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THE UNITED KINGDOM ATOMIC ENERGY AUTHORITY

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OF THE UNITED KINGDOM
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Contents

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12th Annual Report and Press Conference

Sir William Penney, K.B.E., F.R.S., Chairman of the Atomic Energy Authority, made the following introductory statement at the Press Conference on the Authority's Twelfth Annual Report, held on 5th October, 1966.

YOU have been given the Twelfth Annual Report of the Atomic Energy Authority covering the financial year 1965/66. You will later have the opportunity of asking questions, but first I would like to bring you up to date on the progress on a few major items and then make some general comments.

In April, following the Government announcement two months earlier, work started on the site of the Prototype Fast Reactor at Dounreay.

Since December 1965, when the Minister of Technology announced the Government decision that the Authority would modernise and re-activate the Capenhurst diffusion plant, progress has been steady and is on programme.

An event of considerable interest to all members of the European Nuclear Energy Agency is that the DRAGON reactor started its first full power run on 24th April and completed it successfully on 31st August.

The S.G.H.W. station at Winfrith is on time and will be completed next year.

The special purpose cyclotron at Amersham has been operating since May adding new isotopes to the wide range of products sold by Amersham. Steady growth in isotopes sales at home and abroad continues.

I turn now to other matters.

Future of the Authority

Ladies and gentlemen, I think you will perceive from the present report, especially Chapter V, the Reactor Development Programme, that we in the Authority are giving very serious thought to the future of the Authority. We have set down the reactor systems on which we intend to work. There is still a lot to be done in moving on the A.G.R., in completing and exploiting the S.G.H.W. and in the particularly important duty of developing and launching the fast reactors. The H.T.R. system still needs considerable development, and we have to decide whether the undoubted attraction of the system is

Sir William Penney answers a question at the Annual Press Conference

enough to justify the considerable costs of bringing it to the stage of commercial exploitation. Possibilities of civil work on other systems are small reactors, specially for marine propulsion, if we can find attractive economic prospects, which is not the case at present, and in the more distant future, on variations in fast reactors. It seems quite clear that the scale of research and development effort on atomic energy deployed by the Authority must reduce over the next few years. On the plant side, we have made steady improvements in efficiency and we shall continue to make them. We have of course been aware of the situation for the last few years and we have been steadily reducing our total numbers, almost entirely by means of wastage. Thus our total numbers in March, 1962 were 40,560, while four years later in March 1966, our total numbers were 33,552; the reduction over this period was 7,008.

An important policy question for the Government and the Authority to decide is whether the reduction should be continued or whether the fine resources and facilities which will gradually become available from the present atomic effort should be used for non-atomic work or work connected with or stemming from atomic energy. The Authority already has a small amount of non-atomic work under directives from the Minister of Technology, as described in Chapter X, but the Authority would be able to undertake more.

Questions of the same kind are arising elsewhere in the country and a national debate is proceeding and will continue for some time because some profound questions of national technological policy are involved. The major answers affecting the Authority have not yet emerged and therefore the scale of the Authority's programme by about 1970 onwards is not yet known.

Now a few words about the Trading Fund in its first year of operation. The total value of sales was £33·6 million of which £3·1 million was exports, and £6·6 million was supply at cost by the Trading Fund to various Authority sites. The surplus after paying all costs, including interest and depreciation was £2·1 million.

On the overseas front, the last year has witnessed a dramatic rise in the rate of ordering of nuclear power stations in the United States. It will be several years before any country, including the U.S., matches the power reactor operating experience already accumulated in the United Kingdom; but there is now no doubt that international competition will be severe in the days ahead.

Collaboration between British industry and the Authority has stepped up the effort to promote the sale of British reactors overseas. In order to sharpen the impact of British technology in this field, we have formed a new organisation, the British Nuclear Export Executive. Separately, the Authority and the three consortia cannot compete in size and resources with the American giants who are their main competitors. Working together and deciding together where our efforts can best be directed with a good chance of success I think that we can gain the share of the export market which the quality of our products justifies. There are no sales successes to announce today, partly because several countries who will be placing orders within the next two or three years are taking longer than expected to evaluate the various types which are now on offer. However, vigorous British campaigns are in progress. Some of you may have attended the Nuclex 1966 conference and exhibition held last month in Switzerland, and I hope you will agree that the contributions made there by the Authority and British industry were extremely effective.

In short, I remain confident about the overseas prospects. Before inviting your questions I would however like to remind you that the primary purpose of the Authority on the civil side has been the development of means of generating nuclear power economically in this country. There is no doubt whatever that the Authority expenditures have been fully justified on this ground alone. Any benefit that can be obtained from overseas sales is a welcome addition which we must try to achieve; but our first concern must be with the enormous and increasing electricity requirements of the United Kingdom.

Review of the year: *1st April*, 1965, *to* 31*st March*, 1966

On 25th May, 1965, the Minister of Power announced in the House of Commons that he had accepted a recommendation from the Central Electricity Generating Board (C.E.G.B.) that an Advanced Gas-Cooled Reactor system should be adopted at Dungeness "B", this reactor having shown clear economic and technical advantages over the alternative systems and having a good potential for further development. This statement was amplified at the end of July, 1965, by the issue by C.E.G.B. of a detailed appraisal of the technical and economic aspects of Dungeness "B". This showed that the generating cost per unit sent out from Dungeness "B" at 75 per cent. load factor and 20-year life, would compare favourably with generating costs from the best boiling water reactor (B.W.R.) bid and from comparable stations burning coal or oil at British market prices. It also forecast that over a five-year period (the longest period for which C.E.G.B. were prepared to forecast) the cost advantage of the A.G.R. was likely to increase rather than diminish. The reduction in total generating cost which might be achieved within this period was estimated to be about 20 per cent.

The White Paper on Fuel Policy presented to Parliament in October, 1965, announced the decision of Her Majesty's Government that for planning purposes it should be assumed that on average over the six years 1970-75 about one nuclear power station a year would be commissioned, starting in 1970 with Dungeness "B" and possibly including a second Scottish station. The programme would be based on the A.G.R., but the government did not exclude the possibility of another nuclear reactor type making a contribution. It was estimated that on these assumptions, and with further developments in nuclear technology and expected increases in the size of stations, a total of 8,000 Megawatts (electrical) might be in commission under the second nuclear power programme by 1975.

On 9th December, 1965, the Minister

of Technology announced in the House of Commons the government's decision that the Authority's Capenhurst plant should be modernised and reactivated to supply enriched uranium for the manufacture of fuel for the second nuclear power programme. The Minister explained that although the Capenhurst product would initially be more expensive than enriched uranium from the United States, the Authority had designed modifications to the Capenhurst plant that would greatly improve efficiency of production and had forecast that the gap between U.S. and Capenhurst prices should narrow progressively during the 1970s.

Prototype Fast Reactor

On 9th February, 1966, the Minister of Technology announced a major decision in the progress towards commercial fast reactors. He told the House of Commons that the government had approved the construction of a 250 Megawatts (electrical) Prototype Fast Reactor and had decided that it should be built at Dounreay. The fuel production plant would be at Windscale.

On the marine side, the President of the Board of Trade stated on 29th July, 1965, that the government had decided that the prospects of building a nuclear ship that would be economic to operate were as yet too remote to justify the large government expenditure necessary to build a prototype. The Authority would, however, continue to explore methods of improving the economics of the present types of small reactors and to examine new ways of bringing an economic nuclear merchant ship nearer.

These decisions mark out the main components of the Authority's programme for several years to come; in addition they make it necessary for the Authority to attempt to forecast what should be the shape and size of their resources thereafter. The principal target of the Authority's research and development effort has been economically competitive nuclear power. Now that this is within the foreseeable distance of being achieved, it is natural that the research and development effort should be reduced. Major reviews have been carried out within the Authority of both the research and the reactor development programmes in order to determine what resources will be necessary in from five to 10 years' time. At the end of the year 1965/66 these reviews were under consideration by Members.

The Authority's programme of research and development of nuclear warheads for the services continued as authorised by the government. Collaboration with the U.S. was actively maintained and on 10th September, 1965, an underground test of a British nuclear device was successfully carried out by a joint U.S./U.K. team at the Atomic Energy Commission's Nevada test site.

In December, 1965, the Authority

DEPLOYMENT OF RESOURCES:
NUCLEAR CIVIL RESEARCH AND DEVELOPMENT

	Expenditure: £ million (approximate)				Qualified Scientists and Engineers	
	1964/65		1965/66		31.3.65	31.3.66
	Current	Capital	Current	Capital		
1 Reactor Research and Development Programme						
Gas-Cooled Systems	9	1	8	·5	500	425
Water-Moderated Systems	5·5	4	6·5	5	480	410
Fast Systems	9	1·5	10	1	575	670
General Reactor Technology	4	·5	4·5	—	365	375
2 Other Research						
Basic Research	5	1·5	6	1	360	420
Health and Safety Research	1	—	1	—	120	95
Isotope Research	·5	—	·5	—	80	60
Plasma Physics and Fusion Research	3·5	1·5	3	1	200	190
	37·5	10	39·5	8·5	2,680	2,645

published a report on "The Detection and Recognition of Underground Explosions", which reviewed work carried out by the Weapons Group since 1958.

Nuclear power stations in the United Kingdom, including Calder Hall and Chapelcross, continued to perform satisfactorily and by the end of the year had supplied a total of more than 50,000 million units of electricity to the grid. Of the stations in the first C.E.G.B. programme, the second reactor at Hinkley Point, the two reactors at Dungeness "A", and the two reactors at Sizewell were commissioned during the year.

The average full power output for the year from the Windscale A.G.R. was 105 MW(heat), giving an electrical output of 35 MW(electrical) gross. Excluding reductions in power for experimental purposes, a planned availability of 84 per cent. has been maintained since the reactor went on power over three years ago. In the Dounreay Fast Reactor two long irradiation programmes were completed, during the second of which a new high output figure of 64 MW(heat) was achieved. Construction of the Steam Generating Heavy Water Reactor at Winfrith continued to keep to schedule.

The Authority's sales during the year totalled £35·7 million, showing a trading surplus of £2·1 million.

In 1965/66, expenditure from Parliamentary Grants on the Authority's programme of nuclear civil research and development was £48 million of which £39·5 million was current expenditure and £8·5 million was on capital facilities. The number of graduate and professional engineers and scientists employed on the programme in 1966 was 2,725 of whom 80 were doing work on repayment for other organisations.

On 13th May, 1965, the Radiochemical Centre, Amersham, celebrated its 25th anniversary with an Open Day, at which the principal guest was Sir John Cockcroft.

The diversification programme made possible by Section 4 of the Science and Technology Act, 1965, got under way during the year, with the issue by the Minister of Technology of a number of directions to the Authority. So far, just over £1 million has been budgeted for 1966/67.

The principal overseas projection of the Authority's activities during the year was the nuclear energy stand at the British Trade Fair in Tokyo in September, 1965. This coincided with the 9th General Conference of the International Atomic Energy Agency which was held in Tokyo, being the first General Conference of the Agency to be held outside Vienna. Sir William Penney gave a review of nuclear power development in the U.K. at a special meeting arranged by the Japanese Atomic Industrial Forum.

Among the many overseas visitors during the year were Professor A. M. Petrosyants, Chairman of the Union of Soviet Socialist Republics' State Committee for the Utilisation of Atomic Energy, who with four of his colleagues spent two weeks in July and August visiting Authority establishments and nuclear power stations.

One of the principal overseas orders secured by the Authority during the year was a contract for the supply of over 7,000 fuel elements for the 200 MW (electrical) Latina nuclear power station in Italy. This batch of fuel will consist of 80 tons of natural uranium and will yield an output of approximately 2,000 million kilowatt-hours.

Two Finnish utilities, Imatra and Ekona, invited bids for nuclear power stations in the 300/350 MW(electrical) region. The three U.K. consortia decided not to submit bids. The Authority considered that the Steam Generating Heavy Water Reactor (S.G.H.W.R.) was an appropriate system to offer for the conditions applicable in Finland and accordingly submitted bids to both utilities. At the year's end the utilities were in process of deciding on their short lists.*

During the year the Authority and the three Consortia held a number of top level discussions concerning power reactor export promotion, with the general objective of sharpening the impact abroad of British reactor systems and avoiding unnecessary competition overseas between the Consortia. At the year's end these discussions were still continuing.†

*Imatra announced their short list in May, 1966; the Authority were not included.

†The formation of the British Nuclear Export Executive was announced on 10th June, 1966. The members are the Authority; Atomic Power Constructions Ltd.; Nuclear Design and Construction Ltd.; and The Nuclear Power Group Ltd. The offices of the Executive ("B.N.X.") are at Dorland House, 14/16 Regent Street, London, S.W.1.

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

100 "reactor-years"

BRITAIN has accumulated 100 "Reactor-years" of operating experience in the generation of electricity from nuclear power.

This fact was emphasised by Mr. J. C. C. Stewart, Member for Reactors, United Kingdom Atomic Energy Authority, when he addressed an audience of nuclear experts from all over the world at the opening of a nuclear exhibition and conference ("Nuclex '66") in Basle, Switzerland.

"Our experience with gas-cooled graphite-moderated reactors has proved them reliable and safe," Mr. Stewart said. "The lessons learnt in commissioning and operating nuclear power stations through their early years is proving invaluable as new stations are integrated into our national electricity network.

"A young generation of nuclear engineers has matured with the nuclear stations which—to them—are quite 'conventional' in operation.

"We, in the U.K., have placed great emphasis on the development of safe reactors. An independent team of safety experts has devoted some 500 man-years of specialist effort to this work and in my opinion the Advanced Gas-cooled Reactor is the safest power reactor commercially available in the world today.

"The Authority consider that power stations using the A.G.R. could be built close to towns and cities at no greater risk to the inhabitants than there would be from any other industrial project of a similar size and cost.

"At once, a threat to the beauty of remote areas would be removed and atmospheric pollution in our industrial cities would be considerably reduced.

"The first A.G.R. power station is now under construction at Dungeness, and the second will be built at Hinkley Point. Both will be on sites adjacent to existing nuclear power stations, but for the future we consider that there are outstanding technical reasons for greater freedom in siting the A.G.R."

Mr. Stewart also pointed out that commercial nuclear power stations already in operation had been designed to last 30 years.

He continued: "But there is confidence in them exceeding this figure. If this happens some U.K. nuclear power will—by the year 2,000—be producing electricity at an extremely low price based purely on running costs, because at present the capital cost of a nuclear power station in the U.K. is amortised over 20 years".

8th September, 1966

Isotopic power generators

(A similar release is being made by the European Nuclear Energy Agency in Paris.)

DR. R. SPENCE, F.R.S., Director of the Atomic Energy Research Establishment, Harwell, today opened an international symposium on industrial applications for isotopic power generators, jointly organised at Harwell by the U.K. Atomic Energy Authority and the European Nuclear Energy Agency.

More than 200 participants from 17 countries are taking part in a three-day symposium which will survey applications of isotopic power generators for telecommunications, meteorology, oceanography, marine systems, medicine and other fields, and will review the various types of generator now under development in Europe. The main objective of the meeting will be to bring together a wide and varied range of potential users of isotopic power systems so that organisations concerned with the development of such systems can direct future work to the best advantage. Special attention will therefore be given to questions of demand and availability, economics and safety.

The present generation of isotopic thermoelectric power generators use radioisotopes as heat sources and thermocouples to convert heat to electricity. They may be used in a variety of applications where the characteristics of long life, unattended operation and minimum maintenance are important. The first industrial application in Europe is expected to be power sources for navigational beacons, and generators of British design are shortly to be tested under operational conditions by the lighthouse authorities of the U.K. and other countries. The commercial development of other uses of isotopic power generators is expected to follow.

At the end of Dr. Spence's opening address, delegates were invited to an exhibition of isotopic generators and associated equipment by a message, sent from another building, by a radio transmitter powered by an isotopic generator developed at A.E.R.E. The message also announced that isotopic power was now available in the U.K. and that the U.K.A.E.A. could accept orders for the manufacture of isotopic power generators.

Operating isotopic power generators and static exhibits associated with symposium papers are on display. These include six generators made at Harwell, of which three are for operational evaluation by marine navigation authorities in the U.K., Sweden and Denmark. Another important exhibit is an engine developed in Europe which can operate on a variety of fossil fuels and could be considered for use with an isotopic power source.

ENEA Newsletter

The opening of the symposium was also marked by the publication, and distribution to all participants, of the first issue of a specialised Newsletter prepared by the recently created Isotopic Generator Information Centre at Saclay, France. This Centre is jointly sponsored by ENEA and the French Commissariat à l'Energie Atomique, and has been set up in connection with the ENEA study programme on the production of energy from radioisotopes. The aim of the Centre is to centralise all information at present dispersed throughout the many countries and to facilitate the exchange of such information.

The first issue of the Newsletter contains a short statement on its aims and methods, an article on the ENEA study programme and the part the Information Centre is expected to play, an article analysing the development prospects of radioisotope systems for use in space, and a news section collecting together recently realised items concerning isotopic generators. There is also a list of bibliographical references and a table of radioisotopic generators listed according to the isotope used.

Copies of the first issue of the Newsletter are available from the European Nuclear Energy Agency, 38 Boulevard Suchet, Paris 16, France, or directly from the CEA-ENEA Isotopic Generator Information Centre, B.P. No. 2, 91 Gif-sur-Yvette, France.

28th September, 1966

X-rays are safe

The third and final report of the Committee on Radiological Hazards to Patients has been published.

The Committee was set up in 1956 by the Minister of Health and the Secretary of State for Scotland under the chairmanship of Lord Adrian, O.M., F.R.C.P., F.R.S. Its terms of reference were "to review the present practice in diagnostic radiology and the use of radiotherapy in non-malignant conditions, having regard to the Report of the Committee on the Hazards to Man of Nuclear and Allied Radiations, and to make recommendations".

In May, 1959, the Interim Report was published, dealing mainly with mass miniature radiography of the chest. A Second Report followed in December, 1960, which analysed the genetic hazard arising from the use of medical radiology.

In its Final Report the Committee deals with the problem of estimating the dose relevant to any possible somatic hazards arising from the medical uses of ionising radiation.

The Committee report that their findings on the levels of dose relating to somatic effects support the conclusions and recommendations given in their Second Report. The mean annual dose per person from diagnostic radiology is not such that there is any necessity for major restrictions in radiological practice or that the number and type of examinations should be dictated by other than the clinical needs of the patient.

The Final Report of the Committee on Radiological Hazards to Patients is available from H.M.S.O., price 3s. 6d. net.

Atoms at the Abbey

The U.K. Atomic Energy Authority took part in the Science Exhibition from 1st August to 10th September in the Great Hall of Westminster School as part of the 900th Anniversary Year celebrations for Westminster Abbey.

The exhibition, arranged in collaboration with the Royal Society, showed modern scientific and technological developments in relation to the work of the scientists buried in the Abbey.

Rutherford was commemorated by an account of his life and work, and a display by the Rutherford Laboratory.

The impact of atomic energy on society

The following paper was presented by Sir John Cockcroft, O.M., F.R.S., at the Tenth Annual General Conference of the International Atomic Energy Agency in Vienna on 23rd September, 1966.

Sir John Cockcroft, O.M., F.R.S.

I AM honoured and delighted to take part in this celebration of the Tenth General Conference of the Agency. During the course of my evening address to the 1955 Geneva Conference on the Peaceful Uses of Atomic Energy I noted that the United Nations Organisation was in process of giving birth to an offspring—the I.A.E.A.—and hoped that its birth would not be too long delayed. This hope was indeed fulfilled in the following year and I became a member of the Agency's Scientific Advisory Committee during its early years.

During the course of my Geneva lecture I predicted that the speed of development of nuclear energy would be rapid and that the nuclear power stations of 1970 would look as different from those of 1957 as the modern motor car differs from a Model T Ford. I said that there was good reason to believe that in the second decade (1965-1975) the cost of nuclear power would fall below that of power from coal and oil.

We are now seeing the realisation of these prophecies. The nuclear power stations of the 1970s will have outputs of 1,000-2,400 MW in advanced industrial countries and power stations now under construction in the U.K. and U.S. will generate electricity at about 10 per cent. lower costs than those from the most modern coal or oil fired station of similar output which could be built on the same site. The prospects for still further development are extremely good and generating costs will certainly drop to below 0.33d. (4 mills) per kilowatt-hour even with conservative accounting assumptions. The Tennessee Valley Authority in the U.S. have very recently announced that they are to build a 2,200 MW B.W.R. power station using two reactors. The total cost of the projects has been given by the T.V.A. as $116/kW. This reflects the expected economics of scale for larger reactor units and follows the trend of other contracts. The T.V.A. use rather favourable accounting assumptions, no doubt corresponding to their usual practice, of 4½ per cent. interest rates, a 35-year life and an 85 per cent. load factor. On this basis they estimate the generating costs as 2.37 mills/kWh. This confirms the advantages predicted of going to still larger scale nuclear power units. It is not surprising therefore that Britain is planning to install 13,000 MW of nuclear power stations by 1975 and that the Euratom countries will have a similar installed capacity by the mid-1970s and the U.S. three or four times as much. India, Japan and Pakistan are building nuclear power stations of 200-400 MW output and with the short doubling time of electrical load in these countries will no doubt in future build nuclear power stations of greater output bringing greater economic advantages. Nuclear power will not in my opinion be economically worth while for countries who do not have large concentrated loads.

The development of fast breeder reactor power stations already foreshadowed in 1955 through the performance of the U.S.

EBR1 reactor and the U.K. plutonium fuelled zero energy reactor ZEPHYR (which had a breeding radio of two) have been followed by higher powered experimental breeder reactors in the U.K., U.S. and U.S.S.R. and are now leading inevitably to the next stage of constructing 250 and 150 MW(e) prototypes leading in turn, we believe, to 1,000 MW full scale stations in the late 1970s. These are predicted to produce electricity at 0.3d. (3·5 mills) a unit even with conservative accounting assumptions. I must not however trespass any more on the topics on which Dr. Leipunski and Mr. Webster are to speak.

The prospect of obtaining power by the fusion of the hydrogen isotopes seems still, as it was in 1955, at least 20 years away. The long term potential advantages of the project combined with the scientific challenge are however leading to great progress in understanding the behaviour of very hot, dense plasmas. Temperatures of the order of 10 million degrees have been reached and the fusion reaction in deuterium corresponding to these temperatures produces a large number of neutrons which are used for diagnosis of temperature and performance. The task of the experimenter seeking the route to a true fusion reaction is however bedevilled by successive kinds of plasma instabilities. As the experimenter finds a means of overcoming the latest form of instability a further one appears which in turn has to be suppressed. So they have not been able to achieve simultaneously the high temperature, the plasma density and the plasma containment time which are necessary for a fusion reactor to be engineered. So Academician Artsimovich's remarks to the Salzburg Plasma Physics Conference in 1961 still hold: "It is now clear to all that our original belief that the doors into the desired region of ultra high temperatures would open smoothly at the first powerful pressure exerted by the creative energy of physicists have proved as unfounded as the sinners hope of entering Paradise without passing through Purgatory. And yet there can scarcely be any doubt that the production of controlled fusion will eventually be solved. Only we do not know how long we will have to remain in Purgatory".

The impact of nuclear energy on industrial practice has been considerable. The very high standards of reliability and safety required in the operation of nuclear power plants has called for more stringent standards in material specification, in welding techniques, in pressure vessel construction and in fuel element fabrication to obtain the 99·9 per cent. degree of reliability and high burnup which is now required. The new techniques such as vacuum melting and controlled atmosphere sintering developed for fuel preparation and fabrication are also applicable in the non-nuclear field. The good corrosion resistance required of structural materials, fuel element cladding and of the graphite moderator has led to a greater understanding of corrosion processes and to the development of new and improved graphites, stainless and ferritic steel and zirconium alloys. Ceramic materials of high strength and density can now be produced for which there is a growing interest in engineering, electronics and metallurgical industries.

The safety standards of reactors have been enormously increased by the adoption of prestressed concrete pressure vessels; by the integral designs in which the steam generators are contained within the pressure vessel; by fission product absorption systems and by improvement of control systems. Through such developments it should become possible to relax in some degree the rather stringent siting rules which have been justifiably imposed during the early days of nuclear power.

Desalination

One of the by-products of nuclear power stations in the future is likely to be the use of their waste heat for desalination of sea water. Many arid areas of the world are extremely short of water for drinking and industrial uses and already desalination plants using the flash distillation process using fossil fuels to heat the sea water are in operation. During the last decade a great number of desalination plants have been built in such areas with a total installed capacity of about 50 million gallons per day, the largest plant units being about 1-1½ million gallons per day capacity. The cost of desalinated water from plants producing about one million gallons per day at places such as Kuwait with capital charges of 10 per cent. per annum range between 46d. and 67d. per 1,000 Imperial gallons (R. S. Silver, I.A.E.A. Technical Report No. 51). From design studies in the U.K. it appears that with annual capital charges of 8·9 per cent. a 400 MW(e) dual purpose power station could produce about 60 million Imperial gallons per day at a cost of between 44d. and 52d. per 1,000 Imperial gallons with electricity charged at 0·43d./kWh.

Several dual-purpose stations (in Greece, Israel, Mexico, Tunisia, U.A.R. and the U.S.A.) are at present under study. Their combined capacity would be about 550 million gallons per day. The U.S.S.R. are now building a fast reactor dual-purpose power station at Shevchenko to produce 150 MW of electricity and about 30 million gallons per day of water. This is expected to be complete in 1968/69.

Desalinated water may also come into use in some areas in temperate zones by the 1980s. A recent report on water supplies in S.E. England estimated that in 10 years water requirements will be doubled—an increase of 1,100 million gallons a day.

There seems to be little likelihood that desalinated water can be produced at low enough costs for agricultural use. Indeed F.A.O. have said that only when the cost is of the order of 3d. per 1,000 Imperial gallons will the use of desalinated water for agriculture develop on a large scale though for specific purposes 10d. might be paid. Predicted costs will have to be reduced by a factor of 5-10 before agricultural applications are likely.

Radiation for industry

The production of high intensity sources of radiocobalt for industrial applications of radiation is an already established by-product of nuclear power stations. The most important use of radiation for industrial purposes at the moment is for the sterilisation of hospital supplies such as disposable syringes, surgical sutures, surgical scalpels. For this purpose five plants have been built in the U.K., two in the U.S., one in Australia, two in West Germany, one in Canada and more are under construction. All are designed to use cobalt-60 sources ranging from 64,000-2 million curies—giving doses of the order of 2 megarads.

The application to the preservation of foodstuffs is developing In Canada potatoes are given irradiation treatment on a large scale to inhibit sprouting; the U.S. Army issues irradiated canned bacon as a standard ration. Radiation disinfestation of grain can be used in countries where it is handled and stored in large bulks and pilot plant studies are being carried out in the U.S. and Turkey.

There is a potential application in Britain to the elimination of Salmonella from horse meat which is imported at the rate of about 12,000 tons per annum. Doses of the order of 650 kilorads would reduce contamination by a factor of 100,000 at a cost of about 0·4d. per pound (excluding the cost of cold storage). Feeding tests with animals on irradiated horse meat are now being carried out.

Atomic energy has provided important new tools for the physical sciences particularly for structural crystallography and solid state physics. Powerful neutron beams from research reactors are an important complementary tool to X-rays in determining the structure of magnetic materials, chemical compounds and biological molecules since neutrons are especially effective in determining the position of hydrogen atoms and magnetic atoms in crystals. They are also very useful in studying the static imperfections of solids which are of considerable importance in determining their behaviour. They have also been important in the study of the vibrations of crystals since by measuring the change of energy and momentum of the neutrons impinging on the solid, important information about their vibrational states can be obtained. They are also an important tool in the study of liquids. The technological need to study radiation damage processes in reactor components has stimulated the study of all types of imperfections in crystals and created a new branch of solid state physics and of metallurgy. For these reasons there is a need for research reactors producing neutron beams of one or two orders of magnitude higher intensity than those which have been available in the past. Reactors of this kind are coming into commission in the U.S. and the U.S.S.R. There is a Franco-German joint project to build such a reactor and Britain is considering the construction of a High Flux Beam Reactor to be used in collaboration with other European countries.

Radioisotopes such as cobalt-57, tin-119 and tellurium-127 are now being used to apply the so-called "Mössbauer effect" to solid state problems. This is possible because the gamma rays emitted from such sources can have an extremely sharply defined frequency—defined to one part in about 10^{12} of the gamma ray energy. So very minute changes of the frequency produced by oscillating the radioactive source can be detected through the Doppler effect. This can be applied to study a considerable number of physical problems including the study of the electric and magnetic fields near atomic nuclei in solids. The widest application of radioisotopes in solid state physics has been to advance the knowledge of atomic transport in solids by studying diffusion processes.

The availability of helium-3 in large quantities from the irradiation of lithium in reactors has provided a new tool for low temperature physics. Cooling cycles using helium-3 and helium-4 in combination make it possible to reach steady temperatures of ·01 degrees from absolute zero without the use of the elaborate techniques of a decade or so ago. These ultra low temperatures are important in the study of matter in the highly ordered state which occurs at such low temperatures. Helium-3 is also of considerable value as a nuclear projectile in studies of nuclear structure.

Radioisotopes

The impact of atomic energy on chemical science and technology has been considerable. Radiochemistry developed extremely rapidly after the discovery of nuclear fission. Quite apart from the stimulus due to the technical demands of atomic energy projects, radioisotopes became available in greatly increased quantities and new ones were discovered. A new and rapidly growing industry became established for the production of radioisotopes and all kinds of labelled compounds which are widely used in science and industry throughout the world and large scientific and economic benefits have accrued from this. The availability of isotopes of rare elements such as polonium and protoactinium and new elements such as plutonium and other transuranics have led to vastly increased knowledge of the actinide elements. But the benefits to inorganic chemistry are not confined to the actinides. A great deal of new fundamental knowledge arose from the study of chemically important fission products such as ruthenium and zirconium, and our knowledge of the rare earth elements was substantially advanced both because of their technical importance as fission products and through their production in kilogram quantities by means of the new separation techniques developed for atomic energy purposes. The chemistry of the light elements of special nuclear interest such as deuterium, tritium, lithium and beryllium and fluorine has also been greatly stimulated.

The development of radiation chemistry has parallelled that of radiochemistry. There is now a wide range of sources of radiation available to chemists and this branch of science is growing rapidly. The interaction which has recently been taking place with developments in solid state physics is particularly promising.

Atomic energy has given great impetus to analytical chemistry. The techniques of radioactivation analysis, isotopic dilution analysis and polarography have been highly developed in atomic energy laboratories and are now widely applied both in science and industry. Radioactivation analysis is used for routine analysis for trace elements in the petroleum, coal and chemical industries and in semiconductor manufacture. It is used in forensic studies of paint and hair and identification of gunshot residues. A miniaturised automatic neutron activation analysis device is even used in unmanned space research vehicles to study the composition of extra terrestial materials.

The development of atomic energy plants and processes was accompanied by a great deal of research in physical chemistry and chemical engineering which has been of general value. Substantial contributions were made to the theory and design of solvent extraction plants, the principles of fluidised bed processes and the design of ion exchange plants.

Inorganic ion exchangers are possible agents for controlling the condition of high temperature water (in water moderated reactors); very important for corrosion control. Titanium hydroxide has been shown to be capable of concentrating certain trace elements, including uranium, from the sea without itself being dissolved to an appreciable extent. Dr. R. Spence and his colleagues reported to the 1964 Geneva Conference that one site in Britain could produce almost 1,000 tonnes of uranium per annum, assuming adequate absorber performance at a cost of 11-22 dollars per lb. of U_3O_8 (*Nature*, 12th September, 1964). So, these materials may find large scale uses in the future.

One of the most striking consequences of the atomic energy programme was the revolutionary progress which was made in the industrial use of fluorine and its compounds. Elementary fluorine became commercially available through the development of large electrolytic fluorine cells and the plastic polytetrafluoroethylene (PTFE) and the chlorofluoro hydrocarbons are now common articles of commerce.

The utilisation of nuclear radiation in the chemical industry is now beginning to look more promising. Radiation has been used for some time for the cross linking of polymers such as polythene; processes have been proposed for the production of halogenated hydrocarbons and bio-degradable detergents and work is proceeding on the use of radiation for the treatment of plastic impregnated wood to enhance its properties and for the cold curing of paint. It seems likely that the present growth in the application of radiation for sterilisation purposes will ultimately be matched by applications in chemical industry.

The impact of atomic energy on the life sciences has been very great, largely due to the provision of radioisotopes for tracer studies of biological processes. However, I must not trespass on the field of Dr. Aynngar and will confine myself to the effect of the vast amount of research work which has been carried out in atomic energy laboratories directed towards the problems of radiation protection.

The Oak Ridge Biological Laboratories through the work of the Russells have carried out extremely important experiments on the effects of radiation on producing mutations of selected genes in mice indicating that the induced mutation rate is an order of magnitude greater than that found in the early experiments on flies. However, past and current work (Lyon and Morris) at Harwell suggests that the genes selected by the Russells for study may be unduly mutable. The effectiveness of fast neutrons in producing mutations is particularly important as has been shown by recent studies by the M.R.C. Unit at Harwell and at Oak Ridge. So we now assess that a radiation dose of about 20 rem of gamma radiation of 1 rem of fast neutrons will double the spontaneous mutation rate. These studies are important in determining the maximum amount of radiation an atomic energy worker should be allowed to receive during the first 10 or 15 years of his working life so that the chance of producing a genetically deficient child will not be appreciably increased. Arising out of such studies, Ford and Hamerton of the M.R.C. Radiobiological Laboratory at Harwell, developed a method of making mouse chromosomes readily visible for detailed microscopic examination and applied it to human material. As a result of this we now know that a substantial number of human defects are due to chromosome aberrations. For example a triplication of chromosome 21 gives rise to a Mongol child; other chromosome aberrations lead to sex disorders. About one per cent. of our children are born with chromosomal defects. Radiation can lead to chromosome aberrations and it is possible though not certain that a dose of about 40 rem of gamma radiation may double the normal incidence.

Another by-product of the interest in radiation effects has been the realisation that the irradiation of pregnant mothers for diagnostic purposes can give rise to deformities in the embryo and this has led to more stringent restrictions on radiation in the early stages of pregnancy.

Radiation detectors such as whole body counters designed for the study of the radioactive body burden of atomic energy workers have become important diagnostic tools in hospital. An example of this is their use in the study of the ability of individuals to absorb vitamin B12. Pernicious anaemia results from deficiency or malabsorption of this cobalt-containing vitamin.

The development of atomic energy has owed a great deal to international collaboration. The 1955 Geneva Conference provided the first opportunity for an exchange of information on progress in nuclear power throughout the world and also emphasised the great contributions which radioactive isotopes were making to biology. The 1958 Geneva Conference contributed in the same way to collaboration on controlled thermonuclear fusion and many of us will remember the magnificient display of devices and models which were unveiled to show the breadth of the attack on the problems of plasma physics.

Since its foundation the Agency has been very active in promoting collaboration through its training programme; through Fellowships; through the holding of numerous seminars and also through its advisory missions. It also made a considerable contribution to the organisation

continued on page 265

The first ten years of operation of the Calder Hall reactors

By G. R. Howells, M.B.E., General Manager, Windscale, Calder and Chapelcross.

HER MAJESTY THE QUEEN closed a switch at Calder Hall on 17th October, 1956, and for the first time electricity generated from nuclear heat was fed into the British National Grid. This event marked the start of a new phase in the history of electricity generation, and as the Tenth Anniversary approaches, it is well to examine the experience in the operation of the nuclear power station at Calder Hall during this time.

Operation

The primary function of the reactors was to produce plutonium for the military programme and the design was optimised for this purpose. Utilisation of the heat for electrical generation served to reduce the cost of plutonium and provided a system which could be developed for the commercial production of electrical power.

Initial operation was very satisfactory, the commissioning programme was successful, and all design parameters were achieved; the heat output during the first run being 10-15 MW greater than predicted. The reactors proved simple to control with high standards of reliability. Since this time operational effort has been directed to gaining the optimum performance from the plant, and the maximum possible plutonium and electricity output with a high load factor. Improvements in performance are reflected in the heat output from the nuclear reactors, and the changes in thermal power of each reactor during the last 10 years are shown in Fig. 1. This graph shows that during this time the reactor heat output has been increased from 180 MW to 265 MW(Th), and the fact that all ancillary equipment has operated satisfactorily at this increased load with only minor modifications, has underlined the correctness of the decision taken at the design stage, to construct this plant with a reasonable margin for improved performance. Improvements in the performance of the electrical equipment at Calder Works has

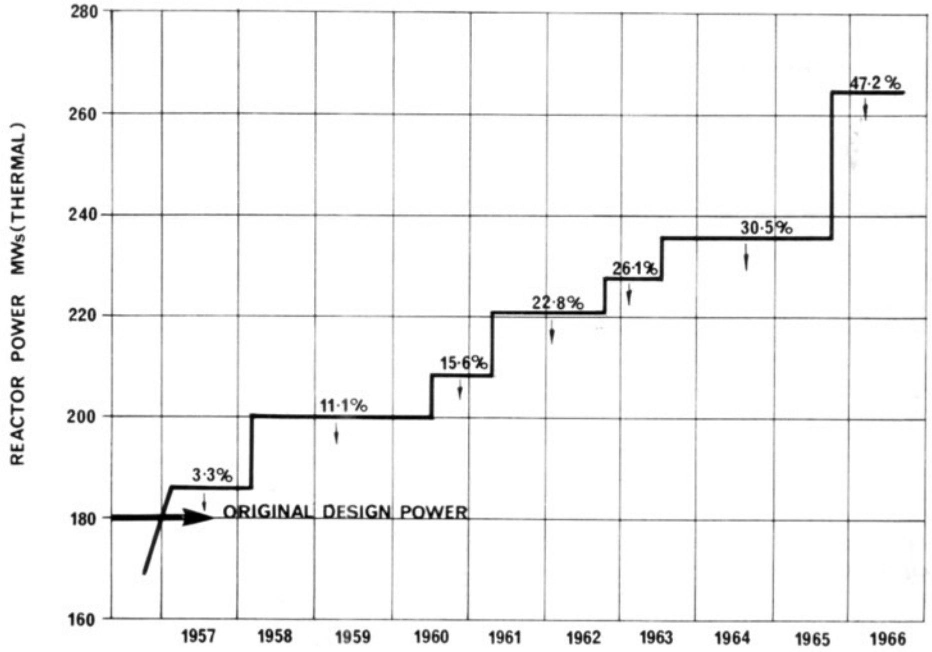

Fig. 1. Reactor power increases achieved

Maintenance, inspection	0·0	0·5	0·6	2·2	0·7	2·6	2·7	2·3	2·1
Experiments, retrims	2·4	3·9	4·7	4·1	2·9	1·0	1·5	1·4	0·9
Faulty fuel—detection/discharge	0·9	2·8	3·1	1·6	0·7	0·1	0·7	0·5	0·5
Reactor trips	2·2	3·3	2·3	1·5	1·4	0·0	0·2	0·1	0·1
Refuelling	15·3	22·5	5·0	6·7	6·2	4·0	2·5	3·9	6·2
Total downtime per cent.	20·8	33·0	15·7	16·1	11·9	8·7	7·6	8·2	9·8

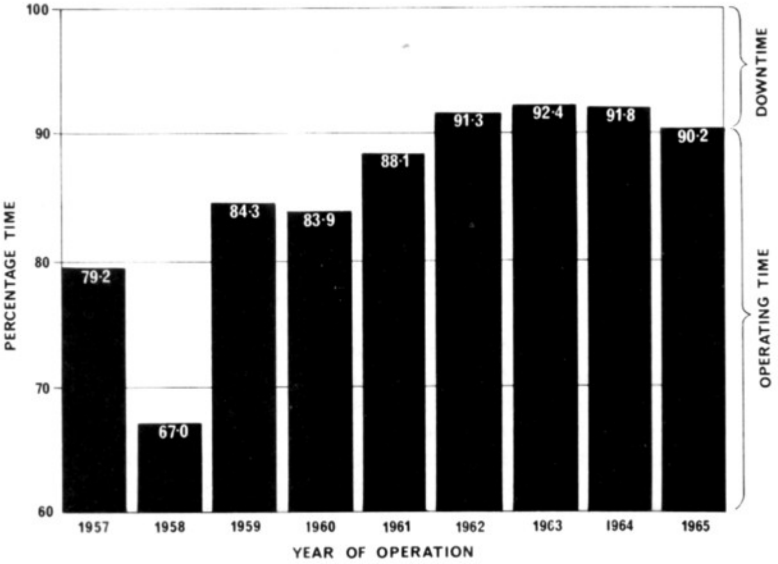

Fig. 2. Reactor availability—Calder

matched that of the reactors, so that it has been possible to utilise all the heat generated. The generating capacity of each turbo-alternator has been increased from 23 to 30 MW(electrical) by reblading a number of stages in the steam turbine.

During this time also, the reactors at Calder and the similar station at Chapelcross have been used to test the performance of fuel elements, and to provide much more detailed information on performance characteristics, safety factors, physics parameters, and the behaviour of the graphite moderator under reactor conditions.

Availability

A great deal of effort has been directed towards improving the availability of the reactors, and reducing the number of employees required to run them, and the results achieved are shown in Figs. 2 and 3. This has largely been accomplished by reducing the refuelling time, and improved methods of maintenance and plant control. Data logging equipment, installed to give quick scanning of temperatures and instrument readings, has eliminated the need for time consuming normal surveys.

Maintenance

Maintenance work on the reactors involved dealing with many items of untried and new design. The range of work covering items such as control rod drives, large variable speed gas circulators, heat exchangers, refuelling machinery, and a wide range of instrumentation and protection gear required a range of specialist skills and training to secure a satisfactory service. All equipment in contact with the reactor core and primary coolant circuit may be contaminated to some degree with radioactive dust, and thus introduces problems of radiation control of personnel on all associated maintenance work.

During early operation of the Calder reactors, a series of failures occurred on the electrical machines used for gas circulator drive. The trouble was repeated flash over on the commutators of the large D.C. machines, and resulted in successive plant outages. The problem was solved by a suitable choice of carbon brushes and meticulous attention to cleanliness of commutator surfaces, avoiding in particular any build-up of carbon dust or traces of oil contamination. Although commutation troubles have been satisfactorily controlled, it is noteworthy that the main cause of loss of generation between refuelling outages is maintenance of brush-gear and commutators on D.C. machines.

Initially it was thought that the inspection of heat exchangers and blower impellers would be required at two-yearly intervals. This was both time consuming and expensive in skilled labour. Experience has shown that this inspection period can be relaxed to four years.

There have been improvements made to simplify and increase the reliability of special handling equipment, and methods of sampling and inspecting the graphite moderator and the internal parts of the reactor and reactor vessel. Great use has been made of television inside the reactor to give better viewing of in-reactor operation, and to reduce the uncertainty of remote control operations.

Attention has been paid to improving maintenance planning, and off-load time has been reduced by the full use of critical path and commuter techniques.

The fuel element

The transverse-finned fuel element originally designed for comparatively low irradiations in the Calder reactors, required only two minor changes to extend its irradiation potential. Firstly, the use of fine-grained magnox for cans irradiated in the lower two channel positions eliminated creep cavitation which gave rise to slowly-

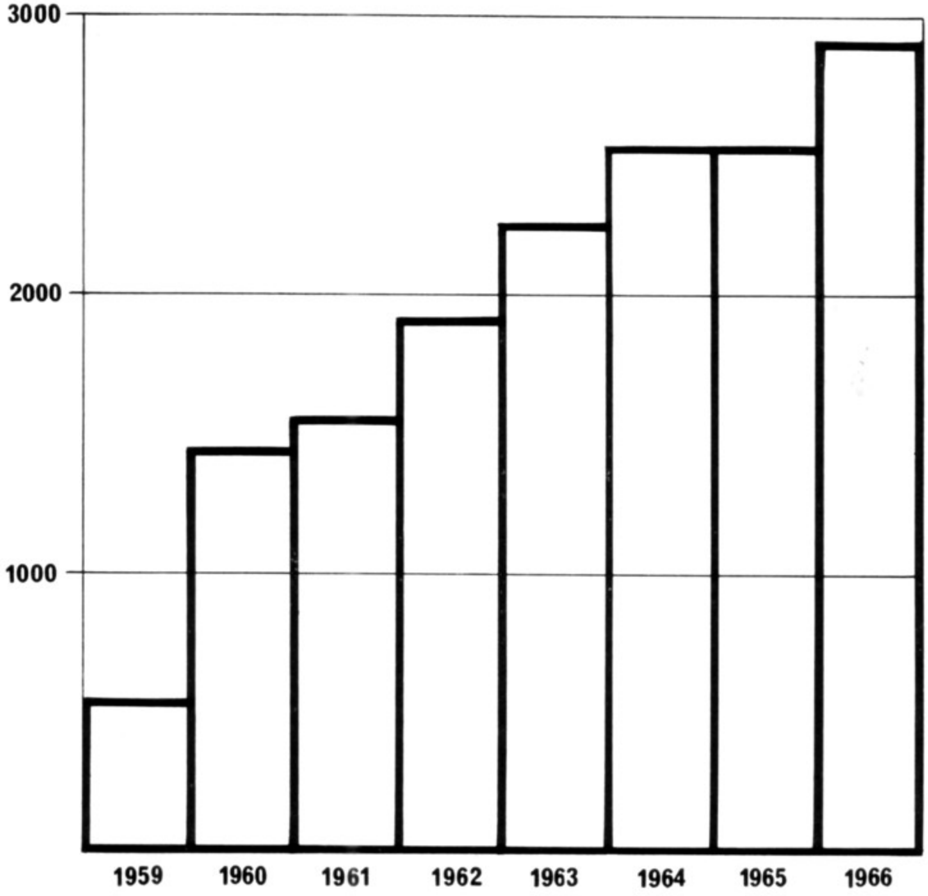

Fig. 3. MWH sent out/employee—Calder

rising signals, and, secondly, the supporting braces were lengthened to reduce the extent of bow in the lower channel positions.

The Calder and Chapelcross reactors have enabled irradiation experience to be accumulated on significant numbers of fuel elements developed for the civil nuclear programme, material problems and design features having been first studied in limited irradiation experiments. Three of the main problems studied in this way have been the elimination of cavitational failures, stability under the coolant gas forces, and strain interactions due to differential thermal expansion.

The cavitational failure problem was solved by the use of fine-grained magnox, although an alternative canning material containing zirconium was at one time favoured because of its increased ductility. However, on irradiation this alloy was found to allow the diffusion of plutonium to the outside of the can, particularly from the higher temperature elements, and this contamination gave signals on the burst cartridge detection gear (B.C.D.G.).

Irradiation limits

The irradiation limits of the magnox fuel elements are determined by the enhanced swelling of the uranium bar, and by the durability of the can under reactor conditions. Improvements in performance have resulted from changes in manufacturing techniques, small design changes and the use of sensitive reactor techniques for the detection of potential failures. A maximum life of 6,000 MWD/T of a fuel element is now expected.

Herringbone cans

Some three years ago a study was initiated to assess the merits of loading a new type of fuel element can in Calder and Chapelcross reactors to optimise the fuel element design and fuel cycle to achieve lower operating costs. The emphasis in the study was to adopt, with the minimum of modification, an existing design of element so as to reduce the development and proving work required for its introduction. It was found that a can with herringbone type fins on its surface offered the greatest improvement in heat transfer and lowered the flow resistance of those studied. In addition, its improved stability obviated the necessity for a stabilising device and avoided a consequent loss of reactivity. This element was first loaded into Calder Reactor II in September, 1965, and gave the expected increase in reactor heat output.

The B.C.D.G. equipment has very adequate sensitivity to give early warning for all types of failure of fuel element cans, with the exception of the so-called "Fast Bursts". These are very infrequent and occur when there is a build-up of oxide inside the can due to diffusion of hot gas through a very long leak path associated with a minor weld defect without a measurable discharge of gaseous fission products. The resultant overheating causes a very rapid burst of the can, and a sharp rise in signal. New fuel is checked for this type of defect immediately after start up, by reducing the coolant pressure, thus causing a differential pressure and a flow of gas from the can. An alternative technique is to impose a small amplitude power and temperature change by reducing blower speeds, which has the same effect of forcing out short-lived fission product gases. Since the above techniques were introduced for checking new fuel after loading, there have been no fast failures in the Calder and Chapelcross reactors.

Graphite

A great deal of information has been obtained about irradiation-induced property changes in graphite from an examination of the moderator of the Calder reactors. Initially a large programme of graphite monitoring was undertaken based on special graphite specimens loaded into the reactors. As this work proceeded it became clear that changes in weight, mechanical properties and thermal conductivity, are unimportant to the safe or economic operation of the Calder reactors.

Physics parameters

Physics measurements made on the Calder and Chapelcross reactors give a better understanding of reactor behaviour and provide data for general operational requirements.

Much of the original work concerned the verification of methods of reactor physics calculation for steady state and kinetic studies. This included measurements of reactivity changes and temperature coefficients of reactivity as a function of irradiation, changes in reactor stability, and measurements of reactor transient responses to system perturbations. The work also involved the development of methods of measurements which were used in commissioning programmes on the commercial reactors.

Theoretical models

Whilst many measurements in support of the safe and efficient operation of a reactor are directly of those quantities of concern, there are others whose objective is also the comparison with theoretical models from which extrapolations (usually in terms of irradiation or temperature) can be made. Thus the operation and safety of Calder reactors do not depend upon empirical measurements alone; considerable reliance is placed on computer codes which represent the reactors as two- or three-dimensional models.

Apart from the well-known applications of reactor physics data to the assessment of shut-down reactivity, the practical problems of control and kinetics and the optimisation of fuel cycles, a considerable amount of effort has been devoted to the study of flux and power distribution in the Calder reactor. This led in the first instance to a method of predicting steady state fuel temperatures, which could take into account all individual aspects of reactor loadings, including variations in irradiation. A more rationally-based temperature criterion was then formulated which took account of each channel in the reactor. Gains in output resulted when the reactor power distribution was optimised within this new criterion, giving a better control of fuel element temperatures.

Reactor output

The net electrical generation of the eight Calder-Chapelcross reactors is given in Fig. 4. This shows an increase from the start of the first reactor in 1956, until 1960, when all eight reactors were in operation. Improvements in operating techniques, increased output from the reactors, and better load factors, have all contributed to a steady increase in net generation until the present time. A more detailed knowledge of the operating parameters, and better understanding of the reactor systems have, at the same time, given safer and more reliable operation.

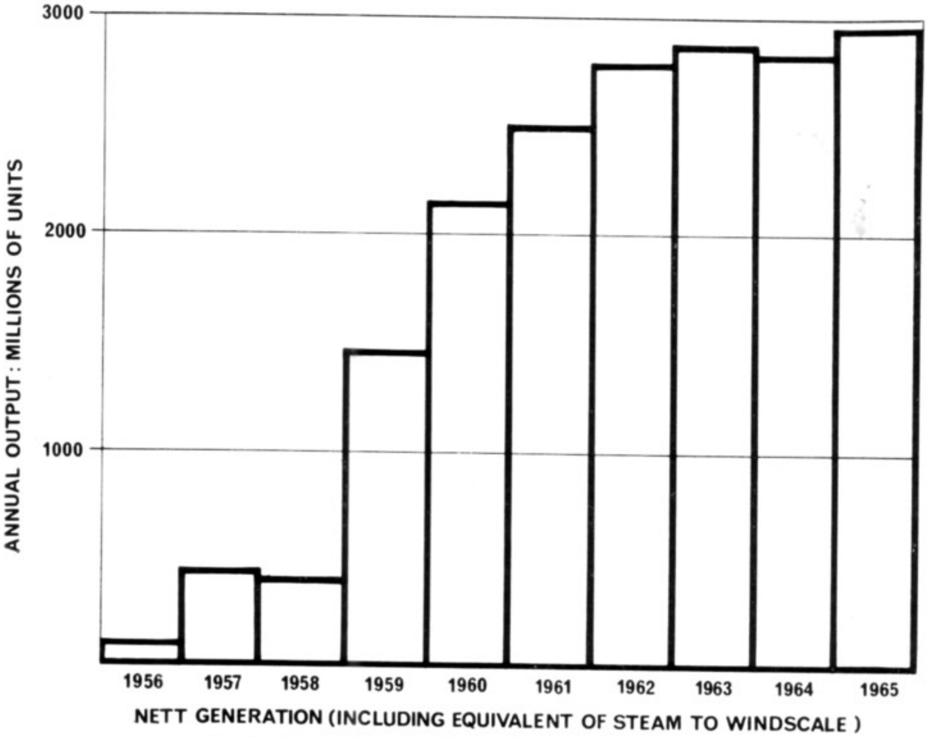

Fig. 4. Annual Output—Calder Hall and Chapelcross

A.H.S.B. Reactor Safety Course No. 5

THE fifth Reactor Safety Course will be held at the Post-Graduate Education Centre, Harwell, from 5th to 30th June, 1967. About 100 scientists and engineers, including over 70 from overseas, have participated in the first four courses.

The course, which A.H.S.B. propose to hold annually in future, is designed with the dual objectives of describing the safety principles and evaluation techniques developed in the U.K. and of providing an opportunity for senior safety specialists of different countries to exchange views on reactor safety problems. It is intended primarily for engineers and scientists with several years' experience, preferably in reactor design or operation, who are concerned with the safety assessment, regulatory control or inspection of reactors.

The principal sections of the course cover the safety aspects of the main reactor systems; pressure circuit and containment engineering; control and instrumentation; and fission product release. The introductory and concluding sessions include lectures on the U.K. nuclear power programme; legislation and organisation; siting and emergency procedures; the analysis and reporting of reactor accidents; and reactor accident simulation techniques.

The course lasts four weeks and includes discussion periods, films and visits to A.E.A. sites and a C.E.G.B. nuclear power station. Most of the lectures are given by A.H.S.B. staff but a number are given by lecturers from other A.E.A. Groups, the C.E.G.B. and Universities. A manual containing notes on some 60 lectures is sent to the students well in advance of the start of the course, so that they can, if they wish, carry out preparatory study.

Details of the arrangements for the fifth Reactor Safety Course may be obtained from Mr. D. A. French, United Kingdom Atomic Energy Authority, Authority Health and Safety Branch, 11 Charles II Street, London, S.W.1. The closing date for applications will be 28th February, 1967.

Members of Reactor Safety Course No. 4 held at the Post-Graduate Education Centre, Harwell, from 6th June to 1st July, 1966. Back row, left to right: J. J. Clifton, U.K.A.E.A.; R. G. Capern, Canada; A. Lumetti, Italy; W. Marshall, C.E.G.B.; P. M. J. De Wringer, Netherlands; A. Turricchia, Italy; F. X. Gavigan, U.S.A.; H. G. Seipel, Germany; F. Ferron, Euratom. Centre row: C. W. Thomel, Germany; T. J. Molloy, Canada; H. J. H. Clarke, Ministry of Power; W. G. Warwick, Vulcan Boiler & General Insurance Co. Ltd.; J. Brown, U.K.A.E.A.; R. Naegelin, Switzerland; E. W. Fee, Norway; H. L. Gjørup, Denmark; E. T. R. Nilsson, Sweden; R. Engevik, Norway. Front row: R. G. Lea, U.K.A.E.A.; G. Toccafondi, Italy; P. V. Crooks, Australia; N. Bernot, Yugoslavia; C. W. Garth, Ministry of Power; A. Osipenco, Belgium; A. Massera, Euratom; J. Hinkley, C.E.G.B.; D. Smith, U.K.A.E.A.; S. Sørenson, Norway

The First Congress and International Meeting of The International Radiation Protection Association (IRPA)

By E. W. Jones, Atomic Weapons Research Establishment, Aldermaston.

THE potentially harmful effects of ionising radiations have been recognised almost since the pioneer discoveries of Becquerel and Roentgen in the middle of the last decade of the last century. The need to provide protective measures and to limit radiation doses was recognised and organisations were gradually set up to assist in this.

The United Kingdom played a prominent part in these activities which led to the formation of the now International Commission on Radiological Protection in the '20s. The great expansion of work involving radioactivity and radiation which occurred during the 1939-45 war served to reinforce the need to achieve high standards of protection and to limit radiation doses. As practical measures a number of physicists, doctors, engineers and chemists became associated with this protective work, and in helping and advising their medical colleagues, and these individuals became collectively known as "Health Physicists" or sometimes "Radiation or Radiological Protection Officers".

In 1955 the Health Physicists in the U.S.A. met and formed "The Health Physics Society", intending it to be an international body, which would sponsor meetings and publish an international journal. The Health Physics Society grew, and did to some extent attract international membership, but its main achievements were in its famous and large annual meetings in the U.S.A., in its sponsorship of the journal, *Health Physics*, and in its value as a meeting ground for radiation protection staff in the U.S.A. and Canada.

In the United Kingdom many health physicists, hospital physicists and doctors were members of the Health Physics Society, and they formed in 1963 a U.K. Section of the Health Physics Society, which was named "The Society for Radiological Protection" (S.R.P.). This Society joined the British Institute of Radiology (B.I.R.), British Occupational Hygiene Society (B.O.H.S.), Faculty of Radiologists (F.R.), Hospital Physicists Association (H.P.A.) and the Institute of Physics (I.P.P.S.) on the *Joint Health Physics Committee*, which, with representatives of the United Kingdom Atomic Energy Authority, the Central Electricity Generating Board and the Radiological Protection Service (R.P.S.), met from time to time to co-ordinate and suggest subjects of common interest for symposia in the U.K.

In the early '60s it was apparent that a truly international body representing health physicists, radiation protection officers and those engaged in medical, veterinary and research activities could only come about with the formation of a new association organised on fully international lines (with the Health Physics Society as a member of the Association, representative of the U.S.A. and perhaps Canada). As a result of a number of meetings in Europe and the U.S.A. the decision to found such an Association was taken and a provisional list of officers and a Provisional Executive Council were drawn up, with the objective of formally inaugurating the new Association at an International Symposium and a General Assembly to be held in Rome in September 1966.

The new Association was to be called "The International Radiation Protection Association" (I.R.P.A.), and would be formed with Associate Societies representative of countries or groups of countries, and with individual members and associate members, who are members of I.R.P.A. through and by virtue of their membership of one of the Associate Societies. This unique federal/individual membership system ensured that both the views of Associate Societies and of individual members could be taken into account. Membership of I.R.P.A. would also entitle Members and Associates to subscribe to *Health Physics*, at the membership rate, through their Associate Societies.

To take part in this Association, a not dissimilar federal Association was formed in the U.K. to take over the work of the existing Joint Health Physics Committee and to enable those covered in the U.K. to join I.R.P.A. through their existing Societies, including the S.R.P. (now no longer a section of the Health Physics Society). This Association is the British Radiological Protection Association, and has as founder members B.I.R., B.O.H.S., F.R., H.P.A. and S.R.P., together with the Society of Radiographers and the Association of University Radiation Protection Officers. The U.K.A.E.A., C.E.G.B. and R.P.S. send observers to its committee meetings. Individuals become Participating Members or Associates through their parent societies, and thus automatically become members of I.R.P.A.

The First Congress and International Meeting of I.R.P.A. took place at the invitation of the Italian Radiation Protection Society this year. The Italian Society had been able to enlist valuable aid from the Italian Atomic Energy Department, from the City of Rome and various Italian Government departments. The meeting also received financial or other support from the following International Organisations: I.A.E.A., I.C.R.P., I.C.R.U., W.H.O., I.L.O., O.E.C.D., Euratom, Eurochemic, E.N.E.A. and C.E.R.N. and from the Health Physics Society. Dr. W. G. Marley (U.K.A.E.A.), the only non-Italian on the Meeting's Board of Management, was Chairman of the Scientific Programme Committee.

This First Congress and International Meeting of I.R.P.A., from 5th to 9th September, 1966, showed that an international bond linking radiation protection societies of many different countries in the world has been successfully established. Over 600 delegates and 200 associates representing 15 of I.R.P.A.'s Associate Societies and drawn from 39 countries and nine International Organisations gathered at the Cavalieri Hilton Hotel on Monte Mario, one of the Seven Hills of Rome, to discuss all aspects of radiological protection and allied subjects. There were 40 delegates from the U.K., including eight senior health physicists from the U.K.A.E.A. Groups.

At the opening ceremony the Congress President, Signor P. Caldirola, referred to Rome's ancient tradition of progressive thinking and its modern association with the work of Enrico Fermi. Dr. K. Z. Morgan, the Chairman and President of I.R.P.A., recalled that the term "health physicists" originated in the Manhattan Project in Chicago in 1942 and spoke of the early hopes that the Health Physics Society in the United States would lead in due course to a truly international association. He reminded delegates that health physicists had a positive role to play in promoting the safe development of the benefits of atomic energy and radiation.

After the opening plenary session, which was addressed by Dr. K. Z. Morgan and by Dr. E. E. Pochin, Chairman of I.C.R.P., the discussion sessions were held in two concurrent series in separate halls, in order to cope with the large numbers of papers presented and the wide range of interests among the delegates.

Scientific programme

It is possible to mention only a small selection of the papers here. (The full proceedings are to be published by Pergamon Press.)

In a session devoted to *Basic Studies of Radiation Effects*, Booz (Euratom) reported an investigation of energy transfer by alpha particles to tissue-like material on the subcellular scale. Tissue-equivalent gas at low pressure in a small diameter proportional counter was used to simulate tissue filaments down to 100 Å diameter. At the lowest pressure, rather large corrections had to be made for changes in the fraction of the counting space involved in electron multiplication. The results show that the LET normally ascribed to alpha particles has no meaning on the micro scale, the energy transferred per 100 Å varying widely up to 40 keV. Studies of numbers of chromosome aberrations in human blood cells following irradiation *in vitro* and *in vivo* were reported by a number of workers. Good correlation with dose was observed at levels relevant to accident dosimetry and some correlation was reported in studies made at occupational exposure levels.

The sessions on *Applied Radiation Biology* and *Internal Emitters* revealed widespread interest in the many problems of estimating organ dose due to contamination of the body. Spiers (U.K.) showed that in order to assess the significant dose from beta emitters to trabecular bone it is necessary to examine and measure the detailed structure of the bone tissue. His method yields data which suggest that marrow dose would be the limiting factor for Sr-90 + Y-90 while for Ca-45 it would be dose to bone. Animal experiments in the U.S.A. on the retention of inhaled plutonium dioxide have given evidence (Cassaret) that aggregation of five particles takes place in some regions of the respiratory system shortly after inhalation and have also shown (Bair) that the physical-chemical state of the oxide particles can affect the quantitative translocation of the material in the body by factors between 2 and 10. A number of papers dealt with the assessment of inhalation exposure in man. Laurer (U.S.A.) described a novel scintillation technique employing optically bonded crystals of CsI and NaI, for *in vivo* measurement of low energy photon emitters. Brodsky (U.S.A.), Ziemer (U.S.A.) and Schultz (U.S.A.) described case studies of inhalation of plutonium-americium, europium oxide, and enriched uranium oxide respectively while Lister (U.K.) reviewed the results of biological sampling following a number of plutonium incidents and suggested a useful approximate relationship between early nose-blow samples and subsequent excretion samples. In the discussion arising out of these papers questions were raised about the definition of "solubility" for inhaled radioactive aerosols. It appears that the term has no precise meaning in this context and that it would be more logical to use another term such as "transferability".

After accidental contamination of the body it may be desirable to administer substances which can accelerate the removal of a particular element from a critical organ or from the whole body. Blum and Eisenbud (U.S.A.) showed that thyroid dose from I-131 which has already entered the system can be dramatically reduced by giving stable potassium iodide orally to block further uptake into the gland and injecting thyroid stimulating hormone to hasten turnover of the existing thyroid burden. With this combined treatment the effective half-life in the thyroid in a typical case was reduced from six days to 2·6 days, while administration of either substance alone gave little or no reduction in effective half-life. The regimen was recommended only in cases where the thyroid burden is greater than 1 mc I-131.

In the sessions on *Dosimetry* rapporteurs dealt with groups of papers on film badge dosimeters and luminescent dosimeters. Large-scale film badge services, employing multiple filter systems for energy determination and using automatic data processing, are established in several countries. A good deal of progress has been made in the development and use of photo and thermoluminescent dosimetry but the discussions seemed to indicate that there is further work to be done and that it is too early to make firm pronouncements about the place of photo and thermoluminescent dosimetry in relation to film badge dosimetry.

Safe working

A large number of papers was included under the heading *Operational Health Physics and Contamination of Working Areas*. Many of these reflected the fact that many years of experience of the operation of atomic energy establishments and nuclear power stations can now be reviewed. In general they amounted to a history of safe working and successful application of health physics precautions in cases of accidents even when the latter gave rise to widespread contamination of plant. Cordes (U.S.A.) described the results of an experiment in which two SNAP 10A/2 space reactors were deliberately destroyed by critical excursions of about 50 MW secs; one in the open and the other below one metre depth of water. In the underwater destructive test the containment of fission products by the water proved almost perfect; only 4 per cent. of the noble gases and virtually none of the other fission products were released. This suggests that the safety factor provided by water immersion may have been grossly underestimated in many safety assessments for critical assemblies.

The sessions on *Spectrometry and Instrumentation* revealed some interesting and ingenious developments. Lippert (Denmark), using a large germanium detector with a sodium-iodide scintillation counter in anti-coincidence, achieves detection limits comparable with scintillation techniques as well as very high energy resolution. Yamoaka *et al* (Japan) described a high resolution detection system for plutonium in wounds. Spectral data are fed into a computer programme which derives the amount of plutonium and also its depth below the skin. It was not clear how this method would be affected by self-absorption in discrete particles of plutonium but this aspect and instrumental considerations were discussed by Jones and Saxby (U.K.). Srdoc (Yugoslavia) has developed a multiple parallel plate counter, filled with neon and bromine, which can operate at up to 10^3 R/h in the Geiger-Muller mode and up to 5×10^5 R/h in the proportional mode. A paper by Musyck (Belgium) which unfortunately could be read in title only, described an improved system for uranium analysis by fluorimetry, exploiting the relatively long afterglow of uranyl salts to obtain selectivity. The principle used improves the detection sensitivity by two or three orders of magnitude.

Criticality accident

The whole of Thursday afternoon, 8th September, was devoted to reports by Belgian and French scientists on a criticality accident which occurred in the VENUS experimental reactor at Mol, Belgium, at the end of 1965. It arose from procedural errors in moving absorber rods in the core. The one man who was irradiated was transferred promptly to the Curie Foundation Hospital in Paris. Detailed dosimetry studies using phantoms showed that the dose was highly non-uniform, ranging from 4-5000 rads at the left foot to about 200 rads at the middle of the trunk. A detailed report was given of the clinical treatment (which did not include bone marrow transplantation as some six inches of low-irradiated spinal column gave a sufficient reserve of viable marrow) and progress of the subject over a period of six months culminating in his discharge from hospital with the loss of one leg amputated at mid-thigh.

Concluding ceremony

In the closing ceremony Congress President Caldirola paid special tribute to "the six pillars of the organising committee". He then handed to President K. Z. Morgan a silver bell presented by the Italian Association for Health Physics and Radiological Protection and asked him to bring it to the next Congress. Speaking of the immediate future President Morgan said that an important task for the new council would be to extend the membership of I.R.P.A. and he looked forward to seeing 30 or more national societies representing some 5,000 radiation protection officers represented at the next Congress in the U.K. in 1970, when Dr. W. G. Marley will be the Vice-President responsible for the organisation.

General Assembly of I.R.P.A.

On the afternoon of Wednesday, 7th September, elected Delegates of the 15 Associate Radiation Protection Societies met in a General Assembly at which I.R.P.A. was formally inaugurated under the Presidency of Dr. K. Z. Morgan with Mr. Y. Nishiwaki as Vice-President, Dr. W. G. Marley as Vice-President for the affairs of the Second Congress, Dr. D. Bonet-Maury as Executive Officer, Dr. P. Courvoisier as Treasurer and Dr. W. S. Snyder as Publications Director, and with six councilmen representing the body of health physicists throughout the world. It was resolved to hold the second congress in the United Kingdom in 1970. The U.K. was represented by five delegates, and there were in addition two U.K. members on the Provisional Executive Council—of these the two councilmen and one delegate were U.K.A.E.A. senior health physicists (Dr. W. G. Marley, Dr. B. A. J. Lister, Mr. W. N. Saxby). Dr. E. E. Pochin and Dr. F. D. Sowby were present as observers.

Technical exhibition

Throughout the week of the Congress, delegates were able to visit a technical exhibition which was held in the foyer of the conference halls. A number of firms and research centres showed instruments, dosimetry systems and literature related to radiological protection, the outstanding display being that staged by the U.K.A.E.A. which was by far the most varied and largest stand in the exhibition.

Non-technical functions

Despite the large number of scientific papers to be discussed it was envisaged that delegates would not spend the whole of their stay in Rome within the conference room, and the Italian hosts had accordingly arranged an excellent programme of social functions and amenities. There were visits to Italian nuclear centres, sightseeing tours for the ladies, and evening receptions at some of the most beautiful and historic buildings of the city.

On Saturday morning, 10th September, His Holiness Pope Paul VI received delegates and their wives at a private audience in his summer palace at Castel Gondolfo. He spoke warmly of the important work being done by health physicists throughout the world and pronounced his blessing on the activities of the Association.

Dr. E. Bretscher, C.B.E.

"*. . . In view of the impending retirement of Dr. E. Bretscher, Dr. B. Rose has been appointed Head of the Nuclear Physics Division and will take up his appointment on* 1*st June. . . .*"—*Extract from Harwell Notice No.* 106 *dated* 14*th March*, 1966.

ON an evening during the early years of the second world war, an air-raid warden patrolling the Cavendish Laboratory site noticed a red warning light burning over the door to the cyclotron building. When the cyclotron was closed down on the outbreak of war the light had been forgotten and had remained to mark, in unspoken defiance of the blackout, the fact that a small band of scientists had convinced the government that nuclear energy was a serious possibility and that nuclear research was restarting at Cambridge. That warden can scarcely have been aware of the importance of this occasion, and it is doubtful if any of the physicists working inside then had much more than an inkling of the effect their work would have on the world. History does not record whether Dr. Bretscher was actually present at this incident, but there is no doubt that he was one of the leading members of the team trying to make nuclear energy a reality.

Egon Bretscher comes from an old Zurich banking family, and it has been our good fortune that he did not follow the family tradition, but in 1921 entered the Technische Hochschule—familiarly known as E.T.H.—to study chemistry, becoming in 1925 a research assistant in organic chemistry. However, it was not long before he changed his discipline and in 1928, after a year spent at Edinburgh University, we find him working as demonstrator in the Department of Experimental Physics at E.T.H., where he remained until 1933. However, the exciting discoveries in nuclear physics being made at Cambridge by Rutherford attracted him and the award of a Rockefeller fellowship in 1934 brought him to the Cavendish Laboratory for a year and, in 1936, at the invitation of Lord Rutherford he returned to England, this time to stay.

The first year of the war must have found little change at Cambridge. True the Examination Schools had become a hospital, the just-built Austin wing of the Cavendish Laboratory had been requisitioned and Cockcroft was away at a radar (then radiolocation) establishment*, but there were undergraduates enough to teach and by then Dr. Bretscher was lecturing on Atomic and Nuclear Physics to final year students as well as demonstrating in the laboratories. However, nuclear fission had already been discovered† and although nuclear physics research at Cambridge was practically at a standstill, with the cyclotron closed down and the tall 2 MeV Cockcroft-Walton generator dismantled for fear of damage by bombing, it was to be restarted in 1940 under Government aegis, and for the first time with a practical objective in mind. From the start Bretscher played a leading role‡ in the U.K. work to establish the feasibility of a nuclear chain reaction, and this work reached a peak during the last months of 1942 with Chadwick, Frisch, Feather, Kinsey, von Halban, Peierls, Kemmer, Pickavance and Kowarski, to mention only a few, all being involved. However, around this time it became clear that only in the U.S. could the resources and effort to liberate nuclear energy be found, and there was a progressive transfer of staff to the laboratories in Canada and the United States. Dr. Bretscher left for Los Alamos on 1st February, 1944, his departure coming as a blow to the staff of the H.T. laboratory.

Although involved from the start, Dr. Bretscher was never fully reconciled to the implications of the successful manufacture of the atomic bomb. It was perhaps ironic, then, that at Los Alamos he found himself working on the reactions of tritium to establish the possibility of the hydrogen bomb, which even at that time was being seriously considered. It must therefore have been with mixed feelings that he first saw the immense number of α-particle pulses from the reaction of tritium and deuterium, which told him not only that he was observing a reaction with a cross-section larger than any known charged particle reactions, but also that the hydrogen bomb was feasible.

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*J. D. Cockcroft was working at A.D.R.D.E. in 1939 and was appointed Chief Superintendent in 1940.

†By Hahn and Strassmann in 1938.

‡Dr. Bretscher was in charge of the team measuring fast neutron cross-sections using the 1 MeV Cockcroft-Walton generator.

Nobody who worked in Los Alamos during that period could remain unaffected by the tremendous vitality that was produced by this concentration of the world's nuclear scientists—a walk through the corridors reading the name-plates on the doors was akin to scanning the names in the physics section of a bookshop—and Bretscher must have been very tempted to stay in America. Nevertheless, although he remained for a year after the end of the war, perhaps because he never completely came to terms with the American way of life (rumour has it that the guard at the Los Alamos gate once wrote "walking!!" opposite his name in the record book) or perhaps because he preferred to send his growing family to school in England, he did return to England in October 1946. However by then Otto Frisch had been appointed head of the Nuclear Physics Division and it was to lead the Chemistry Division that Bretscher came to Harwell. It was not until Frisch left to take a chair at Cambridge that Bretscher became head of Nuclear Physics, the post which he held until his resignation, and in which he is best known.

Harwell in 1947

In 1947 the Division—and indeed Harwell—was very different from today. Practically the only buildings were those from the original R.A.F. station, and the reactor area did not exist. GLEEP had just been built in Hangar 8, BEPO was still not critical and the principal nuclear physics instruments were the 5 MeV Van de Graaff under construction in the old link trainer—later to be moved to Hangar 8—and the 170 MeV cyclotron, which was being built by General Physics Division, and in fact remained with them until the Division was disbanded. All experimental reactor development was at that time carried out within the Nuclear Physics Division and the chief preoccupation of the Theoretical Physics Division was the performance of the production reactors planned for Windscale.

Such was the Division when Bretscher joined it. Although reactor development later split off into the Reactor Division, and when this became too small into the Winfrith establishment, the Nuclear Physics Division still had a major role to play in the nuclear energy field. While recognising that unless there was a healthy proportion of fundamental research Harwell would become sterile, Bretscher's chief contribution was nevertheless his very clear conviction that reactors could only be properly understood and designed when we had accurate and detailed measurements of all the nuclear cross-sections involved. Up to then, reactors were largely considered from a phenomenological approach (i.e. the use of "correlations"). To Bretscher this was wrong; reactor physics could better be summed up in the equation

$$\text{Reaction rate at any point in space and time} = \int_0^\infty \text{Ø}(E)\, \Sigma(E)\, dE$$

where $\text{Ø}(E)$ and $\Sigma(E)$ are the neutron spectrum and the cross-section respectively. He accordingly initiated a programme within his Division aimed at making both the spectrum and the cross-section available to the reactor designer. However, his efforts were not confined to Harwell. Bretscher was a principal proposer (and member) of the original Tripartite Cross-Sections Committee at which the U.S., the U.K. and Canada discussed the cross-section needs and which took co-operative action to obtain the samples of rare isotopes needed to measure these. Out of this committee grew the European American Nuclear Data Committee, on which Dr. Bretscher served continuously and which he chaired from 1963 to 1965. It is not too much to say that the present world-wide acceptance of the "microscopic" approach to reactor physics is in very great measure due to the activities of Bretscher and his colleagues.

A man as individual as Dr. Bretscher could not spend 20 years at Harwell without leaving behind many legends, apocryphal though they may be. No one yet succeeded in translating his dissertation—it cannot be called less—each time he hit his head on the strategically placed steam trap outside his office, though as he was over six feet tall the trap may possibly be excused. It is interesting, too, to speculate whether he really once served teepol at lunch, while his wife washed the dishes with the cider, and many people will remember his fur-hatted figure riding round the establishment on the bicycle brought with him from Zurich in 1936. He would never drive a car himself—and in present conditions who can blame him—but his black Ford, bought in his Los Alamos days and which he refused to part with, was a familiar sight in the district.

Scientific Assistants School

Dr. Bretscher felt keenly the responsibility to educate the junior staff at Harwell and the Scientific Assistants School which, was founded by him and remained in the Nuclear Physics Division until this year, has been a model for similar schools in the Authority. He was also a firm believer in the value of the exchange of staff and ideas between laboratories, and has not only regularly arranged for members of his Division to work in American and European laboratories but has attracted to Harwell many visitors, several of whom were of professorial status. He was awarded a C.B.E. in the 1966 New Year Honours List in recognition of his services to science.

The Nuclear Physics Division of today is very different from the Division he took over in 1947. Gone is the responsibility for reactor physics and gone are many of the faces. As compensation he has left the two new Van de Graaff machines, one of them a Tandem, and an electron linac (the last of a series of three) which, together with its booster target, has provided much of the nuclear data for the reactor programme. What the future may hold is not always easy to see, but one thing is certain, Harwell will never be quite the same without Dr. Bretscher.

Solvent extraction

SOLVENT extraction is today the dominant technique in the modern nuclear process industry, for uranium ore beneficiation plants at one extreme to fission product separation and transplutonium element separation at the other. It was in this context that the U.K.A.E.A. sponsored the 1965 International Conference on the Chemistry of the Solvent Extraction of Metals, at Harwell. The complete record of the conference, edited by H. A. C. McKay, T. V. Healy, I. L. Jenkins and A. Naylor, has now been published by Macmillan & Co. Ltd., Little Essex Street, London, W.C.2 (price £5 5s., postage 3s. extra). This book will be of interest not only to the nuclear industry but also to the many other industries in which solvent extraction is used to separate and purify metals.

The impact of atomic energy on society

continued from page 252

of the 1964 Geneva Conference.

Nuclear power development in many countries seems likely to be based for the next decade on the supply of designs and critical components of nuclear power stations from countries advanced in the art to those who have started nuclear development later. The user country is usually responsible for civil engineering work and such components as can be constructed locally (or bought in the cheapest market). The country carrying the design responsibility usually provides the training for reactor operating staffs and is responsible for the commissioning of the nuclear power station and for dealing with early commissioning troubles. This position will change with the increasingly widespread knowledge of nuclear technology and the supply of information may then be provided through normal commercial licensing procedures.

A large number of the nuclear power stations of the world will require enriched uranium fuel elements. This uranium of low enrichment seems likely to be supplied from large scale diffusion plants such as those in the United States and Britain. Fast reactors can use plutonium advantageously and their development will involve a supply of plutonium on the scale of several tons for a 2,000 MW power station. This plutonium can only come initially from the thermal reactors of nuclear power stations, and is already being supplied in commercial quantities for zero energy and experimental fast reactors. A large scale base of thermal reactor power stations will be needed to provide plutonium for the growth of fast reactor installations in the future.

Fuel elements are likely to be supplied for some time by the organisation responsible for the supply of nuclear power stations and the processing of the spent fuel elements may be carried out for some time in a few large scale chemical processing plants.

The world wide development of nuclear power presents some dangers through nuclear fuel becoming widely disseminated and the Agency is playing a major role through its safeguards system in helping to reduce these dangers. A great deal remains to be done in this field.

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

Irradiated fuel service from U.K.A.E.A.

FUEL which has been irradiated in a nuclear reactor has an extremely high value because of its unused uranium and its plutonium content, but to recover and use every bit of these materials requires special skills and experience.

Experts from all over the world learned of the extent of British experience in this field, from a paper presented by J. A. Williams and M. T. Kavanagh (of Production Group, U.K. Atomic Energy Authority) to the Conference at the International Nuclear Industries Fair in Basle (8th-14th September).

After describing the main factors which have to be considered to extract the maximum value from irradiated fuel—handling fuel when it is removed from a reactor and storing it in a cooling pond, manufacturing transport flasks, choosing the reprocessing plant, devising a route to the reprocessing plant, getting clearance for the journey, arranging insurance in respect of loss and nuclear liability, and the time factor in all the cooling, transport, reprocessing, and re-use or disposal operations, the authors outlined various methods of re-using the recovered uranium and plutonium.

Referring to the re-use of uranium, the authors said, "The recovered uranium will have suffered a substantial reduction in the content of the uranium-235 isotope as a result of burn-up in the reactor and will have to be restored to the required enrichment before it can be made into new fuel. A number of ways exist for performing this operation:—

(*a*) Convert to uranium hexafluoride and feed the entire quantity to a diffusion plant.

(*b*) Blend with uranyl nitrate of higher enrichment.

(*c*) Sell the depleted uranium for credit against the purchase of freshly enriched uranium.

The blending of uranyl nitrate solutions is often the cheapest method because it avoids conversion of the majority of the uranium into the uranium hexafluoride form, and some of the expensive transport back to the diffusion plant."

Describing the special problems associated with plutonium the authors said, "The extracted plutonium will vary as to the percentage of isotopes which are fissile by thermal neutrons and this affects its value for use in thermal reactors. Plutonium moreover, has three particular properties which make handling, storage and transport expensive.

(*a*) It is very toxic and the International Commission on Radiological Protection (ICRP) recommend a tolerance in air of only four disintegrations per minute per cubic metre of air, equivalent to two micro curies per cubic metre, which is near the limit of detection.

(*b*) It will become critical when the necessary mass is assembled in certain geometrical conditions. In aqueous solution no more than 345 gm. may be assembled where the concentration exceeds 5.8 gm. per litre. Otherwise resort is made to 'ever-safe' geometry, i.e. a slab not exceeding 2·4 cm. in thickness.

(*c*) Finally, plutonium has a high specific alpha activity which causes hydrogen gas to be released from aqueous solutions of plutonium nitrate.

All these properties mean that plutonium handling requires specialised facilities and knowledge. With adequate precautions, plutonium can in fact be handled safely since many tonnes of the material have already been successfully treated in various parts of the world. Significant costs are however involved because of the special handling arrangements required."

Emphasising the value of plutonium, the authors stated that "The prospect for the value of plutonium in the next few years is that it will tend to fall as supplies increase, from the present high value for development purposes of about £15/gm. fissile towards a value in the early 1970s of £2-£3/gm. fissile which is approximately its value as an alternative to enriched uranium as a fuel for thermal reactors. Thereafter, as the prospect of fast reactors approaches, the value is likely to rise to about £8/gm. by 1980."

"The larger reprocessing plant operators will become involved in the marketing of plutonium and so will be able to advise reactor operators about methods of using or selling the material."

The U.K.A.E.A. reprocessing plant at

Windscale, with its design capacity of 1,500 tonnes per annum, is the largest in the world and the authors went on to say, "In its various factories, the U.K.A.E.A. performs on a large scale all the operations, including uranium enrichment and oxide fuel manufacture, which are required for a complete fuel cycle and is able to give advice and assistance in reaching a least cost solution to the problems which every reactor operator must face in respect of the treatment of irradiated fuel. It will of course be realised that the U.K.A.E.A. is the operator and designer of a variety of reactor types."

Earlier the authors had stressed the importance of "selecting a reprocessing agent who will be able to take responsibility for the greatest possible proportion of the whole operation from the loading of fuel at the reactor site to the eventual re-use of the contained uranium and plutonium. Such an operator will not only be able to achieve the optimum method of carrying out the operation at lowest cost, taking account of other business with which the transport arrangements in particular can be linked, but will also be able to offer expert advice to the reactor operator at all stages and thus limit the resources and effort which the latter will need to devote to this aspect of his business. Having quoted an overall price for the operation as a whole, the reprocessing agent will himself principally be concerned with the detailed optimisation."

12th September, 1966

New master slave manipulators

A COMPLETELY new range of servo-controlled master/slave manipulators is available from Nuclear Equipment Ltd., of High Street, Watford, manufactured under licence from the U.K. Atomic Energy Authority.

Developed by N.E.L. and the U.K.A.E.A., the manipulators are hydraulically driven in all movements by potentiometers and servo-valve mechanisms and will fit into all apertures designed for models 8 and 9 master/slave manipulators.

The new manipulators can lift considerable weights and the U.K.A.E.A. has already ordered some for its own use.

Load table:

x motion (side -to-side)	300 lb.
y motion (back and forth)	300 lb.
z motion (up and down)	1,120 lb.
grip, direct lift	1,120 lb.
grip, manipulation	100 lb.

Further information can be obtained from Nuclear Equipment Ltd.

13th September, 1966

Industrial diamonds at Harwell

INDUSTRIAL diamonds are widely used at Harwell for machining ceramics, glass and concrete, and examples of the Harwell work were shown at an exhibition associated with the International Industrial Diamond Conference at Oxford, from 19th to 24th September.

The need to prepare ultra-thin sections of concrete, ceramic and other non-metallic materials arises from their widespread use in nuclear engineering and the necessity, therefore, of petrological examination. For instance, pre-stressed concrete is now generally used for reactor containment vessels. The size of aggregates in most concretes precludes the use of conventional methods of slide preparation but sections of concrete one-thousandth of an inch thick and 50 sq. in. in area have been prepared by using specially modified or designed machine tools fitted with a variety of diamond wheels and laps. These sections can be examined under the microscope or by projection on to a screen.

Certain of the ceramic specimens displayed are crystals of magnesia and alumina (sapphire) both of which are extremely difficult to machine because of their physical properties. Many test pieces required for basic research work and machined to engineering tolerances have been prepared using a Universal Grinder fitted with absolutely concentric, specially profiled, metal-bonded diamond wheels.

To meet the need for a wider variety of machining operations on glass and single and polycrystalline ceramic products to fine engineering tolerances, Harwell has developed a universal ultrasonic machine tool; it also greatly improves the rate at which these materials can be machined. This machine comprises a rotating ultrasonic transducer associated with a sonic converter to which diamond impregnated tools are attached for various machining operations such as drilling, threading, end milling, tee slotting and dovetail cutting.

The rotating head allows precise machining operations to be conducted on fixed work pieces to close dimensional tolerances. Suitably shaped diamond tools operating in conjunction with a vertical traversing device are used to screw thread glass and ceramics. Work pieces revolving on a chuck attachment can also be ground on internal and external surfaces. Kerry's (Ultrasonics) Ltd. now have a licence to manufacture this machine.

16*th September*, 1966

Exhibition in Florence

THE Latina nuclear power station and the Advanced Gas-cooled Reactor were featured in an exhibition presented by the U.K. Atomic Energy Authority in Florence during British Shopping Week (8th-16th October).

Latina was a joint Anglo-Italian venture, being an advanced version of the Bradwell reactors. Since it was commissioned in May 1963, it has operated at extremely high availability, particularly during periods of peak demand. In fact, its availability has been better than any other nuclear power station in Italy. It had generated 4,327,610,000 kWh by 1st September, 1966. Latina was built by the Nuclear Power Plant Co. Ltd., now a member of The Nuclear Power Group Ltd., in co-operation with Italian industry.

The A.G.R. is a direct development of the type of gas-cooled reactor used in Latina and the British nuclear power stations. The first commercial A.G.R. power station, Dungeness "B", is being built by the U.K.'s Central Electricity Generating Board, who chose it in preference to light water reactors because it showed a clear economic and technical lead. In particular, it promises to have an extremely high availability. It is expected that several A.G.R.s will be built in Britain over the next few years.

Fuel for both Latina and the A.G.R.s is supplied by the Production Group's Springfields Works which makes 250,000 fuel elements annually and is the largest in commercial operation.

The A.E.A. provides a complete nuclear fuel service which includes chemically reprocessing the fuel after it has been used in the reactor to recover the unused uranium and the plutonium by-product, both of which are extremely valuable.

A.E.A. Reports available

THE titles below are a selection from the Authority's October, 1966 "List of publications available to the public". This list is obtainable free from the Librarian, A.E.R.E. Harwell, Didcot, Berkshire. It includes titles of all reports on sale, translations into English, books, periodical articles, patent specifications and reports which have appeared in the published literature. It also lists the Depository Libraries in the U.K. and the countries with official atomic energy projects who receive copies of U.K.A.E.A. unclassified reports.

AEEW-R 486
A Multi-channel, Fast Scanning, Recorder. By D. J. Adnams, K. J. Salt and C. A. Wintle. May, 1966. 34 pp. H.M.S.O. 5s. 6d.

AEEW-R 491
The F.D.2 Group Averaged Cross Section Set for Fast Reactor Calculations. By R. W. Smith, J. L. Rowlands and D. Wardleworth. August, 1966. 67 pp. H.M.S.O. 9s.

AEEW-R 500
A New Correlation of Non-Uniformly Heated Round Tube Burnout Data. By G. J. Kirby. July, 1966. 46 pp. H.M.S.O. 7s.

AERE-M 1785
Some Thermal-Neutron Flux Measurements in a Mock-up of a Dido 2v Fuel-Plate Test Rig. By I. S. McGill and M. J. Crook. August, 1966. 3 pp. H.M.S.O. 3s. 6d.

AERE-M 1801
Welding Techniques for Small Capsules. By F. T. Ewart and R. A. Carney. September, 1966. 3 pp. H.M.S.O. 2s. 6d.

AERE-R 5237
A New Time of Flight Data Processing System. By J. W. Hall, July, 1966. 13 pp. H.M.S.O. 3s.

AERE-R 5244
Autotoggle—An Aid to PDP8 Program Debugging. By G. C. Best, July, 1966. 11 pp. H.M.S.O. 2s. 6d.

AERE-R 5270
A Programmed Associative Multi-Channel Analyser. By G. C. Best. August, 1966. 11 pp. H.M.S.O. 5s.

PG Report 587(CC)
The Biology of the Solway Firth in Relation to the Movement and Accumulation of Radioactive Materials. II. The Distribution of Sediments and Benthos. By E. J. Perkins and B. R. H. Williams. 1966. 66 pp. H.M.S.O. 10s.

TRG Report 1153(S)
A Survey of the Theoretical Behaviour of Queues. By W. N. Miller. 1966. 65 pp. H.M.S.O. 9s.