ATOM

Number 142 / **August 1968**

MONTHLY INFORMATION BULLETIN OF

THE UNITED KINGDOM ATOMIC ENERGY AUTHORITY

ATOM

MONTHLY INFORMATION BULLETIN
OF THE UNITED KINGDOM
ATOMIC ENERGY AUTHORITY

NUMBER 142

August 1968

Contents

ATOM
monthly bulletin of the U.K.A.E.A. is distributed to the staff of the Authority, to similar organisations overseas, to industrial firms concerned with the exploitation of nuclear energy, to the Press and to others to whom a record of information of the work of the Authority may be useful.
Extracts from U.K.A.E.A. material from the bulletin may be freely published provided acknowledgment is made. Where the attribution indicates that the source is outside the Authority, permission to publish must be sought from the author or originating organisation.

Enquiries concerning the contents and circulation of the bulletin should be addressed to

Public Relations Branch.
U.K.A.E.A.
11 Charles II Street
London SW1
Telephone 01-930 6262

IN PARLIAMENT

Reorganisation of the nuclear industry

The Minister of Technology, the Rt. Hon. Anthony Wedgwood Benn, M.P., made the following statement in the House of Commons on Wednesday, 17th July, 1968:

In the debate on 23rd May, I summarised the Government's objectives in seeking a reorganisation of the nuclear industry following the report of the Select Committee on Science and Technology on this subject.

I have now had the opportunity of considering the matter further and have had the advantage of hearing the results of the informal consultations conducted by the Industrial Reorganisation Corporation.

I have today written to the I.R.C. to invite it to help in the reorganisation of the industry and I am circulating the text of my letter in the OFFICIAL REPORT. The I.R.C. will, of course, be free to recommend to the Government such other measures as it considers advisable to reinforce the new structure. Until the new structure of the industry is fully operative, the Atomic Energy Authority will continue to meet all the obligations it has undertaken or offers to undertake. Arrangements will be made to ensure that thereafter commitments previously entered into will be fulfilled.

I am asking the I.R.C. to assist in the creation of two design and construction organisations to be established in place of the three commercial firms and the design teams working within the Atomic Energy Authority. We have in mind a close integration between these two organisations and the manufacturers of the main constituent elements of the nuclear "islands". The proposed two new companies would need to work in close conjunction with the highly successful fuel organisation set up by the A.E.A. which is already operating on a commercial basis.

The Government have decided that to make this co-operation more effective in the exploitation of reactor systems it would be advisable to establish the

Authority's fuel business as a publicly owned company under the Companies Acts with the initial share capital wholly subscribed by the Government. In order to emphasise the interdependence of fuel and reactor design and supply, the Government intend that the fuel company should take up and hold a minority shareholding in each of the two design and construction organisations. Since the establishment of the fuel company will require legislation, I am proposing that initially the Government shareholding should be taken by the A.E.A.

The exploitation both at home and overseas of new reactor systems, as well as the A.G.R., would then primarily be the responsibility of the new companies, whose activities we would seek to concentrate geographically in such a way as to make the fullest use of the existing services and facilities built up by the A.E.A. at Risley.

In addition, when the proposed new industrial structure takes shape, the Government have in mind the establishment of an Atomic Energy Board on which the A.E.A., the design and construction companies, the fuel company and the generating boards would be represented. This Board would concern itself with research and development programming, export co-ordination and major policy matters. The two new design/construction organisations should be well able to stand up to international competition abroad and should be capable of a powerful effort in overseas markets.

As part of these arrangements, the Government will have to consider the necessity for some modification in the organisation of the A.E.A. in the light of the proposed legislation for the fuel company and the rearrangement of responsibilities for the exploitation of reactor systems.

The necessity for these new arrangements arises from the great success that the A.E.A. has achieved in developing commercial reactors. The reorganisation will be designed to secure that the most effective possible use should be made of this great national asset not only in support of the new organisation of the nuclear industry, but also in conjunction with the Government's own research establishments in the development of industrial technology.

These, then, are the lines along which we hope to see a reorganisation of the nuclear complex achieved. The industrial aspects of this are the most urgent, since it is the new design and construction organisations upon which the task of selling our reactor systems abroad will fall. They will need certainty for the future and I hope that we shall soon be able to reach an agreement, at least in principle, which will allow us to exploit our national research and development in atomic energy to the full.

Mr. David Price: Is the right hon. Gentleman aware that his decision to have two design and construction companies rather than one is in line with the minority Report of the Select Committee and will, therefore, be welcomed on this side of the House? Is he also aware that this is a very full statement, that much of the detail has yet to be filled in, and that it is very difficult at this stage for us to examine it closely? Will he undertake—as his implementation of the strategy in this statement matures—to give the House more detail and that we will have an opportunity to discuss it in detail across the Floor of the House?

Mr. Benn: The rôle of the fuel company in relation to the design and construction organisations meets the need which was dominant in the minds of the Select Committee in its considerations and its Report.

On the question of further reports to the House, I shall be guided by the progress made by the I.R.C. in talking to the industry, but there will be opportunities for further discussions and, as the hon. Member knows, there will be legislation later.

Dr. Ernest A. Davies: I thank my right hon. Friend for making this statement and indicating that action is being taken to deal with the nuclear power industry. I welcome that part of his statement dealing with the treatment of nuclear fuel, but can he explain why he has prevented the I.R.C. from considering the need for a single design and construction unit and has specifically asked for it to deal with two, since this, in effect, according to the argument of the major part of the Select Committee on

Science and Technology, means that we shall have three such organisations and not two?

Mr. Benn: My hon. Friend is wrong on his last point. We shall have two, because the A.E.A. will be working in the two design and construction organisations. As for his first comment, he will recognise that there was also an error in that, because we asked I.R.C. first to go out and seek negotiations on the basis of a single design organisation. This did not prove to be a practicable way of doing it, and the fuel company will meet the need that the Select Committee brought forward.

Mr. Lubbock: Will the Minister confirm that these arrangements will not jeopardise in any way the negotiations entered into by A.P.C. and T.N.P.G. and their European counterparts for the formation of international consortia? Can he say whether it will now become possible for licences to be granted for S.G.H.W. technology? Will it be possible, at a later stage, to consider private participation in the fuel company?

Mr. Benn: We have not yet established a fuel company, but the objective is a publicly-owned company in which the initial shareholding will be by A.E.A. and subsequently a Government holding. Existing commitments will continue on the basis on which they have been entered into. I stress this in relation to A.E.A., but it applies to everybody. It follows from the reorganisation that the two design construction teams will have access to the technology developed by A.E.A.

Mr. Brian Parkyn: Will the Minister give I.R.C. a time limit by which it will have to have its plan completed? Has he given instructions to I.R.C. to see what can be done concerning the tremendous future of H.T.R., and capitalising on it?

Mr. Benn: I do not think that it would be wise to give the I.R.C. a time limit because we are asking it to negotiate with the firms concerned, but since a great deal of work has been done on this matter I should expect that the basis of an agreement probably could very rapidly be found. A certain amount of work is going on in connection with the H.T.R. We attach a lot of importance to the H.T.R., as is evidenced by our support for the DRAGON project.

Mr. Michael Hamilton: In the time remaining to him, will the right hon. Gentleman seek to reduce rather than multiply the number of organisations which are known by their initials only?

MR. BENN: That is a question for others than myself. But it is fairly well-established that the Atomic Energy Authority should be known as the A.E.A. If we have an Atomic Energy Board, it would be hard for me to lay down that it was not to be known as the A.E.B.

Mr. MacLennan: Is my right hon. Friend aware that the decision about the fuel company is unlikely to be welcomed by the Institution of Professional Civil Servants, which has resisted this suggestion all along? Is he further aware that, as a result of his remarks about the geographical grouping of the new work at Risley, there is likely to be considerable concern at the A.E.A.'s establishment at Dounreay, whose continued existence is of such great importance to the area?

Mr. Benn: I do not think that my hon. Friend should anticipate difficulties. If we are to make a change of this kind, there are bound to be many people who will find that the situation alters for them. The object of this reduction is to exploit the highly successful work being done by the A.E.A. in nuclear research and development. I should hope that these changes could be carried through with the good will of all concerned. Dounreay, which is a very advanced fast reactor development, is likely to be the beginning of the very successful exploitation of that system in this country.

Mr. Neave: Is the Minister aware that the reorganisation of the A.E.A. will create considerable staffing problems? Is he further aware of the need for maximum consultation with the staff side and, in particular, for an early decision on the question of transferring pensions?

Mr. Benn: I recognise that there is a great deal more work to be done in this field. There will be the fullest possible consultation with the staff.

Mr. Dalyell: Is my right hon. Friend aware that some of us who signed the majority Report, after seven months' work, will take a great deal of convincing about his rejection of the single nuclear boiler company? May I ask him two specific questions? First, precisely what are the minority shareholdings? Secondly, what does he mean by "close integration"?

Mr. Benn: I recognised what my hon. Friend says about the case for the single design organisation. It was for that reason that we asked the I.R.C. to go for that first. But, in practice, if we are to have international links between the D.C. organisations and other companies abroad as a result of which we hope to sell our reactor systems, there is a case for not trying to merge into a monolithic organisation in this country. This was one of the dominant considerations in our minds. This is the answer to my hon. Friend's second question about the rôle of the fuel company's holding in the D.C. organisations. We recognised, the longer we thought about this, that it was the fuel which, in the long run, played the dominant rôle in shaping the technical standardisation required.

Sir Knox Cunningham: Will this new structure, particularly the formation of the companies, in any way reduce the opportunities of hon. Members to obtain information about this subject in the House?

Mr. Benn: That is a technical question with which the House will be much concerned later, but it is a bit too early to say what the arrangements will be. They will be contained in legislation which will come forward later.

Mr. Atkinson: The answer which my right hon. Friend has just given would seem to mean that it is impossible for a Socialist structure in this country to co-operate with private interests in Europe. That is a view which would be rejected on this side of the House. Would my right. hon. Friend accept that there will be great disappointment that, by choosing this course, he has accepted the Conservative proposals for the future of the industry and has rejected outright the advice given to him in a Motion, signed by 104 Members, to set up a single design authority?

Mr. Benn: I think that my hon. Friend is wrong in two respects. First, if we are to sell our reactor systems abroad, some industrial collaboration is absolutely essential, and that is why we have maintained this option. Secondly, I am somewhat surprised that now that a new publicly owned, science-based industry is to be built up on the basis of public research and development, which is what the fuel company will be, he should find this so unwelcome.

Mr. Evelyn King: Is it possible to infer from the Minister's statement that the possibility of a rundown in the level of employment at Winfrith is more or less likely?

Mr. Benn: I think that it would be foolish of me to try to answer a question of that kind without proper consideration. The A.E.A.'s success in developing a number of reactor systems has now opened up the possibility of a new organisation geared to the idea of exploitation. I think that everybody has always recognised that as the success of the A.E.A. became greater the emphasis would tend to be on the exploitation side. The object of the new organisation which we hope to set up is to give this new emphasis real form.

Mr. Hooley: Is my right hon. Friend aware that the creation of a publicly owned fuel company is entirely acceptable to hon. Members on this side of the House, but that the idea that private enterprise should control the activity of the other two companies is not so acceptable? Is he arguing that in order to collaborate with other countries, complete public ownership is not possible?

Mr. Benn: It is not part of my object to argue that at all, nor is the proposal which I put to the I.R.C. confined solely to the creation of a new publicly owned fuel company. The point is that we should try to build mixed enterprise arrangements inside the two D.C. organisations. If my hon. Friend reads the statement carefully, he will see that this is a balanced proposal designed to get the best out of the A.E.A. combined with the greatest possible prospects of selling reactors abroad, which is the only way in which we shall get a return on the many hundreds of millions of pounds which we have spent on atomic energy research in the last few years.

Sir Ian Orr-Ewing: Would the right hon. Gentleman remind his hon. Friends that this was not only the solution of the Conservative Party? The creation of two design companies was also the solution which was strongly recommended by the biggest customer—the Central Electricity Generating Board. Therefore, this will be very acceptable to the majority of people in this country.

Could the Minister be a little more forthcoming about the question put by the hon. Member for West Lothian (Mr. Dalyell)—why it is necessary to inject public money into the two design and construction companies? They have operated perfectly satisfactorily up to now. It was not clear from the right hon. Gentleman's earlier reply why the Atomic Energy Authority should lend money to the new public fuel company to take a minority shareholding in these two private enterprise companies.

Mr. Benn: I would dispute what the hon. Gentleman says about the arrangements having worked very well up to now. If they had worked very well up to now, we should not have devoted two years to considering how to improve them. We have not sold a reactor abroad for some years, as the House knows very well.

On the second point, about why there should be a link between the fuel company and the two D.C. organisations, under the proposed reorganisation some of the A.E.A.'s staff and assets will be brought into the design and construction organisation in order to achieve the maximum concentration of effort and exploitation of the system.

That is one reason. The other reason is to meet the need which was very strongly pressed by the Select Committee that we want to get the maximum concentration of effort and the minimum of wasteful competition or design competition in a field in which this could be decisive in selling reactors abroad. This matter has been settled not on an ideological basis, but on the basis of finding a consensus of agreement between the public agencies involved and the companies which have to exploit them.

Mr. Rankin: Will the reorganisation of the industry and the creation of the new board be followed by a bigger intake of technologists, scientists and engineers on the administrative side?

Mr Benn: The object of the exercise is to change the emphasis from nuclear research and development, in which we have done very well, to the exploitation of our reactor systems. I should very much hope that more scientists and technologists working in the field would find themselves on the exploitation end, because it is here that we have so much more to do.

Mr. Fortescue: In view of the Government's recent decision, taken against the advice of every nuclear physicist in the country, to withdraw from the proposed European 300 GeV nuclear accelerator programme, how can the Minister be so confident in our long-term export potential for nuclear reactors?

Mr. Benn: I do not think that the two issues are connected. At no stage whatever was the 300 GeV accelerator brought forward on the basis that it contributed to the exploitation of the atomic reactor systems developed by the A.E.A.

Mr. Dalyell: On a point of order. In view of the long-term importance of the Minister's statement, may I ask the Leader of the House whether, before the Summer Recess, he can provide time for a debate?

Mr. Speaker: There is a stage in the House on Thursday afternoon when business questions may be asked.

Following is the letter from the Minister of Technology to Sir Frank Kearton, Chairman of I.R.C.:

I am writing to you, as Chairman, to ask whether the I.R.C. would be ready to help to carry through a reorganisation of the nuclear industry, which has now been under discussion for well over eighteen months.

In our earlier talks about this, you were kind enough to advise me personally from your own long experience of atomic energy matters, as a part-time member of the A.E.A. Board. Later you and your I.R.C. staff also took informal soundings from all the parties involved both on the recommendations of the Select Committee and on the development of their thinking in the light of the Committee's report. All this has been most helpful.

We have, of course, discussed this very fully with the A.E.A. throughout and have now had an opportunity of considering your suggestions in the context of the Government's objectives which I summarised in the House of Commons on May 23rd as follows:

First, to make the best possible use of all the existing resources in this field, cutting out overlapping and duplication, of which there manifestly is some;

Second, to allow those who have worked in the Atomic Energy Authority full scope for carrying their work forward into the exploitation and sale of the systems which they have developed;

Third, to get the maximum possible advantage of the technical standardisation, coupled with the most effective design competition in engineering detail and construction method;

Fourth, to try to link and co-ordinate the efforts in such a way as to relate reactor systems to the fuel elements and reprocessing business at which the A.E.A. has excelled, both technically and commercially, through its fuel production group;

Fifth, to create an organisation which permits the sort of international industrial links which will be of critical importance in all sections of advanced industry and not just in atomic energy;

Sixth, to do this with a special eye upon the future of the European nuclear industry in co-operation with our partners in Europe;

Seventh, to change the emphasis of our national effort in such a way as to increase it on the exploitation side and see that future nuclear research is guided and shaped more directly by the needs of the market at home and abroad;

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

With these in mind, I am writing to invite the I.R.C. to assist the industry in the creation of two design and construction organisations to be established in place of the three commercial firms and the design teams working within the Atomic Energy Authority. I have in mind a close integration between these two organisations and the manufacturers of the main constituent elements of nuclear "islands". The I.R.C. will, of course, be free to recommend to the Government such other measures as it considers advisable to reinforce the new structure of the industry. Until the new structure of the industry is fully operative, the Atomic Energy Authority will continue to meet all the obligations it has undertaken or offers to undertake. Arrangements will be made to ensure that thereafter commitments previously entered into will be fulfilled.

The proposed two new companies would need to work in close conjunction with the highly successful fuel organisation built up by the Atomic Energy Authority, which is already operating on a commercial basis. The Government have decided that to make this co-operation more effective in the exploitation of reactor systems it would be advisable to establish the Authority's fuel business as a publicly owned Company under the Companies Acts, with the initial share capital wholly subscribed by the Government. In order to emphasise the inter-dependence of fuel and reactor design and supply, the Government intend that the fuel company should take up and hold a minority shareholding in each of the two new design and construction organisations.

The establishment of the fuel company will require legislation, and I would propose therefore that initially the Government shareholding should be taken by the A.E.A.

Exploitation both at home and overseas of the new reactor systems, as well as the A.G.R., would then primarily be the responsibility of the new companies. The design units of these two new firms, together with the fuel activities, should be, so far as is possible, concentrated geographically in such a way as to make the fullest use of the existing services and facilities built up by the A.E.A. at Risley.

When the proposed new industrial structure takes shape, the Government have it in mind to set up an Atomic Energy Board, including representatives of the A.E.A., the fuel company, the two new design and construction companies and the Generating Boards. This Board would concern itself with the composition and financing of R & D programmes (to which the two new design/construction companies, and the fuel company, would be expected to contribute), the co-ordination of activities in the export field and major matters of policy. These proposals have already been the subject of discussions between our respective officials. The two new design/construction organisations should be well able to stand up to international competition abroad and should be capable of a powerful effort in overseas markets.

The Government, as part of these arrangements, will have to consider the necessity for some modification in the organisation of the Atomic Energy Authority in the light of the proposed legislation for the fuel company and the re-arrangement of responsibilities for the exploitation of reactor systems. This reorganisation would be designed to secure that the most effective possible use should be made of this great national asset, not only in support of the new organisation of the nuclear industry, but also in conjunction with the Government's own research establishments in the development of industrial technology. The necessity for these new arrangements arises from the great success that A.E.A. has achieved in developing commercial reactor systems.

These, then, are the lines along which we hope to see a reorganisation of the nuclear complex achieved. The industrial aspects of this are the most urgent since it is the new design and construction organisations upon which the task of selling our reactor systems abroad will fall. They need certainty for the future and I hope that the I.R.C. will be able to achieve an agreement, at least in principle, as soon as possible.

Tees-side air pollution

18th June, 1968

MR. TED FLETCHER asked the Minister of Technology what reports he has received from the working party set up by his Department to look into the question of pollution on Tees-side; and what action he proposes to take arising from the recommendations of the working party.

Dr. Bray: The Working Group was not appointed by the Ministry of Technology. It was set up by the Interdepartmental Committee on Air Pollution Research under the chairmanship of the Director of the Warren Spring Laboratory. Work for the Group is being undertaken by U.K.A.E.A., Harwell, under the terms of a requirement my right hon. Friend made in August, 1967, under Section 4 of the Science and Technology Act. Sixty per cent. of Harwell's effort on air pollution is devoted to Tees-side mist, the total cost of air pollution work from August, 1967, to 31st March, 1968, being £52,350. An increased effort is being made in the current year. The limited work so far carried out both at Tees-side and at Harwell indicates that concentration of ammonium sulphate particles at Harwell has been found to be as great as that normally occurring on Tees-side, so the usual level of pollution seems not to be greater than that in the Harwell area. However, ammonium sulphate occasionally occurs on Tees-side in much greater quantities than normal. When this occurs in combination with atmospheric conditions producing a sea fret, the effect may be to make mist more persistent. The problem is confined to some 12 days in the year, mainly in May or June but also in September to November. The incidence of the mist is uneven, affecting some parts of Tees-side more than others.

The work planned for this summer at Tees-side and elsewhere may confirm and extend these ideas. As soon as a report is available, the Interdepartmental Committee will notify direct the Government Departments concerned regarding what action, if any, is required.

Medical technology at Aldermaston

24th June, 1968

MR. BAGIER asked the Minister of Technology what work is being done on medical technology at Aldermaston.

Mr. Fowler: Research work at Aldermaston covers artificial limbs, dental materials, metals and plastics used for implants in the body, cardiac pacemakers, methods for clearing obstructions in arteries, and specialised diagnostic equipment and instruments. Other work concerns the scientific and technical assessment of commercial equipment, such as artificial kidneys, automated laboratory equipment and echo-encephalographs.

Nuclear propulsion

24th June, 1968

MR. WALL asked the Minister of Technology if he will make a statement on progress towards development of an economic nuclear reactor for merchant vessels.

The Joint Parliamentary Secretary to the Ministry of Technology (Mr. Gerry Fowler): No requirement has yet been found for a ship calling for the large power output necessary to make nuclear marine propulsion competitive.

The Government are keeping this under review in collaboration with the shipbuilding and shipping interests.

Mr. Wall: Does the hon. Gentleman believe that further progress can be made without trials and a prototype ship afloat? Does he realise that we, a premier maritime nation, are rapidly falling behind in this important development?

Mr. Fowler: The crucial question here is whether such a project would be commercially viable. It would be madness to indulge in quite heavy expenditure, particularly if such expenditure were borne by the Exchequer, without any commercial prospect for the sale of such a vessel.

Sir H. Legge-Bourke: Does not the hon. Gentleman realise that, since the Padmore Committee reported some years ago, thinking on this matter has changed considerably as a result of the concept of the container ship with a nuclear-powered hull for a quick turn-round? Will he give a little more encouragement to those who have really progressive ideas in this field?

Mr. Fowler: We are encouraging the shipbuilding and shipping interests to discuss this matter in the hope that they may be able to produce a commercially viable project. In recent years, the governmental position in the matter has taken a sharp turn for the better in that both the atomic energy interests and shipbuilding interests are now concentrated in the same Department, the Ministry of Technology.

Generation cost in Scotland

26th June, 1968

MR. EADIE asked the Secretary of State for Scotland what was the cost per unit of electricity sent out in 1967-68 from South of Scotland Electricity Board power stations using coal, oil and nuclear power, respectively, giving the figures in each case to include depreciation and interest on capital invested in power stations under construction.

Mr. Ross: I am advised by the Board that the costs per unit were for coal-fired stations 1.177d., for oil-fired stations 1.122d., for nuclear stations 1.011d., and for gas turbine stations 2.715d. These figures, unlike those given an page 20 of the Board's Annual Report for 1967-68, include depreciation and also interest on capital invested in power stations at present under construction, but make no allowance for subsidy paid towards the cost of substituting coal for oil.

Hunterston "B" nuclear power station

26th June, 1968

MR. EADIE asked the Secretary of State for Scotland what is now the expected total capital cost of the Hunterston "B" nuclear power station, including the initial fuel charge; and how the cost per kilowatt will compare with the existing Kincardine coal-fired station, and the station, also coal-fired, now being built at Longannet.

Mr. Ross: The estimated capital cost of Hunterston " B " is £87.5 million, or £70 per kilowatt sent out, and the initial fuel charge is estimated to cost a further £15.7 million, or £12.6 per kilowatt. Kincardine generating station cost £50 per kilowatt and Longannet is expected to cost £45 per kilowatt.

CERN 300 GeV accelerator

27th June, 1968

MR. LUBBOCK asked the Secretary of State for Education and Science, what decision he has made concerning British participation in the CERN 300 GeV accelerator; and if he will make a statement.

Mr. Edward Short: A statement on Her Majesty's Government's policy in regard to participation in the CERN 300 GeV accelerator project was made at CERN Council meeting last week. I will circulate a copy of this statement in the OFFICIAL REPORT.

The gist of the statement was that the Government regretfully concluded that with their other commitments the expenditure involved on this very large project would not be justified. In reaching this decision they gave full weight to the views expressed by the Science Research Council and the Council for Scientific Policy, but they had also to take account of wider considerations. United Kingdom nuclear physicists will continue to enjoy the basic CERN facilities and we are participating in the large Intersecting Storage Rings project now under construction. At home the national and university facilities for nuclear structure work as well as for high energy physics will continue to be developed as part of the programme of the Science Research Council.

Statement at CERN Council meeting on 20th June, 1968 by the United Kingdom delegate Professor Flowers

At the Council meeting in December I said that my Government were giving very careful consideration to the question of participation in the 300 GeV project. They had obtained advice from various scientific bodies, which has since been published. My Government were particularly concerned at the effect which participation in this project might have on the balance of resources between high energy physics and other scientific activities and they also had to review the implications of the devaluation of sterling.

My Government have now decided in the light of their other commitments that expenditure involved on this very large project would not be justified. Her Majesty's Government regret this decision because they fully appreciate that the project is well conceived and that strong scientific views have been expressed in its favour. But they are satisfied, after an exhaustive review of the arguments, that they should not enter into this commitment.

In reaching this conclusion my Government have had in mind that through CERN, which they will continue to support, the European high energy nuclear physics community already has an important project in hand in the Intersecting Storage Rings. This will give European physicists a unique instrument which will enable some further advances to be made in the physics of very high energies.

Dounreay Fast Reactor

1st July, 1968

MR. KELLEY asked the Minister of Technology if he will state the cost of bringing the fast reactor at Dounreay back into commission after its breakdown in July 1967; and at what date it began to operate following the leak in the coolant circuit.

Dr. Bray: The cost of bringing the Dounreay Fast Reactor back into commission was £105,000. This figure does not include the wages and salaries of the employees engaged on the remedial work, who were diverted from other duties.

The reactor began operating again on 19th June, and was bought to full power on 22nd June.

Hunterston "A" nuclear power station

3rd July, 1968

MR. EADIE asked the Secretary of State for Scotland what is the total capital cost of the Hunterston " A " nuclear power station; and what this cost represents per kilowatt.

Dr. Dickson Mabon: The total capital cost of Hunterston " A " was £64 million, representing £185.5 per kilowatt sent out.

Chapelcross breakdown

3rd July, 1968

MR. EADIE asked the Minister of Technology, what is the cost so far of the breakdown of the Atomic Energy Authority's reactor at Chapelcross; and what is the total period for which the reactor is estimated to be out of action; and what is the expected final cost of the breakdown?

Dr. Bray: The Atomic Energy Authority estimate the cost of repairs on No. 2 reactor has been £150,000 and the loss in electricity sales at just over £1 million. The reactor is likely to be out of action for some months and the final cost of the breakdown cannot be forecast. Further repairs will cost about £10,000 per month with a loss of electricity sales of £90,000 per month. The other three reactors continue to operate at their normal high load factor of about 94 per cent. and the station's overall load factor, with one reactor out of commission, has been 70 per cent.

Fish Preservation

8th July, 1968

MR. W. H. K. BAKER asked the Minister of Technology (1) what official representation he plans to send to the trials of the preservation of fish by ionizing radiation in Iceland;

(2) what plans he has for applying irradiation for the preservation of fish.

Mr. Fowler: Considerable work on this subject has been carried out jointly by Torry Research Station and the Wantage Laboratory of the United Kingdom Atomic Energy Authority. The possibilities of commercial application seem limited and there is concern about a possible health hazard from the product. The sale to the public of irradiated food is generally prohibited in the United Kingdom, individual applications for exemption being considered on merit. There will be no official representation at the trials in Iceland.

Uranium Supplies

9th July, 1968

MR. EADIE asked the Minister of Technology if he is satisfied that supplies of uranium will be adequate for the present nuclear power station programme.

Dr. Bray. Yes. The uranium supplies on hand or under contract will meet requirements in full until well into the 1970's and part of requirements up to 1980. The growth of exploration in many parts of the world should result in sufficient uranium being forthcoming at reasonable prices to meet nuclear power programmes and the Atomic Energy Authority assure me that they foresee no difficulty in making additional contracts when this seems desirable.

New power stations

9th July, 1968

MR. SHINWELL asked the Minister of Power what decision has now been reached about an electricity generating station at Seaton Carew.

Mr. Lubbock asked the Minister of Power when the C.E.G.B. will be allowed to place orders for the Hartlepool and Heysham stations.

Mr. Mason: No decision has yet been reached. The timing of orders for any new power stations will depend on the outcome of the present capital investment reviews.

APACE Centre courses

The staff of the Aldermaston Project for the Application of Computers to Engineering (APACE) have now been running their specialist courses for eighteen months. The training in the mechanical engineering field has fallen into a regular pattern in the light of demand. As from September 1968 a new series of courses in the electronic field is being introduced.

The following will be run in the Autumn:

Computer Appreciation Course for Engineers—4 days, fee £48.
1st-4th October
29th October-1st November.
19th-22nd November.
17th-20th December.

2 CL Users Course—4½ days, fee £54.
16th-20th September.

A.P.T. Part I Course—4½ days, fee £54.
14th-18th October.

FORTRAN *Programming Course for Engineers*—5 days, fee £60.
4th-8th November.

Electronic Computer Aided Design Introductory Course for Engineers—4½ days, fee £54.
23rd-27th September.
11th-15th November.

Circuit Analysis Users Course—3 days, fee £36.
10th-12th December.

Further information about these courses or other APACE services may be obtained from The Secretary, APACE, UKAEA, Blacknest, Brimpton, near Reading, Berks. (Telephone Tadley 4111, ext. 5951/5873). Overnight accommodation is arranged for course members on request.

RIPPLE Colloquium

The full texts of the seven papers presented at the Colloquium on Isotopic Thermoelectric Generators held in London on 30th January, 1968, appeared in the May issue of the Newsletter published by the French CEA and the ENEA. Copies are available from CEA-ENEA Isotopic Generator Information Centre, Boîte Postale No. 2, 91-Gif-sur-Yvette, France.

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

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

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

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

Lecturers in Engineering
16th to 20th September, 1968

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

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

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

continued on page 241

Analytical Research and Development Unit

An Analytical Research and Development Unit is being formed at Harwell on 20th June, 1968. To meet the exacting needs of the nuclear programme, Harwell has built-up wide expertise and resources for the measurement and control of impurities in industrial materials and processes. The new Unit will provide industry with direct access to the Harwell expertise and resources.

Impurities, often at concentrations of one part in a million or less, greatly change the properties of many materials (for example, steels, refractories, catatysts or electronic materials) and discussions with about 30 firms, research associations and other bodies have shown that trace impurity problems are now of growing importance to a wide range of industry. The principal industrial needs are first, better techniques for measurement of impurities, particularly at very low concentrations, or for example in thin surface films or particular chemical forms; and second, the development of non-destructive, high-speed or on-line analytical techniques suitable for subsequent process control.

The Analytical Research and Development Unit will study analytical problems encountered by specific firms or industries, will assess techniques before they are installed in industry and will provide a technical and advisory service on analytical techniques. Specialised analytical methods appropriate to on-line methods of process control, especially those of common interest to a number of industries, will also be developed in such a way as to anticipate future requirements wherever this is practicable. The programme will include both short-term development work on specific problems and research of a more general nature. Courses will be arranged for industry on those areas of analytical science for which no provision is made by other bodies. The Unit will work in close collaboration with industry, including instrument manufacturers, and with government laboratories and research associations. An Advisory Committee will be set up, with representatives of industry, research associations and the Ministry of Technology, to advise the Director of Harwell on the research programme and to keep the progress made under review.

The Unit will form part of the Analytical Sciences Division at Harwell and will be under the general direction of Dr. A. A. Smales, the Division Head. It will be staffed by transferring scientists from nuclear work as the demand for the new services grows. About 14 scientists will join the Unit when it is fully operational when the annual operating cost is expected to reach about £205,000 p.a.

The programme will include sponsored and consultancy work (carried out in confidence at full cost for industrial firms), joint research programmes with industry (to which each partner contributes effort and resources and shares proportionately in the benefits) and work aimed at less immediate objectives having wide potential industrial application. Advice and information will be available free of charge in the first instance. Enquiries should be directed to:—Dr. R. K. Webster, Analytical Research and Development Unit, A.E.R.E., Harwell, Didcot, Berks. (Abingdon 4141, Ext. 2944).

The Analytical Research and Development Unit is being set up following the recent issue of a Requirement to the Authority by the Ministry of Technology under the Science & Technology Act 1965, and will form part of the Authority's programme of non-nuclear work.

Technical note

The following examples indicate the range of applied research that can be undertaken by the Unit. Assistance can also be given with more immediate problems such as the determination of specific trace elements in metals, refractories, slag, paper, electronics materials, etc.

Trace analysis

Development and application of trace element determination techniques to industrial materials.

This could include development of reactor activation methods to achieve higher sensitivity, speed and range of elements; of methods, particularly for light elements, using neutron beam tubes, fast neutrons, charged particles and gamma photons, and exploiting prompt gamma rays where possible; of sensitive mass spectrometric isotopic dilution techniques, and of spark source mass spectrography, for improved speed and accuracy.

Surface distribution and depth profile measurements

Development of techniques for the examination of thin films and surface layers, for example for application to corrosion studies, thin film electronic devices, and possibly for element correlation studies to establish chemical forms.

This could include activation/track counting, X-ray milliprobe, and spectroscopic methods, and the development of charged particle surface scanning and scattering techniques.

Chemical forms and oxidation states of elements

Non-destructive measurements for solid materials by broad line nuclear magnetic resonance, electron spin resonance, etc.; mass spectrometry, for example for the analysis of effluent gases.

Improvement of more conventional techniques for wider industrial use

Namely, gas chromatography, electrochemistry, atomic absorption methods, optical spectroscopy, and faster, or automated, chemical separations. This requirement may arise from an initial materials study using more specialised methods.

Computer techniques

The development of techniques for using computers for direct data acquisition from analytical instruments, control of sample changers, etc. For example, automatic reading of spectrographic plates, automated activation analysis system (using neutron generator, germanium diode detector and data processor), a time-sharing system for the analysis of spectral data from several analytical instruments.

On-line analytical methods

Many of the above could be developed as non-destructive or computer-coupled methods and applied to flowing systems of solids, solutions, fused salts or molten metals as a means of continuous analysis or monitoring.

Facilities available to the analytical research and development unit

Equipment includes:

Standard and high speed rabbit systems to the DIDO reactor.

Elliott K tube and P tube neutron generators.

Mass spectrometers including spark source, thermal emission and gas instruments.

Varian D.P.60 nuclear magnetic resonance spectrometer.

Varian X band electron spin resonance spectrometer.

PDP-8 computers.

Quantimet image analysing microscope.

Optical emission spectrographs including a range of grating and prism instruments, flame photometers, etc.

Laser micro-probe analyser.

Phillips fluorescence X-ray spectrometers.

Telsec Beta probe X-ray spectrometer.

Scanning X-ray milliprobe analyser.

Other analytical instruments i.e. gamma spectrometers, polarographs, coulometers, spectrophotometers, vacuum fusion equipment, gas chromatographs, etc.

Harwell equipment available for use by the Unit includes the DIDO and PLUTO reactors, the 0.5 MV Cockcroft Walton set, the 2 MV, 3 MV, 5 MV and Tandem Van de Graaff accelerators, the 180 MV synchrocyclotron, the variable energy cyclotron and the electron linear accelerator.

11th June, 1968

D.F.R. back on power

The Dounreay Fast Reactor resumed power operation on 22nd June, 1968, after being shut-down on 29th July, 1967, following the discovery of a leak in the primary coolant circuit. The location and repair of the leak was carried out by the D.F.R. operating and maintenance staff assisted by other Dounreay staff and with specialist advice from various parts of the Authority.

For many years it had not been thought possible that a repair of this kind could be carried out and its successful completion gives confidence in the ability to repair radioactive sections of future sodium-cooled fast reactors. The experience gained has enabled modifications to be made in the design of future fast reactors so as greatly to facilitate and shorten the period required to carry out repairs to the plant should these become necessary.

The reactor will now resume its role as a test-bed for the fuels of future fast reactors together with a programme of experimental work being carried out for overseas customers who have placed contracts for work in the reactor worth more than £1 million.

24th June, 1968

U.K./U.S.A. isotope company formed

A similar release was issued in the U.S.A.

The Radiochemical Centre, Amersham, which offers the widest range of radioisotopes in the world, has formed a joint company with G. D. Searle & Co. (Inc.) of the U.S.A. for marketing operations in North, Central and South America.

Searle & Co. are one of the leading manufacturers of pharmaceuticals in the United States. Among their subsidiary companies is the Nuclear-Chicago Corporation, who manufacture nucleonic instruments and have distributed many of the Centre's products in the United States since 1952.

The company, to be known as The Amersham/Searle Corporation, will be under 50/50 ownership and control as between the United Kingdom Atomic Energy Authority and G. D. Searle & Co.

The Board has three British and three American directors. Sir Charles Cunningham, Deputy Chairman of the United Kingdom Atomic Energy Authority, is Chairman of the Board and the other British representatives are Dr. W. P. Grove, Director of the Radiochemical Centre, and Mr. H. Lowis Barman, consultant to the Authority and formerly a director of Rolls-Royce and Associates, Ltd. The American members are Mr. D. C. Searle, President of G. D. Searle & Co.; Mr. W. D. Owens, President of the Nuclear-Chicago Corporation, and Mr. J. L. Kuranz, Senior Vice-president, Nuclear-Chicago.

Dr. C. C. Evans, Manager of the Inorganic Department at Amersham, will be Technical Manager of the new company at its headquarters in Chicago. He takes up his appointment later this month.

The U.S.A. is already Amersham's largest overseas market. Their sales there have more than doubled in the past five years and are now approaching the $1,000,000 a year mark. The total U.S. demand for radioisotopes is currently estimated at $20 million a year and is increasing rapidly.

Amersham's total sales of radioisotopes are now in the region of £3,000,000 a year and increasing by about 15% annually, over one half by value being exported. For their achievements in this new field of technology the Centre received the Queen's Award for Industry last year.

Background notes

The Radiochemical Centre, Amersham

Radioactive work began at Amersham in April, 1940, with the refining of radium and manufacture of luminous paints for the wartime aircraft industry. It was a venture of private enterprise, with a small laboratory working under technically primitive conditions, equipped with few instruments and staffed by no more than a dozen people—but this was the nucleus on which later developments were built.

The Radiochemical Centre was established under public ownership on the same site in 1946. Its purposes were quite definite: to provide radioactive substances, however and wherever they might be needed by doctors, engineers and research workers, at home or abroad —and to do so in a businesslike way as a commercial enterprise.

Today the purposes of the Centre are still the same, but its technical resources have grown immensely. The basic raw materials are derived from research reactors at Harwell and from several production reactors elsewhere within the U.K.A.E.A., so providing a highly dependable service. There are extensive laboratories at Amersham well equipped for all kinds of radioactive work, and a powerful cyclotron has recently been installed there. This is the first machine of its kind to be designed and operated solely for making radioisotopes.

The range of radioactive products has grown to an extent which would have been unbelievable 20 years ago in the age of radium. The current catalogue offers some 2,000 items. There are 150 radioisotopes available in more than 1,000 chemical compounds and in 600-700 kinds of radiation appliance. Standards

Members of the board of the new Amersham/Searle Corporation, formed to market British radioisotopes in North, Central and South America. From left to right (back):—Mr. Kuranz; Sir Charles Cunningham (Chairman): (front row) Mr. Owens; Dr. Grove; Mr. Searle; Mr. Barman.

of quality and purity are extremely high, to meet many specialised uses in medicine, industry and research.

The Centre now employs 500-600 people. In 1966/67 nearly 75,000 consignments of radioactive products were sent out, to almost every country in the world.

Biographical notes

Sir Charles Cunningham, K.C.B., K.B.E., C.V.O.

Sir Charles Cunningham was born in Dundee on 7th May, 1906. He was educated at the Harris Academy, Dundee, and the University of St. Andrews.

He entered the Scottish Office in 1929 and became Private Secretary to the Secretary of State for Scotland, 1935-39; Assistant Secretary, Scottish Home Department, 1939; Principal Assistant Secretary, 1941; Deputy Secretary, 1942; Secretary, 1948. He was Permanent Under Secretary of State at the Home Office from 1957 to 1966. On his retirement from the Civil Service, Sir Charles was appointed to full-time Membership of the U.K. Atomic Energy Authority and became Deputy Chairman of the Authority on 31st October, 1966.

Dr. Walter Patrick Grove, Ph.D. (London), F.R.I.C.

Dr. W. P. Grove was born in 1914. He was educated at Brighton Grammar School, Birkbeck College and University College, London.

His first practical acquaintance with radioactivity was as an assistant in the laboratory of the Radium Institute, London, in 1931, under W. L. S. Alton. Later he worked as a junior chemist in the research laboratories of May & Baker Limited under A. J. Ewins, F.R.S., and of Johnson Matthey & Company with A. R. Powell, F.R.S.

He was a research student of Professor S. Sugden at Birkbeck College, and in 1937 moved with him to University College, London, as an assistant lecturer in the Department of Chemistry. His research topic was the magnetic properties of salts of the platinum metals group.

From the outbreak of war he spent a short time at the Royal Naval Torpedo Establishment at Greenock. In 1940 he joined Thorium Limited with the assignment of starting a laboratory at Amersham for refining radium to meet wartime needs. In 1944 he spent four months with the British/Canadian "Tube Alloys" (nuclear energy) project in Montreal.

The laboratory at Amersham became The Radiochemical Centre in 1946, first under the Ministry of Supply and later as an establishment of the U.K. Atomic Energy Authority. From 1959 the Centre

continued on page 231

Press visit Harwell

On Tuesday, 2nd July, A.E.R.E., Harwell, held a Press Visit at which Dr. Walter Marshall, Director of the establishment, welcomed the Press. His introductory talk is printed below.

On behalf of all the staff, may I first welcome you here today. Since I took over as Director, this is the first opportunity I've had to welcome the Press, but I hope I'll have many more opportunities in the future.

As you all know, in the last few years there has been some uncertainty about Harwell's future and many of you have drawn attention to this in the articles you've written. The main point I want to make today is that I believe these difficulties are mostly resolved and that we ourselves are now quite clear what we should do in the next few years.

We are therefore specially pleased to see you today. We plan to show you some new work which we find exciting—and which we hope you will find exciting also. In total this new work represents a major change in Harwell's programme and in the objectives of the research we do.

Work for industry

The big change we are making is to increase rapidly the amount of work on applied projects for industry. In one sense this is not entirely new, because we have always undertaken applied work of this kind, but in past years these activities have always been secondary to our main role which has been to assist the nuclear power programme. But by this time next year applied research in close association with British industry will be the largest activity in Harwell's programme.

This applied work is divided into two parts. I would like to tell you something more about each of these parts in turn.

The first part is done under the 1954 Atomic Energy Act which gives us the legal powers to pursue industrial objectives provided that these used nuclear techniques, isotopes and radiation, for example. Therefore we have, for many years, done work of this kind. But, in the main, I would describe that work as "missionary" in character: our objectives were to demonstrate to industry at large that nuclear ideas and techniques could help them in their business. We no longer regard this approach as justified and in future our research programme will concentrate on those ideas where we (and British firms) see prospects of an early financial return. Furthermore, as early as possible in the life of each project we shall choose industrial firms as our partners and work with them, in confidence, to obtain the maximum commercial benefit. In other words, we are changing our approach to this work from being "missionary" to "mission-oriented". However, we shall continue to give advice and answer queries about the use of isotopes and radiation.

Non-nuclear work

The second part of our applied work is entirely new and is made possible by the legislation of the 1965 Science and Technology Act. Under that Act the Minister of Technology has the power to require the A.E.A to undertake research outside the nuclear area. Here at Harwell we have responded to the opportunity offered by this Act and have initiated several ideas which have led to requirements from the Minister. So far, we have received about ten formal requirements which authorise us to work outside the relatively narrow field of atomic energy. For each of these requirements we have set up a new project with a nominated project officer to pursue commercial objectives in the national interest. So far the response we have had from British industry has been substantial and we have been very encouraged.

The first non-nuclear project to be approved was on desalination. This is an Authority project in which Harwell takes part. We do work on three methods of desalination: on flash distillation, on freezing, and on reverse osmosis. In each of these areas we collaborate with a single firm and last year the Minister authorised the second phase of the research programme. You will see something of this work today and we have representatives of the firms, Weir Westgarths, Simon Carves and Portal Holdings, here today to help us talk to you about it.

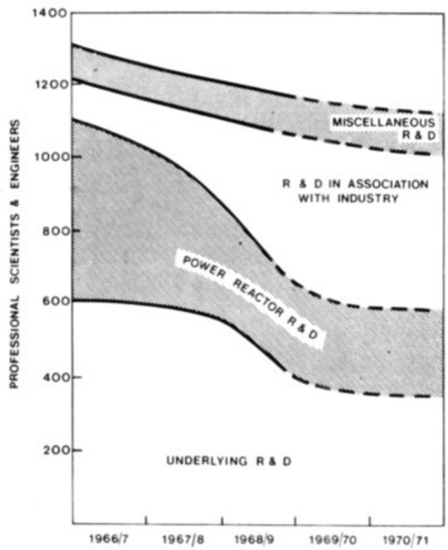
Two other projects, the Harwell Ceramics Centre and the Non-Destructive Testing Centre, were established early in 1967 and have expanded rapidly. Indeed the demands on them are tending to outpace the rate at which we can release staff from other work. We have other projects which we have started more recently and you will see something of all these today.

How projects start

I think you will be interested to hear a little of how we start projects such as these. The initial idea may arise in Harwell, in industry or in MinTech. We then follow up the idea with detailed discussions with industrial firms. This takes place on a large scale: we visit firms, they visit us and the discussions and consultations go on for many months. Many ideas do not survive this stage because we set for ourselves several strict criteria. First we must be able to demonstrate a firm cost benefit to the nation. Second, we do not wish to compete with or replace existing bodies who could undertake the work; for example the Research Associations, N.R.D.C. or industry itself—therefore we must be satisfied that there are special reasons why Harwell is the particular place where this work should be done. Third, we must be satisfied that there are U.K. firms who are keen to collaborate with us from the earliest stages and also are keen to exploit the innovation and make of it a real commercial success. When we are quite satisfied we have a sound and promising idea which it is appropriate for us to follow-up, we make an official request to the Ministry of Technology. When they also are satisfied, and they are not easy to satisfy, the Minister issues a legal requirement for us to do the work.

Much of this applied work is confidential and we cannot show it to you today. This need for commercial security is an essential feature of our work; without it we could not gain the confidence of industry. However, I think you will be interested in what we are able to show you and we have some of our industrial collaborators here so that you can talk to

CHANGES IN HARWELL PROGRAMMES 1966/70



them as well as to the Harwell staff.

In the notes you have been given we have included a list of our principal industrial projects divided into the two parts of nuclear and non-nuclear. We have also included a graph which shows the way we are changing the Harwell programme.

Although this industrial programme is very new and we have a great deal to learn in the next few years, some points of importance seem to stand out already and because these have some general interest I would like to list them for you.

1. The first lesson is that it takes a great deal of effort to get to know industry well. For about a year a large fraction of our staff were out making visits to industrial firms and identifying problems. But, now it is becoming known that we are ready and willing to co-operate, more and more of the initiative is being taken by industry. Nevertheless it is essential to maintain a major effort to keep in contact and learn more about individual firms.

2. It is most important to have our economic objectives quite clearly defined and it is important to make a thorough and hard-headed cost benefit analysis in advance. For this reason we make frequent use of the Programmes Analysis Unit which has been set up

here at Harwell as a joint MinTech-Authority Unit. We also use commercial firms to make market surveys.

3. I have sometimes heard comments to the effect that the Harwell staff were too academic to be interested in the problems of industry. I've always known that to be incorrect and I think you will agree with me after you have met the staff today and seen how enthusiastic they are. Our scientists are interested in these problems, indeed, I think they would be interested in any problems which offered sufficient intellectual challenge. I have also heard comments that industry needs only simple research and not the sophisticated research which is appropriate for a laboratory like Harwell. We have found little evidence for this: the problems put to us by industry are quite difficult and of a kind that need a wide range of the equipment and expertise we have here at Harwell.

4. There is a significant need for information and technical advice to be given to industry. At the present time Harwell receives about 50 serious enquiries every week, many of which we can deal with either by letter or by an hour's discussion.

Reactor work

So far I have talked only about our programme in applied research. I have concentrated on that because the work is new, but it would be quite wrong for me to leave you with the impression that this dominated our future exclusively. We still have an important and well defined responsibility for the reactor power programme. As you know, nuclear power is now competitive with other sources of energy and we are proud that Harwell has had a part to play in establishing this. But now this point has been reached the Authority have reviewed all of their work on reactor development and sharpened it up to concentrate effort on narrower programmes. At Harwell this means a reduced but concentrated reactor research programme aimed at still cheaper nuclear power. Our responsibilities are primarily those concerning materials; that means fuel, cladding, moderators and coolants. You will see something of this work today.

Long-term research

We have also reviewed all our work of a longer term scientific character, work which underlies the reactor and applied programmes of the Authority. We have decided to make a large reduction in it so that in future this underlying research will absorb about a quarter of Harwell, i.e., about 10% of the total R. & D. of the Authority. Although we have thought it proper to reduce the level of effort on this underlying research, I must stress that we consider it very important for the future health of Harwell and of the Authority that we maintain a reasonable effort which is not strictly related to short term commercial objectives.

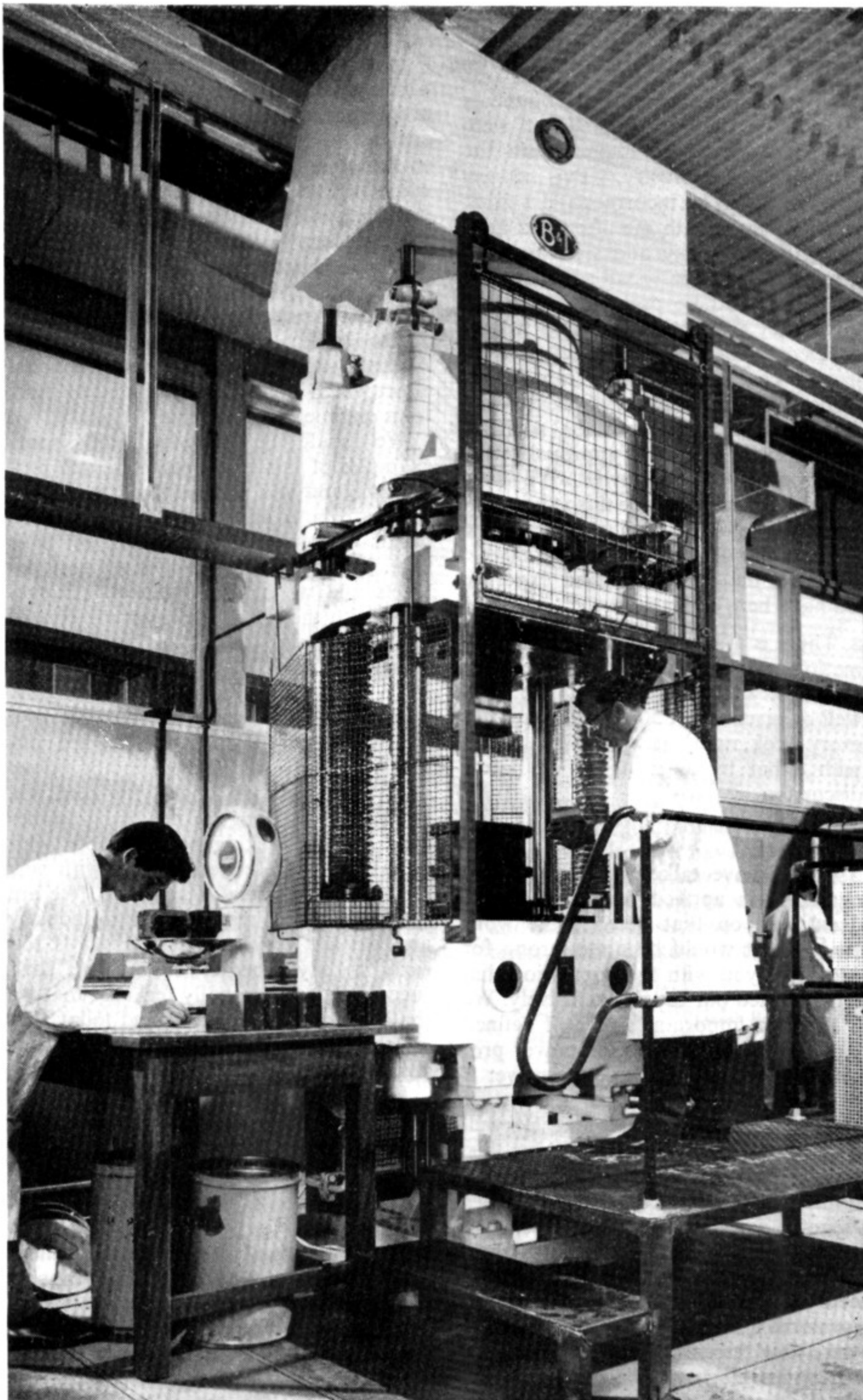
We shall be showing you some examples of this underlying research programme and you will see that the universities are both able and keen to use the major research facilities which we have here. Many of these facilities are national assets and we have a financial arrangement with the S.R.C. to cover the cost of the university research programmes which use them.

To sum up. Harwell is changing rapidly. We have made a beginning on a new orientation of our work. We are continuing with work on the reactor power programme and on underlying research, but we are building up new programmes also. We are seeking new relations with industry; we are experimenting with new kinds of commercial agreements. We are getting a good response from industry and we are very encouraged. It is too early to say whether or not we shall succeed, but I personally feel sure that we shall, and I think you will find today that all the Harwell staff have considerable confidence in the future.

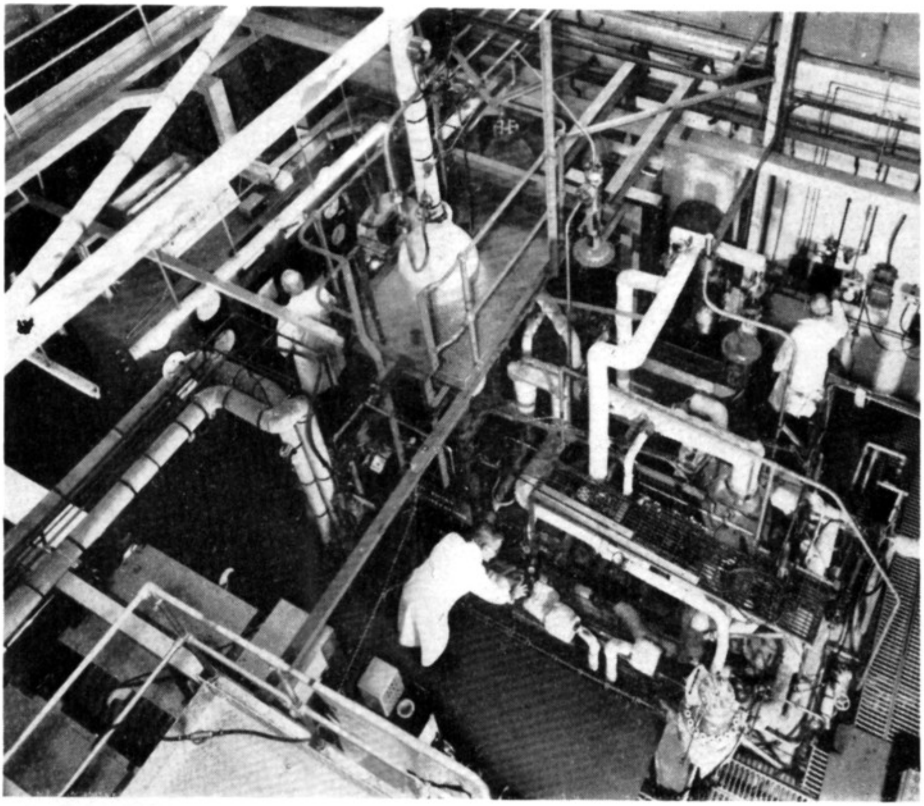
I hope you enjoy yourselves today and I hope you find plenty to interest you. If you find it worthwhile please come back some other day to see some more.

Press tour

After Dr. Marshall's speech the visitors toured the site. The exhibits and laboratories on show were chosen as representative of the research and development programme as a whole. In some areas, notably in the reactor and applied research fields, the extent to which the work could be shown or discussed was limited for commercial reasons or be-



The 350 ton hydraulic press at the Harwell Ceramics Centre.



A high pressure experimental boiling loop at Harwell. One of the many—including some operating up to supercritical pressure for steam systems—available through the heat transfer and fluid flow service.

cause the work was done on a confidential basis.

The reactor research and development programme

The reactor work at Harwell forms a closely integrated part of the overall Authority reactor development programme. A major proportion of the work is devoted to the three systems currently under development, namely the gas-cooled graphite-moderated reactors, the steam-cooled heavy-water-moderated reactors and the fast reactor. The work for thermal reactors is short-term and aimed at enhanced performance and cost reduction. The work for fast reactors is longer-term and aimed at providing data for the civil power reactors of the 1970's.

The main theme of the work at Harwell is the materials technology of fuels, cladding, moderators and coolants. Items in the exhibition illustrated some of the long-term work on these materials, the sophisticated techniques needed to evaluate their performance under the more arduous conditions expected in advanced power systems and the acquisition of more accurate nuclear data. The specific topics covered in the exhibit were:—

Fuel pin irradiation studies.

Small particle fuel irradiation techniques.

Fission product and delayed neutron emission from fuels.

Mechanised properties of fuels and solid fission product effects.

Techniques for determination of burn-up in irradiated fuel.

Determination of nuclear data.

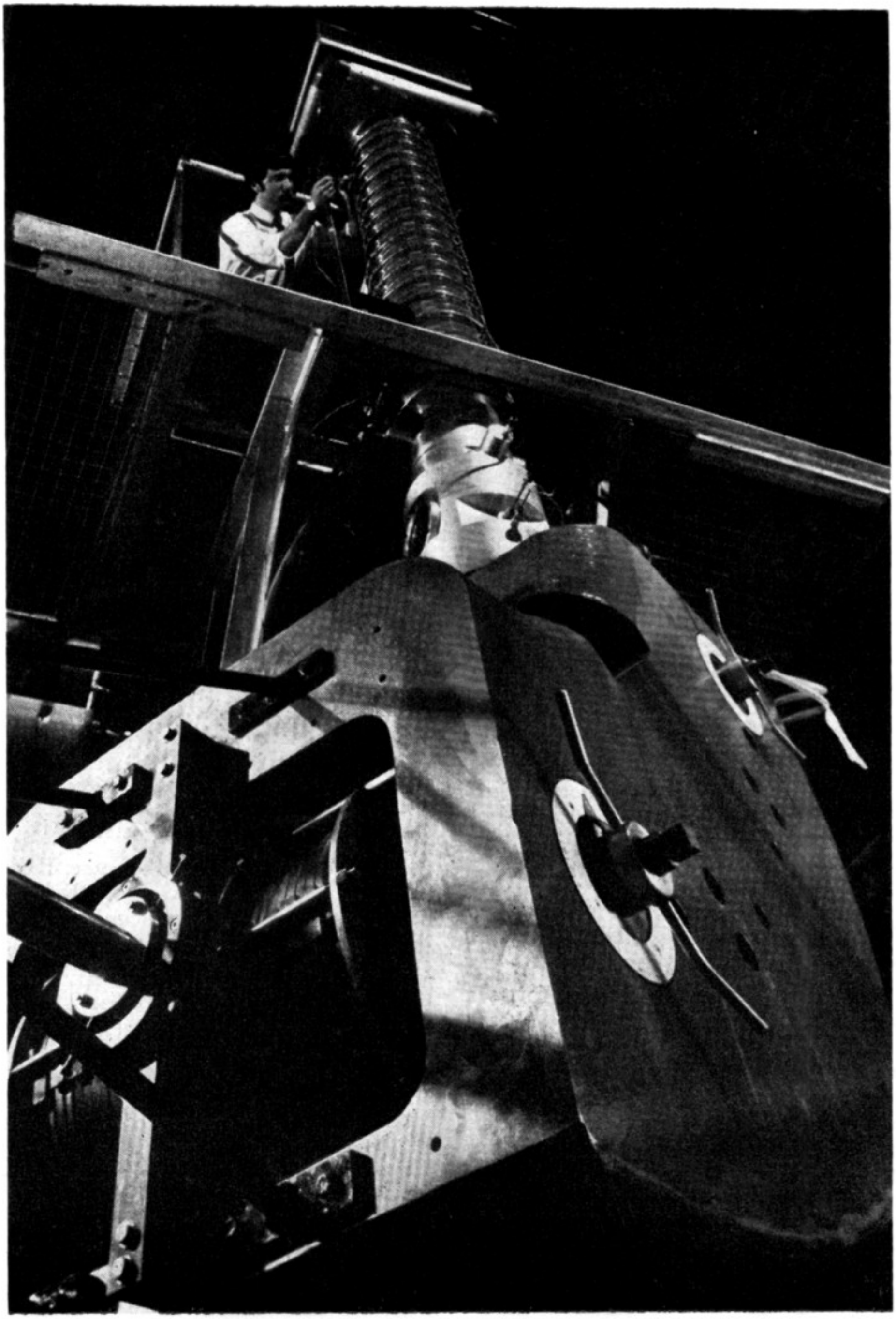
Mass transfer effects in sodium coolants.

Zirconium alloy corrosion in aqueous coolants.

Irradiation embrittlement effects in stainless steel.

Thin film techniques for the examination of irradiated fuel.

Fission product emission for coated particle fuel.



The 500 keV Cockcroft-Walton generator has recently been modified for heavy ion acceleration and a broad programme of work involving also the Nuclear Physics Division is commencing. This accelerator will allow much higher energies than the other heavy ion accelerators at Harwell for the purpose of achieving deep implantations. Part of the Cockcroft-Walton ion implantation machine showing magnet and accelerator tube.

Graphite chemistry.

Cermet fuel irradiation and post irradiation techniques.

Irradiation rigs and techniques.

The underlying scientific research programme

Research using thermal neutron beams

This exhibit showed some applications of thermal neutron beam research. The beams of low energy neutrons derived from thermal reactors have properties which can be exploited to great advantage in connection with the study of atoms aggregated together in solids and liquids. Broadly speaking the capabilities offered by neutron beam studies are:—

(a) the detection of the positions of light atoms (for example, the positions of hydrogen atoms cannot be determined by the use of X-rays);

(b) the study of the magnetism in a crystal on an atomic scale (the microscopic theory of magnetism would not exist in its modern form if it were not for neutron beam experiments);

(c) the possibility of studying individual thermal excitations in a solid or liquid and in this way examining the forces acting between atoms.

These three aspects were illustrated in the selection of work shown.

The determination of the positions of light atoms was illustrated by a collaborative programme between a team led by Professor Dorothy Hodgkin, O.M., F.R.S. (from Oxford University) and Harwell staff on the determination of the positions of hydrogen atoms in a vitamin B-12 derivative. This study also distinguished between the amide and carboxyl groups of atoms in the molecule which was impossible with X-ray methods. Vitamin B-12 is important as an anti-pernicious-anaemia factor.

The usefulness of thermal neutron beams in connection with magnetic studies was shown in work on atomic magnetism in metals and chemical compounds derived from the actinide elements and with alloys based on iron and nickel. Magnetism is associated with the lack of pairing in the outer electron shells of an atom. These same outer electrons are responsible for the bonding and valency properties of a solid and thus the study of magnetism leads to detailed information on bonding electrons. The magnetism in a solid sample can be mapped out by neutron scattering experiments because of the interaction between the atomic magnetic moment and the magnetic dipole moment of the neutron.

The third neutron property i.e. the ability to study in detail thermal excitations and atomic movements) was shown by work on water motion in soil minerals and on thermal vibrations in polymers. Motions of symmetrical molecular groups where the conventional methods, Raman and infra-red spectroscopy, fail) can be studied by the neutron technique. This work has been carried out by Oxford and Manchester Universities and Imperial Chemical Industries Ltd.

An additional exhibit was shown on the Mossbauer effect which provides another method of attack on some of the valency and magnetic problems. The Mossbauer effect is a new type of spectroscopy which employs gamma rays instead of visible light. Gamma rays are capable of penetration so that they provide a non-destructive testing type of experiment.

The variable energy cyclotron and associated experimental work

The special feature of the variable energy cyclotron (V.E.C.) is its versatility; it will accelerate different ions to an energy which can be varied over a wide range and it produces very intense beams of particles. It is used both for general nuclear research and for experiments in support of the reactor programme.

The cyclotron was on show together with a small model. Ions of the type required are produced in an arc discharge at the centre of the magnet gap. They are accelerated to the required energy by an alternating radiofrequency electric field being constrained to move in spiral paths by the magnetic field. At the magnet edge, the particles are pulled out by an electrostatic extractor, after which they travel along evacuated pipes, through bending and focusing magnets into one of the three target rooms where experimental apparatus is set up.

Some of the experiments for which the V.E.C. is being used at present are:—

(a) *Nuclear fission*

The object of this experiment is to gain a better understanding of the mechanism of nuclear fission. The apparatus consists essentially of a collimating system which produces a thin pencil of particles which pass through a 24 in. scattering chamber. The target in which fission occurs is in the centre of the scattering chamber in line with this particle beam. The fission fragments are detected by a pair of solid-state counters set at right angles to the beam. These counters measure the fragment energy spectrum which is then passed through the electronic chain into the analysing system, which consists of a DEC PDP-8 computer.

(b) *Radiation chemistry*

Studies of the influence of radiation quality on the effects produced by ionizing radiation on chemical systems, and of the effects of heavy particle radiation damage on the chemical reactivity of solids. Both topics are related to the possible utilization of ionizing radiation in bringing about chemical synthesis, and the second is also important with regard to the effects of irradiation on solid materials present in reaction systems.

(c) *Preparation of special radioisotopes*

These include plutonium-236, neptunium-235 and gadolinium-151 which are used for research in the British universities and the Authority.

(d) *Metallurgy*

These experiments study damage in crystalline materials and effects such as sputtering, channelling phenomena and the effects of interstitial gas atoms and bubbles (e.g. of helium) on mechanical properties. The materials studied include reactor fuels and canning materials.

(e) *Biological studies (M.R.C. Unit)*

To measure the influence of radiation quality on the response of living cells to ionising radiation. The effects studied are cell killing, production of mutations and production of chromosome aberrations; also being studied are physico-chemical changes in DNA. Work is done with yeast cells, bacterial cells, plant cells and cells from mammalian tissue in culture.

Other experiments using the V.E.C. involve collaboration with the Universities of London, Exeter and Belfast, the Royal Military College of Science, Shrivenham and the Nuclear Power Group.

The applied research programme (nuclear and non-nuclear)

Quality control

Under this general heading, a Non-Destructive Testing Centre has been set up for over a year, and an Analytical Research and Development Unit was established last month.

The task of the Analytical Research and Development Unit is to exploit and extend the facilities built up in the nuclear industry for the identification and control of low levels of impurities. Research will be carried out on industrial problems of impurity effects, for example on the effects of impurities on the properties and behaviour of steels, refractories, catalysts and electronic materials. The Unit will also analyse samples if the problems are appropriate to the resources at Harwell. Techniques for using computers for the more efficient use of analytical instruments will be developed, as will high speed or on-line methods of analytical control.

The exhibit showed a small selection of the techniques available and covered trace analysis using enriched isotopes and mass spectrometry, the principles of neutron activation analysis including a demonstration of the rapid analysis of an aluminium/magnesium alloy for manganese, an outline of activation methods based on neutron generators, cyclotrons and the electron linear accelerator, and a Differential Cathode Ray Polarograph as an example of an instrument developed at Harwell and now manufactured under licence.

The Non-Destructive Testing Centre maintains an Information Service and supplies material for a monthly publication, carries out contract work on industrial problems, develops N.D.T. techniques and instruments and undertakes sufficient research to keep in the forefront of new methods. The Centre is well equipped to make the best use of conventional testing techniques and is developing specialised instrumentation in the fields of ultrasonics, radiography and magnetic testing.

Advanced materials development

This exhibit illustrated a range of industrially-oriented materials work carried out under three projects—the Harwell

Ceramics, the Carbon Fibre Project and the High Temperature Fuel Cell Project. In each case new applied programmes have been based on a range of expertise built up for nuclear power technology. General enquiries are dealt with by the Materials Technology Bureau, which has the general remit to make Authority knowledge available to industry.

The work of the Harwell Ceramics Centre includes oxide refractories, the development of special carbons and graphites, fine refractories for special devices, pioneer work on the use of glow discharge for machining ceramics and other purposes, and the use of the sol-gel method of making oxide particles of controlled size, shape and properties. Some of the work is carried out under contract; some programmes are being carried out as joint projects between Harwell and industrial firms. The larger projects have been evaluated by the Programmes Analysis Unit or by market research consultants.

The Carbon Fibre Project at Harwell is part of a national programme initiated by R.A.E., Farnborough, including industrial firms and co-ordinated by the Ministry of Technology and the National Research Development Corporation. Harwell has worked on methods of producing quantities of fibres, and on methods of dispersing fibres in metals. Examples of this work were shown.

One type of high temperature fuel cell is being developed together with Aldermaston in a project partially sponsored by the Gas Council and the Ministry of Defence. The work exploits the knowledge of oxide chemistry and of ceramic technology available at Harwell in the fabrication of porous electrodes and thin films of oxide electrolyte.

Process development and engineering research

The development of the desalination processes is being carried out in close collaboration with the industrial companies that will exploit the results. To improve the existing process of multi-stage flash distillation, experimental studies are being undertaken firstly on the " flash " vaporisation of hot brine which could lead to more compact plants with a lower power consumption, and secondly on the formation of scale which adheres to the heat transfer surfaces and limits the operation of the plants.

Two other processes, reverse osmosis and freezing are also being developed. In reverse osmosis, water is forced at high pressure through a semi-permeable membrane which filters out the salt. The power needed for this process is low and it is particularly suitable for purifying effluents and brackish water with a low salt content. Porous materials to support the thin membrane against the high pressure (e.g. 1,000 lbs./sq.in.) are being developed; improved membranes are also being prepared and life tested.

It has been established that salt free ice crystals can be grown in sea water and this is the basis of the freezing process. Direct contact heat transfer may be used and as a result low capital and energy costs are possible. A wash column method of completely separating the crystals from the brine and the direct contact production of crystals with the required properties are being studied in equipment on a realistic scale.

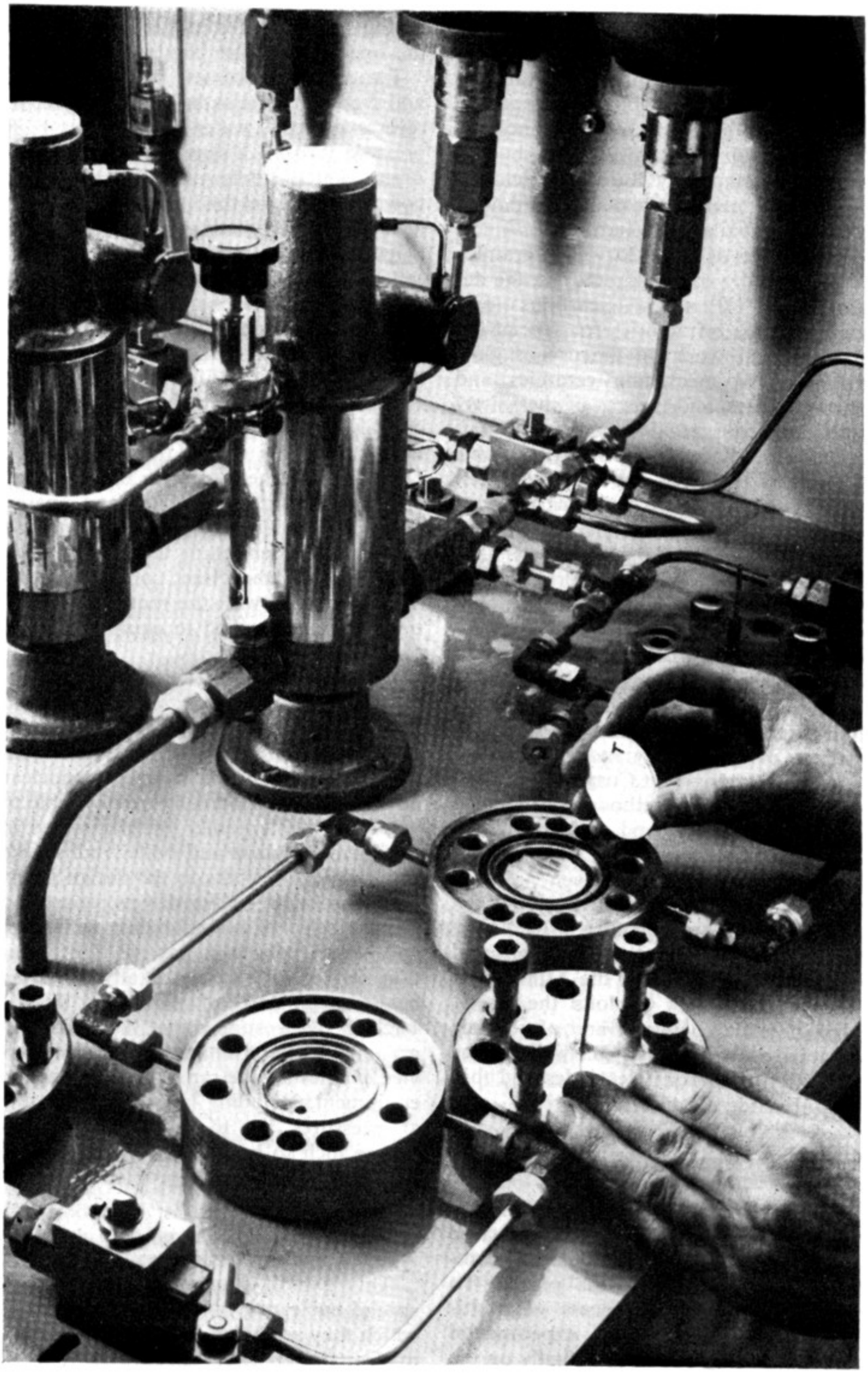
Assistance is also being offered to industry through the heat transfer and fluid flow service. The specialised teams and equipment built up to solve the heat transfer design problems met in nuclear power plant development are now able to help firms with similar problems (e.g. in the chemical plant and boiler industries). Industrial subscribers to the design information service receive design reports on subjects selected in conjunction with them and have access to an extensive information service and specialist advice in the heat transfer and fluid flow field. This is backed by a supporting research programme. The consultancy and testing service enables a wide range of experimental equipment, including large rigs operating at pressures up to 4,000 pounds per square inch to be applied to the solution of specific industrial problems in this field on repayment.

Applied nuclear technology

This exhibit illustrated some of the special nuclear techniques and the way in which they are being exploited outside the nuclear power field.

(a) Doping of semi-conductors by ion-implantation

Experience in the design and operation



As part of the Authority's work on desalination, Harwell is studying the process of reverse osmosis as a technique for both separation and concentration. A joint programme is being undertaken with Portal Holdings Ltd. to develop suitable membrane supports and engineering geometries. A view of a cellulose acetate membrane being placed in a test cell.

of the wide range of particle accelerators at Harwell has made possible the controlled doping of semi-conductors by ion implementation. The advantages of the method were illustrated by an exhibit centred on the Cockcroft-Walton generator, which is one of the machines being specially adapted for underlying research and for the commercial exploitation of this new technique.

(b) Electron-beam curing of paints

Radiation chemistry studies, allied with experience in designing and building electron accelerators, have led to the construction at the Wantage Research Laboratory of a pilot commercial installation for the ultra-rapid cold-curing of industrial paints. The potential advantages of the process are large because the cost of installing and operating ovens and the need for expensive drying storage space is eliminated. Materials can also be treated which are sensitive to heat and cannot be oven-dried.

(c) Power from radioisotopes

Developments in radioisotope-powered generators were illustrated by an operating flashing-light beacon run by a RIPPLE generator and similar to the ones installed in British and European coastal waters, and by a model of the 4-watt RIPPLE-9 generator which powers the ground-to-air radio beacon to be installed in the Outer Hebrides.

(d) Wood-plastic composite materials

Gamma radiation from cobalt-60 is being used for the commercial production of wood-plastic composites. Examples of the materials were shown which illustrate the excellent qualities of this new class of materials. Joseph Rodgers and Son Ltd., Sheffield, are exploiting the use of this new material to make wooden handles for fine cutlery which may be washed in commercial washing machines.

(e) Studying silt movements with radioactive tracers

Radioactive tracers are being used increasingly to study underwater movements of silt. The advantages of the method were explained and some of the results recently achieved near the Rosyth Dockyard in the Firth of Forth shown, with some of the equipment used.

Electronics, engineering and training work

This exhibit, of electronics and engineering work, was on show together with computer scheduling work done directly for industry and the training work carried out by Harwell.

Electronics

Equipment for data acquisition, an essential part of the research programme, has been and is being developed in collaboration with industry. Examples were shown and representatives from some of the firms concerned were present.

Engineering

Much of the equipment of modern technological research requires engineering design and development and a strong engineering design, development and manufacturing organisation exists at Harwell to provide the equipment needed for research. The following equipment and a display of photographs were on show:—

Automatic potentiometric titrator

This completely automatic equipment was designed initially for determining the amounts of certain fissile materials in a sample but has wide general applicability. The system is capable of a precision of 0.04% with 2ml of titrant or of 0.07% with 0.5 ml of titrant. Although primarily designed for automatic potentiometric titration it may also be used for pipetting pre-set volumes accurately at controlled rates and in this role has possible applicability in the medical field.

Particle track computer

It is often necessary to guide the beam of particles from an accelerator into one of a number of alternative target positions which may be many yards away. This is done through evacuated beam pipes using magnetic lenses and steering magnets to focus and steer the beam along the tube. The calculation and checking of the focussing and steering magnet setting is laborious and an analogue computer has been developed which enables the shape and path of the beam within the tube to be visually displayed for any combination of positions and settings. This greatly facilitates setting up the beam transport system for varying target positions, particles and energies. The equipment was designed and developed by the Engineering Division at Harwell and manufactured by Messrs. Camper and Nicholson primarily for use on the Variable Energy Cyclotron Project.

Spectrum plate scanner

This instrument has been designed to measure spectral line positions to a fifth of a micron and to record position and density of the lines digitally. It is directly suitable for on-line operation to a computer or as shown here as a straightforward measuring instrument without modification. Operating under programme control the collection and processing of redundant data can be eliminated, with considerable saving of time. It features temperature compensation, an error correction system, and stepping motors which both drive and form part of the measuring system. This is a method which is successfully employed for computer control in X-ray diffractometers at Harwell. The system and instrument has been designed by the Engineering Support Division for the Analytical Sciences Division at Harwell.

Computer scheduling

Methods for scheduling production so as to minimize costs, including penalties for late delivery and stocking costs for early production, have been developed using computer programs based on a so-called " permutation " technique. These have been successfully applied in a number of industries on a repayment basis, and extensions to related problems are also being undertaken. The novel feature of the permutation techniques is that they allow a near optimal solution to be found economically of an actual problem, without serious over-simplification.

A.E.A. Reports available

THE titles below are a selection from the July, 1968, "U.K.A.E.A. 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 which receive copies of U.K.A.E.A. unclassified reports.

AEEW-M 802
U.K.A.E.A. Nuclear Data Library, January, 1967. By D. S. Norton and J. S. Story. February, 1968. 19 pp. H.M.S.O. 3s. 6d.

AEEW-M 807
Measurement of Depletion of Nominally 0.04% Depleted Uranium Metal Foil by Two Different Methods. By R. A. Millington, W. H. Taylor and P. J. Webber. February, 1968. 5 pp.

AEEW-R 597
On the Thermal Neutron Capture Cross-Sections of Cobalt. By J. S. Story. May, 1968. 11 pp. H.M.S.O. 2s. 6d.

AEEW-R 602
Corrections for Frequency Domain Transformations of Winfrith Binary Cross Correlator Responses. By J. D. Cummins. 1968. 6 pp. H.M.S.O. 2s. 6d.

AERE-R 5773 (Vols. 1-5)
Proceedings of the Conference on the Physics Problems of Reactor Shielding held at the Atomic Energy Research Establishment, Harwell, September, 1967. Sponsored by the British Nuclear Energy Society and the Institute of Physics and the Physical Society. May, 1968. 1,447 pp. H.M.S.O. 188s.

CLM-R 72
Some Observations on the Flow of a Tenuous Plasma in a Magnetic Field. By D. W. Atkinson and J. A. Phillips. December, 1967. 11 pp. H.M.S.O. 1s. 9d.

CLM-R 83
Gravitational and Drift Waves in a Periodic Slab. By K. Rohlena and J. D. Jukes. January, 1968. 20 pp. H.M.S.O. 1s. 9d.

CLM-R 85
The Economic Generation of Power from Thermonuclear Fusion. By R. Carruthers, P. A. Davenport and J. T. D. Mitchell. October, 1967. 33 pp. H.M.S.O. 4s. 6d.

PG Report 832(W)
Analytical Method for the Determination of Plutonium by Amperometric Titration (Argentic Oxidation, Ferrous Reduction). By J. Cherry, J. Holmes and J. J. B. Williams. 1968. 9 pp. H.M.S.O. 1s. 9d.

TRG Report 1601(R)
Physical Properties of some Plutonium Ceramic Compounds. A Data Manual. Compiled by B. J. Sedden. 1968. 66 pp. H.M.S.O. 8s.

continued from page 218

has been responsible for the production and distribution of all the radioactive products offered by the Authority for civil purposes. Dr. Grove's present status is Director. He was awarded the Silvanus Thompson Medal of the British Institute of Radiology in 1962.

Mr. H. L. Barman

Mr. Harry Lowis Barman, age 66, was born in Glasgow and educated at Repton and Cambridge where he took an engineering degree. Most of Mr. Barman's professional life has been devoted to industrial production engineering. He joined Stewarts & Lloyds, tube makers, in 1923, leaving there in 1934 to join Production Engineering Limited. While with Production Engineering, Mr. Barman began his first association with Rolls-Royce when he came to the Company in a consultative capacity in 1937.

Subsequently, while still with Production Engineering, he took charge of the B.O.A.C. airline supplies system, remaining with the Corporation until 1946 when he went to Chance Brothers, glass manufacturers, where he was Director in charge of the Engineering Division. He returned to Rolls-Royce as a member of the staff in 1954. Four years later he was appointed Director of Rolls-Royce and Associates Limited, then newly formed to develop the nuclear activities of the Company. Mr. Barman also held directorships in Rolls-Royce Developments Limited and Renfrew Foundries Limited. He resigned from these appointments in July 1966, but continues to act for Rolls-Royce in a consultative capacity.

Mr. Barman came to the U.K.A.E.A. as a consultant in April, 1967.

Dr. Charles Charlton Evans, B.Sc. (Chemistry), A.R.I.C.

Dr. Evans was born in County Durham on 26th September, 1918. He was educated at Latymer Upper School and University College, London.

He served in the Royal Navy from 1939-1946 and attained the rank of Lieutenant (G) in the R.N.V.R.

He joined Thorium Limited in 1948. As manager of the Inorganic Department of the Radiochemical Centre he has paid frequent business visits to the U.S.A. during recent years.

27th June, 1968

"Dragon" appointment

The following was issued on behalf of the Board of Management of the O.E.C.D. High Temperature Reactor Project DRAGON. *A similar release was made by the Organisation for Economic Co-operation and Development in Paris.*

Dr. Leslie R. Shepherd, formerly Deputy Chief Executive of the O.E.C.D. High-Temperature Reactor Project (DRAGON) has been appointed Chief Executive to the Project in succession to Mr. C. A. Rennie who has relinquished his appointment to act as a consultant, primarily in the field of high temperature reactor technology.

Dr. Shepherd's appointment, approved last week by the DRAGON Board of Management, takes effect as from 1st July, 1968.

The DRAGON Project is one of the European Nuclear Energy Agency's joint undertakings in which 12 of the Agency's member countries are participating. They are: Belgium, France, Germany, Italy, Luxembourg and the Netherlands (all of the European Atomic Energy Community), Austria, Denmark, Norway, Sweden, Switzerland and the United Kingdom.

Mr. C. A. Rennie has been Chief Executive of the DRAGON Project since its inception on 1st April, 1959.

Biographical note

Born on 23rd November, 1918, Dr. Shepherd joined the Nuclear Physics Division at Harwell in 1948. In 1949 he started work on fast reactors and headed the Fast Reactor Physics Group from 1952 until 1956. In 1956 he became a member of the group set up to develop the concept of the high temperature gas-cooled reactor, later adopted as the DRAGON Project.

He is a former President of the International Astronautical Federation and sometime President of the British Interplanetary Society.

Dr. Shepherd has been Head of Research and Development of the DRAGON Project since 1959, subsequently becoming Deputy Chief Executive.

1st July, 1968

Integrated gas turbine plants using CO_2-cooled reactors

This paper, by Dr. H. Kronberger, F.R.S., Scientist-in-Chief, Reactor Group, U.K.A.E.A., E. Maillet, C.E.A., Saclay, France, and G. Coast, Reactor Group, U.K.A.E.A., was presentel at a Symposium on the Technology of Integrated Primary Circuits for Power Reactors organised by the European Nuclear Energy Agency in Paris from 20th-22nd May.

Introduction

Present G.C.R./steam turbine plants are characterised by high thermal efficency, moderately high capital cost and low electrical generating cost. The existing system has a good development potential and further improvements can be expected from savings arising from repetition or development of existing designs, advances in fuel technology, and the possible use of larger units.

At present, the major part of the capital costs are about equally divided between nuclear items associated with the reactor, and the steam turbine/power generating equipment. This implies that cost reductions in either field are equally important. The adoption of an integrated gas turbine system promises a reduction in capital costs without an excessive efficiency penalty.

The possibility of replacing the steam turbine by a gas turbine system has been discussed on numerous occasions since the early days of gas-cooled reactors. It has generally been agreed that although substantial gains should be obtained because of the more compact rotating machinery, the cost of the associated heat exchange equipment, which is required to maintain thermal efficiency, is critical. This situation improves as the reactor core outlet temperature increases and at the present time two possibilities are emerging, namely, a helium-cooled reactor capable of very high outlet temperatures coupled with compact heat exchange equipment, and the moderately high temperature A.G.R./CO_2 system exploiting the imperfect behaviour of CO_2.

Questions of capital cost and thermal efficiency cannot be considered in isolation and it is necessary to analyse thermodynamic cycles in parallel with possible reactor layouts and cost studies. This makes the design situation difficult; however, it is further complicated by considerations of what the final overall design objectives should be. In some cases, a very low capital cost might be more important than generating cost, while in other instances a low generating cost is more attractive.

The purpose of this paper is to outline some of the various thermodynamic cycles that have been considered; to illustrate how, for a particular cycle, a compact integrated system can be engineered; to give an appreciation of the development aspects involved, and to indicate the order of cost savings which might reasonably be expected. Of course, the choice of the particular cycle used, or layout considered, does not imply that this is the best that can be achieved.

Properties of CO_2 and thermodynamic cycles

Carbon dioxide can be condensed at ambient temperature, the critical point occurring at 31°C at a pressure of 75 kg/cm^2. The physical properties of the gas change in the approach to the liquid state and in the region which can be used in the compression stages of a working cycle. As is shown in fig. 1, the isentropic compression energy $\triangle H_s$ for a given compression ratio, decreases as the initial pressure po increases. At the same time the temperature Ts at the end of isentropic compression increases slightly and then decreases. Finally, the specific heat Cp increases more or less, according to the proximity to the critical point.

The saving in compression work makes it possible to reduce the power to be installed in proportion to the work $\triangle H_t$ of the turbine plus that $\triangle Hc$ of the compressor, for a given useful work $\triangle H_t$-$\triangle Hc$. However, the efficiency is only slightly improved since it depends above all on the heat removed, which is proportional

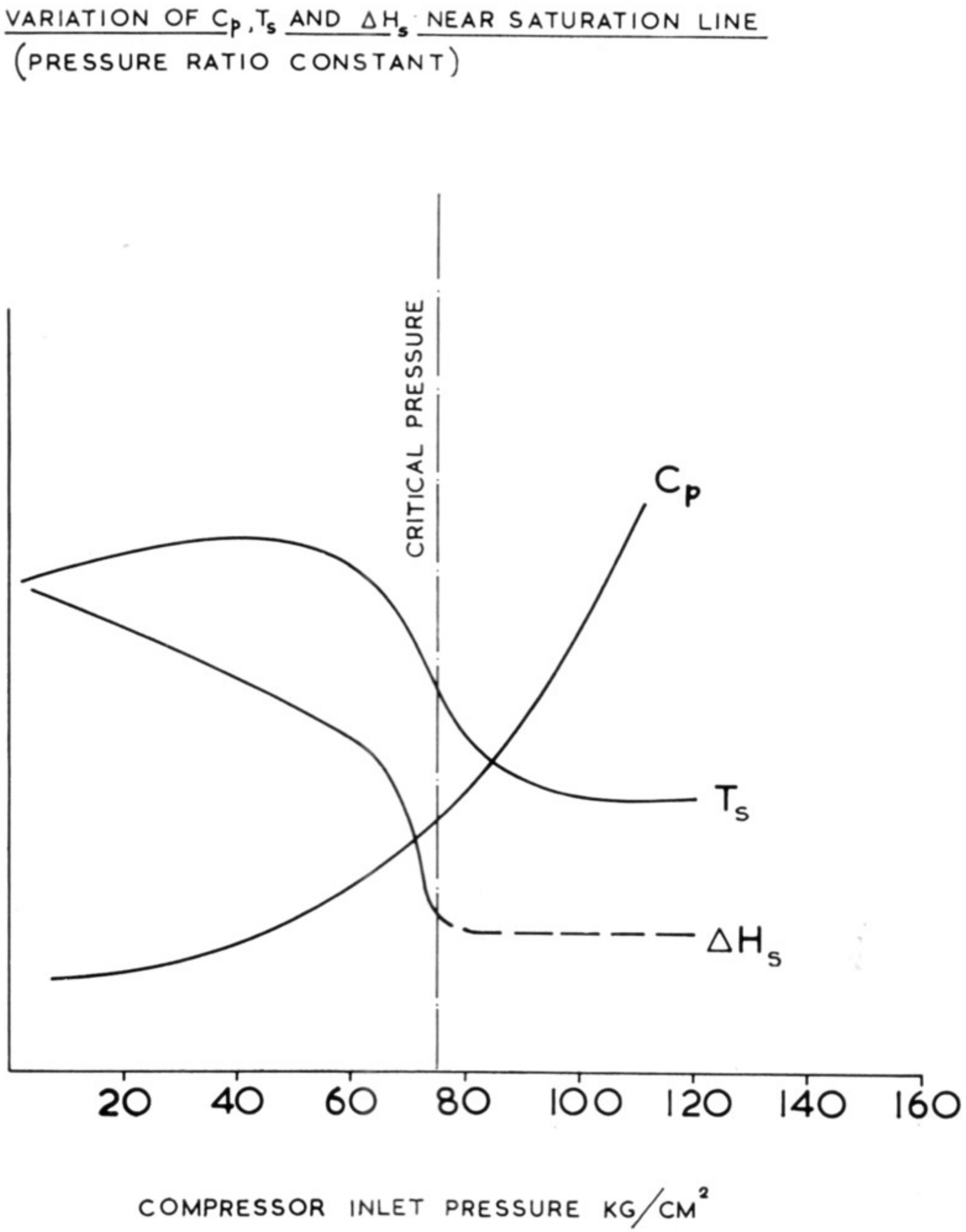
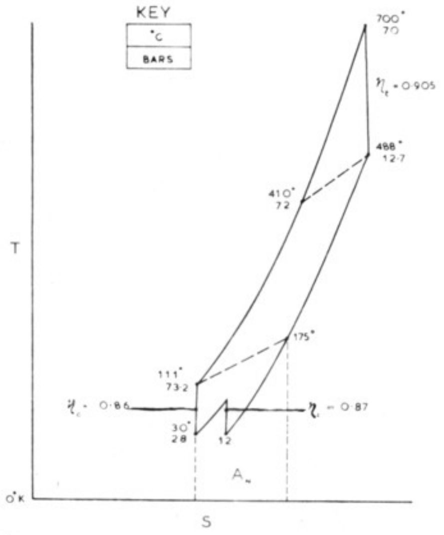


Fig. 1

to the negative area A_N of the cycle (figs. 2 to 5). This area diminishes in height at high pressure but widens as a result of the great differences in entropy on cooling.

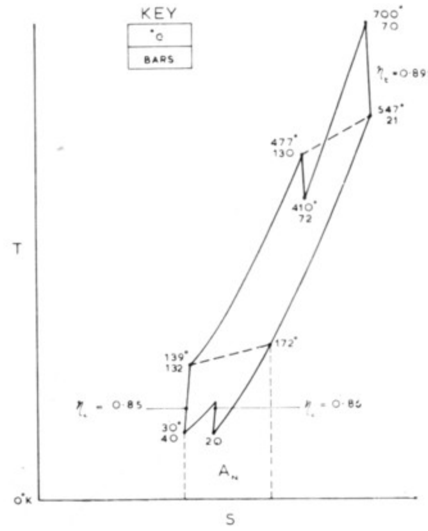
In addition, for a given heat contribution $\triangle Ha$ in the reactor, the heat recycled in the recuperator $\triangle He$, increases with the specific heat for high pressure cycles.

The following cycles, given as an example, have the same maximum temperature and pressure in the reactor, with machine efficiencies depending on the pressure level and the compression or expansion ratio. The efficiency of the recuperative heat exchanger is particu-



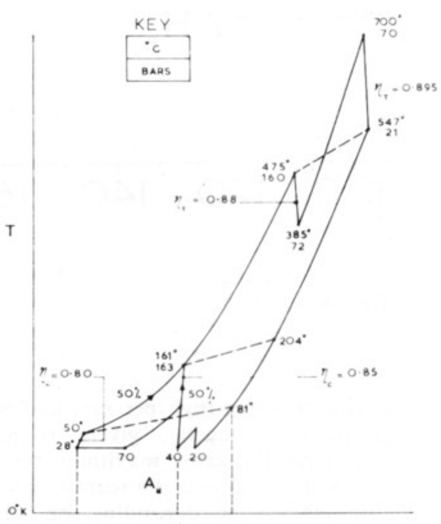
SIMPLE · CYCLE

Fig. 2



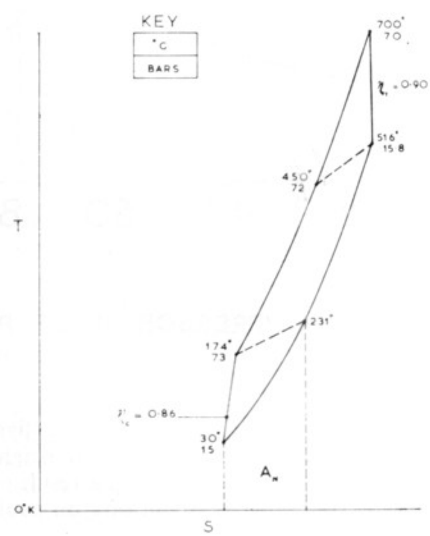
REHEAT CYCLE

Fig. 3



REHEAT CYCLE WITH LIQUID STAGE

Fig. 4



SIMPLE CYCLE WITH HIGH TEMPERATURE HEAT REJECTION

Fig. 5

larly dependent on the minimum cycle pressure.

The ordinary cycle, shown in fig. 2, has the disadvantage of operating at a low minimum pressure and the efficiency of the recuperator will not economically exceed 80%, limiting the cycle efficiency to approximately 38% for 700°C at reactor outlet.

The cycle shown in fig. 3 has the recuperator pressure increased with an expansion before entry to the reactor. Despite a slightly greater proportion of heat recycled △He/△Ha, the surface area and size of the heat exchanger can be reduced and the better recovery efficiency can produce a slightly higher general efficiency of about 39%.

The efficiency would be considerably improved with the cycle shown in fig. 4 where part of the compression is carried out in the liquid phase. However, the equilibrium of the temperature differences in the heat recuperator requires a by-pass of flow before condensation. This reduces the heat rejected to the cold source and one part of the area A_N must be multiplied by a by-pass factor which is of the order $\frac{1}{2}$. This cycle, however, requires more complex machinery and a long heat exchanger. Further, control of the system presents a number of difficulties.

The simple cycle shown in fig. 5 is specially suited to the recovery of heat, for example the desalination of sea water, because of the relatively high temperature of heat rejection. Alternatively, this CO_2 cycle can be combined with a freon system to achieve a high overall efficiency at the cost of additional investment.

Table I summarises the characteristics of these cycles using the Vukalovitch[1] tables for the thermophysical properties of CO_2. Table I does not include external or alternator losses.

It should be noted that the reactor inlet temperature is different for the various cycles and appropriate by-pass cooling flows are necesary to maintain the moderator temperature at a value which ensures acceptable radiation-induced dimensional changes.

There are various methods for controlling the power output; by varying the pressure, change of compression ratio, or reactor outlet temperature. The first method has the advantage of maintaining a high efficiency at part load conditions and although it implies the use of a storage vessel, pumping equipment can be minimised by utilising the large pressure differences existing at various points in the system.

Design concept for a reheat gas turbine system (typical cycle shown in fig. 3)

Design philosophy

Although it is possible to consider an integrated reactor/gas turbine system using a single power turbine and heat exchanger, it appears preferable to use a multiplicity of individual power circuits. With this concept it is possible to obtain a good space utilisation and to ensure that the reactor can be cooled under all fault conditions by arranging the various power circuits in parallel with the core. This scheme also allows the heat exchangers, coolers, turbines and compressors to be housed in " pods ", cast into the wall of the concrete pressure vessel, thereby ensuring adequate shielding and easy access to units requiring maintenance or possible replacement. This layout can also have a significant effect on the station build programme since all the equipment can be factory made and transported to site as complete units which are not required until late in the construction schedule.

Because of the high reactor operating pressure it is desirable to limit the internal dimensions of the pressure vessel as much as possible and these are reduced to a minimum by housing the reactor core only inside the vault. A further consequence of this feature, is that it allows the core support and restraint system to be designed so that the refuelling standpipes and fuel channels are always in alignment.

Description of plant

The design has been based on a fully integrated 750 MW(e) reactor concept and three 250 MW(e) power turbine/generator units have been adopted since this ensures a reasonable sized turbine. It is not desirable to have the generators themselves within the gas circuit and sealed drive shafts are therefore necessary. The reactor, together with the three power plant assemblies are contained in a pre-stressed concrete vessel designed to

Table I Cycle characteristics for unit mass flow $\left(\frac{kg}{sec}\right)$

Cycles shown in Fig	2	3	4	5
(Heat units $\frac{Kj}{Kg}$)				
Reactor heat ΔH_a	349·0	349·0	378·0	303·0
Turbine work ΔH_t	251·0	253·0	275·0	220·8
Compressor work ΔH_c	119·0	116·0	115·0	115·3
$(\Delta H_t + \Delta H_c)/(\Delta H_t - \Delta H_c)$	2·79	2·72	2·41	3·29
Heat recycled ΔH_e	338·0	413·0	505·7	314·5
$\Delta H_e/\Delta H_a$	0·97	1·18	1·34	1·03
Effectiveness of heat exchanger	0·81	0·87	0·86/0·89	0·82
Heat rejected	217·0	212·0	220·0	198·0/167·0
Cycle efficiency $(\Delta H_t\text{-}\Delta H_c)/\Delta H_a$	0·38	0·39	0·42	0·35/0·45

operate at a pressure of 72.5 kg/cm² (1,000 p.s.i.). The high pressure coolant is carried in internal ducts and inside the tubes of the recuperative heat exchanger.

Gas circuit

The coolant flow circuit with the gas conditions at various points is shown in fig. 6. Fig. 7 is a vertical section through the reactor and shows the horizontally mounted power turbines and generators located at ground level and the vertically mounted cooler units. Fig. 8 gives details of the concrete pressure vessel and shows the positioning of the three equally spaced power circuits which are accommodated in the wall of the pressure vessel. Fig. 9 is a vertical section through a power circuit and shows the positioning of the coolers, heat exchangers, turbine/compressor units and the inter-connecting ducting.

The high temperature gas leaving the core is fed to each of the L.P. power turbines through thermally insulated

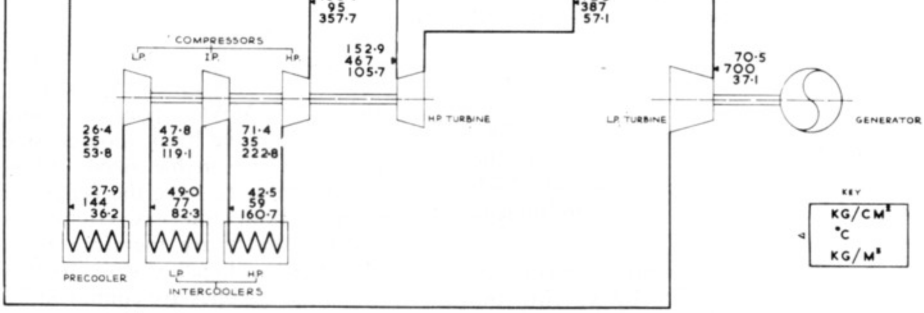
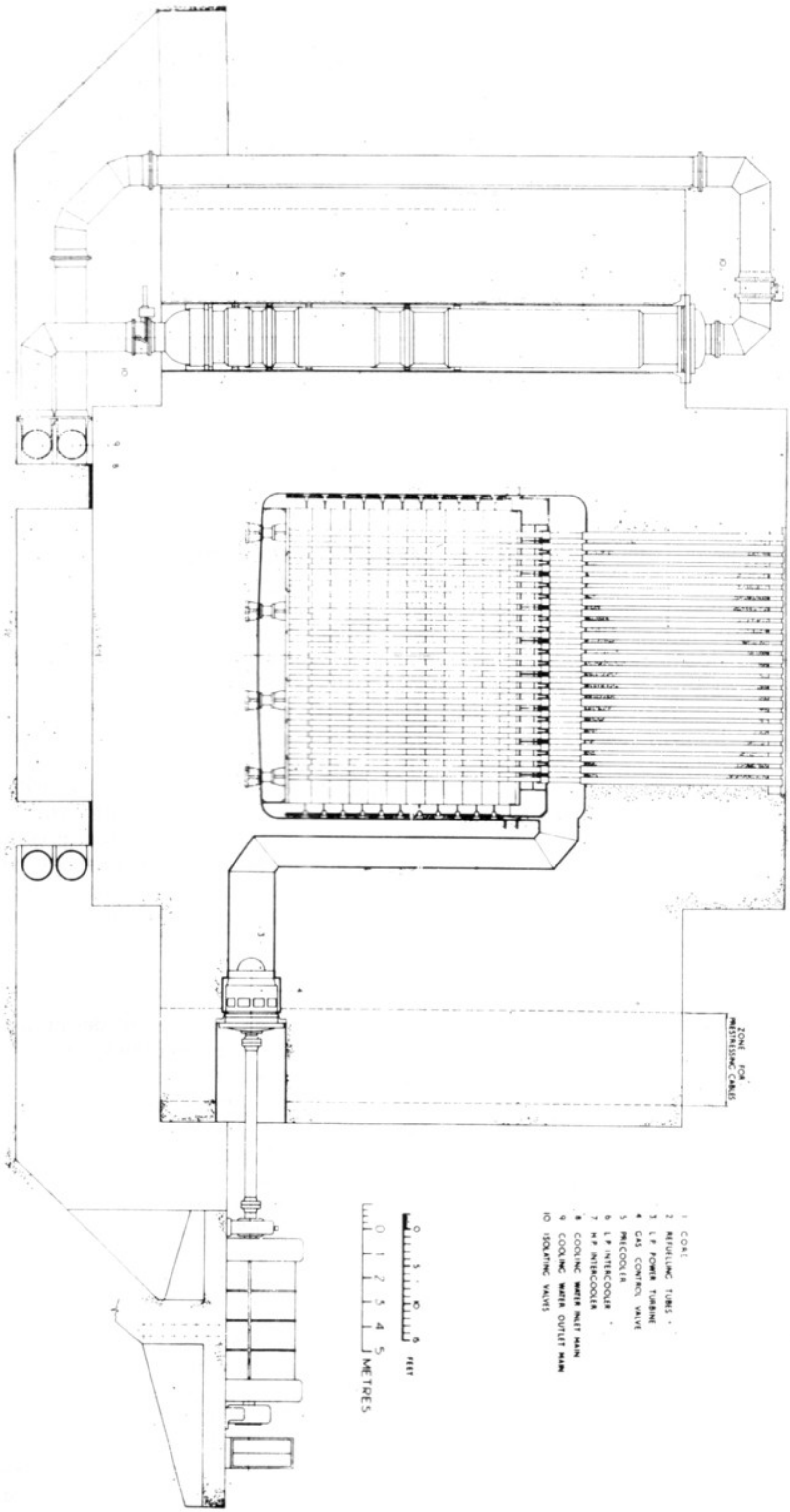


Fig. 6

Fig. 7



ZONE FOR PRESTRESSING CABLES
1 CORE
2 REFUELLING TUBES
3 L.P. POWER TURBINE
4 GAS CONTROL VALVE
5 PRECOOLER
6 L.P. INTERCOOLER
7 H.P. INTERCOOLER
8 COOLING WATER INLET MAIN
9 COOLING WATER OUTLET MAIN
10 ISOLATING VALVES
0 5 10 15 FEET
0 1 2 3 4 5 METRES

water cooled ducts cast into the wall of the concrete vessel.

The turbines exhaust into a collecting chamber and from there the gas is passed to the L.P. side of the axial flow recuperative heat exchanger. The L.P. gas flows upwards over the outside of the heat exchanger tubes to a collector region at the top of the unit and from here the gas is ducted to the pre-cooler section of the cooler unit.

This unit comprises a large number of individual water tubes which run the full length of the unit. Water flows upwards inside the tubes and the gas downwards on the outside giving counter flow conditions. The pre-cooler section is located at the top end of the unit, the L.P. intercooler in the mid-section, and the H.P. intercooler at the lower end. Short horizontal ducts connect the various cooler sections to the appropriate compressors which are housed in a pod situated between the cooler and the heat exchanger.

The H.P. turbine-compressor unit is a vertically mounted single shaft assembly with a 5 MW electric starter motor at its upper end. The L.P. compressor is mounted immediately below the starter unit and below this is located the H.P. turbine, then the H.P. compressor with the I.P. compressor at the extreme bottom end of the assembly. The starter motor has a dual function, apart from rotating the compressors for start-up it allows for cooling of the reactor in the event of a rapid shut down.

On entering the cooler the gas passes through the various stages of cooling and compression, as shown in fig. 9. From the bottom end of the cooler the gas is fed to the H.P. compressor and from there it is ducted to the high pressure side of the heat exchanger. The high temperature H.P. gas is then fed to the H.P. turbine where it is expanded to reactor pressure before entering the interior of the pressure vessel. Approximately half of the gas flows downwards and enters the plenum below the core and the remainder flows upwards to the underside of the top diaphragm, and then through the re-entrant passages in the core to mix with the gas from the bottom plenum before entering the fuel channels.

The whole of the inner surface of the vessel and the upper surface of the top diaphragm together with the appropriate surfaces of the heat exchanger and cooler pods are lined with stainless steel foil insulation. The thicknesses of the foil packs and foil spacing has been assessed on a total heat leakage to the vessel cooling system of approximately 5 MW.

Thermal efficiency and cost

Thermal efficiency can usually be improved by increasing the complexity of the system at the expense of additional capital investment. To fully exploit the advantages of a particular cycle it is necessary to carry out an optimisation study to achieve best results. Although such a detailed investigation has not yet been carried out, present indications are that in the case of the reheat cycle the economic efficiency will be in the region 38-39%.

Development aspects

Pressure vessel and insulation

It is considered quite feasible to design a vessel of the required size for a pressure in excess of the current figure of 72.5 kg/cm^2 (1,000 p.s.i.). There is therefore, the prospect of achieving higher efficiencies and further reductions in plant size and costs.

Some development work will be required in connection with insulation performance at the higher pressures involved, and also to investigate corrosion behaviour and materials to exploit the further advantages of higher gas temperatures.

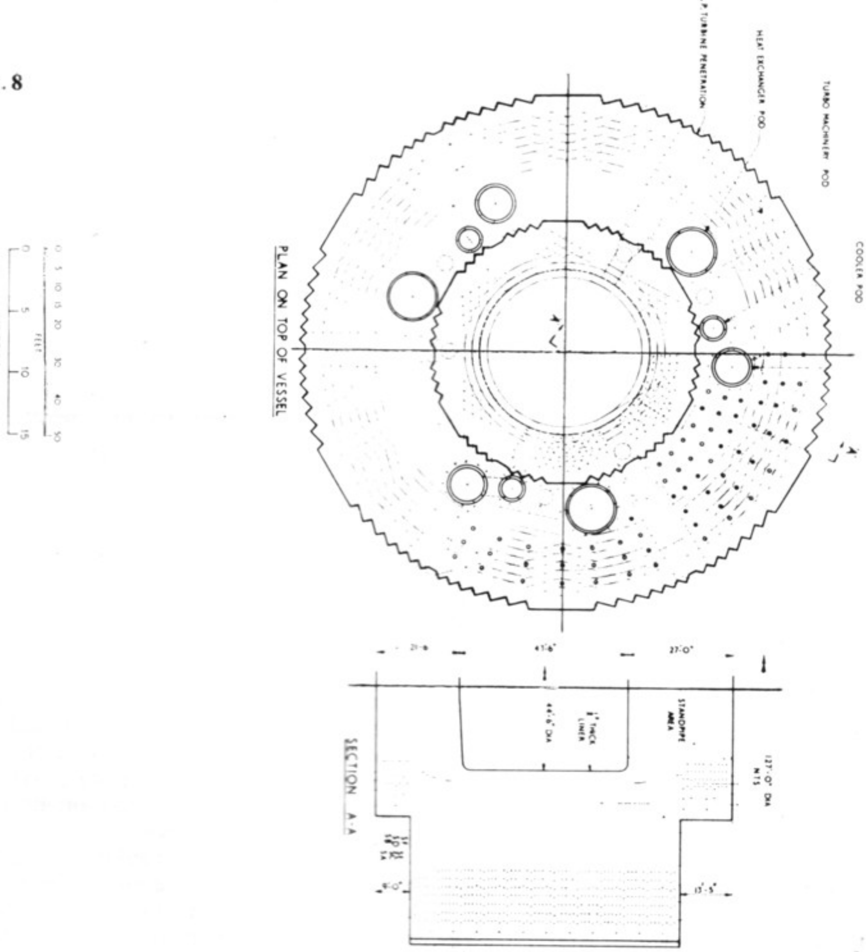
Reactor core

Although the present design assumes a core size corresponding to current A.G.R. parameters, the use of coated particle fuel in silicon carbide, currently being developed by the U.K.A.E.A., could be used to advantage. This fuel would readily facilitate high coolant pressures and temperatures and enable a higher core power density and a more compact core and pressure vessel to be employed than that in the design illustrated.

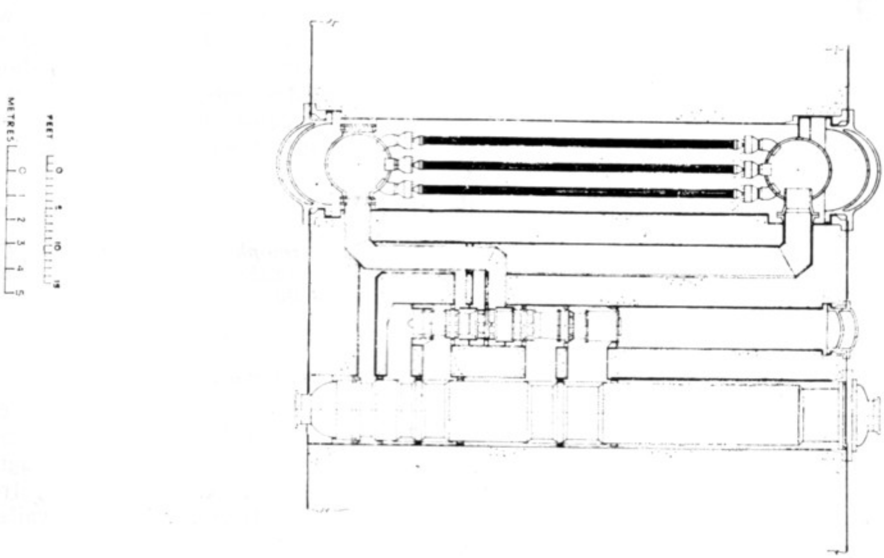
Rotating machinery

It has previously been mentioned that one of the advantages of the high pressure CO_2 cycle is the reduction in compression work and this permits small moderate speed, turbine/compressor units to be used. The main difference in the

Fig. 8



PLAN ON TOP OF VESSEL
L.P. TURBINE PENETRATION
HEAT EXCHANGER POD
TURBO MACHINERY POD
COOLER POD
SECTION A-A
STANDPIPE AREA
METRES
FEET



FEET
METRES

Table II Cost comparison for gas turbine/steam turbine stations

Group	Equipment	Relative Cost*
Heat Transfer	Heat exchangers fluids: Circulation, treatment, supply	84%
Power production	Turbines	31%
Electrical	Generators and auxiliaries, transformers, E.H.V. cabling	132%
Buildings	Main process building	41%
Pressure vessel	Concrete P.V., liners and ducts, C.W. system, thermal insulation	106%

$$\text{* Relative cost} = \frac{\text{cost of G.T. items}}{\text{cost of S.T. items}} \times 100$$

context of development work in this field is that the high gas density, and consequently the blade loadings, are dominated by gas bending stresses rather than centrifugal effects which are small. This has the effect of biasing the blade design more towards hydraulic machinery than conventional gas turbine plant. To establish design principles it is envisaged that a small closed cycle turbine/compressor rig will be a first step towards the development of large units.

Heat transfer equipment

It is well known that the efficiency of a closed cycle gas turbine system is largely dependent upon the effectiveness of the recuperative heat exchanger. An extensive development programme could have an important effect on the ultimate economics of the system in establishing a cheap, compact, and reliable heat exchanger design.

System potential

From the results of a preliminary cost comparison between steam and gas turbine A.G.R. type stations it has been found that the major cost differences can be collected into five main groups: heat transfer, power production, electrical, buildings and pressure vessel. The relative cost for each of those groups is shown in Table II for a typical, non-optimised, reheat cycle having a thermal efficiency of about 38%. The overall cost savings appear to be in the region of 10% or more of the tender price.

These cost savings would suggest that gas turbine systems could give worth while reductions in capital investment. In the final assessment of gas turbine applications the possibility of integrating such plants directly, or indirectly, with fast reactors should not be neglected, and it may be that our present efforts should be regarded as only an initial stage in the continuing development, and much wider application, of gas-cooled reactor technology.

Reference

1 *The Thermophysical Properties of CO_2.* M. P. Vukalovitch and V. V. Altunin Moscow Power Institute 1965.

IAEA agreements

The second edition of "Agreements Registered with the International Atomic Energy Agency ", which lists the agreements registered with the Agency from 1957 to 31st December 1966, is available from HMSO.

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

continued from page 214

Radiological Protection

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

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

Critical Path Methods

8th to 11th October, 1968

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

Medical Radioisotope Generators

15th to 17th October, 1968

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

Commissioning, Use and Maintenance of Reactor Instrumentation

21st October to 1st November, 1968

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

Process Instrumentation

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

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

Introduction to Production Control by Computer

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

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

Magnet Design

18th to 22nd November, 1968
14th to 18th July, 1969

This course is intended to be suitable for both design engineers and scientists with or without experience in the field.

It will cover basic theory, magnetic materials, Fabry factors for coils, forces on coils, digital and analogue computation and computer calculations; field-measurement techniques, technology of low temperature and cryogenic magnets, practical winding design and construction techniques, superconducting magnets and pulsed magnets. Fee: £40 exclusive of accommodation.

BNES conference, 1969

The British Nuclear Energy Society is organising the following conferences and symposia in 1969:—

28th March—"Safety and Siting."

3rd Week June—"The Physics of Fast Reactor Operation and Design."

10th-11th July—"Model Techniques for Prestressed Concrete Pressure Vessels."

Details are available from The Secretary, BNES, The Institution of Civil Engineers, 1-7, Great George Street, Westminster, London, S.W.1.

Spring 1969—"Nuclear Gas Turbines."

Details of this symposium are available from H. H. Heath, Esq., Chairman of the Organizing Committee, M.E.L., c/o English Electric Co. Ltd., Whetstone, Leicester.

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

Symposium on fusion technology

The engineering problems of plasma physics and nuclear fusion research were the subject of a four-day international symposium held at St. Catherine's College, Oxford, from 2nd-5th July.

The symposium, which is a biennial event, is held in a different country on each occasion and this year the hosts were the UKAEA's Culham Laboratory. The symposium was opened by Dr. J. B. Adams, C.M.G., F.R.S., Member for Research and former Director of Culham Laboratory.

Over sixty papers were presented by authors from Germany, France, USSR, Italy, USA, Japan and the UK on a wide range of subjects, including superconductivity, magnetic fields, vacuum technology, cryogenics, switches and energy storage, data processing and particle sources. Other papers described the engineering details of complete plasma physics experiments and the technological problems and probable economics of power generation by fusion reactors.

Delegates from the following countries attended the symposium:—

Germany, France, USA, Japan, Netherlands, Poland, Italy, Belgium, USSR, Switzerland and UK.

Previous symposia (previously called Symposia on Engineering Problems in Controlled Thermonuclear Research) have been held at:—

AERE, Harwell	England	1960
Fontenay-Aux-Roses	France	1962
Munich	Germany	1964
Rome	Italy	1966

26th June, 1968.

How D.F.R. was repaired

As announced in the Authority's press release of 24th June, 1968 (see page 216), the Dounreay Fast Reactor resumed power operation on 22nd June, 1968, after being shut-down on 29th July, 1967, because of a leak in the primary coolant circuit.

Methods of leak detection employing gold and helium were improvised and remote welding techniques specially developed to bring the reactor back into service.

When the leak was detected on 9th May, 1967, the reactor was operating at a thermal power of 60 MW. The total volume of liquid metal which had escaped amounted to only a few litres and all of this had been retained within the argon-filled closely fitting leak jacket which surrounds the whole of the reactor vessel and primary circuit. This leak jacket is divided into several sections, and the leak occurred into the section containing the vessel and the 48 pipes joining the vessel to the heat exchangers. A series of pressure and leak tests confirmed that the leak was extremely small, and it was decided to continue to operate the reactor.

Towards the end of July, 1967, the leak rate had increased to about 200 litres per day and it became operationally inconvenient to have to remove this amount from the leak jacket. The reactor was therefore shut down for repairs.

The leak rate at its maximum was equivalent to that which would occur through a hole 0.015 in. in diameter.

Immediately the reactor was shut down the leakage of liquid metal appeared to stop completely, and it was thought that the leak might have sealed itself off; this would have prevented the use of pressure or leak tests to locate it. This phenomenon however showed that either the leak was in a position where a large temperature reduction occurred on shut-down causing closure of the leak (that is, it was in the lower part of the vessel or outlet pipes) or, conceivably, it was in the region of the coolant free surface whose level lowered by a few inches whenever the reactor power was reduced to zero.

Conclusive evidence that some leakage of liquid metal did occur with the reactor shut-down proved very difficult to obtain. It was obtained on 21st September, 10 days after 10 gms of gold had been added to the 50 tons of primary sodium-potassium coolant to act as a tracer and after holding the primary circuit at a pressure of about 20 p.s.i.g. and a temperature of 210°C. Small samples of coolant taken from the leak jacket drain and examined by activation analysis (involving irradiation in D.M.T.R. and subsequent analysis of the radiation

The section of repaired pipe (in polythene wrapping) being replaced preparatory to welding.

from the sample) showed at this time the characteristic radiation of gold, and its concentration in the coolant was estimated at 0.04 $\mu g/cc$.

Proving that the leak definitely existed at shut-down was a major step forward because in principle it seemed possible to find it, perhaps by detecting the escape of a gaseous tracer such as helium.

Prior to this test the coolant had been lowered on several occasions to just above the top of the core, and the argon cover gas pressurised with helium. No helium had been detected in the surrounding leak jacket at any time, and it was concluded that the leak was most unlikely to be in the upper part of the vessel or connecting pipes. The next stage was to unload all the core and inner breeder fuel elements so that the coolant could be completely discharged and a gas test applied to the lower half of the vessel. On 24th October the coolant level in the vessel was lowered progressively, again with the cover gas pressurised with helium, and as the coolant uncovered the outlet pipes helium was detected in the leak jacket for the first time.

This gas leak was at least 20 times smaller than expected and ceased after a few hours, possibly due to blockage of the hole by oxide impurities.

To re-establish the liquid metal leak the primary circuit was refilled and the temperature raised to 235°C, after which the coolant level was again lowered. Again helium was detected in the leak jacket as the outlet pipes were uncovered and this time the hole remained open although the leak rate was surprisingly small at about 200 cc/day of gas.

This information showed that the leak was in one of the 24 outlet pipes, either at the nozzle where it joined the vessel or at some point along the pipe up to the thermocouple block outside the neutron shield where the section of leak jacket terminated (8 ft. away from the vessel).

At this stage the very small size of the gas leak made it difficult to devise helium detection tests which would give further information on its position. It was known however from supporting experimental work that the rate of leakage from a crack that had gas behind it under pressure but was nearly sealed would be significantly increased if the crack could be strained or moved slightly. It was decided to apply this principle.

The removal of the reactor core and the primary coolant had sufficiently reduced the temperature and radiation level within the vault to around 1 R/hr, was enough to enable personnel to enter. This was done on 12th November. The reactor circuit was pressurised with helium to 50 p.s.i.g. and samples of gas taken from the leak jacket every 30 minutes. The rate of build-up of helium gave a measure of the size of the leak. Each primary heat exchanger in turn was then pulled slightly to one side or was swung gently on its support while the jacket was sampled for helium. It was found possible to open up the leak and increase the leak rate by a factor of ten, and by the end of the tests there was strong evidence that this was associated with movements of No. 10A or 10B circuits.

With a larger leak rate available it was now possible to use another technique which previously with a small leak rate had not given any positive results.

A sensitive piezo-electric microphone was clamped on to each of the 24 outlet pipes at the thermocouple blocks and the vessel was recharged with coolant up to the level of the outlet pipes. This time it was the leak jacket that was pressurised, to 8 p.s.i.g., and the noise of gas bubbles escaping into the coolant was clearly identified from the microphone attached to No. 10A pipe, much less clearly from the microphones on adjacent pipes, and not at all from those on any other pipes. By comparing the time taken for the sound of bubbles to pass through the stainless steel to microphones on two different pipes, in which the difference was no more than one 5,000th of a second, it was possible to obtain further information on the precise location of the leak.

On 12th December these tests were complete and it was clear that the leak was in No. 10A outlet pipe and some distance away from the vessel nozzle.

Preparations were then made for cutting into No. 10A leak jacket and pipe inside the vault so that an introscope (for visual examination), ultrasonic crack detection equipment and gas 'sniffing' equipment could be used to identify the exact position of the crack.

For a time a weld 1 ft. 5 in. from the vessel was also suspect but after being cut out and examined metallurgically it proved to be sound, and the crack was found in a section containing the thermocouple block. It was about 1¼ins. long in a weld containing a severe mis-alignment between the two sections joined by the weld, and also having inadequate penetration. These factors, combined with the existence of a thermal stress in the area when the reactor was operating at power, gave rise to a fatigue failure in the weld; they also explained why the leak disappeared at shut-down—the thermal stress disappeared then.

The thermal stress was associated with the hot trap system, which was originally provided for reducing the sodium oxide impurity content to a very small amount but in practice is no longer required. It was therefore decided to modify some of the associated pipework as well as to renew the section of No. 10A pipe and its leak jacket.

Radiation levels inside the vault restricted the working times of personnel and access to the pipework was difficult. However careful planning enabled work to continue round the clock, although during the cutting and welding precautions continually had to be taken to prevent air entering pipework containing residual sodium-potassium alloy. The most difficult weld was that close to the vessel which had to be carried out remotely using specially developed equipment fully tested on a mock-up.

By 10th April this work had been completed and after the new welds had been satisfactorily radiographed and pressure and leak tested, the vault was finally closed on 24th April. The opportunity was taken to inspect as much pipework as possible and after 10 years' service it was found to be in extremely good condition with no signs of pitting or corrosion, and no thinning of material.

Since then the primary system has been fully charged with coolant, the core and breeder fuel elements have been reloaded and a thorough check-out has been given to all control equipment and instrumentation standing idle since 1967.

The reactor is operating satisfactorily at full power and it is now planned to continue to use it in its role as a fast flux test facility for irradiating improved fuels and canning materials for future fast reactors. *1st July, 1968*