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MONTHLY INFORMATION BULLETIN OF
THE UNITED KINGDOM ATOMIC ENERGY AUTHORITY

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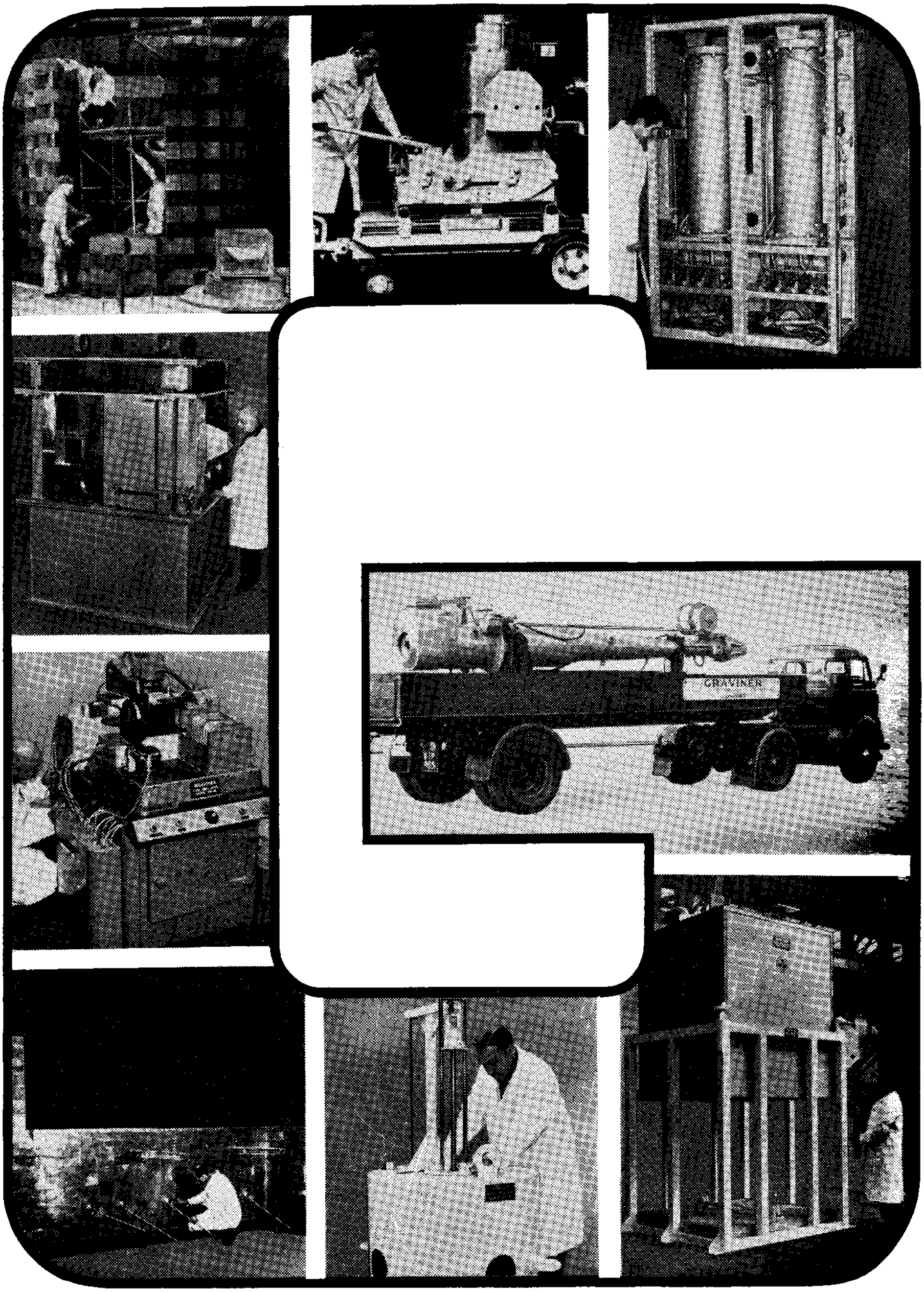
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ATOM

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OF THE UNITED KINGDOM
ATOMIC ENERGY AUTHORITY

NUMBER 141

July 1968

Contents

ATOM
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U.K.A.E.A. PRESS RELEASES

BEPO and DMTR to close down

A rationalisation of materials testing facilities within the Atomic Energy Authority will reduce annual operating costs by £¾ million.

As a result of a recent review designed to ensure that the most efficient use is made of these facilities, the Authority have decided that they can reorganise the irradiation programme to release two of their research reactors—the BEPO reactor at Harwell and the Materials Testing Reactor (DMTR) at Dounreay.

BEPO will be closed down before the end of 1968; DMTR in the middle of 1969.

Among the present uses of BEPO, which has been in operation since 1948, is the production of radioisotopes for the Radiochemical Centre at Amersham, whose annual sales total £2½ million (over half of them in export markets). Alternative arrangements, using the DIDO and PLUTO reactors at Harwell, are being made to meet the part of the isotope requirement now supplied by BEPO.

The staff now working on DMTR will be transferred to other work on site, mainly to the team which will be set up to commission and operate the new Prototype Fast Reactor, due to start up at Dounreay in 1971.

Background notes

BEPO (*British Experimental Pile O*) was the second reactor to be built in this country and the first large, fully-engineered reactor in Europe. It started operating on 5th July, 1948. With a power output of six megawatts of heat it operated initially on natural uranium metal fuel, canned in aluminium; subsequently some low-enriched fuel was introduced. Cooling is by air drawn through the core which is discharged from a high chimney. Graphite is the moderator. BEPO helped to provide British engineers and research scientists with valuable experience of gas-cooled, graphite-moderated reactors leading to the successful development of the nuclear power stations now being installed for Britain's first and second nuclear power programmes. Until the other test reactors at Harwell—DIDO and PLUTO—started operating in the late 1950s, BEPO was the only large irradiation source in

Britain. It also provided a regular supply of radioisotopes to industry and medicine. With the availability, however, of higher neutron fluxes (a measure of the intensity of the nuclear reaction within the reactor core) in the DIDO-type Materials Testing Reactors, its use has gradually declined to the point where it is now no longer economical to operate.

Technical details:

Reactor Type:	Thermal heterogeneous
Reactor Power:	5.4 MW (Th)
Designer:	M.O.S.
Builder:	M.O.W. and M.O.S.
Fuel Element:	Natural or low-enriched uranium in finned aluminium cans.
Number of Elements:	Currently 14,580 in 810 channels. Designed for 17,600 in 880—certain channels no longer usable. Total—33.2 tonnes of uranium containing 250 kg of U235. The average enrichment is 1.036 Co.
Core Size:	Cylindrical 610 cm. diameter, 550 cm. long.
Specific Power:	0.16 kW/kg uranium.
Control:	12 vertical shut off rods; 4 horizontal control rods; 2 safety rods (falling under gravity) of hollow steel lined or filled with boron carbide.
Shielding:	Biological: concrete 198 cm. thick. Thermal: cast iron 15.2 cm. thick.

DMTR (*Dounreay Materials Testing Reactor*) was the last of the three heavy water moderated Materials Testing Reactors to be built for the Authority, the other two — DIDO and PLUTO — being located at Harwell. DMTR was commissioned in May, 1958, and has been used to help meet the demands of the Reactor Group of the U.K.A.E.A. in support of the nuclear power programme. It has a power output of 25 megawatts of heat. Experimental vehicles or rigs have been designed for use in the reactor to study the effects of irradiation, under simulated operating conditions, upon different types of reactor fuel, cladding materials, coolants and reactor structural materials. The three Authority Materials Testing Reactors were designed by the U.K.A.E.A. and built by Head Wrightson Processes Ltd. Three Materials Testing Reactors of this design have been sold abroad—to Germany, Denmark and Australia.

Technical details:

Reactor Type:	Thermal heterogeneous MTR.
Reactor Power:	25 MW (Th.) Max. 21 MW (Th.) Routine.
Designer:	U.K.A.E.A.
Builder:	Head Wrightson Processes Ltd.
Fuel Element:	MTR plates 80% enriched uranium alloyed with aluminium, clad in aluminium: arranged in 4 concentric cylinders with 2 in. hole in centre for experiments.
Number of Elements:	26 arranged in rows 4, 6, 6, 4. Total 3.9 kg U.235.
Moderator:	10 tonnes D_2O.
Coolant:	D_2O outlet temperature 60°C. (bulk).
Core Size:	Approximate vertical cylinder 61 cm. high, equivalent diameter 87.5 cm.
Control:	Coarse control/shut off: 4 arms cadmium in stainless steel sheath; 2 vertical safety rods; 1 vertical fine control rod of cadmium stainless steel tubes; D_2O reflector dumping.
Shielding:	0.65 cm. boral, 10.2 cm. lead (water cooled) surrounded by 40-200 cm. barytes concrete.

16th May, 1968

Copenhagen power plant conference

[This press release was issued jointly by the British Nuclear Export Executive, the British Nuclear Forum and the United Kingdom Atomic Energy Authority.]

A comprehensive survey of nuclear power in Britain will be given by a team of British experts at a one-day conference in Copenhagen on 12th June.

The United Kingdom team will represent the Atomic Energy Authority, the industrial firms who manufacture reactors, components and associated equipment; and the Central Electricity Generating Board who operate nuclear power stations commercially.

Their survey will extend from the first British nuclear power station at Calder Hall, through the reactor types now being operated or built, to the fast reactors which are intended to come into commercial operation in the mid-1970s.

The Conference will be one of the events arranged for the British Engineering Week in Copenhagen.

Conference details

The morning programme, to be held under the auspices of the British Nuclear Export Executive, will consist of the following papers:—

Gas-cooled Reactors in the United Kingdom reviewed by Dr. Gordon Brown, Atomic Power Construction Ltd.

Papers

"Progress in the Exploitation of the Gas-cooled Reactor" by Dr. G. Brown, A.P.C., Dr. G. Insch, N.D.C., and C. V. Wagstaff, T.N.P.G.

"The Performance of Commercial Nuclear Power Stations in the United Kingdom" by R. J. Weeks, C.E.G.B.

Recent reactor development in the United Kingdom reviewed by Dr. T. N. Marsham, U.K.A.E.A.

Papers

"The Design, Commissioning and Operation of the Steam Generating Heavy Water Reactor" by H. Cartwright, U.K.A.E.A.

"The Place of the Fast Reactor in Commercial Power Development" by Dr. T. N. Marsham, U.K.A.E.A.

"The Nuclear Fuel Supplies and Services of the United Kingdom Atomic Energy Authority" by F. W. Bamford, U.K.A.E.A.

The afternoon session, organised by the British Nuclear Forum, will have the following programme:—

Boilers for Nuclear Power Stations. N. G. Worley, Babcock and Wilcox Ltd.

Tube Development for Nuclear Plant. D. K. A. Hockley, Extended Surface Tube Co. Ltd.

Some Aspects of Nuclear Plant Equipment. K. B. Pulford, English Electric Co. Ltd.

Precision Manufacture of Nuclear Components. A. P. Burrows, Rolls-Royce Ltd.

Reactor Instrumentation. A. J. Trott, Plessey Co. Ltd.

Availability and Supply of Uranium Concentrates. B. C. J. Lloyd, Rio Tinto-Zinc Corp. Ltd.

Mr. B. E. Eltham, Director-General of the British Nuclear Export Executive, will preside in the morning and Mr. K. J. McKillop, of the Water Tube Boilermakers Association in the afternoon.

20th May, 1968

Training of NDT Technicians

The Ministry of Technology has invited Harwell to carry out a review of the national need for training and certification arrangements for nondestructive testing technicians and operators and to make recommendations which may include proposals for setting up a nationally approved scheme. The review will be carried out by Mr. A. S. White, Head of the Chemical Engineering Division, Harwell, initially part-time but on a full-time basis from July 5th, 1968, when Mr. White retires from his present appointment.

There is, as yet, no national scheme in Britain for the training and certification of technicians in nondestructive testing techniques although schemes of this kind exist in other countries. The growing importance of NDT in many branches of U.K. industry has caused the British National Committee on Nondestructive Testing, and the other societies and

H.M. King Frederick IX of Denmark (second from left) examining a cut-away model of a Steam Generating Heavy Water Reactor on the UKAEA stand at the British Engineering Exhibition, held in Copenhagen from June 10th-14th. Explaining the reactor to the King is Mr. Pat McTighe of Reactor Group, UKAEA. Mr. G. Booth, Commercial Counsellor at the British Embassy in Copenhagen is on the King's left, and next to him is The President of the Board of Trade, the Rt. Hon. Anthony Crosland, M.P.

organisations involved, to become increasingly concerned about this problem. The formation of an NDT Centre at Harwell in February 1967 has led to further discussions through meetings of the Advisory Committee set up to advise the Director of Harwell on the programme and activities of the Centre. These and subsequent discussions have led to the appointment of Mr. White to carry out the review which will be done with the support of the Advisory Committee, the British National Committee for Non-destructive Testing, the NDT Centre at Harwell and other societies and organisations involved.

All the recognised forums of opinion in the NDT field are being invited to give assistance in the review but individuals, companies or organisations who feel that their experience or advice may be helpful, are invited to write to Mr. White.

Mr. A. S. White, B.Sc., F.R.I.C., C.Eng., M.I.Chem.E., A.E.R.E., Harwell, Didcot, Berks.

22nd May, 1968

Birthday Honours

The Queen has awarded Birthday Honours to the following U.K.A.E.A. staff:—

O.B.E.

Mr. R. H. Campbell, Deputy to Director, Fast Reactor Design, Risley.

M.B.E.

Mr. R. Jones, Engineer II, Dounreay.

Mr. A. Sunderland, Assistant Chief Engineer, Risley.

B.E.M.

Mr. W. Coleman, Non-Tech. I, Range Foreman, Foulness.

Mr. J. W. Gunn, Police Inspector, Capenhurst.

Mr. L. G. Needham, Process Supervisor II, Windscale.

Post-Graduate Education Centre Syllabus

The Harwell Post-Graduate Education Centre has published a new booklet giving details of courses and lectures to be held during the coming months. Copies of the booklet are available from the Post-Graduate Education Centre, (A).

Nuclear power conference in Copenhagen

As announced in the Authority's press release of 20th May, 1968 (*see page 159*) *a conference held in Copenhagen on 12th June, arranged under the auspices of the British Nuclear Export Executive, was one of the events of British Engineering Week in Denmark.*

A paper on *"The performance of the Central Electricity Generating Board nuclear power stations"*, by Dr. D. J. Silverleaf and Mr. R. J. Weeks (C.E.G.B. plant operations engineers) said that the later stations of Britain's first nuclear power programme ("Calder Hall-type" or magnox reactors) would generate electricity as cheaply as oil—or coal-fired stations; the Advanced Gas-Cooled Reactors would provide electricity more cheaply than conventional stations.

They reached these conclusions despite the fact that "nuclear costs are still penalised by the assumption of a 75% load-factor and a 20-year useful lifetime" (compared with 30 years for coal- or oil-fired stations). They pointed out that "the magnox nuclear stations have either already surpassed the design intention of a lifetime load-factor of 75%, are near this achievement or are heading towards this target". They added: "Perhaps the most significant statistics are those relating to the performance of the stations over the winter load period. The nuclear stations have been remarkably reliable and have functioned at full power over extended periods."

Forty reactor years

After referring to the fact that C.E.G.B. now had forty "reactor-years" of operating experience, the authors said: "The most striking conclusions to be drawn from the C.E.G.B.'s experience of reactor operation are, first, the extremely high cumulative load factors achieved; and, secondly, the surprising ease with which this performance has been achieved . . .

"In so far as we have felt any real concern about the reactors or equipment closely connected with them, this has been restricted essentially to two items. The first was the refuelling machinery; once the source of our greatest operational difficulty, it has now become a major engineering success at the earlier stations, a success which we believe will be repeated elsewhere. The second was the remote, but not inconceivable, possibility of fuel melt-out or ignition. Now that an instrument capable of detecting major cladding failures within a few seconds of their onset has been developed, we are confident that this potential hazard will shortly be eliminated.

" Magnox stations are no longer novel. As we move forward to our first A.G.R.'s, which themselves can only be regarded as mildly unconventional, it is interesting to note that the design of these stations anticipates (and eliminates) such difficulties as we have experienced with the magnox stations: the A.G.R.'s will have simple refuelling machinery, oxide fuel and turbines which utilise steam under standard conditions. We look forward to even better load-factors than those achieved by magnox stations and to cheaper generation costs than can be obtained with fossil-fuel stations."

Commenting on "the prompt and efficient supply of fuel" by the Atomic Energy Authority, the authors said: " It is now usual to find not more than one potential failure in a complete charge of 40,000 elements."

Consortia paper

Representatives of all three industrial Consortia were joint authors of a paper entitled *" Progress in the exploitation of the Gas-Cooled Reactor"*. They were: Dr. Gordon Brown, Managing Director, Atomic Power Constructions, Ltd., Dr. G. Insch, Manager of Engineering, Nuclear Design and Construction, Ltd.; and Mr. C. V. Wagstaff, Export Manager, The Nuclear Power Group, Ltd.

Their paper said: "The United Kingdom first generated electricity from nuclear power in significant quantities in 1956, when the first power reactor at Calder Hall was brought into operation, and by 1970 will have 5,000 megawatts of electrical capacity installed at nuclear stations of the same gas-cooled Magnox type. Eight stations are now operating, generating a total electrical output of approximately 3,600 MW. The final station consisting of two reactors in an advanced stage of construction is at Wylfa Head in Anglesey. When brought to power in 1969, the generated electrical output will be 590 MW per reactor; over twice the output of any other reactor of the same type and more than ten times greater than the output from each reactor at Calder Hall."

A number of important advances had been made during the first nuclear programme, resulting in reductions in cost and improved operating and safety characteristics. "A most significant development from a safety consideration", the paper said, "has been the prestressed concrete pressure vessel containing the reactor-core, surrounding shields, boilers and gas circulators. . . . In the unlikely event of vessel failure, this would be a gradual process giving ample warning and allowing the reactor to be safely shut down. . . . The concrete pressure vessel also allows much larger units with higher coolant pressures to be used than is the case with steel vessels. This is an important economic benefit which has considerable development potential."

A.G.R. success

The prototype Advanced Gas-Cooled Reactor at Windscale had "proved an outstanding success and operated at a consistently high availability since commisioning in December, 1962." The Second Nuclear Power Programme of 8,000 MW was announced in 1965 and after careful technical and economic appraisal of both A.G.R. and water reactor offers, the first contract for a 2 × 600 MW(e) station to be built at Dungeness was awarded for an A.G.R. Construction of the first two A.G.R. stations was already under way and a site had just been opened up for a third station. It was anticipated that the order for a fourth station would be placed shortly.

Describing features of the A.G.R., the paper continued: "The use of uranium dioxide for fuel clad with stainless steel, and sub-division of the fuel into a rod cluster, allows ratings to be three to four times higher than in the Magnox system and permits the use of much higher core gas temperatures. This gives boiler steam conditions comparable with those in current fossil fuelled stations. The reactor can therefore be associated with a turbine house which follows modern high temperature steam plant practice. The efficiency of an A.G.R. station is about 42%. Running costs are therefore lower than other reactor systems including the earlier Magnox stations, and the substantial reduction in turbine condenser cooling water requirements per unit generated gives a greater freedom of siting.

"The choice of on-load fuelling permits the use of efficient fuel management schemes, allowing fuel replacement rate to match the reactor load demand. This has important consequences for the operator since he is relieved of predictions of long term operating requirements and has flexibility to operate his reactor in the most efficient manner with consequent reductions in running costs. Refuelling and fuel re-arrangement can be carried out at a leisurely pace since only two or three channels must be changed each week."

The paper went on to describe: progress in the building of the A.G.R. station at Dungeness "B" by Atomic Power Constructions, Ltd.; design features of the Hinkley Point "B" and Hunterston "B" stations being built by The Nuclear Power Group, Ltd.; and a 360 MW A.G.R. design by Nuclear Design and Construction, Ltd., to meet "a requirement for reactors of smaller sizes for export purposes".

Concluding, the authors said: "The technology of gas-cooled reactors has developed continuously and progressively to the current A.G.R., and there are many considerations which show that the development limit is still to be reached.

"Ten per cent of all the power generated in the United Kingdom at the present time comes from nuclear stations.

"Safety is already fully assured, so much so, that the next A.G.R. station in the United Kingdom is planned for either Hartlepool or Heysham, both sites being close to high population centres.

"The freedom to locate the A.G.R. near the load centre, and thus reduce transmission costs, is an additional advantage to a system which has already shown to be fully competitive with conventional and other power generation systems."

S.G.H.W.R.

"*The design, commissioning and operation of the Steam Generating Heavy Water Reactor*" was the subject of a paper by Mr. H. Cartwright, Director, Water Reactors, at the Reactor Group of the United Kingdom Atomic Energy Authority.

He said that S.G.H.W.R. differed from other types of heavy water reactor now in operation in that light water was used as the coolant and heavy water was used only for neutron moderation.

On-load refuelling had been incorporated into the S.G.H.W.R. built at the Authority's establishment at Winfrith, but the system was also suitable for "off-load" refuelling, with little loss of availability.

He continued: "Financial sanction to build the Winfrith S.G.H.W.R. was given in February 1963, work began on site two months later and full power was achieved in January 1968. As this was the first of a new reactor system, the design was not finally complete when construction work started. Even so, component development proceeded largely as planned and progress during construction was good.

"The fact that construction was carried out generally to schedule was made possible because of the pressure tube type of construction which permitted the manufacture of all reactor components at the contractor's works. These were then delivered completed to site. Site work was therefore limited to assembly and erection, which was facilitated by the detailed planning methods used. These latter were based on the Authority's considerable construction experience and included the production of detailed erection procedures, well ahead of the time when the operation had to be carried out. It was also possible to separate the reactor civil work from the erection of plant, so avoiding difficult co-ordination problems."

Full power of 100 MW(e) was first achieved on 7th January and the plant was raised to continuous full power operation on 25th January. The few months of operation after achieving full power had proved very satisfactory and the plant was stable in operation. During March the plant load-factor was 93% and the reactor availability 98%.

Mr. Cartwright pointed out that the most important single feature of the S.G.H.W.R. was that it was a pressure tube reactor. It was this which made possible designs for different outputs using substantially standard units.

Designs of commercial reactors based on Winfrith experience were developed first at around 300 MW(e) but since then the range had been extended to include reactors of over 500 MW(e).

Dr. T. N. Marsham, Director, Technical Operations, U.K.A.E.A., reviewed fast reactor work in a paper "*The place of the fast reactor in commercial power development*".

"The primary object of a new commercial reactor system," said Dr. Marsham, "must be to produce, for the electrical network as a whole, lower average generating costs than would have resulted had it not been introduced, taking into account the conditions that will be created by the continuing large scale installation of the current reactor types. Some of these conditions make the introduction of new systems more difficult, e.g. the benefits of continuing evolution in design, the creation of large scale manufacturing facilities for components and fuel cycle requirements for the existing reactors. For the particular case of fast reactors certain aspects can be made to yield a potentially overwhelming advantage in fuel cycle costs both in terms of reduced requirements for new fissile material and by making the best use of the plutonium and depleted uranium which arises as the 'waste' (or 'tails') from the enrichment plants which provide fuel for thermal reactors. It is essential, however, that this potential advantage is realised with acceptable capital costs and plant operational and safety features".

One of the advantages of the fast reactor system, the author pointed out, was a saving in foreign exchange: "Like many countries in Europe, the U.K. has no exploitable indigenous resources and so the need to make the best use of imported nuclear fuel to avoid other shortages or high import bills has been a major factor in the U.K.'s reactor development programme for the past 20 years. A factor which has also been important is the relatively high cost of coal in the U.K. which led to the early large scale introduction of natural uranium reactor power plants and thus the early creation of a large stock of plutonium and also of depleted uranium. Consideration of the alternative courses of action led to a decision to concentrate on the early development of fast breeder reactors, which seemed to have the best long term potential, reducing uranium requirements by nearly a factor of 100, making the best use of the plutonium arising from the early stations and overall producing the lowest forecast power costs ".

The U.K. had been developing sodium cooled fast breeder reactors for some twenty years and one of 250 MW(e) is now well under construction. This, said Dr. Marsham, would provide a firm base for the introduction of commercial fast reactors in the early 1970s. " Such a programme would also tend to improve the economics of the current large thermal reactor programmes by easing the pressure on the uranium suppliers and providing a more economic outlet for the plutonium they produce than recycling this in the enriched uranium thermal systems. The stocks of depleted uranium accumulated from the enrichment plants would be sufficient to supply a very large fast reactor installation for many decades and ultimately uranium requirements would be reduced to a rate only about one hundredth of that required by present systems."

Fuel Service

Mr. F. W. Bamford (Chief Commercial Manager, Production Group) gave a paper on "*Nuclear fuel supplies and services of the United Kingdom Atomic Energy Authority*".

After referring to the fact that other papers at the conference had described United Kingdom experience with the Magnox, A.G.R., S.G.H.W. and fast reactor types, he pointed out that it was the function of the U.K.A.E.A. to provide a complete fuel service for reactors of all these types in the U.K. and similar services were offered overseas.

For many years, said Mr. Bamford, the U.K.A.E.A. had had the responsibility of fuelling the largest nuclear power programme in the world.

Referring to the reactivation of the Capenhurst diffusion plant to meet the needs of the second nuclear power programme for enriched uranium, he said: " It is believed that this planned expansion of the Capenhurst plant is the first occasion on which a diffusion plant has been constructed with the minimum cost of production—under commercial ground rules—as the prime criterion ".

He continued: " The present estimate is that during the next four or five years the increase in capacity at Capenhurst will fairly closely match the rising U.K. requirement for enrichment, but thereafter spare capacity will become available for the supply of enrichment to overseas customers. U.K.A.E.A. are planning by the end of 1968 to propose contract terms and prices for the supply of enriched uranium to overseas customers, beginning about 1973-1974".

The Authority had unique experience in transporting irradiated fuel from many parts of the world, including Canada, Australia, India, Italy, France and Denmark. In some cases it had proved appropriate to charter a special ship, but experience of transporting irradiated fuel on ordinary cargo vessels was developing.

Describing the fuel services which the Authority could supply in support of a British-designed nuclear power station in Denmark, Mr. Bamford said: " The U.K.A.E.A. has established close relationships with the British Consortia who design and construct nuclear power stations for the British market. On the basis of this domestic co-operation, the overseas customer may receive a single package offer to design and construct a nuclear power station, including the provision of the fuel, and such an offer would have the full technical support of the U.K.A.E.A. Specifically an offer to construct a nuclear power station in Denmark would include all the fuel supplies and services, and these offers can be made available in the form of a comprehensive service or in whatever manner is considered appropriate. U.K.A.E.A. are prepared to operate quite flexibly if the customer desires to provide some parts of the fuel service from other sources.

" As far as guarantees of fuel performance and endurance are concerned, utilities with a great deal of experience and expertise in the operation of nuclear power stations may seek only minimal protection and rely on their own experience in satisfying themselves about the potential performance of the fuel. Others may, however, come to the conclusion that they require guarantee cover in varying degrees of completeness. U.K.A.E.A. working in full co-operation with the reactor supplier, are ready to fit in with customers' wishes in this respect. Guarantee would be available even if some parts of the fuel service are provided from other sources ".

British Engineering Week Exhibition

Britain's nuclear power programmes were outlined on the United Kingdom Atomic Energy Authority's stand at an exhibition held at Bella-Centret, Copenhagen, during 10th-14th June. Data was given on the 27 power reactors now working, and the nine more being built.

Models and details of the SGHWR and the Dounreay 250 megawatt fast reactor were on show.

The exhibit also described research and power reactor fuel elements made at the Authority's Springfields and Dounreay works (the UKAEA has made well over two million reactor fuel elements). The UKAEA offers a complete nuclear fuel cycle service, supplying, transporting and reprocessing fuel all over the world—including that for the British designed DR-3 DIDO type reactor at Risö.

There was also a wide range of engineering equipment from Authority establishments.

From Aldermaston: an audiometer, for testing babies' hearing, an automatic solvent extraction and precipitation apparatus, and a press for compacting and densifying powders.

From Harwell: A RIPPLE radioisotope powered electric generator; one is already installed as a light beacon at Asnaes (Denmark) on the main shipping route to Kalundborg and the Kiel Canal; another is sited at Tegelhällon in the Stockholm archipelago. Also—modular electronics, planetary swaging equipment for use with metal tubes, and geological assay equipment.

From the Radiochemical Centre, Amersham: A display of radioactive sources—Amersham being one of the world's main suppliers of radioisotopes.

A.E.R.E. Post-Graduate Education Centre

THE following courses are due to be held at the Post-Graduate Education Centre, A.E.R.E., Harwell, Didcot, Berks, Further information and enrolment forms can be obtained on application.

Science and Mathematics Teachers and use of Radioisotopes in Schools
9th to 13th September, 1968
24th to 28th March, 1969

This course for science and mathematics teachers, which may also be of interest to teachers in Colleges and Departments of Education, is intended to give a background knowledge of current developments in some of the subjects investigated at Harwell. There will also be an alternative section giving an introduction to the use of radioisotopes in schools in the physics, chemistry and biology syllabus. It will include visits to laboratories and nuclear reactors and short experimental sessions as well as an extensive lecture programme. The aim is to provoke interest in recent applications rather than to provide material directly applicable to a school syllabus. Fee: £5 exclusive of accommodation.

Lecturers in Engineering
16th to 20th September, 1968

This course is intended primarily to give lecturers a background of current developments in the types of engineering and associated subjects of which we have special knowledge. It has been designed for senior members of the Engineering departments of Universities and Technical Colleges and should also be of interest to applied physicists, applied chemists and chemical engineers. Fee: £20 exclusive of accommodation.

Introduction to Radioisotopes
16th to 27th September, 1968
28th April to 9th May, 1969

The course is aimed at those with preliminary training in a scientific discipline who need an introduction to the techniques of handling and measuring radioactive materials, mainly at the tracer level. It is also a useful preliminary to a more specialised course. Fee: £80 exclusive of accommodation.

continued on page 204

Select Committee Report

The following extracts are from the debate on the Select Committee Report which took place in the House of Lords on 8th May, 1968.

LORD SHERFIELD: This is the first Report of the first specialised Select Committee. It is interesting that the Committee should have selected nuclear power for its debut, and though, in terms, the Report is limited to the United Kingdom Nuclear Reactor Programme, it raises some rather broader issues which I shall endeavour to identify. In the first place, it establishes certain facts about the United Kingdom nuclear programme which have long been in dispute. The original purpose of this programme, say the Committee—the establishment of a new lower cost primary energy source for the British Isles—is already attained. The existing Magnox stations have more than lived up to expectations, in terms both of output and availability. It was right, they conclude, that the United Kingdom Atomic Energy Authority should have devoted so much effort to the development of the gas graphite reactor; indeed, they should press ahead for the development of high temperature reactors of this type, and should complete the DRAGON experiment at Winfrith Heath if our European partners drop out of it. It was right, too, to diversify into the field of water reactors, and the A.E.A. and the industry are encouraged and should be enabled to speed up the development of the steam generating heavy water reactor. The Committee approve of the fast reactor programme, and spur the A.E.A. on to further efforts in this field.

The Committee accept the view that as far as the advanced gas-cooled reactor programme is concerned, electricity produced by nuclear fission will be commercially cheaper than electricity produced from coal, and is likely to become cheaper still. The arguments put forward by the Coal Board and others against this view are decisively rejected, and the Government are urged to face the consequences of a rapid contraction of the coal industry.

The Committee go further in saying that the United Kingdom is in danger of falling behind other advanced countries in the rate of installation of nuclear power, especially the United States. They very properly emphasise that nuclear fission is a cleaner and more sophisticated way of obtaining energy than burning fossil fuels, and that cleanliness and avoidance of atmospheric pollution in the large-scale production of electrical energy is already important. The Committee therefore draw attention to the economic advantage to the country of an increase in the size of the present nuclear power programme.

The Select Committee, after full inquiry, have thus given complete endorsement to what has been done so far to develop the nuclear power industry.

I now turn to the more difficult and more controversial question of the future organisation of the industry and of the Atomic Energy Authority. This has quite rightly to come up for review now, mainly because the first phase of the civil nuclear programme has come to an end with the establishment of competitive nuclear power, and we are entering a new era. The Committee first throw an envious glance at the American system under which the main research and development work is let out by the Atomic Energy Commission on contract to universities and to industrial firms. Virtually all the Commission's installations are run for them. This system has proved to have many advantages, but in 1946 it was not one which either British industry or the Government were able or willing to adopt. We plumped for State monopoly in research and development and, as far as the fuel cycle was concerned, for State manufacture. It is too late to put the clock back now and to undo what has been done, though it is not, of course, too late to introduce modifications. The Committee's solution is of a root-and-branch kind. It involves the disbandment of the consortia, and the disintegration of the Atomic Energy Authority.

In considering this question, there are two broad issues which affect one's judgment. They are the question of exports and the question of competition. Our export performance in the civil nuclear field has not come up to expectation, and it is relevant to ask why. I think that part of the explanation is the following. One of the main consequences, and perhaps the main disadvantage, of the enlargement of the civil nuclear programme in the mid-'fifties was that it threw such a heavy load on the industry that the consortia were not able, or not willing, to make a real effort in the export field. On the other hand, the Americans laid the foundations of their success in this period. They moved in quickly after the so-called Atoms For Peace Conference in Vienna in 1956. They made an agreement with EURATOM. They offered co-operation and attractive incentives for nuclear development. Whenever one visited a European nuclear laboratory there was a representative of Westinghouse or of General Electric working in the laboratory alongside the local experts. Of representatives of British industry there was little sign. The benefits of this careful groundbaiting were later realised by the United States.

Another consequence was that such tenders as were put in by British industry were greatly in excess of American and Canadian tenders, which were also accompanied by extremely favourable financial terms. Finally, the Central Electricity Generating Board hesitated over-long in ordering an advanced gas-cooled reactor, which gave the Americans two vital years in which to establish their strength in and inside overseas markets. The Select Committee are inclined to pooh-pooh the suggestion that a domestic order is a prerequisite of a foreign order. Personally, I think that in this they are mistaken. But, however this may be, British industry and the Atomic Energy Authority did make a fresh start in the export field in 1966 with the formation of the British Nuclear Export Executive. This has not so far been successful in securing export orders, and the Select Committee recommend that it should be wound up and the problem of exports passed to the Board of Trade for study. What do the Government think about that? To me it is not very clear what a Government department can achieve where the A.E.A. and industry have not succeeded.

One should not overlook the difficulties that have been encountered, the lost opportunities in the past, the nationalistic attitude of the present, which lead countries to follow uneconomic and expensive protectionist policies in order to build up their own resources rather than to use overseas facilities.

One of the purposes of the organisation of the nuclear industry into a number of consortia was to prevent monopoly and to preserve competition. This view perhaps had some merit, as leading to diversity of approach to a novel engineering and construction programme, at a time when a number of orders for relatively small nuclear stations were contemplated. But it largely lost its *raison d'être* when the size of the individual unit increased beyond expectation. This meant that with at most one order in a year, or in an even longer period, the C.E.G.B. had either to give an order to each consortium in turn, or, in effect, to put one or more out of business. The fearful expense of tendering made the position all the more difficult. Thus, competition in the full sense is not attainable.

The Select Committee recognise this problem, and they advocate two new monopolies, one for the construction of the nuclear boiler—what they call the "nuclear island"—and one for fuel manufacture, the competition coming from the foreign manufacturer, and the Central Electricity Generating Board being encouraged to seek foreign tenders. This is pretty drastic. It involves the elimination of certain vested interests which are not necessarily bad ones; it involves the radical reorganisation of the industry, and the virtual dissolution of the Atomic Energy Authority. Moreover, it is not a solution which commands even majority support, since the Central Electricity Generating Board and an important part of industry are against it.

It seems to me that this puts the Government in a difficult position. Suppose they were to accept the Committee's recommendation? How are they to impose it—by legislation? Moreover, the proposal itself is not very precise. The new company, that is to say the Nuclear Boiler Company, is to comprise a substantial part of the United Kingdom Atomic Energy Authority, together with

> "those design and manufacturing resources peculiar to nuclear engineering"

and

> "so much of the Authority's facilities as is at present devoted to research and development of a commercial nature."

To one who is fairly familiar with the organisation of the Atomic Energy Authority, this poses a problem of dissection so difficult as to be liable to lead to the death of both halves of the patient. By propounding so controversial a solution, the Committee have left others to make what they can of it. I cannot help wondering whether there is not some rather less far-reaching method which might prove to be more workable: for example, having the Atomic Energy Authority and two industrial groups with interlocking shareholdings, a large consortium with a single export organisation, capable of standing behind any export order. This would not provide competition in the true sense, for the reasons I have given, but it would provide a check on monopolistic practices, and it is relevant that the Central Electricity Generating Board consider that the degree of competition offered by two industrial groups in the domestic market would be of value to them.

The second proposal is that a new British fuel supply and manufacturing company should be established to take the place of the present Atomic Energy Authority monopoly of the fuel cycle. I do not myself find this proposal to supersede the existing Authority's control of the fuel manufacture and supply very attractive. This part of the Atomic Energy Authority's activities is, and has been for some time, on a commercial and profitable basis. It is not a process which private industry has taken up in this country, except to a marginal extent. It therefore differs from the design and construction of nuclear stations.

The Committee's reason for making this proposal seems to be partly connected with a belief that it would make easier collaboration with the European Economic Community. But I find this argument rather difficult to follow; nor has it yet been borne out by experience, *vide* the contract for the supply of plutonium to EURATOM announced only this week. In any case, the present system is undoubtedly working well, and there does not seem to be the same urgency about dealing with it as there is in the case of the organisation of the rest of the nuclear industry.

Finally, as regards the Atomic Energy Authority itself, the Committee say they are satisfied that the Authority has done their basic task, that of nuclear research and development, with success. But the Committee go on to suggest, really without further argument, that the Authority should now be broken up into four parts. The consequences of this proposal do not seem to have been fully thought out.

The Parliamentary Secretary, Ministry of Public Building and Works (Lord Winterbottom): From the outset the basic aim of the United Kingdom's civil atomic energy policy has been to encourage the sure and safe development of a low-cost energy source for the benefit of the country's economy. The lines of advance have been, first, to secure the general development of the new technology as rapidly as possible; second, to seek to meet the requirements of the Generating Boards; and third, to develop and exploit export markets for U.K. reactors and fuels.

About three years ago, in May, 1965, with the award of the Dungeness "B" contract to an advanced gas-cooled reactor design the exploratory phase of the atomic energy programme can be said to have ended, in that it marked the stage when nuclear power was seen to have become the most economic source of energy generation in this country. At the same time British reactor designs were shown to be fully competitive. The estimated costs of nuclear power generation have continued to decline. Thus the estimated cost of generation from Hinkley Point "B" is 0.52d. per kWh compared with 0.57d. for Dungeness "B". Further and considerable cost reductions are expected from advanced gas-cooled reactors in the post-1975 period, and the recent White Paper, *Fuel Policy*, predicts that A.G.R. costs will be down by 20 per cent. by 1980. Fast reactors in the 1980s and 1990s will provide even cheaper power.

The disappointing results so far of our efforts to sell nuclear reactors abroad stem from a number of reasons. Some of these are connected with weaknesses in organisation which we now aim to correct. Others lie outside the scope of normal commercial transactions, since in this sort of field where national prestige plays a part, political as well as economic considerations are sometimes decisive. There are also technical factors. The A.G.R. system designed for the domestic market and generating about 500 to 600 megawatts is not ideally suited for overseas markets where smaller units of about 100 to 150 megawatts are in greater demand. The steam generating heavy water reactor (S.G.H.W.) recently unveiled at Winfrith has been designed specifically to meet this demand, and we have high hopes of being able to exploit this versatile design in the export markets.

While it will be necessary to maintain a sizeable effort on research and development in support of systems now in hand, it is clear that the emphasis of our civil nuclear programme has now shifted to the stage where we must do everything possible to exploit the vast store of experience and expertise which has been built up in the last twelve or thirteen years by selling our reactors and fuel in overseas markets. It was because of this change in emphasis, and because of our comparative lack of success in the export field, that early in 1967 the Government came to the conclusion that the existing organisation of the nuclear power industry was unsatisfactory; and this led to the initiation by my right honourable friend the Minister of Technology of discussions with all sectors of the industry and Government concerned with the nuclear power programme with a view to making changes in that organisation. The examination of the nuclear reactor programme by the Select Committee and its subsequent Report was, therefore, most timely.

Since the publication of the Report there have been a number of informal discussions with most of those interests which will be involved in the reorganisation of the industry. It has become clear from these discussions that there is considerable disparity of view about what is practicable and what new form of organisation will be most effective. As noble Lords are aware; the Select Committee was itself divided on the major question whether or not there should be a single organisation to design and organise the construction of nuclear boilers. This division of opinion is reflected in industry and the public authorities concerned.

It is clear, therefore, that any reorganisation will be difficult to achieve. There are, quite naturally, vested interests to overcome. One consortium has already a healthy programme of work. As is only too clear from the evidence given to the Select Committee, there are conflicting views to be reconciled. The interests of the staff of the various organisations involved must be carefully considered, and continuing uncertainty about their future is not conducive to the maintenance of good morale.

In spite of all the difficulties, the Government continue to be most anxious to arrive at an early solution to the major problem of the future structure of the industry. Initial talks with the chairmen of the consortia were held more than a year ago. Inevitably, the work and the Report of the Select Committee have prolonged the uncertainty both in industry and in the Atomic Energy Authority. Apart from the effect on the morale of the people concerned, our efforts overseas are also handicapped, owing to uncertainty about where future responsibility in this field will lie. In particular arrangements for the commercial exploitation both at home and overseas of the two new reactor systems, the steam generating heavy water reactor and the fast reactor, cannot long be deferred. Both noble Lords who have spoken so far have stressed this point. Moreover, the possibility that these new reactor systems and an improved version of the advanced gas-cooled reactor may be very competitive with American designs, particularly in the light of the trend of current costs in the U.S.A. and elsewhere, makes it desirable from the commercial standpoint that any new organisation should quickly be brought into being to take advantage of them.

Successive Governments have over the years spent considerable sums on research and development on nuclear power systems, and the present Government have the right and the duty to see that this investment produces dividends by way of an increase in overseas trade, in addition, of course, to whatever royalties may be obtained from the Central Electricity Generating Board and the long-term industrial and domestic advantage of using a cheaper mode of generating electricity than burning either coal or oil.

The design of the nuclear boiler constituent of a nuclear power station entails the participation not only of the nuclear engineers but also of the boilermakers and manufacturers of other major components who are normally responsible for the detailed design of their respective components within the parameters set by the nuclear engineers. This brings in a number of different industries; and in the actual construction of the complete power station the turbine and other electrical gear manufacturers, working to their own designs, and the civil engineers also have a major part to play.

As your Lordships know, it was decided at the outset of our civil nuclear programme that firms in these various industries should band together in nuclear consortia to design and build nuclear power stations on a turnkey basis. Latterly, after these nuclear consortia had in the process of time been reduced to three, they have been transformed from associations of firms into companies with a separate existence under their own management, and operating to some extent independently of their parent firms. Thus, the present organisation is exceedingly complex, and negotiations on a new structure for the nuclear industry entail discussion not merely with the nuclear companies or consortia but with a large number of their parent firms, many of them of major importance with widespread industrial interests, and often with associate and subsidiary companies overseas interested in one or other aspects of the nuclear business. Discussions are now in progress with the various interested parties. They are bound to be delicate. In these circumstances, I would ask noble Lords to excuse me from giving any further details of what it is in the Government's mind to achieve during these negotiations.

Whatever I might say could possibly prejudice the success of these negotiations, and I am sure that noble Lords taking part in the debate on this Motion will share the view of the Government that the objective must be to try to secure as satisfactory an organisation as possible. I am sure that many of those who will participate in this debate will have had much more intimate and detailed knowledge of the situation in this industry than I can claim. Their views on what it is desirable to aim at and what may be achievable in the reorganisation of the industry will undoubtedly be helpful to the Government in a somewhat tangled situation.

The benefits of competition in this highly specialised field can be overrated, and in this industry such competition as might take place is much more likely to be between different reactor systems rather than between different organisations. From this standpoint there is much to be said for the majority view of the Select Committee, that we should aim to set up a single, strong design/construction organisation, in which the Atomic Energy Authority and the principal manufacturers will participate, formed from elements of the existing consortia and the U.K.A.E.A. The Government have in fact invited the Chairman of the Industrial Reorganisation Corporation to seek the reactions of industry to a reorganisation along the lines of the majority view of the Committee. The Chairman's preliminary report to the Minister of Technology will not be available until later. Following that, delicate and complicated negotiations will be required. We are all anxious to reach a rapid decision, but I think your Lordships will agree that it is even more important to get the right results than to get them quickly, although I know that the noble Lord, Lord Sherfield, believes that speed is an important element in our calculations.

The scope of the present negotiations covers the Select Committee's recommendations in the beginning of the Blue Book. So far as Recommendation 6 is concerned, I should like to say that the British Nuclear Export Executive has done valuable work in studying the prospects in export markets and establishing contact with possible customers, and publicising the achievements of the British nuclear power programme. Until the future organisation of the British nuclear industry becomes clear B.N.X. must stay in business. As regards Recommendation 3, the Government believe that there appear to be good arguments that a separate fuel organisation should be set up. However, the existing organisation has operated very successfully and a decision on the nature and timing of any changes cannot be taken until the shape of the new organisation for the design and construction of reactors has been determined. The remaining recommendations are being considered by the Government Departments concerned, and it is proposed to incorporate the Government's views on these matters either in an early statement or, if negotiations on the major problems of reorganisation are speedily concluded, in a comprehensive White Paper.

The story of nuclear power is one of great success, and given the right organisation the industry and the nation now have a great opportunity to reap the rewards in overseas markets of all the effort and money which has gone into research and development over the past twenty years. To achieve that organisation, sacrifices may have to be made. But given flexibility of outlook, singleness of purpose, and true co-operation between Government and industry, the opportunity can be seized.

Lord Hinton of Bankside: I do not agree with all the recommendations made by the Select Committee on Science and Technology but I should like to pay tribute to them for the very thorough and useful examination they have made of the nuclear power industry. Although I suppose it is unfashionable and it may be indiscreet to confess to disappointment, I am disappointed—and I am sure that my disappointment is shared by many of the other men who worked on the development of nuclear power in the 1950's—over the way in which the industry has developed in this country in the years that have passed since. We felt at that time that we were creating a new industry and we felt too that this country was leading the world in that new industry.

But, my Lords, the success of industry must, I suppose, be measured to some extent by the size of its order books. If we use this criterion in judging the success of the nuclear power industry, we find that the picture is not a very happy one, because in the two years 1966 and 1967 orders for about 40,000 megawatts capacity nuclear powered plant of American design were placed, while less than one-tenth of that capacity nuclear powered plant of British design was ordered. But, perhaps even worse, one finds that while reactors of American design have been ordered and are being built in eight overseas countries, only two countries have ordered a reactor of British design—and that more than ten years ago.

When one meets with disappointment of this kind, I think it is wise to seek the reason for it. I should like to suggest to your Lordships three reasons why progress has been, as I see it, disappointing. In the first place, I think the technological progress in this country was retarded by the large, obligatory, nuclear-powered programme of 1957. I do not seek to criticise the people who were responsible for that programme; indeed, I had some part of it myself. At that time the programme appeared to be absolutely necessary. The official forecast warned the electrical industries that at no date in the future would more than 52 million tons of coal a year be available for electricity generation; the Suez crisis curtailed supplies of oil; and it looked as if we must make extensive use of nuclear fuel, irrespective of cost, as quickly as possible.

But although that programme was reduced when supplies of fossil fuels improved in 1959, the programme remained large. The servicing of that large programme made heavy calls on the resources of the A.E.A. and of the generating boards and I think it diverted attention from the development of more advanced forms of reactors. But, even worse, it gave a guaranteed programme to the nuclear power industry, and that industry knew that, irrespective of economics, the Electricity Boards were bound to go on ordering nuclear power stations—each one of which was certainly better than the last but all of which were less economic than the conventional stations which could have been built concurrently—simply to meet an immutable long-term nuclear programme. That, I suggest, is one reason.

The second reason which I should like to suggest for our comparative lack of success is that it takes too long to build plant in this country; it takes us too long to get off the drawing board and out of the development laboratories into full-scale production. I believe that the figures published by the Central Electricity Generating Board giving a comparison of costs for the Dungeness reactor should convince an unbiased engineer anywhere in the world that in most circumstances there is very little to choose between the A.G.R. and the American reactor systems. But overseas buyers—and particularly those overseas buyers making a choice between two systems whose economics are more or less equal—are likely to follow the majority lead and to place their orders (remembering that there is little to choose) for the type of reactor for which most orders have been placed. If we in this country had been able to get the A.G.R. through the prototype and development stage 18 months or two years earlier than we did, I believe that position could have been reversed and we might have had the American manufacturers trying to catch up with us, instead of our being in the position of trying to catch up with them. That I suggest is the second reason.

The third reason lies, I think, in the extremely vigorous and very expensive promotional campaign waged by the American manufacturers. In considering that, I think we should remember the great support that they get from the large power-plant consultants and engineer architect firms in the United States. Those organisations are an important component in getting overseas orders, because they are most likely to recommend to their clients the reactors which have been developed in their own country and with which they are familiar.

If, as I believe, those are three reasons for our disappointing performance, I think that we should be wise to ask ourselves what lessons we ought to learn from them. In the first place, I think that we should learn that it is a mistake to lay down a long-term, fixed, immutable programme for the use of given quantities of any type of fuel. Certainly broad, long-term Government planning is necessary, but I suggest that it should be flexible and that the decision on the type of fuel to be used in any power station when its construction is under consideration should be determined by the economic evaluation of that specific case; that the fuel to be used should be the fuel which gives the greatest economy and not the fuel which has to be used to meet an immutable Government programme.

In the second place I think that we must learn to do our construction work in this country more quickly. This is important not merely in the field of nuclear power, it is important in all the fields of engineering. The prospective buyer, particularly the prospective buyer from overseas is not impressed by the idea, however brilliant, that he sees on the drawing board, or in the development laboratory; he wants to see ironmongery working, and in order that we can show this before our competitors we must do construction work more quickly.

In the third place, I think we should be careful to see that we build up in this country strong teams of consultants and engineer architects. The existing consortia in the nuclear field, can, I believe, already act satisfactorily as engineer architects. The consultants have recently—I think with a great wisdom—formed a joint organisation for the design of nuclear power plant, but I think we ought always to remember that the great American power plant consortia and engineer architects get off-shore business because they are regularly employed by the United States utilities. Their off-shore business is built on the basis of the work that they do at home. We must aim to achieve this in the United Kingdom. British consultants should, I consider, be similarly employed, and this should be done even though it demands some change in the organisation of the electricity authorities; although I feel that it would be possible to conceive an organisation in which it could be done without any dramatic change in those organisations. I think that we must look to the future, and that as we do so we shall find that it is much brighter than the past has been.

My Lords, the Atomic Energy Authority has within the last six months commissioned the steam generating heavy water reactor at Winfrith Heath. Although that was developed with the primary purpose of competing in the small reactor field, I believe that it has great potentiality in the field of the larger reactors. It may well prove to be a better reactor than the A.G.R. and perhaps, with some limitations on the very largest sizes, it may well prove to be better than either of the American established reactor types. The techniques of manufacture and construction of the steam generating heavy water reactor are very different from those of the A.G.R., and are much more in line with the techniques of the American reactor manufacture and construction. I think that in deciding how to exploit the steam generating heavy water reactor it would be worth while to look at the pattern of industry which has been adopted by those great American manufacturers who have met with such success.

In the early promotional days the American manufacturers were prepared to accept turnkey contracts for the design and construction of complete stations, but as they emerged from the promotional stage they firmly adopted a policy based on the fact that the design and construction of complete power stations, with all the heavy civil and structural engineering which is involved, is not the line of country in which they are outstandingly expert. They now aim to undertake to contract only for what they call the nuclear components; that, in the case of the American reactors, is the fuel, the control mechanism, some of the instrumentation and the reactor vessels. This accounts for about one-third of the total cost of the power station, and the purchasing utility is left free either to design the station himself and place his own contracts for the other two-thirds of the work, to employ consultants to do this for him, or to place the whole station in the hands of an engineer architect.

My Lords, I believe that that system could well be employed and should be carefully considered for the exploitation of the S.G.H.W. The A.E.A. could design and supply the nuclear components plus the fuel. The overall design of the station, the civil, structural and other engineering work, could be done either by the purchasing utility or consultants employed by him, or by the consortia acting as engineer architects. This would have the advantage of keeping together the very highly competent design teams of the A.E.A., but it would confine them to those sections of the work in which they are outstandingly expert. I suggest that the adoption of such a system would not destroy competition because the existing consortia, either merged or kept separate, as they judged best, could still offer the A.G.R., for which they have licences; and they would in any case be able to tender for the two-thirds of the station which represents the bulk of it and comprises everything other than the so-called nuclear components.

With respect to the Select Committee, I do not agree with their proposal that the manufacture of fuel elements should be divorced from the design of the nuclear components, and indeed of the whole power station. I disagree for two reasons. In the first place, many overseas buyers do not like to feel that they are dependent on two separate organisations for the satisfactory performance of the reactor they have purchased: they want to hold one manufacturer responsible both for the design of the reactor and for the performance of the fuel. And in the second place there are, I think, occasions when negotiating for off-shore contracts where it is an advantage to offer a reactor at a promotional capital cost, counting on making one's profit from the later sale of fuel elements. That can be done only if an integrated organisation is retained. If one looks forward into the future, it seems that such an organisation would fit well with the design of the fast reactor as it is at present envisaged.

The following extracts are taken from the debate on the Report which took place in the House of Commons on 23rd May, 1968.

MR. ARTHUR PALMER (Bristol, Central): The Report is the first major Report of the Select Committee on Science and Technology, of which I have the honour to be chairman.

From a score of candidate subjects we selected the nuclear reactor programme for our first major investigation. I think that we did so because it seemed to us to fulfil three conditions that we thought desirable. First, it was and is a great spender of public money. Second, it is an industry of outstanding contemporary national importance. Third, it is generally accepted that changes in public policy are here desirable and urgent.

The House should note that, arising out of the Report and the arguments put forward in it, there are nine broad conclusions. From these spring the eleven specific Recommendations to the House and, of course, to the Government. Three of these concern the general energy field; the remainder deal with the purpose, activity and future organisation of the nuclear reactor industry itself.

The Committee did not set out to find out which primary energy source is the cheapest in any immediate absolute sense. On the evidence submitted to us we looked at the trends and concluded that nuclear power is now generally competitive in relation to other sources of primary energy available to the United Kingdom and that it is likely to become cheaper with, we hope, further improvements in the advanced gas-cooled reactor and, of course, the quicker development of the steam generating heavy water reactor.

We also say firmly that, on the evidence given to us and the conclusions we drew from it, eventually the cheapest source of primary energy to this country will be nuclear power when the fast breeder reactor becomes commercially available. But these were trends in our view rather than statements of contemporary absolute fact.

The Report recommends that in the short term there should be an outside examination by an independent agency of all financial aspects of the costing of all methods of electricity supply. Had there been time, we should probably have commissioned that investigation ourselves.

We argue that in the long term energy is so important to the country that we should give consideration to the establishment of a Parliamentary body similar to a United States Joint Congressional Committee, in this case the committee on atomic energy which some of us saw when we visited the United States. This body could be a public watchdog giving continuous attention to all aspects of energy policy. Its advice and recommendations would be available to the Government in the same way as our advice and recommendations are available to the Government.

As the chairman of the Committee, I say that it is unfair to the Committee to suggest that at any stage there was an automatic party division across the Committee. The issue of future structure in the end seemed to me to be a choice between those who favoured what I shall call the managed solution and those who favoured what I shall call the market solution. The majority favoured the managed solution and the remainder the market solution. But it is wrong to think that it was a simple issue between competition and monopoly.

After all, it must be accepted that reactors cannot be sold as an outfitter sells shirts. Competition in the sale of shirts is natural enough, but reactors are large and expensive and, of necessity, competition must be limited but it can exist. All the members of the Committee appreciated the inevitability of that in one sense or another. The majority doubted the need for competition in the country partly because there was so much competition in the sale of reactors abroad. All were in favour of now ending the turnkey system of consortium tendering and the building of complete nuclear power stations by groupings of companies such as we have had since the start of the construction of nuclear reactors. But this means more competition not less. If, as we recommend, nuclear power stations in future are built as coal- and oil-fired power stations are built, it is bound to mean that much power station construction and equipment will be separately tendered for. The majority of the Committee took the view that once the consortium system is phased out and we depart from the turnkey system for the construction of nuclear power stations, as the United States industry has generally departed from it, then to quote the report, paragraph 142:

The Committee said:

". . . a single nuclear boiler company should be formed. Such a company should comprise a substantial part of the U.K.A.E.A. together with those design and manufacturing resources peculiar to nuclear engineering such as are necessary to create an effective commercial enterprise. Your Committee are satisfied that genuine competition between two or more such companies cannot be realised. This is either because of an insufficient flow of contracts from the C.E.G.B. or because the integration of commercial activities of the U.K.A.E.A. must necessarily preclude it. Your Committee are satisfied that technological progress will continue under the stimulus of a diversity of projects and in response to the challenge of foreign competition. A sufficient element of day to day commercial competition will be provided between specialist manufacturers tendering for smaller items of equipment and components."

I want also to read paragraph 143, because this is often overlooked. It says:

". . . Your Committee wish to emphasise that they do not present their recommendations as an unalterable solution to be adhered to for all time. They have been very much aware throughout their enquiries that great changes in marketing opportunities may take place in the future, particularly if links can be established with continental and other interests. With an increase in the scale of ordering by utilities and others and greater success than hitherto in securing orders it may be that ultimately there will be scope for the operation of additional nuclear boiler companies, whether British or jointly owned with overseas manufacturers. However, the time has not yet come and Your Committee's recommendation is, therefore, shaped to meet the urgent necessities of the foreseeable future."

Whatever may be argued against this, it is no doctrinaire solution. From many points of view it is an extremely liberal solution. This is shown particularly in our willingness to face the realities of international competition, and to assume that if Britain is to sell nuclear reactors overseas successfully occasionally British utilities must consider the possibility of buying a foreign reactor and using it here. This is a realistic solution, sound in principle and practice. It should strengthen the nuclear export position of the country.

I would like to touch on other recommendations that we have put forward. There is first the reconstruction of a smaller Atomic Energy Authority, starting afresh and concentrating on purer research and development. In other words, we want to hive off the industrial part of the Atomic Energy Authority and return the rest to its original purpose as an advanced thinking research and development body. What is mainly commercial in the Authority and already developed on commercial lines should be genuinely commercial and not kept in a framework where it is part subsidised out of public funds.

Another recommendation was that an independent nuclear fuel company, privately or publicly-owned, or half and half, should be established. We believe that the sale of nuclear fuel is a valuable export line in itself. We argue also that the Export Executive should be wound up. This organisation, while it has been working hard and doing its best, we came to the conclusion, was a puny child in the first place, which shows no signs of useful growth. We thought that it would be far better if nuclear exports became the direct responsibility of new manufacturing companies; in other words that those making and selling the reactors should deal directly, on normal commercial lines, with possible purchasers and that the Board of Trade should be encouraged to look at things nuclear in the way they do exports in general.

Sir H. Legge-Bourke: There is one important feature which I should mention. Had we not been in the haste that we were, and had we had from the Minister of Power the papers which were eventually, after pressure, extracted from him, I am inclined to think that we might have made different recommendations about the costing of the industry in relation to coal. Lord Robens is a good, robust witness. He was standing up for something of which he was very proud, and I respect him for having done so. He argued, in particular, that the basis of costing nuclear energy was unfair to the coal industry.

At the end of the last Report of the Atomic Energy Authority, for 1966-67, there is a comment by the Comptroller and Auditor-General, who makes it clear that the original research and development costs of the Magnox system have never been shown in the trading account of the Authority. The Authority defends itself by saying that had these costs been charged to the trading account, it would simply have meant that the Authority's profits would have been lower and, as a result, its reliance on the Treasury in future would have been greater and, therefore, that it was in the interests of the nation and the Treasury that matters should continue as before.

I can well understand that Lord Robens was worried about this matter. We can argue for years about it. We recommended that a special independent study should be made of the relative costings. My belief, for what it is worth, is that probably it would be as well to call it a day and accept this as a proposition and to say that nuclear energy and coal from the East Midlands are probably highly competitive with each other. But so long as, for sociological and perfectly understandable reasons, the coal industry must be kept going, where coal cannot be extracted really economically, then, plainly, the price of coal must be changed and the coal gained in the East Midlands sold to the public at a higher price than it would be if only the East Midlands was producing coal.

If we accept that as a proposition, then Lord Robens, the Authority, the Government and everybody else would get on with the job and decide what should be done about nuclear energy with a good deal more agreement than has proved possible. But I am glad that Lord Robens placed on record, when he appeared before us, the fact that he was not arguing against nuclear energy as such. I hope that he will always take that view.

When the Committee first met, it was aware that the existing three consortia were, perhaps, in the light of events and of the home market for nuclear power stations, likely to be in need of some readjustment and change. I think that the whole Committee was agreed on the recommendation that we should phase out the consortia. What we put in its place is where the rub comes.

The Minister of Technology (Mr. Anthony Wedgwood Benn): The House will probably realise that I am not in a position today to announce a final answer to the problems which the Committee brought to our attention.

I should like to try to set this problem in the perspective of time-scale, cost and complexity. If we look at the time-scale, we are looking back over developments which had their origins in the immediate post-war years, but whose results will be with us until the year 2000 or 2030.

The first series of nuclear power stations, the Magnox stations, which have already generated more electricity from nuclear power than the rest of the world put together, were largely a "fall out" from the post-war military programme.

Looking further ahead the fast reactor is likely to become the mainstay of our power programme a decade from now. Yet this new type of reactor, with its promise of greatly reduced electricity costs, has developed from an experimental reactor, on which building began at Dounreay in 1955, as part of a 20-year programme of research and development.

Between the two, the old and the new, were the advanced gas-cooled reactor, the high temperature reactor and the steam generating heavy water reactor. The basic research which has gone into these reactor systems and their development have cost the country hundreds of millions of pounds.

In looking at the Report of the Committee I will come in detail to the recommendations and points made by my hon. Friend. The Select Committee was satisfied that the Atomic Energy Authority has done its basic task of civil nuclear research and development with success. There is no doubt about that. It is undisputed. We are talking about a technology in which this country is pre-eminent.

No one looking at the record could speak convincingly of any technological gap between this country and the United States in the field of atomic energy. But now that nuclear electricity has "arrived" in a commercial sense the main task is one of exploitation and it is to this that we are turning in this debate; because, despite what I have said—and attention is drawn to it in the Report—Britain has not sold a nuclear reactor abroad for 10 years. There has long been a feeling that the organisation of the British nuclear effort has been inadequate, and that we have failed to exploit our technology in the way that we must if the enormous research and development effort is to be converted into an economic success to enable us to regain what we have spent upon it.

Much of the work of my Department reflects the same basic problem of inadequate exploitation. In January, 1967, when my right hon. Friend the Minister of Transport was Minister of Power, he and I met the consortia and told them we then took the view that a fresh effort to strengthen our position should be made. At that meeting the Atomic Energy Authority and the Central Electricity Generating Board were also represented; and here I want to come to the rôle of the Select Committee, not in a parliamentary but in a specific sense. The Select Committee entered the scene of its own volition.

The Report brings out the views of all the parties; it marshals the facts, and makes clear recommendations. The knowledge that it was working in parallel with us was a great help, and has made is possible to bring to public view all the complexities of the issues and the need for a new start.

We have been engaged in a number of discussions, one set of which has been referred to, namely, the discussions with the I.R.C. whom we asked to put to the industry and the parties concerned the proposals contained in the Report.

I now come to the specific point raised about the rôle of the I.R.C. in this respect. The I.R.C. is responsible to the Secretary of State for Economic Affairs and it has certain powers of its own volition; there are certain things that it can do if it wants to by way of individual activities, if the Secretary of State asks it to do so and it wants to do so.

But here we are talking about something more informal—about the working relationship that we have had with the I.R.C. since its establishment, namely, that a Minister who is faced with industrial reorganisation problems has been able to go to the I.R.C.

Sir Frank Kearton is not only an

independent and external member of the Authority but has been a member of my Advisory Committee on Technology. It was on that intimate and informal basis that I approached the I.R.C. and asked it to undertake this job. I asked the I.R.C. not only to convey the views within the industry about the proposals of the Select Committee but also to advise me, from its own experience, on the ways and means by which we could achieve the objectives that we all have in mind. These discussions are not yet concluded and this is why I hope that the House will not expect me today to anticipate the outcome, but at least it will be able to make its views known before the final stages,

One of the difficulties here is to find a natural break in what is sometimes regarded as a seamless robe of research, development, production and exploitation. There is no absolutely correct solution, but few would regard the present one as the best attainable.

I know that, in studying the American system, the Select Committee was struck by the integration of basic research, development and prototype construction, some parts of which, at least, were mainly done under contract with the commercial organisations. But this is not a pattern which we can easily follow, and we must build on what we have. I do not think that industry in this country could bear the whole cost of the basic supporting research and development which the Authority now undertakes, but what we are engaged in is a reformulation of the relationship between the public sector and the private, between research, design, development and exploitation and the improvements in the links between them which will clearly be necessary.

We are dealing not only with the three consortia, but also with the parent firms, that is to say, the plant manufacturers, for whom the nuclear part of their business is not the only part. We are dealing with the Atomic Energy Authority, which at present spans the range from basic research to the construction and operation of prototype reactors, with the Central Electricity Generating Board and with the South of Scotland Electricity Board.

The logical order in which this now operates is that the basic research and proving of designs is State-financed, through the A.E.A.; the detailed design of power stations and their construction is in the hands of private industry; the State corporations are the customers; and the State monopoly, the A.E.A., produces the fuel. It is against this background that we must try to find objectives which will command wide agreement because I am sure that the Committee was really divided only on the one question, that of the single design authority. Both sides were close together and to us in trying to achieve certain objectives.

I would like to summarise those objectives, as follows: first, to make the best possible use of all the existing resources in this field, cutting out overlapping and duplication, of which there manifestly is some; second, to allow those who have worked in the Atomic Energy Authority full scope for carrying their work forward into the exploitation and sale of the systems which they have developed; third, to get the maximum possible advantage of the technical standardisation, coupled with the most effective design competition in engineering detail and construction method; fourth, to try to link and co-ordinate the effort in such a way as to relate reactor systems to the fuel elements and reprocessing business at which the A.E.A. has excelled, both technically and commercially, through its fuel production group.

Fifth, to create an organisation which permits the sort of international, industrial links which will be of critical importance in all sectors of advance industry and not just in atomic energy. Sixth, to do this with a special eye upon the future of the European nuclear industry in co-operation with our partners in Europe. Seventh, to change the emphasis of our national effort in such a way as to increase it on the exploitation side and see that future nuclear research is guided and shaped more directly by the needs of the market at home and abroad.

Eighth, to establish a creative partnership between the public and private sectors as far as possible by reaching a consensus of agreement so as to allow all the other objectives I have described to be achieved.

I come to the very difficult question of the value of design competition.

Opinions obviously differ on the scope for commercial competition in the United Kingdom for domestic orders, but there can be little doubt that competition between competing designs and in ways of improving an established basic design can be of value. I have heard it argued that very often on engineering design our foreign competitors have had advantage over us. Past experience bears this out—each one of the seven Magnox stations has been more economic than its predecessor. This is the obverse side of the argument on replication.

It is true that the design competition has reduced the generating costs from 1·27d. per kW/hour in Berkeley to the Oldbury costs of 0·64d. kW/hour, just a half, and Wylfa's costs will be less again. With the A.G.R. stations now building, a new downward progression in costs is confidently forecast. There is some argument for saying, therefore, that design competition ought to be the future of the programme and pattern which we aim to see.

I should like to turn to some of the Committee's other recommendations. First, the rôle of the Atomic Energy Authority cannot be determined until the future organisation of the industry is clear. Until then, the British Nuclear Export Executive, on which there is also a comment, must obviously continue to do its work.

The other recommendation was that a technical assessment unit should be established to advise on the merits of projects coming to it from the Atomic Energy Authority. We are considering this, but there are real difficulties in that the Authority is the repository of all the skill, knowledge and national expertise in this field.

What I am trying to do is to apply commercial criteria across the board so that, although I cannot comment on the nuclear physics of what the A.E.A. may say or the detailed design which comes forward, I can ask how projects compare in terms of deployment of our national resources with other investments which may be brought forward.

On the non-nuclear side, where there is some work going on about which the Committee and the House knows, the technical staff of my Department, other Departments and industrial organisations is available. The Programme Analysis Unit, which I set up jointly with the Atomic Energy Authority, is a very valuable tool in examining projects that come up there.

I turn to the recommendation about having a British parallel to the United States Joint Congressional Atomic Energy Committee. We are giving very careful consideration to this, but it is difficult to transplant one type of constitutional procedure from one system of government to another, and it is certainly fair to say that in this case one would be impinging on the statutory responsibilities of the Minister of Power.

The next recommendation was the question whether there should be an independent agency for costing energy supplies. What the Committee suggested was that some entirely outside body might look at the purely financial aspects of this. I cannot go beyond what my right hon. Friend the former Minister of Power said when asked about this. He stated that he was considering the proposal, and that is how the matter stands. But the Ministry of Power keeps the trend of comparative costs critically under review, and—with particular reference to studies of nuclear costs—I am not sure that an independent body could have experience and expertise in this field comparable to that of the organisations which took part in nuclear costs studies made as part of the fuel policy review. Taking part in those studies were the C.E.G.B., the A.E.A. and the Chief Scientist's Division of the Ministry of Power. The National Coal Board also participated in the second stage of that work.

The Committee also said something about the new reactor types and recommended the development of the high temperature reactor, the steam generating heavy water reactor and other water reactors, and that development of the fast reactor should proceed with a view to its commercial exploitation at home and abroad. All these recommendations are being actively pursued by the Ministry and the United Kingdom Atomic Energy Authority.

There was also the recommendation, to which some hon. Members attach considerable importance, on the possibilities of nuclear marine propulsion and a proposal that a Departmental Committee might be set up. I have answered Questions on this. Owing to the reorganisation of responsibilities within the Ministry of Technology, it so happens that I have within my administrative control not only responsibility for shipbuilding and containerisation and executive responsibility for the Ship Division of the National Physical Laboratory, but responsibility for the A.E.A. I am not sure, therefore, that any new Departmental structure is required here.

What is required, as the Committee itself observed, is to decide the point at which marine propulsion would become economically viable. As I have told the House often, it is thought that it is the large container ship of perhaps 200,000 tons that will make marine propulsion viable in the 1970s. There is nothing to prove here. We know that it can be done. It is a matter of at what point to go in for the investment to bring in a return.

Finally, I turn to fusion. This is a subject to which the Committee made reference. The position here is that the A.E.A., which is responsible for the policy of research that it undertakes, subject to the Ministry, is looking at the work done on fusion after a period in which some very brilliant research had been done by a group set up for the purpose with a set time in which to do it.

The A.E.A. set up an internal committee which reported to the Authority, and the Authority decided that there should be a rundown of 10 per cent a year over five years, with provision for review. The provision for review exists. Given the circumstances in which my advisers in atomic energy recommended to me a rundown in this case, I either had to accept that recommendation or say to them, "Despite what you say you must continue with fusion research and with plasma physics research as you have done." I take the responsibility on myself, but, when the Authority made this recommendation, it seemed to me that I had to give great weight to what it said.

I conclude by trying to put this development once more into its broadest context as one of the biggest pieces of industrial reorganisation on which the country has been engaged. It is much bigger than shipbuilding, much bigger than computers, much bigger than the electrical industry, or other industries such as the motorcar industry, and much bigger than the Rolls-Royce-Bristol Siddeley engine merger. We are here talking about the development of an industrial structure which will allow us to get as a return in our balance of payments—and perhaps that is the right way to put it in the end, because this must be one of the dominating factors—and the productive efficiency of our own industry the provision of cheap power, which is the objective which we have in mind.

Mr. Eric Lubbock (Orpington): I cannot agree that yet another body should be established to confirm or dispute the estimates already presented in such detail in our Report which in the end we gouged out of the Minister of Power. These are absolutely conclusive and it is time that people stopped questioning the last 0·01d. by which nuclear power may be cheaper than coal-fired power stations.

I know that this is not popular with all hon. Members, but sooner or later I think they will accept it. Even Lord Robens admits that we may have a fast reactor which will be the mainstay of our electricity programme. It is admitted that it will happen in a few years' time. To that extent inflation, or its importance, has not altered the decisions this country has had to take in the last few years, particularly with the A.G.R. and the second nuclear power programme.

On the question of the organisation of the industry, I do not depart in theory from the view I expressed at the time that the ideal would be a single organisation to construct and export nuclear boilers from the whole of the United Kingdom. The arguments for that on theoretical grounds are indisputable. I shall not go into that in detail but, first, there is the limited size of the programme coupled with the increasing size of units ordered by the C.E.G.B. and the South of Scotland Electricity Board. We have already reached 1,200 megawatts and are shortly to go to 2,400. Possibly there may be even larger stations in future. Each company, we calculated, would only receive orders about once in four years, unless one reduced the number of organisations competing, with the size of the programme we could contemplate on the near and medium term view.

Secondly, there are the marginal benefits which have been derived from internal United Kingdom competition in the past.

Thirdly, there was the difficulty one would have had in sorting out and sharing the research and development facilities of the companies if more than one group remained and we adopted the kind of solution whereby much more of the research and development would be done in the industry and much less in Government establishments.

Fourthly, and very important, there is the need for a very powerful assault on the export market, which might only be possible with a very large grouping. I do not go along with some of the criticism of the industry's export performance in the past. One must give weight to the fact that, for many years, it did not have a saleable product. The Magnox reactor was in advance of its time when first produced, but we did not move quickly enough to the second stage and in the late 1950s and early 1960s there is no doubt that the Magnox system was not competitive with the American light water reactors. To that extent, one cannot blame the consortia for the poor export performance of past years.

I realised at the time of the hearings that there would be some practical objections to the Committee's solution. The C.E.G.B., the industry's principal customer, was resolutely opposed to a single nuclear boiler company and we know that the three consortia do not like the idea also, although Atomic Power Construction proposed a solution in which there would be a single design organisation for reactor cores. Probably the House does not want to be bored with details of the difference, but there is a substantial difference between a single design organisation for reactor cores and what we talk about in the Report—a nuclear boiler company.

I agreed with Lord Penney that, in the last resort, we could not force the construction industry to accept the solution of a single nuclear boiler company and that we could only achieve this by persuasion. Since the Committee reported, a new factor has caused me to modify my opinion. This is the international groupings which are in process of being formed by Atomic Power Construction and the Nuclear Power Group. In the short term, the establishment of these links with the Continent, which I support, might be jeopardised if we insisted on the recommendation of the Committee for the creation of a single United Kingdom company.

For this reason, firms which are competing against each other, for example in Germany or Italy, might not wish to be associated with the same United Kingdow partners. On balance, we ought to be pragmatic about this, and attempt to secure a reduction to two design organisations, two nuclear boiler companies in the United Kingdom, as our immediate objective. In view of the difficulties of apportionment of R. & D. facilities which I mentioned as one of the arguments in favour of a single organisation, this would mean that the Atomic Energy Authority's R. & D. facilities would have to remain under its control.

There is no reason why design teams working on the steam generating heavy water reactor and the gas-cooled reactor should not be transferred to these two new groupings, in return for which the Authority would expect, and be entitled to receive, a minority equity participation in each.

I turn now to discuss the development of reactor systems. Progress has been held up by the refusal of the A.E.A. to license manufacturers of steam generating heavy water reactors on the grounds that such arrangements ought to await reorganisation. I know that this was a valid reason, but I suggest that the sooner the industry gets on with the reorganisation of the kind which I have described, or some other agreement, which I hope the Minister will reach with them at the earliest possible date, then the sooner the industry can get on manufacturing and exporting the S.G.H.W. instead of leaving the whole of the work to the Atomic Energy Authority. Meanwhile, the Authority's policy of pursuing overseas sales of its own account is right.

It must be admitted that the failure to sell advanced gas-cooled reactors overseas so far has been disappointing. There has not been a great deal to choose between the A.G.R. and the American light water reactors in engineering costs. The European utilities have, in general, been brought up on water reactors, and have to be convinced that there is a substantial cost advantage to them in changing over, just as the C.E.G.B. would have to be convinced of a substantial cost advantage if it were to be persuaded to change over from gas-cooled reactors to water-cooled reactors.

The prospects for the A.G.R. sales in our principal overseas markets, are not very exciting at the moment. It has further development potential, as we see from the reductions in capital and operating costs between Dungeness B and Hinkley B and Hinkley B and Hunterston B. The prospects of European orders, for the reason I have given, not because there is not merit in the A.G.R. system, but because water reactors are so strongly entrenched on the Continent of Europe, are not all that attractive.

If we are really going to beat the Americans we must press ahead with major improvements in the family of gas-cooled reactors, in which we have excelled. The Select Committee was much impressed with the work that had been done on the DRAGON high temperature reactor, and recommended that the development of that system should be intensified.

I have become convinced that we could sweep the board if we went ahead with a commercial reactor based on the DRAGON principle at this moment, and do not wait several years, allowing the Americans to overtake us and go ahead.

I make two requests. Let us first of all, open the tenders as they do in the United States so that we can see, roughly, what is the comparison at this stage in time between H.T.R.s and A.G.R.s. Second, may I ask the Minister whether he would consider the Authority providing guarantees of fuel performance to the C.E.G.B. in this case, so as to get H.T.R. going, as the Atomic Energy Commission does in the United States for utilities who are ordering new reactor systems.

Another reason why I am equally enthusiastic with the hon. Gentleman about the H.T.R. concept is that ultimately we can eliminate the transfer of heat from one working fluid to another as we have to do in conventional nuclear stations, and use helium direct in gas turbines. This will lead to very substantial reductions in capital cost. There is work already going on in several countries on this concept, which might lead to spectacular reductions in ten years or so.

In my opinion, fast reactor development should be left in the hands of the Authority. I believe that we are correct in going only for a sodium-cooled prototype at this stage, and I strongly recommend that we do not embark on a diversification programme with a steam-cooled prototype as well. This would be a tremendously wasteful use of the resources of this country. But what might be explored, if what I have said about the tremendous lead of this country in gas-cooled technology is correct, is considering whether, with our European friends, we could embark on the design and development of a gas-cooled prototype fast reactor.

This is a distant concept, but it is one which we might begin to consider before it has commercial implications, when co-operation between different countries is much more difficult to secure.

Overseas participation in non-nuclear work

13th May, 1968

Sir H. Legge-Bourke asked the Minister of Technology if he will list the overseas countries which are participating in the various items of civil non-nuclear work at the Atomic Weapons Research Establishment, giving the amount contributed by each country concerned.

Mr. Benn: None.

A.W.R.E. non-nuclear work

13th May, 1968

SIR H. LEGGE-BOURKE asked the Minister of Technology if he will list the various items of civil non-nuclear work at the Atomic Weapons Research Establishment carried out on repayment conducted under special Ministerial approval, showing the date each was started, the amount so far spent on each, the extent to which each forms part of an international effort, the estimated cost to the United Kingdom in the current financial year, and the proportion which this represents of international total contributions to each item.

Mr. Benn: The following information has been provided by the Atomic Energy Authority.

	Date started	Description	Expenditure to 31st March, 1968 (£'000)	1968-69 (Estimated) (£'000)
A. Civil R and D Work for Government Departments				
1. Work completed ..	April, 1963 onwards	Various	575	—
2. S.R.C.	April, 1965..	Space technology	215	230
3. M.O.H.	April, 1966..	Medical, Engineering and Services	110	180
4. Home Office ..	April, 1966..	Forensic science	110	55
5. M.O.H.	October, 1966	Dental materials	25	20
6. Mintech	October, 1966	Aldermaston project for application of computers to engineering (APACE)	95	185
7. Mintech	October, 1966	Advanced computer inter-connections	75	65
8. M.P.B.W.	August, 1967	Glass fibre reinforced plaster	15	25
9. Other Work in hand (minor projects)	Various ..	Various	(inc. in 1 above)	200
B. Civil R and D work for other customers				
Various customers ..	April, 1963 onwards	Various	90	40
		Total*	1,310	1,000

None of the above projects forms part of any international effort.

* Figures of expenditure cover full cost, including depreciation and similar notional overheads. Full cost is recovered from all customers.

Non-rechargeable and rechargeable projects

13th May, 1968

Sir H. Legge-Bourke asked the Minister of Technology, if he will list, the various non-rechargeable projects undertaken by the United Kingdom Atomic Energy Authority under Section 4 of the Science and Technology Act, 1965, the date on which each was started, the amount so far spent on each, and the estimated cost in the current financial year.

Mr. Benn: The following information has been provided by the Atomic Energy Authority.

	Date Started	Description	Expenditure to 31st March, 1968 (£'000)	1968–69 (Estimated) (£'000)
1.	23rd April, 1965	Desalination	1,461	1,263
2.	21st May, 1965	Biological centrifuge	43	—
3.	11th October, 1965 ..	Hydrostatic extrusion	250	47
4.	31st January, 1966 ..	Transducers	38	—
5.	6th May, 1966	Beryllia ceramics	25	—
6.	27th January, 1967 ..	Non-destructive testing centre ..	143	175
7.	27th January, 1967 ..	Ceramics centre	232	370
8.	9th June, 1967	Improved structural steels ..	39	39
9.	26th July, 1967	Atmospheric pollution	44	95
10.	23rd November, 1967 ..	Heat transfer and fluid flow ..	—	110
11.	28th November, 1967 ..	Tribology	5	100
12.	20th December, 1967 ..	Carbon fibres	25	257
13.	8th April, 1968	Quality control	—	390
14.	Various	Minor Schemes	49	—
		Total*	2,534	2,846

* Figures of expenditure cover current and capital expenditure, and thus represent the cash amounts for which provision is taken in the Atomic Energy Vote. Substantial revenue is expected from certain of these projects as they mature.

13th May, 1968

SIR H. LEGGE-BOURKE asked the Minister of Technology if he will list the various rechargeable projects undertaken by the U.K.A.E.A. under Section 4 of the Science and Technology Act, 1965, the date on which each was started, the amount so far spent on each, the amount recovered from customers, the names of such customers, and the gross expenditure and receipts estimated for the current financial year.

Mr. Benn: The following information has been provided by the Atomic Energy Authority.

Customer	Date started (Section 4 requirement)	Description	Expenditure to 31st March, 1968 (£'000)	1968–69 (estimated) (£'000)
1. E.S.R.O.	16th July, 1965	Scientific package for E.S.R.O. Large Astronomical Satellite ..	143	23
2. S.R.C.	21st Dec., 1966	Advanced Radio Telescopes	20	26
3. Gas Council and Ministry of Defence	4th April, 1967 5th April, 1968	High temperature fuel cells.	20 —	— 75
4. Computer Board ..	14th Mar., 1968	Development of computer links between Culham and 7 Universities (COTAN) ..	—	15
		Total*	183	139

*Figures of expenditure cover full cost, including depreciation and similar notional overheads. Full cost is recovered from all customers.

Finnish tender

15th May, 1968

MR. DAVID PRICE asked the Minister of Technology if he is satisfied that the United Kingdom Atomic Energy Authority steam generating heavy water reactor on offer to Imatran Voima, Finland, is both technically and commercially fully competitive with reactors on offer from other countries; and if he will make a statement.

Mr. Benn: Yes. The United Kingdom Energy Authority and myself are completely confident that the steam generating heavy water reactor is technically and commercially competitive with other reactor systems on offer in Finland. In a commercial competition, we are not, of course, in a position to know details of offers made by other countries.

European Reactor Programme

16th May, 1968

MR. ROSE asked the Prime Minister if he will consider discussions with the European Economic Community and the European Free Trade Association countries about the possibility of a European nuclear programme for the civil development of nuclear energy.

The Prime Minister: We have been collaborating for many years with our friends in both the European Free Trade Association and the European Economic Community on the development of nuclear reactors through the Organisation for Economic Co-operation and Development Halden and DRAGON joint reactor projects. Currently, in the European Nuclear Energy Agency, we are examining with the same countries whether, and if so how, our common interests might be served by collaboration on the development of a more advanced reactor type.

Select Committee Report

16th May, 1968

MRS. THATCHER asked the Minister of Technology if he will state the specific terms upon which the Report of the Select Committee on Science and Technology, concerning nuclear reactors, has been referred to the Industrial Reorganisation Corporation.

Mr. Benn: The Select Committee recommended that there should be a single organisation concerned with the design and construction of nuclear boilers. The Chairman of the Industrial Reorganisation

Corporation was invited to seek the reactions of industry to this proposed reorganisation, and to give me his advice when he had completed his confidential discussions.

Prototype Fast Reactor, Dounreay

27th May, 1968

MR. HECTOR HUGHES asked the Minister of Technology what is now the approximate date in 1971 when the Dounreay experimental fast reactor will come into full operation; what supply in kilowatts and what area will then be supplied in Scotland with particular reference to Aberdeen; and what is the number and status of the persons now and also then employed there.

Dr. Bray: The prototype fast reactor is expected to reach full power during the second half of 1971. Its 250,000 kilowatts output will supply the North of Scotland Hydro-electric Board's area, including Aberdeen.

Employment at Dounreay should remain fairly stable over the next few years at not much less than the present level of 2,300.

A.E.A. Reports available

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Identification and Optimization Studies of the Dynamics of a Small Experimental Boiler. By J. D. Cummins. October, 1967. 55 pp. H.M.S.O. 24s.

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Homogenisation of a Wigner-Seitz Cell in Two Group Diffusion Theory. By F. R. Allen. February, 1968. 15 pp. H.M.S.O. 3s.

AERE-AM 103
Analytical Procedures used by the Bioassay Section at A.E.R.E., Harwell. By J. D. Eakins, A. E. Lally, A. Morgan and F. J. Sandalls. April, 1968. 67 pp. H.M.S.O. 9s.

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The Determination of Traces of Copper, Arsenic and Antimony in Steels and Steel Oxides by Neutron-Activation Analysis. By M. Perkins and T. B. Rees. March, 1968. 18 pp. H.M.S.O. 3s.

AERE-Bib 157
List of Unclassified Documents Lectures, etc. by the Staff of the Chemistry Division, AERE, Harwell, 1967. Compiled by E. A. Bibby. February, 1968. 19 pp. H.M.S.O. 3s.

AERE-M 2008
The Separation of Small Quantities of Mercury from Gross Amounts of Silver in Nitric Acid Solution. By B. M. Maude and K. L. Wilkinson. February, 1968. 10 pp. H.M.S.O. 1s. 9d.

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A Proposed Low-Signal Radiation Detector Incorporating Internal Multiplication. By P. E. Gibbons. March, 1968 9 pp. H.M.S.O. 1s. 9d.

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Measurements of Fast Neutron Spectra in Reactor Materials. By M. S. Coates, D. B. Gayther and P. D. Goode. February, 1968. 38 pp. H.M.S.O. 8s.

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Neutron Monochromator Studies at Atomic Energy Research Establishment. By K. C. Turberfield. February, 1968. 38 pp. H.M.S.O. 5s. 6d.

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The Dido White Beam Scattering Apparatus. By T. Beirne, April, 1968. 16 pp. H.M.S.O. 2s. 6d.

AERE-R 5703
Gamma Ray Spectrometer Systems Using Lithium Drifted Germanium Detectors. By P. E. Gibbons and J. H. Howes. March, 1968. 40 pp. H.M.S.O. 6s.

AERE-R 5758
The Determination of Hydrogen and Deuterium in Zirconium Alloys Using an MS 10 Mass Spectrometer. By K. R. J. Cottell, M. Quarmby and H. I. Shalgosky. March, 1968. 8 pp. H.M.S.O. 1s. 9d.

PG Report 827(W)
A Precise Amperometric Titration for the Determination of Uranium Using Ferrous Sulphate as a Reductant. By J. Cherry. 1968. 9 pp. H.M.S.O. 2s.

Commissioning and operating experience with the Winfrith SGHWR

This paper, by D. Smith, D. English and J. McCrickard, of A.E.E. Winfrith, was presented at a Conference on Steam Generating and Other Heavy Water Reactors, organised by the British Nuclear Energy Society from 14th-16th May, at the Institution of Civil Engineers, London.

Earlier papers to this conference have provided an outline of the work that led to the completion of the construction of the Winfrith SGHWR. Whilst a substantial amount of performance testing and proving had been undertaken before commissioning, the objectives over the first four months of operation have been to demonstrate that the overall plant:

(a) was capable of being operated as a power producing unit;

(b) functioned in a manner which closely confirms the performance predictions made for it.

Since the Winfrith SGHWR first achieved sustained full load capability on 25th January, 1968, it has already generated 135 million units and achieved an average plant availability of 79% which has risen to 96% since 1st March, 1968. Thus, while the time that has elapsed is too short to constitute a full demonstration, there are substantial and encouraging grounds for believing that the design objectives are being achieved. This paper provides the bases for this opinion and is divided into two main parts.

Part A summarizes the commissioning programme and describes the more significant events from the commencement of fuel and heavy water loading including operating experience until mid-April, 1968.

Part B describes the results of the main core performance measurements made during commissioning and initial power operation and their agreement with prediction.

PART A

Organisation and training

In building up the Operations Division for the Winfrith SGHWR, a balance was struck between personnel with experience of commissioning and operating nuclear power stations and those with experience of experimental or prototype reactors. The team was supplemented for the commissioning and early stages of operation by staff with particular expertise.

A training programme was introduced which included specialised courses and attachments to nuclear and non-nuclear plants. A training simulator of the control system was built which could be coupled to the Winfrith PACE analogue model of the SGHWR on which all operators and technologists received several hours of training. The operational shift team were responsible for the operation of plant during the functional tests which preceded the commissioning programme.

Planning

The planning of various stages of the commissioning programme began with the preparation of outline proposals for each individual procedure or test. These identified equipment requirements, safety and operational aspects and provided an estimate of the time that would be taken. Special test or experimental procedures were written for repetitive measurements, e.g., period measurements. The final programme was formulated by arranging the essential work in a manner which would occupy the minimum time.

Operational aspects of commissioning

The commissioning period was divided into three main sections as follows:

- Stage 1 Fuel and heavy water loading, zero power physics measurements and hydraulic tests (24th August-16th October, 1967).
- Stage 2 Completion of construction and safety circuit testing (16th October-20th December, 1967).
- Stage 3 Raising to full power (20th December, 1967-24th January, 1968).

The principal events during these three periods will now be described.

Stage 1

Following the practice developed with

heavy water materials testing reactors of the DIDO class, the moderator system had been completely tested using light water. During this, the volumes of the calandria and dump tanks were calibrated and it was then necessary for the moderator circuit to be thoroughly dried to prevent degradation of the heavy water. The complete drying

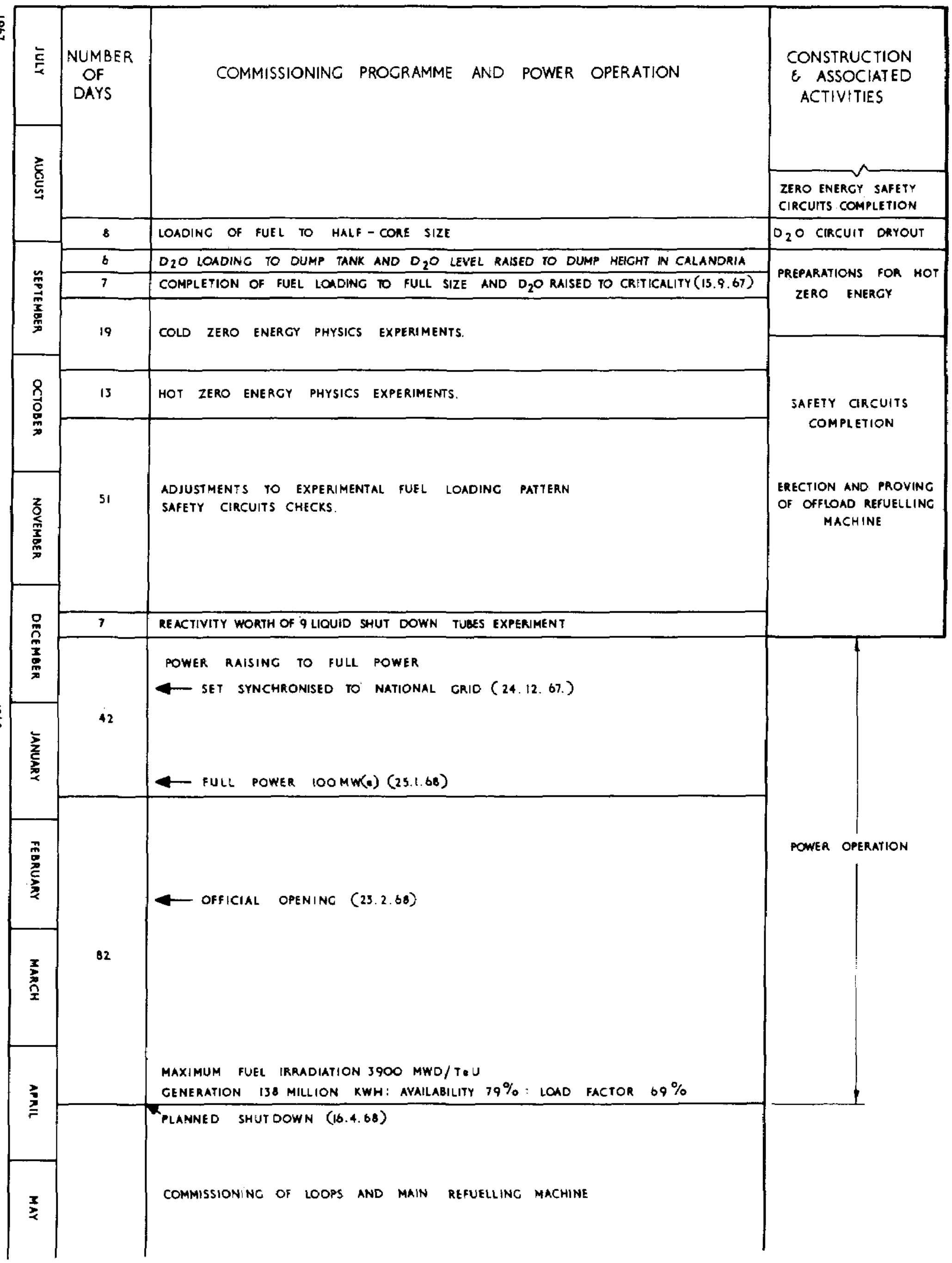

Fig 1 Principal programme events from commencement of fuel loading.

operation occupied six days. Subsequent measurements indicated that this was completely successful since the isotopic concentration of the heavy water suffered a reduction of only 0.02% upon loading to give a final value of 99.75 mole per cent.

Fuel loading commenced on 24th August, 1967, as indicated on Fig. 1 which shows the principal programme events from that date. The fuel had been assembled under dry conditions in the pond area and was loaded directly into the reactor by a temporary building crane. Throughout this period, the primary circuit was full of light water but the first 69 fuel assemblies were loaded with the calandria empty. At this stage, 39 tonnes of heavy water were loaded into the dump tanks. The remaining 35 fuel assemblies were then loaded with the heavy water at dump level. Criticality was achieved on 14th September, 1967, by raising the moderator height to 172 cm from a datum at the base of the calandria. The cold, zero energy physics experiments were then carried out over a period of ten days: the results are discussed in Part B of this paper.

A plant proving run was begun on the 4th October, 1967. The pressure and temperature of the primary circuit were raised to full operational values of 925 lb/in^2 and 280°C using heat generated by running the four primary circulators supplemented by electrical heaters mounted temporarily on the downcomers from the steam drums to these pumps. The total heat input was 2,500 kW which allowed an overpressure test to be made at 1,300 lb/in^2 and 305°C. A number of physics and thermal/hydraulic measurements were made at this point together with a number of plant proving tests and checks, which included the following:

(a) primary circulator tests to determine cavitation limits and run-down rates and to establish the settings required for the rate of change of pressure trip units;
(b) tests of the emergency cooling water (ECW) system to adjust flow to the required level;
(c) operation of the blowdown to the centre pond to determine the rate of depressurisation;
(d) operation of the blowdown to the condenser to demonstrate the correct functioning of the system;
(e) operation of the ventilation plant to set up the appropriate flow rates;
(f) tests on the ancillary cooling water systems to establish and balance the flow of coolant and determine the heat loading;
(g) measurement of thermal movement of the plant and associated pipework to check that these were satisfactory;
(h) measurement of vibration levels to confirm that no section of the plant was subject to high stresses;
(i) tests on the safety valves to recheck lifting pressures.

The run at operating temperature was terminated on the 16th October, 1967, by full depressurisation of the circuit. It was followed by a detailed final inspection of the complete plant, including the steam drums, to check whether anything unexpected had occurred during the early plant operation. This included removal of selected channels of thin-walled fuel for visual examination to verify that no wrinkling had taken place during the hot run. Nothing was observed which might have given cause for concern.

Stage 2

The main commissioning programme was interrupted at this point to allow completion and final testing of the safety circuits. Immediately prior to the planned commencement of the power raising phase, two unrelated delays occurred in the programme. The first was a leak in a superheat channel liner. These liners are thin, helically-wound tubes of zirconium alloy and the damage to the liner concerned had been caused by the application of an excess pressure differential across it during a special pressure test which was made on a section of the primary circuit pipework. It was decided to remove the complete superheat channel tube assembly and, although it had been lightly irradiated (10 h at a power of 2 MWt), this gave rise to no problems. The whole operation including blanking-off the connections to the channel, took only four days because equipment was available for channel tube removal and a procedure had been formulated during the design and construction stages.

The second incident concerned the booster pump unit. This provides an augmented coolant flow to four channels for testing advanced fuel assemblies. The pump was found to have seized during an

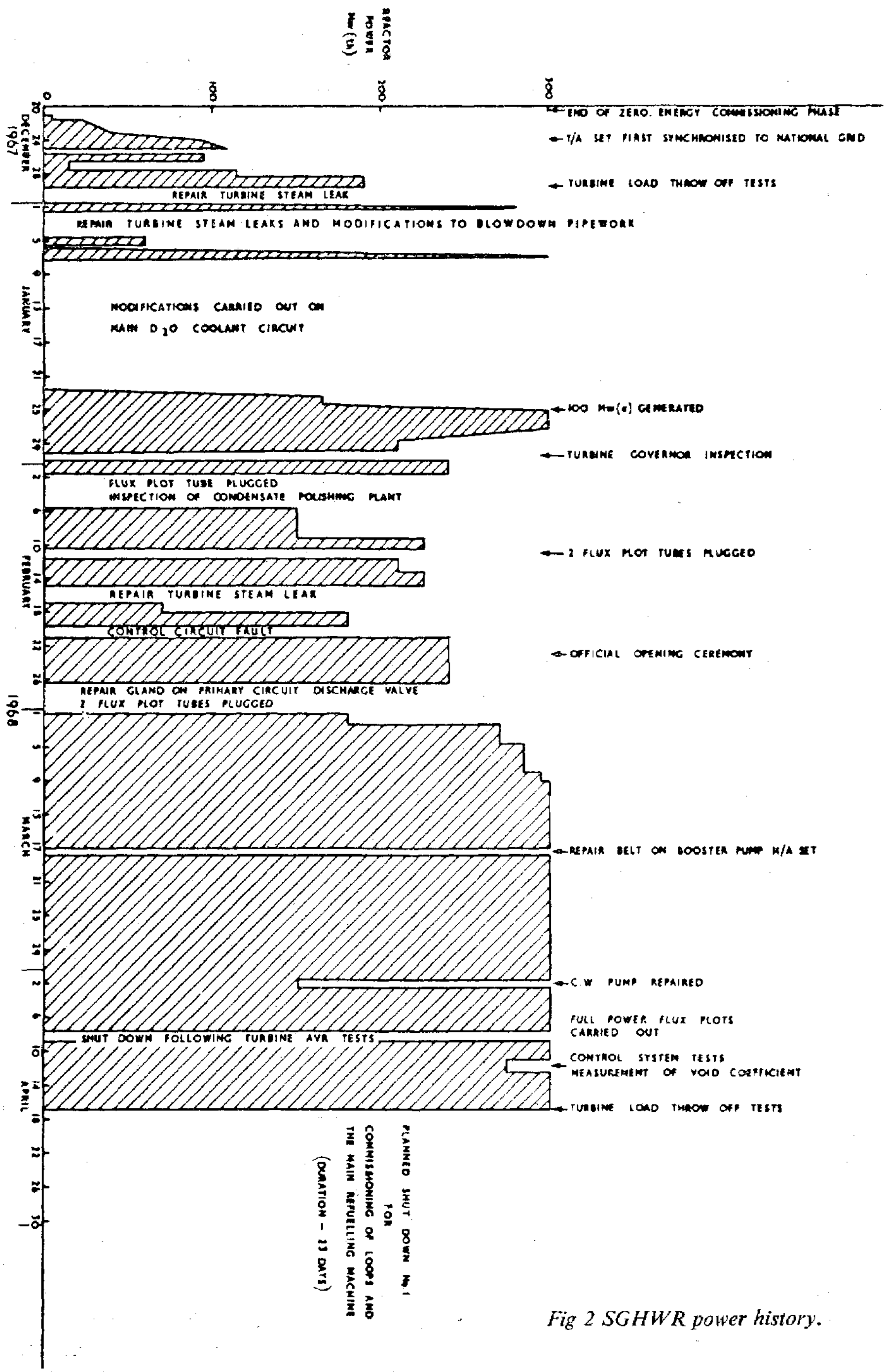

Fig 2 SGHWR power history.

attempt to start the unit and the fault was traced to the windings of the driving motor, necessitating the removal of the unit to the manufacturer's works. The motor was completely rewound and the pump replaced in circuit after works bench tests, the complete operation again taking only four days. The cause of the overheating of the windings was ascribed to excessive friction in the main bearings which may have resulted from the deposition of solids from the water, since the condition arose after the pump had been shut down. Improvements have been made to the display of pump motor current loadings so that repetition of this incident should be avoided.

Stage 3

Power raising commenced on the 20th December, 1967 and, by the 25th January, 1968, an output of 104.6 MWe had been achieved and the plant was considered to be available for sustained full-power operation. Fig. 2 shows the stages by which power was raised; it will be noted that the turbo-alternator was first synchronised to the national grid on the 24th December, 1967, and full-power attained for a limited time on the 7th January, 1968. It will be evident from Fig. 2 that a substantial load factor was achieved during March and the first half of April.

During the power raising process a number of measurements and plant checks were performed as follows:

(a) *Radiation surveys.* These were conducted throughout power raising around the plant and showed no unexpectedly high levels. The values in the turbine hall are close to those predicted and have caused no problems either during operation or when access was required for maintenance. The principal source of radiation is nitrogen-16 (half-life 7 s), which is carried over to the turbine from the steam drums and eventually passes up the discharge stack via the condenser and off-gas system. A typical radiation survey of the turbine hall is shown in Fig. 3 while the variation of the radiation level at a point in this area with reactor power is shown in Fig. 4. From this, it will be seen that the levels vary approximately with power in accordance with a $[\text{reactor power}]^2$ relation.

(b) *Turbo-alternator checks.* Only a very limited number of tests were needed on the turbo-alternator itself as the majority of the initial proving of the machine had been carried out using a temporary commissioning boiler before the nominal plant completion. The additional tests performed during Stage 3 were:

(i) load throw-off at 25 MWe and 53 MWe (tests at 100 MWe were done subsequently);

(ii) bus-bar heat run to measure maximum temperature attained;

(iii) on-load overspeed tests at 15-20 MWe (NB, overspeed tests are carried out at zero output every time the turbo-alternator is synchronized);

(iv) automatic voltage regulator (AVR) setting up and checking;

(v) overspeed-limiting gear operation.

Operation with the package boiler had not permitted all the auxiliary and ancillary plant to be loaded to capacity so that only during this phase could the commissioning of such items as the rotary air pumps, condensate extraction and feed water pumps, feed heaters and the associated bled steam system, and deaerator controls be undertaken.

(c) *System vibration measurements.* The vibration measurements that had been made during the engineering tests and low-power phases of the programme were repeated. They showed that the system was free of vibration except when certain steam lines were being warmed-through and when a blow-down line associated with the primary circuit clean-up was operated. Simple modifications to operating procedures, provision of a limited number of additional physical restraints and the insertion of a nozzle in the blow-down pipework rectified these defects

(d) *Performance checks.* Various physics and thermal performance measurements were made to check the reactor performance and to confirm that operating limits were met. These are described in Part B. In addition, the overall performance of the turbine and feed train and auxiliary equipment has been checked and appears to be satisfactory although the final acceptance tests have not yet been made on the turbine and cooling towers.

(e) *Commissioning of the automatic control system.* Only minor adjustments have been required to the parameters of the automatic control system which had been chosen on the basis

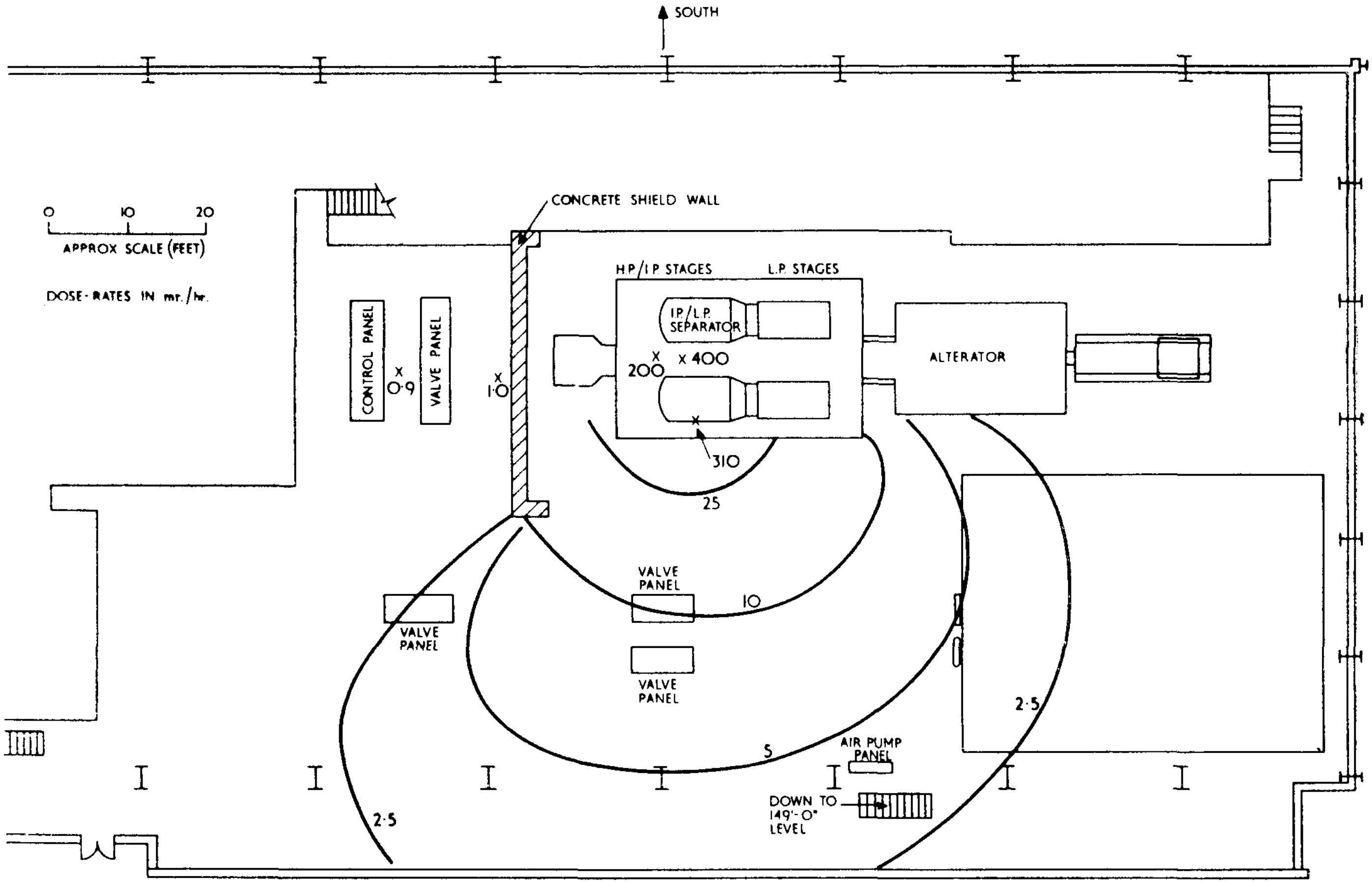

Fig 3 Plan view on turbine floor showing dose rate contours at 100 MW(E).

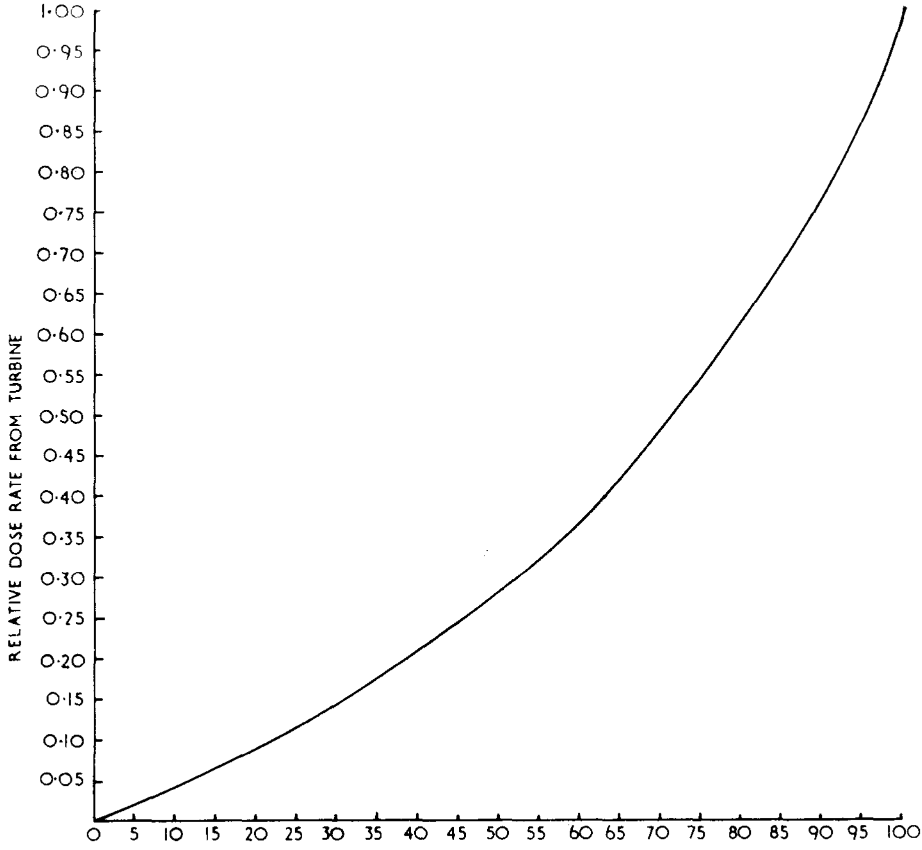

Fig 4 Dose rate from turbine as a function of electrical power.

of simulator studies. The only significant modifications have been associated with the characteristics of the turbine governor.

Outage during this period of power raising resulted principally from a spillage of heavy water. This occurred when the plant was at a power near to 100 MWe and a controlled shutdown was initiated. The unit was fully shut down within 30 min. After access had been gained to the primary containment, it was found that the leakage was from one of the two-plate-type heavy water coolers which had been wrongly assembled.

Early operational experience with the Winfrith SGHWR

Since achieving full power, the operation of the reactor has been very satisfactory. Generally the plant has been operated at or near full-power with only very limited periods of part-load for tests or the correction of the occasional minor plant problem. The main plant performance parameters have agreed closely with predictions. Table 1 gives the basic operational figures up to the 16th April, 1968, when the reactor had a planned shutdown to allow commissioning of the experimental cluster loop and the main refuelling machine.

The performance already achieved indicates the considerable progress made in the very few months since commissioning with the elimination of equipment defects that are commonly experienced when bringing any major plant into operation. It also

TABLE 1

	Since 25.1.68 (first full power)	Since 1.3.68
Availability	79 %	96 %
Load factor	69 %	90 %
Generation	134.841 $\times 10^6$ units	101.052 $\times 10^6$ units

Total generation since 24.12.67 —138,372,000 kWh reflects the growing experience of the operating team which will enable subsequent operating programmes to be formulated with confidence.

Radiation and activity levels. Direct experience has been obtained of access to and work in the primary containment and also of maintenance on the turbine and feed train. Radiation levels in the primary containment after the reactor has been in operation have not prevented essential work or access on any occasion. The general radiation level in the main primary containment plant area is shown in Fig. 5 as a function of time after shutdown. Contamination has been localised to areas near the occasional minor steam or water leak. Provided the basic health physics precautions are taken, no difficultties arise. Most of the activity from any such steam and water leakage is associated with activation products which have been retained by the pipework lagging. This, incidentally, has given a useful method of leak detection when the reactor is shut down and depressurised. The feed heater cell is classified as a restricted radiation area principally because it contains bled steam pipes and the primary circuit polishing plant. However, access has been possible at all times for visual inspection, and some maintenance work has been performed with the reactor at full power.

Chemistry. Experience with water reactors has shown the importance of water chemistry conditions. For this reason, the design of the Winfrith SGHWR included a polishing plant capable of taking the full feed flow, together with a fractional by-pass of the primary circuit water. The quantities of prime interest have been "crud" (iron and copper), silica and chloride. The polishing plant has been effective in maintaining acceptable levels of crud and chloride. However, while the silica has been kept to a suitable level, the polishing plant has not been very effective in achieving its removal principally because of the temperature conditions that exist local to this plant.

The chemistry of the moderator circuit is discussed in detail in another symposium paper (ref. 1). Operationally, the two main aspects have been the control of boron level and the concentration of deuterium in the helium blanket above the moderator. The addition and removal of boron is easily performed although it is not yet fully automated or automatically monitored. The deuterium levels have been higher than predicted but the concentration has been kept below the maximum permissible level of 7%. An increase of the recombination capacity by about 50% is proposed.

Reactor control. Simulator studies had predicted that manual control of the reactor would be satisfactory. This has been confirmed on the plant. However, because of the operational advantages and the need to demonstrate the load following capability of the unit to support commercial designs, it was decided to commission the automatic control system at an early stage of the programme. This maintains key parameters such as system pressure, drum level and steam flow to the turbine at pre-set values. The system pressure is controlled directly by the position of the turbine governor valve, this control action being performed through a conventional governor gear. Some difficulties have been experienced with this and, although it is now giving an acceptable performance, further modifications and optimisation of the system are proposed.

Drum level control assumes a major role in a direct cycle system since it constitutes the interface between the reactor and the turbine-feed train. Control has been satisfactory at full-power but less so at very low powers. However, no significant attempt has been made to optimise the system for these conditions and studies suggest that no inherent difficulty exists with control at low power. Problems have been experienced with noise in the transducer signals. The difficulty was associated with only one of the two halves of the main reactor coolant circuit and was found to be related to the geometry of the pipe runs to the instruments. The effect has now been greatly reduced by re-routing some of this piping. The steam flow to the turbine is controlled by variation in the reactor power which results from adjustments to moderator height. This system has performed very satisfactorily. Use is made of a switch installed to vary the gain of the system thereby providing improved response over the full power range. Steam flow control is normally engaged above 30 MWe.

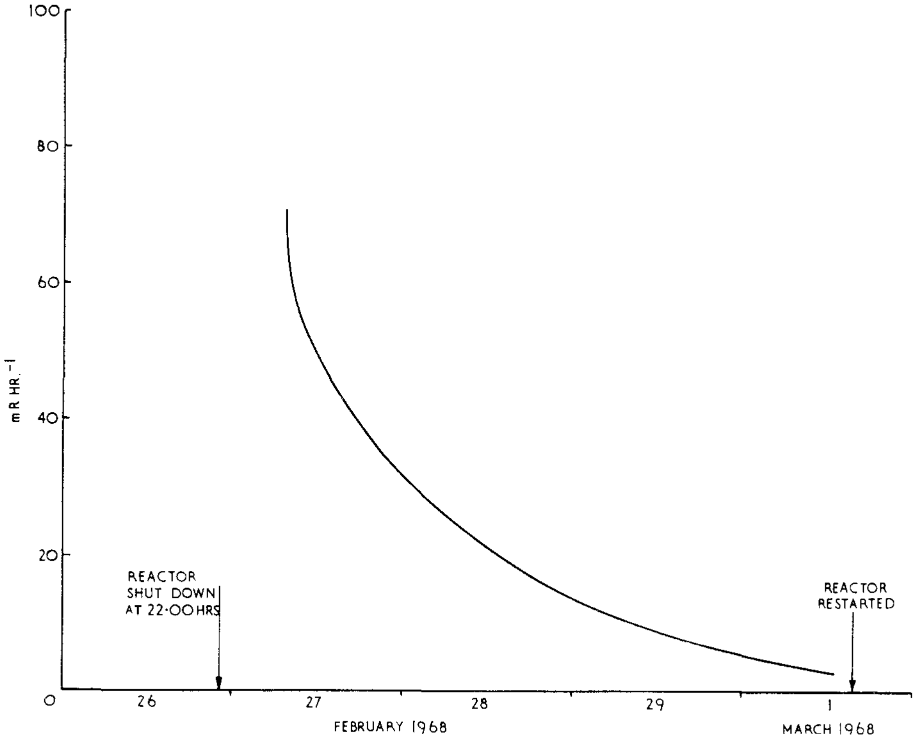

Fig 5 Primary containment radiation levels in main plant area following a period at 80% full power.

Below this level, reactor power is controlled by use of a neutron flux signal from an out-of-pile ion chamber. The pattern of operation employed in bringing the plant to full power involved a number of single power cycles. These were accomplished very smoothly. On one occasion, the reactor was shut down and the booster pump stopped to allow the replacement of a damaged fan belt on the motor alternator which supplies this pump. The whole operation, including the repair work, was completed within 10 hours.

Fuel performance. The reactor fuel charge contains approximately one third experimental channels and has performed very well with the exception of a leaking fuel element which was detected at the end of March. The defect fuel cluster is of an experimental type which is used to monitor the effect of primary circuit water conditions on zirconium alloys. After the initial rise in radiation levels, there was no alteration in the activity from this defect during approximately three weeks of full power operation until the April shutdown. This period of operation included four power cycles, one of which was a reactor trip. The defect gave valuable experience in checking operational procedures and monitoring levels throughout the plant. In fact, it had been intended to load a deliberate defect into the reactor in order to obtain the experience which has been gained from this defect. This experiment will not now be performed. The activity discharged from the reactor was well within acceptable levels.

Outages. Operational time has been lost for a variety of reasons. Since the 25th January, 1968, the following have been the major causes of system outage:

(i) turbine feed train problems;
(ii) spurious trips (mainly in first few weeks of operation);
(iii) failure of experimental flux scanning thimbles;
(iv) mechanical problems associated with faulty construction of the primary circuit polishing plant.

The lost time has been almost equally divided among the above plant problems, all of which have now been overcome. They are thought to be of a non-recurrent type and again represent typical initial or commissioning problems which occur during the first few weeks of plant operation.

PART B

Core performance measurements in the Winfrith SGHWR

Objectives of the measurement programme

The programme of performance measurements was planned with two aims:

(i) to provide data necessary for the safe and efficient operation of the Winfrith SGHWR;

(ii) to provide accurate tests of theoretical models under operational conditions and so achieve a firm basis for design developments in later reactors.

Up to the present, emphasis has been placed on the first of these objectives. Sufficient information has been assembled to demonstrate that safety and operating criteria have been met; attention is now being turned to the more refined measurements needed to attain the second objective.

Operational aims

In order to achieve the design output of 100 MWe, satisfy the safety criteria and meet the needs of the irradiation programme, it was necessary that the initial core loading should satisfy the following main conditions:

(1) possess sufficient reactivity to be taken critical and raised to full power with Xe and Sm poisons;

(2) at initial full power to possess sufficient excess reactivity to run subsequently for 300±30 equivalent full power days;

(3) possess reactivity coefficients and control and shutdown variable responses compatible with the design tolerance of the control system and within limiting values allowed for in the hazards analysis;

(4) give rise to a coolant flow distribution within the tolerances needed to achieve an adequate margin to dryout;

(5) give rise to a power distribution such that

  (i) no standard fuel channel exceeds 4 MW thermal output,

  (ii) the "enriched design" boosted channel experiments operate at thermal powers close to but not exceeding 5 MW,

  (iii) the "natural design" boosted channel experiments operate at 3.5 MW.

Initial core loading

The initial core loading chosen to satisfy the requirements is shown in Fig. 6. The reasons for this choice of loading have been discussed in companion papers (refs. 2, 3 and 4). A basic 3-batch arrangement of 2.28%, 1.56% and 1.24% fuels has been perturbed to include a number of irradiation experiments (ref. 4). The most important perturbations are:

(a) the so-called boosted channels (A9, C9 ("natural" design) and A11, C11 ("enriched" design)) which are provided with an additional pump and are fuelled with relatively highly-enriched experiments;

(b) four 3.0% enriched fuel elements (E19, S21, U17, W15) intended for extra long irradiations;

(c) two small (pencil) loops in positions H16 and R16 which are at present unfuelled;

(d) the superheat channels, at present unfuelled, but causing local flux disturbances.

Prediction basis

It was evident that the accurate prediction of reactivity levels and power distribution for such a complicated loading would provide a severe test of the PATRIARCH computer codes (refs. 2, 3). In many cases, it has been necessary to use the SOLOMON synthesis code to obtain an adequate representation. This combines the AIMAZ XY-reactor physics model with the CUSH multi-channel primary circuit representation and the TIRAZ coupled nuclear-thermal-hydraulic single channel model.

Scope of the measurements

Valuable reactor time was saved by carrying out some of the preliminary reactor physics measurements with the power reactor fuel loaded into a core mock-up in the tank of the DIMPLE zero energy assembly. However, due to the limited size of the DIMPLE tank, a maximum of 68 fuel elements was all that could be accommodated and some extrapolations

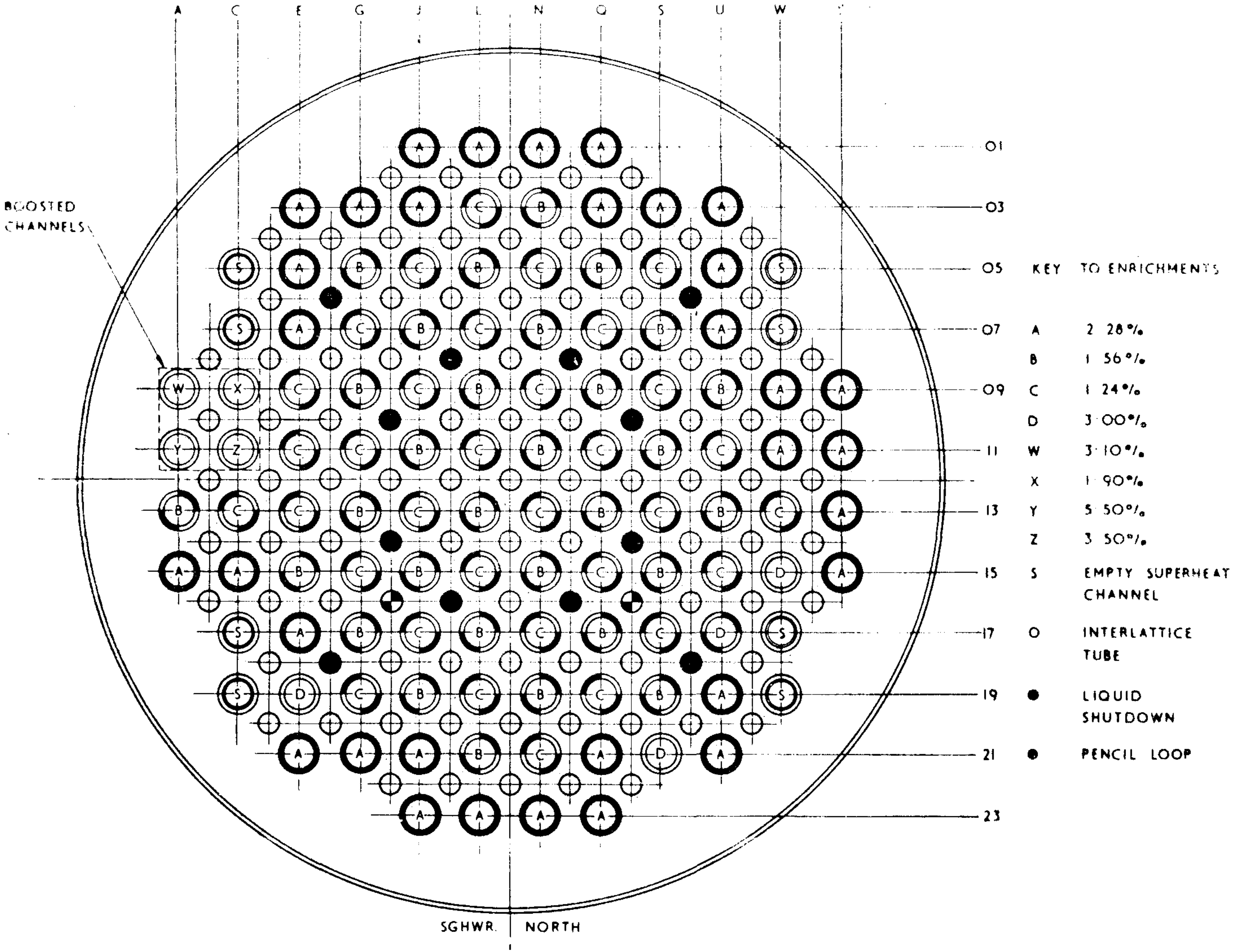

Fig 6 SGHWR prototype core plan.

from these results were still necessary.

Performance measurements were made on the power reactor itself during the following phases of the commissioning programme:

(a) hydraulic tests before fuel loading;
(b) cold zero energy experiments;
(c) hot zero energy tests;
(d) power raising;
(e) full power operation.

The more important results will now be reviewed.

Reactivity levels

Cold zero energy

The reactor was taken critical with moderator boron concentrations ranging from 4.1-12.7 ppm and immersed fuel heights from 109-360 cm. A convenient indicator of the accuracy of reactivity calculations is provided by the closeness of the predicted K_{eff} to unity for states known to be just critical. Over the range of states

predicted $K_{eff}=1.0068 \pm 0.0015$.

Hot zero energy

Similar tests with the H_2O coolant and D_2O moderator raised to full operating temperatures (280°C and 65°C respectively) by electrical heat gave

predicted $K_{eff}=0.9995 \pm 0.0004$.

These results, showing the disappearance of small overprediction bias in reactivity levels at operating temperature, were consistent with expectations from previous zero energy measurements.

Full power operation

At full power the reproduction factor is reduced by the build-up of Xe and Sm poisons, the action of the fuel temperature coefficient (mainly due to Doppler broadening of U-238 resonances) and the presence of steam voids. The boron concentration in the moderator must therefore be reduced to compensate. Since the zero energy tests show that the influence of boron on reactivity has been accurately predicted then a comparison between the calculated and measured boron concentrations with the reactor operating steadily at full power is a direct indication of the accuracy of calculations of reactivity level. Since the fuel was necessarily slightly burnt up during the preliminary operations at less than full power it is necessary to apply some small corrections to the measurements. These have been reduced to a standard state in which the core is operated with equilibrium Xe and Sm poisons at zero irradiation. The following comparison emerges:

measured B^{10} concentration $=6.66 \pm 0.20$ ppm

SOLOMON prediction $=6.36$ ppm.

Since 1 ppm $B^{10} \simeq 1\%\ \Delta K_{eff}$ these results suggest that the core is approximately $\frac{1}{4}\%$ more reactive than expected in the hot full power condition.

Reactivity changes

Burn-up

It is still too early in the first cycle of fuel burn-up to make firm predictions of the cycle length. Nevertheless during the month of March when the reactor was operating essentially at steady full power:

observed B^{10} burn-up rate $=1.9 \pm 0.2 \times 10^{-2}$ ppm/EFPD (Effective Full Power Days)

SOLOMON prediction $=1.7 \times 10^{-2}$ ppm/EFPD (Effective Full Power Days).

When taken in conjunction with the agreement on initial B^{10} level previously noted, this suggests that a cycle length within the design tolerance of 300 ± 30 EFPD will be attained.

Steam void reactivity effects

Zero energy measurements made in the core mock-up using H_2O/D_2O mixtures to simulate coolant of various effective densities showed that

measured void coefficient $K_v=-0.016 \pm 0.001$

calculated $K_v=-0.016$

where K_v=(fractional reactivity change)/(fractional void change).

Since the mock-up contained only 68 fuel elements against the 104 of the power reactor, there was more neutron leakage and the void coefficient correspondingly more negative. The same method of calculation gave for the complete power reactor at full power

$K_v=-0.009$

for perturbations involving small increases in reactor power.

A first check on the magnitude of void reactivity effects in the power reactor was made by perturbing coolant flow by partially opening and closing two of the four pump discharge valves with the reactor running at a thermal power of 75 MW. No discernable change in the slow drift of

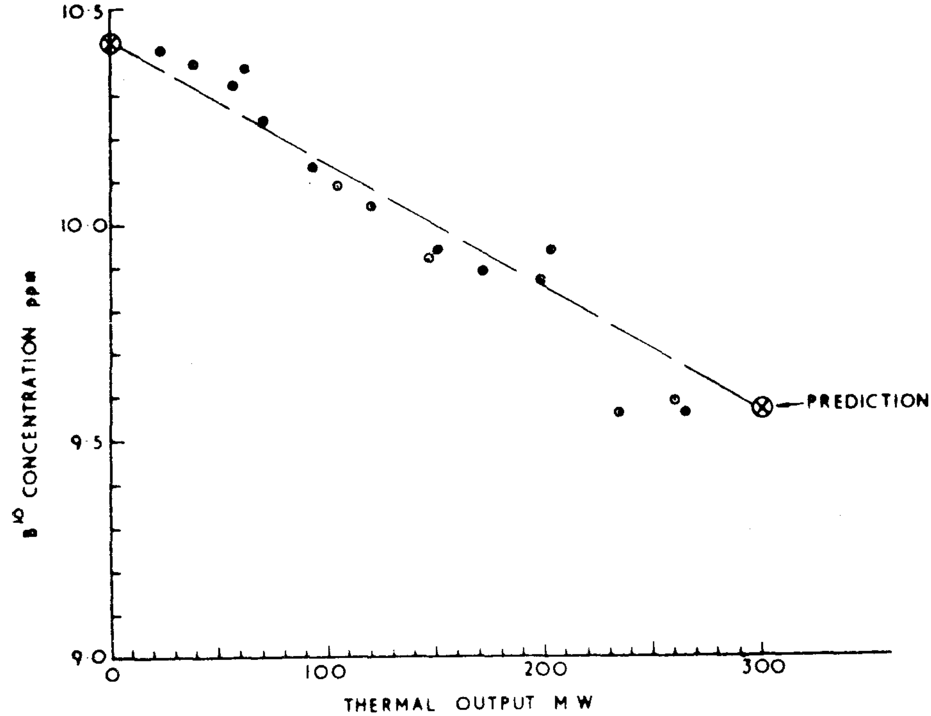

Fig 7 Prompt power deficit experiment.

critical height with xenon build-up was detected. This was consistent with the very small effective void coefficient of $K_v = -0.0002$ computed for this type of flow perturbation.

A further experiment was made with the plant running at about 90 MWe. Two high pressure feed heaters were disconnected in succession while the reactor was operated at constant neutron flux. The sub-cooling at channel entry was therefore increased and less steam voids created. This produced a perturbation in critical height which was interpreted as equivalent to

$K_v = -0.007 \pm 0.002$

compared with (for this type of perturbation)

predicted $K_v = -0.006$.

Power deficit

It is difficult to separate the true power-void coefficient from the fuel temperature coefficient since both operate approximately simultaneously. For many practical purposes, e.g., assessment of the adequacy of the shutdown system, it is not necessary to make this separation. Estimates of the combined effects of coolant voids and the fuel temperature coefficients were made during power raising since this often lasted for several hours. It was necessary to apply corrections for changes in coolant and moderator temperature and in xenon reactivity. The latter correction was facilitated by using a xenon computer with the equilibrium value normalised to a SOLOMON estimate. Not surprisingly, there is a considerable scatter in the data and a typical run-up is shown in Fig. 7.

To summarise the available evidence on void and power coefficients:

(1) the power coefficient (combined effect of voids and fuel temperature coefficient) is certainly negative, probably rather more so than predicted;
(2) the void coefficient is small and negative and well within the control system tolerance;
(3) it is likely that the fuel temperature coefficient is more negative than expected.

Moderator and coolant temperature coefficients

These coefficients were measured during the hot zero energy phase of the programme. As expected they are about

TABLE 2
Moderator and fuel temperature coefficients

Boron concentration (ppm)	Moderator coefficient mN/°C		Coolant and fuel coefficient mN/°C	
	Experiment	Calculation	Experiment	Calculation
9.35	14.5±0.5	20.47	−8.4±0.2	−12.30
11.48	19.8±1.6	23.69	−7.8±1.3	−12.64

5 mN/°C (1 mN$=10^{-5}$ $\Delta K_{eff}/K_{eff}$) less negative than predicted. Similar discrepancies have been observed in other liquid moderated systems. The effect is, however, small and of little practical significance in SGHWR. Results of the measurements are presented in Table 2.

Control variable effectiveness

As has already been discussed the zero energy experiments have confirmed closely the predicted influence of moderator boron and hence its predicted effectiveness as a control variable.

Measurements of moderator height coefficients have been made by measuring reactor periods with excess moderator height. The coefficients are 25% smaller than predicted but are within control system tolerance. Smaller discrepancies of about 8% had previously been observed in zero energy measurements in DIMPLE.

Liquid shutdown tube worth

Pulsed source and rod drop techniques were used to estimate the worth of the 12-liquid shutdown tubes. The agreement with prediction through the zero energy phases was in all cases within ±0.15 ΔK_{eff} and the combined worth was 3.4% ΔK_{eff} at hot zero energy with a full tank.

It was demonstrated, by measurements of critical boron concentration, that even if three liquid shutdown tubes near to the booster channels failed to fire then the remaining nine tubes would hold down 2.1% ΔK_{eff}. This is considerably larger than the combined power deficit and is therefore sufficient to ensure shutdown.

Primary Circuit Hydraulics

Total flow

Estimates of coolant flow in the circuits were based on data derived from full-scale tests on most of the major components including the fuel elements. In view of the complexity of the pipework, it was difficult to prejudge the likely accuracy of the overall prediction. Total flows were measured by Dall tubes situated in the main downcomers to the pumps, over a range of thermal powers up to 300 MW. The predictions were within the scatter of the measured points. At full power the comparison was as shown in Table 3.

These results indicate that the flow in the South circuit is about 3% higher than in the North. This is due principally to the fact that one of the pumps in this circuit, although of the same design as the others has a higher head versus flow characteristic.

Flow distribution

An important feature of the Winfrith reactor is that each channel is fitted with hydraulic instrumentation in the form of inlet and outlet Venturi meters. The inlet Venturis measure the total flow and have shown that the distribution of flow at full power is well predicted. Individual channel flows are predicted to ±5%. Only at zero power was there a significant difference between the measurements and prediction, and this was a local effect observed in the channels fed from the four sub-headers nearest to the main circulating pumps. With no steam voidage in the core these channels were receiving 10% to 20% less flow than the average value for the core as a whole. It is believed that this starving of the end sub-headers at zero power was due to momentum effects in the bottom header (not included in the model) and the sharp radius of curvature of the pipe joining the pump to the bottom header. At power the effect was less significant due to the increase in

TABLE 3
Circuit flows

	Measured gall/min	Predicted gall/min
N circuit	16,800±200	17,160
S circuit	17,300±200	17,180
Total:	34,100±300	34,340

the total circuit pressure drop associated with core voidage.

Power distribution

Zero energy measurements

Provision has been made in the Winfrith reactor for the insertion of flux measuring wires along the axes of the fuel elements. Wires may be loaded or withdrawn with the reactor on power. Copper wires were used during the zero energy experiments to check the radial and axial neutron flux distribution.

At cold zero energy with a high concentration of boron in the moderator some large discrepancies amounting to a 40% underprediction of copper reaction rates were observed in the vicinity of the boosted channels. As the core was raised to operating temperature and the critical boron concentration was reduced from 13 ppm-10 ppm, the discrepancy was greatly reduced and fell to the few per cent overprediction level which had been expected on the basis of DIMPLE experience with high enrichment perturbations. As a precautionary measure to avoid possible delays at the beginning of power operation reactivity was reduced in the booster channel area by changing channels E11, C13 and A13 to the enrichments shown in Fig. 6. Previously these channels had been fuelled with 1.24%, 1.24% and 2.28% fuel elements respectively.

Subsequent theoretical studies have suggested that the form of coarse mesh diffusion theory used in the standard applications of the AIMAZ code does not represent the high local current flows from relatively highly enriched fuel to a highly borated reflector with sufficient accuracy. The problem is, however, much less significant at the lower boron levels arising at power operation.

Power operation

The outlet Venturi meter fitted to individual channels in the Winfrith SGHWR provides a means of measuring exit steam quality and hence channel power. The equation relating quality meter differential pressure Δp, channel flow w, and steam quality x, were obtained from out-of-pile tests using an electrically heated facsimile of the fuel cluster in a full scale model of the channel and riser pipework under reactor conditions. A general relationship for the normal operating range of quality was demonstrated of the form

$$x = \frac{a\,(\Delta p - 17.0\,w^2) + b}{w^2}$$

where a and b are constants for a particular channel pipework configuration.

During commissioning, channel measurements were made at various reactor powers using the inlet flow meters and quality meters. At zero power, i.e., with no steam quality, checks were made of the channel flows as measured by the inlet and outlet Venturi meters respectively, and where they did not agree within 5%, those channels were excluded from the subsequent analysis of core power distribution. In addition certain of the channel instruments had developed faults and could not be repaired at this stage because access is only available during shutdown. Nevertheless the instrumentation in 77 out of the 104 channels proved to be satisfactory and provided a detailed survey of core power distribution.

In order to facilitate comparisons with theory by smoothing random errors in meter calibration (±6%) and to fill in gaps where the instrumentation is not operative, the results have been processed through the SAMSON code, which produces a best fit consistent with neutron diffusion theory. Fig. 8 shows the results and presents a comparison with the SOLOMON predictions. It is clear that the peak standard channel is operating at below 4 MW and the booster channels at just under 5 MW as required. It also appears that SOLOMON follows the channel to channel variations associated with the enrichment loading pattern quite closely. However there is a systematic tendency for the observed powers to be about 10% higher in the booster channels and other high flux regions and proportionately lower elsewhere.

The quality meter power distribution measurements at steady full power operation are now being supplemented by wire activation scans made with 1.5% Cu/titanium alloy. At the time of writing the first results have not been fully analysed. There are indications that the axial power form factor will be 1.56±0.02 which is 8% higher than the original figure used in the design analysis. The difference appears to be related to the effect of the bottom reflector but is not of great practical

SOUTH

	A	C	E	G	J	L	N	Q	S	U	W	Y
1					2·49 1·99 A	2·68 2·44 A	2·69 2·58 A	2·50 2·32 A				
3			2·27 1·93 A	3·00 2·40 A	3·34 2·87 A	2·52 2·22 C	2·88 2·65 B	3·34 3·30 A	2·95 2·83 A	2·20 2·11 A		
5		S	2·91 2·53 A	2·86 2·57 B	2·74 2·38 C	3·24 2·88 B	2·81 2·64 C	3·10 2·88 B	2·47 2·37 C	2·79 2·70 A	S	
7		S	3·41 3·27 A	2·72 2·42 C	3·24 3·08 B	2·89 2·77 C	3·29 3·16 B	2·82 2·76 C	3·02 3·08 B	3·25 3·25 A	S	
9	3·30 3·46 3·10%	3·42 3·28 1·90%	2·75 2·77 C	3·24 3·14 B	2·89 2·86 C	3·36 3·53 B	2·94 2·99 C	3·26 3·36 B	2·78 2·92 C	2·97 3·24 B	3·10 3·00 A	2·25 1·95 A
11	4·45 4·98 5·50%	4·57 4·89 3·50%	2·91 2·82 C	2·88 2·85 C	3·31 3·51 B	2·98 3·16 C	3·38 3·72 B	2·88 3·11 C	3·19 3·47 B	2·72 2·80 C	3·34 3·44 A	2·54 2·49 A
13	2·38 2·40 B	2·62 2·64 C	2·80 2·72 C	3·16 3·22 B	2·81 3·00 C	3·31 3·71 B	2·90 3·13 C	3·18 3·37 B	2·72 2·96 C	3·04 3·19 B	2·39 2·44 C	2·52 2·44 A
15	2·32 2·29 A	3·11 3·29 A	2·88 3·02 B	2·57 2·65 C	2·98 3·10 B	2·74 2·88 C	3·13 3·25 B	2·61 2·74 C	2·91 2·97 B	2·48 2·68 C	3·41 3·37 3·00%	2·22 2·31 A
17		S	3·12 3·15 A	2·75 2·75 B	2·53 2·45 C	3·03 2·91 B	2·66 2·60 C	2·90 2·78 B	2·45 2·40 C	3·54 3·47 3·00%	S	
19		S	3·07 3·01 3·00%	2·30 2·23 C	2·85 2·65 B	2·62 2·43 C	2·99 2·78 B	2·57 2·39 C	2·72 2·50 B	2·79 2·54 A	S	
21			2·16 2·11 A	2·81 2·61 A	3·13 3·03 A	2·71 2·57 B	2·40 2·33 C	3·23 3·07 A	3·32 3·05 3·00%	2·25 2·00 A		
23					2·37 2·20 A	2·56 2·56 A	2·57 2·52 A	2·43 2·33 A				

NORTH

BOOSTED CHANNELS. (A 9, A 11, C 9, C 11)

℄ (between rows 11 and 13)

KEY

MW	SOLOMON PREDICTION.
MW	BEST FIT TO QUALITY METER MEASUREMENT.
%	ENRICHMENT:– A = 2·28%, B = 1·56%, C = 1·24%

Fig 8 Comparison of predicted and measured power distribution in SGHWR normalised to 300 MW(Th).

significance since sufficient thermal design tolerances exist, especially as the peak channels are operating at below the 4 MW design limit.

Conclusions

The time taken to bring the Winfrith SGHWR to full-load capability from the nominal completion of construction and initial fuel and heavy water loading bears favourable comparison with that taken to commission a conventional power plant containing equipment which replicates that already proved in existing generating stations. This has resulted, in part, from careful planning and training but also from the design which permits extensive component testing and proving before assembly on site and follows closely many aspects which are well established in conventional power plant. In the first 2½ months after reaching full-load capability, the plant availability has been high while the system has demonstrated that it is flexible, readily controlled and affords simple access for maintenance and adjustment.

As regards the performance of the Winfrith SGHWR, measurements have shown that this is close to prediction. In particular, the core has been brought to full-power without exceeding the channel output limits and it provides sufficient reactivity margin to give the designed burn-up.

Acknowledgements

This paper is published by kind permission of the Managing Director, The Reactor Group, UKAEA, Risley. Thanks are due to the many colleagues, particularly at Winfrith, responsible for the work reported.

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U.K.A.E.A. SCIENTIFIC AND TECHNICAL NEWS SERVICE

Thermal diffusivity equipment

Equipment which enables the thermal diffusivity of small samples to be measured quickly and accurately over a wide range of temperatures has been developed jointly by the U.K.A.E.A. and Goulding and Partners (Consulting Engineers).

The Authority have licensed Goulding and Partners, of Essex Road, Acton, London, W.3, to manufacture further equipment of this type.

With this equipment, under suitable conditions, up to 50 measurements can be made in one eight hour working day compared with approximately one per day by steady state methods.

In the equipment a sample is heated to the test temperature in a suitable environment and a heat pulse is directed at one face. The temperature change at the other face is measured and recorded on a high speed recorder or by photography of an oscilloscope trace. The method is very versatile and the equipment exists in the following forms:—

A simple sample holder for measurements at ambient temperature, the samples being cylindrical up to 0.50 in. long by 0.25 in. diameter. This version uses a photoflash tube as the heat source and a thermocouple detector on the sample. It is very suitable for routine thermal conductivity determinations at a very high measurement rate.

Equipment similar to the one described above, but with the sample holder contained in a Dewar flask for measurements from ambient temperature to the boiling point of liquid nitrogen (−196°C).

Equipment using a laser pulse as the heat source and an infra-red detector with an optical system, for operation from 500°C to 1200°C (versions for measurements from ambient to 500°C, and up to 2000°C are being constructed).

Equipment using a Q-switched (fast pulse) laser and an infra-red detector, together with a high speed oscilloscope, to determine the diffusivity of very thin films (10^{-3} cm. or less) or of a thin film on a substrate. This operates from ambient to 800°C.

10th May, 1968

Heavy water reactor conference

The British Nuclear Energy Society held a conference on " Steam Generating and other Heavy Water Reactors " at the Institute of Civil Engineers, Great George Street, Westminster, London, S.W.1, from 14th-16th May.

Delegates included representatives from 18 countries overseas apart from a large U.K. representation drawn from industry, the Electricity Generating Boards and the U.K. Atomic Energy Authority.

Many of the papers presented featured the Steam Generating Heavy Water Reactor, a 100 megawatt version of which was opened last February by the Duke of Edinburgh at Winfrith, Dorset. This is the Atomic Energy Authority's largest operational reactor and although only recently commissioned has produced nearly 150 million units of electricity. This reactor, with its straightforward design and relatively simple construction, is attracting widespread interest abroad.

The conference was organised in the following sessions: Tuesday, 14th May: Afternoon — SGHWR general design; Wednesday, 15th May: Morning — SGHWR performance; Afternoon — SGHWR materials and operation; Thursday, 16th May: Morning/Afternoon — The broader scene. This included papers on heavy water reactors in Canada, France, Germany, Italy, Sweden and the U.S.A.

14th May, 1968

Amersham at Liège

The Radiochemical Centre participated in the International Symposium on Hormones, Polypeptides and Proteins at Liège, Belgium, from 19th-25th May.

The main item exhibited by the Centre was the insulin immunoassay kit, which in the last six months has been supplied to 43 countries in all five continents.

The kit offers a sensitive and convenient method—requiring no specialised training or experience—of measuring the insulin content in blood plasma.

Insulin is a protein hormone, the action of which in the human body is being better understood because of the ease with which large numbers of measurements can be made with the immunoassay kit.

The kit consists of insulin iodinated with radioactive iodine-125, and anti-sera, the latter prepared in collaboration with the Wellcome Research Laboratories. Specially batch-tested " Oxoid " membrane filters are also available.

The test depends upon the competition of the insulin in the samples of blood plasma being investigated with the iodinated insulin for combination with anti-sera. The anti-sera binds the insulin molecules and is separated from the solution on membrane filters; the amount of radioactivity measured on a filter is inversely proportional to the insulin in the plasma sample.

Further information is available from The Radiochemical Centre, Amersham, Bucks.

16th May, 1968

Atom Show '68

The UKAEA's Production Group exhibited at the Toronto Atom Show 10th-12th June, the main theme being that it can meet worldwide demands for nuclear fuel services and products.

The exhibit emphasized that the UKAEA operates a fully integrated fuel cycle service and that the commercial activities of the Production Group are financed by a separate trading fund, not by government subsidy. Thus the Group acts in a strictly commercial way, under single management.

Part of the display described the Group's reprocessing facilities. For the reprocessing of nuclear fuel to be of maximum value to the fuel cycle it must be done by the fastest and most economical methods. This is only possible with large-scale plant and the UKAEA operates at Windscale the world's largest commercial reprocessing plant (its capacity exceeds 2,000 tons a year). Recent contracts have included the reprocessing of irradiated oxide fuel from the two 350 MW(e) PWR's under construction at Beznau, Switzerland, and the irradiated metal fuel from the 166 MW(e) Tokai Mura gas-cooled reactor in Japan. The plant has also reprocessed fuel from the Canadian NPD reactor and a continuing contract for the reprocessing of fuel from the Latina reactor in Italy has been in operation for some years.

Another feature of the exhibit was the international transportation of irradiated nuclear fuel—a field pioneered by the Production Group.

The UKAEA operates the world's largest centre for nuclear fuel manufacture, at Springfields. It already makes fuel for 29 power reactors, which have produced over two-thirds of the world's nuclear electricity, and is backed up by two decades of fuel manufacturing experience.

An integrated nuclear fuel service should include the enrichment of uranium and a section of the exhibit described the Capenhurst gaseous diffusion plant's programme to meet increasing world demand.

Another section of the display described the manufacture of plutonium fuels—the UKAEA has made fuel for the Dounreay Experimental Fast Reactor, the Swedish Ågesta reactor, the German Kahl reactor, BR3 in Belgium and the Italian Garigliano reactor. A major fuel manufacturing plant is under construction at Windscale. Due for completion in 1968, its main task initially will be to supply fuel for the Prototype Fast Reactor at Dounreay.

The show also included research and materials testing reactor fuels which are supplied to a number of reactors in the UK and overseas.

Radiation shielding windows

In conjunction with two industrial firms, the U.K.A.E.A. showed radiation shielding windows of advanced design at the International Trade Exhibition for Medical and Hospital Equipment, in Vienna, 15th-19th May, and at the British Medical Exhibition in Madrid, 21st-27th June, 1968.

These windows, for the observation of patients in radiotherapy units or for use

A three foot thick Harwell type zinc bromide viewing window used in the Betatron cancer unit at St. Luke's Hospital, Guildford.

where radioactive materials are handled, are based on ten years' design and user service in the U.K.A.E.A. Safety, combined with excellent viewing, sound economy and simplified installation are the criteria for their design and both manufacturers have access to Harwell's expert advice in this field; similar types of window are already installed in many hospitals and nuclear establishments in the United Kingdom and abroad.

Two types of window were shown.

The solid glass window is one of an extensive range with thicknesses from 5 mm. to 2 metres or more; densities are from 2.5 gm cm^{-3} to 6.1 gm cm^{-3} and the glasses are radiation stable up to at least 2 x 10^9 rads. The wide range available enables windows of this type to be used with all the normal shielding media.

The manufacturers are Chance Pilkington, Glascoed Road, St. Asaph, Flints.

The zinc bromide window is a major advance, being compact in design, circular in cross section and priced considerably lower than any comparable window. It is one of a range with thicknesses from 60 cm up to 150 cm and matching the biological protection of a normal density concrete wall; for thicknesses above 150 cm, a special combination of solid glass and zinc bromide window is available.

The manufacturers are Parglas Ltd., Barton Manor, Bristol 2.

A.E.R.E. Post-Graduate Education Centre

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Radiological Protection

30th September to 4th October, 1968
4th to 8th November, 1968
24th to 28th February, 1969
9th to 13th June, 1969

This short course aims to give users of radioactive substances and radiations in industry, research or teaching a broad introduction to the principles and practice of radiological protection, with a strong emphasis on practical considerations. Fee: £40 exclusive of accommodation.

Critical Path Methods

8th to 11th October, 1968

This course is intended for staff of graduate standard who are or will become users or managers of the system rather than for mathematicians already working in the field. Lectures are given by managers who have first hand experience with the system. Harwell has developed its own C.P.M. computer programme (CAPSTAN) details of which will be given during the course. Fee: £30 exclusive of accommodation.

Medical Radioisotope Generators

15th to 17th October, 1968

Arranged in collaboration with the Radiochemical Centre, Amersham, this course aims to give users and potential users of radioisotope generators, practical experience of established and newly introduced systems. Fee: £24 exclusive of accommodation.

Commissioning, Use and Maintenance of Reactor Instrumentation

21st October to 1st November, 1968

This course is intended for commissioning, operation and maintenance engineers working on nuclear reactor instrumentation. Participants should have some knowledge of the basic principles of nuclear reactions and reactors, electronics and the measurement of physical quantities. Fee: £80 exclusive of accommodation.

Process Instrumentation

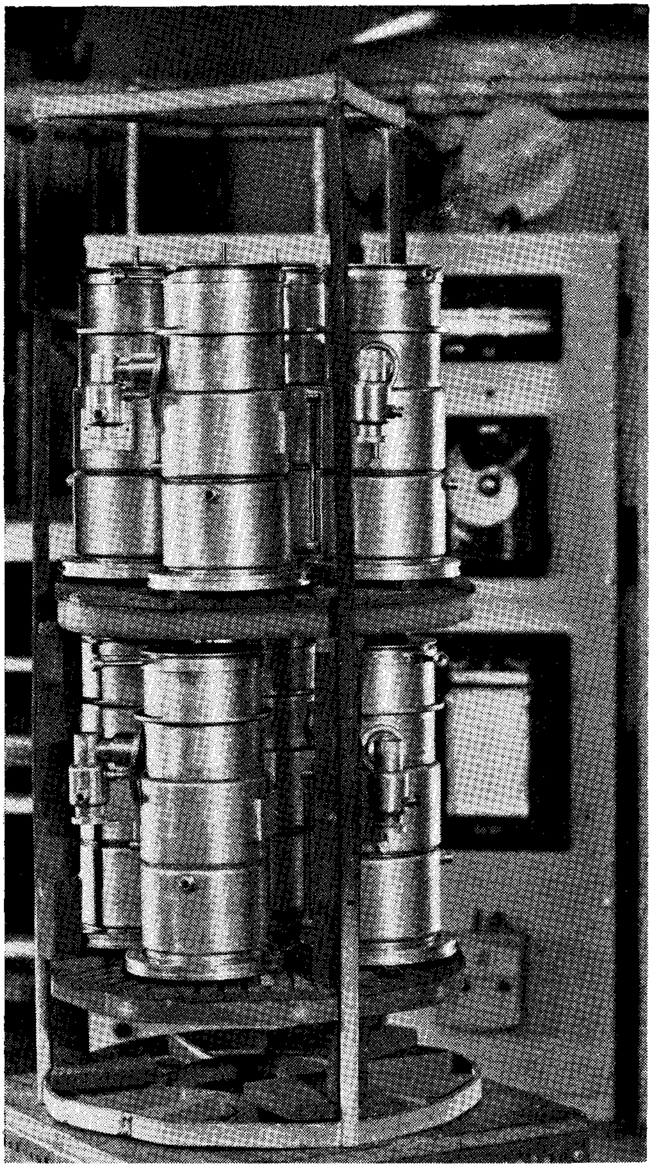
21st October to 1st November, 1968
10th to 21st March, 1969

This course is intended for graduates who are working on the instrumentation of process plant, nuclear reactors and scientific apparatus or who have a direct interest in the subject. A visit will be arranged to a process plant or a power station where modern control techniques are being applied. Fee: £80 exclusive of accommodation.

Introduction to Production Control by Computer

30th and 31st October, 1968
4th and 5th December, 1968
31st March and 1st April, 1969

A new system of production control (WASP) which ensures better loading of machine tools has been devised at Harwell. The course will show how " WASP " may be used on its own, or in conjunction with other computer control systems. Fee: £25 exclusive of accommodation.



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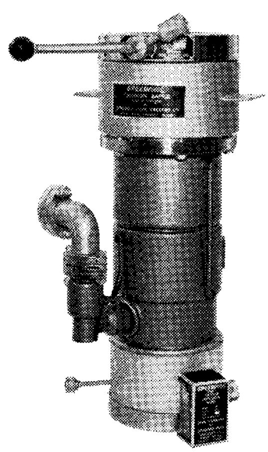

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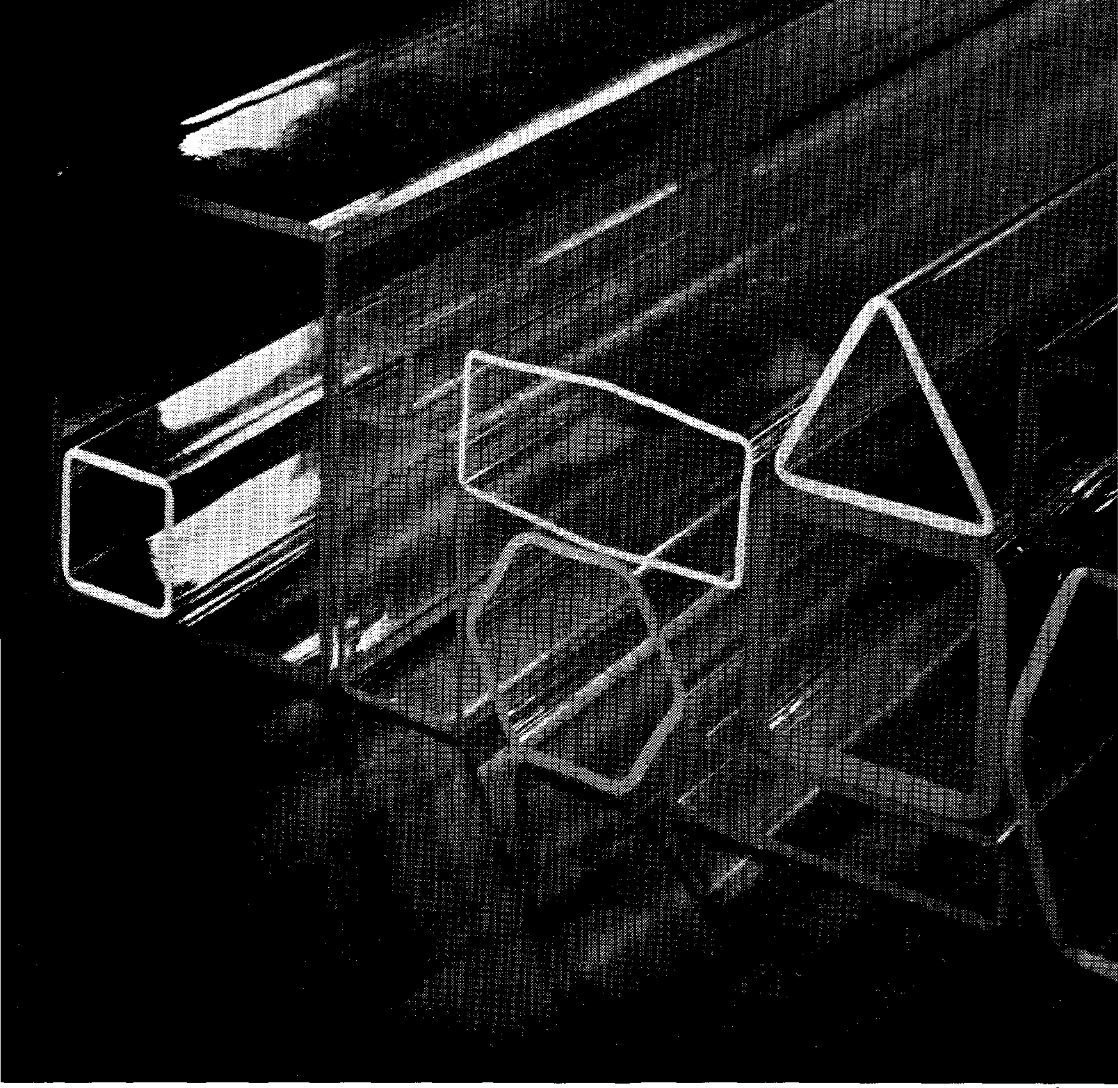

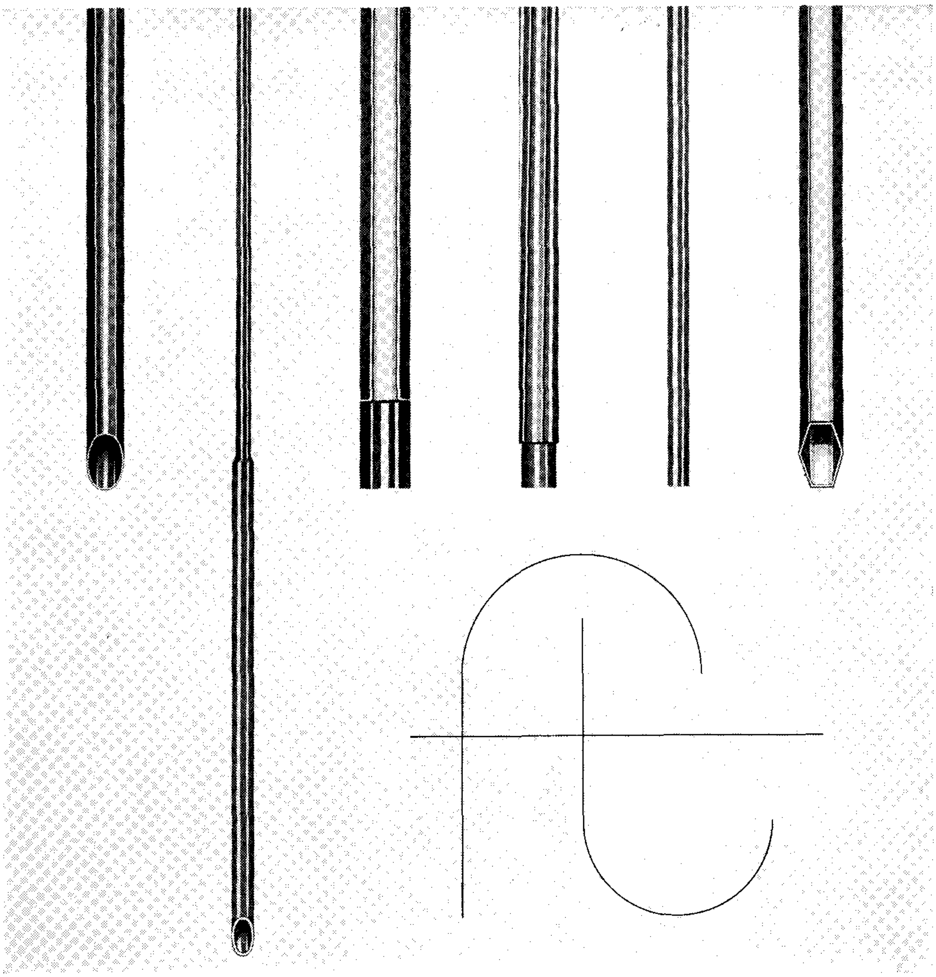

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