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MONTHLY INFORMATION BULLETIN OF

THE UNITED KINGDOM ATOMIC ENERGY AUTHORITY

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Contents

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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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A.E.A. appointments

The following appointments in the Reactor Group of the U.K.A.E.A. have been announced:

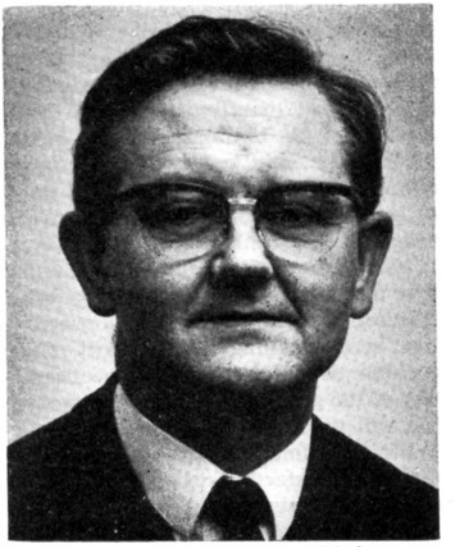
Mr. H. Cartwright, at present Director, Fast Reactor Systems, Reactor Group, has been appointed Director, Atomic Energy Establishment, Winfrith, to succeed Mr. D. W. Fry, who will shortly be retiring.

Mr. J. Moore, at present Chief Technologist, Water Reactors, Reactor Group, has been appointed Director, Fast Reactor Systems, Reactor Group. He will be a member of the Group's Board of Management.

Dr. J. E. R. Holmes, at present Chief Physicist, Atomic Energy Establishment, Winfrith, has been appointed Deputy Director, Atomic Energy Establishment, Winfrith.

Mr. K. H. Dent has been appointed Deputy Director, Sales and Services, Technical Operations Directorate, Reactor Group.

Dr. N. L. Franklin



Dr. Norman L. Franklin, chief executive of B.N.F.L., has been elected chairman of URENCO, the British-based part of the tri-national gas centrifuge uranium enrichment organisation. He succeeds Dr. Heinz Schimmelbusch, who has now retired from URENCO, as well as from his post as joint managing director of NUKEM. Dr. Franklin continues as B.N.F.L. chief executive.

IN PARLIAMENT

Steam Generating Heavy Water Reactors

22nd January, 1973

MR. W. H. K. BAKER asked the Secretary of State for Trade and Industry what progress has been made with regard to the design and feasibility study of the use of steam generating heavy water reactors by electricity generating boards in the United Kingdom; and if he will make a statement.

Mr. Tom Boardman: The nuclear design and construction companies have recently made joint proposals to my Department which are being urgently examined in consultation with the Atomic Energy Authority and the electricity generating boards.

Mr. Baker: Will my hon. Friend tell the House when the decision will be taken on the considerations which are being undergone at the moment? Does he agree that in view of the undoubted success of the prototype S.G.H.W.R., it would be better to press ahead with that rather than to buy American, as some sources have suggested?

Mr. Boardman: The object of the review announced on 8th August was to enable all these matters to be evaluated over the 18-month period. I hope we shall be able to keep to that target, although it will depend on the number of generating boards wishing to place an order.

Mr. Palmer: Does the Minister agree that the Steam Generating Heavy Water Reactor at Winfrith Heath as a prototype has been working satisfactorily for a number of years and could be used by any of the generating boards if there were the will to do so?

Mr. Boardman: Yes, it has been working very satisfactorily, but the hon. Gentleman will agree that further work is needed before it can be translated into a commercial reactor.

Radioactive waste disposal

23rd January, 1973

MR. SPEARING asked the Secretary of State for the Environment which Departments have responsibilities for disposing of waste radioactive materials from defence and civil establishments in the United Kingdom.

Mr. Graham Page: Control of the disposal of radioactive waste from premises is exercised in England by the Department of the Environment, in Wales by the Welsh Office, in Scotland by the Scottish Development Department, and in Northern Ireland by the Ministry of Development. In some special cases, for example where the premises belong to the Atomic Energy Authority, the disposal of radioactive waste is authorised jointly with the appropriate Agriculture, Fisheries and Food department.

Although Government establishments, both defence and civil, are exempt from the statutory controls provided in the Radioactive Substances Act 1960, they are subject to the same controls as other users, applied by administrative rather than by legislative means.

B.R.P.A. meetings

A meeting sponsored by the British Radiological Protection Association, on "Risks and benefits in medical uses of ionising radiations" is to be held at Birmingham University on Tuesday, 9th October, 1973.

Organised jointly by the Society for Radiological Protection, the British Institute of Radiology, and the Hospital Physicists Association, the meeting will include a visit to the Birmingham University Activation Analysis Facility.

The meeting will open with a presentation on the skin, gonad and other tissue doses involved in the medical uses of ionising radiations with a special section devoted to *in vivo* activation analysis. The benefits as well as the risks will be considered in a survey of the somatic and genetic implications of the doses involved.

Further information can be obtained from Professor J. H. Martin, The University, Dundee DD1 4HN, Scotland.

A symposium on the monitoring of electron capture nuclides and soft beta emitters will be held at Nottingham University on Friday, 13th April, 1973, organised by the Association of University Radiation Protection Officers, a Constituent Association of B.R.P.A.

Application should be made to H. J. Gale, The University, Nottingham NG7 2RD, before 31st March, 1973.

Neutron activation analysis as an aid to geochemical prospecting for uranium

The following article by D. Ostle, Institute of Geological Sciences, London, R. F. Coleman, Atomic Weapons Research Establishment, Aldermaston, Berkshire, and T. K. Ball, Institute of Geological Sciences, London, is an abridged version of a paper published in the Uranium Prospecting Handbook. *Editors S. H. U. Bowie, (I.G.S.), Michael Davies (U.K.A.E.A.) and Dennis Ostle.*

Geochemical methods were relatively slow to be accepted as an effective aid to the discovery of uranium deposits, and they are still not applied to the same extent as in the search for many other metals. Initially, the reluctance to develop and apply such methods could be attributed to the ease of detection of outcropping uranium deposits by direct radiometric means, and the difficulty of conducting precise determinations of uranium at very low levels of concention, except under the most sophisticated laboratory conditions.

Even at the early stages of applied geochemistry development, however, which coincided approximately with the post-war boom in uranium prospecting, it was appreciated that the chemical detection of uranium could have useful applications. An orientation study in the area of the disused uranium-radium property at South Terras, Cornwall, demonstrated the potential of the hydrogeochemical approach, and it has been used extensively elsewhere, with varying success. One of its main advantages lies in the size of the area which can be sampled—a valuable factor in regions which are difficult of access.

More recently, it has become apparent that the establishment of uranium supplies for the future must depend to an increasing extent on the discovery of ore-bodies which have no surface radiometric expression and studies of the distribution of chemically-determined uranium in soils and stream sediments, as well as in water, may serve to indicate the presence of such hidden deposits.

Accepting the validity of the geochemical prospecting methods, therefore, the basic requirement for the study of all types of dispersion is a sensitive, rapid, precise, relatively accurate and low-cost method of sample analysis. Delayed neutron measurement, following neutron activation, adequately meets most of the criteria for an analytical technique applicable over the whole range of geochemical sampling for uranium. A system of analysis employing the HERALD reactor facility at the Atomic Weapons Research Establishment (A.W.R.E.), Aldermaston, and developed by A.W.R.E. in collaboration with the Institute of Geological Sciences (I.G.S.), has been used virtually exclusively for the geochemical aspects of the uranium reconnaissance in the United Kingdom undertaken by the Institute on behalf of the Atomic Energy Authority.

The advantages of the delayed neutron method are discussed later. It is appropriate, however, to emphasise that its major disadvantage (the need for access to a reactor and the consequent limitation on the location of analytical facilities) requires, at the outset of a programme, an acceptance of the necessity to transport all samples to a single laboratory, which may be remote from the sampling areas.

Sampling procedures

Standard field procedures are employed in taking samples for analysis by delayed neutron determinations.

The dimension of the pneumatic sample transfer system at the reactor is such that the size of sample must be limited to that required to fill a 1-oz (30-ml) bottle). In most cases, water is collected directly in the field in 30-ml polyethylene bottles which are screw-capped ready for further treatment. At the field base the screw cap is removed and replaced by a well-fitting plug of

polyethylene rod, heat-sealed into the neck of the bottle. No further treatment is required prior to analysis.

In the event of a scavenging stage being introduced to achieve greater sensitivity, and if the water samples are to be stored for some time prior to treatment, then the pH of the water must be adjusted to <1.5 to avoid loss of uranium to the walls of the vessel.

Stream sediments are initially wet-screened through a 1/10 in mesh nylon sieve. The undersize is dried at 150°C and sieved on a suitable nylon mesh, normally—100 B.S.S. mesh, a split of 5g being retained for multi-element analysis, where this is required.

Soil samples are taken by auger or spade and dried, sieved and weighed in the same way as the stream-sediment samples. Most of the simple preparation can be carried out in a field laboratory by relatively unskilled assistants.

Since the technique is non-destructive, all samples are available for further investigation following a suitable decay period.

Analysis of uranium by delayed neutron measurement

Uranium analysis by the emission of delayed neutrons, following fission of U-235, has been described by Amiel[1] The present paper is concerned specifically with the application of the method to the analysis of large numbers of samples arising from a geochemical survey.

The samples collected in the field must be in containers suitable for irradiation and free of uranium contamination, because the sample is not separated from the container following irradiation.

For irradiation the sample container is placed in a "rabbit", made from resin-bonded fabric, which is transferred pneumatically from the laboratory to the side of the HERALD reactor core (flux 5×10^{12}n sec^{-1} cm^{-2}). It would simplify operation if it were not necessary to remove the sample from the rabbit before counting, but the possibility of external contamination of the rabbit precludes this modification.

The arrival of the loaded rabbit at the reactor core triggers the timing unit and all subsequent operations are automatically timed. After 60 sec the sample is returned to the laboratory and the rabbit is opened manually with a tool —to eliminate direct handling and thereby minimise the radiation dose to the hands. The sample is transferred to the neutron detector for a 60-sec count, (Fig. 1) which automatically commences after a 25-sec delay. At the end of the count the sample is ejected into a shielded store and the neutron count and sample number printed out by an Addo-X printer. The timer has two channels, so a second sample can be irradiated while the first is being counted. With this system samples can be analysed at the rate of 33 per hour.

In order to obtain consistently reliable analysis it is essential to perform a few simple checks to ensure the correct functioning of equipment. At the beginning of each day the following procedure is necessary:— (a) Irradiate and count a standard sample to check the efficiency of the equipment; (b) Irradiate and count 0.5g pure aluminium to check that the gamma rejection of the counter is adequate; (c) Irradiate and count either an empty container used for solid samples or a polythene container filled with pure water. The normal background for polythene containers is less than 1 count, so the counter background of 4-6 counts is recorded. The pure water sample results in a count of about 20 neutrons, mainly due to N-17.

Throughout the day it is usual to perform about six checks on the background with an empty or water-filled container and to repeat counts on the standard three times.

The uranium content of each sample is simply determined from the relationship

$$\text{Weight of uranium} = \frac{C_S - C_B}{C_{Std}} \times \text{weight of U standard}$$

where C_S is the neutron count due to sample, C_B is the mean neutron count for blank samples and C_{Std} is the mean neutron count for standard samples.

The method is subject to very few interferences when used for the analysis of natural materials. U-235 is the only nuclide which gives rise to delayed neutrons following irradiation in a thermal neutron flux and a decay period of 25 seconds. In most reactors however, there is a significant flux of fast neutrons which can cause fission of Th-232 re-

Analysis of solutions of known concentration of uranium (μg/l U)

Added	0.7	0.8	1.6	1.7	3.3	3.6	5.7	6.8	8.1
Found	0.9	0.4	1.5	0.8	3.0	4.3	6.8	7.0	8.6
Error (1σ) Calculated	0.6	0.6	0.6	0.6	0.7	0.8	1.0	1.0	1.1

sulting in similar fission products to U-235. Also the reaction O-17 (n,p) N-17 gives rise to N-17, which has a half life of 4.2 seconds and decays by neutron emission. In the HERALD reactor the sensitivity for thorium is about 0.3 per cent of that for natural uranium: thus, only rarely is thorium likely to cause significant interference. The N-17 decay results in the emission of 0.7 neutrons per gram of oxygen following a 25-second decay period. This is not significant for solid samples but it is the limiting sensitivity factor in the direct analysis of natural waters.

For low uranium concentrations, the accuracy of the method is dominated by the counting statistics (see table). The error quoted is for a single determination based on counting statistics alone and includes in the calculation the error on a mean of six blank determinations. It can be inferred that the limit of detection is approximately 1μg/l of uranium.

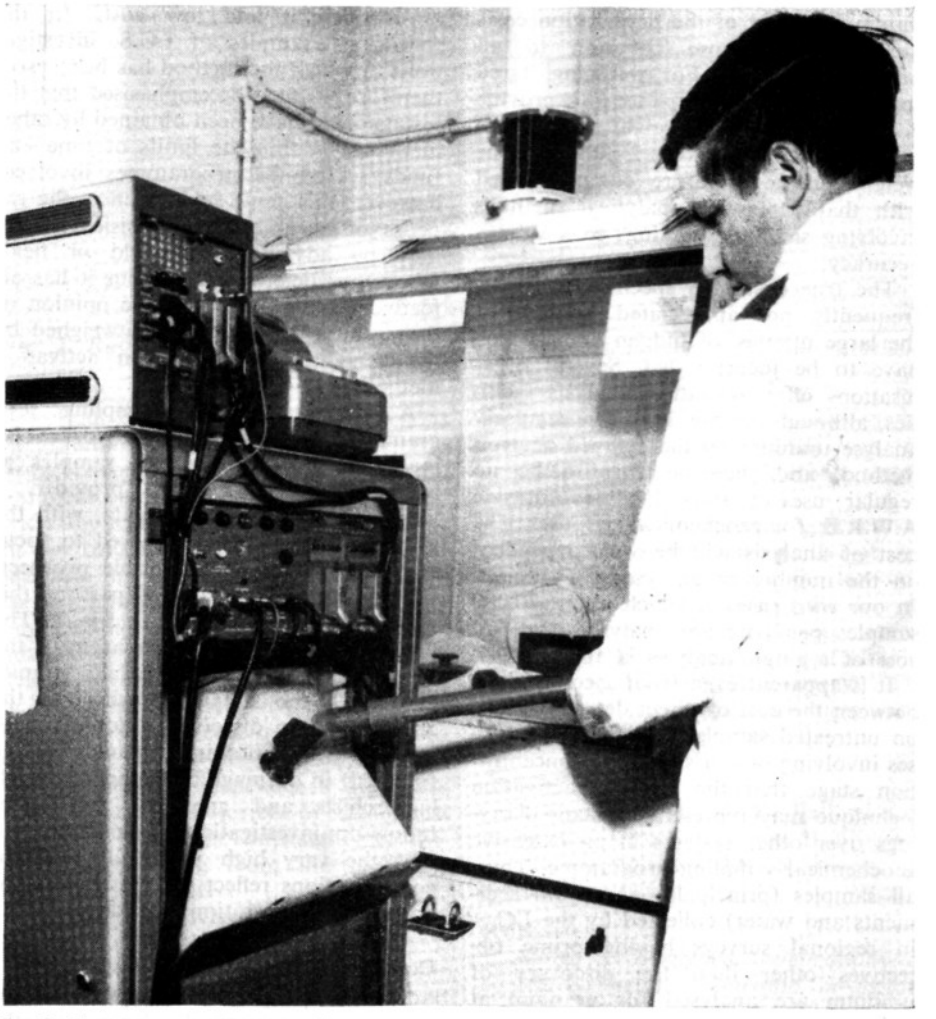


Fig. 1. *Neutron counting assembly.*

For samples with a uranium content of more than 10μg the relative standard deviation is approximately 3 per cent.

In order to obtain consistent and reliable results for tens of thousands of samples per year it is important to take stringent precautions against contamination in the laboratory.

Analysis of water samples containing less than 1μg/l of uranium are of importance in some areas and can be achieved by this method providing a concentration step is included.

Costs

Because of the relative freedom from matrix effects during analysis, the work involved in the preparation of samples for neutron activation is reduced to a minimum. Most of the preparation costs are therefore those common to all analytical systems. For weighing, tared top-loading balances are used to provide a standardised sample weight of 1g, which is normally weighed to ±2 per cent. The weighing time therefore compares well with that for other analytical methods involving smaller weighings to a similar accuracy.

The true cost of a specific analysis is frequently not appreciated because of the large number of hidden items which have to be incorporated. Several organisations offer activation analysis facilities, although, so far, very few regularly analyse uranium by the delayed neutron method, and there appears to be no regular use of such facilities, outside A.W.R.E., for geochemical purposes. The cost of analysis will be very dependent on the number of analyses carried out. In our own case, in which about 20,000 samples per year are analysed, the full cost of a single analysis is about £0.25.

It is apparent even from a comparison between the cost of direct determinations on untreated samples and that of analyses involving only a simple preconcentration stage that the neutron activation technique may represent substantial savings over other systems in an extensive geochemical sampling programme. Thus, all samples (principally of stream sediments and water) collected by the I.G.S. in regional surveys having prime objectives other than the discovery of uranium are analysed for uranium at little additional cost. The uranium distribution patterns resulting from such routine analysis may contribute the first indications of favourable prospecting areas. Even in circumstances in which analyses for other elements are carried out remote from a reactor facility, the small size of sample required for delayed neutron determinations minimises the cost of freightage. The analytical technique is therefore well-suited to the economical inclusion of uranium in all multi-element regional geochemical surveys.

Example of application of the method

Advantages in the application of the delayed neutron technique are due principally to its reliability, the lack of interference in geological samples, the speed of throughput and low cost. In the following examples of I.G.S. investigations in which the method has been used, therefore, it must be emphasised that the results could have been obtained by other methods. Within the limits of time and funds set by the programmes involved, however, this could have been at the expense of accuracy and precision. There may be advantages in field or field-laboratory determinations, but it has already been stated that in the opinion of the authors these are far outweighed by the benefits of the neutron activation method.

A very rapid water-sampling programme in the north of Scotland, involving only the collection of samples at road-stream intersections, provided a large amount of valuable data, with the minimum of effort, and served to focus attention on broad favourable prospecting targets. The results of part of this programme are presented in Fig. 2. The broken line represents the margin of the Newer Caledonian Helmsdale granite mass. All the streams flowing off the granite contain dissolved uranium: with one exception, uranium is undetectable (< 1 g/l) in drainage from the surrounding schists and gneisses. Subsequent follow-up investigations have confirmed that the very high values of uranium concentrations reflect the distribution of uranium concentration in bedrock.

Conclusions

The discovery of new deposits of uranium will increasingly depend on the

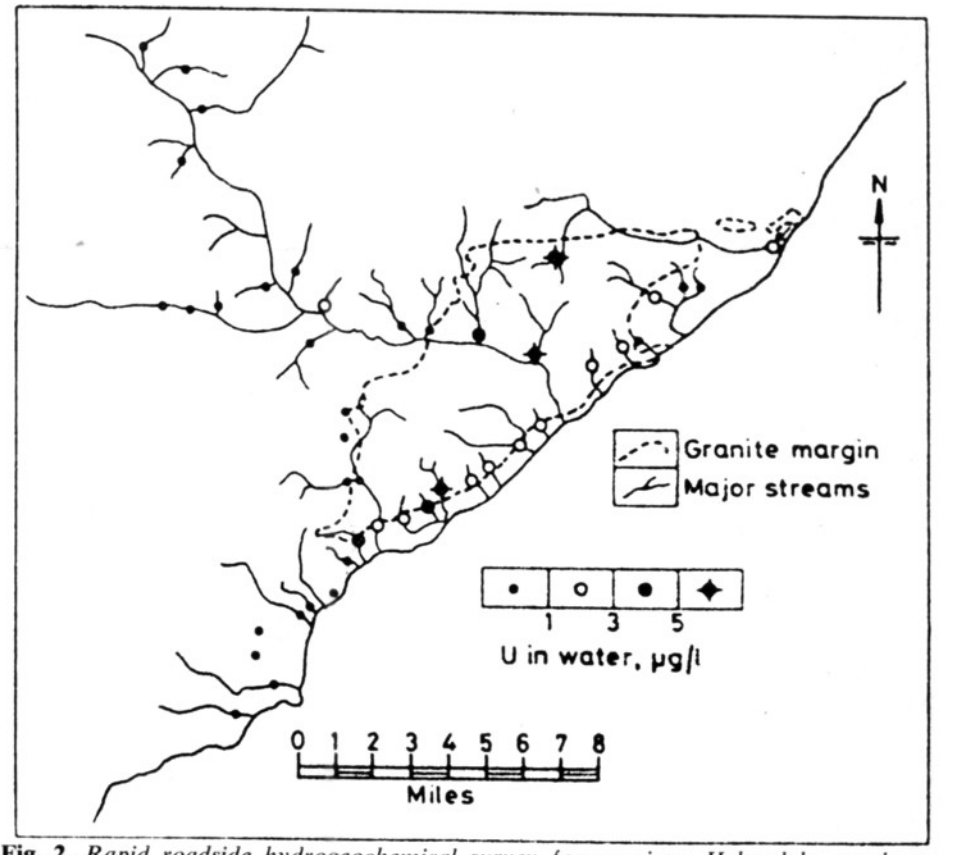


Fig. 2. *Rapid roadside hydrogeochemical survey for uranium, Helmsdale, northern Scotland.*

detection of highly-tenuous dispersions of uranium in superficial materials. Hydrogeochemical surveys, soil and stream-sediment sampling should therefore find wide application to uranium prospecting in the future, and the determination of uranium by delayed neutron measurement following irradiation is a relatively new technique which offers considerable advantages over other analytical systems. These advantages are low cost, specificity, high sensitivity (0.03μg U), high precision (3 per cent relative standard deviation at the 10-μg level), rapid throughput and independence of matrix for the great majority of geological materials. They far outweigh any disadvantages arising from the need for access to a reactor.

The limit of detection obtainable by direct determinations on untreated samples has been shown to be adequate for effective uranium reconnaissance and follow-up investigation in a variety of environments. Higher sensitivity (with commensurately higher cost) can be achieved by the introduction of a simple pre-concentration stage.

In addition to its value to geochemical programmes aimed specifically at uranium mineral discoveries, the low cost and operational simplicity of the delayed neutron system provide an economical means for the routine analysis of samples collected in broader-based surveys. The resulting data may indicate favourable uranium prospecting areas.

Acknowledgment

D. Ostle and Dr. T. K. Ball wish to thank the Director of the Institute of Geological Sciences for permission to publish this paper.

Reference

1. Amiel S. *Analytical applications of delayed neutron emission in fissionable elements.* Analyt. Chem. 34, 1962, 1683-92.

British Nuclear Energy Society

A four-day International Conference on Fast Reactor Power Stations to be held at The Institution of Civil Engineers, London from 11th to 14th March (incl.), 1974 (followed by an optional one-day visit to Dounreay Experimental Reactor Establishment), has been arranged by B.N.E.S. in collaboration with the I.A.E.A.'s International Working Group on Fast Reactors.

The objective of the conference is to discuss recent experience relevant to the use of fast reactors in nuclear power stations. It is hoped that such experience will be reported on by all those countries with major programmes aimed at the production of power from fast reactors and that this will include recent development, commissioning and operating data from experimental and prototype/demonstration power plants.

It is hoped that the conference will include discussion on the following topics:

Plenary Topics:

(a) Brief descriptions of current and proposed prototype/demonstration fast reactor power stations.
(b) Commissioning and operating experience.
(c) The effect of experience on safety philosophy.
(d) Future use of operating reactors and plans for the introduction of commercial fast reactors.

Specialist Topics:

(a) Nuclear performance.
(b) Control and kinetics.
(c) Coolants.
(d) Steam generators.
(e) Fuel handling and fuel cycles.
(f) Safety experiments and special instrumentation.
(g) Thermal performance and hydraulics.
(h) Core components including fuel.

The Organising Committee invite offers of papers not exceeding 5,000 words for consideration for inclusion in the Conference programme. Abstracts (approximately 250 words) should be sent to the Secretary of the Organising Committee:—Mr P. McLaren, c/o Fast Reactor Training Centre, Dounreay Experimental Reactor Establishment, Thurso, Caithness, Scotland—before 16 March, 1973.

Further details of the Conference will be issued later but meantime further information may be obtained from the Conference Secretary—Mrs. J. Grahame, British Nuclear Energy Society, Institution of Civil Engineers, 1-7 Great George Street, London SW1P 3AA.

A.E.A. Reports available

The titles below are a selection of the reports published during the past month and available through H.M.S.O.

AERE-M 2372
A simple Beam Position Monitor using Y.S.I. Precision Thermistors. By B. P. Clear. December, 1972. 11pp. HMSO. £0.50. SBN 7058 0412 7.

AERE-R 7168
Certain Matrix Eigenvalue Techniques Discussed from a Geometric Point of View. By B. Parlett. January, 1973. 18pp. HMSO £0.50. SBN 7058 0472 0.

AERE-R 7293
Fortran Subroutines for the Solution of Sparse Systems of Non- Linear Equations. By J. K. Reid. November, 1972. 53pp. HMSO £1.00. SBN 7058 0462 3.

AWRE/LIB/BIB/24
Sweat, Chemical Composition, Bibliography of References Published 1966-1972. By D. Beck. January, 1973. 11pp. HMSO £0.50. SBN 85518 040 4.

AWRE 0-65/72
Some Seismic Results of the Cannikin Underground Explosion at Amchitka, Aleutian Islands. By P. G. Gibbs and C. Blamey. December, 1972. 32pp. HMSO £1.00. SBN 85518 035 8.

AWRE 0-1/73
An Experimental Study of the Shock Wave in Free Air from Spherical Charges of TNT and 60/40 RDX/TNT. By R. Potter and C. V. Jarvis. January, 1973. 39pp. HMSO £1.00. SBN 85518 037 4.

AWRE 0-5/73
An Analysis of Seismic Waves from Earthquakes and Explosions in the Sino-Soviet Area During 1966. By P. D. Marshall and P. Filey. January, 1973. 34pp. HMSO £1.00. SBN 85518 039 0.

SRD-R13
Some Preliminary Considerations Relating to an Equation of State for Irradiated Nuclear Fuel. By A. J. Brook. October, 1972. Various paging. HMSO £1.50. SBN 85356 022 6.