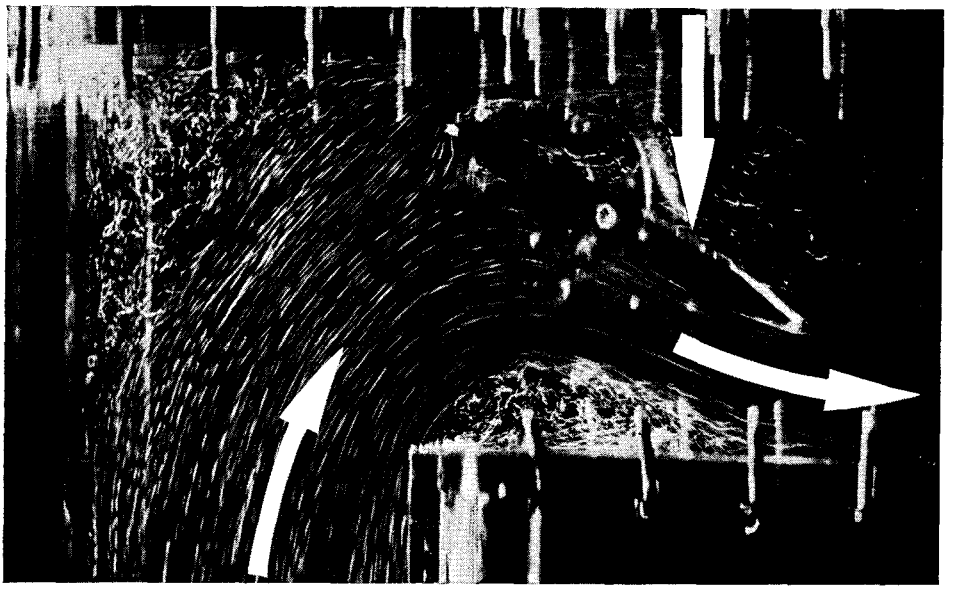
ATOM

Number 150 / **April 1969**

MONTHLY INFORMATION BULLETIN OF

THE UNITED KINGDOM ATOMIC ENERGY AUTHORITY

LUCAS ENGINEERING LABORATORIES, BURNLEY



Flow visualisation by Lucas

Using a transparent 1/12th scale model of the Dounreay Prototype Fast Reactor, in conjunction with a water flow analogue, Lucas engineers have worked in close collaboration with U.K.A.E.A. to study local flow regimes in the primary circuit, pump intakes and cooling circuits giving the unique opportunity to get into the heart of the reactor and understand local flow conditions not possible in the actual plant.

The flow visualisation technique has been developed over the years by Lucas, and has been extensively used in fuel element design and development, and in the study of liquid, gas and air flow in a variety of applications.

The photograph shows the flow patterns associated with the valve for the S.G.H.W.R. suppression system. Basic data on the fluid dynamic forces encountered in this valve was obtained by hydraulic analogue technique.

Lucas are constantly extending the range of application of this technique into other fields and the Laboratory facilities are available for further work.

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OF THE UNITED KINGDOM
ATOMIC ENERGY AUTHORITY

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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.

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Gas centrifuge development

The following press release was issued by the Ministry of Technology on 11th March, 1969.

Ministers of the Federal Republic of Germany, the Netherlands and the United Kingdom met in London today to continue their discussions begun at The Hague on 25th November 1968, with a view to creating an appropriate framework for collaboration in the development and exploitation of the gas centrifuge method of uranium enrichment.

The meeting was attended by:

German Delegation

Dr. Stoltenberg (Minister of Scientific Research)

Dr. Harkort (Acting State Secretary, Foreign Affairs Ministry)

Netherlands Delegation

Mr. L. de Block, Minister of Economic Affairs

Mr. J. M. A. H. Luns, Minister of Foreign Affairs

Mr. H. J. de Koster, State Secretary of Foreign Affairs

U.K. Delegation

Mr. A. Wedgwood Benn, Minister of Technology

Mr. F. Mulley, Minister of State, F.C.O.

Ministers noted that considerable progress had been made in meetings of officials. They recognised the importance of European technological progress in the peaceful uses of atomic energy and of creating in Europe an independent capacity to provide enriched uranium. They took the view that results of experiments with the gas centrifuge method at its present stage of development in their respective countries offered good prospects for the creation of enrichment capacity on a competitive basis.

Ministers reached broad agreement on the structure of a tripartite collaborative venture. It was agreed that two organisations should be set up—a " Prime Contractor " for the manufacture of centrifuges and the construction of enrichment plants, and an " Enrichment Company " for the operation of enrichment plants. The participation of industrial enterprises from all three countries will be provided for. Research and development on the centrifuge process would be integrated

and as much use as possible would be made of existing national and industrial laboratories.

Ministers agreed that an inter-governmental Joint Committee should supervise the collaboration, and in particular deal with such questions as safeguards on the use of nuclear material, security procedures, relations with other countries and the siting of plants.

Ministers agreed that the construction of the two first joint enrichment plants would begin simultaneously in the U.K. and in the Netherlands, and that the administrative and managerial Headquarters of the Prime Contractor would be in the Federal Republic of Germany.

Ministers recalled their agreement at The Hague that the collaborative arrangements would have to be consistent with the policies of the three Governments in relation to the non-proliferation of nuclear weapons and to their international obligations in this field. They agreed that it would be necessary to include in the proposed agreement on centrifuge collaboration appropriate mutual undertakings; and provision for appropriate safeguards to be applied in relation thereto.

Ministers, noting the interest of other European countries, stressed their readiness to associate such countries with the joint venture after its establishment and set up a special Working Party to examine what forms of co-operation may be envisaged.

Ministers instructed officials to proceed to the preparation of a draft agreement on centrifuge collaboration. They agreed to meet again in Bonn on June 9, 1969, to review progress, with a view to bringing the negotiations to a successful conclusion as soon as possible thereafter.

Plasma physics summer school

A plasma physics summer school is being organised at the Culham Laboratory from 7th-18th July, 1969.

The School provides an introduction to theoretical and experimental plasma physics. No specialised knowledge of the subject will be assumed.

Application forms and further details are available from The Summer School Office, Culham Laboratory, Abingdon, Berks.

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

AEA re-organisation

As from 1st March, 1969, the staff and functions of the Engineering Group of the United Kingdom Atomic Energy Authority will be allocated to the Reactor and Production Groups.

The majority of Engineering Group staff are, with effect from 1st March, being transferred to Reactor Group to constitute a new Engineering Division. The staff of the three Plant Design Offices, together with some staff from the Planning and Inspection and Progress Sections, will become part of Production Group.

Mr. H. V. Disney, C.B.E., Managing Director of the Engineering Group, will become manager of the Engineering Division of the Reactor Group.

28th February, 1969

U.K. reprocesses more Italian fuel

On 4th March, 1969, the m.v. Stream Fisher docked at Barrow-in-Furness, carrying the first consignment of irradiated nuclear fuel from the Garigliano nuclear power station of Ente Nazionale per l'Energia Elettrica (ENEL) for reprocessing at the Authority's Windscale Works, under a contract signed with ENEL on 28th November, 1968. The plutonium and uranium resulting from reprocessing will subsequently be returned to ENEL for use in the Italian nuclear power programme.

This consignment is the first international movement of irradiated fuel from a boiling water power reactor and consists of two flasks each weighing 53 tons and containing 3.88 tonnes of uranium oxide fuel elements.

At the same time, the m.v. Stream Fisher is carrying six flasks containing some 15 tonnes of irradiated magnox fuel from the Latina nuclear power station of ENEL. This fuel was manufactured by the UKAEA. Over the past three years, 20 shipments have been made from Latina—a total of 280 tonnes of irradiated uranium.

Background notes

ENEL. Ente Nazionale per l'Energia Elettrica (ENEL) is the Italian State elec-

tricity supply organisation. In addition to numerous conventional power stations, ENEL operates three nuclear power stations, viz., the 200 megawatt gas-cooled graphite moderated reactor station at Latina, of U.K. design, and two stations of U.S. design: the 150 megawatt BWR station at Garigliano and the 257 megawatt PWR station at Trino.

Garigliano. The Garigliano nuclear power station of ENEL has a 150 megawatt(e) boiling water reactor. It is situated on the Garigliano river between Rome and Naples and has been in operation since 1963.

4th March, 1969.

Nuclear electronic equipment standards

[This release was issued on behalf of the European Standards of Nuclear Electronics Committee].

International agreement has been reached between technical experts representing 26 national and international nuclear laboratories in Europe on a standard—known as CAMAC—for the design and manufacture of electronic instruments. Instruments designed to meet the new standard are electrically and mechanically compatible and can be inter-connected through a specified data highway to form simple or complex systems for signal and data processing. Such systems are independent of the choice of computer or other processing device. The new standard, if widely adopted, will not only simplify the task of designing and commissioning measurement and control instrumentation systems but will also permit manufacturers to sell their products in wider markets than has hitherto been possible. The CAMAC design specification may be used free of charge and without seeking permission by any organisation or company; full details will shortly be available in a EURATOM report of which advance copies are obtainable from the Electronics and Applied Physics Division, Harwell, Didcot, Berks.

The CAMAC standard was developed by the European Standards of Nuclear Electronics (ESONE) Committee. The Committee is an informal forum of nucleonic instrumentation and data processing experts in Europe which was originally set up, in 1960, on the initiative of the EURATOM Research Centre, Ispra. The membership is drawn exclusively from national and international laboratories and universities in Europe and a full list of membership is attached for reference. The need for new standards for advanced data processing in the nucleonic field was recognised by the ESONE Committee in 1966 and final technical agreement was reached in the autumn of 1968. There is liaison with the equivalent committee on nucleonic standards in the United States (the NIM Committee).

The CAMAC standard anticipates and exploits the growing use of automatic means for data acquisition and processing (especially on-line to digital computers or equivalent equipment), and the widespread adoption of integrated circuit components. The standard prescribes the physical format of the modular instrument units, the electrical characteristics of power supplies and signals, and the means used to transfer data on a multiwire highway. These features are independent of the types of transducer or computer used in any specific measurement or control system and they are defined in such a way that operational needs may readily be met in both simple and complex systems.

This press notice is being issued in the U.K. by the UKAEA at the request of the ESONE Committee. A similar announcement is being made in all European countries represented on the ESONE Committee at about the same time.

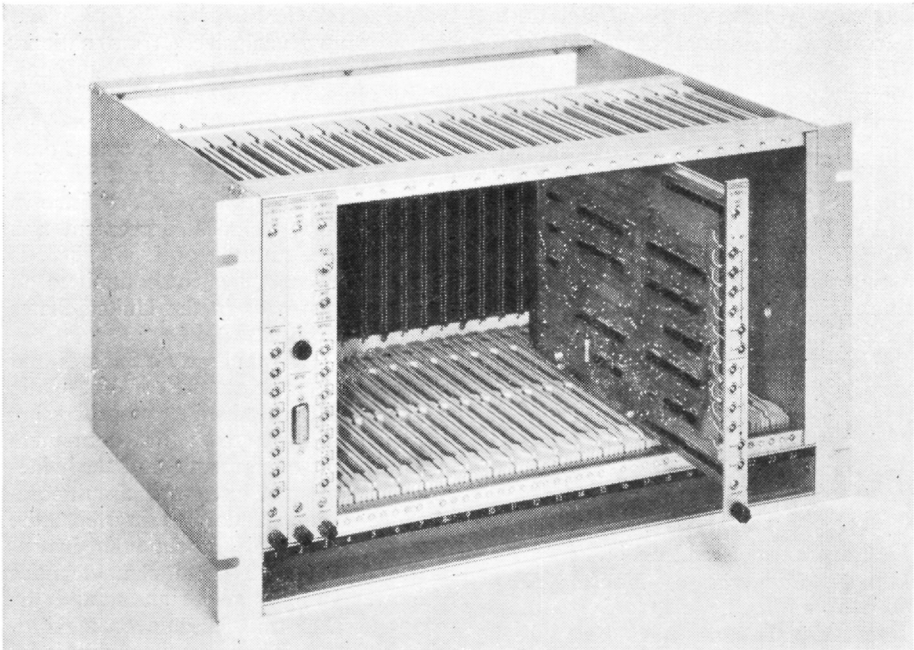
Membership of the ESONE Committee taking part in the specification of the CAMAC system:

International
CERN, European Organisation for Nuclear Research, Geneva.
Centro Commune di Ricerca (EURATOM), Ispra.
Bureau Central de Mesures Nucléaires (EURATOM), Geel.

Austria
Studiengesellschaft für Atomenergie, Vienna.

Belgium
Centre d'Etude de l'Energie Nucléaire (CEN), Mol.

Britain
Atomic Energy Research Establishment, Harwell.



CAMAC compatible crate with modules

Rutherford High Energy Laboratory (SRC), Chilton.
Daresbury Nuclear Physics Laboratory (SRC), Daresbury.

France
Centre d'Etudes Nucléaires, Saclay.
Centre d'Etudes Nucléaires, Grenoble.

Germany
Physikalisches Institut der Universität, Marburg.
Deutsches Elektronen Synchrotron, Hamburg.
Hahn Meitner Institut, West Berlin.
Kernforschungsanlage, Jülich.
Kernforschungszentrum, Karlsruhe.
Physikalisches Institut der Universität, Frankfurt.

Holland
Reactor Centrum Nederland, Petten.

Italy
Laboratori Nazionali (CNEN), Frascati.
Centro Studi Nucleari (CNEN), Cassaccia.
Centro Studi Nucleari Enrico Fermi (CESNEF), Milan.
Centro Informazioni Studi Esperienze, Milan.
Instituto di Fisica, Bari.

Yugoslavia
Boris Kidric Institute, Belgrade.

Switzerland
Institut für Angewandte Physik der Universität, Basle.

Secretariat
Dr. W. Becker, CCR, EURATOM, Ispra.

5th March, 1969

Large markets opened up by CAMAC

The ESONE Committee decision to adopt and publish the CAMAC specifications means that nuclear laboratories throughout Europe, and possibly some in the United States, will adopt CAMAC and will, therefore, be prepared to buy equipment designed to comply with these specifications. Hitherto, the lack of a widely accepted and technically advanced signal data processing standard has tended to cause individual nuclear laboratories to set their own standards or adopt the standards used by particular manufacturers. The new informal agreement thus offers the prospect of greatly increased international markets for nuclear data processing equipment.

Although the CAMAC system is designed primarily to meet computer-based measurement and control requirements in the nuclear field it is also likely to be of

value in many other measurement and control situations, especially those which involve the use of a controlling computer. In these applications CAMAC is complementary to other schemes that have been or are being developed.

Harwell staff have played a leading role in the development of the CAMAC system and originally proposed the basic principles to the ESONE Committee in 1966. Since then detailed study of the mechanical, electrical, signal and data transfer aspects of the scheme, by the national and international laboratories involved, has led to the complete formulation of the standard and its final approval and publication. Care was taken throughout to ensure that equipment designed to the USAEC (NIM) standard would also be compatible with equipment designed to CAMAC standards.

There are many ways in which the CAMAC specification can be fulfilled in a series of modular electronic instruments. One method has been worked out in detail at Harwell and this forms the basis of the "Harwell 7000 Series" of nuclear and data processing instruments. This series is being developed rapidly by a Harwell design team (Electronics and Applied Physics Division) working in close partnership with design teams from the two principal licensees for the series, namely, Dynatron Electronics Division of EKCO Electronics Ltd., and Nuclear Enterprises Limited. The two companies are now marketing the first instruments of the series. As a further service to industry, a series of one-day appreciation courses on the CAMAC system is being arranged at the Education and Training Centre, AERE, Harwell, Didcot, Berks; interested firms or organisations are invited to apply direct to the Centre for information about these courses.

5th March, 1969

Leaflets available

New editions of two illustrated leaflets on atomic energy, "Atoms at Work" and "British Nuclear Power," have been produced by the Atomic Energy Authority. Copies are available free of charge from Public Relations Branch, Room 102, U.K. Atomic Energy Authority, 11, Charles II Street, London, S.W.1.

IN PARLIAMENT

Nuclear Installations Bill

The following extracts are from the debate by the Second Reading Committee on the Nuclear Installations Bill on Wednesday, 5th March, 1969.

THE PARLIAMENTARY SECRETARY TO THE MINISTRY OF POWER (MR. REGINALD FREESON): I beg to move,

That the Chairman do now report to the House that the Committee recommend that the Nuclear Installations Bill ought to be read a Second time.

The purpose of the Bill is to amend the Nuclear Installations Act, 1965, to bring it completely into line with the international Conventions on third party liability for nuclear damage caused in the most unlikely event of accidents in the peaceful uses of nuclear energy. To explain what is being done I must outline this system of liability.

There are three of these Conventions. One of them was negotiated under the auspices of the International Atomic Energy Agency, and was signed at Vienna in May, 1963. The other two were negotiated within the Organisation for European Co-operation and Development. Of these, one was signed at Paris in July, 1960, and the other at Brussels in January, 1964. Both were amended in 1964 to make them compatible with the Vienna Convention. These three Conventions provided a basis for a uniform international code dealing with third party damage liability, in the interests of developing peaceful uses of nuclear energy and easing the international movement of nuclear material for this purpose.

The United Kingdom, as a developer and exporter of nuclear technology, has a considerable interest in this objective and played a leading part in the negotiations for the Conventions. The Government have signed and ratified the Paris and Brussels Conventions. As yet, we have not ratified the Vienna Convention. The Paris Convention is in force between, so far, the United Kingdom, Belgium, France, Spain, Sweden and Turkey.

Our law must obviously, therefore, be consistent with the Conventions, and the Nuclear Installations Act, 1965, set up in United Kingdom law the necessary

system of liability. The features of this system are: to channel all liability to the operator of the nuclear installations in which the incident happened, or on whose behalf nuclear material is sent; to impose on the operator absolute liability; to limit that liability to a prescribed amount which should not be less than the equivalent of 5 million dollars per incident; and to ensure that adequate funds are made available from which the operator can meet this liability, and that they are used exclusively for that purpose.

In addition, the Brussels Convention provides for the unlikely event of a disastrous nuclear accident. Under these provisions, claims in excess of the operator's liability are met from public funds —partly from international contribution— up to the equivalent of 120 million dollars.

I can now turn to the provisions of this Bill. The 1967 devaluation of the pound took the financial provisions of the 1965 Act out of line in some respects with the compensation provisions of the Conventions. Because the Conventions specify certain dollar sums the 1965 Act used their then sterling equivalent, but devaluation brought these sterling sums below the Convention requirements.

It is not necessary to adjust the limit of £5 million in the 1965 Act for a United Kingdom operator's own liability. This is still well above the minimum limit of 5 million dollars in the Conventions.

As required by the Conventions, the Act sets the liability of other Convention countries' operators at the limit ruling in their own country, or £1¾ million, whichever is the greater—the sterling equivalent to the Convention minimum figure of 5 million dollars. This figure of £1¾ million needs to be corrected now to £2,100,000.

It is also necessary to correct the sum which the Act requires to be set aside as a minimum from the available compensation funds to meet the general run of claims if an accident involving nuclear matter in transit causes damage to the ship or other means of transport conveying the material. This was set at the 5 million dollar equivalent of £1¾ million, so needs to be corrected to £2,100,000.

The Act also puts the Government in the position of being able to operate the Brussels Convention system of meeting claims which outrun the operator's liability under the Paris Convention. For this, it provided for claims above £5 million, and up to £43 million to be met from public funds. This sum was the equivalent of 120 million dollars and, following devaluation, it needs to be corrected to £50 million.

In addition to this, we have found that, in two ways, the Act's rules of liability do not quite match the Conventions. I have already mentioned that the Conventions intend liability for injury and damage to property caused by a nuclear incident to arise only within the terms of the Conventions, and to be channelled to the responsible operator. It appears, however, that the 1965 Act would in law allow a liability to be imposed in certain circumstances on a person other than the operators. For example, the operator might be able to make the supplier of a faulty component liable for damage to the reactor itself if negligence could be proved. Property on the site of a nuclear installation which is used in connection with the operation or the construction of the installation is excluded by the Conventions from the liability of the operator. In its present form, however, our Act would allow the owner of such property to claim against the operator if negligence could be established. The Bill excludes these possibilities.

Secondly, the Conventions intend that so far as possible an operator shall not be liable for damage suffered in a country which is not a party to the Convention. They recognise, however, that in some circumstances a person other than the operator may find himself obliged to pay damages in such a country. For example, the owner of a ship carrying the nuclear material concerned in an accident might find himself obliged to do this. To cover such cases the Conventions allow such a person to make a corresponding claim against the operator concerned. The right which the 1965 Act confers in this respect is not quite wide enough in the types of accident which it covers, and the Bill would widen it to make it consistent with the Conventions.

Looking at the financial implications of the Bill, I should emphasise that

although the Bill increases the potential liability to the public funds from £43 million to £50 million the chances of a nuclear accident which would cause damage to such an extent are exceedingly remote, as are the chances of any nuclear accident of significance. It is, indeed, highly unlikely that an accident would occur causing damage exceeding even the compulsory £5 million cover of the operator. During what now amounts to a very substantial total experience of the operation of nuclear power stations no accident whatever has occurred that has had any effect outside the site of any commercial station. The only accident of consequence which has involved compensation claims was that which occurred at the Atomic Energy Authority's plant at Windscale in 1957, and which, incidentally, was of a kind which could not occur in a nuclear power station. This resulted in claims totalling less than £100,000.

The proposition which I am putting to the Committee is that our ratification of Conventions relating to nuclear damage means that our domestic law must be consistent with their provisions. We now find that it is not quite so, and this Bill will remedy the defects.

Mr. David Price: The Explanatory and Financial Memorandum tells us that the purpose of the Bill is to amend the Nuclear Installations Act, 1965, which is the consolidated Act, and bring that Act into full compliance with the international Conventions on liability for nuclear damage. I am sure that the Committee will agree that that is a very sound purpose deserving of our support. It is very important that international Conventions on these matters are kept up to date, and none of them is more important than those Conventions dealing with nuclear damage which we seek to bring up to date in our domestic law today.

I suggest that this will not be the last that we shall have to say about nuclear hazard and liability. I would remind hon. Members that nuclear power has now come of age. This point was stressed strongly in the Report of the Select Committee on Science and Technology when it looked at the civil nuclear programme. It is no longer an esoteric scientific adventure. Nuclear power stations are part of normal power programmes today. It follows from that that there will be more use of nuclear fuels and, as many hon. Members know, there is a wide variety of them. Furthermore, we know that radioactive isotopes are used increasingly as trace elements in industry. There is a greater use of them in medicine, in research and in survey work. They are being used considerably by hydrographers and water engineers. Therefore, it is right that we should make adequate provision for anything that might go wrong. Then there is the whole subject of nuclear-powered vessels. It would be interesting to know whether these Conventions and the Act cover the future use of nuclear-powered vessels in the merchant marines of the world.

I anticipate an increasing international trade in nuclear substances, and that there will be an increasing number of nuclear installations. In my view, the majority of those installations will be built by international companies, in the form of consortia, large companies of an international nature, or by *ad hoc* agreements between companies across frontiers. It therefore means that there will be more trade and more trafficking in substances in which there is a nuclear hazard.

It is essential that our domestic law be kept up to date. I go further. It is essential that our domestic law should anticipate developments so far as is technically possible. We all know how often our law gets behind events. This raises, in the subject before us today, even greater problems. We all agree that this cannot be dealt with purely domestically. It must be dealt with internationally.

This raises the problem: how are the appropriate international Conventions kept up to date? It is difficult to keep our domestic law up to date; I suggest that it is even harder to keep international Conventions up to date. We not only have to agree an international Convention; we have to persuade all the signatories to it to ratify and implement it in their own domestic law. Therefore, it is a three-tier operation. I hope that the Parliamentary Secretary can reassure us that the necessary international machinery is there to ensure that these Conventions are kept up to date.

I am sure that the Committee will agree that we must bend over backwards

to ensure that the risks of nuclear damage are as low as possible and that we should err on the generous side on the question of liability and compensation for damages.

I suggest that, about radiation hazards, many people have, deep down, a fear, a disquiet, which they do not have about other hazards which may, in practice, be more common. That is because they cannot see radiation, but they can see a motor car. Many people are rather cavalier in their attitude to road risks. They take them as part of their normal lives without worrying too much about them. But fear about radiation, particularly with overtones of nuclear war which are carried through into the civil use of nuclear substances, is something deep in many people's emotions. Therefore, I suggest that both in our international commitments and in our domestic law this hazard is one which we should over-insure.

As the Parliamentary Secretary has indicated, the safety record of the nuclear industry has been the most remarkable of any industry in the history of technology. I know of no industry which has developed from scratch to the level which it has reached today with so few casualties and so little damage. Compared with the development of coal mining, the iron and steel industry, the development of the motor car and the railways, the casualties as a result of nuclear damage have been minimal. We all know that at Harwell the danger is not the nuclear installations; it is the Oxford to Newbury road. I hope that the Committee has taken on board what the Parliamentary Secretary has told us; that as yet there have been no claims under the original Act.

I now turn to the changes in the Bill. I find Clause 1 highly technical. Therefore, I will defer any comments till we get to Standing Committee and, possibly, on the Question: That the Clause stand part of the Bill, we might have a word about it.

Clause 2 is the direct consequence of devaluation. It must be right internationally to keep the figure we implement in our domestic law up to the true international value. That was implicit in the Conventions which we signed.

Clause 3 seems a sensible extension of the coverage of these Conventions and must be agreeable to the Committee.

I should put to the Parliamentary Secretary and the Committee the wider point raised by the Bill: how do we cope with the changing nuclear scene? Should we do it by amending legislation, which has to go through the whole Parliamentary process, or should we write into the Bill or into the substantive Act delegated powers so that changes can be made more rapidly by Statutory Instruments? That is often a convenient way of altering the detail of an Act.

It seems to me that at present it is right that this should be done by amending legislation, though I should look to some point in future when we can see the uses of nuclear substances more clearly, when it should be possible to give general powers to implement conventions through Statutory Instruments. That is a personal view. However, I am sure that it is right at this stage to proceed by amending legislation rather than by delegated legislation.

Finally, I ask the Parliamentary Secretary how our Government, with partner Governments to these Conventions, propose to keep these Conventions up to date. Will the instrument be the International Atomic Energy Agency? Shall we work through the European Nuclear Energy Agency, the O.E.C.D., or simply by multilateral discussions? I think the latter is the least satisfactory because it is not permanent. I do not know whether I am right in assuming that the main instrument will be the International Atomic Energy Agency.

Mr. Alex Eadie: My purpose in taking part in the debate is to put a specific question to the Parliamentary Secretary. We are told that within the Bill there are certain insurance provisions which are carried out internationally. From time to time I have quoted reports from the international Press in which allegations have been made that strange things have happened because of the discharge of nuclear effluent. For instance, I remember quoting a report which alleged that fish with two heads had been caught. The report suggested that because of the discharge of nuclear effluent into the sea marine life had been damaged. I do not know whether it is factual, but papers have been submitted on this matter sug-

gesting that, because of the discharge of nuclear effluent, damage has been caused to marine life. We are talking about safety. It is no use talking about adequate financial insurance provisions, and saying that everything is safe and that we can be complacent because nothing has happened if, in the discharge of nuclear effluent in the sea, marine life is being damaged. Surely we have some responsibility to discuss this aspect to some extent in considering the Bill. I know that my hon. Friend is knowledgeable on this. Therefore, I should be obliged if he would make some comment on it.

Mr. Nicholas Ridley: I should like to make two points on the Bill. First, I am not absolutely clear why this liability cannot be insured, and treated as an insurance matter. The operators of nuclear stations and nuclear isotopes and those who engage in carrying them round the world could be asked to pay premiums to insure against the risks which they are causing. As far as I can make out, the whole liability for any explosion or damage which might occur falls fairly and squarely upon the British taxpayer. Though it may be right, in view of the delicate nature of the subject, to put the ultimate responsibility on the Exchequer, I do not see why those who cause the risks to arise by operating nuclear plants should not be required to make at least a contribution by way of premiums.

The right thing to do is to lay down certain statutory requirements for insurance and require nuclear operators to insure in an insurance market against any risk which might occur. It is compulsory to insure a motor car against third party accidents. That does not mean that the taxpayer has to pay every time there is an accident. Not a bit. The insurance risk is carried by the companies and premiums are paid according to the total amount which has to be paid out. I should like the Parliamentary Secretary to explain why we cannot treat this matter in the same way

Why cannot this be dealt with by an Order in Council, if the limits must be raised because there has been a further fall in the value of the £? Such a procedure could go through with little discussion and the full force of a Bill would not be necessary. Alternatively, instead of mentioning £50 million we could state the sum of 120 million dollars so that every time the Government devalue the £ the Bill would hold good.

The Government have gone to great lengths at Basle to guarantee the deposits of foreign holders of sterling in Britain. They have also taken care to see that Parliament cannot debate that because it is a purely administrative action. Yet on a matter like this we have an opportunity to debate the increased amount of dollars we must pay to cover these liabilities and I suggest a more flexible procedure should be thought out. If the Government will not accept any of my solutions, there is a strong reason for changing the whole basis of nuclear insurance. If we must have a Bill like this every time there is a change in the value of the £, we shall need a sort of floating Bill; although many hon. Members believe like me, that we should have floating exchange rates.

We must bring our rules up to date in line with our obligations under the Conventions. For this reason I support the Measure, although it is a clumsy way of dealing with the issue. We must have a more sensible and more flexible approach.

Mr. Arthur Palmer: This country has taken a lead in the practice and installation of nuclear power for peaceful purposes. I do not know if the Americans have overtaken us, but for a considerable time we have been the largest manufacturers of nuclear power stations for electric energy. It seems odd, therefore, that we should now be following, rather than taking a lead in, these Conventions. May we have on assurance that, in terms of compensation for losses resulting from nuclear accidents, this country is, in international standards, in the forefront? That should be our position.

The standards of safety in nuclear stations depend, first of all, on the skill and knowledge of the engineers and others who operate them. However, those who check them in the legal sense on behalf of the Ministry are the inspectors appointed by the Department. May we have an assurance that there are enough inspectors and that they are of a sufficiently high quality to keep pace with latest technological developments? I know from experience that there was concern a few years ago in the electricity

power industry about the nuclear inspectorate—I say nothing in criticism of these inspectors; they are devoted and hard-working people—and about whether the Ministry was having trouble recruiting them. We must ensure that they compare well technically with those in the industry whom they are supposed to check. May we be assured that the quality, standards and numbers of nuclear inspectors are being maintained?

I am grateful for the Explanatory and Financial Memorandum to the Bill. That is, in itself, difficult to comprehend, leaving aside the Bill. Clause 3 is headed, "Extension of Compensation in Certain Cases", and seems to deal with circumstances in which there are mishaps or disasters involving an international liability and where there might be a claim against a Government Department or the United Kingdom Atomic Energy Authority. The Explanatory and Financial Memorandum mentions:

". . . or in the case of a licensee to the extent to which the total claims were thereby taken above his insurance cover, there could be an extra charge to the votes."

In other words, the deficiency would have to be made good out of public funds. There is a specific reference to the Atomic Energy Authority and Government Departments. I take it that this assumes that the Central Electricity Generating Board and the Scottish electricity boards which are actual or potential operators of nuclear power stations will look at this matter commercially.

Mr. Freeson: the hon. Member for Eastleigh (Mr. David Price) asked whether the Bill as proposed would cover the position of nuclear-powered ships. The answer is that it does not cover nuclear ships, which would require separate legislation, and if there were an issue involved here it would be a matter for us and other countries to pursue through the appropriate machinery.

That brings me to the main question which I think he posed, namely, what procedures we adopt to keep this kind of legislation under review, and to consider how far further legislation or an extension of international Conventions might be needed. The machinery used is that of the I.A.E.A. and O.E.C.D. I think that it is the Paris Convention that requires a conference to be called five years after its ratification, which, I think, is in 1973, for a review of its operation, which could cover any up-dating of procedures. The Vienna Convention has a similar provision.

My hon. Friend the Member for Midlothian (Mr. Eadie) asked whether we had reason to believe that damage is being caused to marine life by nuclear waste. We have no evidence of this, despite the occasional stories in the Press. It may be that, in casting their minds back, my hon. Friend and others have confused this with some of the reports at the time of certain nuclear military tests in the Pacific Ocean many years ago, when there were most unfortunate results, but they had no connection with the waste from the peaceful use of nuclear energy.

Much stress has been laid on the question of the specific figures written into the Act and now being amended by the Bill. I was asked why we could not find another way of writing into the Bill a figure —120 million dollars was suggested— which would avoid bringing further Bills to the Committee in the future. It would be possible to write into the Bill the equivalent of the units used in the Brussels Convention. It would be possible to give power to do this by means of a Ministerial order. But the answer is that I and the Government are confident in the exchange rates of the £ and do not see the need for this.

I was also asked why the operators should not insure. The answer is that they do. The Conventions require it, and commercial operators carry £5 million insurance. They carry all liability in order to avoid the pyramiding of insurance by everyone who might be involved in an accident, if it occurred. That is why we are seeking to avoid by further amendment of the principal Act any possibility of people seeking damages by negligence, in order to prevent a repercussive effect arising from any accident which might occur in the future.

My hon. Friend the Member for Bristol, Central (Mr. Palmer) also raised a question about the writing of figures into the Bill, with which I have dealt. His other chief question was whether, in the light of reports of some years ago that there were difficulties with recruitment to the nuclear inspectorate, we were satisfied with the competence of the inspec-

torate. I can assure him that my right hon. Friend is fully satisfied as to the establishment of the nuclear inspectorate, and that it is fully capable, in numbers and expertise, of carrying out its duties in regard to safety in the nuclear industry. It keeps fully in touch with developments in this field, and we have no worries on that score. I do not say that complacently. There is an important duty on the Government here, which the inspectorate is carrying out.

I think that I have dealt with all the points put to me. I can do no more than ask the Committee to support the Second Reading.

Dungeness B

4th February, 1969

MR. EADIE asked the Minister of Power to what extent he expects the delay and increases in capital and generating costs now arising at the Dungeness B nuclear power station to recur in the cost of the later advanced gas-cooled reactor stations.

Mr. McGuire asked the Minister of Power what effect he expects the difficulties now being experienced at the Dungeness B nuclear power station to have on the costs of the Hinkley Point B nuclear station.

Mr. Freeson: The Central Electricity Generating Board has assured my right hon. Friend that the recent mechanical engineering difficulties at Dungeness B are specific to that station and have no implication for the other advanced gas-cooled reactor stations.

Mr. Eadie: Will my hon. Friend agree that we hear far too much about mechanical breakdowns of power plants in this country? Would he not further agree that every time a question is asked on power stations the case is strengthened for an independent investigation, into power costs, as outlined by the Select Committee on Science and Technology?

Mr. Freeson: The last part of the question has already been met by the studies which we have undertaken, and are undertaking, in the Ministry into the construction of power stations and bringing them into commission. On the implication of this question and answer and the previous question and answer on the position between nuclear power and conventional stations, it would be wrong to draw any conclusions on this because difficulties of the same kind are experienced with conventional stations and with nuclear power plants.

Desalination in the U.K.

5th February, 1969

MR. CLIFFORD WILLIAMS asked the Minister of Housing and Local Government, in view of the increase in demand for water for domestic and industrial purposes of the past 20 years and of the limited number of places now available in the country for the storage of water, if he will make a statement on the number of desalination plants which have been installed, on the gallonage they treat per annum, and on the price of such water as a commercial proposition.

Mr. K. Robinson: There are no desalination plants in this country producing water for general supply. However, the Water Resources Board, which will be reporting fully on desalination in a few months' time, advise that the cost of desalinated water will be some twice to three times the estimated average level of costs between now and the end of this century of water from conventional sources. It considers therefore that desalination is unlikely to play a large part in meeting increased demands during that period, although there may be scope for special applications of desalination.

Desalination research

5th February, 1969

MR. DALYELL asked the Minister of Technology what experimental facilities for the improvement of desalination plant have been commissioned at Harwell.

Mr. J. P. W. Mallalieu: Harwell is continuing R & D into three desalination processes:

(*a*) Small scale experiments on the freezing process are being carried out and there is also a pilot facility to examine the growth of ice crystals and the separation of them from the waste brine.

(*b*) Reverse osmosis experiments are undertaken, concentrating upon tests on a variety of membranes and the development of a modular design of equipment suitable for large scale manufacture, and

(*c*) The flash distillation research at Harwell includes experiments on the control of scaling deposits and investigations into how sea water boils in the separate stages of a flash distillation plant. The facilities include experimental equipment for corrosion tests.

Mr. Dalyell asked the Minister of Technology if he will make a progress report on the second programme of work by the Atomic Energy Authority for a period up to 31st March, 1971, involving a continuing study of desalination plants powered by nuclear reactors.

Mr. J. P. W. Mallalieu: The Atomic Energy Authority and its industrial partners are studying improvements in present methods of desalination and are developing alternative methods, for use with nuclear or other heat sources.

Completed design studies using both the A.G.R. and S.G.H.W. reactor coupled with multi-stage flash plants, are available should suitable commercial opportunities arise.

Commercial tenders are now calling for 5 million gallons a day plant units and an integral part of the Authority's R & D programme is the development of large module distillation plants of 10 million gallons a day capacity; this size is large enough to cope with the water outputs envisaged in proposed nuclear dual purpose schemes.

Dungeness B progress

11th February, 1969

MR. PALMER asked the Minister of Power if he will make a statement about the progress of work at Dungeness B nuclear power station.

Mr. Freeson: Work is in hand to remake the upper part of the metal liners of the pressure vessels which were distorted during welding. The first reactor may be delayed by at least 18 months and the second by a year. This was a defect in mechanical engineering, not in the technology of the A.G.R. It therefore carries no implications for later A.G.R. stations.

11th February, 1969

MR. WOOF asked the Minister of Power whether, in view of the delays in the construction of the Dungeness B nuclear power station and the consequent effect on costs, he will now set up an independent inquiry into nuclear power costs.

Mr. Mason: The Chairman of the Central Electricity Generating Board assures me that the recent mechanical engineering difficulties at Dungeness B are specific to that station and have no implications for the other advanced gas-cooled reactor stations. Consequently, the difficulties there do not provide any new reason for an outside inquiry into generating costs generally.

Harwell Programmes Analysis Units

11th February, 1969

MR. MARPLES asked the Minister of Technology if he will list the qualified staff, showing their qualifications and Civil Service rank, of the Programmes Analysis Unit at Harwell; and if he will list the projects which they have so far analysed.

Mr. Benn: There are 23 qualified staff engaged in the Programmes Analysis Unit as at 6th February, 1969. Their equivalent Civil Service grades are:

Chief Scientific Officer	1
Assistant Secretary	1
Senior Principal Scientific Officer	3
A/D Engineer	1
Principal Scientific Officer ...	7
Chemist 1	2
Engineer 1	1
Chief Executive Officer	2
Senior Experimental Officer ...	1
Senior Executive Officer	1
Experimental Officer	2
Executive Officer	1

A high proportion of these staff have been drawn from the U.K.A.E.A. and about one-third have substantial previous experience in industry.

The staff hold qualifications at first degree or higher level in the following disciplines:

Mathematics	3
Physics	3
Chemistry	6
Chemical Engineering	2
Electrical Engineering	1
Mechanical Engineering	3
Economics	1
Law	1
Other Arts Subjects	1

Some members have additional qualifications in operational research and statistics. Other economists are attached to the Unit from time to time.

Among the research projects or proposals on which the P.A.U. have completed reports are the following: Desalination, carbon fibres, aspects of marine technology, levels of basic nuclear research, radiation sterilisation and pasteurisation.

This sample covers about one-quarter

of the projects on which the Unit has worked and is not necessarily representative but most of the reports make use of confidential information from industry and their nature cannot be disclosed.

A.E.A. research programmes

12th February, 1969

MR. MARPLES asked the Minister of Technology if he will list all the research programmes which are not directly concerned with defence or nuclear energy being carried out in the civil and defence research establishments of the Atomic Energy Authority.

Mr. J. P. W. Mallalieu: The following is the list:

Desalination.
Hydrostatic extrusion.
Ceramics Centre.
Non-destructive testing.
Improved utilisation of steels.
Atmospheric pollution.
Tribology.
Heat transfer and fluid flow.
Graphite fibres.
High temperature solid electrolyte fuel cells.
Analytical research and development.
Physico-chemical measurements.
Water renovation (reverse osmosis).
High temperature chemical technology.
Ultra-violet astronomical satellite.
Advanced radio-telescopes for Manchester and Cambridge Universities.
Computer software and applications.
Space technology.
Aldermaston project for the application of computers to engineering.
Biomedical technology.
Forensic science projects.
Advanced computer interconnections.
Glass reinforced plaster.
Advanced metallurgical techniques.
Mass-spectrometry data studies.
Stratospheric radiation hazard.
National balloon project.
Animal-borne telemetry studies.
Evaluation of machine tools.
Adaptive control of machine tools.
Group technology.
Support to transport research assessment unit.
Radar targets for meteorology.

Thermonuclear and gas centrifuge development

18th February, 1969

MR. JUDD asked the Prime Minister what action he is taking to co-ordinate the responsibilities of the Ministry of Technology and the Foreign and Commonwealth Office in the control of international aspects of thermonuclear and gas centrifuge developments.

The Prime Minister: My right hon. Friends are already in close consultation on these matters.

Mr. Judd: Does my right hon. Friend agree that these developments provide a loophole through which the proliferation of nuclear weapons could take place, and that the international form of co-operation proposed could unfortunately result in increased East-West tension? Has not the time therefore come for the Ministry of Technology and the Foreign Office to get together in proposing ways in which the scope and powers of inspection of the International Atomic Energy Agency could be extended?

The Prime Minister: My right hon. Friends have been very close together on all these matters from the very outset of the problem. I have been very much concerned with it myself from the moment that my right hon. Friend the then Minister of Technology informed me more than two years ago of the breakthrough British scientists had achieved in this respect. I do not share my hon. Friend's anxieties about the possible proliferation of nuclear weapons arising from the tripartite co-operation which we are having in the civil use of nuclear energy.

Harwell and Culham staff

21st February, 1969

MR. J. E. B. HILL asked the Minister of Technology if he will show separately the total number of qualified engineers and scientists who have joined or left Culham Laboratory and Harwell Atomic Energy Research Establishment, respectively, during the last 12 months, indicating in each case the numbers who came from or left for other Government research establishments, universities, industry, or overseas.

Mr. J. P. W. Mallalieu: The information is as follows for permanent staff:

	Harwell	*Culham*
Recruits to: from:		
Government research establishments	2	6
Universities	24	4
Industry	8	2
Overseas	4	2
	38	14
Leavers from: to:		
Government research establishments	6	3

Universities	4	5
Industry	16	5
Overseas	6	3
Others (including deaths and retirements) ...	2	1
	34	17

In addition, a number of qualified scientists and engineers are granted fixed-term appointments as Research Fellows or Research Associates. The number of such appointments and termination of appointments during the last twelve months were:

Appointments to: from:	*Harwell*	*Culham*
Government research establishments	Nil	Nil
Universities	1	6
Industry	1	1
Overseas	16	10
	18	17
Terminations from:	*Harwell*	*Culham*
	23	9

A complete analysis of the destination of these leavers is not available.

Nuclear research expenditure

26th February, 1969

MR. BIDWELL asked the Minister of Technology what proportions in percentage and financial terms were spent on nuclear energy research and production for peaceful and war potential purposes for 1964-65, 1965-66, 1966-67, 1967-68, and for the latest period available over last year.

Mr. J. P. W. Mallalieu: It would not be in the public interest to publish details of expenditure on nuclear work done under defence contracts. The remainder of the information is:

	1964-65	*1965-66*	*1966-67*	*1967-68*	*£ million 1968-69 Estimate*
Civil nuclear R. & D.	67	68	69½	58½	55
Weapons research (excluding military contracts)	8	7	6	6	5
Civil production	34	33	28	33	38

Radiological Protection Board

27th February, 1969

MR. NEAVE asked the Secretary of State for Social Services when he expects to set up the proposed Radiological Protection Board; what will be its functions; and who will be its members.

Mr. Crossman: The Government intend to bring together the Radiological Protection Service, the Radioactive Substances Advisory Committee and part of the United Kingdom Atomic Energy Authority Health and Safety Branch, into one organisation under a new National Radiological Protection Board. Legislation to establish the Board will be introduced as soon as time permits.

A.G.R. stations

3rd March, 1969

MR. GARDNER asked the Minister of Power if he is satisfied that the Central Electricity Generating Board has ensured that advanced gas-cooled reactor stations possess adequate flexibility in accordance with paragraph 140 of its Report and Accounts for 1967-68; how modern stations using traditional fuels compare with advanced gas-cooled reactor stations in ensuring flexibility; and if he will make a statement.

Mr. Freeson: Work continues to ensure that each AGR station will have appropriate flexibility in responding to fluctuations in load. The flexibility requirements of these and conventional stations are not the same, but in both cases the Central Electricity Generating Board is taking steps to ensure that they will be met.

Comparative generating costs

4th March, 1969

MR. MARQUAND asked the Minister of Power whether he is satisfied, in view of recent constructional difficulties at the new nuclear power stations, that the estimates of .52 and .48 pence per kilowatt hour in Command Paper No. 3438 are still appropriate for the purpose of comparing the cost of electricity from coal-fired and nuclear power stations; and if he will make a statement.

Mr. Mason: The estimates of nuclear and conventional generating cost per unit in paragraph 2 of Appendix III of the Fuel Policy White Paper of November, 1967, have been revised to take account of developments since then, but recent studies of comparative generating costs confirm the basis of existing policies.

5th March, 1969

MR. ASHTON asked the Minister of

Power (1) how the reduced prices per kilowatt hour estimated to result from the construction of a second power station at Drax compare with the revised anticipated cost of the Dungeness B station;

(2) What is the latest estimated cost, inclusive of any element for research development and royalty, of Dungeness B nuclear station.

Mr. Mason: The C.E.G.B.'s latest estimate of the base load generating cost of the whole Drax station is 0.61d. per unit. The cost of the second half considered separately would be rather less than this. The Board advise me that there should not be any significant change at Dungeness B from the figure of 0.57d. per unit which was given to my hon. Friend the Member for Ince (Mr. McGuire) on 5th March, 1968. This estimate included the royalty of 0.014d. per unit payable to the Atomic Energy Authority on AGR stations.

In relation to decisions about fuelling of new stations, the relevant comparison is with the cost of a contemporary nuclear station rather than Dungeness B which was ordered in 1965 as the first commercial AGR station.

Welding research

5th March, 1969

MR. LUBBOCK asked the Minister of Technology if he will issue a direction to the Atomic Energy Authority under Section 4 of the Science and Technology Act, to carry out research on improving the quality of welding.

Mr. Fowler: As part of its nuclear development programme the Atomic Energy Authority is making a substantial effort in this field. We are keeping under review the possibility of the issue of a requirement to the Authority in respect of non-nuclear applications.

Mr. Lubbock: Is the hon. Gentleman aware that the work which has been done by the Reactor Fuel Laboratory at Springfields has been in connection with the nuclear programme and that substantial fall-out could exist in the general welding sphere, in which hundreds of millions of £s have been wasted annually through welding defects? Will he consider my suggestion carefully and issue a Section 4 direction and so enable this work to be dispersed throughout the welding industry?

Mr. Fowler: We will consider the hon. Gentleman's suggestion carefully. We are aware of what is being done at Springfields. We already support to the tune of £290,000 a year the work that is done at the Welding Institute.

Sir H. Legge-Bourke: What efforts are being made by the United Kingdom Atomic Energy Authority in this respect? Is the fullest possible advantage being taken of the research that has already been done by the research association?

Mr. Fowler: There is close co-operation between the Authority and the Welding Institute, which is what I think the hon. Gentleman had in mind when he referred to the "research association". Both my Department and the Authority have nominated representatives on the Research Board of the Welding Institute.

Uranium from sea-water

5th March, 1969

MR. DALYELL asked the Minister of Technology what work he is doing at the Underwater Research Centre at Portland into research into the extraction of uranium from sea-water.

Mr. Fowler: Research on the extraction of uranium from sea-water is being undertaken by the United Kingdom Atomic Energy Authority at the Atomic Energy Research Establishment, Harwell, and a small testing station leased from the Ministry of Defence (Navy Department) at Portland. Research is leading to improvements in the process and tests on increasing the scale from laboratory experiments are being mounted at Portland.

Fish farming at Hunterston

11th March, 1969

MR. PARDOE asked the Minister of Agriculture, Fisheries and Food what plans he has to establish fish farms at power stations using sea water for cooling.

Mr. Hoy: Experimental work is being undertaken by the White Fish Authority on rearing soles in warm water effluent from the Hunterston Nuclear Power Station, but until the considerable scientific and practical problems have been overcome it would be premature to plan for the widespread adoption of this technique on a commercial basis.

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. The fees shown are exclusive of accommodation.

High-Voltage Technology
23rd April to 2nd May
Designed for graduate engineers and scientists who are new to high voltage technology or whose experience of this subject has been limited to a specialised aspect, this course is in three parts. The first covers electrical break-down mechanisms in gaseous, liquid and solid dielectrics. The second is concerned with the application of basic knowledge to the design of high voltage equipment and the third deals with laboratory techniques. The third part which can be taken separately, covers voltage sources, laboratory design and measuring techniques for high voltage power equipment.
Fee: £64. Fee for Part 3: £16.

Introduction to Radioisotopes
28th April to 9th May
15th to 26th September
A general introduction to the principal techniques used in tracer applications of radioisotopes in research and technology. The course is designed to be followed by a specialist course or can stand alone as a general introduction. Fee: £80.

Radioisotopes in Industrial Measurement and Control
12th to 16th May
An introduction to the principal radioisotope methods used in industry for professional engineers and others who need to keep up to date with modern methods. Fee: £40.

Commissioning, Use and Maintenance of Reactor Instrumentation
12th to 23rd May
13th to 24th October
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.

Introduction to Reactor Instrumentation and Control
13th to 21st May
14th to 22nd October
Primarily for graduates who are new to the nuclear field and who, whilst not working directly on reactor instrumentation or control, nevertheless need a broad knowledge of these subjects. Participants should have some basic knowledge of nuclear reactors, electronics, the measurement of physical quantities and automatic feedback control. Fee: £56.

Seminar on Harwell's Multi-access Computing System
20th and 21st May
9th and 10th September
The objective of the seminar is to describe and discuss the multi-access computing facilities developed at Harwell for use on the IBM system/360 computer. The system is designed to operate efficiently with conventional batch-processing. Fee: £16.

Reactor Safety
2nd to 27th June
This course has been designed to cover all aspects of nuclear technology relating to safeguards and safety assessment of the more important reactor systems. It is for senior engineers and scientists with some years' experience, preferably in reactor design and/or operation. They should be engaged now or in the future on the safety assessment, regulatory control or inspection of nuclear reactors. Fee: £160.

Radiological Protection
9th to 13th June
8th to 12th December
This course is designed to give some experience in the safe handling of radioisotopes. While it is assumed that students are normally graduates in science or engineering, or hold equivalent qualifications, such qualifications are not considered essential to attendance. This course is intended to be of use to "competent persons" since it contains information about safety precautions when using x-rays, industrial uses of radioisotopes, instrumentation and the regulations applicable to the use of ionising radiations. Fee: £40.

The corrosion and protection of uranium

This article by Dr. S. Orman, A.W.R.E., Aldermaston, is reprinted, with permission, from AWRE News.

The phenomenon of corrosion is unfortunately familiar to all of us, as the destructive means whereby our metal possessions slowly revert to a thermodynamically more stable state. This can take the form of tarnishing, as exhibited by silver, to the more extreme cases of motor car bodies which we are convinced slowly become a compact of rust held together by paint. In all cases of corrosion, combination with one or more constituents of the environment is occurring and metal atoms are thereby converted into chemical compounds. Some of these compounds are extremely adherent and almost impervious to the atmosphere from which they were formed. They are then able to prevent further reaction and the metal may be described as corrosion resistant. This type of behaviour is typified by the stainless steels. However, many metals and alloys form non-adherent corrosion products, of the iron rust type and these materials slowly disintegrate unless preventative action is taken.

The problem studied at A.W.R.E. for a number of years was to retard and if possible prevent the corrosion of uranium in either air or synthetic atmospheres from which water vapour was not necessarily excluded. This article will explain some of the difficulties encountered and illustrate how the many disciplines within the Materials Department combined to solve both the basic and the technological problems involved.

The bulk of corrosion knowledge has been derived over a great many years from the results of work conducted with the ferrous metals, iron and iron alloys. Two common ways of protecting these metals are painting and electro-plating, but early attempts to protect uranium by these methods proved to be useless. An idea of the problems involved may be given by a description of three simple experiments. In the first, a piece of mild steel and a piece of uranium are stored, partially immersed in distilled water, at room temperature for a few days. The steel shows evidence of heavy corrosion, while the uranium only tarnishes. In the second experiment two similar pieces of metal are stored in an oven at 60°C. Under these conditions the steel remains bright and untarnished while the uranium shows evidence of heavy corrosion, forming a lot of loose powdery oxide. In the third experiment the two metals are again stored over water at room temperature, but this time in a special chamber from which all the air has been removed. Under these conditions the steel would again be bright and untarnished while the uranium would be heavily oxidised. These experiments illustrate the lack of similarity between uranium and ferrous metal corrosion and it was realised that before adequate protection was likely to be achieved a basic study of the uranium-water reaction would have to be made.

Previous workers had already shown that uranium reacts readily with water vapour, the oxidation rate in humid air being greater than the corresponding rate in dry air at the same temperature. By the use of a vacuum line and ancillary apparatus it was possible to investigate the reaction of uranium separately with each of the major constituents of air and subseqently with synthetic mixtures. The experiments were performed with samples as illustrated in Figure 1. The clean weighed uranium was sealed into the glass ampoule together with an environment of known composition and after storage at a controlled temperature for a period of days the atmosphere within the ampoule was analysed and the uranium reweighed. By this means it was possible to show that uranium reacted very slowly with dry oxygen (rate=1) more rapidly with wet oxygen (rate=50) and very rapidly with pure water vapour (rate= 2,500). In addition to the rate variation a change in atmosphere also changed the products of the reaction, the evolution of hydrogen gas, which is a major product of the uranium-water reaction, being

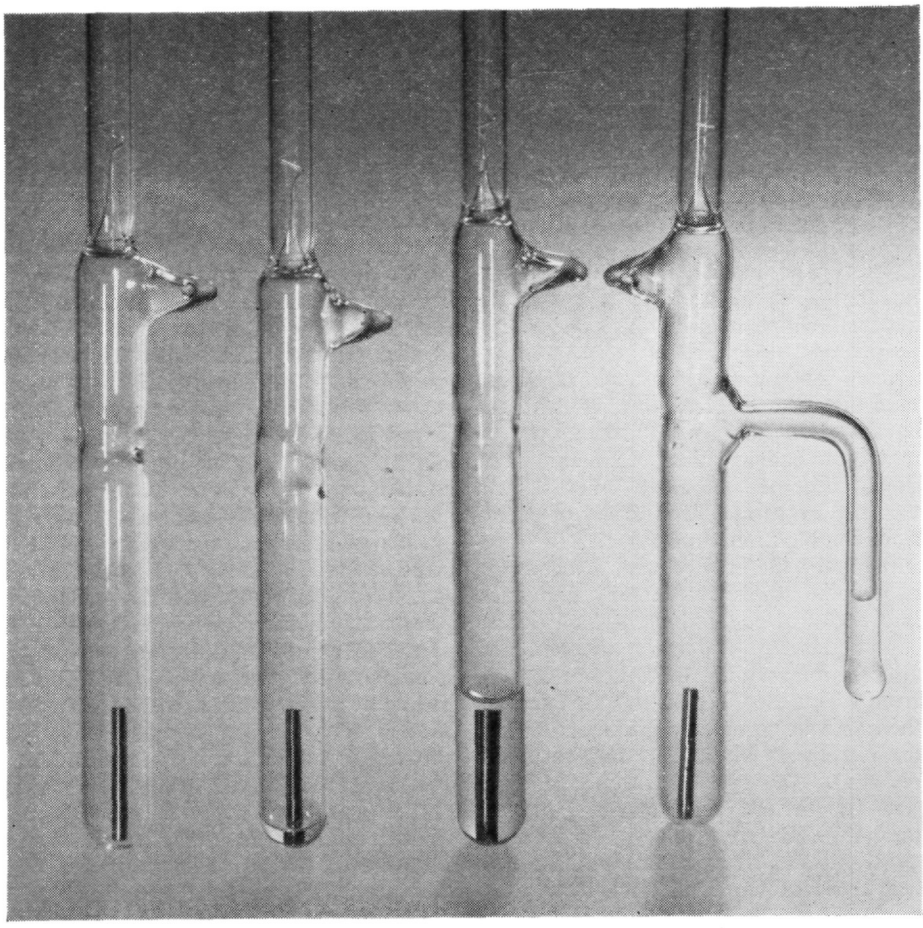


Fig. 1: *Uranium samples prepared for controlled temperature storage under different environmental conditions. From left to right: dry oxygen, partial immersion in water, complete immersion in water and water vapour at any desired vapour pressure.*

almost completely suppressed in the presence of oxygen. After a great deal of detailed work it was possible to show that oxygen retarded the uranium-water reaction, but in doing so was consumed and converted into water. This is illustrated in the two simplified equations.

$$\underset{\text{uranium}}{U} + \underset{\text{water}}{2H_2O} \longrightarrow \underset{\text{uranium dioxide}}{UO_2} + \underset{\text{hydrogen}}{2H_2} \quad \ldots (1)$$

$$\underset{\text{uranium}}{U} + \underset{\text{oxygen}}{O_2} + \underset{\text{water}}{2H_2O} \longrightarrow \underset{\text{uranium dioxide}}{UO_2} + \underset{\text{water}}{2H_2O} \quad \ldots (2)$$

Thus in a closed system originally containing both oxygen and water, the oxygen will be consumed, without any net loss of water and the atmosphere will eventually become one of water alone, resulting in a fifty-fold increase in corrosion rate. This behaviour is illustrated in Figure 2.

Another important aspect of these reactions was the dependence on water vapour pressure. The quantity of water vapour in the air varies over a very large range and is dependent on geographical position and temperature. The simplest way of describing the quantity of water vapour present is to use the units of relative humidity (rh) which expresses the quantity of water vapour present as a percentage of that required to saturate the air at the same temperature. Thus a humidity of 100% rh is the highest attainable and 0% rh represents dryness. The forms of dependence of the uranium-water and the uranium-water-oxygen reactions on relative humidity are shown in Figure 3.

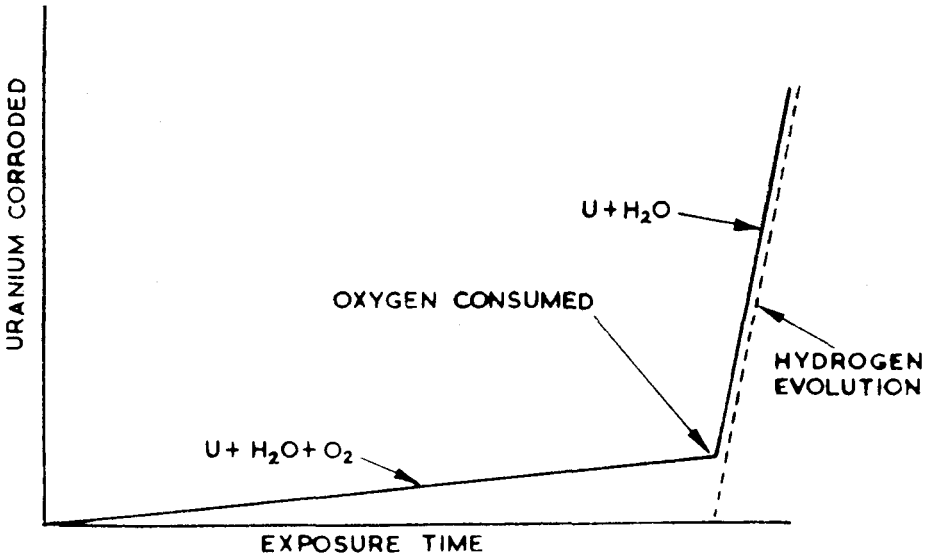


Fig. 2: *Conversion of oxygen to water during uranium-water-oxygen reaction and eventual rate increase (in the order of 50x) when all oxygen is consumed.*

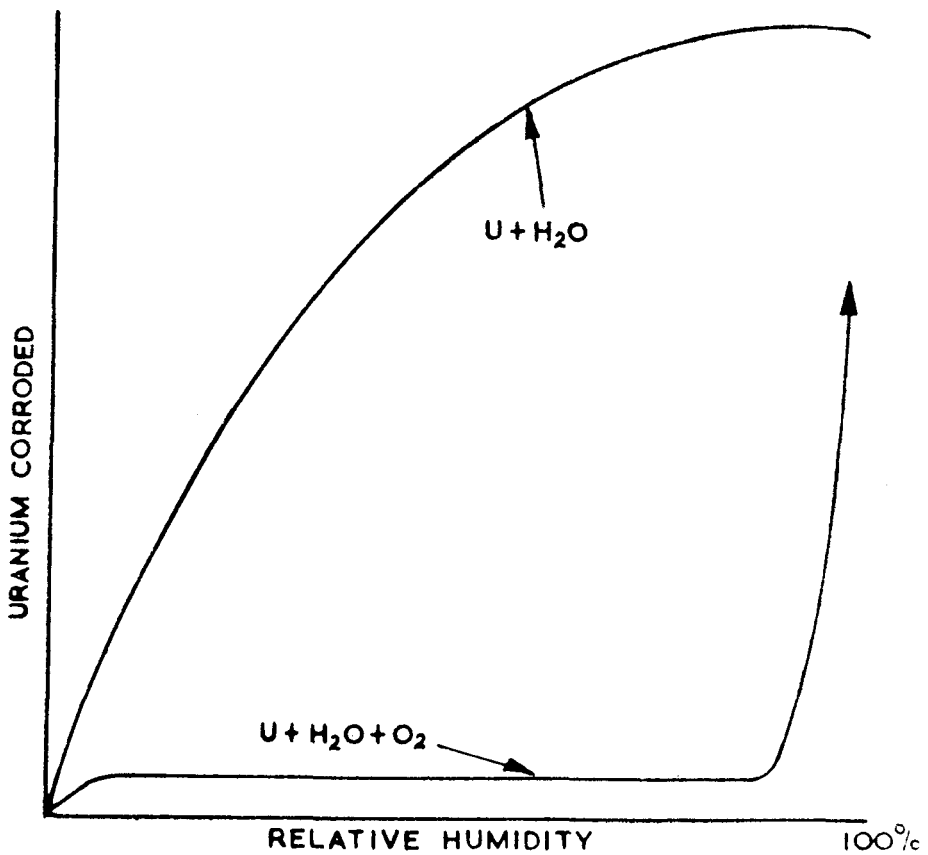
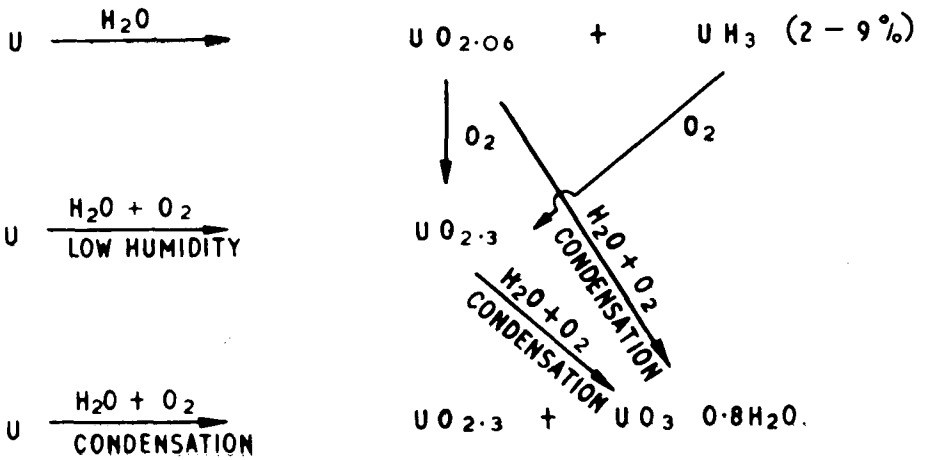


Fig. 3: *Effect of water vapour pressure on the uranium-water and the uranium-water-oxygen reactions.*

The uranium dioxide formed in reaction (1) is a non-stoichiometric compound. In chemical terminology a stoichiometric compound is one in which the constituent elements have combined together in a simple integral number relationship, such as H_2O, the formula for water. In practice with increasingly sensitive analytical techniques it has been found that many compounds are non-stoichiometric, although to the first approximation most may be considered as stoichiometric materials. The uranium dioxide formed in reaction (1) has the constitution $UO_{2\cdot06}$. When this material is exposed to air or oxygen, its constitution changes to approximately $UO_{2\cdot3}$. This compound is still uranium oxide, but extra oxygen atoms have been accepted into the lattice and this form of the material is the one which is produced in reaction (2). In addition to this change in uranium dioxide composition, another material is formed as a minor product in reaction (1), but it is not produced in reaction (2). This material is uranium hydride, UH_3. The quantity of uranium hydride formed in reaction (1) varies from 2 to 9% and has been shown to be dependent on the relative humidity of the corrosion environment. A final complicating feature of these reactions is that occasionally a bright yellow corrosion product is formed in addition to the usual black dioxide. It was shown that this material is a hydrated form of a higher oxide, uranium trioxide UO_3, $0.8H_2O$ and is only formed under condensation conditions in the presence of oxygen. The complex inter-relationship between the solid products formed under the different exposure conditions is outlined below.

While the uranium-water reaction was being studied by chemists in the Chemistry and Chemical Technology divisions, methods of painting uranium were being studied in the Chemical Technology Division and of electroplating in the Metallurgy Division. Surface coatings known to provide good protection to other metals were selected and normal accelerated evaluation tests performed. In most cases the coating appeared to accelerate rather than retard corrosion and multiple coats merely made the condition worse. This acceleration of corrosion by multiple coats was at variance with commonly accepted practice whereby it is considered that the greater the film thickness the better the protection provided. An explanation of this behaviour is afforded by reference to Figure 3. The water permeability of organic surface coating materials is always greater than the corresponding value for oxygen, thus a painted uranium specimen exposed to humid air (lower curve), may see an atmosphere sufficiently denuded in oxygen to be effectively oxygen-free and thus the reaction rate will correspond to the higher curve. Thus a painted specimen will corrode faster than an unpainted one when exposed to humid air. To overcome these difficulties a paint system with a very low water permeability was devised for use on uranium and has performed satisfactorily in service. The coating is a styrene-butadiene copolymer containing a special form of powdered aluminium



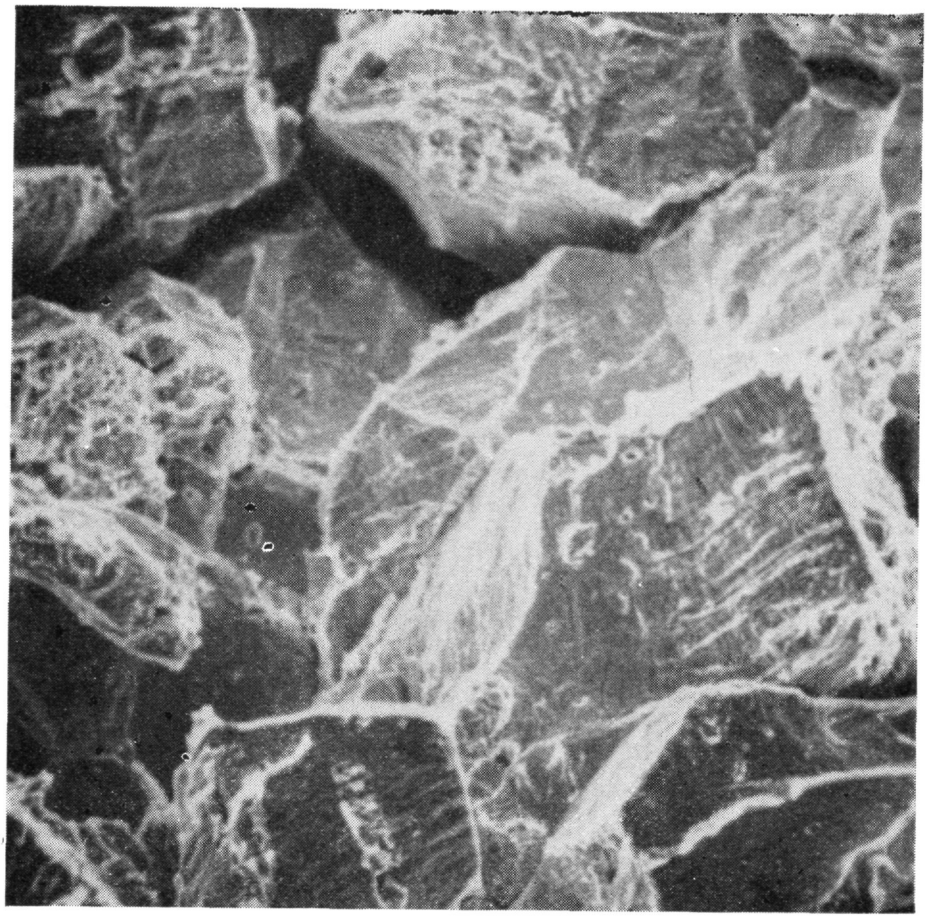


Fig. 4: *Fracture surface of uranium tested in water.* ×*570.*

and reduces the corrosion rate of uranium by a factor of at least tenfold at temperatures up to 40°C.

The protection of uranium by an electrodeposited metal coating was also studied and a considerable number of difficulties encountered. Nickel was found to be the most promising material but the problems of good adherence and the production of pore free films proved to be difficult hurdles to overcome. However this study was continued because both the durability and the potential protection of an electrodeposited coating would be superior to a paint system under abrasive conditions of service or where recoating would be impracticable. Eventually satisfactory coatings have been produced which at a thickness of three thousandths of an inch reduce the corrosion rate of uranium by a factor of about fiftyfold in humid air at temperatures up to 60°C. In oxygen free atmospheres the corrosion rate of the uranium is somewhat higher thereby indicating that the nickel is not acting simply as an impermeable barrier. The mechanisms of protection and final breakdown of the electrodeposited nickel film are aspects which are still under investigation, using the techniques and the information obtained during the basic studies.

Nickel plating has provided the technological means of protecting uranium from adverse environments for periods of years while the paint system can be used as a much cheaper alternative when the conditions and time of exposure are less demanding. Both coatings have proved to be very satisfactory in service and exhibit longer lifetimes than would have been predicted from accelerated laboratory trials.

Another form of corrosion which has

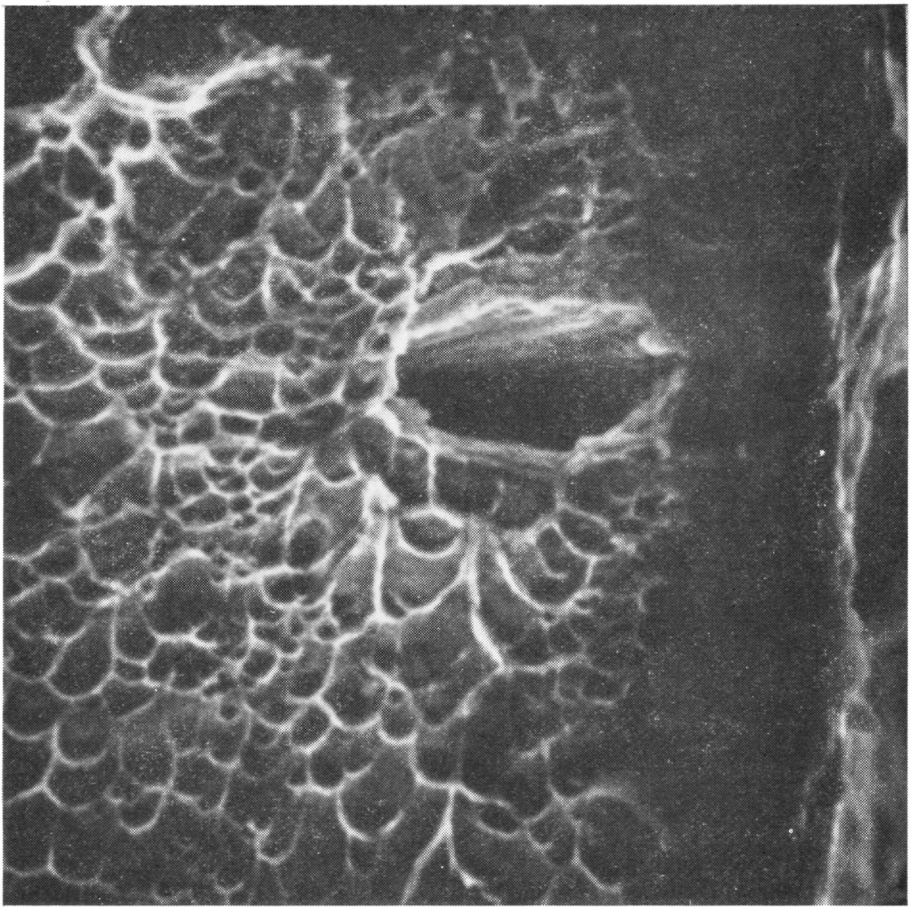


Fig. 5: *Fracture surface of uranium tested in air.* ×*2400 (Figs. 4 and 5: Dr. C. J. E. Smith, Metallurgy Division A.W.R.E.).*

been widely studied in recent years is stress corrosion. In this type of work the effect of an environment on the mechanical properties of a material are examined. Stress corrosion is usually described as the effect of the combined action of stress and a corrosive environment on a metal, although occasionally the same effects may be observed by prior exposure to the corrosive environment and then subjecting to stress. When the material is susceptible to stress corrosion the mechanical properties are severely reduced and failure will often occur at levels well within a normally acceptable working stress. It has been found that the stress corrosion susceptibility of an alloy is specific to the constituents of an environment and a change in these may eliminate the problem. As a general rule stress corrosion occurs in alloys rather than pure metals and high strength alloys are more likely to be susceptible.

Uranium exhibits stress corrosion if used in water condensation conditions, and its room temperature ductility is reduced from about 37% to less than 10%. The mechanism controlling this behaviour has been the subject of a research programme currently in hand in the Metallurgy Division. It has recently been shown that the stress corrosion behaviour can be explained in terms of the static corrosion mechanisms which were postulated from the A.W.R.E. work described earlier. The great difficulty encountered was to separate the effects of the uranium-water reaction and the possible subsequent hydrogen-uranium reaction, the hydrogen resulting from reaction (1) above. This was particularly difficult, since it has recently been demonstrated

that hydrogen in concentrations of one part by weight in ten million parts of uranium can adversely affect the mechanical properties of the metal.

An interesting aspect of this work is the complete change in fracture characteristics when the material is tested in corrosive and non-corrosive environments. These fracture surfaces are shown in Figures 4 and 5 and the photographs were taken on a scanning electron microscope. The fracture surface of the embrittled uranium is shown in Figure 4, the grain boundaries having parted and the individual metal grains are clearly discernible. The ductile fracture is shown in Figure 5; here the parting has occurred within the grains and the appearance is quite different from that of the brittle fracture. The Metallurgy Division is still concerned with these types of problems and is currently studying the corrosion and stress corrosion characteristics of a variety of metals and alloys.

The work described in this article occupied a period of about four years, during which many Aldermaston staff were engaged on the various projects. All contributed towards our understanding and eventual solution of the problem and a list of open publications on the various aspects of the study is given below.

1. The effect of certain gases on the rate of oxidation of uranium by water vapour by S. Orman, Chemistry and Industry, p.1692, 1963.
2. The corrosion of uranium and its prevention by organic coatings, by S. Orman and P. Walker, Journal of the Oil and Colour Chemists Association, Vol. 48, p.233, 1965.
3. A novel method for investigating metal-water reactions, by S. Orman and P. Robertson, Chemistry and Industry, p.1905, 1965.
4. The uranium+water reaction Part 1. Kinetics, product and mechanism, by M. McD. Baker, L. N. Less and S. Orman, Transactions of the Faraday Society, Vol. 62, p.2513, 1966.
5. The uranium+water reaction Part 2. Effect of oxygen and other gases, by M. McD. Baker, L. N. Less and S. Orman, Transactions of the Faraday Society, Vol. 62, p.2525, 1966.
6. Oxygen inhibition of the uranium-water reaction by M. McD. Baker and S. Orman presented at Corrosion Inhibitors: Theory and Practice, Birmingham, 1966.
7. Stress corrosion of uranium metal by S. Orman and G. Picton presented at the Corrosion and Protection Association, 9th Annual Meeting, Swansea, 1968.
8. Protective coatings for uranium by L. W. Owen, Journal of Less Common Metals, Vol. 4, p.35, 1962.
9. Surface treatment for electroplated coatings on uranium, by J. Addy and L. W. Owen, Plating Vol. 11, p.1012, 1963.
10. A microscope study of the initiation of the hydrogen-uranium reaction by L. W. Owen and J. A. Scudamore, Corrosion Science, Vol. 6, p.461, 1966.
11. The oxidation and protection of uranium at temperatures near ambient by J. R. Alderton and L. W. Owen presented at NACE Conference on Metallic Corrosion, New York, 1963.

M.Sc. course in radiation and nuclear chemistry

A one-year course from 15th September, 1969, leading to the degree of M.Sc. of the Council for National Academic Awards is available at the Liverpool Regional College of Technology (proposed Liverpool Polytechnic). This post-graduate course deals specifically with all radiation phenomena, including the action of ionising radiations, electrical discharge processes and photochemical reactions. Nuclear reactions, a natural extension of interaction processes, are also dealt with in depth. The course is designed for honours and Grad.RIC chemistry graduates who wish to advance their knowledge in these fields. The first eight months of the course consist of formal lectures, tutorials, seminars, and laboratory classes; the final four months being spent on a development or research project. The degree is awarded on the basis of examinations and a project report. The Department of Chemistry and Biology is particularly well equipped for work in this field.

Further information is available from the Head of the Chemistry and Biology Department, Liverpool Regional College of Technology, Byrom Street, Liverpool, L3 3AF, or telephone 051-207 3581.

A.E.A. work in medical engineering

Work by A.W.R.E., Aldermaston and A.E.R.E. Harwell on medical engineering problems is described in a series of data sheets produced by the UKAEA. Most of the Aldermaston work is sponsored by the Department of Health and Social Security. Two aspects of this work, in the field of cardiac pacemakers, are described below. Brief details of the other data sheets, which are available from Public Relations Branch, U.K.A.E.A., 11, Charles II Street, London, S.W.1, are also given.

Cardiac pacemaker encapsulation

Research is being undertaken at Aldermaston for the Department of Health and Social Security, to study the long-term reliability of implantable cardiac pacemakers and to examine possible improvements which could be made in the protection of the electronics by encapsulation.

The implantable pacemakers now in use consist of an electronic circuit powered by several small mercury cells. The unit is encapsulated in a block of synthetic resin and often further encased in a layer of clear or opaque silicone rubber. Electrical leads traverse the encapsulating resin and terminate at external connectors, to which leads to the heart and an 'earth' electrode are connected.

Two aspects of the research work are described: a study of pacemaker performance under simulated body conditions, and a study of encapsulating resin characteristics.

Pacemaker performance under simulated body conditions

When functioning in the body the pacemaker is subjected to an electrical load of approximately 300 ohms, to continuous contact with body fluids, and to a constant temperature of 37°C, which is appreciably higher than the normal laboratory temperature. To simulate these conditions in the laboratory, the pacemakers are immersed in Ringer's Solution in a constant temperature bath at 37°C, with the leads connected to a standard resistance. The pacemakers are monitored daily for pulse height, pulse width and pulse frequency on an oscilloscope.

Twenty-five pacemakers of six different manufacturers, both British and foreign, are at present under observation. Faults and failures similar to those reported *in vivo* are being obtained.

Characteristics of encapsulating resins

The basic requirements for the encapsulating systems are:

(i) ease of application and curing at only mildly elevated temperatures;

(ii) low temperature rise (exotherm) during cure;

(iii) low shrinkage during cure;

(iv) low swelling with moisture;

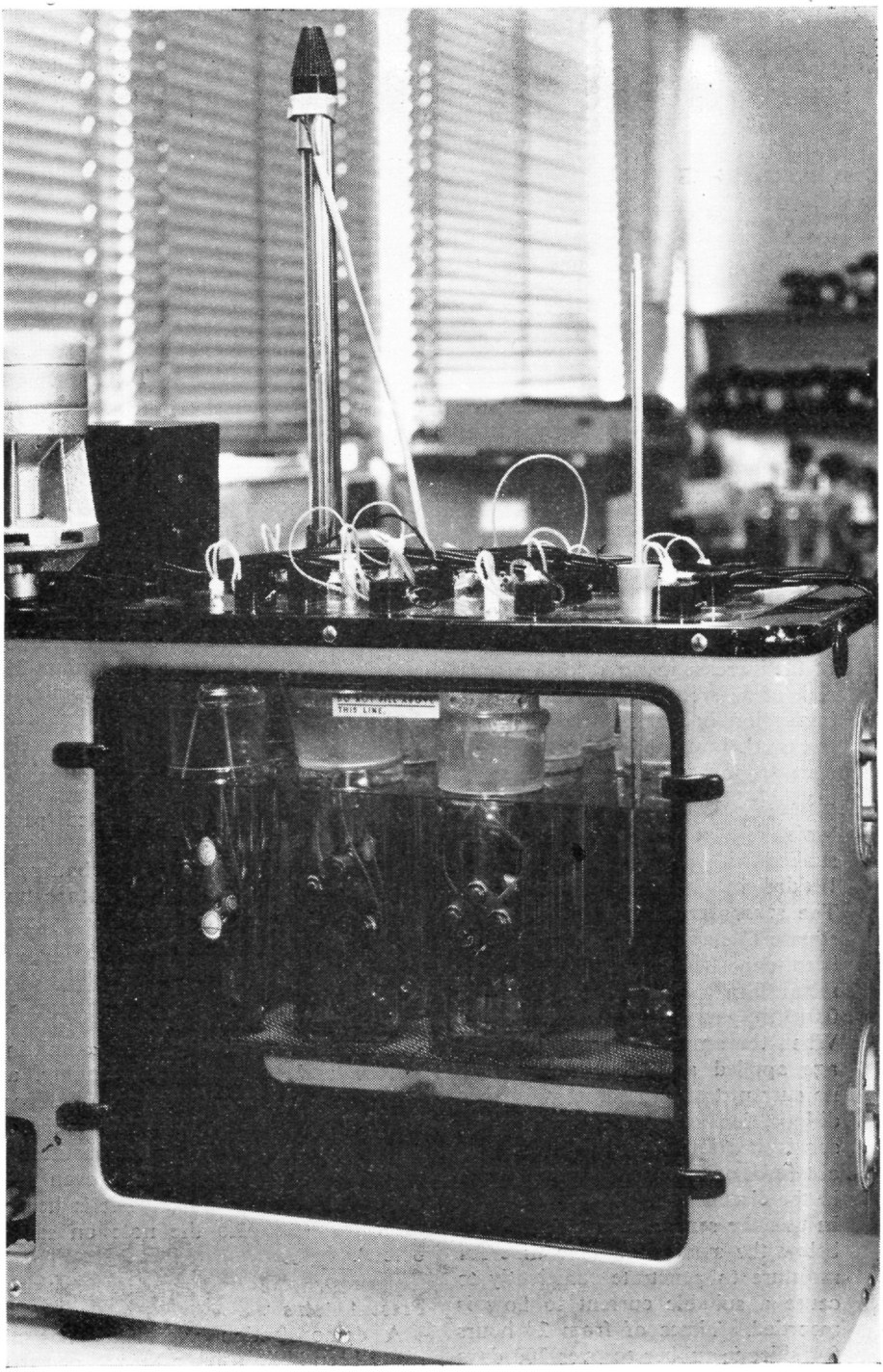
(v) low moisture permeability.

Epoxide resins are universally used for pacemakers encapsulation and research effort has therefore been concentrated on resins of this type.

(i) To satisfy the first requirement all the resin systems examined have been liquid resins which could be cured at an ambient temperature of 40°C.

(ii) The exotherm characteristics have been studied using an embedded thermocouple in resin samples of different sizes. An indication of the variation in temperature rise during cure (with an external temperature of 40°C) can be obtained from the table where internal temperatures from 47 to 162°C are recorded.

(iii) Shrinkage during curing is a difficult characteristic to measure because of the liquid-to-solid transition. A useful technique employed at Aldermaston makes use of a thin latex rubber bag which is completely filled with the resin system under examination and then immersed in water at 40°C. The apparent weight of the sample in



Tests are being carried out at A.W.R.E. Aldermaston on the encapsulation of commercial cardiac pacemakers. The equipment in the photograph simulates the physiological environment in which the pacemaker is placed. The pacemakers are the small square-shaped objects which can be seen in the bottles behind the window.

Characteristic of Encapsulating Systems

System	*Max. Temp. during curing at 40°C ambient*	*% Volume shrinkage during curing*	*Linear swelling in water after 100 day immersion*	*Time for moisture to penetrate through $\frac{1}{8}$ in.*
Epoxide A	99°C	5.6	1.1 thou/in.	Over 200 days
Epoxide B	87°C	5.3	9.0 „	182 „
Epoxide C	65°C	5.1	5.5 „	100 „
Epoxide D	47°C	3.9	20.7 „	78 „
Epoxide E	55°C	3.5	11.3 „	30 „
Epoxide F	50°C	4.9	10.5 „	18 „
Epoxide G	55°C	4.7	5.5 „	11 „
Epoxide H	47°C	4.9	Test incomplete	Test incomplete
Epoxide I	162°C	6.4	„ „	„ „
Silicone Rubber	—	—	—	1 day

water is continuously recorded during curing and the volume shrinkage obtained by Archimedes Principle. Shrinkages of from 3.5 to 6.4% have been recorded.

(iv) The studies of swelling in moisture have been based on the measurement of the increase in length of 6 in. cast rods of different resin systems during immersion in water at 37°C. This test is continuing but results after immersion for 100 days are given in the table.

(v) Moisture permeability is being studied with a moisture sensor embedded in the encapsulating resin. The sensor consists of a thin glass square ($\frac{1}{2}$ in. x $\frac{1}{2}$ in.) on which has been deposited a metal film. The metal film has been severed by a 0.010 in. gap cut with a laser beam. When the sensor is dry, a low voltage applied across the gap causes no current to flow; but in moist conditions, for example, when the sensor is breathed upon, a reading is obtained on a galvanometer placed in the circuit.

In use, the sensor is embedded $\frac{1}{8}$ in. below the surface and the time for moisture to penetrate sufficiently to cause a suitable current to flow is recorded. Times of from 24 hours for silicone rubber to over 200 days for the best epoxide have been found.

The validity of the test has been confirmed on selected systems by sorption-desorption studies.

Isotope-powered cardiac pacemakers

A long life battery, suitable for use in implantable heart pacemakers, is being developed at the Atomic Energy Research Establishment, Harwell. It converts the spontaneous heat generated by the radioactive isotope plutonium-238 into electricity, using a thermopile, as shown in Fig. 1. The battery is matched to the pacemaker circuit by a d.c. to d.c. convertor, which can be designed to enable any circuit to be used. A schematic view of a completed pacemaker is given in Fig. 2.

The ultimate lifetime of this battery is limited by the decay of the isotope but, with Pu-238 (half-life about 90 years), lifetimes of greater than 10 years are feasible. The reduction in output power due to the decay of the Pu-238 over 30 years is shown in Fig. 3.

Pu-238 is primarily an α-emitting isotope and, with reliable canning, an ultra safe source capsule can be produced; it will neither emit radiation harmful to the patient nor constitute a hazard to the general public even if—and this is highly unlikely—it is heated to 850°C (see also the note on safety below).

Present status

A demonstration pacemaker has already been built, using a Pu-238 powered battery and its associated d.c. to d.c. convertor, to drive a commercially designed pacemaker circuit built at the Atomic Weapons Research Establishment, Aldermaston. This has now

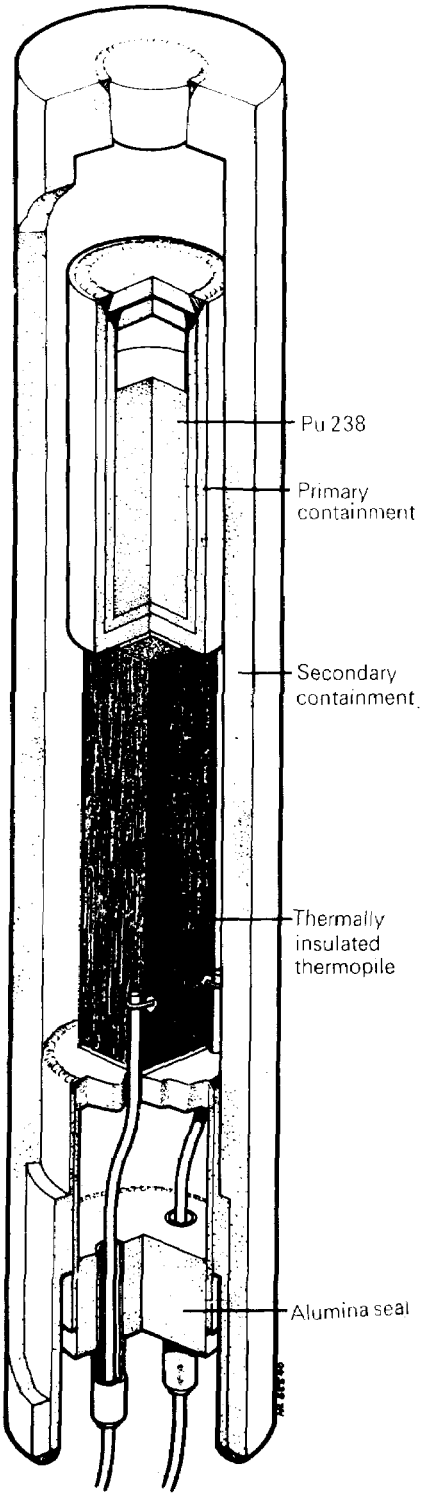


Fig. 1: *Isotope battery (approx. size 4.5 × 1.5 cm.)*

operated for many months, having been initially sealed off on 7th June, 1968.

Future developments, which are necessary before this is available for use in a patient, will be aimed at improving the efficiency (i.e., reducing the Pu-238 inventory) and ensuring that the lifetime of greater than 10 years can be reliably guaranteed.

The isotope battery and d.c. to d.c. convertor

The battery is a heat engine which uses an isotopic heat source, with a thermopile to convert the heat to electrical power. It therefore has no moving parts. Heat losses are minimised because the source and the thermopile are surrounded with thermal insulation inside an outer can, which also serves as a secondary containment of the isotope. The can, which is made of stainless steel and is hermetically sealed, will maintain its integrity up to 600°C. The thermopile, however, may be damaged by temperatures in excess of 150°C. Even so, this is more than sufficient for sterilization, and it does mean that the temperature to which the complete unit can be raised will be limited by the electronics rather than by the battery, as at present.

Thermopiles can, in principle, be built to gentrate any value up to a few volts, but in practice in such a small device as this the output is limited to less than 1 volt. To obtain a useful voltage (>4 volts) a d.c. to d.c. convertor is needed. The convertor in use is an electronic circuit consisting of three stages. The first stage is a multivibrator (using germanium power transistors to reduce the internal voltage loss), which converts the d.c. to a.c. This is then transformed to a higher voltage a.c. in the second stage. In the third stage the a.c. is rectified and stabilized. Convertors of this type can be made more than 60% efficient with 0.25V input if care is taken to match them to the battery. Also, they can be built to match any pacemaker circuit, either existing or proposed, to the battery.

Safety of the plutonium source

Provided that the canning of the plutonium is maintained intact no risks whatsoever are involved in its use. It is imperative, therefore, that the primary

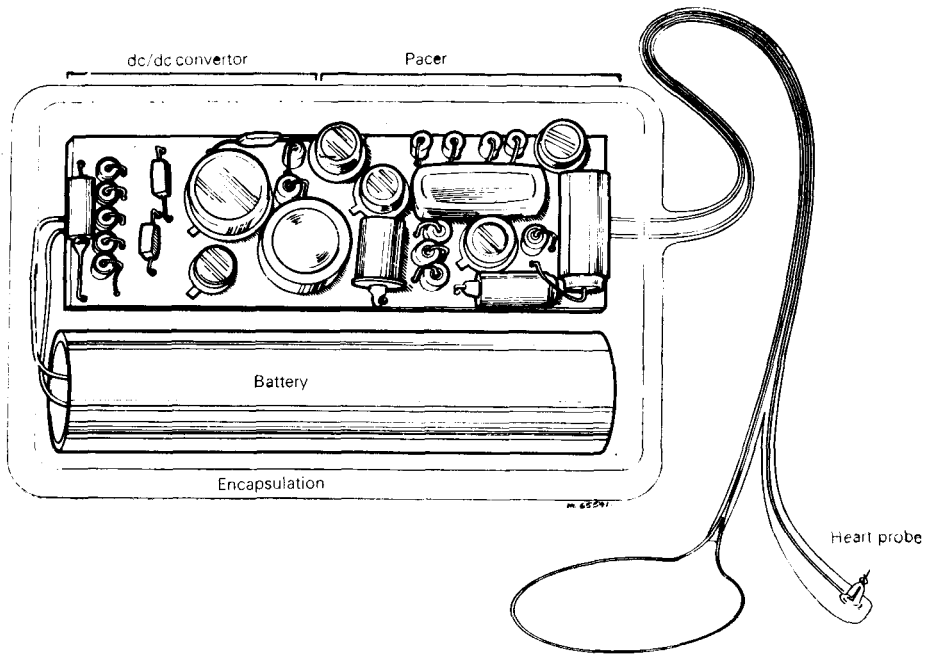


Fig 2: *General view (approx. size 5 × 3 × 2 cm)*

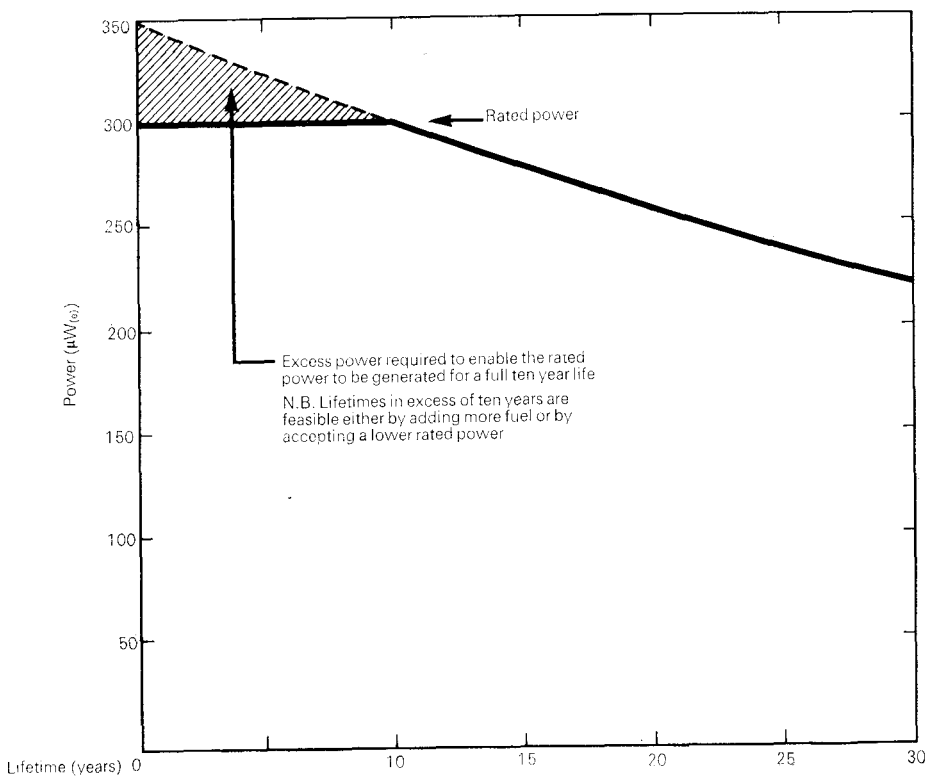


Fig. 3: *Electrical power change due to decay of the Pu-238*

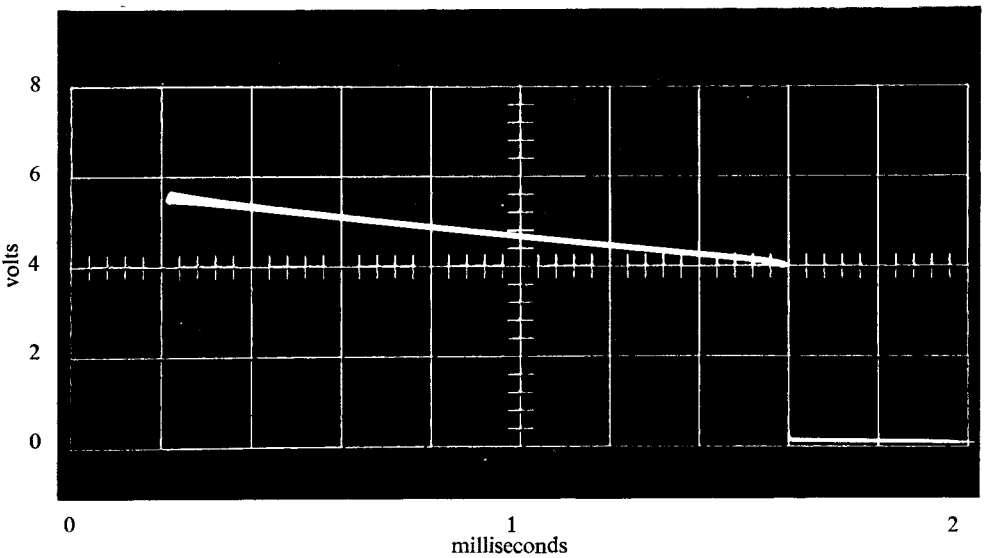


Fig. 4: *Output pulse from demonstration pacemaker (load: 330 ohms, rate 78 ppm)*

containment be designed and tested to ensure that it will not burst under any conditions likely to be met either in use or if the pacemaker is lost. Three major hazards exist:—

(1) Mechanical crushing.
(2) Internal pressure build up.
(3) Heating to 850°C for ½ hour (cremation).

Initial crushing tests on typical capsules have been carried out, and although a 2-ton crushing load between steel jaws did distort the capsules, they did not burst.

Internal pressure build up is easily withstood under normal operating conditions, but to enable the capsules to withstand the pressures involved at temperatures of up to 850°C, care has to be taken in design and manufacture of the capsule, which has to be constructed using one of the Hastelloy steels. Calculations

TABLE 1 Properties of Isotope-Powered Pacemakers Battery and Convertor

				Demonstration	*Fully Developed*
Source	Fuel	Isotope		Pu 238	Pu 238
		Chemical form		Oxide	Metal
		Half Life	(years)	87·4	87·4
	Can	Material		Inconel	Hastelloy
		Wall Thickness	(mm.)	1	1·5
	Shield	Material		none	Heavy Alloy
		Thickness	(cm.)	0	<0·5
	Radiation at 2 cms.		(mR/hr)	5	1
Thermopile	Optimum Output at 38° C	Voltage	(V)	0·175	0·5
		Current	(mA)	3·7	0·6
		Power	(μW)	650	300
d.c./d.c. Convertor Output		Voltage	(V)	5·5	4·5*
		Current	(mA)	55	45*
		Power	(μW)	302	200*
Pacer Output‡					
Battery Weight			(gm.)	20	<140
Battery Life			(years)	>0·5	>10
Maximum temperature of Battery**			(°C)	120	150

*These are sample values and can be altered to suit a particular requirement.
**See also note on safety on the source. ‡See Fig. 4.

show that a can in this material will not burst even if maintained at 850°C for several hours with an internal pressure of 10,000 p.s.i. As it will take up to 120 years for pressures of this size to build up, no danger is envisaged.

Dental materials

Two aspects of this work, on porcelain and inorganic anterior fillings, are described in the data sheets.

Ion exchange has been applied to dental porcelain to produce a compressive stress in the surface layer. This stress reduces the effect of surface defects on the flexural strength. Modulus of rupture increases of up to 80% have been obtained.

The corrosion of dental silicate cements by acids which occur in the mouth and/or are taken in food and drink has been studied as a preliminary to research into compositions with improved acid resistance. In rapid corrosion tests, improvement of up to 50% has been obtained.

Semiconductor radiation detectors

Developed at Harwell, these are used in the measurement of beta activity in the diagnosis of surface tumours (including those of the eye), in the location of intestinal bleeding of unknown origin, in blood flow measurements, in counting in tissue and body cavities during tracer investigation, in *in-vivo* X-ray or gamma ray dosimetry during radiotherapy, to monitor X-ray beams, and to measure absorbed dose distribution produced by high energy radiation therapy sources.

Automated Factor VIII equipment

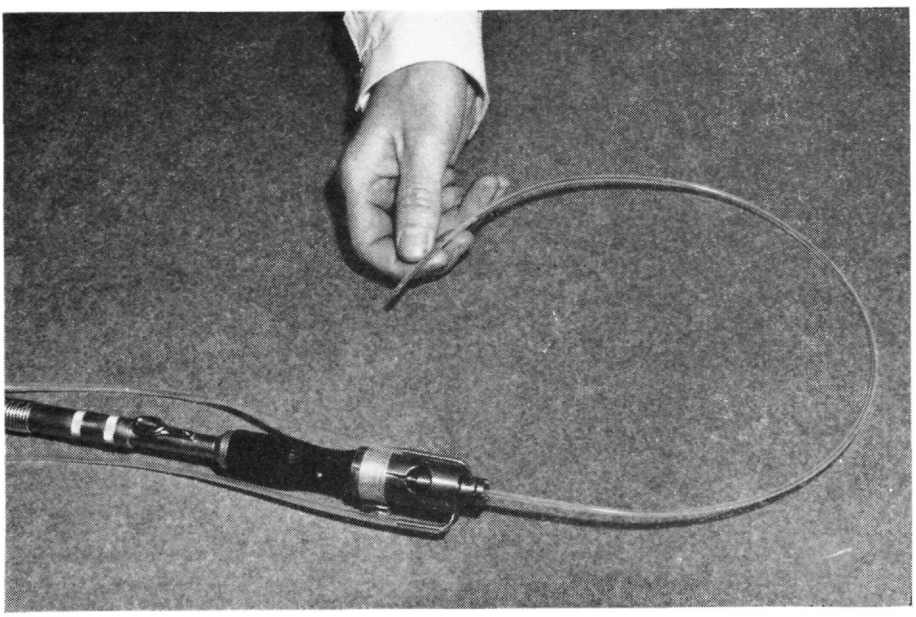
Factor VIII is one of several components of blood involved in the clotting mechanism, and a knowledge of its level in blood is important in the diagnosis and control of haemophilia. An apparatus has been produced in collaboration with the MRC Haemophilia Centre at Churchill Hospital, Oxford, to provide an automatic means of determining the Factor VIII level.

Short range radio telemetry system for patient monitoring

Two single-channel sets have been used to examine the application of radio telemetry to patient monitoring. Of particular interest is the maintenance of unbroken vigilance on a patient throughout the various stages of an operation.

Dual viewing attachment for medical endoscopes

The attachment is intended as a diagnostic teaching aid that enables the



The experimental artery drill developed at A.W.R.E.

student to see the same aspect of a body cavity as the surgeon controlling the endoscope.

Dental drill

Aldermaston, in association with the Eastman Dental Hospital, is working on a flexible fibre optics light guide to provide illumination of a dental drill point.

Medical infra-red scanner

An experimental infra-red scanner has been designed specifically for medical use. Its principal function is to provide information which will permit an accurate assessment of the value of quantitative thermography in medical diagnosis.

Artery clearance

An experimental apparatus has been designed to investigate the possibility of clearing an obstructed femoral artery with a high-speed drill.

Corrosion of surgical implants

The conditions under which metal surgical implants corrode are being examined, with the aim in the short term of increasing the corrosion resistance (by, for example, improving the finish of existing specification grade materials), and in the long term of investigating and developing special alloys, probably titanium based.

Chemical studies of artificial kidneys

In subjects with chronic renal failure, the products of body metabolism (metabolites) are not eliminated via the kidney and so their concentration increases in the blood. A programme aimed at characterising metabolites by chromatographic means is being carried out at A.W.R.E. A study is also being made of the removal of metabolites from the blood, using sorbent materials.

Gamma camera using a solid state detector matrix

This new type of gamma camera system uses lithium-drifted germanium detectors. The basic detector unit is prepared from a slab of germanium, about 5 cm square, by cutting a set of parallel grooves in both faces of the slab; the two sets of grooves are orthogonal and produce, in effect, a matrix of small detector elements. A gamma event generates an output in a particular "row" and "column" combination and its position is, therefore, accurately determined.

Automatic potentiometric titration apparatus

The outstanding features of this sensitive and accurate instrument are: operation of readily interchangeable micrometer burettes, variable control of pumping speeds over a wide range, using stepping motors, burettes which may also be used for pipetting selected pre-set volumes, and automatic digital presentation of information.

Computer course at Harwell

Conventional computer courses tend to concentrate on particular computers and languages, giving detailed information about techniques suitable for them. A more fundamental approach is to present the concepts underlying many systems, and consequently give a broader foundation to people working in the field, on which they can design and build systems for particular environments.

Such a course on Fundamental Concepts in Advanced Programming has been provided for computing staff at A.E.R.E., Harwell, and was given again on 24th-28th March, 1969 for the wider computing community.

The course was based on the premise that people in the computing field spend so much of their time doing their work that they have too little left to think about the broader aspects of what they are doing.

The material of the course was advanced, and presumed serious creative experience in high-level languages. It was designed for people planning, selecting, and designing computer systems and included operating environments, real-time interaction, data management, application languages and communication and exposition of these. The prospective benefit was an improvement in the clarity, efficiency and usefulness of programmes designed with these concepts in mind, and in the quality of judgments and proposed solution of problems in software and hardware.

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

Physico-Chemical Measurements Unit

[*This release was issued jointly by the U.K.A.E.A. and the S.R.C.*]

Following discussions between the Atomic Energy Authority and the Science Research Council a new national service, the Physico-Chemical Measurements Unit, has been set up.

The aim of the Unit is to provide a mail order service for refined measurements which require expensive and complex modern analytical instruments. The Unit will operate from A.E.R.E., Harwell, headquarters of the Unit, and A.W.R.E., Aldermaston.

The P.C.M.U. will provide a service to universities and to industry, mostly to those concerned with the structure and identity of organic chemicals including fields such as pharmaceuticals, pesticides, plastics and polymers, natural products, paints and varnishes, oils, fats and waxes, dyeing, surface finishes, etc.

The fees are sufficiently modest to be attractive to very small companies who cannot justify the purchase of expensive instruments and the Unit is willing to provide interpretation of spectra for those without skilled scientific staff. Large companies will find the Unit valuable should their own instruments break down or become overloaded.

At present the techniques available are infra-red absorption spectrometry, organic mass spectrometry and nuclear magnetic resonance spectrometry.

The Science Research Council is meeting the running costs of the Unit in respect of University and other S.R.C. users. During the early stages of the Unit's operation, a free service will be provided for them and enquiries about this should be directed to Dr. J. A. Fendley, Science Research Council, State House, Holborn, London, W.C.1. Industry will be charged for services direct by the U.K.A.E.A.

The Unit is under the direction of Dr. A. A. Smales, Head of Harwell's Analytical Sciences Division. Prospectuses giving full technical details of the services and specimen containers and packaging are available free on request to: P.C.M.U., Harwell, Didcot, Berkshire. Telephone: Abingdon 4141, Ext. 4151.

Background note

The Science Research Council set up a panel under the Chairmanship of Professor G. Porter, F.R.S., now Director of the Royal Institution, to examine ways of providing workers in industrial, university and government laboratories with economic access to the modern analytical instruments they need.

The Physico-Chemical Measurements Unit has been established in response to the recommendations of the panel and following the issue of a Requirement on Quality Control to the U.K.A.E.A. by the Minister of Technology under the Science and Technology Act 1965.

Under the same Requirement, an Analytical Research and Development Unit (A.R.D.U.) was established at Harwell in June 1968, also under the direction of Dr. A. A. Smales, and the two units will keep in close touch to provide practical solutions to industrial problems. The two Units are complementary in that A.R.D.U. undertake research and development work under contract to industry and the P.C.M.U. will provide a continuing measurements service.

P.C.M.U. facilities

Infra-red spectrometry

For high resolution work in the fundamental frequency region a Perkin-Elmer Model 225 spectrophotometer with a flatbed recorder is used and the resolution is better than 0.5 cm^{-1} over the entire frequency range of 5000-200 cm^{-1} and approaches 0.1 cm^{-1} in favourable circumstances: the frequency accuracy can be as high as 0.001%. Extremely high energy is available over the entire wavelength range which ensures good signal/noise ratios and permits even highly opaque samples to be examined quantitatively.

The low-frequency region of 400-20 cm^{-1} in which there are many absorptions of special interest to inorganic chemists is covered by a Research and Industrial Instruments Co. Ltd. Model FS 720 interferometer with coupled wave analyser. This gives an almost instantaneous spectrum with a resolution of up to 1 cm^{-1} so that a prompt service can be provided by the Unit. Higher resolutions approach-

ing 0.1 cm^{-1} are available but in this case the interferogram is recorded on punched paper tape and the spectrum is computed overnight.

Organic mass spectrometry

The application of mass spectrometry to organic chemistry has expanded greatly in the past decade. Low resolution spectra are adequate for establishing the molecular weight of a compound, for its identification by comparison with a reference spectrum or for structural elucidation of an unknown molecule from its fragmentation pattern. The last of these can be aided by precise measurement of the mass of selected peaks in the spectrum using high resolution. The P.C.M.U. can undertake both low and high resolution work using an A.E.I. Ltd. MS 902 spectrometer at Aldermaston. The resolving power is varied from about 1000 for low resolution spectra up to 40,000 for precise mass requirements. Specimens can be introduced by an all-glass heated inlet system or a direct evaporation probe.

Nuclear magnetic resonance spectrometry

High resolution nuclear magnetic resonance spectrometry became available in the early 1950's and was rapidly developed as a means of investigating the magnetic environment of the protons in a molecule. Measurement of the position, intensity and multiplicity of the spectral lines can indicate the identity of adjacent atoms or groups of atoms and the technique is particularly powerful in distinguishing between two possible structural or geometrical isomers. The number of protons associated with each line can be assessed by integration of the spectrum and this can be extended to the quantitative analysis of 2 or 3 component mixtures. A Varian Model HA-100D 100 MHz instrument is used by the P.C.M.U. at Harwell.

This instrument has a specified resolution of 0.3 Hz and has been designed to accept a wide range of accessories. The option of field sweep operation combined with homonuclear and heteronuclear decoupling facilities allow the operator to select the optimum conditions for complicated interpretive work.

24th February, 1969

Engineering tribology

A three-week course in engineering tribology is to be held at the University of Salford from 14th April-2nd May, 1969.

The importance of tribology to the national economy has been established at an annual saving of £500,000,000 (Jost Report 1966) if the available knowledge on friction, lubrication, and wear could be more widely disseminated. The course is thus presented as a contribution towards this objective and will deal with the basic physical concepts and their practical significance.

The course is in three parts. The first week consists of lectures intended to provide a general understanding of the basic concepts appropriate to tribology. The second and third weeks cover design, and metal cutting and forming respectively, giving specific orientation to the application of the basic principles. The programme will also include visits to university laboratories and neighbouring centres.

Students may register for the whole course, or for one or more separate weeks.

The course is intended for those with graduate or equivalent qualifications who wish to obtain a more comprehensive appreciation of the subject.

It is sponsored by the National Centre of Tribology (U.K.A.E.A., Risley) in association with the University of Salford, the University of Manchester, and the University of Manchester Institute of Science and Technology.

Fees

The course fee, which includes the cost of lunch and other refreshments each day will be £18 per week or £54 for all three weeks. Overnight accommodation will be available at the Halls of Residence at the rate of £2 7s. 6d. per night for evening meal, bed and breakfast.

Further information

To obtain an application form and a booklet giving full details of the course, contact the Administrative Assistant (Short Courses), Room 328, University of Salford, Salford M5 4WT (Telephone 061-736 5843, Ext. 449).

10th March, 1969

Analytical Research and Development Unit

A brochure describing the Analytical R & D Unit at Harwell has been published by the UKAEA.

The Unit was set up last year to help to identify, measure or control impurities in industrial materials, for example, during the development or investigation of a new product, at pilot plant or full-scale production stages, or after product specification failures.

The brochure outlines how the Unit can undertake the development of:

(a) new or improved techniques for the investigation of impurities at major, minor or trace concentrations; in thin surface films, or where location or chemical form is required;
(b) high speed or on-line analytical methods for process control;
(c) interfaces and software required for the direct use of small computers with analytical instruments for on-line data acquisition or automation.

The brochure also lists the range of instruments available for the analysis of samples, and then describes how the initial approach by an enquirer

" is followed up by further discussion or a visit to ensure a detailed appreciation of the problem. In many cases an enquiry requires only a reference to published literature, or an analytical instrument company. At present no charge is made for this technical and advisory service.

" Research, development or measurement projects are carried out in complete confidence at full cost for industrial firms, or other laboratories. A technical appreciation is prepared to define the project and to outline the proposed programme. This is discussed with the enquirer, modified as required to provide an acceptable proposal, and an estimate of cost is prepared. If appropriate, the proposal can be broken down into a short feasibility study and one or more subsequent stages, subject to a progress report and a review at each stage. The proposal is submitted to the enquirer with a request for an instruction to proceed with the project.

" Other commercial arrangements such as licensing agreements, or proposals for joint programmes with several industrial firms, where each partner contributes effort or resources and shares proportionately in the benefits, are made by agreement with industrial sponsors."

The Analytical Research & Development Unit was set up following the issue of a Requirement on Quality Control by the Minister of Technology under the Science and Technology Act 1965. It was established at Harwell in June 1968 and has already undertaken work for a wide range of companies with industrial interests covering ferrous and non-ferrous metals, refractories, glass, electronics, plastics and rubber, paper, minerals, chemicals and fertilisers.

Under the same requirement a Physico-Chemical Measurement Unit recently came into operation and is providing a mail order service for refined measurements. The two units, both of which are under the general direction of Dr. A. A. Smales, are complementary, and keep in close touch to provide practical solutions to industrial problems.

Copies of the ARDU brochure are available from the Public Relations Office, Building 77, A.E.R.E., Harwell, Didcot, Berks. Telephone Abingdon 4141. Ext. 3122.

12th March, 1969

AEA exhibit in Brazil

British achievements in nuclear power were featured at the British Industrial Exhibition held in São Paulo, Brazil, from 5th-16th March.

Brazil recently announced her intention to build her first nuclear power station. It will be of 500 megawatts capacity and is to be completed by 1975.

A 3,000 square-feet stand organised by the United Kingdom Atomic Energy Authority highlighted the fact that Britain has generated 120,000,000,000 units of electricity from nuclear power—more than the rest of the world combined. Models, photographs and animated diagrams illustrated the 27 nuclear power reactors already operating in Britain and the eleven under construction.

Background information was given on the three main systems included in Britain's programme of nuclear power de-

Mr. T. Tuohy, C.B.E., Managing Director, Production Group, led the team which represented the Authority at the British Industrial Exhibition in S o Paulo, Brazil, from 4th to 16th March. He is seen here (right) on the Authority stand with (left to right): Dr. Pedro B. Camargo, Director, Nuclear Engineering Division, Atomic Energy Institute, São Paulo; Dr. Mário P. Bhering, President, Elétrobras; Sr. J. Aflalo Filho, Elétrobras.

velopment: gas-cooled; steam-generating heavy-water; and fast reactors. The exhibit also provided full details of the Authority's comprehensive service for the manufacture, transport and re-processing of a variety of reactor fuels. The Production Group has manufactured 2½ million fuel elements to date and its products and services are already used by 28 countries.

Britain has built more desalination plant than anyone else in the world and some of the A.E.A.'s research in this subject was outlined, e.g., for dual purpose S.G.H.W.R. designs to give electricity and pure water.

The A.E.A. exhibit also discussed the uses of radioisotope sources for the large-scale radiation sterilisation of medical products (such as scalpels, syringes, etc.) and for producing electricity on remote sites, e.g., for marine and aviation navigational beacons. Britain is a world leader in these fields and has exported five gamma sterilisation plants.

The stand also showed a uranium prospecting meter, (Brazil has recently announced plans to intensify her search for uranium ores), mineral analysis equipment and a novel chemical processing technique for making metal powders. A cinema showed films outlining Britain's achievements and capabilities in the peaceful uses of atomic energy.

The integrating nephelometer

A.E.R.E., Harwell, has developed an instrument for the measurement of visibility in the atmosphere as part of its programme of research into atmospheric pollution. This instrument, an integrating nephelometer, was one of the exhibits of the U.K.A.E.A. at the Physics Exhibition, Alexandra Palace, London, last month.

In the integrating nephelometer, visibility is determined from the amount of light scattered by a small volume of the atmosphere under study. This is much more convenient than the usual transmis-

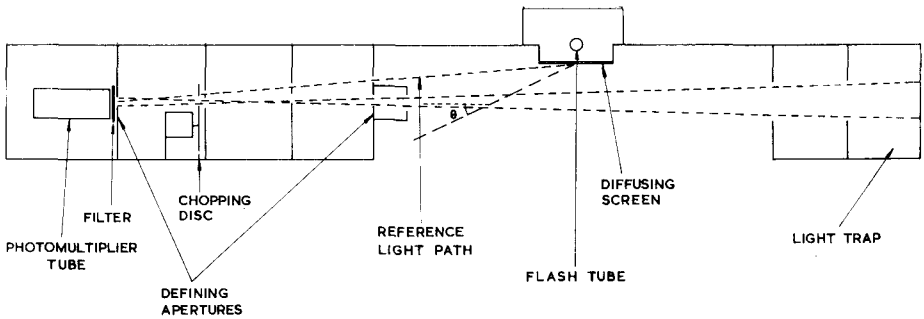


DIAGRAM OF THE OPTICAL ARRANGEMENT OF THE INTEGRATING NEPHELOMETER

sion instrument since it does not need a long optical path or optical alignment at the site of measurement. Its range of useful measurement is also much greater; the transmission instrument is accurate only when the visual range lies between the length of the optical path and 40 times that length, while the nephelometer is capable of measuring any visual range greater than about 5 metres. The sensitivity of the new instrument can be held constant for periods of a few weeks and, with a suitable recording system, is capable of long periods of fully automatic operation.

The optical arrangement is simple in design. The atmosphere near the instrument is illuminated by the light of a xenon flash tube diffused by an opal glass screen. A photomultiplier tube sees light scattered from a thin cylindrical sensitive volume of atmosphere defined by two diaphragms, against a black background of a light trap.

The flash tube operates at 10-second intervals. A rotating disc allows the photomultiplier to see the diffusing screen through a pinhole and the sensitive volume at alternate flashes. When the diffusing screen is seen directly a feedback loop operates to control the voltage on the photomultiplier in such a way that the photomultiplier output on these occasions is kept constant. This eliminates long term sensitivity drift due to ageing of flash tube or photomultiplier. The use of a highly stabilised power supply for charging the flash tube condenser, and integration of the photomultiplier output over the duration of each flash eliminates short term changes in the output.

Visibility frequently depends very strongly on relative humidity. Heat sources in the detector assembly are therefore avoided as far as possible. The sensitive volume is left as open as possible to encourage free circulation of air through the instrument.

Further information is available from Public Relations Branch, U.K.A.E.A., 11, Charles II Street, London, S.W.1.

AEA at the Physics Exhibition

The UKAEA had exhibits at the Physics Exhibition (Alexandra Palace, London, from 10th-14th March, 1969) from Aldermaston, Culham, Foulness, Harwell, and Windscale.

The exhibits were:

Plasma focus experiment

The plasma focus device produces a plasma which, in the respect of energy density, is perhaps unique in laboratory plasmas. The density is at least 10^{19} electrons cm^{-3} and with an electron temperature of about 3×10^7 °K, an extremely high energy density of 5 kJ cm^{-3} is created. The kinetic pressure of the plasma is at least 40,000 atmospheres. This energy density is achieved at the expense of the small plasma volume, about 10^{-2} cm^3, and the short confinement time, about 10^{-7} S.

Low voltage working model for producing field configurations used in plasma confinement experiments

The exhibit represents stages in the development of a new high-beta, high-density plasma confinement experiment,

currently under construction at the Culham Laboratory, UKAEA, and due for completion in late 1969. The central feature of this exhibit was a full-scale model of the toroidal assembly, which is energized by a low voltage (40 V) model of the high energy bank, constructed, using transistors as switches. The inductance, capacity and series resistance of this low voltage bank are identical to those in the high voltage bank, and it will therefore produce identical magnetic field distributions, readily measured with sensitive magnetic probes.

Industrial applications of the Mössbauer effect

Mössbauer spectrometers are being used in studies of the production of ferrites for microwave devices, the running of blast furnaces, and the manufacture of glass.

The modulation polarograph

A significant limitation, in the past, to the speed and convenience of operation of polarographs has been the need to remove dissolved oxygen from solutions before these could be analysed for traces of polarographically detectable ions. This limitation has been removed (for many supporting electrolytes) by this new instrument which uses a novel principle, measurement of the amplitude modulation of the high frequency component of the voltage developed across a polarographic cell when a low frequency voltage and a high frequency current are applied simultaneously to the cell electrodes.

Proportional sampler for flowing liquids

The exhibit demonstrated what is believed to be a novel sampling system in which no control loop is required. It comprises essentially a conduit in which the liquid level bears a known relationship to the flowrate, and a device for withdrawing, at regular intervals of time, a volume proportional to the flowrate. A key feature of the withdrawal unit, a specially developed automatic pipette, is that the volume taken is an adjustable function of the liquid level. The volume is made proportional to flowrate by designing the pipette in such a way as to incorporate the flow level relationship of the conduit.

The application of ion implantation to semiconductor technology

This exhibit showed the progress made since the 1968 Physics Exhibition in the applications of ion implantation to semiconductors. The details of two ion accelerators specifically designed at Harwell for the implantation of semiconductors were given. The advances in the design and characteristics of semiconductor devices were demonstrated by a range of devices which included special diodes, MOST's and nuclear particle detectors.

Medical applications of holographic visual displays

Holography allows a multiplicity of pictures to be stored on a single photographic plate. The pictures may be stored so that all of them can be viewed simultaneously in some predetermined array, or alternatively so that only two or three of them are seen from any given viewpoint The first technique has been used to produce three-dimensional reconstructions of the uterus by multiplexing a sequence of ultrasonic recordings. The second technique has been used to produce three-dimensional X-ray images from a sequence of radiographs.

The automatic scanning microphotometer

In emission spectography and spark source mass spectrometry, photographic plates are widely used for storing information. The retrieval of this information is a tedious and time-consuming operation when carried out manually, and the automation of the process should produce benefits with regard to speed, accuracy and manpower efficiency. A scanning microphotometer has been designed to measure automatically the emulsion blackening of plates of up to 10 inches in length. The plate is scanned by a narrow beam of light and the transmission through the emulsion is measured at closely spaced intervals by a solid state light detector.

C-Spring deflection gauge

This deflection gauge was designed to record transient and oscillation deflections and works on the principle of measuring the change in curvature of a bent thin spring beam as one end of it is

moved. Bonded on the beam is an electrical resistance strain gauge which will change in resistance as the curvature of the beam alters. In the model shown, four gauges are bonded to the beam to form a complete bridge network giving increased output and stability compared to either single- or two-arm bridges.

Indicating manometer used for industrial excess pressure warning system and blast pressure measurement

This is a simple device, employing basic physical principles, which is easy to operate and inexpensive to make. It consists of a U-tube initially filled with liquid. The right-hand limb opens into a sealed tubular chamber while the pressure to be measured is applied to the liquid surface at the mouth of the left-hand limb. This pressure drives liquid into the sealed chamber until the air in it attains the forcing pressure when equilibrium is established. The height of liquid collected at the bottom of the sealed chamber is, therefore, a measure of the applied pressure.

Argon arc image furnace

This uses the radiation from a novel gas flow restricted arc as a source of heat in an image furnace, This has greater convenience and produces a more severe thermal environment than image furnaces using the anode crater of a carbon arc as a radiation source.

High intensity stress measurement

Piezo resistive stress transducers have been developed, capable of recording stress pulses of up to several hundred kilobars which have been generated in solids and liquids by explosions or the impact of rapidly moving objects. The transducer is based on the linear change in resistance of manganin wire with applied pressure. Rise times as short as 0.1 microsecond can be readily achieved and stress-time profiles can be recorded for several microseconds.

A detector for the metastable ions observed in the mass spectra of organic compounds

This is a sensitive ion detector that can record the normal and metastable components of the mass spectrum of a compound. Alternatively it can suppress (usually by a factor 10^4) the normal spectrum and display the metastable spectrum at a higher gain. In the latter mode it detects metastable transitions and can be used to examine the different fragmentation pathways in the decomposition of an organic ion.

Electrohydraulic crusher for small samples

An electrohydraulic crusher has been developed for laboratory use; it is intended for crushing small samples while introducing only controlled contaminants. The contamination from the electrode material amounts to about 1 p.p.m. per discharge, and the metal used for the electrode may be chosen so as to minimise the interference in any subsequent process, e.g., chemical or spectroscopic methods of analysis.

17-channel rotating disc camera

A specialised recording system has been developed in which the signal is recorded by causing it to deflect the spot of a CRT, the deflection being photographed on a moving film. In the recorder shown, a disc of film which rotates in a horizontal plane is used, the signal appearing as a radial deflection near the periphery of the disc. 17 channels are available, and these produce 17 traces in a band on the disc, which is about $1\frac{1}{4}$ inches wide.

X-ray grating spectrograph

The X-ray grating spectrograph represents some advance over existing instruments of this type in that it extends into the X-ray region of the spectrum the wavelength range over which focusing grating instruments can be employed.

Measurement of small deflections of inaccessible structural members using a millimetre wave interferometer

This exhibit showed a method of locating the surface of a moving metal bar which cannot be touched by a mechanical probe or viewed optically. It is capable of measuring displacements of 10^{-2} mm. (0.0005 in.) with a time response of 1 μs. Radiation in the millimetre wavelength range is reflected from the surface of the conductor, represented here by an oscillating bar, and the phase of the incident beam compared with that of the

reflected beam. Variations in the phase difference between the beams are directly related to the changing position of the bar.

Techniques for reducing electrical interference between high current pulse circuits and measurement and control circuits

Two techniques were displayed. One uses a pulse of infra-red light to carry a signal between units while maintaining their electrical isolation; the other uses double screened transformers, and a method of producing very simply a wide range of broad-frequency-band transformers having two independent screens was described.

A method for the absolute calibration of vacuum gauges using tritium gas

The method depends upon measuring the radioactive decay current generated by a known volume of tritium. Calibrations, in the pressure range 10^{-8} to 10^{-5} torr, have been made for a mass analyser and an ionization gauge which are commercially available.

The APEX goniometer

The Automatic Precision Elemental X-ray (APEX) Goniometer is a precision instrument that obviates the main errors in the measurement of X-ray diffraction angles, using special procedures that are carried out automatically. Tests show that diffraction angles are measured such, that when translated into terms of lattice parameters or wavelengths, a precision of 1 part in 10,000,000 is being attained.

Desk-top computer in nuclear measurements

In some applications it is neither appropriate to compute results continuously (on-line) nor to wait for time on a central computer. To meet these requirements a "desk-top" computer has been modified to accept data directly from Harwell 2000 Series Scalers or from punched paper tape.

Low-energy X-ray machine

This equipment has been designed to study the effect of low energy (250-1500 eV) characteristic X-rays on biological materials for which high doses are required. The X-rays are produced by a high current electron beam from a glow discharge "anode mesh gun". Electron beams of 20 mA and 15 keV can be obtained.

The integrating nephelometer for visibility measurement

See page 111 of this issue of ATOM.

A.E.A. at Oceanology '69

Radioisotopes in sea-bed tracing, Britain's desalination R & D programme and the Marine Technology Support Unit (MATSU), were described in the AEA's contribution to the U.K. Government's display at Oceanology '69, which was held at Brighton, from 17th to 21st February.

MATSU was set up at Harwell by the Minister of Technology with the following terms of reference:

To formulate an R & D programme in accordance with the interests of the Committee on Marine Technology.

To establish and assess the technological problems associated with such a programme.

To consider how such a programme might best be carried out.

To carry out technical work, as necessary, arising from programmes agreed by the Minister and the Committee as a result of the above.

MATSU is headed by Dr. J. L. Putman, of the Isotope Research Division (A.E.R.E., Harwell), at Wantage Research Laboratory.

Radioisotopes in sea-bed tracing

A display by Wantage Research Laboratory described the use of radioisotopes as sea-bed tracers, to follow the movement of shingle, sand, dredged silt and minerals.

Wantage has 15 years' experience of this work and the equipment used in the investigations and the locations of some of them were shown in the exhibition. The work in the Firth of Forth was described in detail. In this, a preliminary study showed a substantial upstream movement of silt from the existing spoil-ground back to the dredged areas. This

was confirmed, with quantitative studies, in 1964. A nearby alternative spoil-ground was suggested and evaluated in 1965 and 1966, and it was shown that no upstream movement occurred from this area. The use of the new spoil-ground can be expected to lead to large reductions in the volume of dredging required, and to annual financial savings far exceeding the costs of the investigation.

Desalination

The UKAEA desalination programme is administered by Reactor Group HQ at Risley and draws on the resources of AERE Harwell, AEE Winfrith, and the Engineering Group at Risley. Work has been sited within the UKAEA, where existing skills and facilities have made an immediate impact in terms of plant improvement.

It is the aim that any new ideas should find their way quickly into the design of commercial plants and the large-scale experimental work of the joint programme is carried out in the laboratories of industrial firms concerned.

A new sea water experimental establishment was constructed by Weir Westgarth at Troon (Scotland), where services are sufficient to test plant features of up to the 10Mgal/d size.

Similarly, large-scale facilities are being operated or are under construction in other industrial laboratories on freezing and electrodialysis plant.

A.E.A. Reports available

THE titles below are a selection from the March, 1969, "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-R 609
An Investigation into the Effects of a Cosine Axial Heat Flux Distribution on Burnout in a 12ft. long Annulus using Freon-12. By G. F. Stevens, R. W. Wood and J. Pryzbylski. September, 1968. 9 pp. H.M.S.O. 4s. 6d.

AERE-Bib 127 (Revision 1, Suppt. 1)
List of Unclassified Reports and Papers Published by Staff of the Isotope Research Division During the Period January, 1966-July, 1968. By A. O. Armstrong. January, 1969. 19 pp. H.M.S.O. 3s.

AERE-Bib 162
List of Unclassified Documents, Lectures, etc., by the Staff of the Analytical Sciences Division, A.E.R.E., Harwell, 1968. By J. M. Leatham. January, 1969. 11 pp. H.M.S.O. 2s. 6d.

AERE-M 2009
The Derivation of a Triton Energy Response Function for Lithium-6 Semiconductor Sandwich Spectrometers. By M. G. Silk. June, 1968. 12 pp. H.M.S.O. 3s. 6d.

AERE-M 2157
Average Fission Cross Sections and Resonance Integral Contributions Between 10 eV and 20 keV Deduced from SC ISRS Data Tapes. By G. D. James and M. G. Schomberg. January, 1969. 14 pp. H.M.S.O. 2s. 6d.

AERE-R 5872
The Constant-Rate-Injection and Velocity Methods of Flow Measurement for Testing Hydraulic Machines. By C. G. Clayton and G. V. Evans. December, 1968. 55 pp. H.M.S.O. 8s.

AERE-R 5876
An Automatic Counter for Proton Tracks in Nuclear Emulsions. By G. H. Ross and J. B. Rae. December, 1968. 13 pp. H.M.S.O. 3s. 6d.

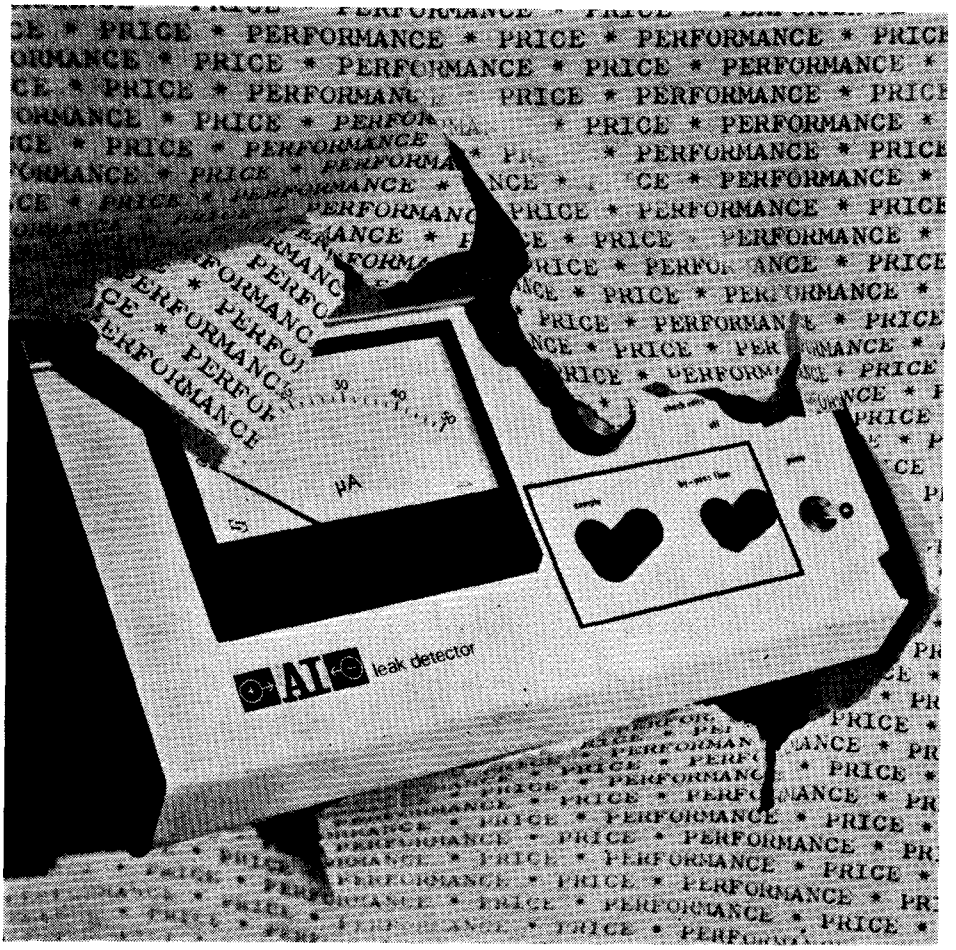
AERE-R 5929
Optical Density Measurement by a Null-Method for an Automatic Densitometer. By J. B. Rae. December, 1968. 14 pp. H.M.S.O. 2s. 6d.

AERE-R 5958
Traces of Spin Operator Products and their Use in Physical Problems (Spherical Basis). By N. W. Dalton and D. E. Rimmer. 1968. 248 pp. H.M.S.O. 32s. 6d.

AERE-R 5962
Cassandra. A Megachannel Time-of-Flight Analyser. By J. W. Hall. November, 1968. 4 pp. H.M.S.O. 3s.

AERE-R 5991
An Assessment of a Low Pressure Cloud Chamber for Range Measurements of Low Energy Electron Tracks. By H. J. Delafield. December, 1968. 30 pp. H.M.S.O. 5s. 6d.

AERE-R 6000
Atomic Vibrations in Carbon Fibres. By M. F. Collins and B. C. Haywood. January, 1969. 6 pp. H.M.S.O. 1s. 9d.



Leak detector for 1×10^{-11} atm cc/sec breaks the barrier

(and others like portability and reliability too)

Write for details of **SF6B Leak detector**
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Range of standard leaks

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ATOM 150 April 1969
Printed by Straker Brothers Ltd., 194-200 Bishopsgate, London, E.C.2.