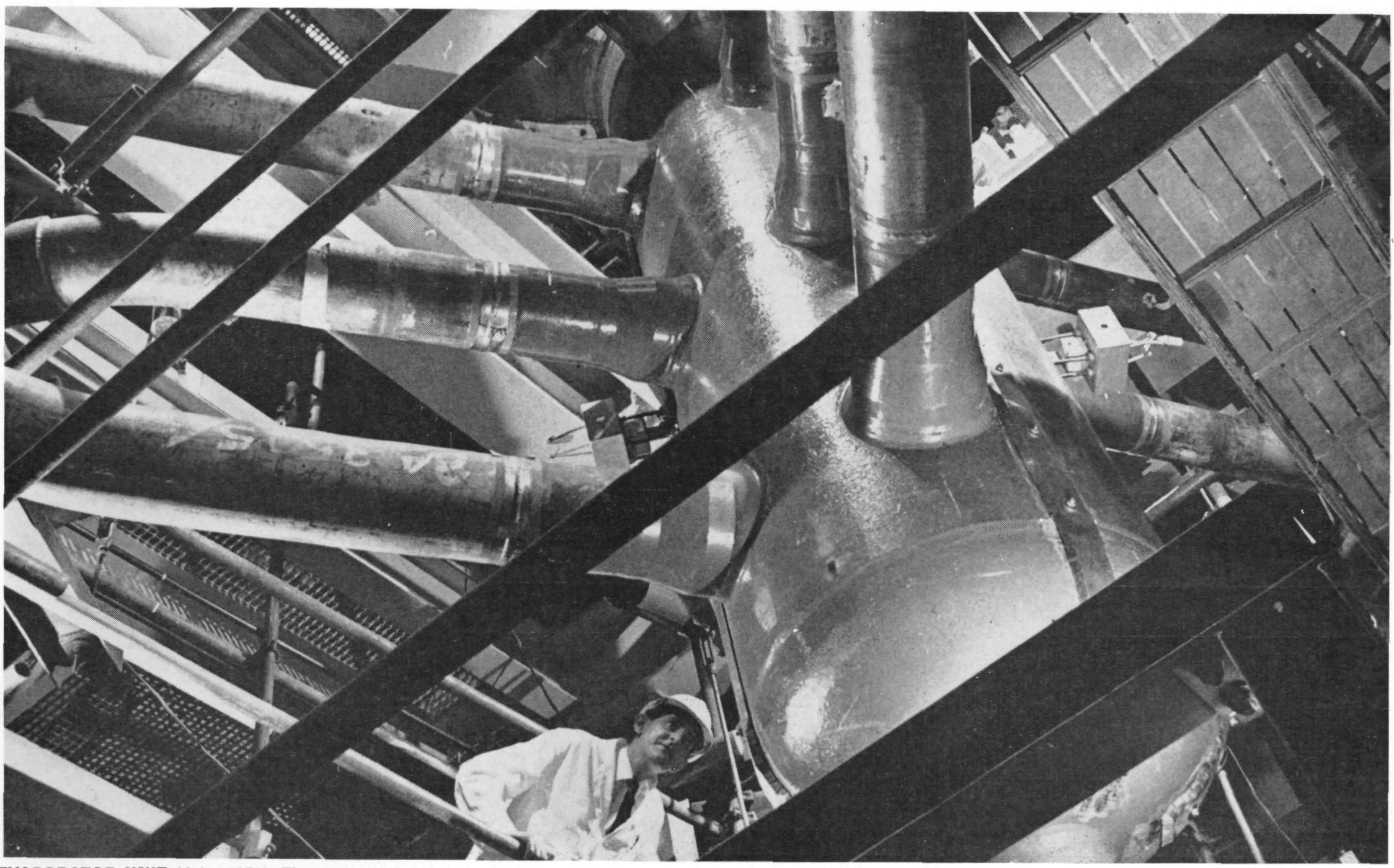
The first steps have been taken towards the provision of a Fast Reactor Training Centre associated with the PFR at Dounreay. The intention is to offer courses to British and overseas organisations. A range of courses is being devised on fast reactor technology and on the use of liquid metals. A simulator of the PFR station (with flexibility for conversion to simulation of commercial fast reactor stations) for use by the Centre and by the PFR operating team will be available towards the end of 1971.



**TURBINES.** The PFR turbine hall as it was in June, 1970. The reactor will produce 250 MW of electricity when it reaches full power. Early commercial stations are likely to have reactors of 1,320 MW(E).




**STEAM GENERATOR BUILDING** (July, 1971). Steady progress in the construction of PFR has been made in the year under review. Photograph shows the fixing of a gauge to a valve in the main 23-inch line from an intermediate heat exchanger.



**EVAPORATOR UNIT** (July, 1971). The reactor operations staff at Dounreay have been engaged on a programme of plant familiarisation and operator training preparatory to commissioning and the progressive take-over of the plant on completion of construction.

## UKAEA REACTORS

| | | |
|---|---|---|
| **DIDO** | Harwell | Studies of nuclear reactor materials. Isotope production. Neutron and solid state physics. Radiation chemistry. |
| **PLUTO** | Harwell | Studies of nuclear reactor materials. Isotope production. Neutron and solid state physics. Radiation chemistry. |
| **DAPHNE** | Harwell | To simulate DIDO or PLUTO; to provide basic physics information in support of these reactors. |
| **GLEEP** | Harwell | Routine testing of the quality of graphite and uranium. Research with oscillator. Biological irradiations. Neutron flux standards. |
| **LIDO** | Harwell | Thermal reactor studies including shielding and neutron spectra measurements. |
| **FAST REACTOR (DFR)** | Dounreay | Fast neutron irradiation testing of advanced fuels, structural materials, etc. Development of fast reactor technology. |
| **PROTOTYPE FAST REACTOR (PFR) (under construction)** | Dounreay | To obtain the information necessary for the design of high power, commercial fast reactors. |
| **ADVANCED GAS-COOLED REACTOR (AGR)** | Windscale | To study the advanced gas-cooled power reactor system and to test fuel elements for commercial AGR's. |
| **STEAM-GENERATING HEAVY WATER REACTOR (SGHWR)** | Winfrith | To obtain experience with the SGHWR concept and to test fuel for commercial SGHWR's. |
| **ZEBRA** | Winfrith | Reactor physics studies of the PFR and other large fast reactors. |
| **HECTOR** | Winfrith | Oscillator reactor reactivity measurements on materials and fuel elements. Temperature coefficient measurements of samples of reactor lattices. |
| **JUNO** | Winfrith | Testing a wide range of liquid-moderated lattices. |
| **ZENITH** | Winfrith | Reactor physics investigations for advanced graphite-moderated reactors. |
| **NESTOR** | Winfrith | Sources of neutrons for sub-critical assemblies giving thermal fluxes of $10^8$ in the assemblies. |
| **DIMPLE** | Winfrith | Testing a wide range of lattices at uniform temperatures up to about 80°C. |
| **HORACE** | Aldermaston | To obtain basic nuclear information for HERALD. |
| **HERALD** | Aldermaston | Studies in neutron physics, radiochemistry and nuclear reactor materials, including work with universities and CEGB. |
| **VERA** | Aldermaston | Experimental studies of fast reactor systems. |
| **VIPER** | Aldermaston | Pulsed reactor; experimental studies of the effects of intense, transient bursts of neutrons and gamma radiation. |
| **CALDER HALL (Four reactors)** | Calderbridge | Power and plutonium production; process steam supplied to Windscale site services. |
| **CHAPELCROSS (Four reactors)** | Annan | Power and plutonium production; experimental work in aid of the UK power programme. |

**NOTE:** The Calder Hall and Chapelcross reactors are now operated by BNFL.

# Reactor services on repayment

The Authority have devoted much effort during the year to selling the services they can offer from the accumulated skills and facilities being built up during the reactor development programmes, either alone or when possible in association with the British nuclear industry. The success of these endeavours is shown by the figures in the table below. It will be seen that the volume has now reached £5½ million a year, of which a substantial proportion comes from abroad (from 30 customers in 15 different countries).

All the Authority establishments involved in reactor development contribute to this growing business, which is being carried out in full co-operation with the British industrial organisations; but the growth in this year has been maintained notably by a very high level of income from fast reactor work at Dounreay and the initiation of a wide range of repayment work at Winfrith. An indication of the broad scope and diverse nature of this class of work is given below.

All the work being done by the Authority on Mk. I (Magnox) gas-cooled reactors was under contract, mainly to the Central Electricity Generating Board and to the Authority's Trading Fund (now represented by the fuel and radiochemical companies); this included fuel development and examination of irradiated fuel. Similarly some fuel development for Mk. II gas-cooled reactors (Advanced Gas-Cooled Reactors) was carried out for the Trading Fund, and the active handling caves at Winfrith are being made available on commercial terms to CEGB to examine irradiated fuel from their Mk. II reactors.

The Mk. II gas-cooled reactor fuel handling rig at Windscale is being used by the two design and construction companies for development of the geometry of fuel handling routes for their specific Mk. II station designs, while other rig work has been done for the industry on the mechanical behaviour of fuel elements in fuel channels. Development work was also being carried out at Winfrith on improved reactor electronic equipment for both the CEGB and the Trading Fund.

| | INCOME 1967/68 |
|---|---|
| Reactor services to UK nuclear industry including Trading Fund | 1·10 |
| Reactor services to overseas nuclear industry and Dragon Project | 1·53 |
| **TOTAL** | **2·63** |

The Authority's facilities are also used to support export business in nuclear fuel; for example, the Winfrith plutonium laboratories made plutonium-containing fuel of various configurations to satisfy Japanese and European orders. Rigs at the Reactor Fuel Development Laboratory, Springfields, and at Winfrith were used for test work and fuel management studies made at Winfrith in support of the Trading Fund's sales of water reactor fuel abroad.

The Authority's reactor development facilities also attracted orders direct from overseas nuclear organisations. Dounreay in particular has earned a substantial income from irradiations in the DFR, complemented by the use of fuel manufacturing, reprocessing and post irradiation examination facilities at the establishment. In many instances the assembly and testing of the specimens used in the experiments and the scientific examination of the specimens after irradiation have been done at Dounreay, while in others customers provide specimens already irradiated elsewhere for examination by specialist Dounreay staff using the wide range of equipment in the Authority's laboratories. (Care is taken to maintain confidentiality of the information.) Dounreay has also completed orders from a number of overseas countries for the supply and reprocessing of Materials Testing Reactor fuel. Irradiations in other Authority facilities, e.g. at Harwell the MTR's DIDO and PLUTO, and the VEC have contributed to this large volume of business, which meets an evident need.

Post-irradiation examination of fuel has also been carried out at Harwell and at Winfrith for the Dragon project, for which the Authority continued to operate the reactor experiment and to provide associated services at Winfrith on a repayment basis.

In addition to the work described above, other experimental and assessment work has been undertaken for overseas and UK organisations on a variety of reactor subjects, including for example, reactor physics studies for fuel management schemes, reactor shielding calculations and heat transfer work. During the year the Authority launched a post-manufacture reactor plant inspection service, using techniques developed in Authority programmes, with particular applicability to the inspection of pressure vessels for water-cooled reactors abroad; methods of developing and exploiting this service have been discussed with appropriate organisations in the UK.

(£ million)

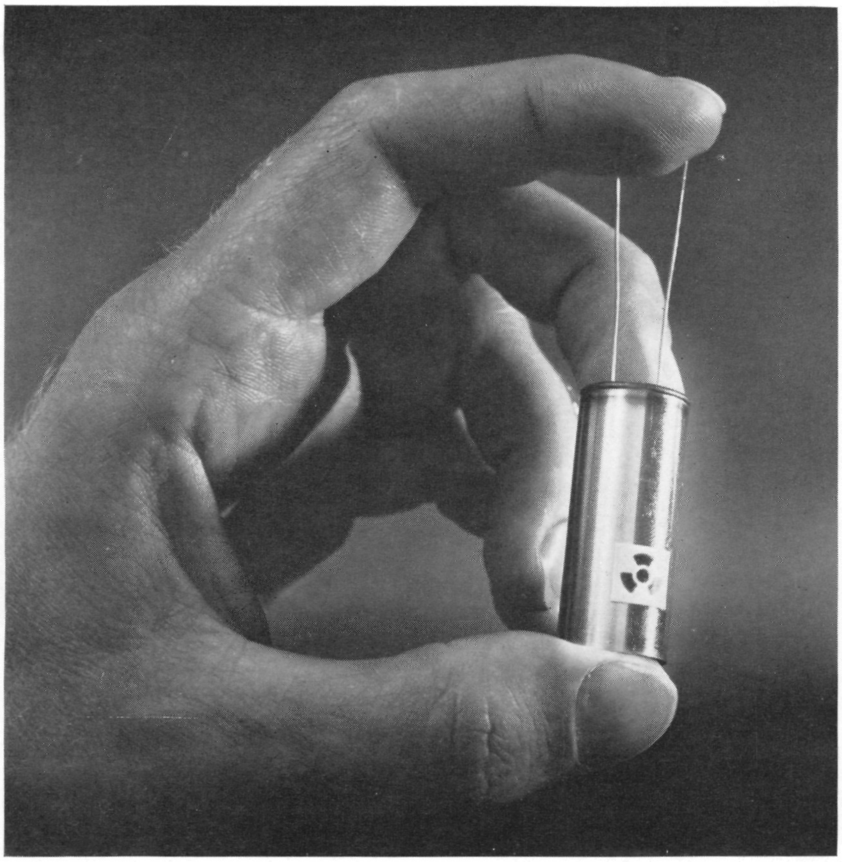
| | 1968/69 | 1969/70 | 1970/71 |
|---|---|---|---|
| | 2·10 | 1·95 | 2·80 |
| | 2·23 | 2·69 | 2·72 |
| | 4·33 | 4·64 | 5·52 |

## 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** |
| | 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** |
| | Two pumped sodium loops; one used to study corrosion, mass transport and deposition of corrosion products in reactor coolants—the other used in the development of on-line oxygen and carbon impurity meters. Sodium heated high pressure water rig (2500 p.s.i.) for steam generator tube integrity testing. | **Harwell** |
| **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. | **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, stereoscan and electron microscope, metrology and radiography. Examination of plutonium-bearing and highly enriched fuels and experimental fuel elements after irradiation in MTR's and DFR. Rig radiography, dimensional measurements and neutron radiography of irradiated materials. | **Windscale, Harwell and Winfrith** |
| **Accelerators** | Cockcroft-Walton Generator, 3 and 5 mV Van der Graaffs, 14 meV Tandem Generator, Synchrocyclotron, Electron Linear Accelerator, Variable Energy Cyclotron produce beams of electrons, hydrogen and other gases, boron, phosphorus, iron, nickel and other metals. These are used for studying ion implantation, reactor physics, nuclear spectroscopy, radiation damage, detector development, basic physics, fast reactor research, physics of liquids and chemical research. | **Harwell** |
| | 6 MV Van de Graaff Generator. | **Aldermaston** |
| **Experimental Fuels** | Authority centre for development and fabrication of experimental fast reactor fuels. | **Windscale** |
| | Fabrication of plutonium-containing fuels. | **Winfrith** |
| | PFR prototype fuel plant for experiments into full-scale manufacture of sub-assemblies. | **Aldermaston** |
| | Manufacturing and testing facilities for fuel elements based on uranium and its alloys, ceramics, cermets and coated particles. | **Springfields** |
| | Fabrication of plutonium-containing fuels and of test experimental fuel elements. | **Harwell** |
| **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 gas-cooled reactor sub-assemblies. | **Windscale** |
| | Out-of-pile loops for dynamic and endurance tests on water reactor fuel sub-assemblies. | **Springfields** |
| **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. Large-scale rig for the performance testing of re-boilers, shell and tube heat-exchangers and air-cooled heat-exchangers. Cryogenic test facilities. | **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, Culcheth and Harwell** |
| **Quality assurance** | Extensive NDT equipment for X, gamma and neutron radiography, ultrasonic tests, etc. Metrology facilities for calibration of high-precision components and equipment. Pressure testing facilities up to 200,000 p.s.i. hydraulic, 100,000 p.s.i. gas. Mechanical and high vacuum testing. | **Harwell, Springfields, Culcheth and Windscale** |
| **Subcritical Assemblies** | A range of subcritical (and critical) assemblies for research in water, gas-cooled and sodium-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. | **Windscale and Winfrith** |
| | The Materials Testing Reactors at Harwell have high pressure water, gas and liquid nitrogen loops as well as a cold neutron source. | **Harwell** |
| **Tribology** | Friction and wear characteristics of materials. | **Risley** |
| **General Materials Testing** | Design and manufacture of rigs for a wide range of temperatures, pressures and environments. | **Dounreay, Windscale, Winfrith and Harwell** |
| **Systems Reliability** | Large computing facilities and comprehensive data bank. | **Risley** |

# Nuclear 'know-how'



**NUCLEAR BATTERY.** The Harwell nuclear battery (2 inches long and $\frac{3}{4}$ inch across) uses heat from the radioactive decay of plutonium to generate electricity. It has a design life of 10 years. Its first application has been in heart-pacemakers. It is licensed for manufacture in the UK and USA

**PROSPECTING.** An instrument developed by Harwell and the Institute of Geological Sciences measures the radon content of sub-soil air and can locate uranium deposits too deeply buried for direct measurement of their gamma radiation. It is manufactured under UKAEA licence by Ekco Instruments, Ltd.

## MINIATURE NUCLEAR BATTERIES

Development of an isotope-powered thermoelectric battery continued with emphasis on optimising the present design and evaluation possible causes of long-term failure. Improvements to thermoelectric materials permitted a reduction of the fuel load to 0·18g plutonium-238 and laboratory experiments on a revised battery design confirmed that the long-term goal of a fuel load of 0·1g or less of plutonium-238 was realistic. Limited clinical trials of heart pacemakers using the Harwell battery were initiated in July 1970 by the Department of Health and Social Security. The Authority appointed Mining and Chemical Products Ltd. licensees for battery production in the UK and the Gulf General Atomic Company, of San Diego, California, have been licensed to manufacture in the USA.

## HYDROLOGICAL TRACERS

The main objectives of the hydrological tracer and coastal sediment studies at Harwell are to develop radioisotope techniques for studying the behaviour of groundwater and the movement of silt and coastal sediments, and to make these techniques available to industry and public bodies.

The natural tritium in over 500 samples of surface and groundwater was measured under a contract from the Water Resources Board and the Natural Environment Research Council. Data were obtained showing that water transport occurred mainly by the slow process of exchange with water already stored in the damp chalk and not by flow through fissures. This proof of slow downward percolation has important implications on the movement of pollutants in chalk aquifers and work continued in close collaboration with the Water Resources Board.

## MINING AND QUARRYING

The aims of the Nuclear Techniques in Mining and Quarrying project are to apply nuclear instrumentation and the expertise gained in the search for and development of uranium and thorium ores to problems in the mining and quarrying industry in general and thus help to find and recover new ore deposits. The application of non-dispersive X-ray fluorescence in a wide range of analytical problems is being examined. Negotiations are proceeding with Machlett X-ray Tubes (GB) Ltd. for commercial production of the tube and, with other firms, for the manufacture under licence of instruments incorporating it.

Commercial availability of the world's first X-ray fluorescence borehole probe for tin was announced by the Authority's licensee, Ekco Instruments Ltd. Work started on a borehole probe for copper ores operating below the present economic ore grades. The construction of a new type of measuring head for the analysis of copper in copper ore slurries was successfully completed.

Equipment for geochemical exploration of the Continental Shelf is being designed at the request of the Institute of Geological Sciences. Initial development is aimed at instruments which can be towed or deposited on the sea-bed.

## URANIUM SUPPLIES

A joint project to improve the techniques for uranium ore discovery and recovery was started by the Institute of Geological Sciences, the Natural Environment Research Council and the Authority.

Advances were made in field prospecting instruments for detecting the deeper lying deposits which would not be found by air-borne $\gamma$-survey.

The exploitation of the Authority's accumulated expertise and resources for the benefit of industry outside the nuclear power field continued by means of applied nuclear projects (and the non-nuclear work made possible under the Science and Technology Act, 1965, which is described on pages 18–19).

Harwell, in collaboration with the Institute of Geological Sciences, designed and developed a portable radon monitor which is now marketed by Ekco Instruments Ltd., and a 2-channel portable $\gamma$-spectrometer for field measurement of the relative abundance of uranium and thorium in ore samples; a few models are being made for field testing and use by geologists. This complex instrument has fully automatic standardisation of measuring circuits and results are indicated numerically; it represents one of the first designs in a new class of portable field instruments for radiological survey.

## MILLION VOLT ELECTRON MICROSCOPE

Following the installation last year of the new AEI-EMI 1 MeV electron microscope (EM7) at Harwell, its performance was evaluated and new specimen stages and devices (including a new camera system) to improve operation and versatility were designed and built; some were sold to other EM7 owners. Harwell also demonstrated, on behalf of AEI, the instrument's experimental capabilities to potential buyers. Already a wide range of applications has been identified in the materials development field and the instrument was used extensively both by universities and industry (on repayment) and in support of Harwell's own programme. In studies of radiation damage the very high damage rate (with copper, for example, it is possible to displace each atom once a minute), coupled with the ability to observe and record the damage as it occurs, enables high dose experiments to be carried out quickly and efficiently.

## RADIATION CHEMISTRY

A small electron beam gun was assembled for studying paint curing and other surface treatments as part of Harwell's R & D programme and for preliminary trials for customers. Experimental runs were carried out on the larger demonstration plant for a number of customers, whose interests included resin curing, cross-linking of polymer films and other applications.

The treatment of wood for articles such as brush backs, drumsticks, etc., continued, and trials related to these and other products were carried out for interested firms. A contract was secured for treating timber for use in walkways in a chemical plant and possible applications to veneers and wood flooring were pursued. Investigations continued with other materials such as concrete and fibreboard, guided by an independent market survey.

## NEUTRON ACTIVATION ANALYSIS

The Activation Analysis Unit continued to undertake sponsored research and development of methods and applications of neutron activation analysis and sample analysis for a wide variety of customers from industry, universities, hospitals and government laboratories. Examples of the 80 separate jobs completed during the year are the determination of vanadium in oil, phosphorus in aluminium, nickel and chromium in soap, trace elements in water, and mercury in various metals.

## RADIATION STERILISATION

As a consequence of the closure of the Wantage Research Laboratory and the transfer of staff to Harwell and the leasing of the two package irradiation plants to LRC International Ltd., the project on food sterilisation and preservation by gamma-irradiation was closed; the functions and interests retained by the Authority in this field and in the sterilisation of medical products and other microbiological aspects were merged into a small new radiation sterilisation and radiobiology project. Irradiated Products Ltd., a subsidiary of LRC, took over the running of the Wantage plants in November 1970 and continued the commercial irradiation service (mainly for disposable medical supplies) previously offered by the Authority. Under the agreement with LRC the Authority has access to the plants for research purposes.


**CAMAC.** Harwell 7000 Series equipment conforms to the internationally agreed CAMAC (Computer-Aided Measurement and Control) specifications. Authority licensees sell the world's largest range of CAMAC—compatible equipment. Shown above is the computer-based data acquisition and display system for the analysis of nuclear events recently commissioned at the CEGB laboratories at Hornsey.

## ION IMPLANTATION

Research and development on the techniques of ion implantation and on its application to the production of semi-conductor devices is a major objective of this project. The technical advantages of ion implantation for introducing controlled amounts of impurities such as boron and phosphorus, into defined shallow layers at the surface of silicon were established in a number of important cases. Detailed processing schedules for the manufacture of types of complex semiconductor integrated circuits were worked out in collaboration with industrial laboratories which are now assessing the economic benefits of the process.


**LONDON AIRPORT.** Engineers of BOAC's non-destructive testing unit preparing to radiograph an aircraft engine intake. A Pantatron depleted-uranium container is being used to carry up to 100 curies of Iridium-192.

## MATERIALS TECHNOLOGY

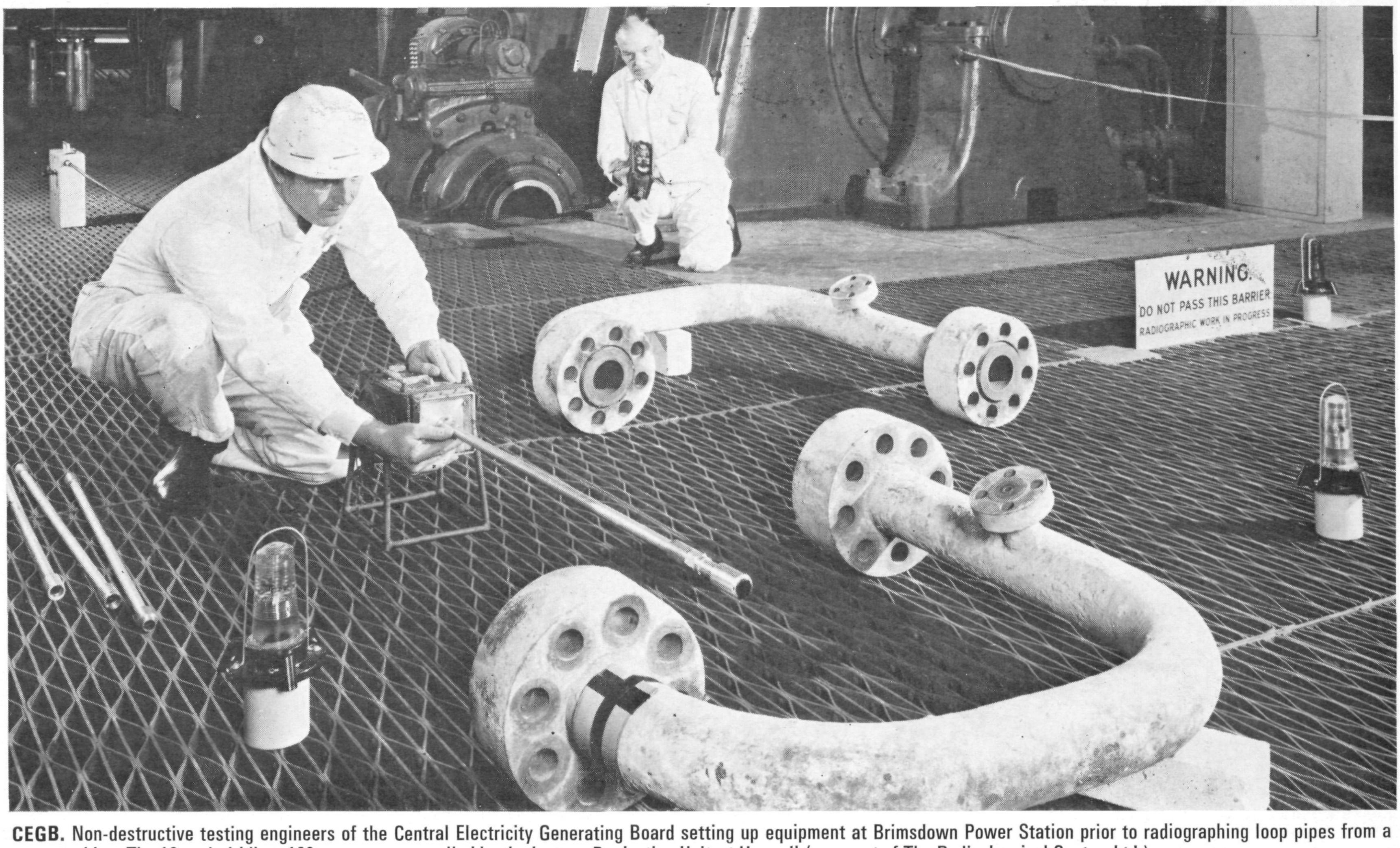
The Authority's knowledge and experience in the general field of materials technology is offered to industry and research organisations through the Materials Technology Bureau. During the year, 190 enquiries were dealt with and 160 representatives of firms with widely different material requirements visited the Bureau to discuss their special problems and to see the experimental facilities. As a result, the Bureau conducted 65 individual investigations on full repayment terms; in other cases it was instrumental in directing work to the most suitable Research Association or other laboratory or to the appropriate Authority non-nuclear project.

## RADIOISOTOPES IN INDUSTRY

The use of radioisotope instruments and tracer techniques permits new standards of accuracy in flow measurement in industry. A gas and liquid flow-meter calibration service was brought into operation at Harwell for flow-rates of up to 2000 lb/min. for liquids and 550 ft$^3$/min. for gases, measured within an accuracy of $\pm$ 0·2 per cent. In addition, *in situ* calibration (using tracer techniques) was introduced and aroused considerable interest from industry.

Leak testing continued to be an important service, applications ranging from underground pipelines and reactor vessels, to the position and orientation systems of the satellite Intelsat IV which is now in orbit. Special techniques were devised for studying wear rates and the flow of material through cement kilns.

New radioisotope instruments developed under contract to industry include an improved level gauging system for a major oil company, and a nucleonic belt-weighing system (in collaboration with Nuclear Enterprises Ltd.) of which the prototype is undergoing on-line trials by the British Steel Corporation. Techniques for measuring the thickness of chromium on steel in new 'tin-free-steel' processes were also developed and design started of prototype equipment for laboratory and on-line application. An extension of neutron moderation and scatter techniques for measuring moisture in low density materials was completed.




**CEGB.** Non-destructive testing engineers of the Central Electricity Generating Board setting up equipment at Brimsdown Power Station prior to radiographing loop pipes from a steam turbine. The 10-curie Iridium-192 source was supplied by the Isotope Production Unit at Harwell (now part of The Radiochemical Centre, Ltd.).

# Non-nuclear projects

**CERAMICS.** The Harwell Ceramics Centre undertakes a widely based programme of ceramics research geared to the needs of British industry. Two-thirds of its work is being carried out under agreements with 22 private firms. Fabrication methods include plasma spraying of ceramics (above).

Exploitation of the Authority's technological skills for purposes other than the development of atomic energy is conducted under Requirements issued to the Authority by the Secretary of State for Trade and Industry under Section 4 of the Science and Technology Act 1965. Under each Requirement, the Department of Trade and Industry authorises for a specified period programmes of work which fall into three broad categories:

(a) information, consultancy and development services in particular technological fields
(b) projects with specific objectives of industrial or commercial importance
(c) projects with social objectives.

In categories (a) and (b) the work may be on a full repayment basis or it may be undertaken on the basis that the Authority shares the risk with an industrial partner in the expectation of recovering costs through future royalties. Examples of projects in category (c) with a social objective (where the costs are borne by public funds) are biomedical technology and the control of atmospheric pollution.

In all projects, the proportion of the work done directly in association with industrial customers and government departments increased. For example, the subscription service of the heat transfer and fluid flow service expanded to cover over 40 customers and eight major design reports were completed. Greater use was made of the measurement and consultancy services offered by the National Centre of Tribology, and by the Non-Destructive Testing Centre. A marked increase in business was shown by the high temperature chemical technology and electrotechnology projects and by the Ceramics Centre where a substantial contract was placed by an industrial consortium for the development of silicon nitride as an engineering material.

The major programme of work on desalination continued and, in collaboration with other laboratories, good progress was also made in other environmental activities, including investigation of **atmospheric pollution, water renovation and the disposal of hazardous wastes.**

Eight new authorisations were received during the year from the Department of Trade and Industry, seven of these for work under the existing Requirements on heat transfer, electrotechnology and quality control. A new project on computer optimisation (previously part of APACE) was also authorised, under the Computer Software Requirement.

## DESALINATION

The second phase desalination programme authorised by the Ministry of Technology ended in March 1971 and proposals for an extension are under examination. The original objectives were to establish and exploit by the early 1970's the full development potential of multi-stage flash (MSF) distillation and to develop and demonstrate four processes, a cheaper and more efficient multi-effect distillation process, the freezing process, reverse osmosis and electrodialysis. The two latter processes are for the treatment of brackish water.

The Authority assisted Weir Westgarth Ltd. to make major savings in the costs of MSF distillation plants and thereby to maintain their competitive position. The development programme at Troon progressed to the point where little further experimental work was required to provide confidence in the designing of the ten-million-gallon-a-day (mgd) plants which are likely to be ordered from overseas in the coming years. The recently commissioned 1·5 mgd Jersey MSF plant provided a valuable test bed for design ideas arising from the programme.

An advanced vertical tube multiple-effect evaporation process with enhanced heat transfer was successfully proved on pilot plants and in the Authority's view will provide considerable competition to MSF. A commercial demonstration of this multi-effect distillation process to meet a fresh water need in Gibraltar is being considered. Collaboration continued with Aiton & Co. of Derby on their novel horizontal tube multiple effect system and a two-effect 80,000 gd pilot plant was built using steam from the Dungeness 'A' power station.

A detailed design study was conducted, jointly with Simon Engineering Ltd., of the 1-mgd experimental plant using the freezing process which is to be constructed at Ipswich. There are problems of scale-up which can only be studied by designing and operating an experimental plant.

The reverse osmosis field testing programme using 5,000 gd tubular supported membrane units enabled Paterson Candy International, the Authority's industrial partners, to offer commercial units which were competitive with overseas plants and had performance guarantees.

The planned programme of evaluating electrodialysis as a system of water renovation was delayed because of difficulties in commissioning the conventional coagulation pre-treatment unit. The test is now under way and no difficulties are evident in the process. Electrodialysis plants of up to 4·5 mgd capacity were sold.

## ATMOSPHERIC POLLUTION

Three automatic sampling stations from Harwell were used to monitor the effects of pollution on mist and fog formation on Teesside. Many of the fogs were associated with natural sea-mist conditions, but their severity and persistence were enhanced by high concentrations of pollutants, especially ammonium sulphate. These concentrations were observed when the land and sea breeze situations were such as to cause substantial oxidation of sulphur dioxide to ammonium sulphate and recirculation of pollutants trapped under a shallow inversion. The importance of such effects in relation to the siting of industrial emitters of pollution in coastal and estuarine conditions had not previously been fully recognised.

Work on the life history of sulphur dioxide is particularly relevant to the present concern about the long-range transport of sulphur dioxide in Europe and the acid rain observed in Scandinavia. The Authority and other interested bodies in the UK are co-operating, under the aegis of the Department of the Environment, in the international study of sulphur pollution sponsored by the Organisation for Economic Co-operation and Development (OECD).

## WATER RENOVATION

In a joint programme with the Water Pollution Research Laboratory, field trials were carried out on the treatment by reverse osmosis of sewage effluents and organically polluted waters.

## SYSTEMS RELIABILITY SERVICE

The work of the Systems Reliability Service in its first year ranged from assessment of the reliability of protective systems for chemical plant to investigations of the reliability of high pressure diecasting machines. A number of UK and overseas concerns were recruited as fee-paying Associate Members.

## RELIABILITY OF ENGINEERING PLANT

Three activities related to the reliability of engineering plant are: the Non-Destructive Testing Centre at Harwell; the Systems Reliability Service at Risley (both of these are also active in the field of quality control of materials); and the National Centre of Tribology at Risley. Examples of work concerned with the performance of engineering plant include the Heat Transfer and Fluid Flow Service and the Improved Utilisation of Steels project, the aim of which is the better use of steel through a more detailed understanding of the phenomena governing failure during use.

## CERAMICS CENTRE

The Ceramics Centre's collaboration with industry continued to develop and two-thirds of its work was carried out under agreements with 22 firms. A substantial contract was placed with the Centre by Advanced Materials Engineering Ltd., a joint company formed during 1970 by Clarke Chapman Ltd., Doulton & Co. Ltd., British Leyland Motor Corporation, Ransome, Hoffman & Pollard and the NRDC. The new company is identifying possible applications of silicon nitride as an engineering material and the Centre is developing methods of fabricating it.

A collaborative programme involving the Centre, the University of Reading and an industrial partner on the development of a porous ceramic heater device for a specific application was completed and the industrial partner is now preparing units for field trials. The use of underwater sparks for crushing brittle materials, electrohydraulic crushing, is being explored in large-scale crushing trials for user firms.

## NON-DESTRUCTIVE TESTING

The Non-Destructive Testing Centre's links with industry were strengthened by new development contracts, by demands for instrumentation systems, and by setting up the Centre's Northern Unit at Risley.

Additional development was undertaken of ultrasonic holography, of methods of evaluating impurity inclusions in steels, and of techniques to test adhesion bonds. Instrumentation systems were developed to monitor water content and layer thickness, and systems based on ultrasonic technology were developed to monitor the progress of machining operations and to provide sensitive thickness-measuring systems for industrial application. Radiography of aero engines using high energy X-rays and $\gamma$-rays enabled precise measurement to be made of internal dimensional clearances under a variety of test-bed operating conditions.

## NATIONAL CENTRE OF TRIBOLOGY

In its third year of operation the National Centre of Tribology was asked to solve a greater range and number of problems than in previous years and it also initiated lines of development subsequently taken up by industry. The latter ranged from a new design of window pivot (specifically designed for high-rise flats and now being produced commercially under licence) to gas bearings. The Authority have been in the forefront in developing gas bearings, but as originally designed these were expensive. Recent work in the Centre is likely to lead to a bearing of great promise for use in textile machinery and capable of being mass-produced.

## HEAT TRANSFER

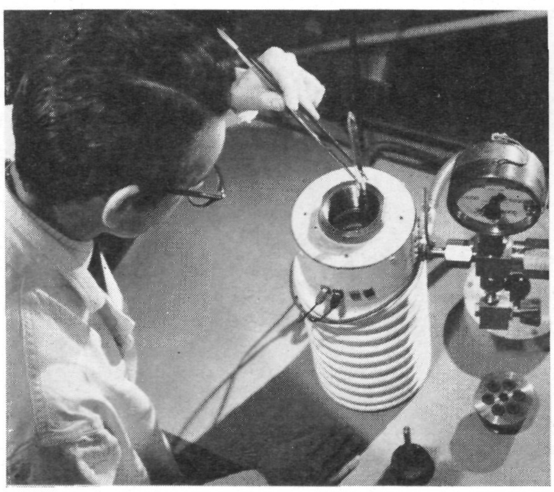
The Heat Transfer and Fluid Flow Service at Harwell and Winfrith provides a Subscription Information Service, the aim of which is to improve the methods used in industry to design heat transfer equipment, and undertakes general and sponsored research on industrial topics. The Subscription Service was expanded; over 40 companies participated and eight major design reports were completed on such subjects as two-phase flow in shell and tube heat exchangers and cryogenic heat transfer. More than 300 enquiries for information were received and many sponsors made use of the consultancy service.

In the unsponsored research programme, undertaken in collaboration with the National Engineering Laboratory, advances were made in the understanding of condensation in tubes, of evaporation in horizontal boiler tubes and of two-phase flow in coils. A programme on recirculation in air-cooled heat exchangers was completed successfully for the Kellog International Corporation.

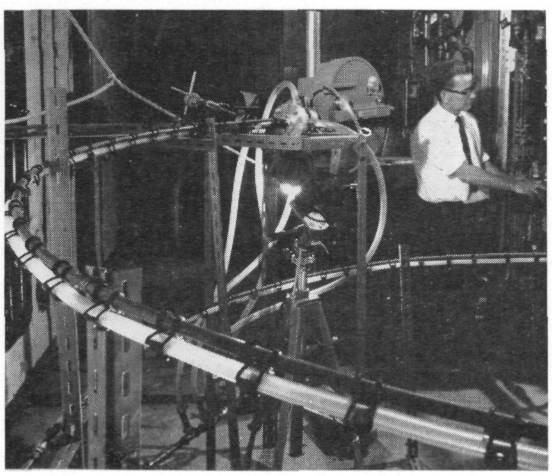
Winfrith became increasingly involved in sponsored research and carried out major programmes for John Thompson Ltd. and Clarke Chapman Ltd. on new designs of serpentine and helical coil boilers. At Harwell sponsored research was undertaken on waste heat boilers and flow patterns in catalyst beds for ICI, and (in collaboration with Parkinson Cowan Appliances Ltd.) on the production of miniaturised central heating boilers.

## HIGH TEMPERATURE CHEMICAL TECHNOLOGY

Work in the High Temperature Chemical Technology project was concentrated on the development



**Analytical R & D.** Harwell has developed a portable autoclave, for work on dissolution problems, that will work at 320°C and 4000 psi.



**HTFS.** The Heat Transfer and Fluid Flow Service—centred at Harwell—draws on facilities at Risley, Windscale and Winfrith.

**Medical Engineering.** A six-joint articulated laser-beam manipulator for experimental surgery has been devised by Aldermaston.

of high temperature processes of industrial importance. More than one-third of the work was devoted to ten collaborative or sponsored programmes with industry.

A joint project with the British Oxygen Company on the application of moving bed techniques to production processing progressed to the design of a prototype plant. Collaboration with Osborn Steels Ltd. on problems in the production of special steels resulted in process improvements which are undergoing plant trials. Laboratory investigations of molten salt/molten metal equilibria led to a computer program which predicts chemical changes in alloys during electroslag refining as a function of process conditions and slag compositions, and this is now being offered as a service to industry. Allied techniques were being applied in a joint programme with the British Oxygen Company aimed at improving high temperature processes for metal extraction.

## HIGH TEMPERATURE FUEL CELLS

The High Temperature Fuel Cell Project undertook a feasibility study and cost estimate of a large assembly of high temperature fuel cells and also laboratory-scale work on key material problems.

At the end of 1970, a small team from Energy Conversion Ltd. engaged in fuel cell research moved to Harwell under an agreement whereby the Authority manages the programme on behalf of the company.

## ANALYTICAL R & D

The Analytical Research and Development Unit completed several industrial and government contracts covering both the design of computer systems and programs for on-line use with analytical instruments, and the development of new instruments for plant and laboratory use. For example, the first phase of a time-shared computer/instrument system was undertaken under a joint contract with Computer Technology Ltd. and the Department of Trade and Industry; the computer was installed at Manchester University for final tests of interfaces and software to suit mass spectrometry, nuclear magnetic resonance and gas chromatography. A new laboratory microwave spectrometer, CAMSPEK, was developed in collaboration with Cambridge Scientific Instruments Ltd. The Unit also carried out a wide variety of analytical measurements for industrial firms and other laboratories, e.g. for the Royal Radar Establishment programme to develop new electronic materials and for an Institute of Hydrology study of rainwater catchment areas.

## PHYSICO-CHEMICAL MEASUREMENTS

More than 90 university departments and 80 industrial companies have now received analytical measurements from the laboratories of the Physico-Chemical Measurements Unit at Harwell and Aldermaston. The university work, which is the greater part, is financed by the Science Research Council. Infra-red, nuclear magnetic resonance and mass spectrometry techniques were used mainly in support of structural studies of newly synthesised organic chemicals. The Mössbauer spectrometry service, which was opened last year, proved equally popular for studies of iron and tin compounds. Compared with last year, business increased by 50 per cent and over 5,000 specimens were examined.

## ELECTROTECHNOLOGY

The Industrial Electrotechnology Project at Culham expanded rapidly. Thirty-five programmes were carried out for customers in the electrical power, textiles and synthetic fibres, printing, metal fabrication, electronics, computer hardware, aerospace, rubber, glass, cable-making, and scientific instrument industries. Significant advances were made in the application of high power lasers to industrial processes, in techniques for producing large superconducting coils, and in high speed electronic data processing. Developments of high voltage and high current techniques led to contracts for the simulation of lightning strikes on aircraft components and for the design and manufacture, in collaboration with industrial firms, of special equipment for laboratories in the UK and abroad.

The development programme on mercury ion satellite thrustors was reorientated to include new requirements for station keeping by communications satellites. A contract from the European Space Research and Technology Centre (ESTEC) for a study of colloid thrustors was won in collaboration with an industrial firm against over 50 competitive tenders.

The development of prototype circuitry for commercial companies continued at Aldermaston. A two-year programme was drawn up to further the work in conjunction with, and financed equally by, a consortium of private companies and the Department of Trade and Industry.

## MARINE TECHNOLOGY

The Marine Technology Support Unit (MATSU) whose task is to provide technical advice to the Committee on Marine Technology, and in appropriate cases to undertake related research and development, completed the formulation of a programme of research and development in marine technology, in which some 60 research and development activities were identified, of which 28 were in progress, seven had been completed and 25 were new proposals. Reviews were also presented on suspended diving chambers and external pressure testing facilities in the UK.

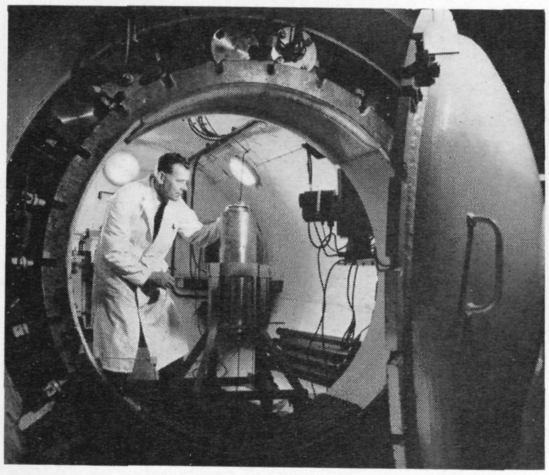
MATSU is managing on behalf of the Department of Trade and Industry a design study for a cable-controlled unmanned submersible and a study of the feasibility of modifying an unmanned Ministry of Defence vehicle for civil uses. The Unit is also acting as engineering design consultant to the National Institute of Oceanography for a new external pressure test vessel, and to the Continental Shelf Unit (Edinburgh) of the Institute of Geological Sciences in the design of an underwater rock sampler. A design and cost study by external consultant engineers for a float-out platform showed it to be feasible. Operational trials of the submersible PISCES and of a sonar system for hydrographic survey on M.V. CLIONE, belonging to the Ministry of Agriculture, Fisheries and Food, were carried out. Proposals from industry for hydrographic sonar are being examined.

## BIOMEDICAL TECHNOLOGY

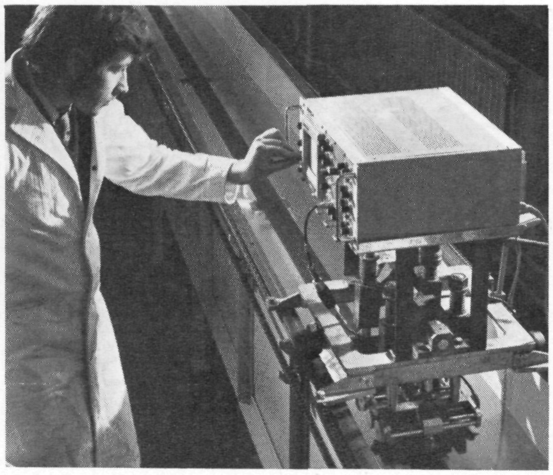
Further research and development work was carried out at Aldermaston in support of the Department of Health and Social Security and, where appropriate, progress was made towards commercial exploitation. Two medical diagnostic instruments, the semiconductor gamma camera and the infra red scanner, underwent clinical trials with encouraging results. A fibre optic oximeter was completed and tested satisfactorily on animals. Development work on various types of cardiac pacemakers was continued in collaboration with industry. Investigations into possible methods of making simple checks on the efficiency of hospital X-ray image intensifier systems were extended and some equipment is now being tested in clinical situations. Further research work was carried out on artificial kidneys, including systems incorporating sorbent materials aimed at reducing size and cost. Accelerated tests were carried out on new materials which might be used for surgical implants and investigations were also carried out on the mechanical properties of surgical bone screws. Progress was made on the development of new dental materials and on associated studies. Clinical work using the prototype artery drill has given encouraging results and preparations were made for further clinical trials with a more versatile device.

## COMPUTER SOFTWARE

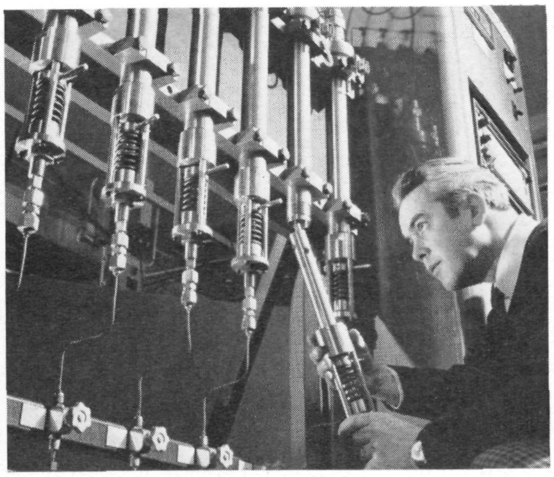
Substantial support was given by Harwell to the main contractor, The Plessey Company, for the data processing system associated with the Linesman Project for air traffic control.



**Pressure Testing.** Assembling a pressure vessel inside a safety cell for testing at 100,000 psi at the Harwell Pressure Testing Laboratory.



**NDT.** Ultrasonic facility for inspecting tubes up to 10 metres in length and 2 tons in weight (Non-destructive Testing Centre, Northern Unit, Culcheth).



**Tribology.** The National Centre at Risley offers consultancy on all aspects of tribology, test facilities and R. & D.

# NUCLEAR FUSION

The Authority's fusion research programme has as its aim the release of nuclear energy from the light elements in a controlled fashion to provide electrical power. The main method being studied is to generate thermonuclear reactions in a very hot gas (a "plasma") which is confined and held away from normal surroundings by means of a magnetic field.

If a self-sustaining fusion reaction is to be achieved, a light-element plasma has first to be heated to a temperature of the order of 100 million degrees. Then it has to be confined for a sufficiently long time to ensure that the fusion energy output exceeds the energy input. For a system employing the most favourable fuel, a deuterium-tritium mixture, the density of the plasma has to be of the order $10^{14}$ nuclei/$cm^3$ and the confinement time about one second.

For the confinement of high temperature plasma a variety of different magnetic field configurations are being studied throughout the world. These systems fall into two general classes, the closed-line (or toroidal) class in which the magnetic field lines close on themselves and the simpler open-ended class, in which the field lines leave the confinement area and the plasma can to some extent excape along the lines.

**"With so much of our thinking in nuclear power directed to cost effectiveness, replication, rationalisation and industrial re-organisation, I hope we will not lose all sense of striving for the future or of interest in the undiscovered, nor refuse to make any journey unless every step can be counted and measured in advance. The road to a successful and economic fusion power station is uncharted. I hope we can maintain our resolve to continue the exploration."**

SIR JOHN HILL, Chairman, UKAEA, in an address to the Fourth International Conference on the Peaceful Uses of Atomic Energy, Geneva 1971.

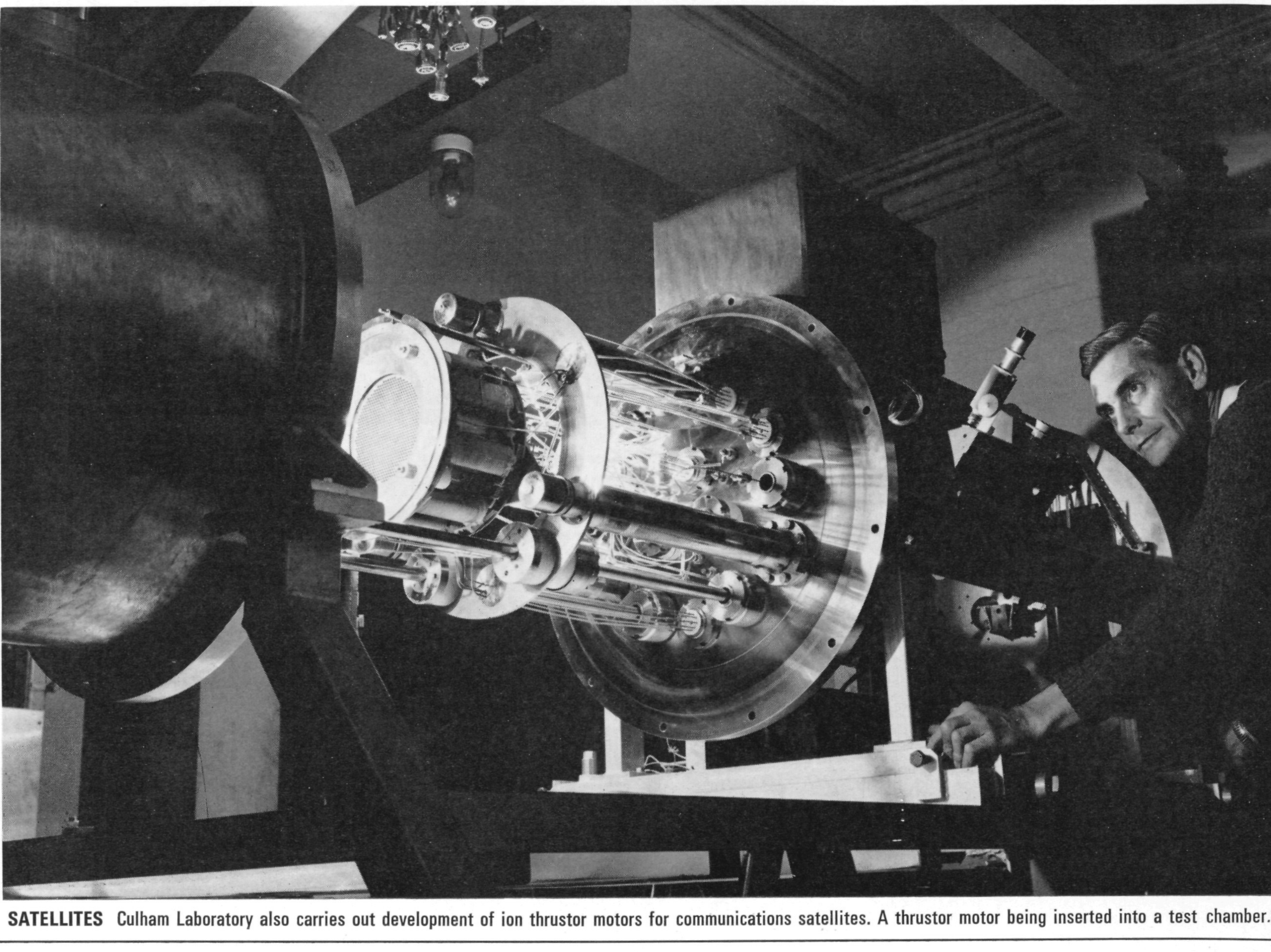
Although it is too soon to say which confinement system should be chosen for intensive development as the basis of a reactor, the closed-line class seem to offer the greatest potential, and the main research is devoted to systems of this class—stellarators, toroidal pinches and multipoles—together with programmes on plasma production and heating, and a small amount of work on open-ended systems.

Experiments with magnetic traps of the "closed-line" class were extended to cover a range of plasma densities and a variety of methods of plasma production were employed. Results were sufficiently encouraging to justify the authorisation of further research apparatus.

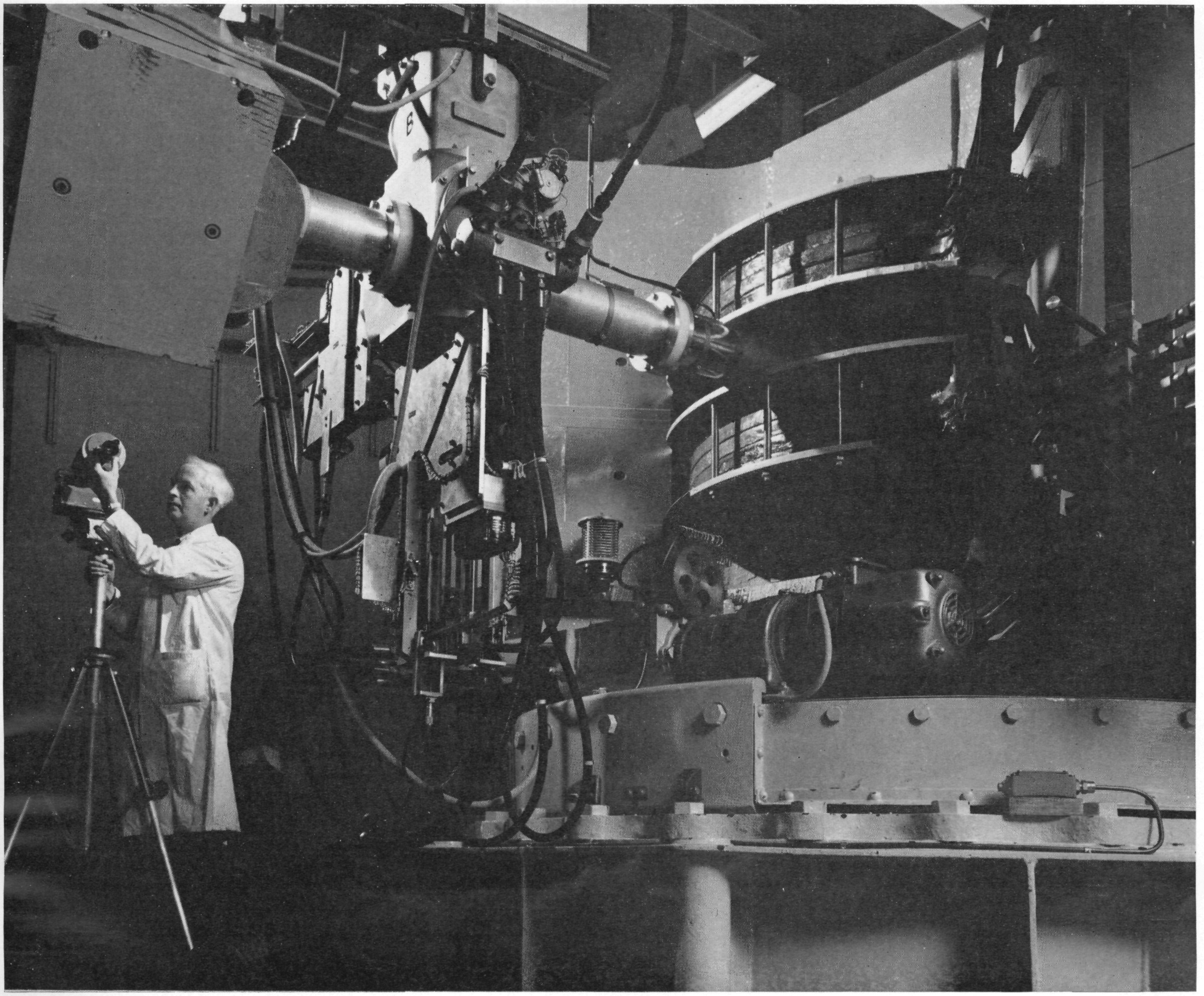
The scale of supporting plasma physics research has been further reduced, but studies of the technological and economic factors of envisaged reactor systems have been slightly increased.

To maintain contact with work over the wider field, collaboration with fusion projects in other countries was further developed. Exchanges of information and scientists continued both with American and Russian fusion laboratories, and during the year an exchange was started of representatives between Culham and the Euratom scientific committee planning the forward research programmes. Culham is represented on the International Fusion Research Council set up by IAEA following exploratory meetings held at Trieste in June.

Overseas laboratories are showing an increasing interest in Culham technology, and several are planning to use equipment designed and built at Culham.



**SATELLITES** Culham Laboratory also carries out development of ion thrustor motors for communications satellites. A thrustor motor being inserted into a test chamber.



**VEC.** Harwell's Variable Energy Cyclotron (shown above)—together with the tandem and Van de Graaff generators and the million volt electron microscope—has made possible the much more rapid testing of materials used in the structure of fast reactors and for the cladding of their fuel.

# Scientific and technical support

The Authority's programmes of reactor research and development and the new industrial projects are supported by a flexible, broadly-based programme of underlying research, involving many disciplines and employing an extensive range of specialised equipment (research reactors, accelerators, computers, radiochemical laboratories and high-activity cells for examining irradiated materials). These facilities, with the skills of the staff who use them, constitute an important national asset. A broad range of industrial and academic problems can be studied with these resources and the Authority derived a significant income from their use by industry, universities and government departments.

The capabilities of the tandem and Van de Graaff accelerators were extended by the development and installation of metal ion sources. By the use of these two machines, and by that of the Variable Energy Cyclotron and the million volt electron microscope installed last year, a major breakthrough was achieved in understanding the phenomenon of void formation, previously only observable in materials subjected to a very much longer irradiation in a fast reactor. This made possible much more rapid testing of the irradiation behaviour of fast reactor fuel cladding and structural materials. The electron microscope also proved a valuable means of observing microstructure, for example, of new ceramics, such as silicon nitride, and of carbon-fibre composites.

The research reactors DIDO and PLUTO at Harwell were fully utilised; the closure last year of the Dounreay Materials Testing Reactor brought additional experiments to these reactors and many new materials testing rigs were designed and constructed. A substantial increase also took place in the use by universities of the neutron beam equipment installed on these reactors and on HERALD at Aldermaston.

Underlying research was kept continuously under review and changes in emphasis were made to meet changing needs of the reactor and applied programmes. Although the overall effort was reduced, effort in three areas was increased; on electrical and optical properties of solids, which is closely linked with radiation damage work and with applied programmes on ion implantation, radiation detectors and thermoelectric generators; on fabrication and testing of new materials, necessary because new technologies must be developed before new materials such as carbon fibres and composites can be fully exploited; and on fluid dynamics, where the need for fundamental research became clear in the course of heat transfer and fluid flow investigations.


**REPROCESSING.** The Windscale reprocessing plant for the extraction of plutonium and uranium has a capacity of over 2,500 tonnes of irradiated nuclear fuel a year.

# The Production Group *

The Production Group factories again increased their overall output during the year. Springfields worked to full capacity on the manufacture of enriched uranium oxide fuel for the Mk. II gas-cooled reactors now under construction. The initial charges for the two Dungeness 'B' reactors were completed. The uranium hexafluoride plant at the factory worked to more than its designed capacity to meet the needs of Capenhurst and overseas orders.

At Capenhurst, production of enriched uranium increased by 50 per cent. Completion of construction of the modified plant for low enriched uranium production was achieved by the target date of April 1970. The plant is expected to have sufficient separative work capacity to meet the demands of the United Kingdom nuclear power programme for several years ahead.

**Throughout 1970/71, development of the gas centrifuge process continued. Experimental cascades, consisting of small numbers of centrifuges, were operated satisfactorily for long periods in uranium hexafluoride, and, by February 1971, a larger-sized cascade, consisting of centrifuges of an improved design, had been commissioned and brought into operation.**

At Windscale, there was an increase of 16 per cent in the amount of irradiated fuel put through the reprocessing plant. A start was also made at Windscale on the production of fuel for the initial charge of the Prototype Fast Reactor (PFR).

All eight reactors at the Calder and Chapelcross power stations operated in accordance with programme throughout the year.

The total value of export sales completed during the year was £5·4 million and the total value of new export contracts signed and letters of intent received was £7·3 million. At the end of the year, outstanding export business covered either by long- or short-term contracts was valued at approximately £21·4 million.

Sales were made to Belgium, Canada, Greece, Holland, Italy, Japan, Norway, Roumania, Sweden, Switzerland, the USA and West Germany.

New contracts won include three in the USA, with Combustion Engineering, Western Nuclear Inc., and Vermont Yankee Nuclear Power Corporation, for conversion of uranium ore concentrate to uranium hexafluoride. **These successes represent a significant breakthrough in the US market in spite of continued keen competition in this field.** Other hexafluoride manufacturing contracts were obtained with Allmanna Svenska Elektriska Aktiebolaget, Sweden; and Nordostschweizerische Kraftwerke A.G., Switzerland. Contracts were also signed for the supply of further plutonium for Power Reactor and Nuclear Fuel Development Corporation, Japan, and for the reprocessing of irradiated oxide fuel from the Whiteshell reactor in Canada, the Lingen reactor in Germany and the Tsuruga reactor in Japan.

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The nuclear industry had its origins in defence requirements in the 1940s. In January 1946 the Prime Minister informed the House of Commons that an organisation had been formed "to make available, as speedily as possible, fissile material in sufficient quantity to enable us to take advantage rapidly of technical developments as they occur". The organisation first established was part of the Ministry of Supply.

Uranium ore was first treated at the Springfields factory in 1948 and the first plutonium production reactor at Windscale came into operation in 1950. Other developments followed in rapid succession. Irradiated uranium was first processed at Windscale in 1952, the diffusion plant for uranium enrichment at Capenhurst started up in 1953 and in October 1956 the world's first commercial scale nuclear power station at Calder Hall started to supply electricity to the National Grid.

In August 1954 the United Kingdom Atomic Energy Authority was formed as a public corporation. The Industrial Group of the Authority, forerunner of the Production and Reactor Groups, took over responsibility for the Springfields, Windscale and Capenhurst factories. Since that time the activities of these factories have been greatly expanded as the home and overseas commercial business of Production Group has been developed to the point where the Group has established a leading position among the world's suppliers of nuclear fuel services.

By 1964 this business had reached a level at which it was considered desirable that it should be operated under financial arrangements of a fully commercial character. Accordingly there was set up on 1st April 1965, a Trading Fund, in which the net revenue from the sale of nuclear fuel, electricity, radioisotopes and associated services would be retained and used to meet fixed and working capital requirements and to create reserves for future expansion.

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*** Now British Nuclear Fuels Ltd.**


**AMERSHAM** is the world's largest international supplier of radioisotopes and related products. In 1970/71 the number of consignments sent to all parts of the world was 119,000.

# The Radiochemical Centre*

In 1970/71, the net sales of radioactive material from The Radiochemical Centre, Amersham, again increased, to £4·8 million, of which £2·8 million (61 per cent) was exported. **The proportion exported was the highest so far, and the growth of sales by 19·3 per cent this year followed an increase of 21·3 per cent last year.**

The growth of sales was not limited to any particular products or markets, but particularly good progress was made in radioactive pharmaceuticals and radiation sources for industrial and medical use, with a substantial proportion on account of new products developed in recent years at Amersham.

The number of consignments sent to all parts of the world increased to 119,000 and good progress was made with the construction and fitting out of a major new building complex to provide additional laboratory and warehouse facilities. **A new comprehensive catalogue in four parts was distributed worldwide to 25,000 isotope users.**

Further valuable developments in production methods and in the product range have been obtained as a result of a planned increase in the effort allocated to research and development. There have also been important improvements in methods of quality control in support of the Centre's well-established reputation for reliability and high purity products.

In the Organic Department increased emphasis on longer-term development has been made possible by the filling out of the product range during the past few years. Improvements during 1970 in production of carbon-14 and tritium nucleosides and nucleotides have put the Centre in the leading position as a supplier of these important compounds. 23 new carbon-14 and 58 new tritium compounds were added during the year, many not available elsewhere. Well over 90 per cent of orders were met from stock.

Over the last few years iodine-125 has become the most important isotope of iodine in the diagnostic nuclear medicine field. A new process, based on the safe irradiation of enriched xenon-124 gas under pressure in a reactor, has given high yields of iodine-125 of 100 per cent isotopic abundance and excellent quality for protein labelling. **As a result the UK is now self-sufficient for the supply of this important isotope.**

Shortlived radionuclides such as technetium-99m, strontium-87m and indium-113m are also used extensively in medical diagnosis. They are prepared as required at the hospitals from generators loaded with the corresponding parent radionuclides. Generators supplied by The Radiochemical Centre have hitherto been non-sterile, and the products from them required sterilisation procedures before they could be injected. Sterile generators have now been developed which permit direct preparation of a sterile product. The design adopted gives other advantages. **These improvements have led to marked increases in sales in the U.K. and in Europe.**

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The Radiochemical Centre was established under public ownership in 1946 with the purpose of providing an adequate supply of radioactive isotopes for scientists, doctors and technologists, who were expected to use them increasingly as they became more readily available as byproducts of the development of nuclear energy. A small privately owned laboratory at Amersham, which since 1940 had been producing radium and luminous paints for wartime purposes, was used as the nucleus of the new establishment. In the early years while the facilities and staff at Amersham were being expanded, the development of the radioisotopes service was undertaken jointly between Amersham and the Isotope Division at Harwell. In 1959 the Authority reorganised its work in the isotope field and placed a full responsibility with the Radiochemical Centre for manufacturing and marketing all radioactive isotopes for civil use.

The original concept was of supplying UK requirements only, and at cost; but opportunities for exporting radioisotopes were soon realised, despite the early American lead in this field, and from 1954 when the UKAEA took over, the operation was systematically developed as a profitable commercial enterprise and the Centre became a leading international supplier with worldwide custom. From then on, until its incorporation as a limited company following the Atomic Energy Authority Act of 1971, the Centre has operated as a virtually separate business, latterly within the Authority's Trading Fund.

Growth of sales has been rapid, averaging 15 per cent per annum in recent years, with consistently more than half the total exported (as credited by two Queen's Awards for Industry). By Vesting Day the enterprise had grown to have a turnover approaching £5 million per annum, employing about 700 people and with extensive laboratories and offices on the 18 acre site at Amersham and a Department at Harwell.

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*** Now The Radiochemical Centre Ltd.**


**FRONT COVER :** New large zero-energy critical facility, ZENITH II, under construction at Winfrith. It will be used to study the specific design characteristics of Mark III (High-Temperature) Gas-Cooled Reactors.

**CENTRE PAGES :** The Dounreay Experimental Reactor Establishment in Caithness, Scotland. The Prototype Fast Reactor, due for completion in 1972, can be seen on the extreme left of the photograph. Its forerunner, the Dounreay Fast Reactor, is identifiable by its distinctive metal sphere nearer the centre of the picture.

**ABOVE :** Ultrasonic thickness micrometer in use at the Non-Destructive Testing Centre, Harwell. This instrument, which gives a digital reading of the wall-thickness of tubing, is typical of the specialised systems available for the solution of specific industrial problems.

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