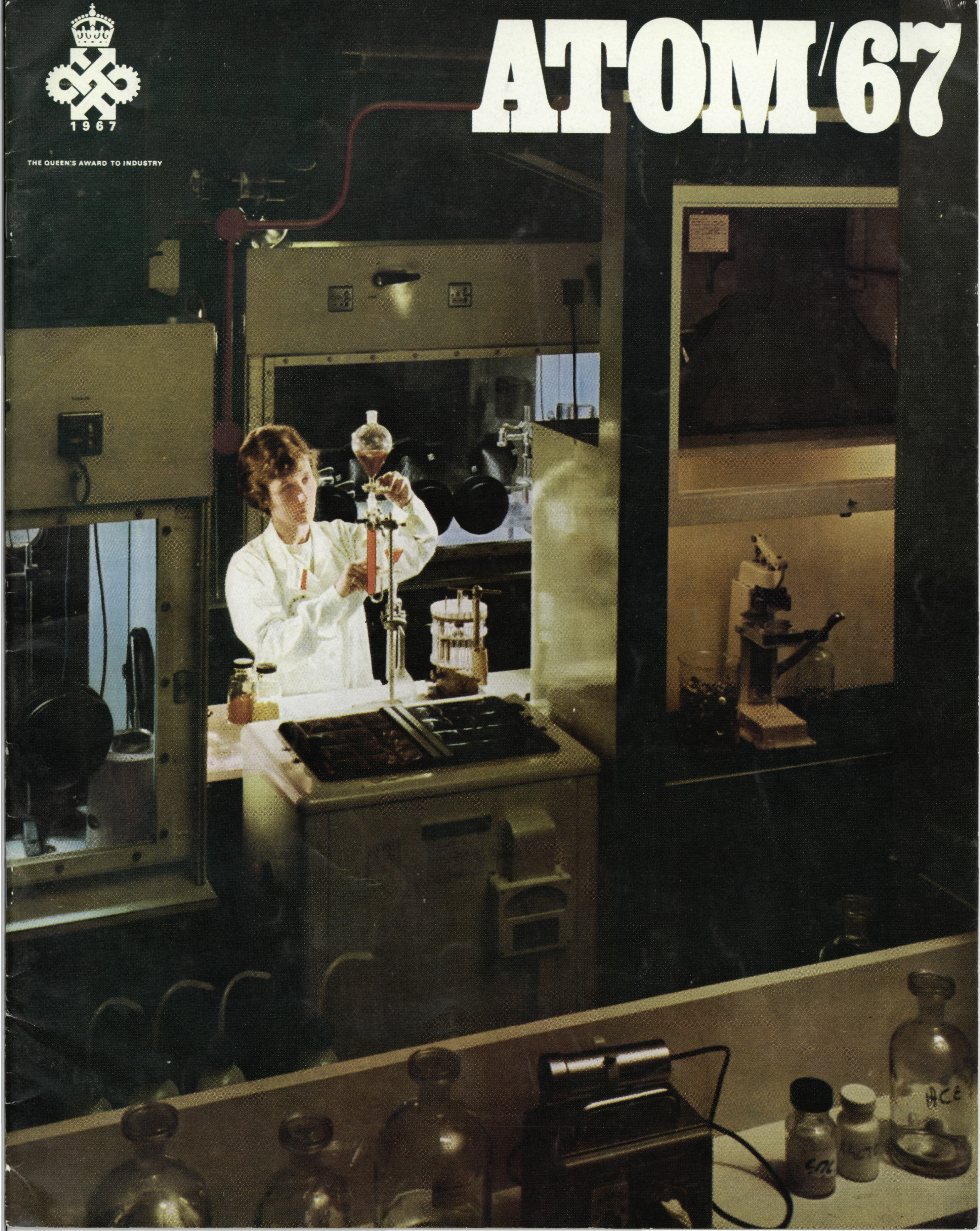
An illustrated summary of the thirteenth annual report of the United Kingdom Atomic Energy Authority from 1st April 1966 to 31st March 1967

1967

THE QUEEN'S AWARD TO INDUSTRY

ATOM/67



1966/67

The ten years since the opening of Calder Hall have seen the acceptance of nuclear power as an economic alternative to the more traditional methods of electricity generation. In 1956, Calder Hall was a daring step forward. No one at that time could be sure that this installation – the first of its kind in the world to produce electricity on an industrial scale – would achieve the results which its designers intended. In the event, the performance of the Calder Hall and Chapelcross reactors over ten years has been remarkable for its reliability and increasing efficiency. These reactors have consistently achieved high load factors, averaging 93% in 1966/67 as in the previous year.

The first two reactors at Calder Hall were designed to produce 70 Megawatts of electricity. Developments have been so rapid that the Central Electricity Generating Board, together with the South of Scotland Electricity Board, plan to have a total of 13,000 Megawatts of nuclear power commissioned by 1975. This means that British scientists and engineers, in both Government and industry, are accumulating unrivalled experience in designing, building and operating nuclear stations. At present—although of course the balance will change over the coming years—almost half the world's total operating capacity for generating electricity from nuclear power is in this country. Already over 10% of all electricity in England and Wales comes from nuclear power; in Scotland the proportion is twice as high.

Through its substantial investment in thermal reactor power stations, the U.K. will be building up the stocks of plutonium needed to fuel the fast breeder reactors with which the long term future of nuclear power will lie. The greater part of the Authority's reactor development effort is devoted to the fast reactor, on which the U.K. is further advanced than any other country with the exception of U.S.S.R.

These achievements in the nuclear power field reflect only part of the Authority's activities. The Authority continue to meet the requirements placed upon them by the Ministry of Defence and also carry out a substantial programme of more fundamental research and development.

Production

The Authority operate under one management plants which provide a comprehensive fuel service and also a radioisotope manufacturing and marketing organisation.

The existing production plants operated satisfactorily during the year and fulfilled the requirements of both home and overseas users. The major capital projects under way are the modification of Capenhurst (estimated to cost £14.4 million) to increase the output and reduce the cost of enriched uranium, the installation of the oxide fuel production lines at Springfields and, at Windscale, the "head-end" plant to permit the reprocessing of uranium oxide fuel and the plant for manufacture of plutonium-bearing fuel for the Prototype Fast Reactor (P.F.R.). All these projects proceeded according to programme.

Commercial and Financial Operations

The Authority's sales, primarily of nuclear fuel services, electricity and isotopes, but including also transfers of material within the Authority, totalled £32.3 million in the year, with a net surplus of £3.3 million. All the electricity, and the larger part of the fuel service sales, were to the U.K. electricity generating boards, but substantial overseas fuel service business was secured. Sales of radioisotopes increased by 12½ per cent. to £2.5 million, of which over one half by value was exported. The achievements of the Radiochemical Centre, Amersham, were recognised by the grant of the Queen's Award to Industry.

There is now little doubt that for the first five years of trading, the Trading Fund—set up in 1965—will more than meet its target surplus of £3.9 million, after taking account of the effects of taxation. Trading results confirm the hope that the investment of about £14 million in the expansion of the Capenhurst factory can be provided from the resources of the Trading Fund without borrowing.

The non-trading estimate for 1967/68 totalled £17.2 million net (£71.5 million gross). The deployment of the Authority's expenditure on civil research and development and of the professional staff engaged thereon is shown in the table below.

Reactor Export Promotion

On 10th June, 1966, the Authority and the three Consortia established the British Nuclear Export Executive (B.N.X.) with three main functions viz., to co-ordinate sales presentation and promotion of British reactor systems in overseas markets; to act as a focal point to which foreign utilities and other organisations interested in nuclear power could direct their enquiries; to select, subject to any particular wishes of the customer, the consortium considered to be in the most suitable position to handle each particular project.

In the short time since its formation, B.N.X. has established valuable contacts in a number of overseas countries. The Authority provided considerable assistance in sales promotion activities in support of B.N.X. and of individual consortia to which particular projects had been assigned. Particular mention should be made of support activities in Belgium, Austria, Switzerland, West Germany and Rumania. In addition, by agreement with B.N.X., the Authority have taken the lead in sales promotion in Finland, Greece and Japan.

Reactor Development Programme

The Authority's reactor development programme is aimed primarily at establishing the reactor systems which will be used for electricity generating stations in the U.K. The Authority also participated in the nuclear aspects of the submarine programme, and a limited effort was applied to studies of small reactors for civil purposes.

Nuclear Research and Development

In addition to research in aid of production processes and in direct support of the reactor development programme, nuclear research and development is conducted by the Authority in five main areas:-

- General research and development;
- Plasma physics and fusion research;
- Weapons and the detection of nuclear explosions;
- Radioisotope applications;
- Health and safety.

The general research and development programme is aimed both at the solution of current technical problems and anticipating future problems, as well as the development of new materials and processes for future application. Much of this research is directed towards extending knowledge of existing materials and to the preparation and evaluation of new or improved fuel, cladding or structural materials suitable for use at the high temperatures and burn-up envisaged for future reactor systems.

Intense neutron beams from reactors provide an important method of investigating the properties of materials on an atomic scale. A design study was completed for a high-flux beam reactor to provide very high neutron intensities and a detailed proposal to build such a reactor at Harwell was submitted to the Minister of Technology.

The variable energy cyclotron at Harwell was commissioned during the year.

The Authority's general research and development activity often leads to the development of new techniques and equipment many of which have applications outside the nuclear field. The largest single programme of the Authority's non-nuclear activities is research and development on desalination.

The programme of plasma physics and fusion research has continued at the Culham Laboratory. The Authority set up a working party during the year to review this programme and their report was under consideration at the end of the year*. The fusion research programme is supported by technological and other work, some of which is capable of wider application notably in the fields of stellar spectroscopy, super-conducting magnets and cryogenics, and improved methods of utilising fast computers.

Work continued at the Atomic Weapons Research Establishment, Aldermaston, at the request of the Ministry of Defence, on the development of better methods of detecting nuclear explosions in different environments from below ground level to outer space. Confirmation of theoretical predictions on the behaviour of seismic surface waves has led to the possiblity of improved diagnosis of underground explosions.

During the year the Authority reviewed the inter-group machinery for allocating and directing research and development resources. This review resulted in the setting up of three committees, each under a Member of the Authority and responsible to the full-time Members collectively, dealing respectively with reactor research and development, general nuclear research and development and non-nuclear research and development. The relevant groups of the Authority are represented on these Committees. These arrangements (which replace a number of previous bodies, including the Authority Reactor Programme Committee and the Research Policy Committee) were designed to ensure that full advantage can be taken of the close links between all parts of the Authority's overall programme, including their military and production responsibilities. In addition, the Authority's Committee on Efficiency Services has been reconstituted and is securing economies in manpower.

In February, 1967, the Ministry of Technology and the Authority set up a Joint Programmes Analysis Unit at Harwell, responsible to the Member for Research but serving both organisations. The Unit will maintain records of the deployment of research and development resources both in Ministry establishments and within the Authority, develop criteria and techniques of analysis by which the benefits of such programmes can be assessed and apply these criteria and techniques to the assessment of current and proposed programmes.

* The Authority concluded that their present effort on plasma physics and fusion research should be reduced over the next five years by about ten per cent. a year, and the Minister of Technology informed the House of Commons on 26th July, 1967 that he had endorsed this conclusion.

NUCLEAR CIVIL RESEARCH AND DEVELOPMENT

	Expenditure £ million (Approximate)										Qualified Scientists and Engineers	
	1962/63		1963/64		1964/65		1965/66		1966/67		31.3.66	31.3.67
	Current	Capital	Current	Capital	Current	Capital	Current	Capital	Current	Capital		
Reactor research & development programme												
(i) Major Development												
(a) Gas Cooled Systems	11.0	5.0	10.0	1.5	9.0	1.0	8.0	0.5	7.5	0.5	425	395
(b) Water Moderated Systems	3.5	1.0	5.0	2.0	5.5	4.0	6.5	5.0	7.0	6.5	410	405
(c) Fast Systems	6.0	3.0	7.0	1.5	9.0	1.5	10.0	1.0	9.0	2.0	670	660
(ii) General Reactor Technology	4.5	1.0	4.0	1.0	4.0	0.5	4.5	—	4.0	0.5	375	320
Other research												
(a) Basic Research	5.0	1.0	5.0	1.5	5.0	1.5	6.0	1.0	7.0	1.0	420	400
(b) Health and Safety Basic Research	0.5	—	1.0	—	1.0	—	1.0	—	1.0	—	95	100
(c) Isotope Research	1.0	—	0.5	—	0.5	—	0.5	—	0.5	—	60	65
(d) Plasma Physics and Fusion Research	3.0	2.5	3.5	1.5	3.5	1.5	3.0	1.0	3.5	0.5	190	190
	34.5	13.5	36.0	9.0	37.5	10.0	39.5	8.5	39.5	11.0	2645	2535

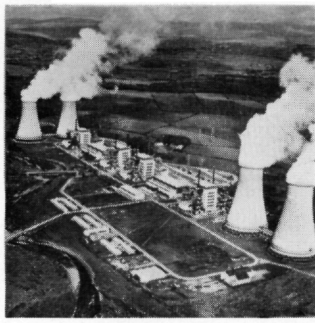
The Authority's Reactor Development Programme provides for three prototype reactors:

	Start Construction	Commence Operation	Estimated Cost £ million
A.G.R.	1957	1962	10
S.G.H.W.R.	1963	1967	16
P.F.R.	1966	1971	30

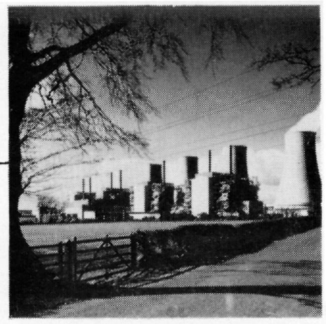
Non-nuclear research and development

Cash expenditure in 1966/67 on research and development on non-nuclear projects (undertaken in accordance with Section 4 of the Science and Technology Act, 1965) amounted to £772,000. In addition, civil non-nuclear work on repayment undertaken mainly for Government Departments and Universities amounted to £383,000.

Dounreay Prototype Fast Reactor under construction

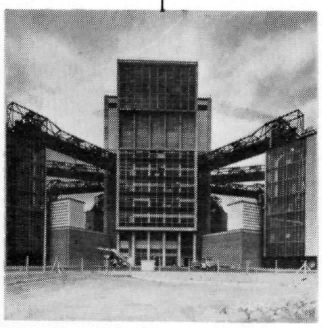


Calder Hall
1956

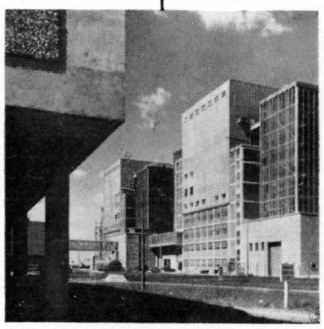


Chapelcross
1958

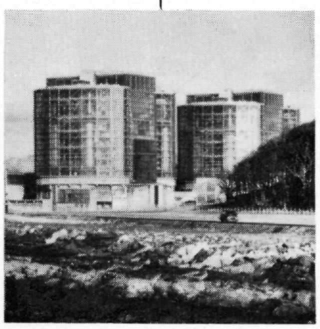
NUCLEAR POWER IN BRITAIN



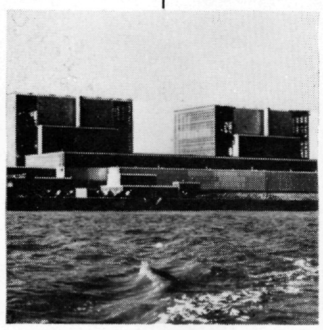
Berkeley (CEGB)
1962 275MW



Bradwell (CEGB)
1962 300MW

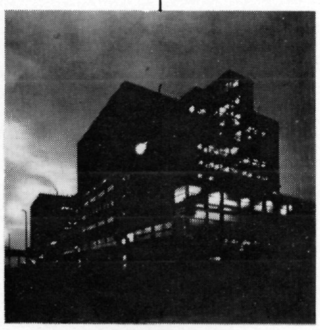


Hunterston (SSEB)
1964 320MW

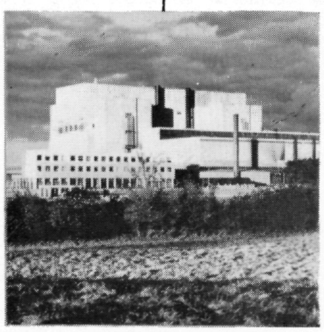


Hinkley Point A (CEGB)
1965 500MW

Trawsfynydd (CEGB)
1965 500MW

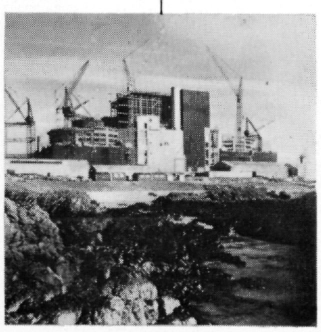


Dungeness A (CEGB)
1965 550MW



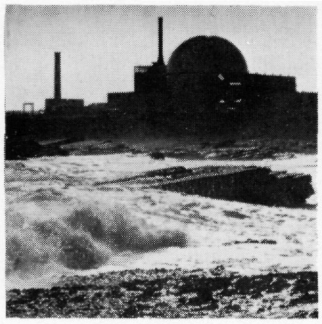
Sizewell A (CEGB)
1966 580MW

Oldbury A (CEGB)
1967 600MW



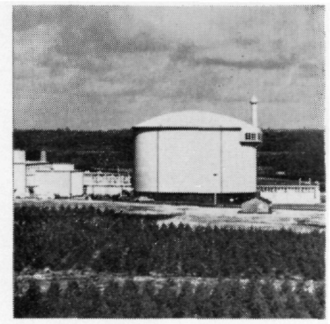
Wylfa (CEGB)
1969 1180MW

A.G.R., Windscale
1962

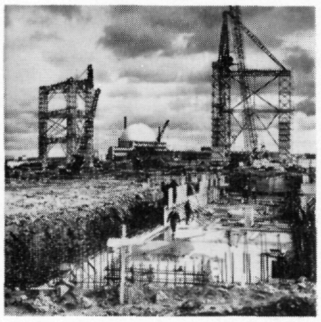


D.F.R.
1959

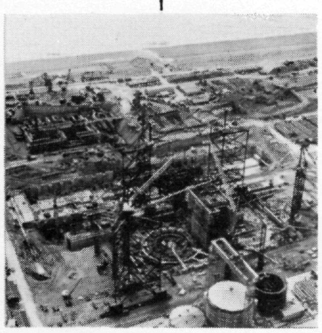
S.G.H.W.R.
1967



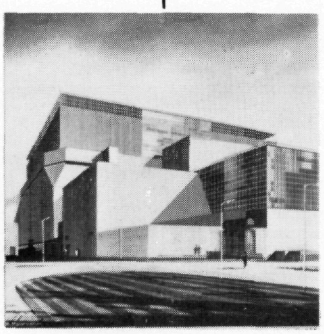
H.T.G.R. (Dragon)
1964



P.F.R.
1971 250MW



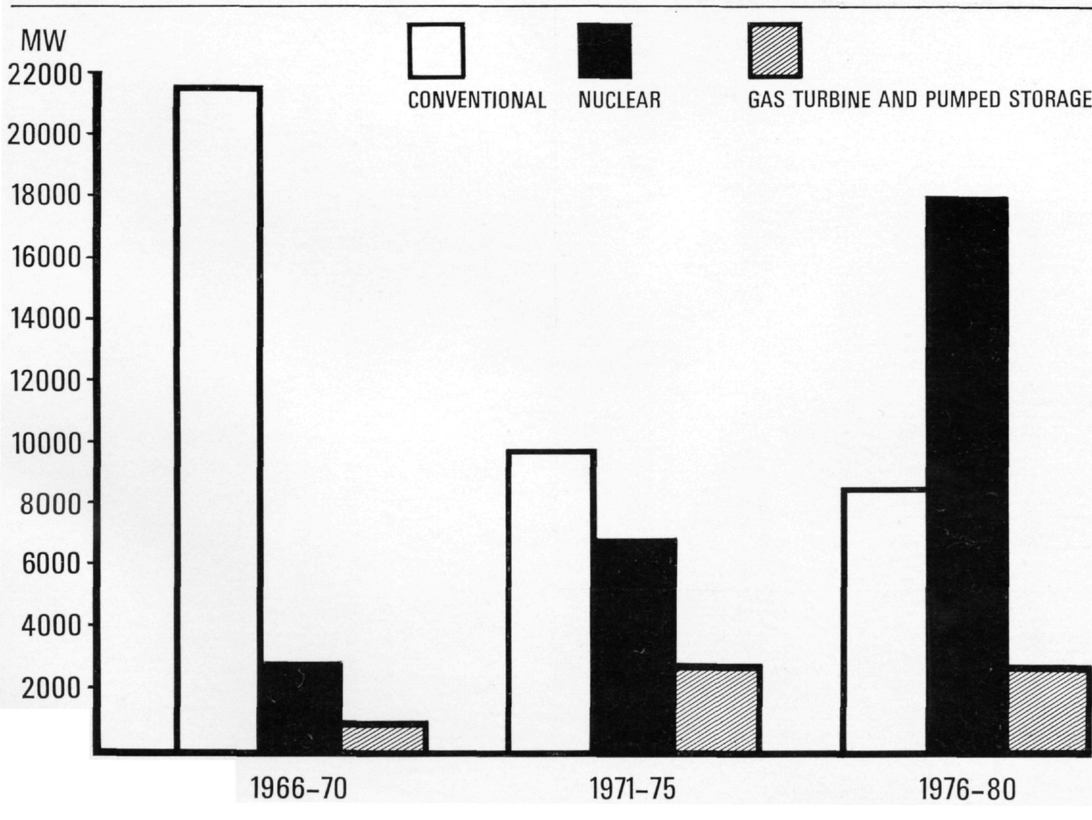
Dungeness B (CEGB)
1970 1200MW



Hinkley Point B (CEGB)
1972 1250MW

Approval has also been given for a 1250 MW A.G.R. at Hunterston "B". Completion of the Second Nuclear Power Programme will give the U.K. a total of 13,000 MW by 1975.

THE CHANGING PATTERN OF POWER



NEW PLANT PROGRAMMED BY CEGB

The diagram (left) illustrates the following passage in a memorandum submitted by the Central Electricity Generating Board to the Select Committee on Science and Technology:

"Plant commissioned and programmed to be commissioned by the Generating Board up to 1980 is as follows:-

Period	Conventional MW	Nuclear MW	Gas Turbine and Pumped Storage MW
1961-65	8,638	2,415	1,069
1966-70	21,666	2,670	800
1971-75	8,000-11,000	6,000- 7,000	2,000-3,000
1976-80	6,000-11,000	16,000-20,000	2,000-3,000

"There is no definite programme of nuclear plant beyond 1975, but indications are that nuclear will be the most economic source of base load power. Fuel policy, however, remains to be decided but on economic grounds it seems likely that by 1980 the major portion of the Board's new capacity should be nuclear.

"On this basis, by 1985 the amount of nuclear plant in service could be more than is required to meet the base load. Nuclear plant would then have to compete with conventional plant and gas turbines, both in flexibility of operation and generation cost at lower load factors".

POWER REACTOR DEVELOPMENT

The Authority's reactor development programme is aimed primarily at establishing the reactor systems which will be used for electricity generating stations in the United Kingdom. The main activities during 1966/67 were: ■ Supporting work on and further development of the **Advanced Gas-Cooled Reactor** system (A.G.R.), at present being installed in the first stations of the Second Nuclear Power Programme. ■ Completion of the Authority's prototype **Steam Generating Heavy Water Reactor** (S.G.H.W.R.) power station at the Atomic Energy Establishment, Winfrith. ■ Development of **Fast Reactor** systems for exploitation in the 1970's, including the operation of the Dounreay Fast Reactor and the construction of the 250 Megawatt Prototype Fast Reactor. ■ Continued participation in the O.E.C.D.'s **High Temperature Reactor Project** ("Dragon").

ADVANCED GAS-COOLED REACTOR

Collaboration was maintained with the Electricity Generating Boards and the Consortia on the development of the Advanced Gas-Cooled Reactor for commercial power stations.

Assistance was given by the Authority on the tender assessments for Hinkley Point 'B' (Central Electricity Generating Board) and Hunterston 'B' (South of Scotland Electricity Board) and in preparing the specification for a further station.

Outline designs for A.G.R. power stations were prepared for certain overseas utilities. For example, the Authority carried out a joint study with a Japanese company to prepare A.G.R. station designs and cost estimates for construction to Japanese standards and geological conditions. Results indicate that an A.G.R. can be built, with competitive generating costs, to withstand the seismic conditions prevailing in Japan.

The Advanced Gas-Cooled Reactor at Windscale has operated successfully and has been used for experimental fuel irradiations for over four years **with an average availability of 84 per cent.**

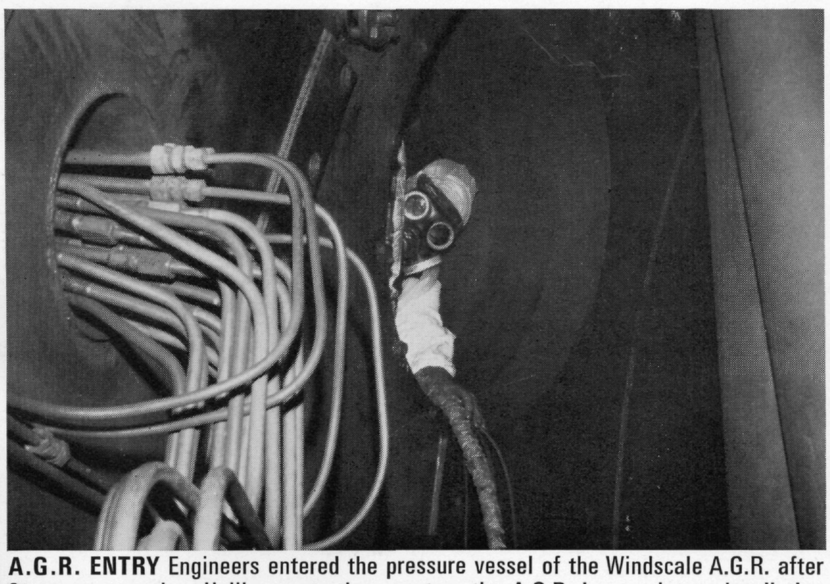
An important factor contributing to the success of the Windscale A.G.R. has been the excellent performance of engineering plant and equipment—in particular, the refuelling machine. About 650 on-load refuelling operations have been completed since the machine was commissioned. This is equivalent to **over ten years**' fuel cycle operation in a 600 Megawatt A.G.R. power station.

Improvements introduced during the year for the fuel to be used at Dungeness 'B' (the first commercial A.G.R. station of the Second Nuclear Power Programme) will also be specified for later stations.

As a further development, experimental work proceeded with **all-ceramic fuel** which offers the prospect of significant economic advances as it can operate at a higher temperature, rating and burn-up.

A significant event during 1966/67 was the entry into the pressure vessel of the Windscale A.G.R. to inspect parts of the internal structure.

The examination was carried out **with a full load of radioactive fuel** in the reactor core and confirmed confidence in the ability to design internal shielding of A.G.R.'s to allow the gas-circuit to be entered for inspection after the reactor has been in operation.



A.G.R. ENTRY Engineers entered the pressure vessel of the Windscale A.G.R. after 3½ years operation. Unlike most other reactors the A.G.R. has an internal radiation shield that allows entry for inspection even when the reactor is full of radioactive fuel.

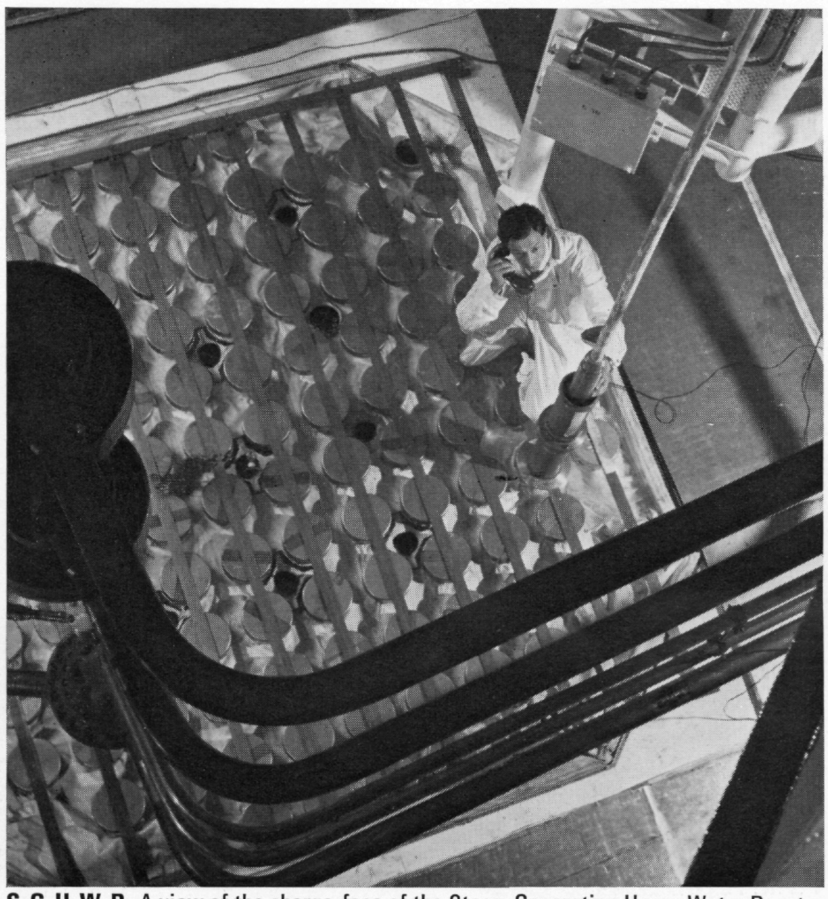
STEAM GENERATING HEAVY WATER REACTOR

Construction and testing of the 100 Megawatt (electrical) prototype Steam Generating Heavy Water Reactor proceeded ahead of programme, but expectations of advancing the fuel-loading to the Spring of 1967 had to be abandoned in February when contamination by a mercury-containing compound caused corrosion in one area. Repair work set back the fuel loading by about four months, but work has proceeded on other parts of the reactor and the programmed on-power date (end of 1967) will not be affected significantly.

Experience with the prototype has confirmed that a comparatively short construction time can be achieved with this type of reactor. This is largely due to the fact that all the major reactor components can be shop-fabricated and the essential building and civil work can be carried out before erection of these components needs to take place.

Minor changes in the S.G.H.W.R. fuel can increase its heat rating by about 30%, and this improved fuel has been incorporated in a design of a 350 Megawatt reactor (using enriched uranium—like the prototype) which should be competitive in world markets.

The design development of an S.G.H.W.R. fuelled with natural uranium has begun. A team of engineers from Australia and New Zealand is participating in this work at Reactor Group headquarters at Risley. The study will last for about two years.



S.G.H.W.R. A view of the charge-face of the Steam Generating Heavy Water Reactor at Winfrith which is programmed to go on power at the end of 1967. Shop-fabrication of all major reactor components allows a comparatively short construction time on site.

PFR: Steel structure being erected: June ,1967

FAST REACTORS

The plutonium fuel produced in thermal reactors can be burned in fast reactors, which will also breed more plutonium. The aim of the Authority's fast reactor development programme is to make possible the commissioning—by a generating board—of the first large commercial station of this type in the middle to late 1970's.

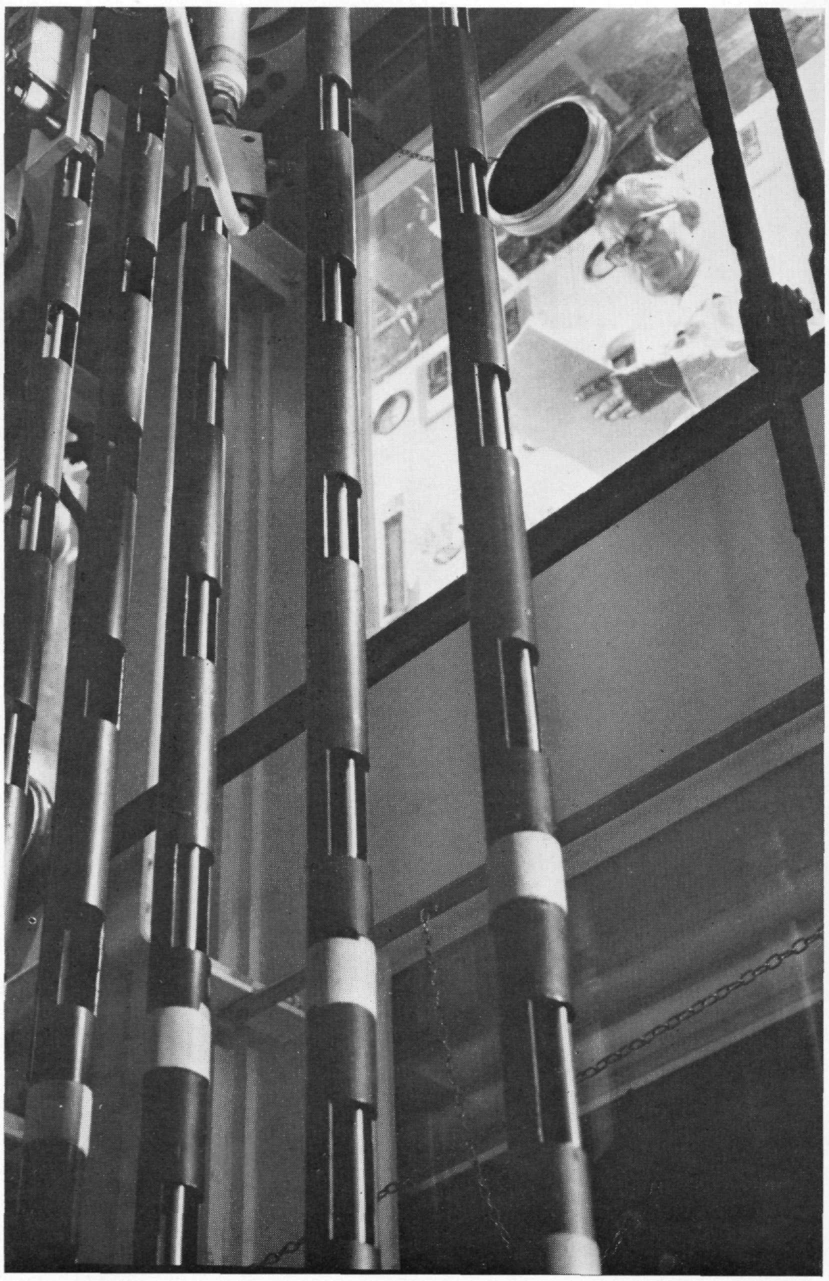
A major stage in the development programme was reached in the spring of 1966, when the construction was started of the 600 Megawatt (heat)/250 Megawatt (electrical) Prototype Fast Reactor.

By March, 1967, work on site was well advanced and most of the major contracts had been placed.

Experience with this prototype will be one of the major factors in establishing the design of large fast reactor power stations. An engineering feature of great importance is the large, single-tank primary circuit, which has never been attempted before in such a size (40 feet in diameter and 50 feet deep). The design and stress analysis of the tank has indicated that, in spite of the complex problems involved, such an approach is feasible and economically attractive for larger reactors.

The Dounreay Fast Reactor has for some years been used as a test facility in support of the Prototype Fast Reactor, S.G.H.W.R. and A.G.R. projects. It is used in the fuel development programmes and also to obtain information at accelerated rates on irradiation damage received by reactor structural materials.

The Dounreay Fast Reactor has produced more units of electricity than any other fast reactor in the world.



P.F.R. FUEL Manufacturing processes for the fuel of the Prototype Fast Reactor are being studied in a small-scale plant at Aldermaston (picture shows P.F.R. fuel elements in transport tubes). Construction of the 250-Megawatt P.F.R. began at Dounreay in the spring of 1966.

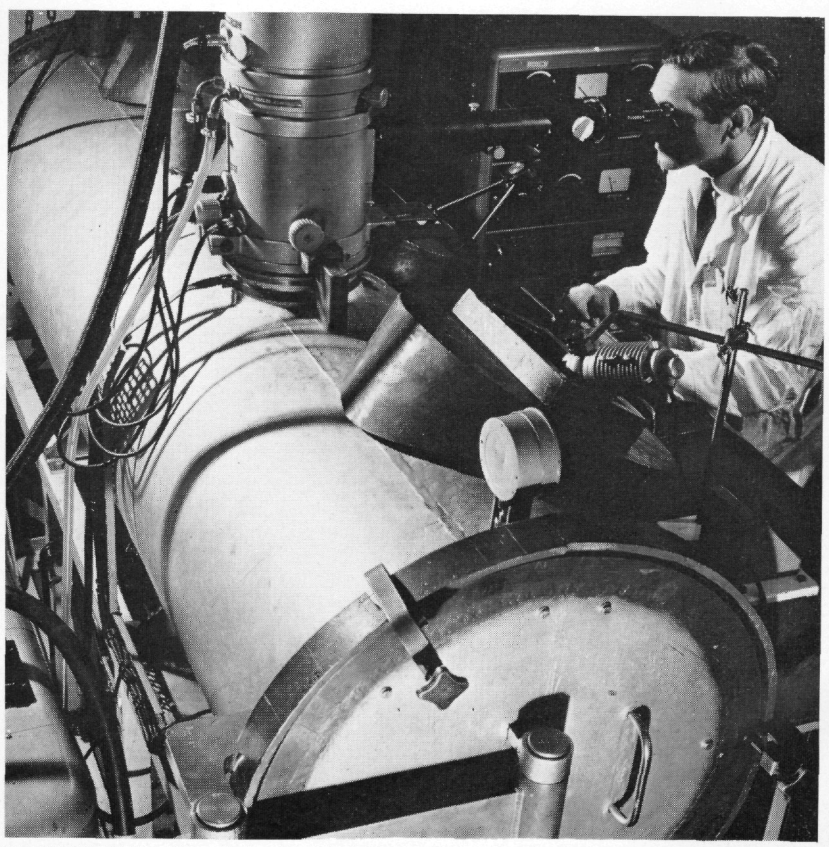
HIGH-TEMPERATURE GAS-COOLED REACTORS

Operation of the Dragon reactor experiment on behalf of the Organisation for Economic Co-operation and Development continued satisfactorily. Design power of 20 MW(H) was first achieved on 24th April, 1966, and operation at full power with the first fuel charge continued until 1st September. The performance of all major plant components was satisfactory. Reactor operation restarted in December, 1966, and the reactor is at present running at its design power.

Operation of the Dragon High Temperature Gas-Cooled Reactor demonstrated the satisfactory solution of the engineering problems involved in using helium as a coolant at high temperature and pressure.

In July, 1967, the Minister of Technology, Mr. Anthony Wedgwood Benn, announced that—to avoid premature shut down of the project—H.M. Government had offered to bear most of the cost for 1968. This offer had been made in the hope that the other major contributor, Euratom, would be in a position by mid-1968 to agree to the extension of the project to 31st March, 1970.

DESIGN Teams from Australia and New Zealand are working with the Reactor Group on the development of an S.G.H.W.R. fuelled with natural uranium. Above—left to right—Dr. J. Aspden and Mr. A. V. Hatrick (New Zealand) are with Mr. R. V. Moore (Managing Director) and Mr. D. R. Ebeling (Australia).



PRECISION The Metallurgy Division of the Dounreay Experimental Reactor Establishment develops and fabricates fuel elements for the fast reactor and the Materials Testing Reactor. It also examines fuel elements and other reactor materials after irradiation. The photograph shows precision welding of M.T.R. fuel tubes.

RIPPLE

The first isotope-powered marine light in Europe was installed by Harwell at the Dungeness 'B' nuclear power station in June, 1967.

A one-watt RIPPLE (Radioisotope Powered Prolonged Life Equipment) generator provides electricity for a flashing obstruction light placed offshore to mark the platform over the cooling water intake for the power station.

The installation was made in co-operation with the Central Electricity Generating Board and the Board of Trinity House. Trinity House are the general Lighthouse Authority for England and Wales and are anxious to take this opportunity of obtaining in-service evaluation of such generators.

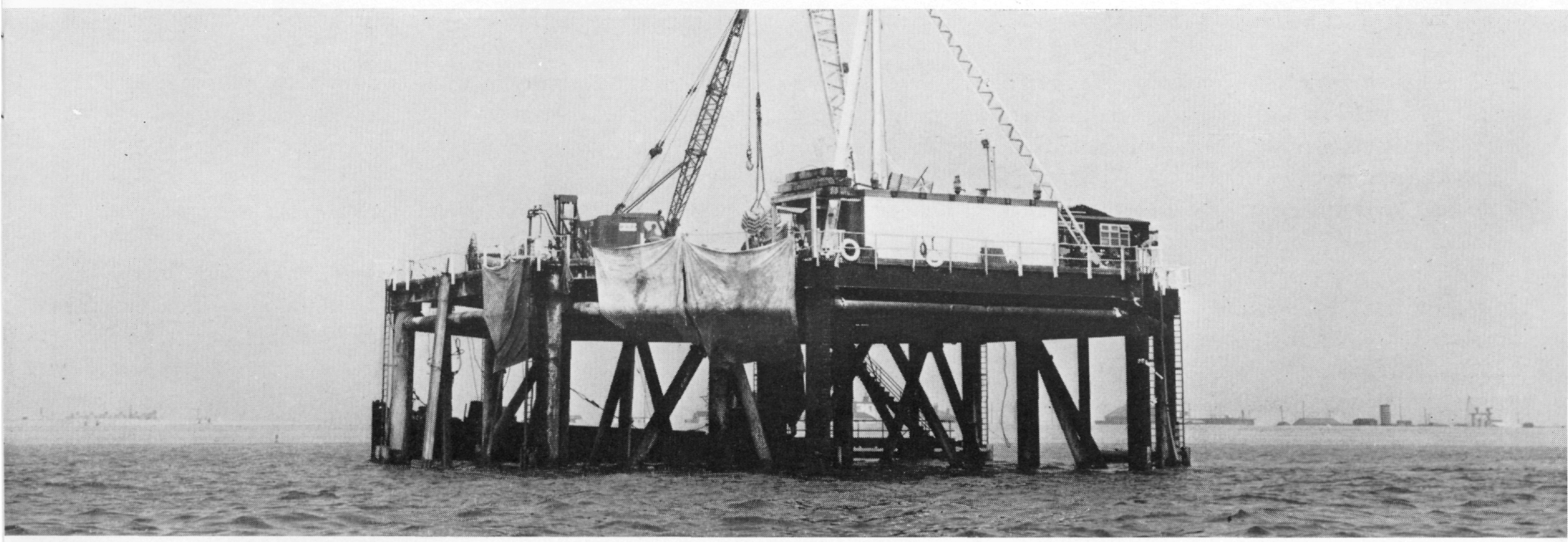
RIPPLE generators use the heat from the decay of radioactive strontium to generate electricity in an assembly of thermocouples. The strontium is obtained from the spent fuel of nuclear power stations.

The whole system is inherently reliable and is capable of operating unattended for very long periods; design lives of five to ten years are easily possible and extension of the life to 20 years is projected. Developments are in hand to extend the capability of the generator to the 25-watt power range.

Two prototypes similar to that in use at Dungeness are to be used by the authorities in Sweden and Denmark for in-service evaluation while supplying power to navigational lights. A fourth 4-watt generator built by Submarine Cables, Ltd., will be used as the power source for an airport outer-marker beacon under the auspices of the Board of Trade (Civil Aviation Department). Under a recently negotiated agreement, Submarine Cables, Ltd., are to manufacture generators to designs based on the Harwell work.

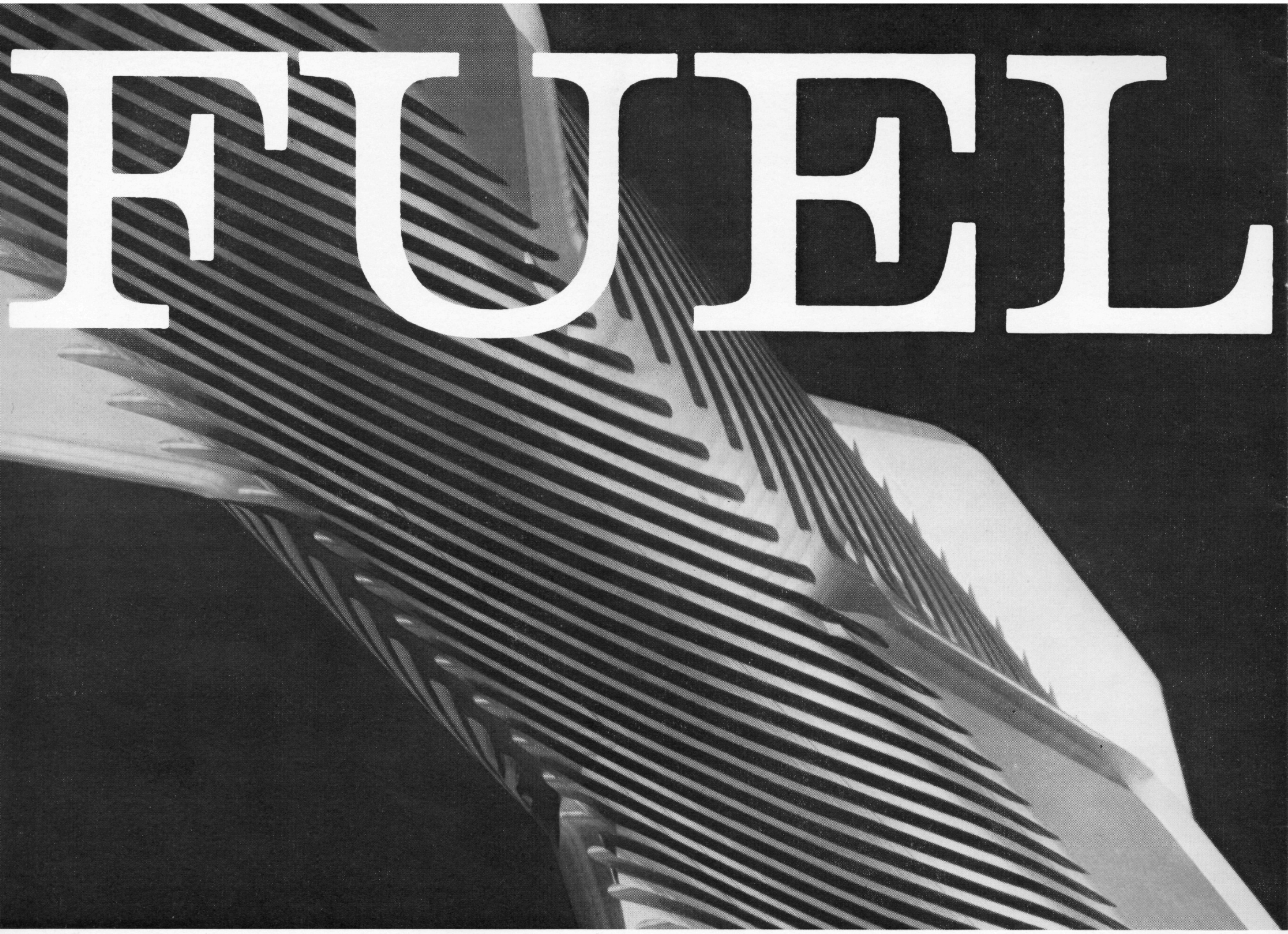
One of their concerns is with submersible repeaters for underwater cables. A RIPPLE 3 (0.4 watts) has been loaned to the U.S. Navy Department for evaluation in an underwater application.

Land-based applications can range from marine navigational lights to unmanned weather-stations, aircraft beacons and complete radio-communication systems. In all of these the ability to operate for long periods without fuelling or maintenance makes the generators attractive.



At top of page: The RIPPLE beacon at Dungeness nuclear power station. *Above:* The offshore platform marked by the beacon.

FUEL



Most of the manufacturing effort at the Springfields fuel-element plant is still devoted to the production of metallic fuel elements for the First Nuclear Power Programme (of Calder Hall-type stations).

Civil engineering work has, however, started on the installation of the full-scale oxide fuel production lines which will be required for the Second Nuclear Power Programme (by which the Advanced Gas-Cooled Reactor has been introduced into the electricity generating system).

The production line for the fabrication and assembly of fuel for the Steam Generating Heavy Water Reactor at Winfrith was commissioned and operated during the year.

The Capenhurst plant—for the production of enriched uranium—is to undergo modifications which will increase output and reduce costs. Approval has been given to modifications which will cost £14.4 million. These—which involve the total reconstruction of the larger process units of the plant—will enable it to provide the enriched uranium required for the first three stations of the Second Nuclear Power Programme: Dungeness 'B'; Hinkley Point 'B'; and Hunterston 'B'.

Beyond 1971 the capacity of the modified plant will be inadequate to meet forecast United Kingdom requirements for enriched uranium and a new and larger process unit will be needed.

The power requirements of the Capenhurst plant, which will be about 200 megawatts in 1970, are expected to increase several-fold during the next decade. Furthermore, payments for power represent about a half of the cost of enriching uranium in a diffusion plant. For these reasons the Authority have considered the possibility of constructing a nuclear power station which would supply power to Capenhurst, and have discussed with the Rio Tinto Zinc Corporation the possible supply from the same station of power for a large aluminium reduction plant. Proposals were submitted to Her Majesty's Government and were under consideration at the end of the year.

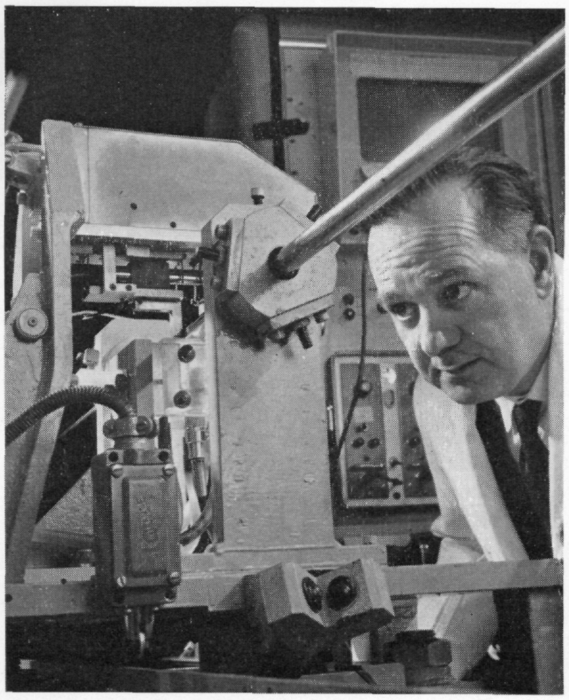
Among overseas orders totalling £2.6 million during 1966/67 were:—

The supply of 68.5 tonnes of replacement fuel for the Latina reactor in Italy.

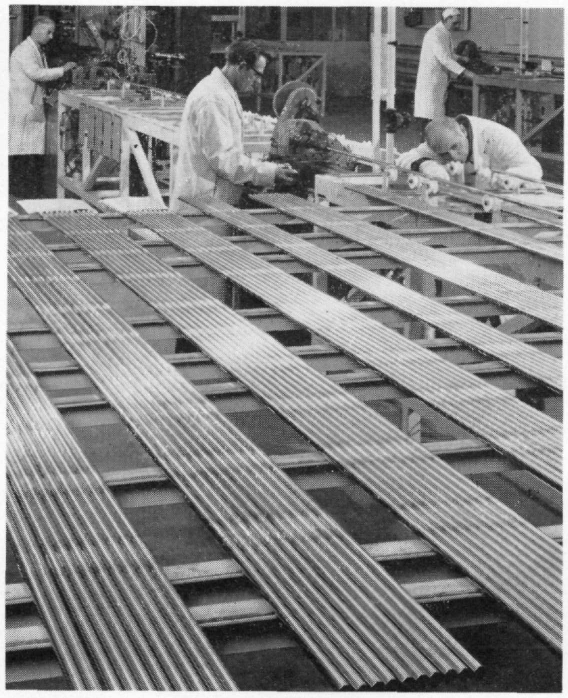
The supply of 73 tonnes of replacement fuel for the Tokai Mura reactor in Japan.

The supply of plutonium-enriched experimental fuel pins for the Garigliano reactor in Italy.

Other contracts were obtained from Sweden, France, Belgium, South Africa and Canada.

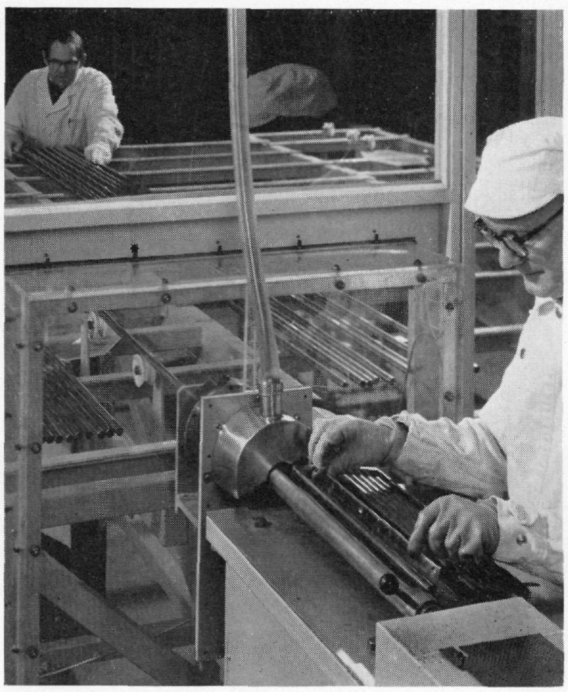


TESTING a zirconium fuel tube.

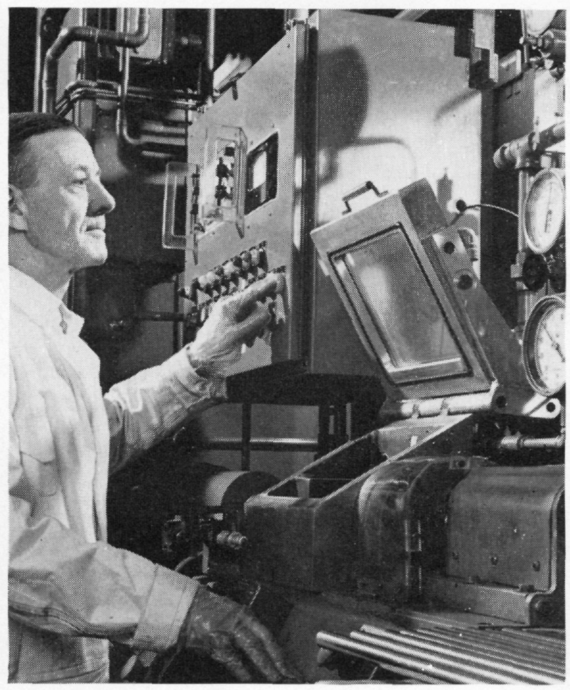


PREPARING zirconium tubes for pellet loading.

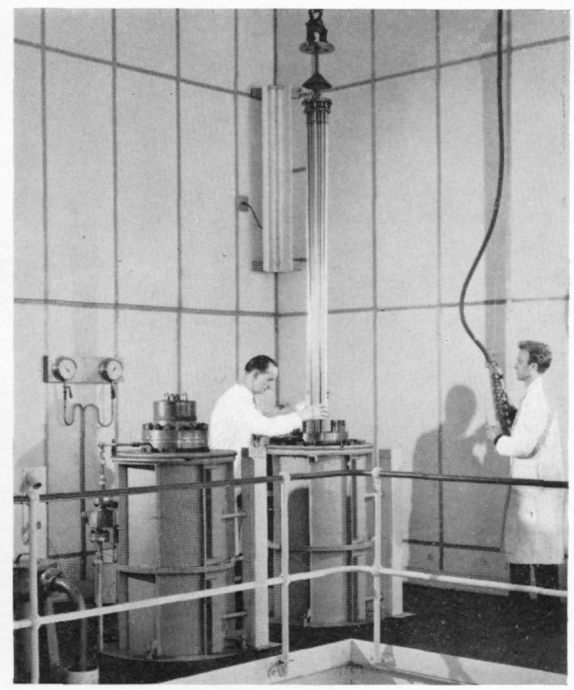
INSPECTING and preparing uranium oxide pellets.



FEEDING pellets into zirconium tubes.



WELDING end caps to full zirconium tubes.

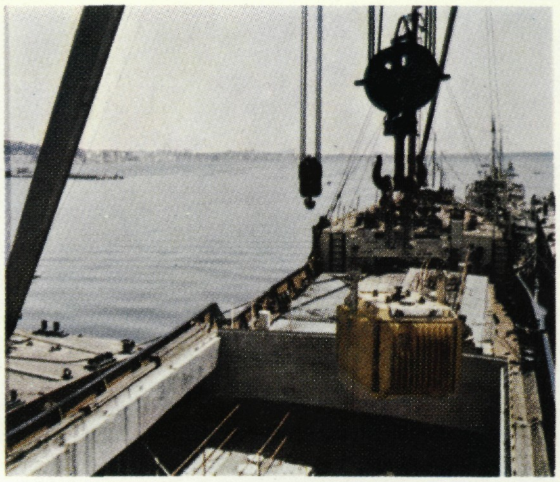


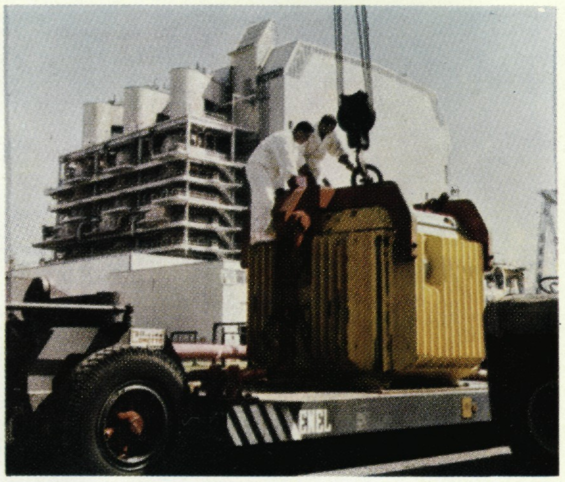
INSERTING fuel pins into an autoclave.

ASSEMBLING pins into a fuel element cluster.

LIFTING a fuel cluster prior to final inspection.

PREPARING to pack a complete fuel element.

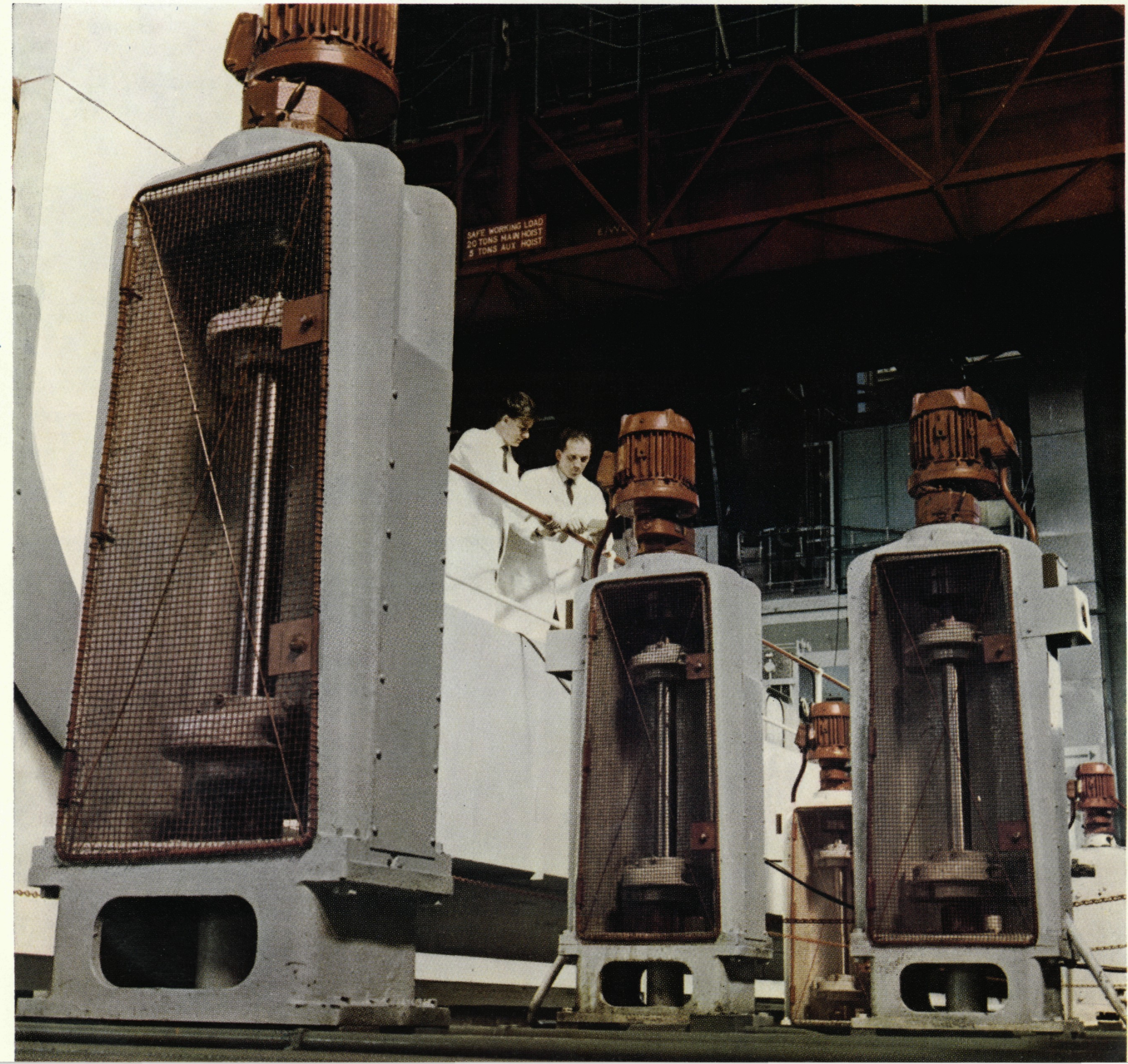




Canada: Irradiated fuel from the Canadian N.P.D. reactor *en route* between Chalk River and Montreal, for reprocessing at Windscale.

Italy: Production Group reprocesses fuel from the Latina power reactor, near Rome. *Centre*—a flask being loaded on to the M.V. "Stream Fisher" for the sea journey to Barrow, whence the cargo travels by rail to Windscale. *Right*—irradiated fuel in its protective steel flask leaving Latina for the port of Anzio.

Reprocessing: At the Windscale reprocessing plant, plutonium is extracted from irradiated nuclear fuel. The feed to the plant in 1966/67 was greater than in previous years and progress in operational and technical methods resulted in a further increase in productivity. Plutonium can be used in fast reactors, which will also "breed" more plutonium.



Desalination

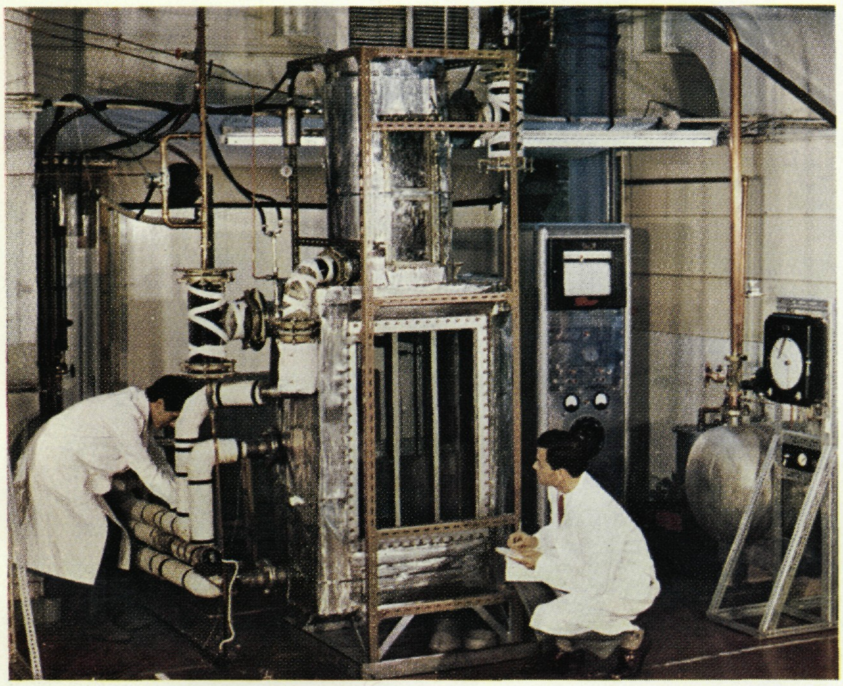
The largest single programme among the Authority's non-nuclear activities is that concerned with research and development on desalination.

The first objective of the United Kingdom desalination programme was to exploit the development potential of multi-stage flash distillation.

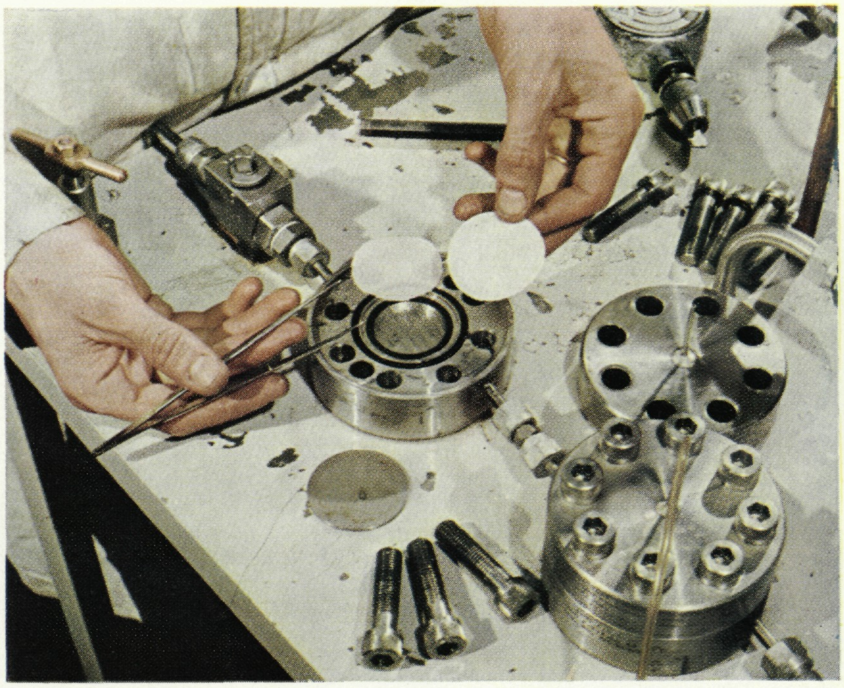
The Authority's Engineering Group, in collaboration with Weir Westgarth Limited, completed a design study of a 30 million gallon-a-day plant, which helped to identify "cost-sensitive" areas in plant capital and operating cost. A programme has been undertaken at Winfrith and Harwell and by Weir Westgarth, Limited, to investigate these areas.

To assist in developments on a significant engineering scale, a sea-water facility has been built as part of the joint programme at Weir

"Water for Life" is the title of a new Authority film on desalination and the contributions it can make to solving the world's water supply problems. The antiquity of the distillation method of desalting is illustrated in a drawing specially made for the film (above). It is based on a description given by Alexander of Aphrodisias in A.D.200, when he wrote that "sailors at sea boil sea-water and suspend large sponges from the mouth of a brazen vessel to imbibe what is evaporated. In drawing this off the sponges, they find it to be sweet water".



Flash Distillation Nearly two-thirds of the world's large-scale land-based desalination plants have been built by British industry. Most are based on the technique of multi-stage flash distillation. The Authority are helping to develop the potential of this system. The photograph shows apparatus at Harwell for studying flash flow in vertical ducts.



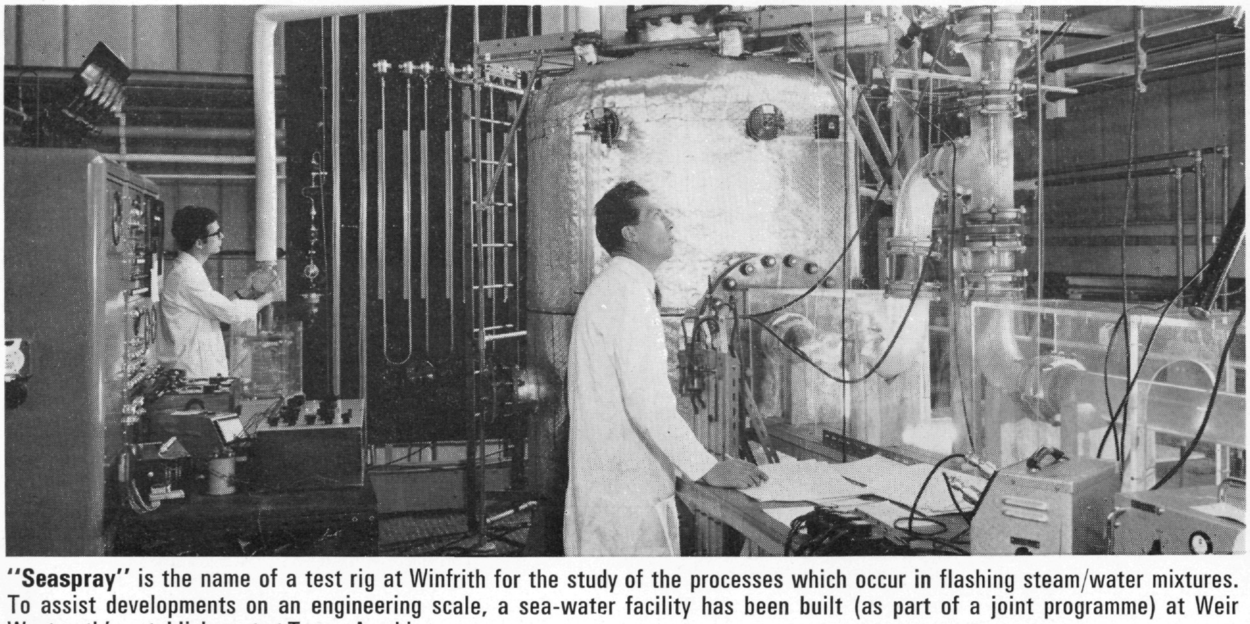
Reverse Osmosis One of the alternative methods of desalination is reverse osmosis, which is also being studied at Harwell. The picture above is of a dismantled "cell", for research on reverse osmosis, showing the acetate membrane and filter pad. This and other modern techniques are illustrated by animated diagrams in "Water for Life".

British achievement in desalination was described by the Minister of Technology to President Johnson at the U.K. exhibit at the Washington "Water for Peace" conference.

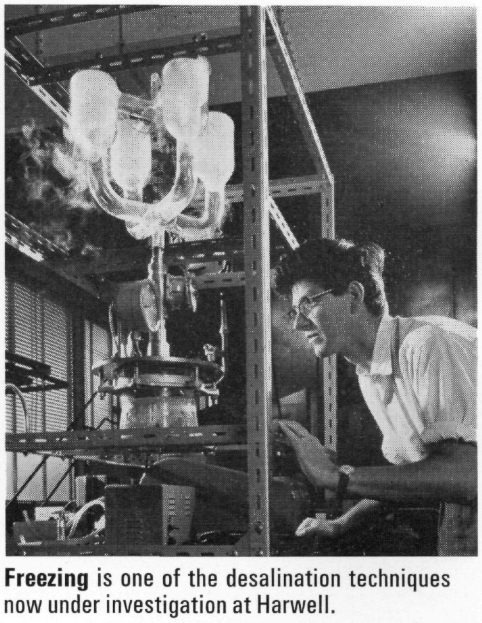
Westgarth's establishment at Troon, Ayrshire. Many of the new ideas emanating from the Authority and reaching the pilot-plant stage will be tried out at Troon.

Computer optimisation by Winfrith of multi-stage flash plant flowsheets and costs is now used in all design work; and more advanced constructional engineering techniques introduced by the Engineering Group will lead to cost savings.

The choice of alternative methods of desalination has been narrowed to electrodialysis, freezing and reverse osmosis. Freezing and reverse osmosis are still at the research and development stage. A 50,000 gallons per day electrodialysis pilot plant, built under the collaborative agreement between the Authority and William Boby Limited, is being operated in conjunction with an Essex water undertaking, to prove its reliability and to provide a facility for the development of better operational techniques.



"Seaspray" is the name of a test rig at Winfrith for the study of the processes which occur in flashing steam/water mixtures. To assist developments on an engineering scale, a sea-water facility has been built (as part of a joint programme) at Weir Westgarth's establishment at Troon, Ayrshire.



Freezing is one of the desalination techniques now under investigation at Harwell.

Space

The Authority are working on various aspects of space research in their laboratories at Aldermaston and Culham.

The European Space Research Organisation (E.S.R.O.) selected a British design for the scientific payload of their first major project—a Large Astronomical Satellite (L.A.S.). The choice was made after a competition with studies from other European groups. This would be the largest space experiment planned outside the U.S.A. and U.S.S.R.

The design study was prepared by staff from Aldermaston, Culham, the Royal Aircraft Establishment, Farnborough, and University College, London.

E.S.R.O. also indicated their intention of placing a contract with the Authority for the design, development and production of L.A.S. E.S.R.O. were later obliged to put this into suspense because of budgetary limitations but the nucleus of the Authority team at Culham has been retained.

At Aldermaston the Authority have provided the tape-recorder used in Ariel 3, the first all-British satellite, now orbiting the earth at an altitude of 330 miles.

Negotiations were concluded during the year with the Science Research Council for Aldermaston to provide a service for the regular firing of Petrel and Skua space research rockets over the next few years.

The service includes the ordering and preparation of components of the rocket assemblies; range supervision; firing, tracking and telemetry services; and engineering work to accommodate the experimental "packages" in the forebody of the rocket.

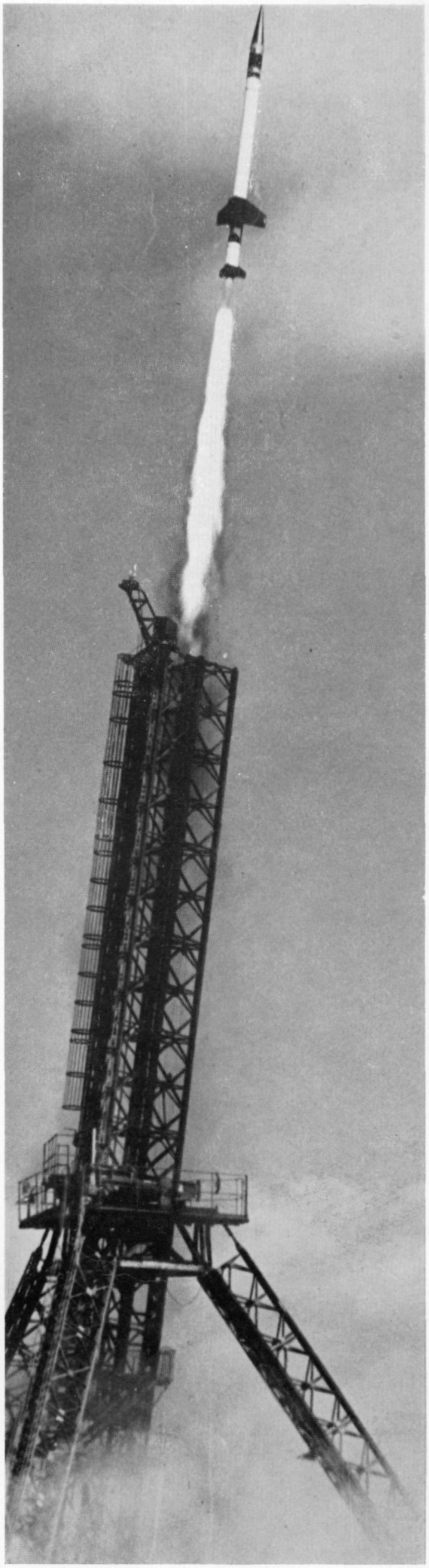
The telemetry receiving station at the South Uist range is run by Aldermaston.

The Authority are assisting the Science Research Council in the development and building of an improved radiotelescope to augment the existing Manchester University installations at Jodrell Bank.

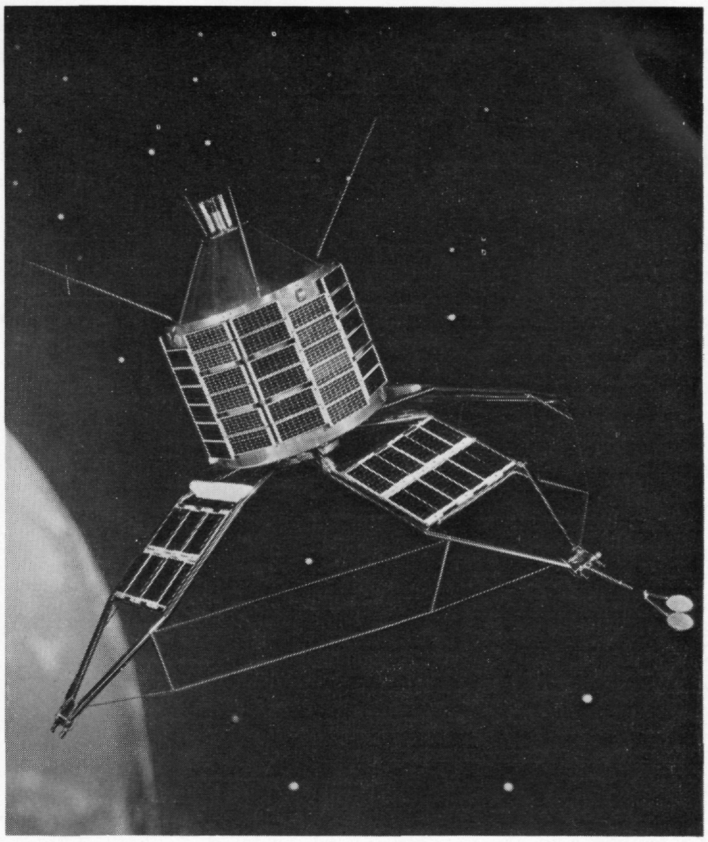
The bowl—likely to be 400 feet in diameter—must be able to operate in all weather conditions up to wind speeds of 40 knots.

The Engineering Group of the Authority are acting as the S.R.C.'s agents for the feasibility studies.

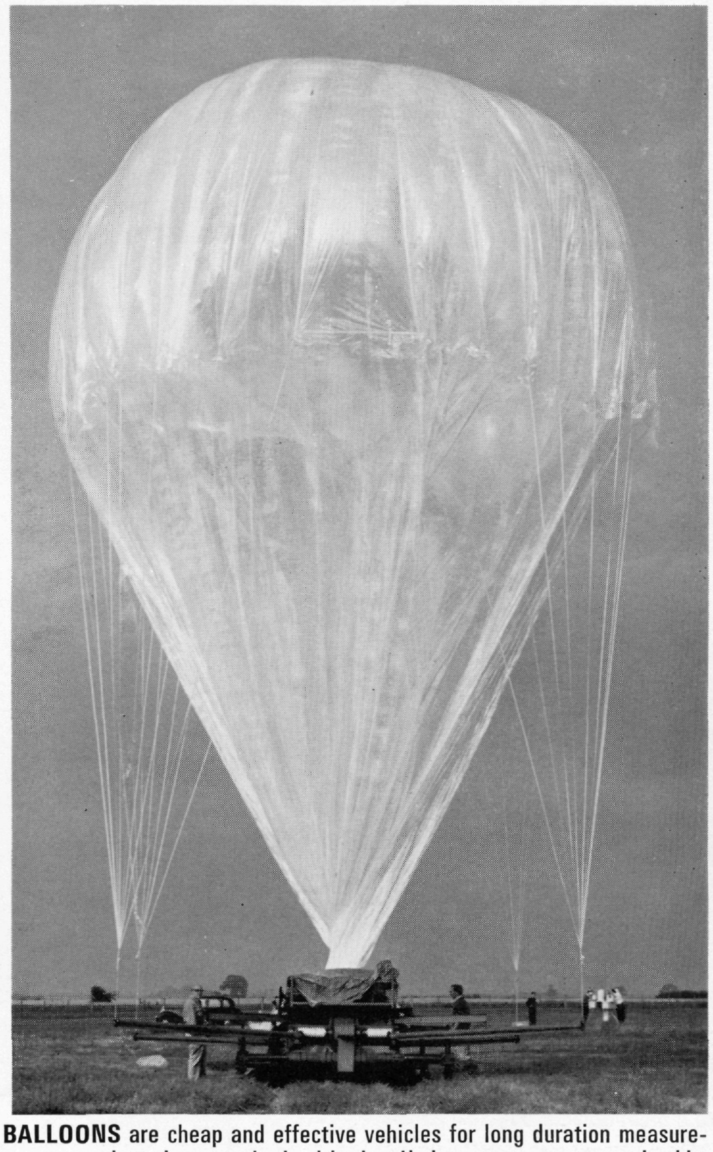
The Authority are associated with a similar project for the S.R.C. in respect of new radiotelescope facilities proposed for Cambridge University.



SKYLARK rocket being launched at Woomera, Australia. Spectrographs developed at the Authority's Culham Laboratory have been flown in Skylark rockets to record the solar ultra-violet spectrum on film. Their nature can be determined from the radiation emitted – which lies in the extreme ultra-violet and soft x-ray region of the spectrum. Plasmas similar to those studied in fusion research are found in the sun.



ARIEL 3 Aldermaston have provided the tape-recorder used in Ariel 3, the first all-British satellite. It stores experimental data when the satellite is out of range of ground stations. This work was carried out under a development contract with R.A.E., Farnborough. Aldermaston carried out data-processing for the U.S.A./U.K. satellite, Ariel 2.



BALLOONS are cheap and effective vehicles for long duration measurements at selected stratospheric altitudes. Under a programme organised by the Science Research Council, Aldermaston manages and launches balloon flights for Bristol University. The balloons carry instruments to measure cosmic radiation.

NON-NUCLEAR WORK

Two new Centres have been set up at Harwell, for Ceramics and Non-Destructive Testing. The object of these Centres is to apply the Authority's expertise in these fields to problems of importance to industry. Besides providing advice, the Centres will undertake specific problems for individual firms, and research and development programmes, some of them in collaboration with industry.

A Materials Technology Bureau—complementary to the Ceramics and Non-Destructive Testing Centres—has also been set up at Harwell to provide an advisory and consultancy service in the general field of materials technology.

At the request of the Ministry of Technology a review has been carried out of the Authority's work on instruments and control methods for plant and processes. Some 350 items of possible value to industry have been identified.

A report of this review is being studied by the Ministry and by organisations representing instrument makers and users.

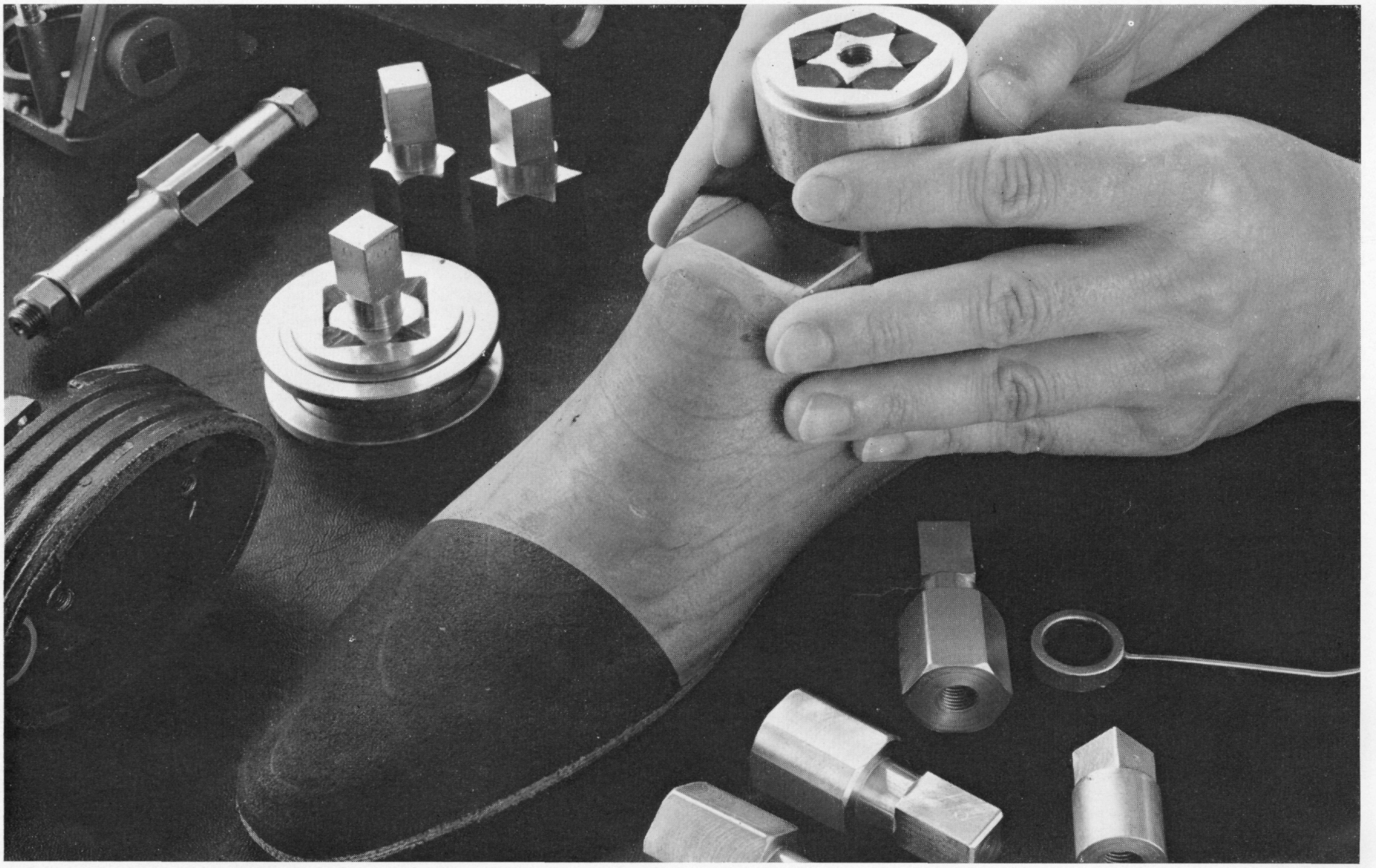
Work has continued on the design and development of cheaper transducers for conversion of such variables as pressure, flow, etc., into electrical signals suitable for data processing or computer control applications.

Although the original objective was a reduction in cost by simplification, experience has shown that these simpler versions also give greater accuracy in measurement. Close collaboration with industry is being maintained.

The Authority have acquired considerable expertise in tribology ("lubrication") in the course of their nuclear development work and have established research facilities at the Reactor Engineering Laboratory, Risley, as well as at Aldermaston and Harwell. Proposals are being considered with the Ministry of Technology for a significant contribution by the Authority to the national scheme for scientific research envisaged in the Jest Report on "Lubrication (Tribology)" to the Department of Education and Science in 1966.

Proposals are under consideration to explore, in conjunction with other interested bodies, the possibility of more effective control and economic development of the natural environment. One aspect is the problem of air pollution, and the Authority's extensive experience of problems involving radioactive aerosols and gases, and the special techniques and facilities that have been developed, can readily be adapted to studying non-radioactive pollutants.

Another aspect is the further development of the marine environment and, in conjunction with other bodies, the Research Group has been exploring possible programmes in the field of marine technology. A national conference on the technology of the sea and the sea bed was held at Harwell in April, 1967, following which proposals are being examined for Authority collaboration with other bodies for developing technological capability of exploiting the sea and the sea bed.



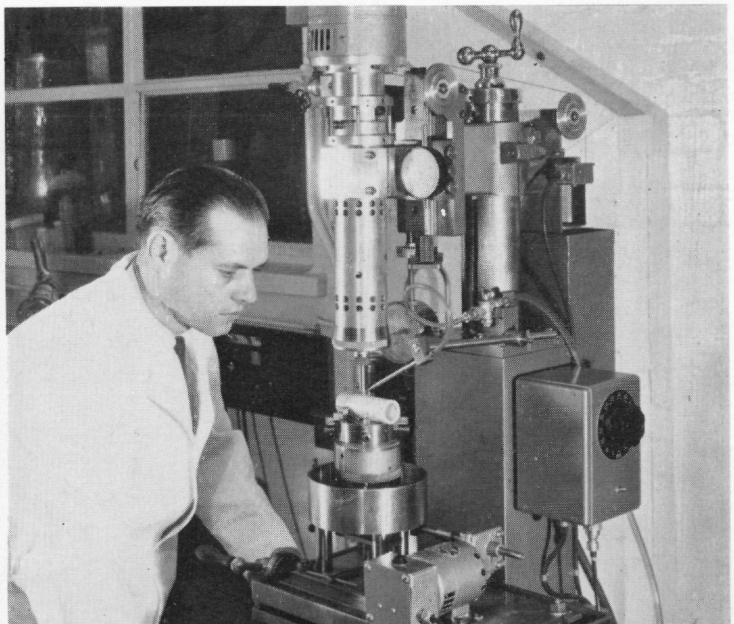
DEVELOPMENT WORK for the Ministry of Health on artificial limbs continued at Aldermaston. Improvements made to the mechanical and electronic design of the artificial hand, following clinical and laboratory experience gained with the early models, will result in greater reliability and more widespread application. A split hook, interchangeable with the hand, was also developed; this has advantages over a cosmetic hand for some purposes, for example, when picking up small objects, since the loss of sensory perception leads to a great reliance on visual feedback.

Development was undertaken for the new Biomechanical Research and Development Unit at Roehampton of an improved ankle joint for an artificial foot. The main objective here is to increase the life of the joint and the experimental model uses the principle of rolling compression. The design is also expected to make use of plastics to reduce weight.

Other work has included advice and feasibility studies on patient monitoring systems; cardiac pacemakers; the development of new denture materials; and experimental work on the corrosion of surgical implants and dental filling materials.

The first of two multi-channel spectrographs for the American universities of Pennsylvania and Yale was shipped from Aldermaston; components were supplied largely by British industry. The magnet assembly consists of 24 segments weighing approximately 1.5 tons, the working surface of the segments being ground flat within 0.0005 in; the whole system is enclosed within a vacuum vessel (an 11 ft. diameter cylinder for Pennsylvania and a 16 ft. diameter sphere for Yale). Orders for similar machines have been obtained from the University of Oxford and the Max-Planck Institute at Heidelberg.

APACE staff using graphics console A project for the application of computers to engineering (APACE) began operations during the year in a small country house adjacent to Aldermaston. This project is sponsored by the Ministry of Technology to assist industry to apply modern computer aids to engineering design, planning and production, including the use of numerically controlled machine tools, and there has been a widespread response from industry seeking advice and instruction in this field.



Machine tools Licensees were appointed for a universal ultrasonic machine tool which enables glass and ceramics to be accurately machined more rapidly. Interest is growing in a ball-bearing rotary swage with which stainless steel tubing, for example, can be swaged to an accuracy approaching 0.0002 in. Its use rectifies the inferior metallurgical structure occuring in the weld zone of seam welded tubes fabricated from strip.

←

Oxide Resistor Furnace

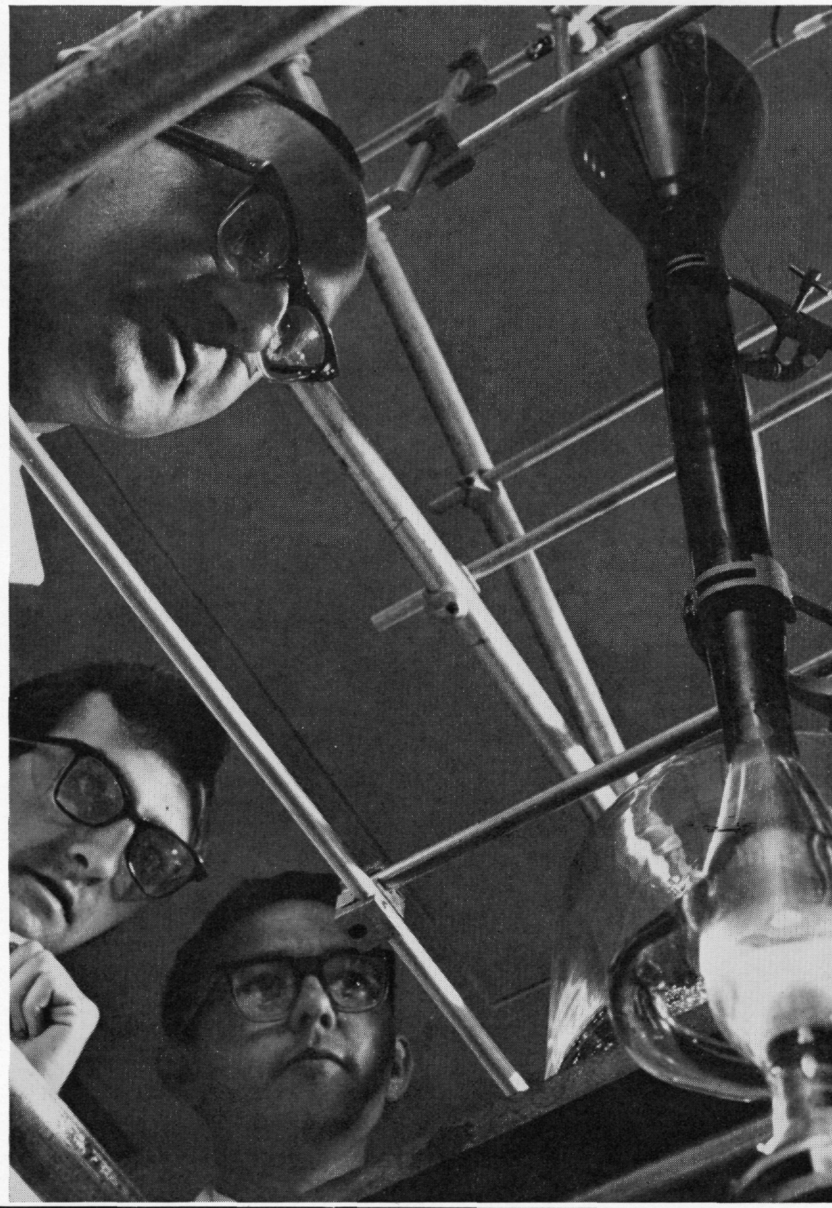
The furnace shown at the Physics Exhibition in 1966 was intended specifically for neutron diffraction studies. A general purpose version has now been developed in conjunction with industry, which can heat specimens uniformly at temperatures about 2000°C in either oxidising or neutral atmospheres.

Ceramics Centre →

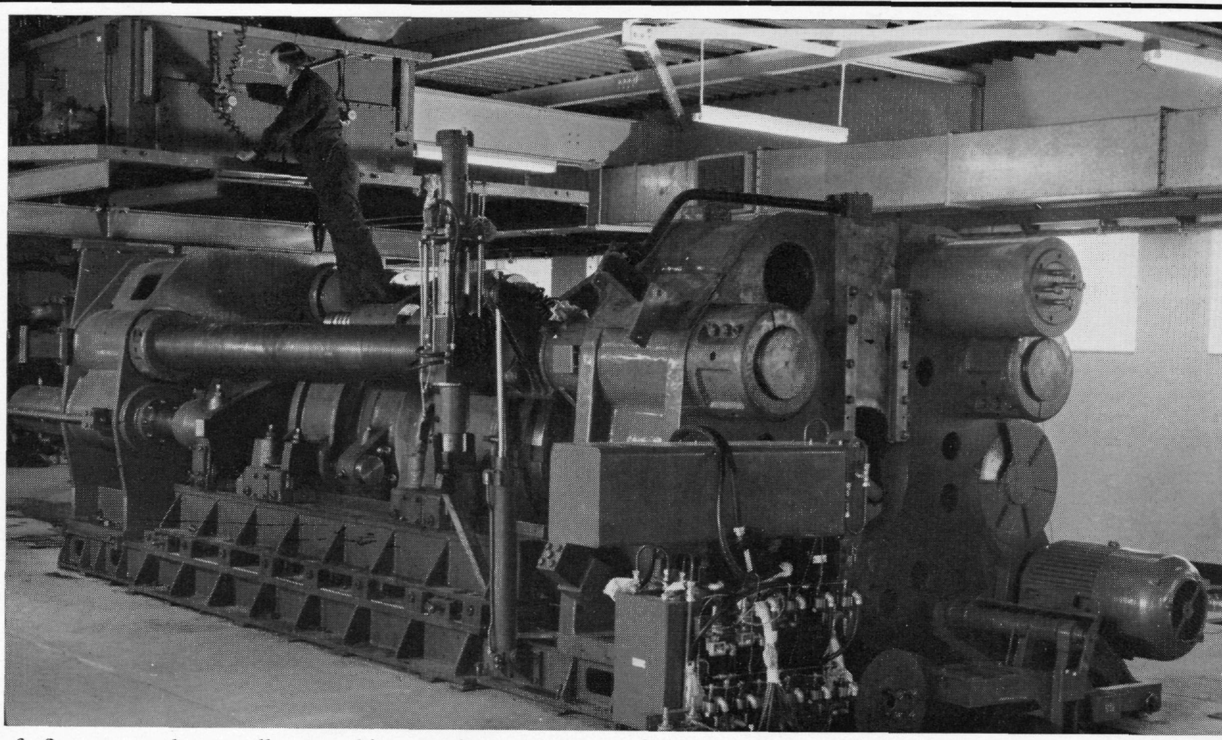
A programme of research and development is being planned in conjunction with industry and the research associations for the Ceramics Centre at Harwell. In some projects with industry both sides will be committing effort; in others, e.g. the use of ion and electron beams for machining and welding ceramics, emphasis is placed on industrial involvement through licensing arrangements. The illustration shows work on the sol-gel process for producing oxides (e.g. zirconia, alumina) in spheres or fragments in the 10-500 micron diameter range.

Harwell Refrigerator

A commercial version of the Harwell refrigerator was developed under contract by an industrial firm and has operated at 0.05°K under steady conditions; further developments are in progress to extend the operating range to below 0.02°K. Sales include some overseas orders.



HYDROSTATIC EXTRUSION



Under a three-year development programme in collaboration with Fielding and Platt Limited a 1600-ton power hydrostatic extrusion press was completed and tested at the company's works at Gloucester, and is now installed in the Reactor Fuel Element Laboratory at Springfields (R.F.L.).

Considerable interest has been shown by industrial firms, in both the United Kingdom and overseas, in the potentialities of hydrostatic extrusion for a variety of materials including aluminium, copper, steels, nickel alloys and sinters, ceramic insulated conductors and heaters, superconductive alloys and molybdenum and tungsten. There is also interest in using the press as a forging machine for hollow components. As a result of trials carried out on behalf of a number of firms on the smaller machine already in use at R.F.L., some similar equipment has been sold under licence by Fielding and Platt Limited; applications to hire production and development time on the 1600-ton press are also expected.

The technique of differential extrusion was successfully established whereby a brittle alloy is extruded under high pressure into a 'back-pressure' vessel, as opposed to the more normal extrusion into a low, or atmospheric, pressure. This method prevents the cracking often associated with the handling of such alloys and it is being further developed to achieve a flexible process and improve control.

An important variation of the basic hydrostatic extrusion technique is continuous extrusion and a prototype semi-continuous extrusion rig has been designed, constructed and proved at R.F.L.

Non-destructive testing centre

The purpose of the Non-Destructive Testing Centre at Harwell is to assist industry to make the best use of modern test and inspection techniques.

To achieve this it tries to find commercially available equipment to suit an enquirer's needs. It is, however, prepared to develop special equipment for individual firms, and sponsor and carry out major research projects and long range investigations for companies, groups of companies, and research associations.

The Centre is equipped with a full range of conventional equipment and has at its disposal many research techniques. Working in confidence with its customers, it utilises these resources in carefully costed programmes which begin with a detailed analysis of the work and continue, after equipment has been installed and commissioned, with technical advice and discussion.

ORGANISATION

THE INFORMATION SECTION provides a comprehensive library and technical enquiry service to industry on all aspects of non-destructive testing.

THE APPLICATIONS SECTION is equipped with an extensive range of conventional inspection equipment which enables current NDT practices to be used to evaluate customers' problems. The Section also evaluates the performance of instruments developed at the Centre.

THE DEVELOPMENT SECTION devises new techniques to solve customers' problems, adapting, as far as possible, commercially available equipment.

THE RESEARCH SECTION undertakes a general research programme that can be used to consolidate the understanding of existing inspection techniques, to define new approaches to inspection, and to obtain a better understanding of the relationships between those material properties on which inspection specifications are ultimately based.

HOW IT WORKS

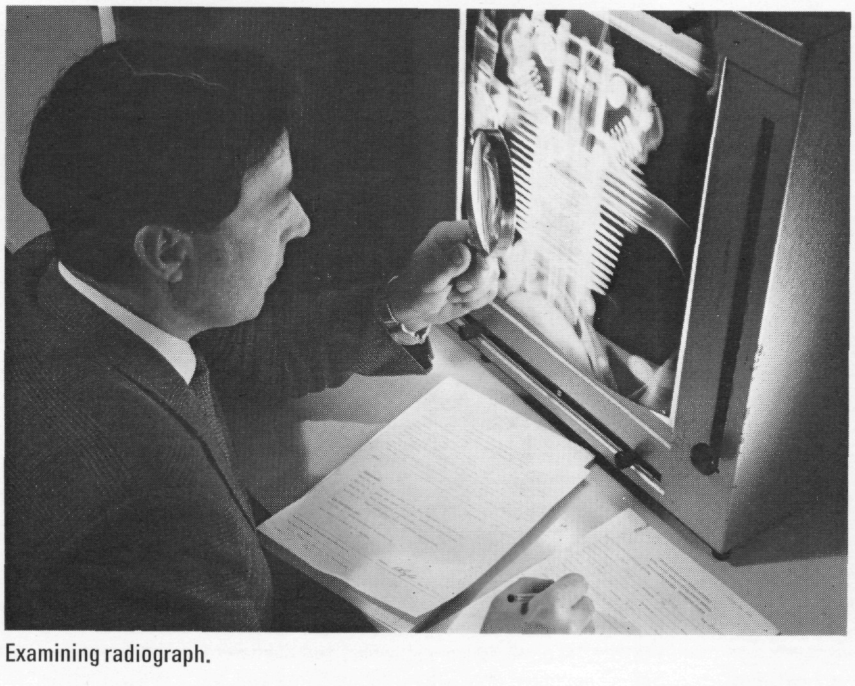
A request for work to be undertaken by the Centre can be made by letter or by telephone.

It is normally followed by a meeting between senior staff of the Centre and the company or organisation making the request so that the problem can be understood in more detail. A literature search is then initiated and the suitability to the customer's needs of instruments commercially available is assessed. **No charge will be made to the customer for this, and no further action may be needed.**

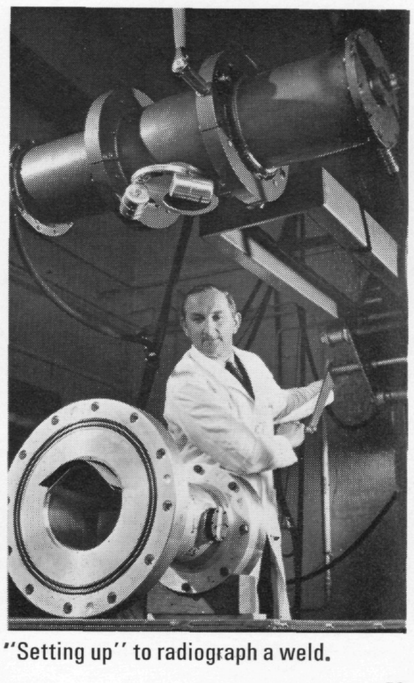
Ultrasonic probe assembly.

If, however, a research and development programme is needed to develop suitable techniques the Centre will submit a technical specification to the customer. The customer might be required to provide samples of his products before this can be done. The technical specification defines the problem and sets out in some detail a method of tackling it. **It is accompanied by an estimate of cost, based on the proposals in the specification, and a forecast completion date.**

At this stage the customer can still reject the programme or discuss its detail until modified objectives and terms are agreed. **Work commences as soon as the firm has accepted the estimate.**



Examining radiograph.



"Setting up" to radiograph a weld.

ISOTOPES

Sales of radioactive products through the Radiochemical Centre, Amersham increased by 12½ per cent. as compared with the previous year to £2.5 million, of which over one-half by value was exported. The number of consignments sent out increased to 68,000 for the year.

Liaison visits to the principal users of isotopes, particularly those overseas, have proved a most effective method of sales promotion—an activity in which the production of technical literature also plays an important part. A revised and enlarged edition of the Centre's Radiochemical Manual was published in June, 1966 and 4,000 copies have already been sold.

The Amersham cyclotron was taken over from the manufacturers at the end of April, 1966, and was quickly brought into routine use for the production of radioisotopes. The whole of the Centre's sales of the most important cyclotron isotopes are now supplied by this machine whose performance and reliability have been outstandingly good.

A new department has been set up at Amersham which embraces the existing functions of product testing and process control, but extends them to a wider concept of total quality control. **Detection of a radiochemical impurity to the extent of one part in a million (in a product that is virtually weightless) is by no means an exceptional requirement.**

Industrial problems

The Wantage Research Laboratory has a continuing programme of work on the investigation of industrial problems using radioisotopes. In two years the demand for the industrial neutron activation analysis service has doubled. A recent survey by the Science Research Council shows that there is **a national requirement for more than four times the Laboratory's current turnover.**

Radioactive tracer techniques are now the accepted method for commission testing of cooling water pumps in the Central Electricity Generating Board's power stations and two teams from C.E.G.B. have been trained at Wantage to take over the work.

Although radioisotope instruments for measuring thickness are well established in industry, a present requirement is for greater precision. A recent development at Wantage substantially reduces the error due to movement of the material in the gap between the radioactive source and the detector in transmission-type thickness gauges.

Package irradiation

The Package Irradiation Plant at Wantage has continued to be used mainly for the radiation sterilisation of medical supplies but the growth of the commercial use of gamma radiation not only for this purpose but the sterilisation of animal feed stuffs led to the installation of a second plant at Wantage to handle a greater variety of packages. New legislative measures were introduced to ensure a high standard of safety for irradiated food and food products intended for human consumption.

A study of the economics of radiation processing for the elimination of *Salmonella* in imported pet foods has given encouraging results. Scientific data on the efficacy and safety of the process will be submitted to the Advisory Committee on the Irradiation of Food.

In the mass production of painted sheet and strip material substantial savings in cost and factory space can be made by using electron irradiation (instead of heat) to "cure" the paint. Because it extends the shelf-

continued on page 22

2,000 PRODUCTS The marketing activities of the Radiochemical Centre involve the supply of 2,000 products to 5,000 users spread over 50 to 60 countries. Distribution requires meticulous timing when the isotopes supplied are perishable on account of their short "half-life".

SILT MOVEMENT There has been a considerable expansion of the use of radioactive "tracers" for the study of the movement of silt in estuaries. An investigation in Swansea Bay established the suitability of a site for material from the new iron ore terminal at Port Talbot. Two others in the Severn Estuary confirmed the acceptable dispersal of material dredged from Newport and deposited in Newport Deep. A study of silt movement in the Clyde Estuary is being conducted in collaboration with the University of Strathclyde.

THE ISOTOPE PRODUCTION UNIT at Harwell supplies Cobalt 60 for use in radiotherapy. At St. Luke's Hospital, Guildford, the patient is positioned under the 5000 Curie Cobalt Unit, which then rotates round him, directing the radiation to the exact point requiring treatment.

life of polyester paints indefinitely and is particularly attractive for curing coatings on heat-sensitive surfaces, the method enables the range of application of these paints to be greatly increased.

First in Europe

An experimental machine has been in operation at Wantage since early 1967 and the use of radiation for the cold curing of paint has proved sufficiently promising to justify the installation at Wantage of a pilot-scale processing plant (incorporating a 300 kV accelerator and capable of handling sheets up to 4 ft. wide). To be commissioned later this year, it is the first of its kind in Europe. More than 40 U.K. companies are interested in the process.

Investigations have begun into its possible use for hardening printing-inks, treating textile fabrics, and the coating of paper.

As a result of the interest shown by the Hydrographic Department of the Navy, the Board of Trade and consulting engineers following the investigations in the Firth of Forth during 1961, 1964 and 1965, there has been a considerable expansion of the use of radioactive tracers for the study of silt movement in estuaries.

Projects undertaken during the year were all concerned with the movement of dredged material deposited in an estuary and most of them are of considerable economic importance since the results affect the selection of the "spoil ground" within the estuary.

The series of investigations in the Firth of Forth was completed and the spoil ground selected as a result is now in commercial use. Further investigations have been undertaken in Swansea Bay; the Severn estuary; and the Clyde estuary.

BRITISH DESIGNED GAMMA STERILIZATION PLANTS

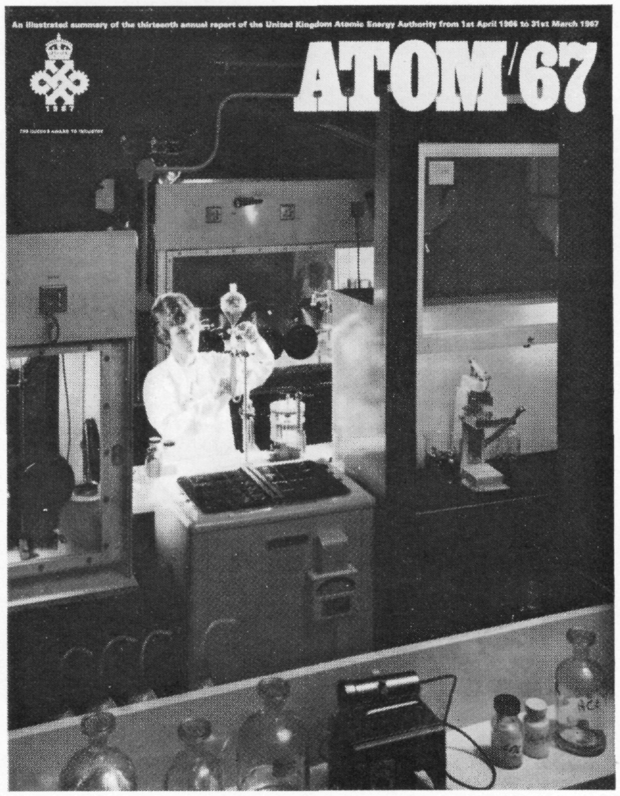
Location	Built and Designed by	Date of Operation	Principal Purpose	Maximum Design Loading of Cobalt-60 (curies)
Wantage Package Irradiation Plant	Rubery Owen	1960 August	Sterilization of medical supplies and pharmaceuticals, packaging materials and special service for hospitals.	500,000
Gamma Sterilization Pty. Ltd, Dandenong, Victoria, Australia.	Gamma Sterilization Pty. to U.K.A.E.A. design.	1960 September	Sterilization of goat hair for carpets. Medical products.	2,000,000
Johnson's Ethical Plastics Ltd. Slough.	H. S. Marsh Ltd.	1962 November	Sterilization of disposable syringes and needles.	750,000
Ethicon Ltd. Edinburgh.	Nuclear Chemical Plant Ltd.	1963 January	Sterilization of surgical sutures	250,000 250,000
Gillette Industries Ltd. Reading	H. S. Marsh Ltd.	1964 May	Sterilization of surgical scalpels and disposable syringes.	750,000
Swann-Morton (Manufacturers) Ltd. Sheffield.	Vickers Ltd.	1966 February	Sterilization of disposable scalpel blades.	75,000
Ethicon G.m.b.H., Hamburg, Germany.	H. S. Marsh Ltd.	1966	Sterilization of medical products.	750,000
SPV. Wageningen, Holland.	H. S. Marsh Ltd.	1967 August	Sterilization of fruits and vegetables.	250,000
Grain Irradiation Plant, Iskenderun, Turkey.	Nuclear Chemical Plant Ltd.	1967 February	Grain disinfestation.	360,000
Helinos A.B. Skärhamn, Sweden.	H. S. Marsh Ltd.	1968	Sterilization of medical products.	1,000,000
I.C.A. Bologna, Italy.	H. S. Marsh Ltd.	1967	Sterilization of disposable syringes.	250,000

A Study Tour on the use of isotopes in industry was organised by the I.A.E.A. in 1966. The countries visited were the U.S.S.R., Czechoslovakia, France and the U.K. Members of the party from Greece, the United Arab Republic, India and Israel are seen above with Mr. E. G. Hall, of the Radiochemical Centre, Amersham.

Right:
The energy from this 150 keV electron accelerator at Wantage is being used to develop a cheap and rapid method of curing mass-produced painted sheet and strip material without the use of heat. Samples move under the beam on the conveyor in the centre of the picture. A larger installation is to be built for trials on an industrial scale.

FRONT COVER PICTURE

The Organic Department laboratory for the production of radiopharmaceuticals at the Radiochemical Centre, Amersham. The Centre's achievements have been recognised by the grant of the Queen's Award to Industry.



Designed by Ronald Terry

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BACK COVER PICTURES

1 **Ultrasonic Testing** by a member of the staff of Harwell's Engineering Inspection Group, who provide expert advice to the new Non-Destructive Testing Centre. The Group uses a complete range of modern equipment and techniques.

2 **Hydrostatic Extrusion** is being developed for industrial application by the Authority. A 1,600 ton press manufactured by Fielding and Platt, Ltd. has been installed at Springfields. The picture shows the main power cylinders and ram, weighing 30 tons, being unloaded on site.

3 **Precision Welding** of irradiation rigs with automatic welding apparatus at the Metallurgy Division, Dounreay. This Division develops and fabricates fuel for the Dounreay Fast Reactor and Materials Testing Reactor.

4 **Springfields.** The work of the Fuel Element Laboratories is concerned with problems of fuel, canning materials and the production and testing of complete fuel elements. A major loop endurance test rig for the S.G.H.W.R. is illustrated.

5 **Fusion.** The photograph shows the application of insulated copper foil conductors to the torus of the CLASP experiment at the Culham Laboratory which is concerned with research on fusion and plasma physics.

6 **Oxide Fuel** production at Springfields. Oxide fuel will be used in the Advanced Gas-Cooled Reactors being built for the Second Nuclear Power Programme which will bring Britain's installed nuclear power capacity to 13,000 Megawatts.

7 **Design Work** at Risley embraces complete reactor systems and chemical and mechanical plant for fuel manufacture and reprocessing. It ranges from a nuclear power plant to a tiny transducer.

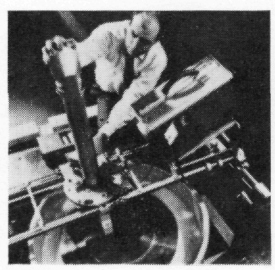
8 **Rocketry.** Aldermaston co-ordinates research and development of the PETREL research rocket at the request of the Science Research Council. PETREL is being developed for use in space research projects by universities and other organisations.

9 **Famous Name** on the package is "Sir Edmund Hillary". The address is "Khatmandu". Amersham supplied radioactive iodine for use in a research programme on goitre among the Sherpas. Sir Edmund has established a hospital twelve miles from Everest.

10 **Desalination.** Harwell is one of the Authority establishments conducting research designed to improve the efficiency and economy of desalination plants. The experiment shown is concerned with the deposition of crystals on metals from salt water.

11 **S.G.H.W.R.** Work in progress on the charge-face of the Steam Generating Heavy Water Reactor at Winfrith which will supply 100 Megawatts of electricity to the national grid.

12 **Cyclotron.** The Variable Energy Cyclotron at Harwell is one of the most versatile machines of its kind in the world. It is used for radiation chemistry, radiochemistry and radiation damage studies.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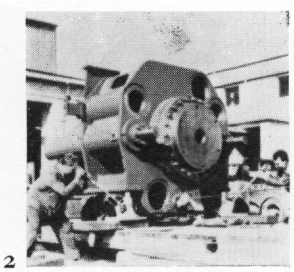
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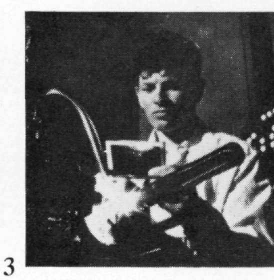
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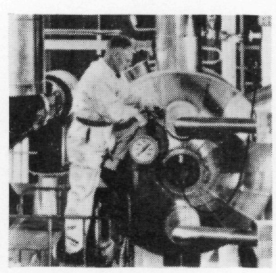
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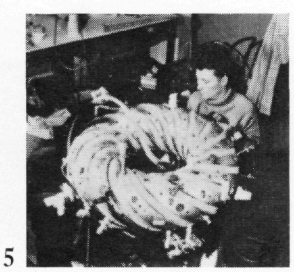
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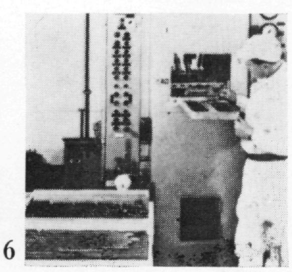
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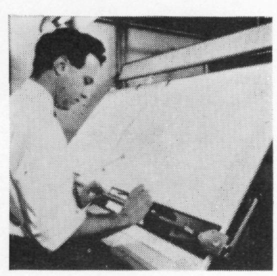
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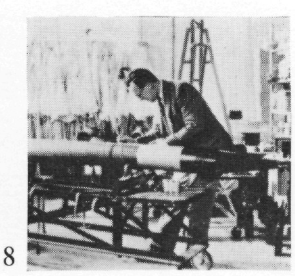
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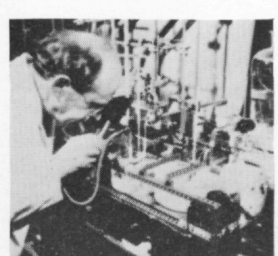
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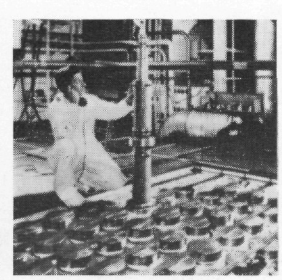
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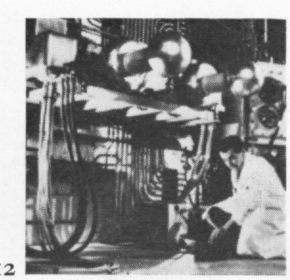
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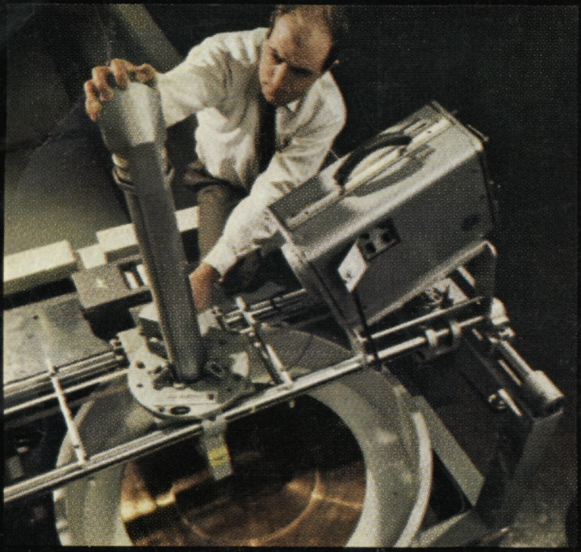
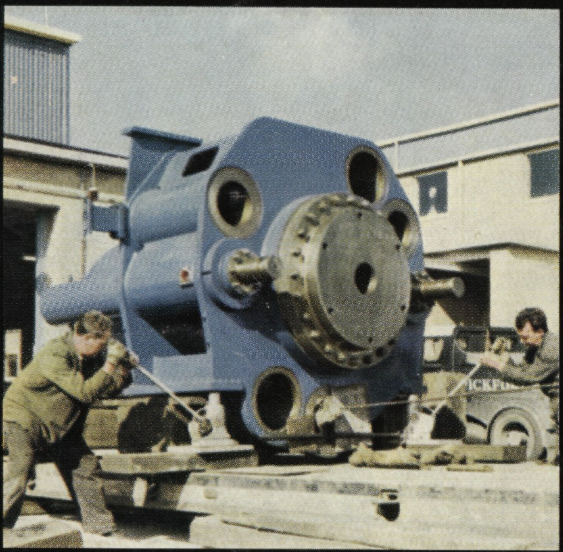

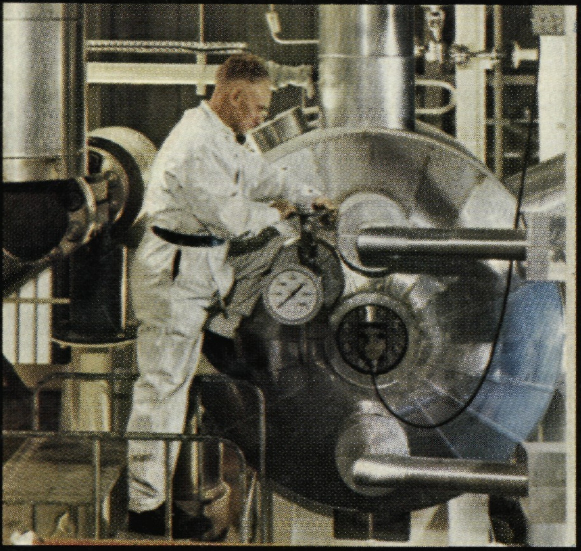
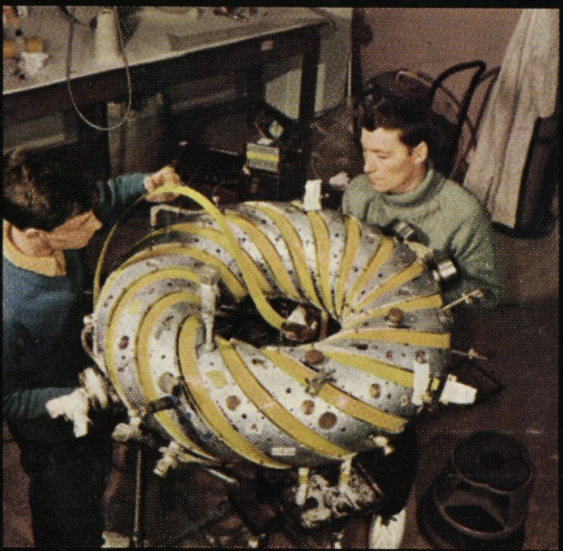
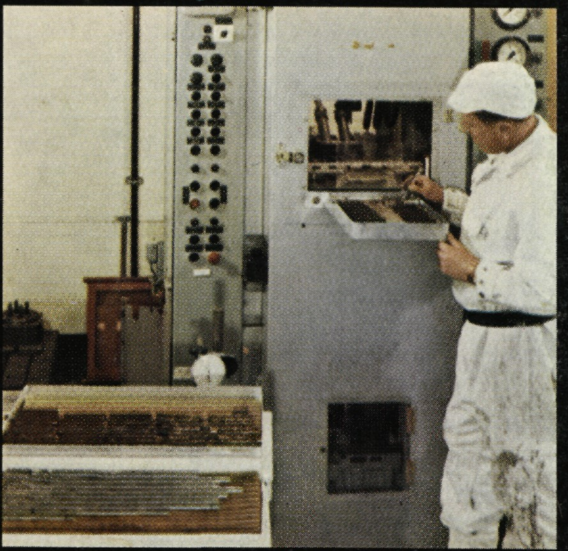

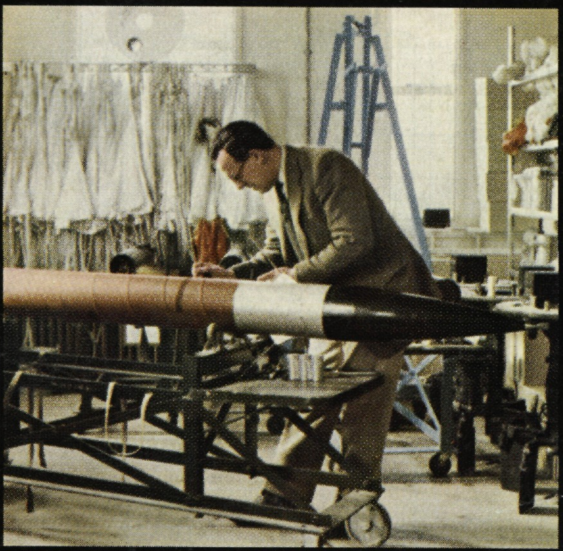

SIR EDMUND HILLARY,
BRITISH EMBASSY,
KHATMANDU.