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THE UNITED KINGDOM ATOMIC ENERGY AUTHORITY

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OF THE UNITED KINGDOM
ATOMIC ENERGY AUTHORITY

NUMBER 115

MAY 1966

Contents

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

Collaboration between A.E.A. and New Zealand

[*A similar release is being made in New Zealand*]

SIR WILLIAM PENNEY, the Chairman of the United Kingdom Atomic Energy Authority, and Dr. W. M. Hamilton, Director-General of the New Zealand Department of Scientific and Industrial Research, recently exchanged letters reviewing existing collaboration between the two organisations on the peaceful uses of atomic energy and outlining the form in which this should take in the future.

Collaboration on nuclear energy between the two countries has existed for some 20 years on an informal basis and has covered training arrangements for staff and attachments to research establishments as well as exchanges of information.

5th April, 1966

Shorter apprenticeships

THE National Joint Industrial Council for the United Kingdom Atomic Energy Authority have agreed to the introduction of a reduced period of craft apprenticeship in the industry.

The length of these apprenticeships will be reduced from five to four years for boys recruited this year (1966) and the training schedules are being revised accordingly.

This step has become possible partly because of the increasing introduction of advanced training workshops to supplement the training given in the first year apprentice schools run at the Authority's establishments, and partly through the greater use of block releases of apprentices to technical college training.

As a result it will be possible for a boy, who is 16 years of age on entry, to complete his training and qualify for subsequent employment in the Authority as a craftsman at the adult craft rate of pay, at the age of 20.

This agreement will in due course help the Authority to augment by up to 20 per cent the flow of craftsmen who are in short supply in many of the areas where their establishments are sited.

Further discussions are to be held on revising apprentice rates of pay between the ages of 16 and 20.

6th April, 1966

Sodium cooling: a new technology

By K. G. Eickhoff, Reactor Engineering Laboratories, U.K.A.E.A., Risley. This article originally appeared in The Reactor, *and is reprinted by permission of the editor.*

In the Reactor Engineering Laboratories at Risley a new technology is being developed —the technology of sodium cooling. From 1980 onwards an increasing proportion of the nuclear power generated in the U.K. will be produced by fast reactors, which will burn the plutonium produced by the magnox and A.G.R. stations and in addition make further plutonium for themselves. For nuclear reasons the core of a fast reactor is small—a given volume of a fast reactor core produces roughly a hundred times as much heat as the same volume of an A.G.R. core—and therefore a coolant with exceptionally good heat transport properties is needed to take the heat from the core to the steam generators. Because of its good thermal conductivity, high boiling point (880° C.), low specific gravity (0·8) and good nuclear properties, the first generation of fast reactors in the U.K. will be cooled with liquid sodium.

R.E.L. first started work on the problems of sodium cooling in 1954 (when the laboratories were sited at Capenhurst) to provide the necessary design information for the Dounreay Fast Reactor. Now most of the work is aimed at the Prototype Fast Reactor, but a proportion is devoted to basic development of general application to sodium systems. The laboratory's programme includes development of components for the reactor coolant circuits, working out techniques for operating sodium circuits, investigation of fluid flow problems in the reactor vessel, and provision of instruments to monitor the reactor core and coolant circuits.

Rigs

Among the basic tools used in this development work are a number of sodium rigs. These are closed loops of pipework, some quite small, made of 1 in. dia. pipes, some fairly large, made of 12 in. dia. pipes, through which liquid sodium metal is pumped. By working with these rigs, many of the problems of operating a full-sized sodium-cooled reactor can be recognised. investigated and solved.

One of the major problems of operating a sodium circuit is to keep the sodium pure. The sodium dissolves impurities, mainly oxygen, from the walls of the pipes and this forms sodium oxide which is soluble in high temperature sodium but becomes less soluble as the sodium temperature falls. This can lead to the precipitation of sodium oxide in the cooler portions of the loop leading to circuit blockage. In addition, impurities in the sodium greatly increase the rate of corrosion of the pipe walls and for both these reasons it is necessary to control the concentration of impurity in the sodium. This is done by passing the sodium through a vessel, called a cold trap, which is cooled so that the impurities precipitate in it but is so designed that it does not itself become blocked. Careful measurement of the amount and nature of impurities found in the R.E.L. rigs, and of their rate of removal by the cold traps is providing information for design, construction and operation of the P.F.R.

Although at first glance one would expect the problems of a fast reactor core to be mainly nuclear, it is, in fact, a complex mechanical structure which, because of its compactness, is subjected to large temperature gradients and hence to severe differential expansions or thermal stresses. The fuel pins which produce the power are held in grids with which they must remain in contact to maintain their correct location. The temperature gradients cause some fuel pins to expand more than others and there is, therefore, sliding of the pins through the grids. Pin and grid material must be chosen carefully to avoid undue wear and experiments on the wear and friction of materials in sodium provide the necessary basic design information. This data is, however, obtained under ideal conditions and a more realistic simulation of the conditions in the core is obtained from thermal cycling experiments in which actual fuel pins are forced to expand and contract in a fixed grid assembly immersed in sodium.

Information from these sodium experiments, combined with other mechanical and fluid dynamic information, gives confidence in the fuel assembly design but it is finally necessary to test the complete fuel assembly in flowing sodium at the correct temperature. This immediately raises the problem of how to produce a flow of 300 g.p.m. of sodium at 650° C., the major difficulty being how to pump sodium at such a high temperature. The solution, as might be expected, is one of compromise. The electromagnetic pumps used in the Dounreay Fast Reactor, which will pump sodium at 250° C., have been modified by improving the electrical insulation of their windings, so that they will work at 375° C., and the rig has been constructed in two portions, a hot section and a cool section, connected by a heat exchanger. The hot sodium from the test section which contains the fuel assembly under test, in flowing through the heat exchanger, heats up the cool sodium coming from the pump and is itself cooled in the process. Thus the pump is kept cool, and the test section is kept hot. The rate of heat transfer from the hot sodium to the cold in this heat exchanger is 10 MW, but the heat exchanger is only 30 in. dia. × 12 ft. long. This gives some indication of the excellence of sodium as a heat transfer medium (see Fig. 1).

It will be noticed that, although the sodium in the test section is at 650° C., it leaves the heat exchanger at only 640° C., and 400 kW topping up heat has to be provided to make good the losses from the rig and raise the sodium the final 10° C. This heat is provided electrically in a novel manner by using a transformer whose primary windings are supplied from the mains and whose secondary winding is the sodium loop itself. In this way the electric current necessary to heat the sodium is induced directly into the sodium without the neces-

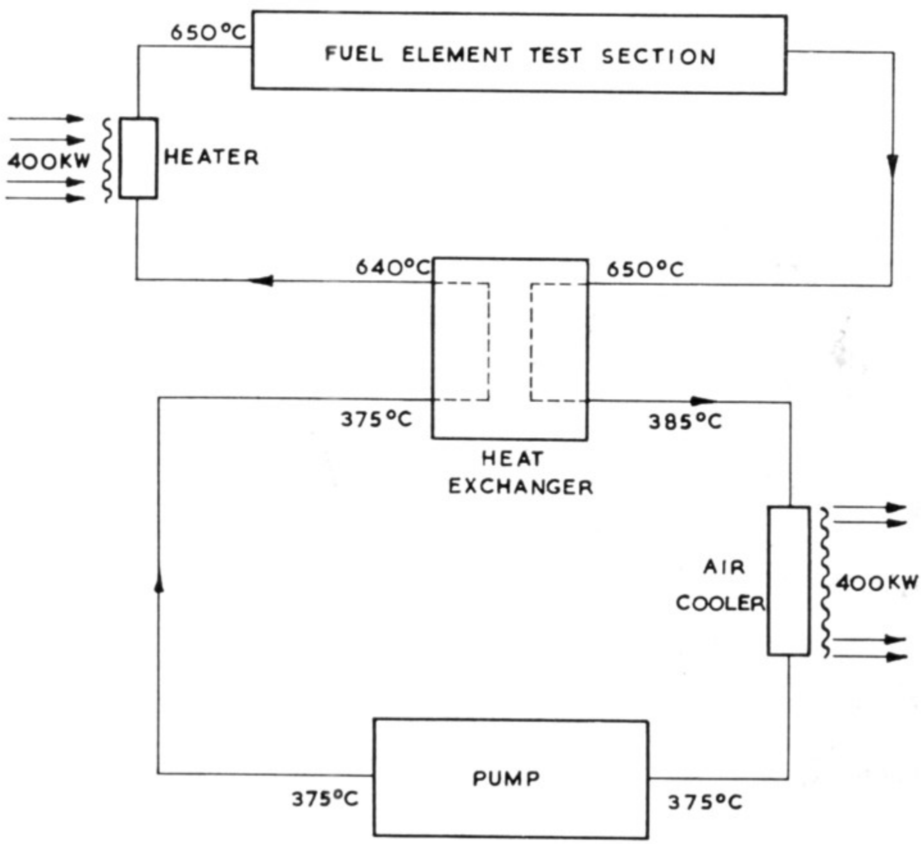


Fig. 1. *Fuel element test rig*

Mock-up of a fuel sub-assembly for the Prototype Fast Reactor to be built at Dounreay

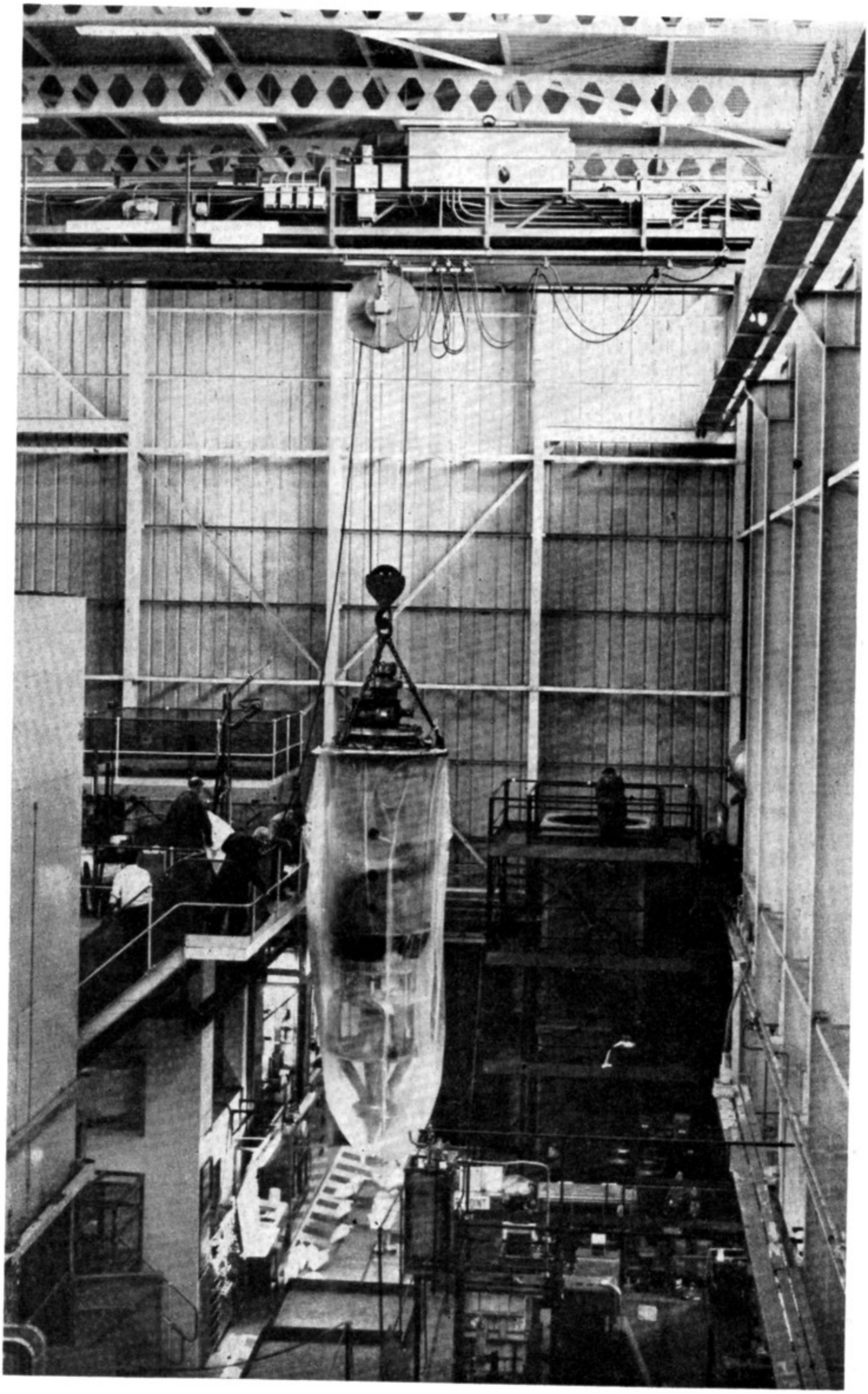
sity of any heavy current cables. This is one example of the way the metallic properties of sodium may be turned to advantage.

Because it reacts violently with water, sodium is commonly considered to be a hazardous material to deal with, but experience has shown that, provided proper engineering standards are maintained and elementary precautions are taken, the hazard can be reduced to a very low order. In R.E.L. each sodium rig is enclosed in a sheet metal cubicle, the bottom of which is formed by metal trays some 2 ft. square × 4 in. deep. If a leak should occur in one of the rig pipes, the sodium will drip into these trays and the rig operators will be completely protected by the cubicle. The sodium will catch fire and burn, but is readily put out by smothering it with dry soda ash. Before entering the rig cubicle, the firemen put on protective clothing which is sodium-resistant, and similar clothing is used when carrying out maintenance work on components which have been contaminated with sodium.

Prototype pump

The quantity of sodium to be circulated through the P.F.R. core is so large that electromagnetic pumps similar to those used in the D.F.R. would not be economic and mechanical pumps must be used. The most convenient design of mechanical pump is a vertical centrifugal pump with a shaft long enough to penetrate the thick biological shield of the reactor. The upper bearing of this shaft can be a conventional oil-lubricated one but the bottom bearing must be submerged in the sodium and lubricated by the liquid metal. After some initial development work at R.E.L. to prove the feasibility of this sodium-lubricated bearing, a prototype pump of 475 h.p. circulating 6,000 g.p.m. of sodium at 400° C. was designed by F.R.D.O. and manufactured by C. A. Parsons. At the same time, a rig to test it was built in R.E.L.; it was made of 12 in. dia. pipe and contained 10 tons of sodium.

The progress of the pump tests illustrates how unexpected results can alter the emphasis of a development programme. The pump was delivered to R.E.L. early in 1964 and was assembled and installed in the rig without incident. When the pump was run at full speed, however, a great deal of noise was generated and it was a matter of some concern to establish its source. Failures due



Removal of the mechanical sodium pump from its test rig at R.E.L.

to metal fatigue caused by excessive noise had recently occurred in the carbon dioxide circulator of a magnox reactor, and it was essential to show that a similar failure could not occur in the sodium pump rig pipework. The control valve, which was used to vary the loop hydraulic resistance, came under suspicion and these suspicions were confirmed when a similar valve was tested in the R.E.L. Water Loop and was found to be cavitating severely. The offending valve was cut out of the loop and replaced by a series of perforated plates designed to drop the pressure without cavitation. This work involved draining the sodium from the whole loop, cutting out a length of 12 in. pipework which was by then contaminated with sodium, and welding in a new length of pipe.

At the same time the English Electric Company, who had some experience of acoustic fatigue failures, were called in to fit strain gauges to various parts of the rig to determine whether the strains set up by the noise were large enough to be dangerous. Fortunately, when the rig was started up again, it ran very quietly, showing that the great majority of the noise had been produced in the valve.

The pump was run for over 3,000 hours, mostly at the design conditions, and in order to test the sodium-lubricated bearing under the most adverse conditions, it was started and stopped over 200 times. It was then lifted out of the rig into a polythene bag, 6 ft. dia. × 15 ft. long, filled with argon to prevent the sodium remaining on the pump from catching fire, and transferred to supporting framework.

When the pump was stripped for inspection the various components were found to be in excellent condition, but the liquid sodium had penetrated down screw threads and between mating parts to such an extent that the dismantling process was unexpectedly difficult. The early discovery of this effect means that the P.R.F. pumps will be specially designed to facilitate disassembly, and this particular problem will be avoided in future.

This brief survey of the engineering-scale sodium development has shown that, based on over ten years' liquid metal experience, sodium rigs have been built in R.E.L. larger in size and operating at higher temperatures than any in the country. This advance in our technology is providing information for many aspects of the P.F.R. project. The rigs are being used to develop the major mechanical components of the reactor, and more work of this nature has already been started. Thus, fast reactors need devices to move their fuel elements about and move their control absorbers in and out, and these devices must work in the sodium pool. The next scheduled advance is to make representative components of these devices —bearings, cams, lead screws and the like —and determine their performance in sodium. When the behaviour of the parts is known, the whole intricate device can be designed, and a further step will have been taken in expanding a new technology.

Amersham at Atlantic City

WITH exports already accounting for over half the total annual sales (£2,000,000) of radioisotopes, the Radiochemical Centre, Amersham, took part in the exhibition held during the 50th Annual Meeting of the Federation of American Societies for Experimental Biology (F.A.S.E.B.). The meeting, held at Atlantic City from 12th to 16th April, is the world's largest meeting of biologists—over 19,000 registered last year.

The Radiochemical Centre has a record of 25 years of experience in the processing and sale of radioisotopes. It now supplies 180 radioisotopes in more than 1,000 chemical compounds and in over 400 kinds of radiation appliance; the current catalogue offers over 2,000 items. In 1965 the Centre sent out more than 50,000 consignments of radioactive products, doing business in every advanced country. Sales have increased four-fold in ten years.

In biology, radioisotopes are used mainly as tracer compounds, usually in organic substances labelled with carbon-14 or tritium, although compounds labelled with sulphur-35 and isotopes of iodine are of growing importance. Such materials offer a method of unrivalled sensitivity for studying the chemical reaction mechanisms and physico-chemical transfers involved in biological systems. At the F.A.S.E.B. meeting, the Radiochemical Centre displayed literature describing labelled compounds of special interest to biochemists. The Centre's agents in America for carbon-14 and tritium compounds are Nuclear Chicago Corporation.

The place of environmental monitoring in the radiological protection of the worker

By K. P. Duncan and H. J. Dunster, Radiological Protection Division, U.K.A.E.A. Authority Health and Safety Branch, A.E.R.E., Harwell.

The following paper was delivered at a symposium, "The Radiological Protection of the Worker by the Design and Control of his Environment", held at Bournemouth from 18th–22nd April and organised by the Society for Radiological Protection.

THE achievement of safe and satisfactory working conditions is the principal aim of occupational hygiene. Historically this aim has been pursued by relating medical signs and symptoms among employees to environmental conditions, and sometimes by considering the effect of these environmental conditions on accident rates and on output. Inevitably, much of this work has been of a qualitative nature. In the more specialised field of radiological protection, the quantitative approach has been much more marked. One important reason for this is the inability of the body to feel exposure to radiation except in grossly supra-lethal doses. Another is the absence of early warning clinical signs of radiation injury. By the time these signs are detectable or become apparent to the individual, the degree of injury is severe and usually irreparable. Other reasons are the simplicity and sensitivity of detection devices compared with those needed for other environmental factors, and the extremely rapid increase of scale of the handling of radioactive materials in the last twenty years. In combination, these factors have resulted in a dependence on quantitative measurement which at times amounts almost to a preoccupation.

The basic function of radiological protection is the protection of people from the harmful effects of ionising radiation and radioactive materials, without imposing unbalanced restrictions. Measurements correctly play a major part in achieving this aim and also in demonstrating its achievement—they are not, however, an end in themselves. Monitoring has been defined by Committee 4 of I.C.R.P. as:

> "The measurement of radiation or radioactivity for reasons related to the assessment or control of exposure to radiation or radioactive material."

One implication of this definition is that monitoring involves more than measurement. It must also include interpretation in terms of the effects on people. Even then monitoring is only a means to one of two ends. Either it must help in achieving safety or it must demonstrate that safety has been achieved. The primary justification for a monitoring programme must be found in one or other of these objectives. There may be supplementary benefits in industrial or public relations, or other functions such as training, but these will not themselves provide sufficient justification for a programme.

Basic standards

The ideal form of monitoring would be one which detected biological effects resulting from radiation before these effects progressed to the point of constituting damage or injury. At present, the relationship between biological effects produced by low doses of radiation and subsequent damage to health is too vague to permit such effects to be used as a basis of radiological control. The most direct basis currently available in practice is that of radiation dose or radioactive intake to individual workers. The recommendations of the International Commission on Radiological Protection provide criteria against which to judge direct measurements or assessments of dose or intake. However, many forms of monitoring produce results which cannot be directly interpreted in terms either of dose or intake, and direct comparison with I.C.R.P. recommendations is thus not feasible. It might be argued that measurements which cannot be interpreted in this way do not provide information capable of being used in radiological protection. This, however, is to over-simplify the situation. Nevertheless, it is true that a monitoring measurement that, either alone or in combination with others, cannot be related to some standard ultimately derived from I.C.R.P. or similar recommendations is unlikely to provide a worthwhile contribution to radiological protection. In order to establish standards against which to judge indirect measurements of this type, it is necessary first to obtain a clear picture of the function of these measurements. This Symposium is concerned only with monitoring of the working environment, and so it is with this aspect that the remainder of this paper is concerned.

The special functions of monitoring of the working environment

I.C.R.P. recommendations for maximum permissible doses and intakes by individuals and the corresponding measurements relate to long periods of time, for example, thirteen weeks or longer. Moreover, the results of the measurements are usually available only after some delay. Direct monitoring of dose and intake is thus usually thought of primarily as a means of demonstrating compliance with I.C.R.P. recommendations rather than as a means of achieving control. Greater emphasis on the control aspects is found in the somewhat rare circumstances where radiation doses and intakes are likely to approach closely the I.C.R.P. recommended limits.

Measurements intended for control purposes can be thought of in two groups. They may be used for immediate executive decisions affecting current operations, or they may be used to build up experience useful in the control of subsequent operations of a similar character to those monitored. Clearly, the standards against which to judge the results of measurements will depend critically on the objective for which the measurement was made. Monitoring of the working environment is particularly suitable for short-term control, but its interpretation is difficult because it is only indirectly related to the fundamental requirement of safeguarding the health of the workers. However, the results can also be used in a more qualitative way to provide a system of early warning of deteriorating conditions in an area and to give a broad indication of the personal doses and intakes likely to be occurring. This broad picture is often very valuable in assessing the need for personal monitoring. Some types of personal monitoring, notably fast neutron monitoring and analysis of excreta, are difficult and expensive to carry out and difficult to interpret unequivocally in terms of I.C.R.P. recommendations. If the results from environmental measurements are low enough, they may often be used to demonstrate that personal monitoring of these more difficult types can be dispensed with. By contrast, personal monitoring methods that are both cheap and simple to interpret may provide the most satisfactory way of demonstrating that the working methods and environmental conditions in an area are satisfactory. This is a legitimate use of personal monitoring as an indirect form of environmental monitoring because the most effective methods of control of dose are usually applied to the working methods and environment rather than to the individual.

Environmental monitoring also provides useful information affecting the extent and form of medical supervision. These decisions are influenced not only by the expected doses and intakes to people in the area but also on the general environmental conditions likely to be encountered. For this purpose the monitoring should include not only numerical assessments of radiation and radioactivity but also a qualitative appraisal, preferably by the supervising doctor himself, of normal conditions and of the likelihood of large accidental doses or intakes.

Interpretation of the Results of Environmental Monitoring

No form of environmental monitoring can be easily interpreted in terms of exposure of the worker. Interpretation in these terms is always complex and always needs a great deal of supplementary information. It is rarely capable of high precision. In fact the most usual form of interpretation is not in terms of estimates of radiation dose or intake, but rather in terms of the likely upper limit to such doses or intakes. In some cases, the calculation of these upper limits is quick and simple. For example, it is easy to assess hand doses incurred in the handling of fuel, by measuring the radiation dose rate of the fuel and estimating the time spent in close contact. Although this method is quick and simple, experience has shown that it is far from precise and that estimates of dose obtained in this way are usually substantially higher than the true doses. In other circumstances, for example the assessment of the results of measurements for surface contamination, the interpretation in terms of dose or intake is too complex to undertake for each measurement and a different technique is necessary. It is then convenient to use a stylised model of exposure pathways to provide a quantitative link between maximum permissible doses or intakes and the environmental conditions being measured. The extent to which the stylised model represents the true situation depends largely on the degree of generalisation required. If the model is to apply to a wide range of measurements, then it will inevitably be far from representative for some of these circumstances. On the other hand, if a single model is to be used in relation to a closely defined set of circumstances, a large number of different models may be necessary to cover the whole field of experience. It is implicit in the use of a model in this way that numerical values derived from it must be used only with the reservations implicit in the model itself.

Derived working limit

In practice, the most convenient way of using a stylised model is as a link between the appropriate I.C.R.P. recommendations and a secondary standard to be applied to the environmental measurement. The status of this standard differs substantially from that of an I.C.R.P. recommendation because of the additional assumptions and simplifications which have to be made in its derivation. It is therefore convenient to introduce a different term and increasing use is now being made in the United Kingdom of the term "derived working limit" for this purpose. A typical derived working limit is that applied to radioactive contamination of surfaces. The possible exposure pathways include resuspension of dust followed by inhalation, contamination of the body followed by ingestion and direct radiation from the surfaces. A very wide range of circumstances can be involved and the exposure models are therefore very highly stylised. As a consequence, the resulting derived working limits are very widely applicable but contain large factors of safety in many, but not all, of these applications. Compliance with the D.W.L. is then an adequate demonstration of the maintenance of a satisfactory working environment in the sense that doses and intakes to workers from this cause will almost certainly be well below those recommended by I.C.R.P. Exceeding the D.W.L. in the environment calls for further assessment of the situation but, even if systematic, does not necessarily imply excessive exposures because of the inevitable degree of caution in the derivation of the working limit.

Derived working limits of this type are not only useful in interpreting environmental measurements in terms of I.C.R.P. recommendations, but they can also be used quantitatively in extending the functions of environmental measurements. For example, regular compliance with the D.W.L. will often be sufficient to indicate that personal monitoring can be dispensed with, and that other more complex forms of environmental monitoring need be done only experimentally or intermittently. It is also appropriate to use the D.W.L. in assessing the importance of changes from previous conditions. This is more logical than depending only on the magnitude of the change from the past because this method depends too heavily on the values encountered initially. The fact that conditions have deteriorated by a factor of, say, 2 or 10, may be of some interest to the plant or laboratory operators if they were otherwise unaware of the changes, but gives insufficient information to the health physicist. The health physicist has to consider not only the safety aspects, but the managerial and financial implications as well, and should give his advice on a comprehensive foundation. He cannot do this on the basis of a change in monitoring results unrelated to a derived working limit.

This insistence on a derived working limit and on the quantitative aspects of environmental monitoring carry with them their own dangers. The limitations in the application of a D.W.L. are very easily overlooked and compliance with an inapplicable, and therefore meaningless, D.W.L. can give rise to an entirely false sense of security. At the other extreme, a widely applicable D.W.L. may be elevated to the status of a legal requirement and while compliance may well be an adequate proof of satisfactory conditions, failure to comply is not necessarily reprehensible, though it is difficult for the law to permit of this distinction. Another danger is that numbers obtained for immediate short-term control purposes may be regarded as significant in a wider, more long-term context. There is then pressure to accumulate records of numbers which have long since outlived their usefulness, and experience has shown that attempts to abandon these records are often regarded as synonymous with reductions in the standard of safety.

The existence of derived working limits, necessary though they are, has the effect of increasing these dangers by appearing to simplify the interpretation of monitoring results and thence to encourage expansion of monitoring programmes. It is important to review carefully and regularly the objectives of a programme and the way in which the results meet these objectives. The development of automatic equipment has made it easy, though not cheap, to obtain vast amounts of data and not all of these have been sensibly related to the objectives. There is sometimes a tendency to feel that any results are better than none, and it is certainly true that even meaningless results can often be used to build up the confidence of both management and men. Apart from the obvious professional duty of the health physicist to avoid this kind of charlatanism, there is the practical danger of gross loss of confidence should the true position ever become apparent. It is mainly this danger which invalidates most of the public relations and medico-legal reasons for carrying out monitoring programmes unless these programmes can be genuinely justified in terms of the safeguarding of health. In practice, these remarks apply much more to routine measurements than to those which are made with the immediate objective of short-term executive control.

Lessons for the future

The lessons for the future are simple, but of fundamental importance. The objectives of a monitoring programme must be clearly established and the methods of interpretation of the results clearly defined in terms of those objectives. The scale and type of the programme must then be chosen to achieve these objectives, but not to provide more information than is necessary. The programmes must be reviewed from time to time as experience accumulates, and unnecessary and useless measurements must be ruthlessly eliminated. It seems probable that much of the monitoring of the working environment fails to achieve a satisfactory balance between the objectives and the effort involved in achieving them. The International Commission on Radiological Protection has set up a Task Group of Committee 4 to make recommendations on the basic principles to be applied to monitoring of the working environment in the hope that a clarification of these principles will encourage an improvement in the quality of radiological protection services and, at the same time, allow some economies to be made in the measuring programmes.

New laboratories at Imperial College

AT Imperial College, London, new laboratories were occupied in April 1966, to provide advanced facilities for nuclear chemical technology teaching and research and to allow the scope and scale of present research studies to be extended.

The facilities include a 17,000 curie cobalt irradiation unit and a 2 MeV Van de Graaff electron accelerator which, in addition to providing high intensities of ionizing radiation for fundamental studies, are also designed for operation as pilot plants. The University of London 100 kW nuclear reactor is available for neutron irradiations.

The chemical laboratories are equipped for work with plutonium and other alpha-active materials as well as for beta-gamma emitting isotopes. There is also a 2,000 sq. ft. pilot plant for a wide range of studies under extreme conditions of temperature, pressure and radiation.

The Imperial College postgraduate course in Nuclear Technology extends over 1 year and leads to the award of the M.Sc. of the University of London and the Diploma of Imperial College (D.I.C.). The curriculum serves as an advanced course of study for those intending to enter the nuclear industry. For those eventually wishing to work in other fields, it provides a comprehensive training in the techniques of measurement, handling and application of radio-active materials.

"Nuclear Engineering"

THE March issue of ATOM contained an article *Transport of Irradiated Fuel from Latina to Windscale* by M. T. Kavanagh, Chief Commercial Manager, U.K.A.E.A. Production Group, and G. Gualtieri, Dirigente della Direzione Construzioni Termiche e Nucleari, E.N.E.L. It should have been made clear that this article was originally published in "Nuclear Engineering" and was reprinted by permission of the Editor, to whom apologies are due.

Capital expenditure at Dounreay and Windscale

15th February, 1966

MR. WINGFIELD DIGBY asked the Minister of Technology what is the split of capital investment between Dounreay and Windscale for the prototype fast reactor and its fuel production plant.

MR. COUSINS: Capital investment at Dounreay, including the strengthening of the grid attributable to the project will be about £27½ million and capital investment at Windscale about £2½ million.

MR. WINGFIELD DIGBY asked the Minister of Technology if he will give his estimate of the yearly capital expenditure at Dounreay and Windscale on the construction of the prototype fast reactor.

MR. COUSINS: Planning is not yet sufficiently advanced to attempt an estimate of expenditure year by year. However, the expenditure at Dounreay will rise to a maximum of about £8 million in 1970–71; and maximum expenditure at Windscale will be about £1 million in 1967–68.

P.F.R. site

15th February, 1966

MR. EVELYN KING asked the Minister of Technology what estimate he made of the extra cost involved in building the prototype fast reactor at Dounreay rather than Winfrith.

SIR CLIVE BOSSOM asked the Minister of Technology (1) what estimates he made of the capital expenditure on the prototype fast reactor if located at Dounreay, Windscale, Winfrith, and Chapelcross respectively;

(2) if he will give the operating costs which were estimated for the prototype fast reactor if located at Dounreay, Windscale, Winfrith and Chapelcross, respectively.

MR. DALYELL asked the Minister of Technology (1) what estimate he made of the costs, to the nearest hundred thousand pounds, of building the prototype fast breeder reactor at Dounreay and Winfrith, respectively;

(2) what estimates he made of the running costs, after completion of basic capital expenditure, of a prototype fast breeder reactor, if located at Dounreay, Winfrith and Chapelcross, respectively.

MR. COUSINS: As I told the House on 9th February, the difference between the estimated capital and operating costs of siting the reactor at Dounreay and Winfrith did not play an important part in the decision. Some of the factors involved in the siting of the prototype fast reactor are exceedingly difficult to quantify and it would be misleading to make precise comparisons in money terms. Estimates of the capital expenditure were not prepared for Windscale and Chapelcross, which would have required additional research facilities to support the reactor.

Construction force for P.F.R.

15th February, 1966

MR. REES-DAVIES asked the Minister of Technology if he will give his estimate of the number of people who will be employed on the construction of the Atomic Energy Authority's prototype fast reactor at Dounreay, and the fuel production plant at Windscale, in each of the years 1966, 1967, 1968, 1969, 1970, and 1971.

MR. COUSINS: The maximum labour force on construction at Dounreay will be about 700 men. At Windscale the comparable figure will be about 70 men. Planning is not yet sufficiently advanced to attempt a detailed year by year breakdown for either site.

Critical path methods

16th February, 1966

MR. BIFFEN asked the Minister of Technology whether a critical path network analysis has been made for the prototype fast reactor project at Dounreay.

MR. COUSINS: Yes, and critical path methods will be used throughout the project.

Aldermaston programme

16th February, 1966

MR. ASTOR asked the Minister of Aviation whether the programme of development and research at the Atomic Weapons Research Establishment, Aldermaston, will ensure the continued useful employment of the staff and facilities of this establishment; and if he will make a statement.

MR. MULLEY: I am responsible only for the military work undertaken by the Atomic Energy Authority at Aldermaston.

The Authority announced two years ago that the staff required for this work would fall gradually over a period of years. I understand that the Authority expects to achieve this reduction by natural wastage. Facilities will continue to be used at Aldermaston in the most effective manner that the special circumstances of the establishment permit.

MR. ASTOR: Is the right hon. Gentleman aware that there is a great deal of anxiety locally and a suspicion that the Government intend to run down the facilities at Aldermaston? Can he get together with the Minister of Technology to develop a programme that will ensure the continued useful employment of the qualified staff and the facilities there?

MR. MULLEY: I accept the need to maintain the staff at Aldermaston if possible and I undertake to consult my right hon. Friend the Minister of Technology, as the hon. Gentleman suggests.

Windscale and Chapelcross

23rd February, 1966

MR. AWDRY asked the Minister of Technology if he will list the additional research facilities which would have been required at Windscale and Chapelcross to support the prototype reactor if it had been built at either Windscale or Chapelcross.

MR. MARSH: Chapelcross would have required post-irradiation examination facilities, additions to analytical laboratories, and further health and safety facilities. Moreover, there would also have been a need for additional water cooling works. Windscale is to have the fast reactor fuel production plant; to put the reactor there as well would have overcrowded a site which is already very intensively developed.

P.F.R. contracts

28th February, 1966

MR. ALISON asked the Minister of Technology on what date he expects tenders to be invited for the construction of the prototype fast reactor and its fuel production plant.

MR. COUSINS: This comes within the field of the Authority's management responsibility. The Authority informs me that there will be numerous individual contracts for civil engineering work and for plant and equipment for the two projects. Invitations to tender will be issued over several months, starting almost immediately.

Single purpose transducers

1st March, 1966

MR. ELDON GRIFFITHS asked the Minister of Technology if he will list the civil non-atomic projects which have been launched by the Atomic Energy Authority.

MR. COUSINS: I would refer the hon. Member to the reply which I gave to the hon. Member for Sheffield, Hallam (Mr. J. H. Osborn) on 30th November. In addition to the projects I listed in that reply the Authority is now undertaking scientific research in the design and development of single purpose transducers suitable for incorporation in electronic instrumentation systems.

Waste disposal at sea

2nd March, 1966

MR. WALL asked the Minister of Agriculture, Fisheries and Food what arrangements are made about dumping atomic waste at sea; what degree of pollution results; and whether this is increasing.

MR. HOY: Dumpings are made by the Atomic Energy Authority subject to detailed conditions prescribed by authorisations issued by my right hon. Friend and my right hon. Friend the Minister of Housing and Local Government.

The radioactivity of the wastes is so small in relation to the natural radioactivity of sea water that no measurable degree of contamination results.

MR. WALL: I thank the hon. Gentleman for that reply. Is he aware that there is growing concern at the pollution of the sea by oil, industrial waste and atomic waste? In view of the increasing dumping by European Powers, will he see that the regulations are adequate in an international as well as a national sense?

MR. HOY: I think that the hon. Gentleman will agree that that widens the Question a little. The question of the safety of sea disposal has been considered by a panel of the International Atomic Energy Agency and the conditions which we enforce comply with its recommendations.

SIR KNOX CUNNINGHAM: Can the hon. Gentleman say whether any of this waste is dumped in containers? What is the life of those containers? Are we not laying up for ourselves a good deal of trouble in the future?

MR. HOY: I hope not, because the dumpings have been made in selected areas. They are made away from the fishing grounds and, indeed, beyond the Continental Shelf. They have to be at a depth of not less than 1,500 fathoms and we take tremendous care to see that no contamination results from them.

Research expenditure

8th March, 1966

MR. BIFFEN asked the Minister of Technology what proportion of the total research and development financed by the Atomic Energy Authority in each of the last five years has been carried out in non-Governmental research establishments.

MR. COUSINS: I am informed by the Atomic Energy Authority that the proportions for civil research and development are approximately as follows:

	Per cent
1960–61	11
1961–62	9
1962–63	11
1963–64	9
1964–65	10

Annual Report of the U.K.A.E.A.

8th March, 1966

MR. WINGFIELD DIGBY asked the Minister of Technology whether he will request the Atomic Energy Authority to review the form of its annual report, so as to make it more informative.

MR. COUSINS: The Authority's Annual Report is generally regarded as a very informative document, but, if the hon. Member has any specific proposals for making it even more so, I shall be happy to pass them on to the Authority for their consideration.

Dounreay staff

8th March, 1966

MR. HECTOR HUGHES asked the Minister of Technology how many persons have been employed during each of the last five years at Dounreay experimental station and the adjoining reactor station, respectively; how many are now employed there, and in what capacities; and whether the work there is increasing or diminishing.

MR. COUSINS: I am informed by the Atomic Energy Authority that the number of people directly employed at its Dounreay Experimental Reactor Station has not changed significantly over the last five years. At present about 2,400 are employed there, of whom nearly three-fifths are industrial workers.

As to the last part of the Question, I would refer my hon. and learned Friend to the Answer I gave to the right hon. Member for Argyll (Mr. Noble) following my statement to the House on 9th February.

Vulcain

9th March, 1966

MR. READER HARRIS asked the Minister of Technology if he will make a statement on the progress being made with the joint Anglo-Belgian programme on the VULCAIN reactor.

MR. COUSINS: Experimental testing in the Belgian BR3 reactor began in July, 1965, but early results showed a need to modify some of the core pipework. Modifications have now been completed and the experimental programme is expected to restart next month.

Marine reactors for the Navy

9th March, 1966

MR. WINGFIELD DIGBY asked the Secretary of State for Defence what type of reactor the new package-type reactor designed for the Royal Navy will be.

MR. J. P. W. MALLALIEU: Besides the improvement of our existing submarine reactors, we are studying the possible development of a new submarine reactor, and the application of nuclear propulsion to surface warships. Until these studies are complete we will not decide what new types of reactor would best suit the needs of the Navy.

Erratum

THE April issue of ATOM reported a speech by the Minister of Power, Mr. Fred Lee, stated to be made at the annual dinner of the British Nuclear Engineering Society. The speech was, in fact, delivered at the annual dinner of the Nuclear Engineering Society, Risley.

Publications received

The following publications are all by members of the staff of the U.K.A.E.A.

Physics of Nuclear Reactors
by D. Jakeman, Reactor Group, U.K.A.E.A.

This book is intended for graduate engineers and physicists who wish to become acquainted with the branch of physics dealing with nuclear reactors. No prior knowledge of the subject is assumed, but it is anticipated that the reader will be familiar with calculus and elementary nuclear physics.

Some introductory remarks on the latter are given in the first chapter.

Published by the English Universities Press Ltd.

Thermal Neutron Scattering
Edited by P. A. Egelstaff, A.E.R.E., Harwell, U.K.A.E.A.

Specially designed for experimentalists, whether they be research workers, teachers or postgraduate students, this book presents a concise and authoritative survey of the theory and experiment of neutron scattering by condensed matter.

Processes in which the neutron gains or loses energy in the collision are discussed, and are analysed in terms of the dynamical behaviour of the sample.

An aim of the mathematical presentation is to underline and describe the physical processes, rather than present a rigorous treatment of the theory.

Published by Academic Press Inc., (London) Ltd.

Semiconductor Counters for Nuclear Radiations
by G. Dearnaley, A.E.R.E. Harwell and D. C. Northrop, Manchester College of Science and Technology.

Since the first edition of this book was published, there have been major advances in its field. The most striking development has been in the preparation and use of lithium-drifted germanium devices for gamma ray spectrometry, but lithium-drifted silicon detectors have also been developed further. Semi-conductor detectors are now used more widely than ever before, both within nuclear physics and outside it, for example in medicine and space physics, and the manufacture of ancillary electronic instrumentation has burgeoned correspondingly. There have been further advances in our theoretical understanding too: fresh explanations and descriptions have been put forward of the physical processes involved in surface barrier formation, and the recognition of channelling as a factor to be considered in the behaviour of charged particles in single crystals has complicated the basic explanation of nuclear radiation in solids.

These and other advances have made necessary extensive changes in the content of the first edition. About 25 per cent of the second edition is new material, and there are almost 50 new figures. The structure of the book remains the same, however.

Published by E. & F. N. Spon Ltd.

Protecting the worker

EXPERIENCE has shown that radiation plays a negligible part in the 400 or so lost-time accidents that occur each year in the U.K. Atomic Energy Authority.

The basic reason for this success, in an organisation employing 34,000 people, is the protection to workers which is built into their environment.

The design and control of these environments was the subject of a symposium held at The Pavilion, Bournemouth, from 18th to 22nd April. Entitled "The Radiological Protection of the Worker by the Design and Control of his Environment", the symposium was organised by the Society for Radiological Protection. (A paper from the symposium is reprinted elsewhere in this issue.)

The symposium covered the philosophy of the subject, selection and design of operational procedures, containment and ventilation, problems of surface contamination and re-suspension of particles into the atmosphere, new developments in shielding, and the role of monitoring (excluding instrument design).

At an exhibition associated with the symposium, the U.K.A.E.A. displayed monitoring instruments, personal dosimeters, protective clothing, decontaminants, glove boxes, the use of depleted uranium for shielding, standards for instrument calibration, and ventilation and fire protection systems.

A.E.A. at the Physics Exhibition

At Stand 51 of the Physics Exhibition (Alexandra Palace, London, from 28th-31st March), the U.K. Atomic Energy Authority showed some of the new instruments and techniques developed at its establishments. The exhibits were:

Photographic radar

A pulse of light of 20 nanoseconds duration can be considered as a "packet" of light of length 20 feet (6 metres). As it passes a set of objects only those within this region of 20 feet are illuminated at any instant. A system of photographic radar has been developed which produces a light pulse of 20 nanoseconds and uses a camera with the same exposure time. The camera is fired so as to record the progress of the light packet.

The measurement of atmospheric turbulence

The study of atmospheric turbulence is important for understanding the spread of pollution in the atmosphere. This simple portable instrument, suitable for field use, has been designed to measure the intensity of turbulence.

Ultra-high-speed image tube framing camera E12A

The type E12A camera records sequences of images at a frame rate of 60 million per second.

Multi-channel image tube camera 6E14

This is a high-speed camera capable of taking a sequence of six high-resolution pictures. Each picture is recorded in an independent channel, consisting of an objective system, image tube, photographic recording system, and electronic pulsing system. The image resolution is 1,250 line-pairs per picture diameter and the duration of the exposure may be adjusted from 50 to 300 nanoseconds.

Concord in-flight radiation warning meter

Supersonic aircraft such as the Concord will fly at heights up to 65,000 feet, at which altitude radiation levels due to cosmic rays are higher than those normally met by civil aircraft (which usually fly below 40,000 feet). If the level of radiation approached that at which the crew and passengers would suffer an unacceptable radiological dose, this instrument would provide a warning signal. The pilot would then gradually reduce height in order to provide a layer of atmosphere above the aircraft that was sufficiently thick to absorb the radiation.

Portable chromatograph for the analysis of high purity helium

Designed to provide on-line analysis of impurities in helium to parts per million by volume levels, this instrument incorporates features which allow extension of the range to sub-parts per million, and the analysis of hydrogen in helium.

Valveless differential gas chromatograph for the analysis of high purity helium

Unlike conventional chromatographs, this instrument uses the sample gas as a carrier. Impurities are concentrated quantitatively from the sample stream and then released back into the sample stream in a concentrated pulse. The impurities in this pulse are separated on a column and detected by a katharometer which has unconcentrated sample gas flowing through its reference side.

High temperature transducers

Several designs were shown of high-temperature sensors for measuring physical variables such as mechanical displacement and liquid metal levels. These included a pneumatic displacement gauge for monitoring in-pile creep of irradiated specimens within the range 0 to 0.018 in. at up to 300°C. Examples of electromagnetic transducers were also shown, including a displacement gauge for monitoring movements of up to 0.02 in. in liquid alkali metals at up to 400°C.

Entrained gas sampler

Although separation of large gas bubbles from liquids may be readily achieved with conventional cyclone separators, greater difficulty is experienced in removing gas bubbles more than about 0.2 cm. in diameter. However, very much smaller bubbles (0.02 cm. diameter) can be removed by mounting a perforated gas collector co-axially in the cyclone.

Thermocouple techniques

Metal - sheathed mineral - insulated thermocouples are widely used for temperature measurement in nuclear reactors.

Examples of application and fabrication techniques were exhibited. These included hand tools for stripping sheaths and examples of pressure glands and cable connectors. A rapid and effective method of producing insulated hot-junctions in metal sheathed cables was shown. This is the plasma arc welding method which is used in forming hot junctions and sheath closure welds with cables from 0.125 in. down to 0.01 in. outside diameter.

Superconducting coils using composite stranded cables

Recent work on composite conductors, which are made up of a mixture of superconducting and normal materials, has shown improvements over the performance of purely superconducting wires and coils in the generation of steady magnetic fields of high strength. Whereas a 0.010 diameter superconducting wire when wound into a large coil is only capable of carrying 10 amps in its own field of 20 kilogauss, the same conductor, suitably treated and stranded with normal conductors, is capable of carrying a current in excess of 150 amps in the same field.

2,000°*C ceramic oxide resistance furnace for neutron diffraction studies*

Neutron diffraction studies require the heating of specimens of materials to high temperatures in either an oxidising or a neutral atmosphere and with a minimum of absorbtion or scattering of the neutron beam by the furnace elements. A furnace has been designed and developed which will meet these requirements and which will uniformly heat material samples of up to one inch diameter and two inches long to a minimum temperature of 2,000°C.

Mossbauer spectrometer

This exhibit showed a spectrometer capable of highest performance. The channel widths differ from each other by less than 1 part in 104; thus, in the absence of absorption, no spurious absorptions greater than 0.01 per cent are produced. The energy scale is linear to within 0.2 per cent over the whole scale.

The arrangement of the spectrometer is flexible. When less than the full number of channels will suffice for a spectrum, the store can be divided and several spectra stored. If the counting equipment and vibrator assembly are duplicated, several spectra can be taken simultaneously without increasing counting losses.

Elementary particles

At the invitation of the Institute of Physics and the Physical Society, the Atomic Energy Research Establishment, Harwell, and the Rutherford High Energy Laboratory of the Science Research Council staged a special exhibit on elementary particles (Stand No. 67).

One section of this exhibit traced the development of the study of these particles from the end of the last century to the present day whilst the other section illustrated some of the applications of various elementary particles in modern medicine, industry and research.

1024 *channel pulse height analyser*

The Harwell 2000 Series range of instruments has been established in a transistorised form to meet the needs of the nuclear scientist. Some further units have been developed which permit the assembly of a multi-channel analyser. This consists of units which, with the exception of display, control and storage units, are all in the 2000 Series format. The analyser thus conforms to the 2000 Series philosophy in that alternative or improved units can be substituted without changing the system.

Radiochemicals at Warsaw

SCIENTISTS from the biochemical societies of twenty-one countries met in Warsaw from 3rd to 8th April for the Third Annual Congress of the Federation of European Biochemical Societies.

Taking part in the associated exhibition was the Radiochemical Centre, Amersham, with a display featuring a variety of radioactive products of biochemical research interest. It included a description of the range and quality of organic compounds labelled with carbon-14, tritium and other isotopes which are now available from the Centre for tracer work. Other sections of the display described recently developed radioactive materials for medical diagnosis and reagents for clinical chemistry, including an iodine-125 labelled insulin kit for immunoassay and sulphur-35 compounds such as thiosemicarbazide and thioTEPA.

A colour reproduction of a mural depicting the history and use of radioisotopes appeared as a general background to the exhibit.

A.E.A. reports available

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

AEEW-R 441
Splosh II. A Dynamics Programme for Nuclear-thermal-hydrodynamic behaviour of Water-cooled Reactors. By D. Moxon. January, 1966. 66 pp. H.M.S.O. 9s.

AEEW-R 464
Further Buckling Measurements on a Heated Graphite Lattice with 0.8 *per cent* PuO_2/UO_2 *Clusters.* By D. J. Wilson. 1966. 25 pp. H.M.S.O. 4s. 6d.

AERE-R 5097
Proceedings of the Seminar on the Preparation and Standardisation of Isotopic Targets and Foils, Held at AERE, Harwell, October 20–21, 1965. Edited by M. L. Smith. December, 1965. H.M.S.O. 27s.

AERE-R 5122
Routine use of the Silver-cobalt Activity Ratio Method to determine Epithermal Indices for large Neutron Dose Irradiations. By M. J. Cabell and M. Wilkins. February, 1966. 28 pp. H.M.S.O. 4s. 6d.

AERE-R 5129
The Analysis of Uranium Silicides. By G. W. C. Milner, D. H. Rowe and G. Phillips. January, 1966. 16 pp. H.M.S.O. 2s. 6d.

AERE-R 5163
Disorption Studies on Graphite Surfaces Irradiated in CO_2–CH_4 *and* $CO_2/CO/CH_4$ *Mixtures.* By J. Bromley. February, 1966. 27 pp. H.M.S.O. 5s.

AWRE-O 100/65
A Calibration System for Piezo-electric Accelerometers. By D. P. Welham and R. Allison. February, 1966. 19 pp. H.M.S.O. 3s. 3d.

AWRE-O 103/65
The Calculation of Group averaged neutron Cross-sections. The Development of Galaxy 3 *Facilities in S*2 (*Fortran*) *Language for the IBM* 7030 (*Stretch*) *Computer during* 1965. By P. Gately, K. Parker, P. Stanley and D. V. J. Williams. February, 1966. 43 pp. H.M.S.O. 6s.

PG Report 695 (W)
Analytical Method for the Determination of Methylbenzenes in Humidrier Liquors (Gas Chromatography). 1966. 10 pp. H.M.S.O. 1s. 2d.

TRG Report 1160 (S)
System C.I.D. (*Computerised Interpretation of Data*) *An Illustration of the use of a Digital Computer in the Storage, Interpretation and Recovery of Materials Data.* By L. E. Raraty and J. H. Gittus. 1966. 15 pp. H.M.S.O. 2s. 6d.

TRG Report 1168 (W)
The Structure of 20 *Cr-25Ni-Nb Steel after Ageing for up to* 2000 *hours in the Temperature Range* 600–800° *C.* By R. Sumerling, J. H. Pearce, S. Freeman and E. Dobing. 1966. 22 pp. H.M.S.O. 5s.

Battersea Radiation Protection courses

Two courses in radiation protection will be held at the Proposed University of Surrey (Battersea College of Technology) during the session commencing October 1966:

1. *Principles and Practice of Radiation Protection*—a course leading to a Diploma; suitably qualified students may be allowed to proceed to the M.Sc. degree by dissertation. Studentships may be available for full-time students. The course may also be taken on a part-time basis.
2. *Radiological Protection*—an evening course leading to a Certificate.

The courses are suitable for those with qualifications in science, medicine or engineering.

The Department of Education and Science will accept the Diploma or the Certificate as evidence of instruction in health physics for teachers in schools, establishments of further education, or teacher training colleges.

Holders of either a Diploma or Certificate are eligible for Associateship of the Institute of Physics and the Physical Society, provided they have gained not less than five years subsequent experience in physics at an appropriate level.

The Radiation Unit of the Proposed University also accepts students reading for research degrees.

Further information may be obtained from the Director of the Radiation Unit, The Proposed University of Surrey, *at* Battersea College of Technology, London, S.W.11.

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

Radioisotopes in the Firth of Forth

RADIOACTIVE tracers have been used to measure the extent of spoil movement from dumping sites in the Firth of Forth, Scotland. It has been shown that rapid and extensive upstream movement occurs from the site at Oxcars Deep. Since, therefore, the use of this site for deposition of silt from dockyards and harbours increases the frequency of dredging, a critical examination with radioisotopes of an alternative dumping ground has been made. This has resulted in the use of an ebb channel adjacent to Oxcars, which could considerably reduce the cost of dredging Rosyth dockyard.

An extensive annual dredging programme is required in the approaches to Rosyth dockyard to maintain a navigable approach channel and tidal basin. Dredged material is transported by hopper and deposited at the Oxcars spoil ground, six miles downstream. This spoil ground is also used for deposition of material from other areas of the Firth of Forth.

The Atomic Energy Authority, on behalf of and in collaboration with the Ministry of Public Building and Works, and with the assistance of the Hydrographer of the Royal Navy, began investigations in 1961 by depositing a tracer—ground glass labelled with the radioisotope scandium-46—on the bed of the estuary at the western edge of the Oxcars Deep. The glass was ground to match in size the natural silt at Rosyth.

Movement of the tracer was plotted with scintillation counters, which detected the gamma radiation from the radioisotope. Each point of measurement was fixed by the simultaneous use of two sextants. Measurements were generally made on traverses across the estuary to delineate the spread of the tracer.

The subsequent movement of this material was generally upstream and the results were used to plan a second investigation in which the method by which spoil is normally deposited was used—that is ground glass was labelled as before but this time was mixed with a hopper-load of spoil. By using this technique and measuring the tracer quantitatively in the dockyard, an estimate of the quantity of deposited spoil returning to the dockyard was obtained.

The initial spread of the tracer from the point of deposition enabled the spread of spoil released by a hopper in a deep estuary to be determined; this pattern had not previously been studied by this technique.

The investigation showed that no significant fraction of the spoil is carried downstream beyond the Oxcars Deep, even though it was deposited at high slack water. Nor does the spoil remain statically in the Deep. It is moved upstream by scouring bed currents, at least 30 per cent of the deposited material in the 1964 investigation being upstream of the deposition point within 18 days. Some of it appeared upstream of the Forth Railway Bridge only two days after deposition. Measurements up to 114 days after deposition confirm that the bed transport of material is upstream.

It was decided that the ebb channel to the south of Oxcars might provide a spoil ground from which material would be transported downstream. A preliminary three-day investigation was carried out in 1965, ground glass labelled with the radioisotope lanthanum-140, being mixed with spoil and deposited from a hopper at high slack water. Lanthanum-140 was chosen because its half-life is long enough for a three-day investigation but short enough to enable repeat investigations to be carried out as required. The results showed that the spoil would be widely distributed downstream of the deposition area without approaching existing harbours on the estuary. Upstream movement of spoil was very limited.

The ebb channel is now in use but long term movement has not been examined, nor has the effect of deposition at low water or during a flood tide. A further investigation is planned for 1966.

Surveys have shown no evidence of the transport of radioactive material to the shore or on to sand areas during these investigations.

The investigations are described in two reports available from H.M.S.O. They are:

AERE—R 4980 Silt Movement Investigation in the Oxcars Spoil Ground, Firth of Forth, Using Radioactive Tracers, 1961 and 1964. Price 4s. 6d. net.

AERE—R 5080 An Investigation Using Radioactive Tracers into the Silt Movement in an Ebb Channel, Firth of Forth, 1965. Price 4s. net.

14th March, 1966

50,000,000,000 kWh generated

FIFTY-THOUSAND-MILLION units of electricity have been generated by nuclear power in Britain—much more than in the rest of the world put together.

Furthermore, about 2,000,000,000 kilowatt hours are now being generated each month, nearly 14 per cent of the total monthly electricity production in Britain.

Nine stations (22 gas-cooled graphite-moderated reactors) are now in operation, with the capacity to send out 3,380,000 kW to the grid. The seven of these in operation during the recent winter—Calder Hall and Chapelcross (U.K.A.E.A.), Berkeley, Bradwell, Hinkley Point and Trawsfynydd (C.E.G.B.) and Hunterston (S.S.E.B.)—maintained load factors in excess of 90 per cent during much of this period; all seven have exceeded their design capacity.

Two C.E.G.B. stations, Dungeness A and Sizewell, came on power only recently. Sizewell, designed to send out 580,000 kW, is the most powerful nuclear power station in operation in the world.

All of these stations use Calder Hall type gas-cooled graphite-moderated reactors, and two more, Oldbury and Wylfa (each with two reactors), are being built for the C.E.G.B. These will complete the first nuclear power programme of about 5,000 MW. Dungeness B, the first commercial Advanced Gas-cooled Reactor (A.G.R.) type of power station is now under construction for the C.E.G.B. This is the first power station of the second nuclear power programme of 8,000 MW.

In addition to the power stations two experimental reactors, the Windscale A.G.R. and the Dounreay Fast Reactor, produce electricity for the national grid, although the output of these reactors is subject to the demands on the reactors as research and development facilities.

The fuel for all these stations is produced at the U.K. Atomic Energy Authority's plant at Springfields, near Preston, where fuel elements are manufactured at the rate of 250,000 per year.

17th March, 1966

D.M.T.R. uprated

THE Dounreay Materials Testing Reactor (D.M.T.R.) is now running at 25 MW—two-and-a-half times the power for which it was originally designed.

The increase is due to the use of a new type of fuel element—the same as that recently installed in the PLUTO reactor at Harwell. PLUTO is now operating at 20 MW; it, too, was designed to operate at 10 MW.

The new fuel elements could be used without modification to produce a more economic performance from the existing reactors of similar type in Australia, Denmark and Germany. Their manufacture involves new methods of fabrication developed by the A.E.A. and industry, and the techniques employed might result in an increased British export market for fuel elements for many different types of research reactors.

The purpose of raising the power of D.M.T.R. and PLUTO is to increase the neutron intensity within the reactor. In practice, this is equivalent to increasing the space available in the reactor and has been necessary to meet the demand for space for experiments in support of the British nuclear power programme.

Although D.M.T.R. and PLUTO commenced operation at a power level of 10 MW, both have operated at 15 MW for some years.

Tests with the new concentric fuel element at Harwell in December, 1965, gave satisfactory operation of PLUTO at 22½ MW. Further tests have been carried out recently at Dounreay and on Saturday, 19th March, the D.M.T.R. was operated at a power level of 25 MW. This level is the highest to which any of the A.E.A. research reactors has been taken.

Routine operation of both D.M.T.R. and PLUTO reactors will, from henceforth, be between 20 MW and 25 MW.

21st March, 1966

Harwell refrigerator

A REFRIGERATOR employing new principles will maintain temperatures five times lower than those previously possible under steady conditions. The system, based on the properties of liquid mixtures of the two isotopes of helium, was first conceived at the Atomic Energy Research Establishment, Harwell. It has been developed under contract and is now available commercially.

The refrigerator employs the first entirely new refrigeration cycle to be discovered and successfully demonstrated in the last 25 years and is a major advance in the technology of low temperatures. It works in a temperature range within one tenth degree of absolute zero (0 degrees K or approximately −273 degrees centigrade) and opens up a new range for research involving steady temperature conditions. Solid state, quantum and nuclear physicists, metallurgists and chemists will be able to extend the range of their investigations to a region of temperature where properties are of a particular interest. Up to now scientists have only been able to obtain these temperatures by means of the technique of adiabatic demagnetisation which does not give steady temperature conditions. The new refrigerator is capable of maintaining steady temperatures in this range for periods of days if necessary.

Background note

Helium-3 (the rare light isotope) has a lower boiling point than any other liquid. Below 0.35°K the vapour pressure is so small that little cooling can be effected by evaporation and up to now this temperature has been the lowest that could be maintained continuously.

In 1952 a scientist from A.E.R.E. suggested that a process of diluting liquid helium-3 with liquid helium-4 (the more common isotope) would produce a cooling effect in much the same way as a gas cools on expansion. In 1956 it became known that below 0.9°K a liquid mixture of the two isotopes of helium separates out into two distinct layers with the helium-3 lying above the helium-4. It was predicted that as molecules of the upper liquid helium-3 crossed the boundary into the lower liquid helium-4, which at this temperature is a superfluid, a cooling effect would occur. If the process could be made continuous the temperature of the whole system would fall and could be maintained at a much lower temperature than the previous limit. Several systems by which the principle could be made to work were suggested in 1958 and an Authority contract was awarded to Manchester University to work on this subject. This led to their first successful demonstration of the principle during 1965 when the lowest temperature reached was 0.065°K.

The Oxford Instrument Company Limited is manufacturing a commercial version under licence from the U.K.A.E.A., which holds patents covering the refrigeration cycle.

Further details can be obtained from the Oxford Instrument Company Limited, Osney Mead, Oxford (Tel. Oxford 41456), which has designs for a number of modifications so that the refrigerator can be used for different experimental systems, including those involving superconducting magnets.

24th March, 1966

Critical path methods

THE Atomic Energy Research Establishment, Harwell, can now offer industry a three-day course on critical path methods together with access to a computer programme especially written for the engineer-manager. The programme is designed to provide sophisticated outputs including manpower levelling, budget forecast data, etc., but in a manner which is simply understood and operated with the minimum of effort by busy executives. Access to the programme initially will be through a data centre in London, but later at other centres.

Lecturers on the course are Authority staff who developed the system or who have first hand experience of its application. Critical path methods are demonstrated manually or by use of the A.E.R.E. computer programme, which is particularly suitable for the smaller project. A fee of 15 guineas is charged to cover the cost of the course and a further 60 guineas for those wishing to have the right to use the programme. The only subsequent cost arises from charges paid to the chosen data centre for use of computer time.

Applications of critical path methods in the U.K.A.E.A. range from planned reactor maintenance periods to planned "change over" periods in production lines. The methods are also used in the planning and control of construction projects which have costs ranging from thousands to millions of pounds and construction periods ranging from days to years.

The next course on critical path methods will be held at A.E.R.E., Harwell, from 25th–27th May, 1966. Further details may be obtained from The Post Graduate School, Building 455, A.E.R.E., Harwell, Didcot, Berks.

29th March, 1966