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Number 152 / **June 1969**

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MONTHLY INFORMATION BULLETIN OF
THE UNITED KINGDOM ATOMIC ENERGY AUTHORITY

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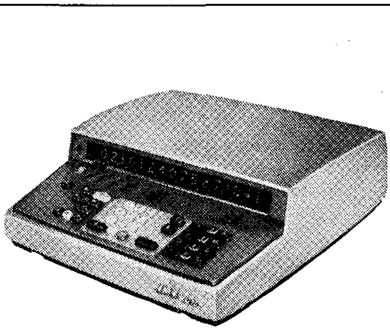

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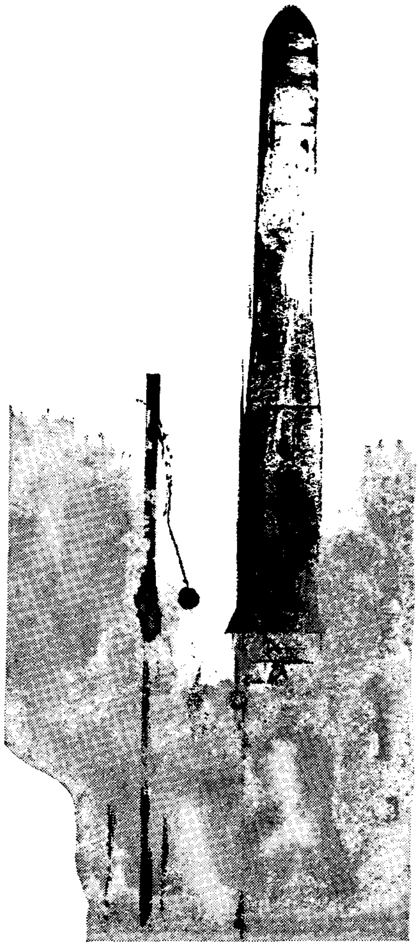

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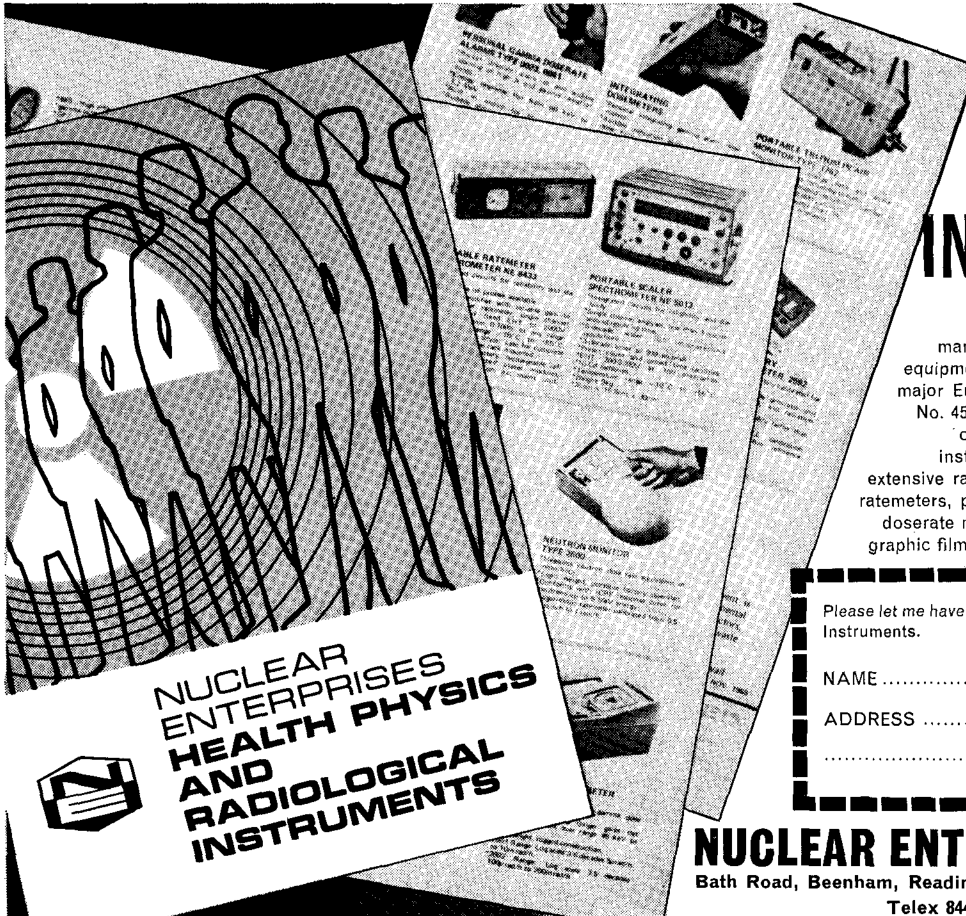

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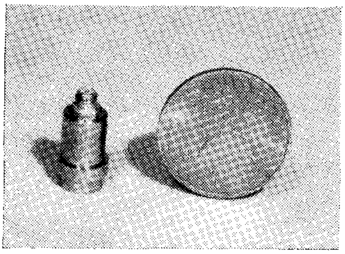

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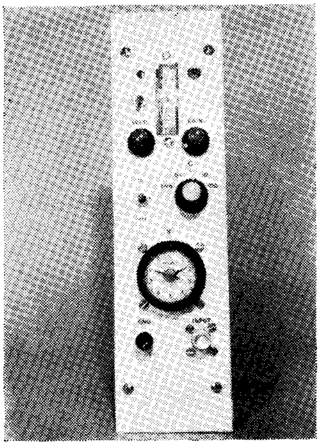

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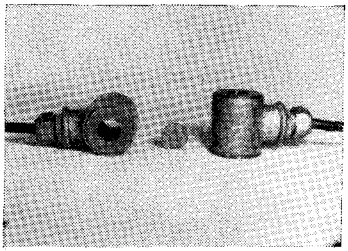

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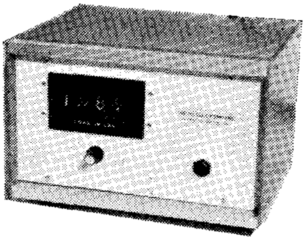

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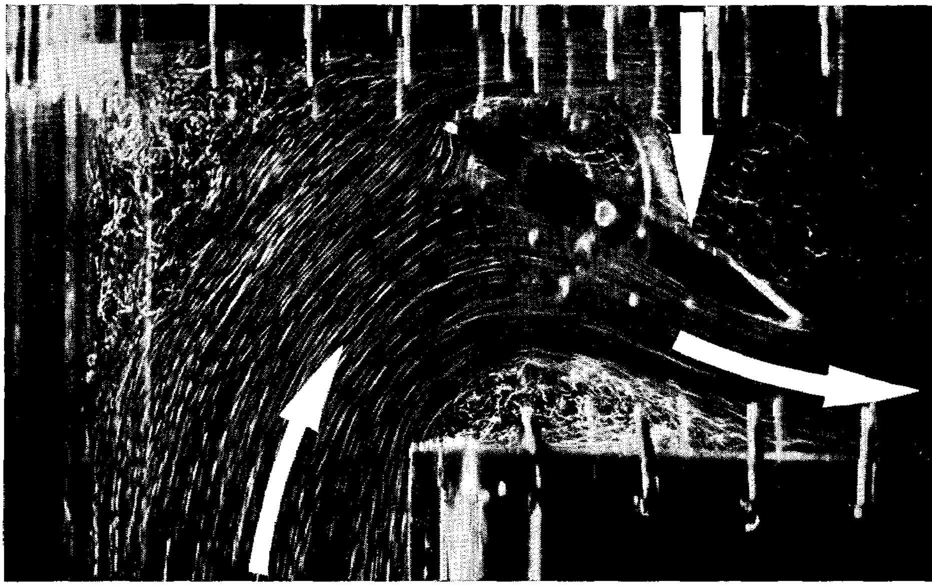

Flow visualisation by Lucas

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

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

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

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

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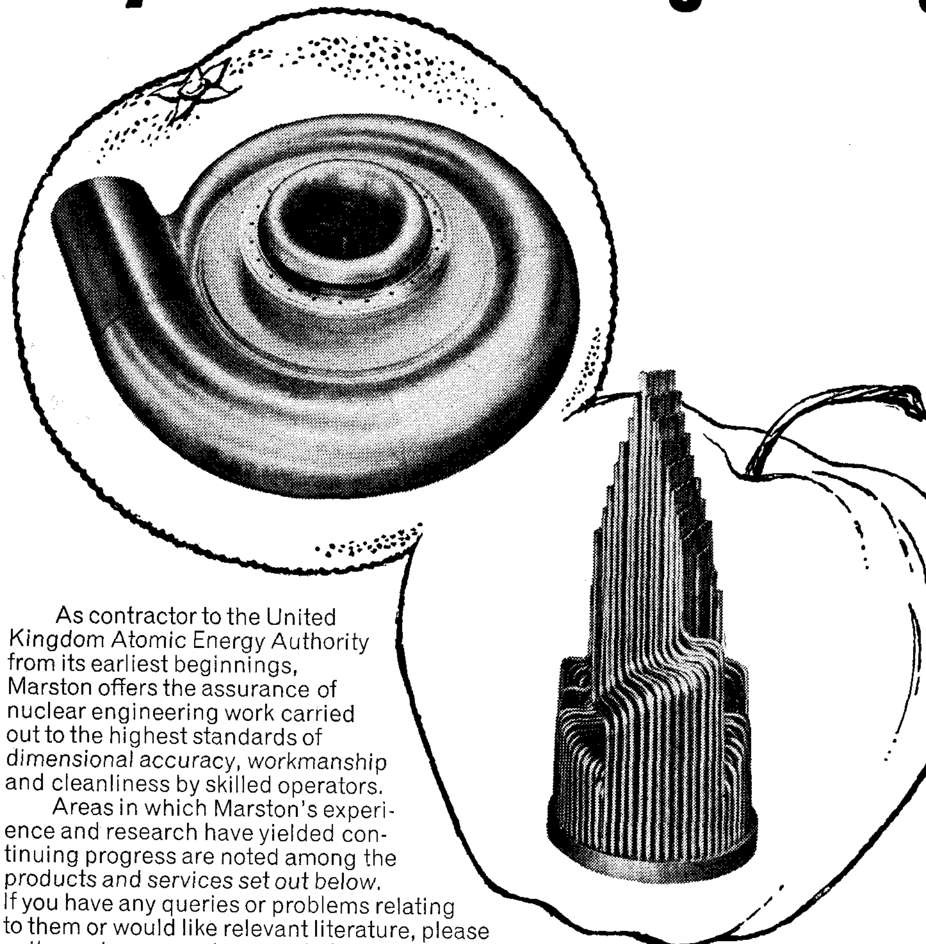

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ATOM
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U.K.A.E.A. PRESS RELEASES

Commercial contracts for DFR

Hire of irradiation space in the Dounreay Fast Reactor (DFR), Caithness, Scotland, to overseas nuclear agencies has been operated on a commercial basis over the last three years.

The latest agreement brings the total value of the contracts for work in DFR to more than £2m. in foreign currency.

This agreement has been signed between the United Kingdom Atomic Energy Authority and the Power Reactor and Nuclear Fuel Development Corporation of Japan for the irradiation of Japanese experimental nuclear fuel in the reactor.

The work forms part of the Japanese nuclear development programme on fast reactors. Further agreements with other agencies are being negotiated.

DFR has been the key facility in the development of the British sodium-cooled fast reactor system and is the key test-bed for the testing and development of future fast reactor fuels and materials. DFR was also the world's first fast reactor to produce electricity for commercial consumption. It generates some 14 megawatts of electricity and has produced about 250 million units of electricity, most of which has been exported to the Scottish grid.

The next stage in the development of the fast reactor system is the Prototype Fast Reactor, which is also sited at Dounreay. This reactor will produce 250 megawatts of electricity, and construction is due to be completed by the end of 1971.

Apart from work for fast reactors, the DFR has also been used for testing fuel and non-fissile materials (e.g., fuel cladding and graphite moderator materials), whose behaviour under neutron irradiation is important to the design of reactors, other than fast reactors. DFR is of particular value in performing such experiments since it provides accelerated damage rate conditions and so enables a material under test to receive an equivalent lifetime radiation dose in a much shorter time.

14th April, 1969

Nuclear power station in Greece

[*A simultaneous release was made in Greece*]

The Public Power Corporation of Greece and the United Kingdom Atomic Energy Authority have decided to build a nuclear power station from Britain in Greece.

To this effect, a protocol has been signed with the approval of the British and Greek Governments, whereby the Public Power Corporation will purchase a nuclear power station of approximately 450 megawatts (electrical) of the Steam Generating Heavy Water type from the U.K.A.E.A. and a long-term credit will be granted to the Public Power Corporation for this purpose.

The station, which is due to achieve full power during 1974, will be built at a site near Lavrion (30 miles south-east of Athens).

In parallel and simultaneously, the protocol provides for the sale by the Greek Tobacco Board of 40,000 tons of neutral-type Greek tobacco to Britain under a long-term exclusive contract with United City Merchants, Ltd., of London, for the use of Greek tobacco by the United Kingdom tobacco industries.

1st May, 1969

Co-operation with Austria

[*A similar release was issued in Vienna*]

To strengthen the existing and long-established co-operation between Austria and the U.K. in the peaceful uses of nuclear energy, an exchange of letters took place on 5th May, 1969 between Dr. John Hill, the Chairman of the U.K.A.E.A., and Dr. Richard Polaczek, the Head-of-Department in the Federal Chancellor's Office responsible for the co-ordination of questions of nuclear energy.

This action formalises co-operation between the two countries involving the exchanges of reports, meetings, visits and the secondment of staff.

For some years now there has been active co-operation between the competent Austrian authorities and the United Kingdom Atomic Energy Authority. Contacts between the authorities dealing with nuclear energy in the two countries have also been promoted by Austrian participation in the joint O.E.C.D. project of the DRAGON High Temperature Reactor at Winfrith, Dorset, and by visits of Austrian experts to British nuclear power plants.

8th May, 1969

Dounreay Materials Testing Reactor

As part of the continuing process of making sure that the effort of the Atomic Energy Authority matches fresh needs as they arise, the Dounreay Materials Testing Reactor (DMTR) has been closed and the staff transferred to other work on the Dounreay site—mainly to the team which is being set up to commission and operate the new prototype fast reactor.

The closure of DMTR is part of a plan announced in May 1968 to reorganise materials testing facilities and thus reduce annual operating costs by £¾m.

The DMTR had operated for eleven years. There was a short ceremony today (May 12), when the Director of the Dounreay Experimental Reactor Establishment, Mr. Peter Mummery, pressed the control button which shut down the reactor for the last time.

12th May, 1969

Enzyme assay

The use of radiochemical methods of assaying enzymes has greatly increased with the development of new techniques and better availability of labelled compounds. It is often the preferred method, and sometimes the only practical method of measuring enzyme activity in routine analyses or in single investigations.

For the best results the labelled substrates have to be carefully prepared with a precise composition, and it has been customary for each worker to do this for himself, relying on the general supply of labelled compounds for the radioactive constituent.

The Radiochemical Centre has published a technical bulletin, introducing a series of carbon-14 labelled substrates that have been designed to give reliability, precision, economy and convenience in this particular application. Copies of the technical bulletin, No. 69/3, "Labelled Substrates for Enzyme Assay", are available from The Radiochemical Centre, Amersham, Berks.

IN PARLIAMENT

Uranium supplies

14th April, 1969

MR. KELLEY asked the Minister of Power if he has considered the recent survey of uranium production and demand, made by the European Nuclear Energy Agency, details of which are in his possession; and whether a shortage of uranium in the future as envisaged in that report will be fully assessed before any further nuclear power stations are built.

Mr. Mason: The Atomic Energy Authority are responsible for the procurement of uranium. I understand they have studied this report, but that they do not interpret it as envisaging a shortage of uranium. Prospects for future prices of all kinds of fuel are factors which I would take into account in reaching a decision on a proposal to build a particular power station.

Ship propulsion study

15th April, 1969

MR. WALL asked the Minister of Technology if he will make a further statement on progress over negotiations for a prototype nuclear propelled merchant ship.

Mr. Fowler: In the light of information received from shipbuilders and others, we have decided to make a study of probable costs and benefits of Government support for a nuclear ship project. We shall talk to interested parties during the course of the study.

Gas centrifuge process

16th April, 1969

MR. DAVID PRICE asked the Minister of Technology if he will make a statement on his plans for joint Anglo-Dutch-German co-operation in the development of gas centrifuge processes for uranium enrichment.

Mr. Benn: Discussions have continued between the three countries since the Ministerial meeting of 11th March in London. A number of issues remain to be settled before the Governments concerned will be in a position to reach decisions and I will make a statement at that stage.

Mr. Price: In the interim, will the right hon. Gentleman inform the House whether his Department and the A.E.A. are of the view that the gas centrifuge process is, on total cost evaluation, to be preferred to the traditional diffusion separation process?

Mr. Benn: Broadly speaking, the reason why there is such interest in the gas centrifuge system is that its operating and capital costs show an advantage, and it is on this basis that the three countries concerned began their discussions. I hope that we can bring this to a conclusion, subject always to the economic criteria which I have rigidly laid down both for international collaborative ventures and at home.

Fast reactors

16th April, 1969

MR. EADIE asked the Minister of Technology what is his estimate of the extent to which Great Britain is ahead in research for rapid reactors compared with other countries; and what discussions have been held with other European governments about technological co-operation in this field.

Mr. J. P. W. Mallalieu: With the possible exception of the Russian reactor at Shevchenko, the United Kingdom's prototype fast reactor at Dounreay will be first in operation by several years. The only other prototype under construction is in France, where work has just commenced. These reactors are all sodium-cooled. The United Kingdom is engaged in discussion in the European Nuclear Energy Agency as to the possibility of joint European study of the gas-cooled fast reactor.

Carbon fibre

16th April, 1969

MR. RANKIN asked the Minister of Technology what steps are being taken to conserve United Kingdom interests in carbon fibre, in view of its importance in the development of aircraft.

Mr. Fowler: In collaboration with other Government Departments, the A.E.A., and industry, the Department is continuing an extensive research and development programme in carbon fibre technology. This should ensure that a leading position is maintained in both carbon fibre and composite materials incorporating the fibre, at present mainly for aerospace applications. Through the medium of N.R.D.C., licensing arrangements have been made with industry with the intention of securing the maximum economic benefit for this country.

16th April, 1969

MR. HORDERN asked the Minister of Technology when he will reply to the Report of the Select Committee on Science and Technology on carbon fibres; and if he will make a statement.

Mr. Fowler: The Report of the Select Committee on Carbon Fibre Technology is now being studied in detail by the Department. For some time, in collaboration with N.R.D.C., we have been exploring with industry how best to establish a large-scale plant for producing carbon fibre in the United Kingdom which was one of the main recommendations of the Report. The importance of carbon fibre technology is fully recognised and my right hon. Friend will inform the House of his considered views at the earliest opportunity.

PFR delay

16th April, 1969

MR. HECTOR HUGHES asked the Minister of Technology if he will set up a public inquiry into circumstances which have led to the delay of one year in the completion of the new prototype fast reactor at Dounreay, with special reference to work of the engineers employed there and including an assessment of the extent of the consequential loss in money and production to the economy.

Mr. J. P. W. Mallalieu: No. The delay is due to technical difficulties in the fabrication of the radiation shield roof. These difficulties do not concern the fast reactor system as such but only the constructional engineering involved in this one project. Contractors' engineers, and to a certain extent Authority design engineers, have been involved in the technical difficulties, but not A.E.A. engineers permanently based at Dounreay.

Capenhurst

16th April, 1969

MR. BROOKS asked the Minister of Technology whether he will now make a statement on the consequences for the Capenhurst gaseous diffusion plant of the decision to embark upon the gas centrifuge process of uranium enrichment.

Mr. Benn: The gaseous diffusion plant at Capenhurst will continue to supply enriched uranium for many years. Provided that development work continues satisfactorily, the gas centrifuge process will be used to supplement it by providing the additional enrichment capacity which will be required to meet the United Kingdom's needs for enriched uranium in the 1970s.

Mr. Brooks: Will my right hon. Friend clarify the future of the enrichment company which is proposed? Will he say where and when the headquarters of this company will be set up? Will it have power over the production pricing of the enriched uranium which will come from the traditional diffusion process?

Mr. Benn: I can tell my hon. Friend that there would not be a link between our existing diffusion arrangements and the new tri-partite arrangements which might come from the discussions. Beyond that it is too early to say what the detailed arrangements will be or finally where all the relevant plants and managerial headquarters will be.

Mr. Lubbock: Up to what date will the diffusion capacity now being added at Capenhurst meet the requirements of the United Kingdom? Can the Minister say what the time scale of the centrifuge development will be and whether the centrifuge production will come on stream in time to meet the requirements of the Central Electricity Generating Board for enriched fuel?

Mr. Benn: I cannot answer in detail, because we are in the middle of talks. But the timetable of the talks with our partners in Holland and Germany is related in our minds to providing enriched uranium in time to meet these needs. This is what has led us to go on with some speed. On the detailed question about the date on which the Capenhurst facilities will expire, it depends whether we need the uranium from them. Physically they will last for some time.

AEA research costs

21st April, 1969

MR. MARPLES asked the Minister of Technology if he will give a breakdown of the total cost in 1968-69 of civil research and development by the Atomic Energy Authority, exclusive of the net cost of Atomic Energy Authority research establishments.

Mr. J. P. W. Mallalieu: The Authority's accounts for 1968-69 are not yet available. An estimate of expenditure on civil research and development, including non-nuclear (£3 million), is £58 million in terms of full commercial costs. The net cash costs of the Authority's civil R. & D. establishments in that year as given in my reply of 4th February were estimated to amount to nearly £30 million. The balance of some £28 million is broadly attributable as follows:—

	£ million
Expenditure on international projects	2
Interest, depreciation and other non-cash items at the Authority's civil R. & D. establishments	18
Expenditure at other Authority sites	8

Power station programme

22nd April, 1969

MR. EMERY asked the Minister of Power if he will list the sites of nuclear power stations now built or proposed together with details on the fuel used, and the estimated unit cost of electricity now based on a 25-year life of the plant.

Mr. Freeson:

Existing C.E.G.B. power stations

Berkeley.
Bradwell.
Dungeness A.
Hinkley Point A.
Oldbury-on-Severn.
Sizewell.
Trawsfynydd.

Stations under construction

Dungeness B (0·56d.).
Hartlepool (0·52d.).
Hinkley Point B (0·52d.).
Wylfa.

The figures in brackets are the estimated base-load generating costs of A.G.R. stations using enriched uranium, based on a 25-year life and 8 per cent. interest, and assuming a 75 per cent. load factor. The C.E.G.B.'s decision to adopt a 25-year life for A.G.R.s does not apply to earlier nuclear stations using natural uranium.

Wylfa

23rd April, 1969

MR. MCGUIRE asked the Minister of Power when he now expects the Wylfa nuclear power station to come into operation; what extra costs will arise from the delay; and what is the latest estimate of the cost per unit sent out from this station.

Mr. Mason: The C.E.G.B. inform me that the station is expected to come into operation early in 1970 and that estimates of the cost of delay cannot be readily broken down to individual stations; their estimate of base-load generating cost per unit remains at 0·70d.

Consortia

23rd April, 1969

MR. EDWIN WAINWRIGHT asked the Minister of Technology if he will give the names of the firms in the two consortia which have been set up to design and construct nuclear reactors and power stations at home and abroad.

Mr. Benn: The two nuclear design and construction companies are the Nuclear Power Group (T.N.P.G.), and British Nuclear Design and Construction Ltd. (B.N.D.C.). The firms which have shareholdings in them are:

T.N.P.G. (The Nuclear Power Group)

Reyrolle Parsons.
Sir Robert McAlpine.
Clarke Chapman.
John Thompson.
Head Wrightson.
Strachan and Henshaw.
Whessoe.

B.N.D.C. (British Nuclear Design and Construction Ltd.)

Babcock and Wilcox.
English Electric (i.e., General Electric and English Electric Co.).
Taylor Woodrow.

The Atomic Energy Authority and the I.R.C. also have shareholdings in each.

Uranium supplies

29th April, 1969

MR. EADIE asked the Minister of Power what study he has made of the survey of uranium supplies made by the European Nuclear Energy Agency and the International Atomic Energy Agency, a copy of which is in his possession; and whether he still expects nuclear power stations to be competitive with those using coal.

Mr. Mason: I see no reason to change

the assumptions about relative generating costs outlined in the Fuel Policy White Paper (Cmnd. 3438), and would refer my hon. Friend to the reply I gave to my hon. Friend the Member for Don Valley (Mr. Kelley) on 14th April.

Mr. Eadie: Does not my right hon. Friend agree that the expected world shortage of uranium supplies could affect our nuclear energy programme? Does not he further agree that it is, therefore, desirable to have a complete reappraisal of the use of coal, our own indigenous resource?

Mr. Mason: Questions about the availability of uranium should go to my right hon. Friend the Minister of Technology and not to me, but I understand that stocks plus imports under existing contracts are likely to meet our requirements until well into the 1970s and that no significant increase in the price of uranium is expected over the next five years.

Advanced gas-cooled reactors

29th April, 1969

SIR. J. EDEN asked the Minister of Power what consultations he had with the Central Electricity Generating Board before the ground rules for advanced gas-cooled reactors were changed; and when the decision was taken.

Mr. Mason: I have been aware since my early discussions with the C.E.G.B. in the summer of last year that a change was under consideration. The C.E.G.B. formally notified me of its decision last month.

Sir J. Eden: In view of the strong argument and discussion which is now taking place between the Coal Board and the C.E.G.B. as to the costs of nuclear power versus coal-fired stations, does not the right hon. Gentleman think that it was disingenuous, to say the least, to have allowed the ground rules to be changed and go through as a footnote in Written Answer rather than making a proper declaration to the House about which industries are concerned?

Mr. Mason: No, I did not think that was so. It has been under consideration for some time and could have been announced prior to the Seaton Carew decision, but if the C.E.G.B. had done it then and I had informed the House, it would have been charged with being biased. There is always this difficulty over nuclear or coal-fired stations as to when the announcement should be made, but I did not think it warranted a statement to the House just before the Board had changed one of its ground rules.

A.E.A. expenditure

30th April, 1969

MR. MARPLES asked the Minister of Technology if he will give a breakdown of the £18 million which is spent on interest, depreciation and other non-cash items at the Atomic Energy Authority's civil research and development establishments.

Mr. J. P. W. Mallalieu: An approximate breakdown of the £18 million which is spent on interest, depreciation and other non-cash items at the Atomic Energy Authority's civil research and development establishments is as follows:—

	£s million
Interest	6
Depreciation	9
Superannuation	2
Other items (including insurance)	1

Adaptive control of machine tools

The Ministry of Technology is supporting an investigation into the adaptive control of machine tools—built-in controls which adapt the machine tool to changing conditions as metal is being cut, giving faster machining times. One aim of the project is to provide a link between machine tool manufacturers, users, research establishments and University research.

Mintech has placed a £50,000 contract for the investigation with the United Kingdom Atomic Energy Authority's Atomic Weapons Research Establishment at Aldermaston.

The contract provides for work at AWRE, Aldermaston, and research at other organisations which have expertise on some of the problems involved.

Work at AWRE will be on machinability—investigating the factors which affect cutting performance, tool wear and workpiece quality—and on sensor development—developing methods for measuring cutting force, assessing vibration levels and measuring surface finish while the metal is being machined.

Non-destructive testing

This paper, by R. S. Sharpe, Project Manager of the Nondestructive Testing Centre, Harwell, was presented at the Ninth Commonwealth Mining and Metallurgical Congress in London on 9th May, 1969, and is published by courtesy of the organizers.

Synopsis

The range of techniques available for non-destructive testing is indicated, and areas in which there is active development are highlighted. Areas in urgent need of further attention are discussed.

The organization and operation of the Nondestructive Testing Centre are described, and the nature and significance of some of its development programmes are discussed.

Introduction

The idea that non-destructive testing is an expensive, time-consuming and unprofitable appendage to design and production still lingers on in many quarters. It arises from a misguided philosophy that the techniques have been specifically developed 'to detect scrap'—an approach to quality and the true concept of materials testing that is as negative as one could imagine. Such an attitude to its use; the outdated understanding of many

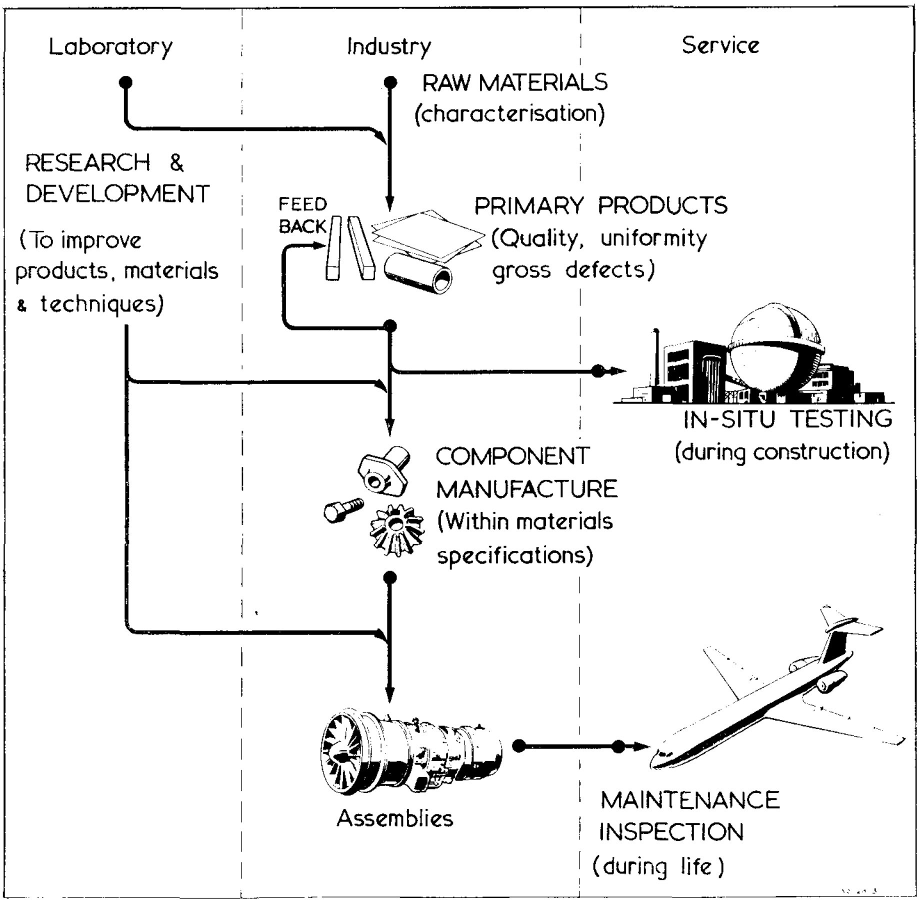

Fig. 1 *Application of nondestructive testing (each black spot corresponds to an area of application)*

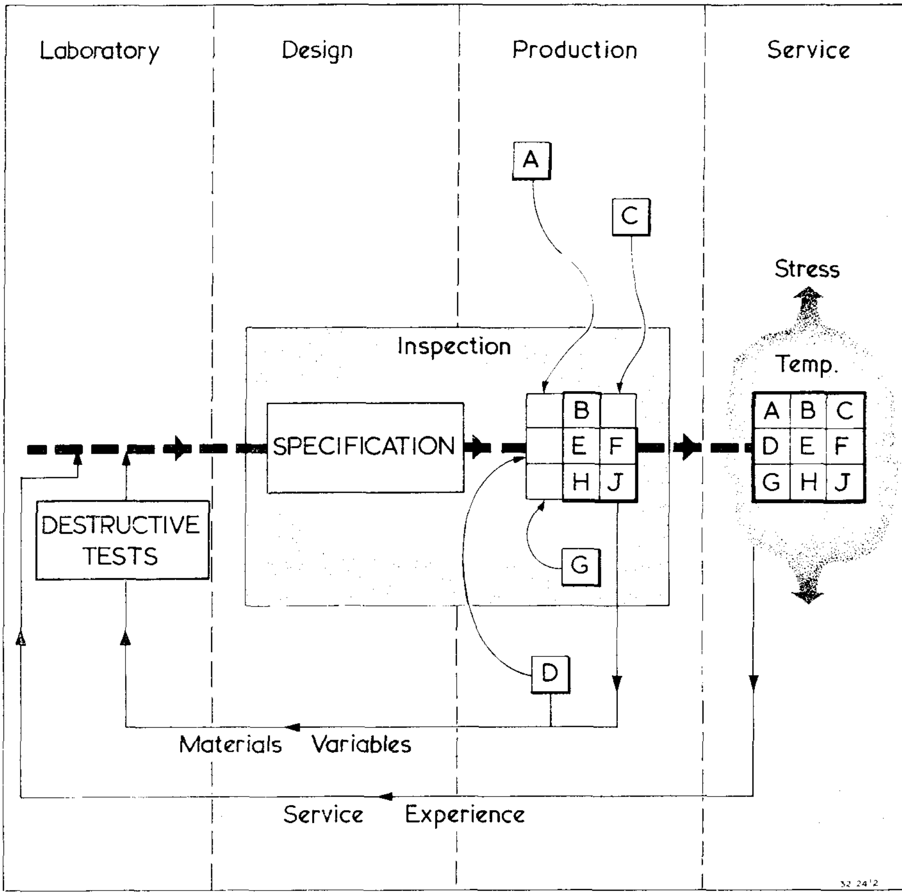

Fig. 2 *Evolution of nondestructive testing techniques showing the essential information feedback loops from production and service.*

managements of its significance; the slow introduction of training courses and a nationally accepted operator certification scheme; and the poor support from academic and research centres have fostered a feeling that the subject—and those who practise it—are the poor relations of the metallurgical fraternity. Unfortunately, many of these anti-attributes do exist but, despite them and despite the associated scientific stigma that they have engendered, the subject is now a very live and active branch of materials science.

It is the purpose of this paper to identify and underline the positive side of the subject; to outline and interpret current development areas; and to forecast how and where non-destructive testing, both as a subject and as an industrial practice, is likely to expand.

Non-destructive testing is widely practised in all industries. In primary fabrication processes, techniques have been developed to ensure that the product is of consistent quality and free from gross defects; the possibility of incorporating the techniques into feedback loops for process control is a logical development. In component manufacturing non-destructive testing is an essential pre-requisite to ensure that all variables likely to influence subsequent performance are within design specification and to ensure a product of uniform quality; *in situ* testing is called for when installations or structures are being built to tight civil or mechanical engineering standards or to the requirements of insurance company specifications; in-service surveillance and maintenance inspection are areas of growing interest, since the detection of incipient failure, the location of materials

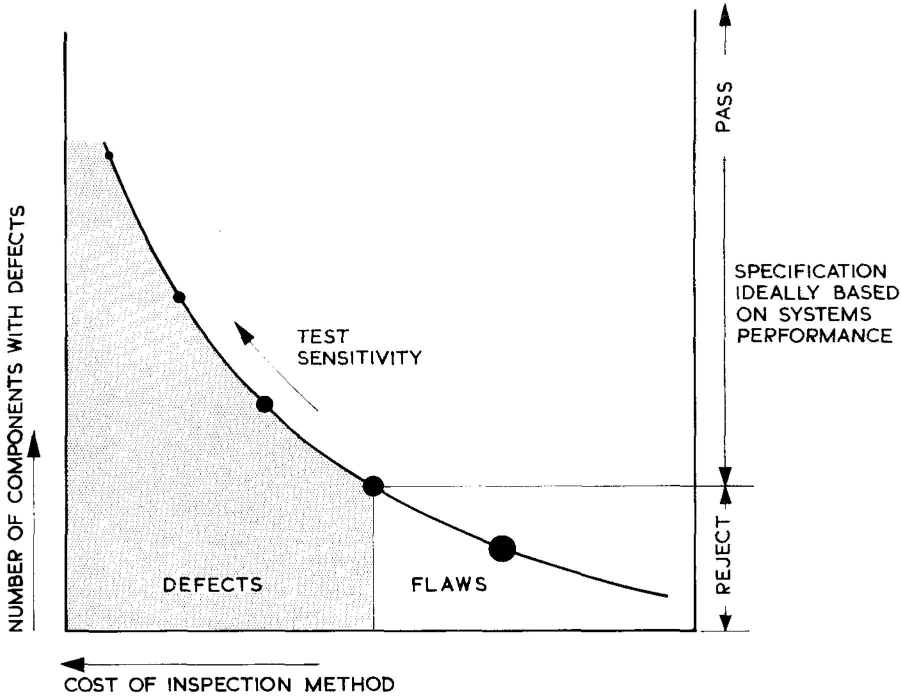

Fig. 3 *Economic importance of setting a realistic specification to distinguish between harmful 'flaws' and acceptable 'defects'.*

degradation and the monitoring of growing cracks are often essential to safe and economic operation. The techniques of non-destructive testing can also be used in the research and development stages to suggest ways of improving a product or process (Fig. 1).

Non-destructive testing techniques generally evolve in the laboratory and are most effective when they result from co-operation between the materials, engineering and instrumentation interests. In the design department of a company the techniques are married to the product and a test specification is prepared. It is then generally the responsibility of the inspection department to implement this in production (Fig. 2). Feedback of information and experience from the production shop and from in-service performance should continuously be used (in conjunction with supporting laboratory tests) to improve and update the inspection techniques and modify the test specification. Only by employing closed feedback loops in this way can non-destructive testing techniques be effectively and efficiently used—without them there is a tendency for the development of non-destructive test techniques to develop out of context with requirement and for undue sophistication to be built into the methods and the objectives (Fig. 3).

Non-destructive testing in perspective

The decision as to what variables to control and what properties to monitor is a very difficult one and still relies largely on a mixture of subjective elements such as intuition and experience. Naturally, cracks and other discontinuities are fairly obvious objects of suspicion, although they are, in fact, only one of a large number of materials variables that need to be examined (Fig. 4). This dominant interest has tended to bias the way non-destructive testing and its associated techniques have developed. Indeed, 80-90% of all non-destructive testing carried out today is probably still orientated to the concept of 'crack detection'.

If the factual information were available, poor or inadequate design, unwise choice of materials or lack of appreciation of service conditions might be found to account for 75% of all service failures.

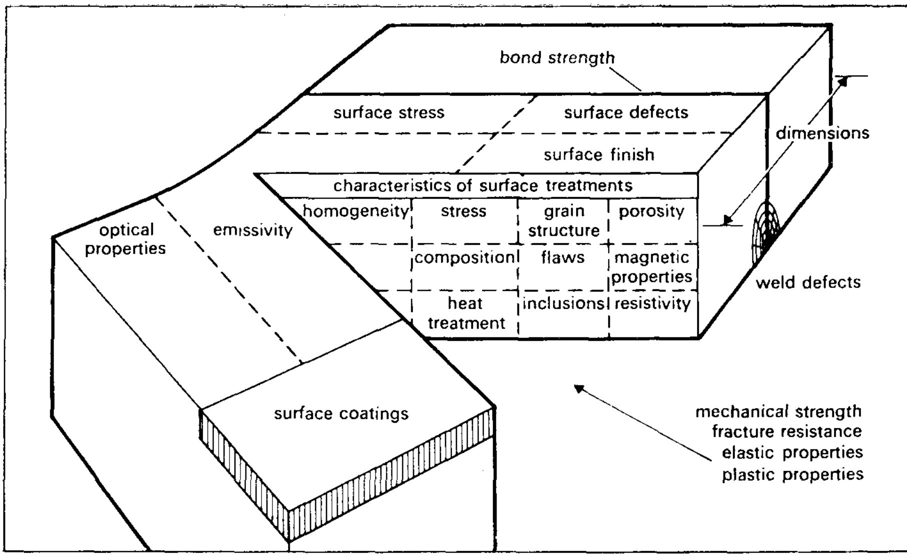

Fig. 4 *Scope of non-destructive testing indicating range of materials variables that can influence mechanical strength.*

Even considering the minority, only a small proportion could probably be traced to defective materials as distinct from, say, faulty assembly or bad workmanship. It is worth viewing nondestructive testing against this broader background to bring the subject and its application into perspective. Having said this does not, of course, downgrade the importance of nondestructive testing in locating out-of-specification materials. Almost invariably, materials flaws are difficult to locate and difficult to identify, and, even more important, their presence is usually difficult to forecast: their significance, of course, may be quite unpredictable in quantitative terms, until service experience can be amassed or a complementary programme of destructive tests mounted.

Nondestructive testing techniques

Techniques to detect surface flaws are relatively simple in that many of them only supplement what can already be achieved by visual inspection. In fact, penetrant and flaw detection techniques can be looked upon as methods to focus attention on individual flaws whose detection visually or optically without such aids would be very slow and painstaking. Fig. 5 shows a range of techniques now available for detecting surface flaws. The choice of technique depends on the material, the accessibility and the sensitivity required.

For ferrous components the magnetic flux leakage method is as versatile and sensitive as any if the magnetizing current or magnetizing field is correctly applied and of adequate strength; dc resistivity and eddy current methods can be equally sensitive, but are inherently less selective in that many other metallurgical factors can influence surface resistivity and produce consequent background 'noise'. In the case of eddy currents, multi-frequency excitation and

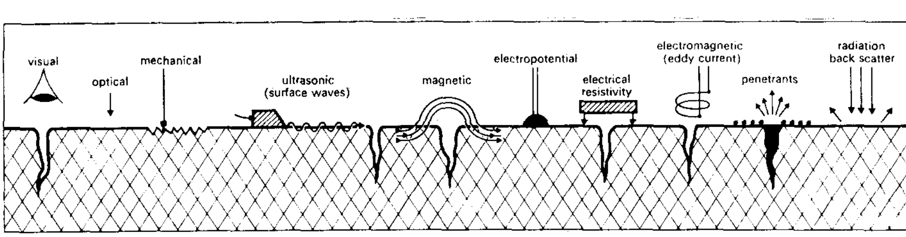

Fig. 5 *Methods of inspecting surfaces non-destructively.*

facsimile recording are being used to provide better discrimination and, hence, make the defect interpretation more reliable.

For internal defects the problems of inspection are obviously far more difficult in that all of the information must be gleaned by interpreting the modulation or modification of a beam of radiation, an electric current or a magnetic field introduced into the component.

Fig. 6 summarizes the types of interaction that can occur between the probing beam and the 'defect' and these collectively form the basis of a very wide range of testing techniques. The incident beam can be X-rays, γ-rays, neutrons, β-particles, infrared radiation, microwaves or sonic or ultrasonic vibrations excited in a variety of modes.

Once inside the material, velocity, attenuation or dispersion of the primary beam may be used to identify structural variables. At a discrete 'defect' forward or backward scatter is also generated and this, as well as the transmitted beam, contains information which can be analysed and used to determine the characteristics of the 'scatter centres'. These signals will be masked to varying degrees by background scatter or 'noise' which is generated by second-order variations in the structure. The transmitted beam will also contain a lot of unmodified signal which will dilute the 'defect' information in the modulation. Thus the choice of technique and the method of detecting the information and extracting unwanted 'noise' requires considerable understanding of the characteristics of the material and, in many cases, sophisticated instrumentation to give unambiguous interpretation.

These techniques have, in the past,

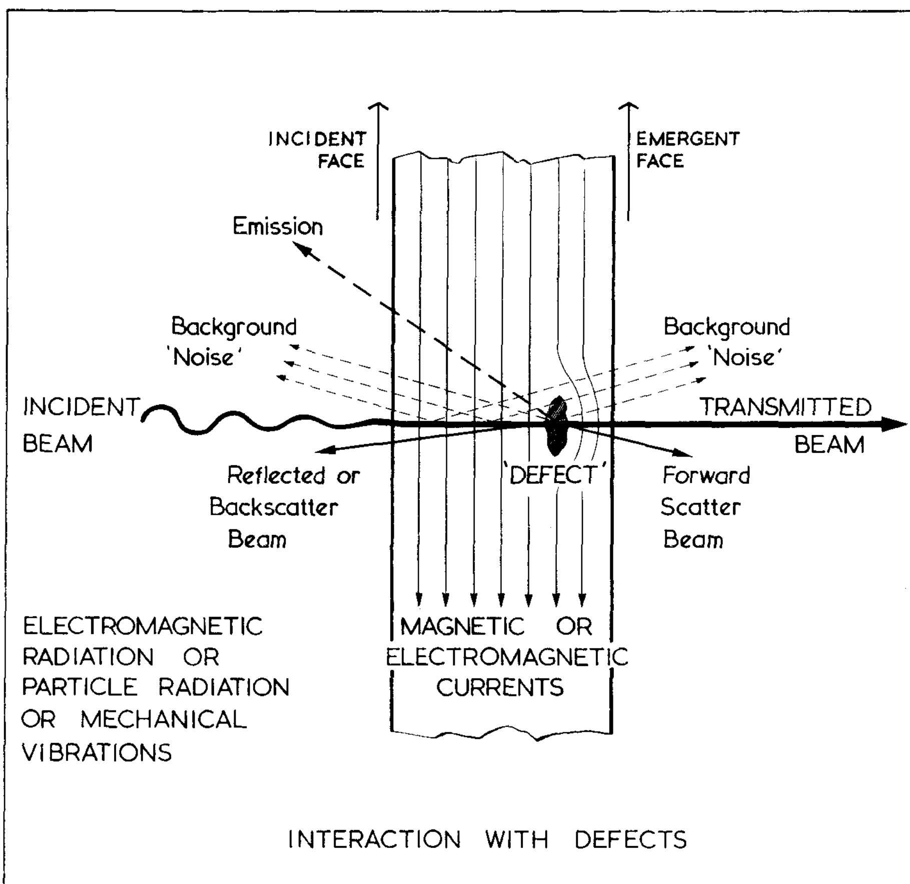

Fig. 6 *Interaction effects on which nondestructive methods of internal flaw detection are based.*

tended to concentrate on detecting singular flaws such as internal cracks, inclusions or lamination, but interest is now being aroused in the study of the 'noise' itself to monitor micro-structural variations such as grain size, preferred orientation or internal stress.

Instead of a probing beam of radiation, electric currents and magnetic fields can often be induced into a component without the need for any contacts, and these again will be modified in intensity and their flow patterns perturbed by internal flaws or structural variations.

A different method again of detecting internal flaws is to study the sonic or ultrasonic emissions that they generate when stressed. In fact, the whole subject of acoustic emission, as it is called, is a wide-open field for further development. It provides a very positive and sensitive means of detecting internal deformation processes (which may or may not be associated with existing internal defects) without the need for any externally applied probing beam at all. It has already been used, in conjunction with a proof test, to determine the co-ordinates of regions of weakness and potential failure in welded pressure containers and is currently being used to monitor the strength of adhesively joined assemblies.

Non-destructive testing is concerned with the mechanisms of these interactions: with the design and operation of the transducers required to transmit and receive the energy; with the signal processing required to extract and present the information in as positive and decisive a way as possible; and, finally, with the quantitative interpretation of this information in terms of structural discontinuities and materials variability.

Current developments

Some of the current areas of development in non-destructive testing can best be illustrated by considering two basic techniques—radiography and ultrasonics.

Radiography

This is one of the early techniques of non-destructive testing and relies on the use of a beam of penetrating radiation to detect internal flaws. In its usual form the transmitted radiation is recorded on a photographic film and variations in photographic density are interpreted in terms of variations in absorption in the path of the beam. The sensitivity of the technique depends on the wavelength of the radiation (and, hence, kilovoltage in the case of an X-ray tube), the density and thickness of the material (which contribute to background scatter or 'noise') and the characteristics of the film. The definition of the image depends on the size of the source of the radiation and the geometry of the radiographic arrangement. The interpretation of a radiograph is thus very dependent on the variables of the test itself and these must be carefully controlled and identified on each radiograph by means of image quality indicators.

There is a considerable amount of current development work in radiography, and the areas of primary interest are detailed in Fig. 7.

Field emission X-ray tubes now make it possible to obtain high bursts of radiation in as short a time as 75 nsec for very high speed single shot radiographs of dynamic processes. When a dynamic process needs to be studied over a period of time, however, there are advantages in using sequential ciné photography of a fluorescent screen image. This inspection technique has been applied to the study of metal casting procedures and illustrates the use of nondestructive testing in the development stage of a process in order to understand the mechanism of the process so that a more consistent and satisfactory product can be assured. As alternatives to film recording, a number of image intensifier systems and television viewing methods have been specifically developed for radiography. An electronically scanned Vidicon tube directly sensitive to X-rays is now in use that does away entirely with the need for an intensifier screen and, hence, results in considerably enhanced resolution while still retaining the advantages of a non-film type of radiographic presentation. Semiconductor plates have been used instead of film in the technique known as xeroradiography and, although there has been no widespread interest in this technique in its present form, it is the forerunner of solid state intensification panels which are being developed for all forms of radiation and which, if successfully exploited, may find widespread application.

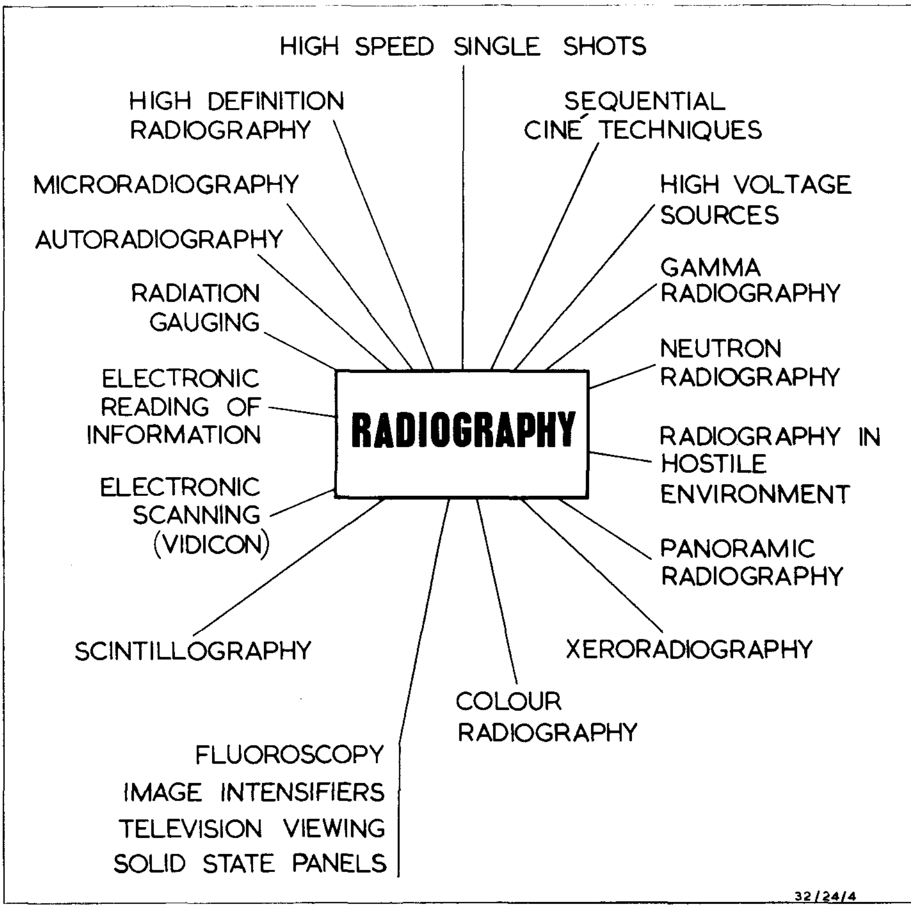

Fig. 7 *Areas of current development in radiography.*

A range of linear accelerators and betatrons is now commercially available for radiographic application in the range 1-30 MeV for thick sections. For site radiography, where these large static installations are of limited use, a wide range of radioisotope sources is now in widespread use, covering an energy range of from 60 keV to 2 MeV.

Very high definition radiography is now possible using ultrafine focus X-ray tubes (1-10 μm) with very high specific loadings ($\sim 10^6$ W/cm^2). The ultimate in definition (~ 0.1 μm) can be achieved in microradiographic techniques at the lowest kilovoltages (10-25 kV) using thin slivers of metal as a semi non-destructive test. On sheet metal and miniature electronic components extremely high definition is possible with medium kilovoltages ($<$ 100 kV) using special X—ray sources in which the electron beam is magnetically focused on to water-cooled targets.

Considerable interest is currently being shown in the use of thermal and epithermal neutron beams for radiography instead of X-rays or γ-rays. The absorption characteristics of neutrons are very different from X-rays and these lead to applications (such as detecting hydrogen-containing materials) which are virtually impossible by any other technique.

Neutrons do not directly produce an image on a photographic plate and the technique usually employed is to 'transfer' the image by means of a metal foil on which the image is first impressed by an activation process. This technique has also led to neutron radiography having considerable potential as a means of radiographing extremely radioactive fuel elements and irradiation rigs. This particular problem of radiographing components in the 'hostile environment' of a high gamma-radiation background has also led to techniques of panoramic scanning, the use of colour films and the development of photographic emulsions with a large sensitivity differential at the two ends of the energy scale (more sensitive to X-rays, less sensitive to γ-rays).

Ultrasonics

Ultrasonics first came into prominence during the second world war to locate hairline shrinkage, which was not detectable by radiographic methods. As usually applied, pulses of ultrasound (0.5-15 MHz) are launched into the metal either as a compressional wave or a shear wave. Part of the energy will be reflected from internal defects and, if these are suitably orientated, the energy can be picked up in a receiver transducer. The time of transit of the pulse gives the range of the defect and the amplitude of the returning pulse contains information about the size, shape, orientation and nature of the defect.

Ultrasonic testing techniques have generally found less favour because of the basic difficulty of flaw interpretation associated with the methods of data presentation currently used, which have not materially advanced during the past twenty years. Fig. 8 shows the ways in which developments are currently being channelled to improve and extend the techniques and make them less operator-sensitive.

Ultrasonic image converters (ultrasonic cameras) have been developed to give a facsimile presentation of the energy pattern direct on to a T.V. monitor tube. This provides a high-speed method of inspection but, as its use is at present limited to continuous wave ultrasound, the technique can only be used to inspect

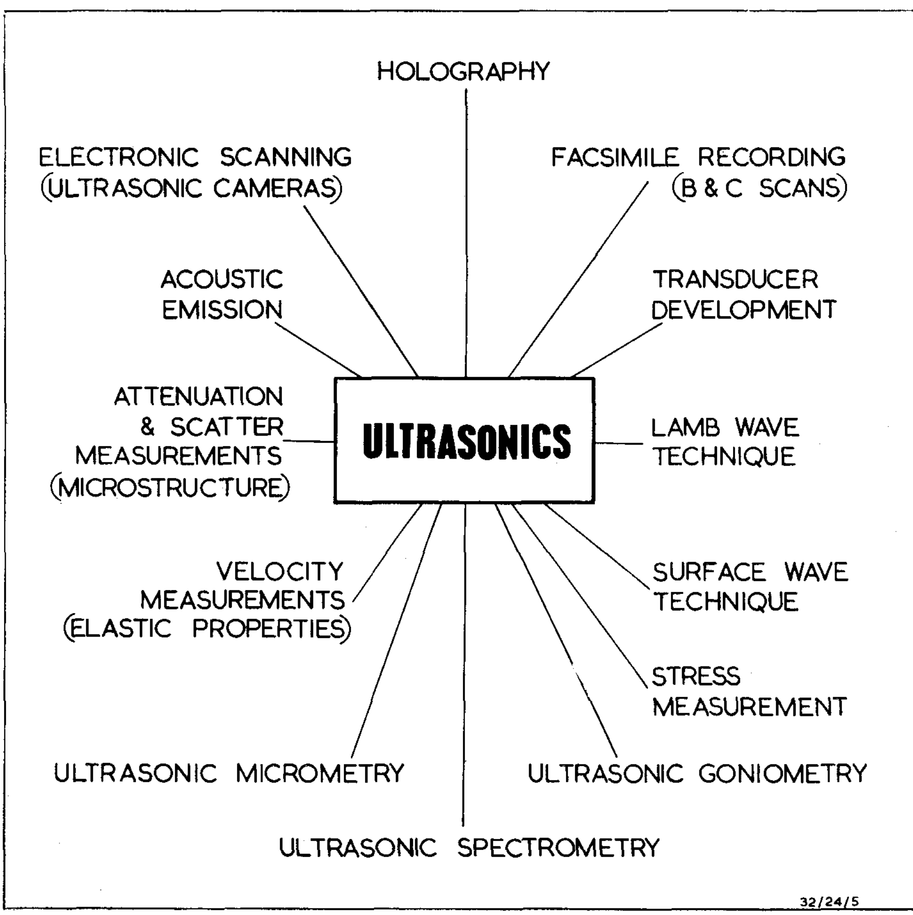

Fig. 8 *Areas of current development in ultrasonics.*

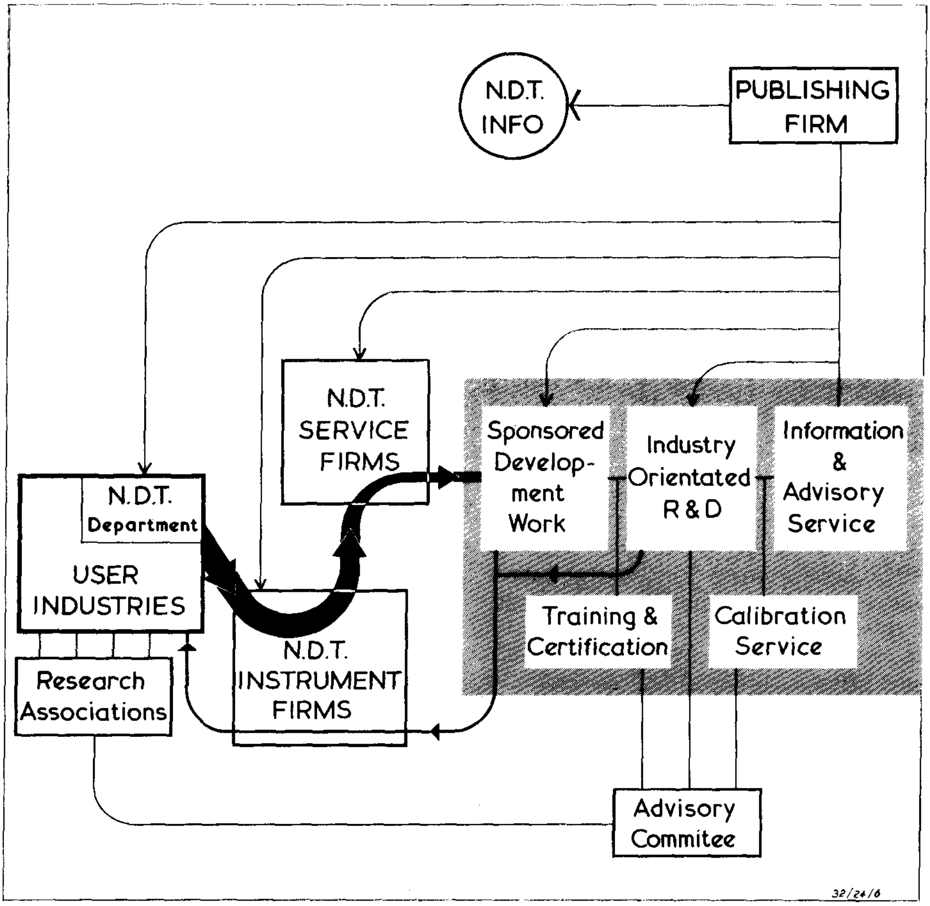

Fig. 9 *The Nondestructive Testing Centre (shaded) and its interrelation with industry and other organizations.*

thin plate samples. Potentially a more versatile technique is ultrasonic holography, in which both phase and amplitude of the returning signal are recorded as a hologram which can then subsequently be reconstructed to give the maximum possible amount of information about the internal 'scatter centres'. Frequency analysis of the returning pulses (ultrasonic spectroscopy) is also being used to provide additional information about internal defects, since reliance on amplitude variations alone—as generally practised—very much limits the usefulness of ultrasonic testing.

Transducers are necessary to generate and receive the ultrasonic pulses and these are receiving considerable attention. Greater sensitivity, high definition, higher frequency, more efficient coupling and higher-temperature operation are all being studied. Attention is also being given to obtaining greater uniformity of response and to methods of characterizing and testing the performance of the probes themselves. Air-coupling techniques are now being developed to supplement the more usual contact and liquid coupling techniques.

Lamb waves and Rayleigh waves are being used to extend the scope of ultrasonic testing on to thin sheets and surfaces respectively. A very promising area of development here is the precision monitoring of reflection amplitudes (ultrasonic goniometry) as a means of sensitively monitoring variations in surface properties such as stress, hydrogen content and hardness.

Velocity measurements and associated resonant frequency measurements are being used to monitor materials variables and dimensions and average body stresses can be monitored by measuring the velocity difference between shear waves polarized in two directions at right angles.

The attenuation of ultrasonic beams is dependent on a number of micro-structural variables and ultrasonic techniques form the basis of methods to monitor grain size variations and, on a more micro scale, to study dislocation densities.

The Nondestructive Testing Centre

A Nondestructive Testing Centre has been set up at Harwell to provide central research and development facilities for British industry (Fig. 9). The Centre has the following objectives: (a) to provide a comprehensive information and advisory service on every aspect of nondestructive testing; (b) to carry out sponsored research and development for industry under normal commercial arrangements; (c) to initiate industry-orientated research where a general need exists; and (d) to act as a focal point in such matters as education and training, operator certification, calibration and standardization.

In seeking to achieve these objectives the Centre's activities are periodically reviewed by an Advisory Committee. It also maintains strong links with research and trade associations, where appropriate, and works collaboratively with nondestructive testing instrument manufacturing firms and nondestructive testing service firms by supplementing what their resources can collectively provide.

The Centre is administratively part of the Materials Physics Division at Harwell, but its organization and staff spread across divisional boundaries so that the fullest direct use can be made of the specialized facilities and expertise available in the Electronics, Engineering and Isotope Research Divisions.

Programme of work of the Nondestructive Testing Centre

In the unsponsored area the programmes of work will vary to meet the medium- and long-term requirements of industry. One major programme at present is concerned with the inspection of fibre-reinforced composite materials, which are a constructional medium of growing interest and potential. An attempt is being made to identify the significant variables as regards the strength and serviceability of composites and to determine nondestructive methods of monitoring them. This work calls for the development of new ultrasonic and X-ray characterization techniques, and a careful analysis of the results of a supporting programme of destructive tests. It can be considered as an ideal approach insofar as the monitoring techniques will be related specifically to *significant* variables and the procedures will be developed in the laboratory while the materials themselves are still in the active stages of development. Since adhesion between fibre and matrix is a highly relevant feature affecting composite behaviour, the problem of adhesion testing is also being examined in much greater detail.

Apart from these materials aspects of nondestructive testing, the research and development programme is directed towards improving the technique and data analysis of the more conventional methods of testing. From the list of current research and development work at the Centre (see Appendix) it can be seen that many of the frontier areas is ultrasonics and radiography referred to earlier are, in fact, being studied.

By centralizing effort on nondestructive testing research and development in this way there is a hope that more rapid and more incisive progress will be made towards introducing the most appropriate inspection techniques into industry and ensuring that the lines of communication between, on the one hand, their requirement and, on the other, their application are kept as open as possible.

Appendix

Research and development programmes

The Nondestructive Testing Centre currently has the following unsponsored programmes of research and development in hand.*

Composite materials

To obtain an understanding of the structural features influencing the mecha-

(* The text of this paper was submitted to the Conference organisers in mid-1968 and since then some of the R. & D. programme objectives have been modified and extended to meet the changing interests and requirements of industry.)

nical strength of fibre-reinforced plastics and to define the physical properties which can be used to monitor them non-destructively.

Bond strength

To examine and analyse the factors contributing to bond strength; to study the significance of the bond variables with an analogue; and to try to improve methods of bond inspection of adhesive joints by monitoring both cohesive and adhesive strength.

Wave propagation across interfaces

To determine quantitative data on ultrasonic propagation across thin air-filled gaps and to interpret the results in terms of the significance to detecting laminar defects.

Microwaves

To review the subject and to set up experimental equipment to study the capability and potential of microwave techniques in non-destructive testing.

Ultrasonic transducers

To develop improved transducers—from the standpoint of the piezoelectric material characteristics, the mechanical design and the construction.

Characterization of ultrasonic test equipment

To develop and set up a range of testing procedures to measure the relevant characteristics of ultrasonic transducers; to define the relevant variables of ultrasonic test equipments.

Data handling

To experiment with advanced forms of data handling to remove the human element from assessment and interpretation of test results; to study computer handling of non-destructive testing data in relation to automated inspection.

Ultrasonic signal correlation

To apply correlation techniques to ultrasonic test signals in order to develop improved forms of flaw assessment.

Modular circuitry

To design a range of modular non-destructive testing equipment, using integrated circuits, to provide maximum flexibility for research and development work.

Ultrasonic propagation

To study wave propagation through materials containing highly scattering centres, by using suspended particles in liquid as a model in which the significant

continued on page 174

Group Technology Centre

With Ministry of Technology support, the Atomic Weapons Research Establishment of the United Kingdom Atomic Energy Authority has set up a Group Technology Centre at Blacknest, Brimpton, near Reading.

Group Technology is a new technique for identifying and grouping components of similar shape and production requirements which can be sequentially produced in batches with very little change in machine tool settings between each batch.

This grouping should lead to a reduction in the variety of components, encourage standardisation of designs and increase effective batch sizes so that economic advantages similar to those obtained from continuous flow-line production can be achieved.

There are several coding classification systems for identifying groups of components and development work in this field is still going on.

Because of its unique position in the field, the AWRE project will readily be able to keep abreast of the related developments and to evaluate the relative merits of systems under actual working conditions.

The centre is staffed with experienced design and production engineers from the Atomic Weapons Research Establishment, and has offices, a library, lecture rooms and the use of a conference hall.

It will offer training in group technology techniques and in the related techniques of information retrieval, production planning and work scheduling. Training will be sufficiently flexible to match the needs of industrial managers, and will consist of general and specialised lectures and tutorial courses arranged to meet specific requirements. An essential feature of the Centre's activities will be the emphasis on the practical application of group technology, and consultancy services will be available to assist industry to deal with particular problems.

The staff of the centre will seek the co-operation of selected industrial organisations in different parts of the country who are using group technology to provide prospective users in comparable industries with a fund of experience in the application of the techniques.

Gas sampling of fuel elements by laser piercing techniques

By W. Lilley, Engineering Support Division, A.E.R.E., Harwell.

As part of the A.E.R.E. research programme for the design and development of nuclear fuel elements, Metallurgy Division carry out post-irradiation studies to establish performance data which helps them to arrive at final designs of fuel elements. Gas sampling plays a very important part in these studies and it is for this purpose that a new gas sampling facility, using laser piercing techniques, has been designed by Engineering Support Division.

This article, which first appeared in Harwell Engineering Review, describes the work involved to produce a practical laser piercing system from information obtained during feasibility experiments.

Introduction

During the manufacture of a prototype encapsulated fuel element, a measured volume and pressure of gas (helium or

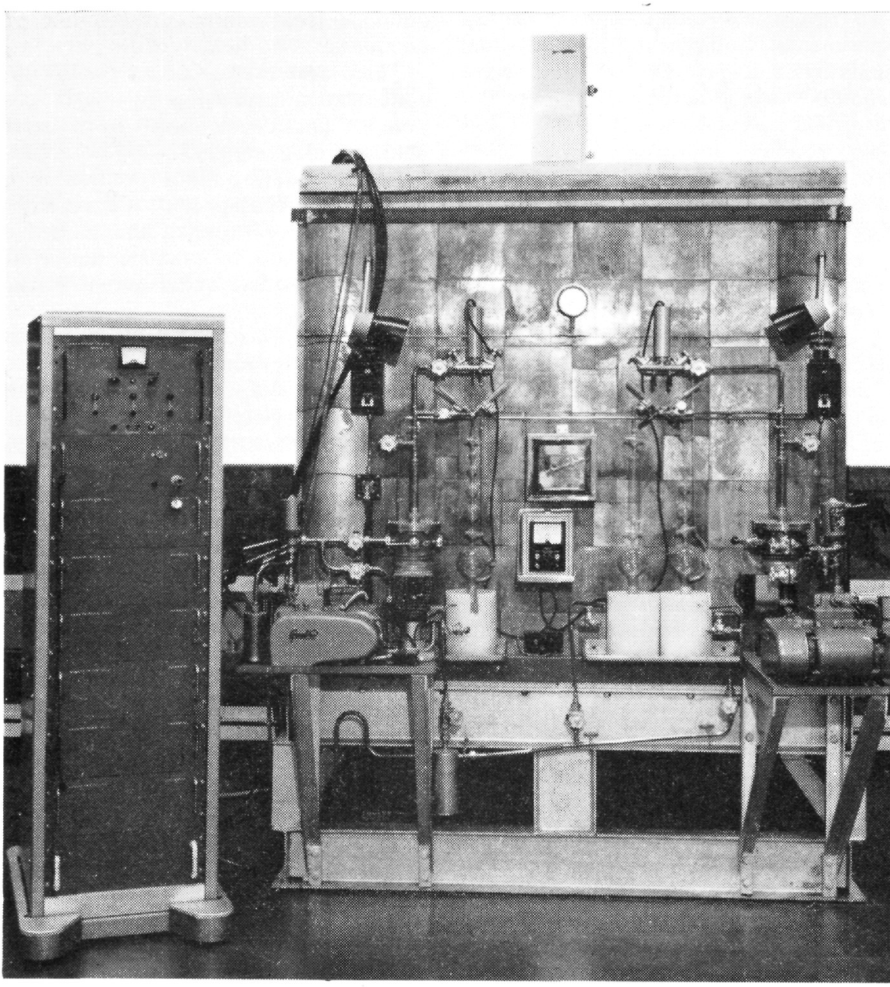

Fig. 1 *General view of the new cell for the gas sampling of irradiated fuel elements using laser piercing techniques.*

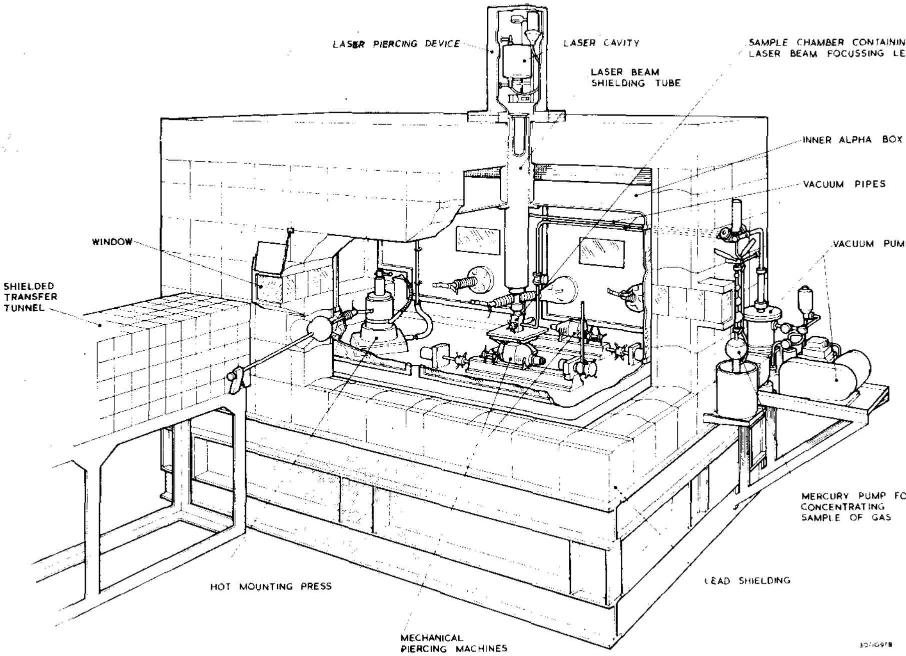

Fig. 2 *Diagrammatic layout of the laser piercing equipment. The mechanical drilling equipment is also shown.*

argon) is introduced before final sealing of the capsule. This gas improves the heat transfer between the fuel and capsule and is used for leak testing of the finished fuel element.

After a period of irradiation in a materials testing reactor the prototype fuel element is removed for metallurgical examination to provide information concerning the compatibility of both the fuel and the encapsulating material. By piercing the encapsulation under vacuum conditions and measuring the volume of the gas extracted it is possible to check the integrity of the capsule and calculate the maximum internal pressure to which the capsule has been subjected, provided no leak has occurred. Analysis of the gas sample establishes the type of gaseous fission products that have been produced and their effect both on fuel performance and on the encapsulating material.

Previously, gas samples were obtained by piercing the end caps of the capsules by mechanical drilling [1], a method which was restrictive in application and could not be applied to ceramic or cermet-encapsulated fuel elements.

Investigations into the feasibility of using a pulsed ruby laser beam for piercing fuel element cans were carried out at A.E.R.E. by M. R. Allen and J. T. Demant.

Design considerations

In their article [2], Allen and Demant recommended that the laser beam should enter the cell through a vertical wall.

Reappraisal of laser beam alignment and and focusing techniques, together with shielding and safety requirements, indicated, however, that it would be safer and simpler to enter the laser beam through the roof of the cell. Other facets that were considered essential for the success of a laser piercing facility include the following:—

1. Robust construction giving permanence of alignment and ease of adjustment to the laser unit and beam alignment system.
2. Accurate and permanent focusing of the laser beam.
3. Shielding of the operator from nuclear and laser radiation and, in particular, protection from laser flash to the eyes.
4. Safe operation of the high voltage power supply necessary for the laser unit.

5. The gas sampling chamber should:—
   (a) accommodate fuel elements of various sizes and be easy to load and unload using remote handling equipment.
   (b) have simple and positive alignment within the laser beam.
   (c) be easy to transfer between stations whilst loaded with a fuel element.

Description of equipment

Figs. 1 and 2 show the arrangement of the equipment, with the laser unit and beam shielding tube supported by the roof plates of the cell. The laser unit can be removed and the beam shielding tube left *in situ* to seal against contamination of the cell atmosphere.

Laser unit. The laser unit[3] consists of a $\frac{5}{8}''$ dia. × 6″ long ruby rod, flash tube, trigger wire, reflecting cavity, high voltage coil, rear mirror and front prism, as shown in Fig. 3.

To facilitate adjustment and ensure permanent alignment, the ruby rod is held rigidly in housings at each end.

Beam shielding tube. The beam shielding tube is of mild steel, 3′ 6″ long × 5″ dia., fitted with levelling screws and a seal unit at the upper end, and an adjustable nose-piece to locate the gas sampling chamber at the in-cell end. A window at the upper end seals against the cell atmosphere.

The laser unit and beam shielding tube, which form a 5′ 6″ long composite structure, weighs 150 lb. including all fittings, and is designed to have a minimum natural deflection.

Gas sampling chamber. The gas sampling chamber is from naval brass, finished size $7\frac{1}{2}''$ × 2″ × 2″, and will accommodate fuel elements ranging from 0.1″ to 0.5″ diameter and up to 4′ 0″ in length. It is shown in sectioned form in Fig. 4.

An equi-biconvex lens, of 10 cm focal length, is sealed into a removable lens-holder which is screwed to a threaded clamping tube. The distance from the centre of the lens to the end of the clamping tube is machined to 10 cm to ensure correct focusing of the laser beam.

A disposable, silica-glass, anti-spatter window is interposed between the lens and the fuel element to protect the lens from vaporised material after piercing.

A valve attached to the gas sampling chamber is used to isolate from the vacuum system and enables the sampling chamber to be moved, whilst under vacuum, thus facilitating batch production. Positioning of the gas sampling chamber in the laser beam is effected by an electrically-driven laboratory jack (see Figs. 5 and 6).

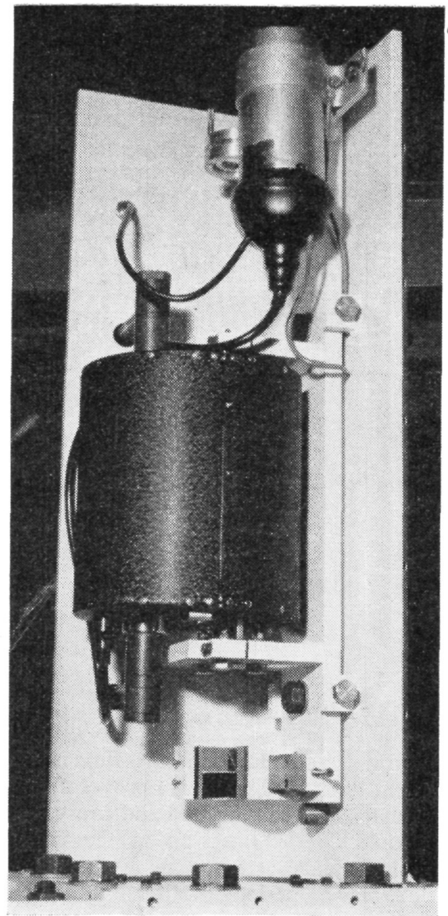

Fig. 3 *Installation of the laser unit and beam shielding tube on the roof of the cell.*

Power unit. The power unit[3] consists of a capacity drive unit fitted with charging and earthing circuits and a triggering device for firing the laser unit; the seven banks of capacitors which comprise the unit have a total energy output of 10,100 joules at 2.5 kV (see Fig. 1).

Commissioning trials

A series of trials to check the laser piercing facility was conducted and comprised the following:—

1. Alignment of the ruby and back reflecting mirror with the aid of an optical pyrometer and front prism, using the re-reflected image technique.
2. Alignment of the unfocused beam with the lens of the gas sampling chamber by trial-firing the laser beam on to discs of graph paper, located in turn on the window of the beam shielding tube and in the lens-holder of the gas sampling chamber.
3. Investigation of the pulse characteristic for the laser unit and the effect of the window in the beam shielding

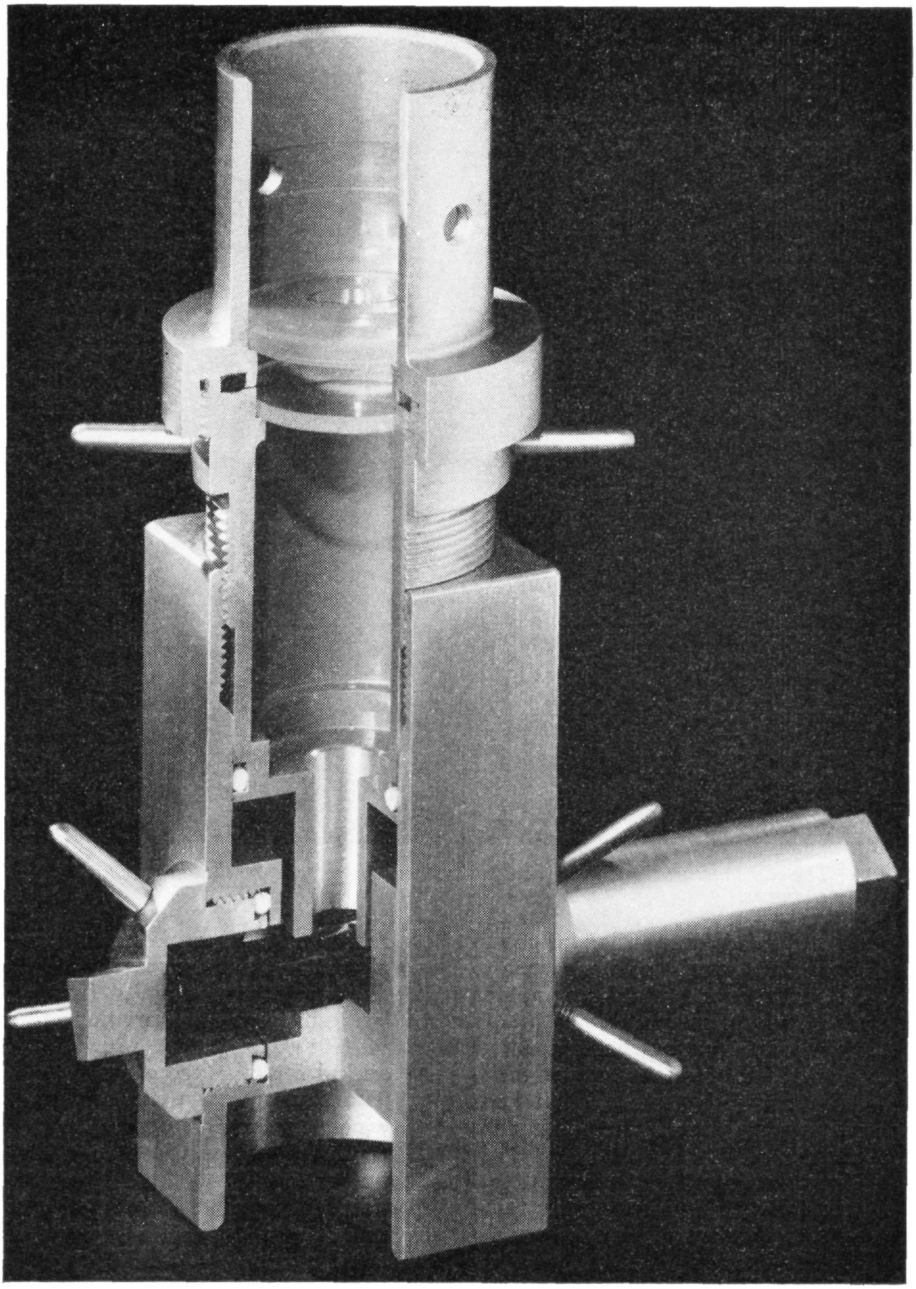

Fig. 4 *Sectioned view of the gas sampling chamber.*

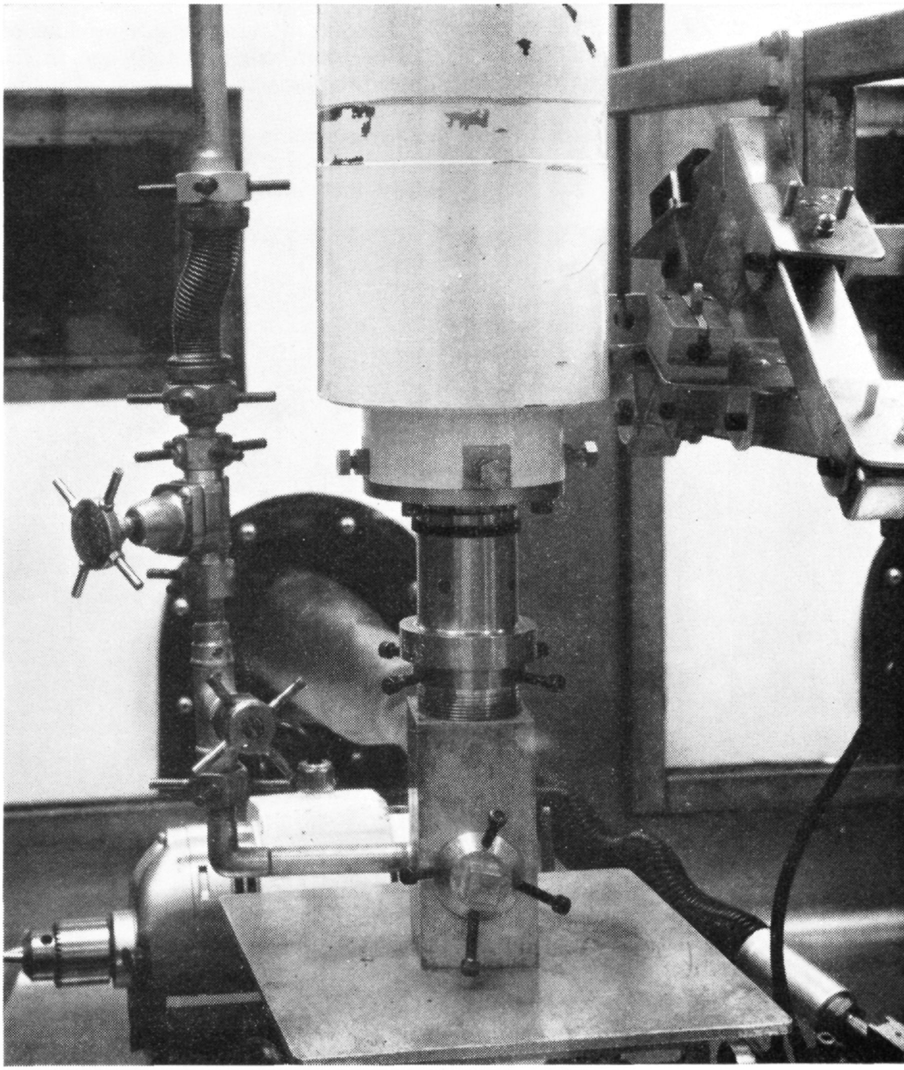

Fig. 5 *The arrangement of the vacuum system connected to the gas sampling chamber.*

tube were checked using a photodiode and attenuator connected to an oscilloscope, and photographing the display from the screen. (As a result of this investigation and due to the damaging effect of the unfocused laser beam, the original Perspex window was replaced with silica glass.)

4. Determination of the minimum focal spot size by trial-firing the laser unit on to a thin metal plate, located at pre-set distances from the lens, enabled the minimum pierced hole size and true focal length to be established. A comparison of holes pierced at the true focal length with different energy outputs from the laser unit showed a variation in dia. of 0.017″ to 0.030″, which is not critical for this type of work.
5. The effect of a silica-glass anti-spatter window, interposed between the lens and the target, was investigated in a similar manner to the previous test, using the true focal length. The anti-spatter window had no significant effect on the pierced hole size.
6. Penetration of the focused laser beam was assessed by trial-firing on to

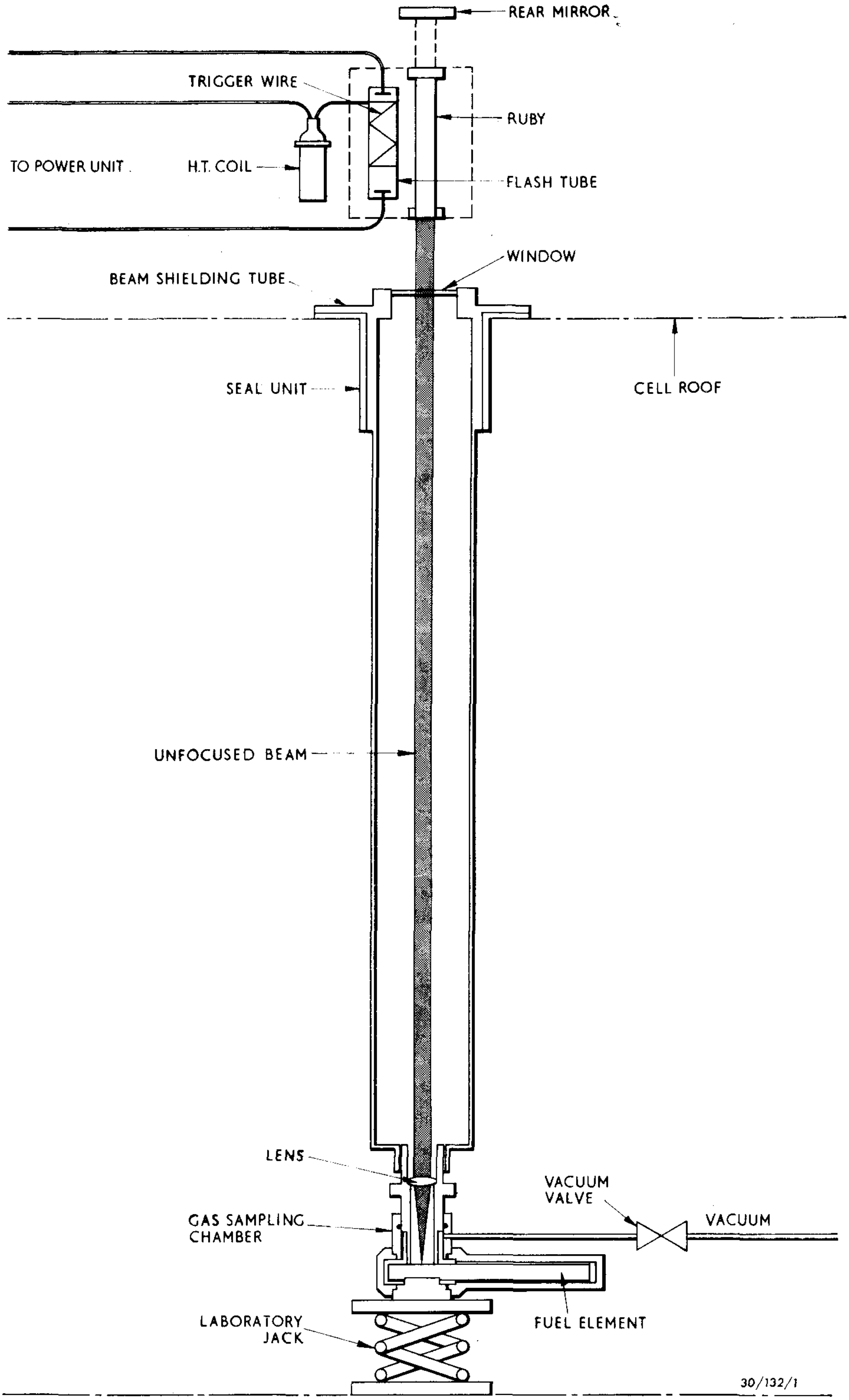

Fig. 6 *Diagrammatic arrangement of the laser unit and gas sampling chamber.*

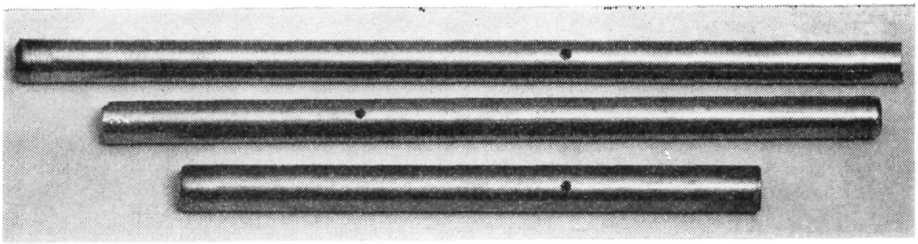

Fig. 7 *Examples of trial-firings which were carried out on different thicknesses of tube.*

different thicknesses of tube and observing the depth of hole or number of shots required to achieve penetration (see Fig. 7).

7. Determination of the efficiency of the laser unit using, alternatively, a reflecting prism and a reflecting mirror was measured by firing the unfocused beam into a copper cone-type calorimeter which was calibrated to indicate the output energy of the beam in joules. (A higher efficiency was obtained with the mirror, and alignment of the ruby proved easier than when using a prism.)
8. The following parameters of the laser unit were obtained:—
   (a) Characteristic curve showing output/input relationship which enables the efficiency for any input to be determined.
   (b) Divergence of the unfocused beam was determined by using a long focus lens (1 metre), measuring a focal length and diameter, and substituting these measurements in a standard formula. For this laser unit, the divergence of the beam was calculated to be 13 milli radians.
   (c) An indication of pulse length to energy output was determined using the apparatus mentioned in item 3 above.
9. Investigation of the power loss of the laser unit, due to frequent firing, showed that an interval of 20 minutes between shots should be observed if power loss and heating of the ruby are to be avoided. (Cooling the ruby by introducing clean dry air into the reflecting cavity showed that the interval between shots can be reduced to three minutes. Air or nitrogen cooling is being arranged.)

Safety

Safety of the equipment is considered in three categories, i.e., nuclear, laser and electrical.

Nuclear safety. Nuclear safety is applicable to equipment working under radioactive conditions (alpha/gamma type containment). An inert atmosphere of nitrogen is maintained in-cell; the avoidance of direct shine paths, the provision of adequate lead shielding, and remote handling equipment and good visibility are essential requirements.

Laser safety. Laser safety requires that the beam shall be totally-enclosed so that no light or flash is visible to unprotected eyes, and the target area must be suitably protected to prevent access to the laser whilst it is being fired. (In this laser piercing facility, the beam is totally-enclosed, and light-tight shutters are fitted to all the windows of the cell; in due course, interlocks will be fitted to each shutter so that the laser cannot be fired until all shutters are closed.)

Electrical safety. Electrical safety is applicable to high voltage equipment, particularly to capacitor banks. When the power unit is charged it may be discharged either through the laser or through an earth circuit; access to the interior of the unit is not possible when the capacitors are in a charged condition.

Control of the laser unit is delegated to one operator, and the operation of the power unit is restricted by use of a key switch, one key being issued only to the operator. A time switch, which will discharge the capacitors after a period of $1\frac{1}{2}$ minutes, will be fitted to avoid the risk of leaving the power unit charged and unattended.

Operating experience

A fuel element was cleaned and placed in the gas sampling chamber and the clamping tube screwed down until the fuel element was held in position. The end seals were replaced and the chamber located on the laboratory jack and placed under the beam shielding tube. The vacuum connection was made and the gas sampling chamber evacuated until the pressure rise reduced to less than 0.5 microns/min. Shutters on all cell windows were closed, the power unit charged and fired. Observation of a Pirani gauge installed in the vacuum system indicated the pressure pulse, as gas was released from the fuel element.

Stainless steel encapsulated elements were pierced in one or two shots; ceramic encapsulated elements required five or six shots.

Some discoloration of the lens had taken place due to nuclear radiation but a spare lens and holder were quickly fitted to the gas sampling chamber whilst the existing holder was decontaminated and fitted with a new lens. (The expendable anti-spatter glass was replaced when discoloration, or spatter, restricted light transmission to the fuel element.)

Conclusions

Although the efficiency of a pulsed ruby laser is only of the order of 1% with an output energy of 100 joules, the very short duration of the pulse (about 1 milli sec), together with the small area of the focused beam, results in a high energy and power density which makes the ruby laser a particularly useful tool for piercing difficult materials.

The laser piercing gas sampling facility is simple to use, adaptable for various sizes of fuel element, easy to maintain and capable of piercing all materials. In operation, the average time taken to gas sample one fuel element is 16 hours, and for one-off jobs there is little saving in time since it takes 15 hours to evacuate the gas sampling chamber and fuel element to acceptable conditions for sampling.

The laser facility, however, is particularly suited to batch production, and if two gas sampling chambers were used and evacuated in parallel the time saving would be of the order of seven and a half hours per sample and would increase with the number of sampling chambers in use.

continued on page 176

A.E.A. Reports available

THE titles below are a selection from the May, 1969, "U.K.A.E.A. list of publications available to the public". This list is obtainable free from the Librarian, A.E.R.E., Harwell, Didcot, Berkshire. It includes titles of all reports on sale, translations into English, books, periodical articles, patent specifications and reports which have appeared in the published literature. It also lists the Depository Libraries in the U.K. and the countries with official atomic energy projects which receive copies of U.K.A.E.A. unclassified reports.

AEEW-M 845
The Wims Multigroup Scheme. Status and Difference Between Versions. By M. J. Roth. February, 1969. 8 pp. H.M.S.O. 1s. 9d.

AEEW-M 860
Numerical Studies of the Hydrogen Equivalent of Some Structural Materials in Their Effect on U-238 Resonance Capture. By A. C. Aldous. March, 1969. 7 pp. H.M.S.O. 1s. 9d.

AERE-Bib 164
A Selected Bibliographic Guide to Conference Papers on Nondestructive Testing 1955-1967 (with Abstracts). By R. Morgan. 1968. 350 pp. H.M.S.O. 35s.

AERE-M 2159
Studies of Two-Phase Flow Patterns by Simultaneous X-Ray and Flash Photography. By G. F. Hewitt and D. N. Roberts. February, 1969. 11 pp. H.M.S.O. 7s.

AERE-M 2175
The Lotus (LOng TUbe System) Air-Water Loop Design and Description. By D. N. Roberts. February, 1969. 13 pp. H.M.S.O. 3s. 6d.

AERE-R 5997
Mechanical X-Ray Safety Shutters for Use on Philips PW 1008 and 1016 Tubeshields. By C. F. Sampson and W. B. Bremner. January, 1969. 12 pp. H.M.S.O. 3s.

AERE-R 6009
The Determination of Sulphur in Nickel. By A. Parker, C. G. Wallace and T. J. Webber. March, 1969. 14 pp. H.M.S.O. 2s. 6d.

AERE-R 6012
Studies of the Behaviour of Disturbance Waves in Annular Flow in a Long Vertical Tube. By L. E. Gill, G. F. Hewitt and D. N. Roberts. March, 1969. 22 pp. H.M.S.O. 3s. 6d.

AERE-R 6035
A Time-of-Flight Spectrometer for Cold-Neutron Studies on the DIDO 6H Hole.

By G. C. Stirling. January, 1969. 14 pp. H.M.S.O. 3s. 6d.

AERE-R 6037
Automatic Calibration of Radiation Monitoring Films. By P. D. Holt. March, 1969. 12 pp. H.M.S.O. 2s. 6d.

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A Fortran Subroutine to Invert a Rectangular Matrix of Full Rank. By M. J. D. Powell. April, 1969. 14 pp. H.M.S.O. 2s. 6d.

AERE-R 6075
Computer Science Research, 1968. By I. C. Pyle, R. G. Garside, R. C. F. McLatchie, T. D. Phillips, D. E. Rimmer, J. R. Taylor and D. G. Vincent. April, 1969. 26 pp. H.M.S.O. 4s.

AWRE/LIB/BIB/18
List of Unclassified Publications and A.W.R.E. Reports by Staff of the Weapons Group Published During the Year 1968. By R. S. Every. April, 1969. 42 pp. H.M.S.O. 5s. 6d.

AWRE 0-21/69
The Ductile-Brittle Transition of Uranium. By A. N. Hughes, S. Orman, G. Picton and M. A. Thorne. March, 1969. 19 pp. H.M.S.O. 4s.

CLM-R 94
Thermonuclear Reactors Based on Mirror Machine Confinement. A Report from the Culham Mirror Study Group, 1967-1968. By P. C. Thonemann, G. Francis, J. D. Jukes, D. W. Mason, B. McNamara, D. R. Sweetman, J. B. Taylor, C. J. H. Watson and F. A. Julian. January, 1969. 40 pp. H.M.S.O. 5s. 9d.

TRG Report 1539(D)
Vera Core 18. An Assembly Built to Test Calculation Methods and Data for D.F.R. By J. C. Smith, H. Atkinson and M. H. McTaggart. 1969. 40 pp. H.M.S.O. 5s. 6d.

TRG Report 1754(D)
Improvements in Dosimetry for Experiments in DIDO-Type Materials Testing Reactors. By E. W. Etherington. 1969. 15 pp. H.M.S.O. 2s. 6d.

Non-destructive testing

continued from page 165

variables are controllable.

Magnetic techniques

To review available techniques and to develop improved methods of detecting flux leakage at the surface of magnetic materials.

High-definition radiography

To develop techniques of ultra-high definition radiography and X-ray microscopy; to extend the techniques to study the crystallographic orientation in reinforcement fibres.

High-speed radiography

To improve techniques and develop applications of ciné and stereo flash radiography using field emission X-ray sources.

Ultrasonic goniometry

To design and manufacture an ultrasonic goniometer (to measure the critical angle of surface wave mode conversion) for application studies.

Electropotential monitoring

To develop a technique to monitor variations of surface electropotential and to study applications in the nondestructive testing field.

Neutron radiography

To improve techniques and extend the application potential of neutron radiography.

Supporting work

The Centre also receives considerable experimental support from the Electronics and Applied Physics Division, Harwell, and non-destructive testing work there is currently being undertaken in the following areas.

Grain size monitoring

To develop an ultrasonic test for monitoring grain size by statistically analysing scatter intensities.

Ultrasonic holography

To set up experimental equipment to record phase and amplitude information in ultrasonics and to reconstruct the information holographically.

High-frequency ultrasonics

To assess CdS transducers operating in the range 50-150 MHz.

Eddy current testing

To examine some features of the generation and propagation characteristics of eddy currents in relation to their non-destructive testing applications.

Ultrasonic micrometry

To perfect the design of single and double transducer high-speed ultrasonic resonance micrometers with advanced forms of data presentation.

Profilometry

To perfect the design of a servo-controlled flying spot profile follower and to study its performance on non-destructive testing applications.

APACE Centre exhibit

The work of the UKAEA's APACE Centre was featured at the recent 'Cadex 69' (Computer Aided Design Exhibition, Southampton University, 15th-18th April, 1969). The APACE Centre is the Ministry of Technology sponsored project operated by AWRE Aldermaston, and came into being at the end of 1966 to assist industry by fostering the use of the computer in engineering. The main service offered by APACE in the design field is a consultative one, supplemented where required by specially arranged training on a tutorial basis. Such training covers electronics, graphics, programming, numerical control of machine tools and management techniques. In the photograph Dr. Jeremy Bray, Joint Parliamentary Secretary, Ministry of Technology (left), is talking to Mr. F. L. West, Manager of APACE (right), and Mr. P. E. Love, Senior Engineer in charge of the electronic CAD section of APACE (centre). Further information about APACE may be obtained from The Secretary, APACE Centre, UKAEA, Blacknest, Brimpton, near Reading, RG7 4RS, Berkshire.

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

Fracture toughness concepts symposium

An international symposium on Fracture Toughness Concepts for Weldable Structural Steel, was organised by the Reactor Materials Laboratory (Culcheth) of the Reactor Group, U.K.A.E.A. on 29th and 30th April, 1969, at Risley, Warrington, Lancs.

In addition to 130 delegates from the U.K., there were present representatives from Australia, Belgium, Denmark, France, Germany, Holland, Italy, Japan, Sweden and the U.S.A.

The symposium was opened by Mr. J. M. Hutcheon, Head of the Reactor Materials Laboratory, U.K.A.E.A., and was attended by practising engineers and metallurgists from fabrication, design, inspection, and research organisations.

The purpose of the symposium was to have detailed discussions on methods for selecting materials which will reduce the risk of welded steel structures failing by brittle fracture. Such failures have, in the past, occurred in ships, pressure vessels, storage tanks, bridges, masts and oil rigs, and they can have serious consequences including hazard to life and large financial losses.

Over recent years, two new assessment techniques have been developed, one based on linear elastic fracture mechanics and used for higher strength materials, and one based on measurement of the local strain at fracture near to an initiating defect (crack opening displacement).

The technical sessions were devoted to discussing theoretical and experimental evidence supporting the use of these, and other, techniques, and a considerable body of data obtained by collaboration between the Reactor Materials Laboratory, Culcheth, and various industrial laboratories was published for the first time. The R.M.L. work was part of the programme authorised by the Minister of Technology under Section IV of the Science and Technology Act, 1965.

Industrialists at Harwell

So many Midlands executives wanted to see the industrial research section of the Atomic Energy Research Establishment at Harwell, that the Ministry of Technology's West Midlands Regional Office in Birmingham has organised a second visit.

The Regional Office asked firms if they were interested in visiting Harwell and 60 said they were—double the number expected. When a similar visit was arranged in 1967, only 19 firms took part.

The next visit was on 22nd May and senior technologists, chief chemists, technical directors and development managers from a wide range of firms—including some of the biggest concerns in the country—took part.

At Harwell, they were shown the analytical research and development unit and the physico-chemical measurement laboratories. They saw non-destructive testing, fabrication techniques in metal and ceramics and experiments with heat transfer and fluid flow. They also had discussions with some of the chief scientists.

Because of the increased interest, the Ministry's West Midlands Regional Office is extending its programme of visits to research establishments.

Ion exchange conference

An international conference on ion exchange in the process industries, organised by the Society of Chemical Industry, will be held at the Imperial College of Science and Technology, South Kensington, London, S.W.7 from 16th-18th July.

Topics to be discussed are preparation and properties of organic resins; developments in the design of ion exchange plant; developments in the design of ion exchange processes; radiochemical separations and radioactive treatment; sugar processing; developments in inorganic exchangers; water and effluent treatment.

Some 60 papers have been accepted of which 40 are from overseas. Most of the leading centres of research, development and application are represented.

Registration forms and programmes are available from the General Secretary, Society of Chemical Industry, 14 Belgrave Square, London, S.W.1.

UKAEA at medical exhibition

THE U.K.A.E.A. exhibited at the Medical Instrumentation Exhibition, held at the Mayfairia Rooms, Marble Arch, London, W.1, from 22nd-25th April, 1969.

This exhibition was organised following the cancellation of M.E.D.E.A. earlier this year because of a labour dispute, and most of the exhibits that would have been shown there were on display. They included the results of work sponsored by the Department of Health and Social Security.

Gas sampling of fuel elements

continued from page 173

Acknowledgements

The writer wishes to thank all his colleagues of the Engineering Support, Metallurgy, and Production and Works Divisions for their assistance with this project, and in particular Mr. J. T. Demant for his advice on lasers and the work he did during the commissioning trials.

References

1 Gas release methods used in the Harwell Metallurgy Post-Irradiation Laboratory by J. H. Venables.
The International Symposium on Working Methods in High Activity Hot Laboratories (Grenoble 15-18 June 1965, Paper No. 55).
2 Lasers and their applications by M. R. Allen and J. T. Demant, A.E.R.E., "Engineering Review", January 1966, Vol. 5 No. 1.
3 Laser unit type 350 and power unit type PU 350/10 by G & E Bradley Ltd. London.

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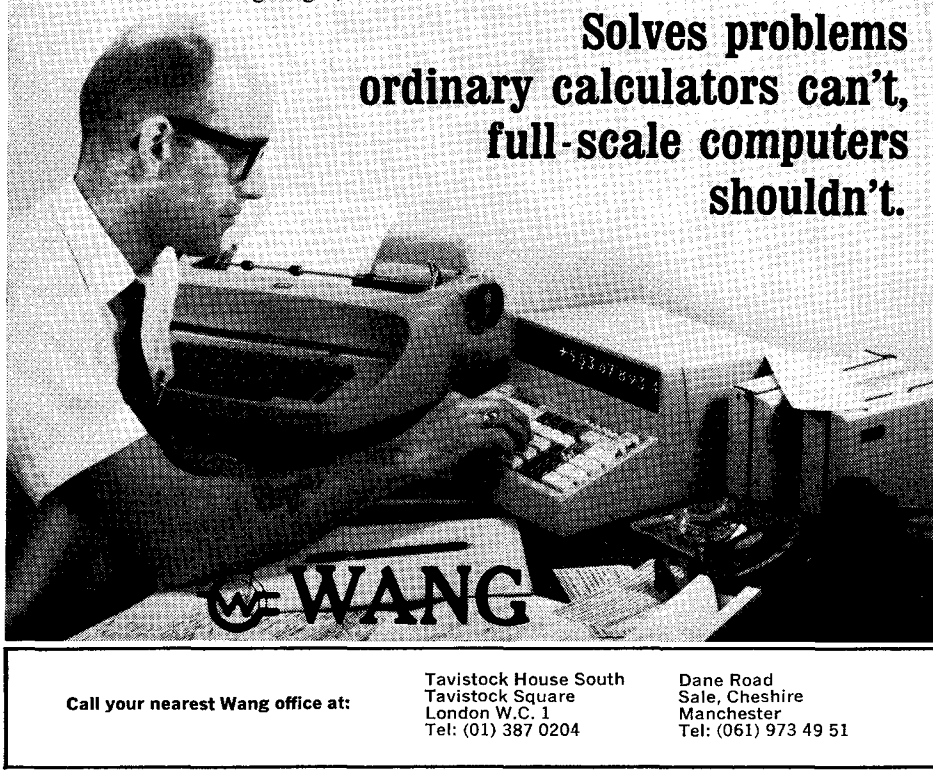

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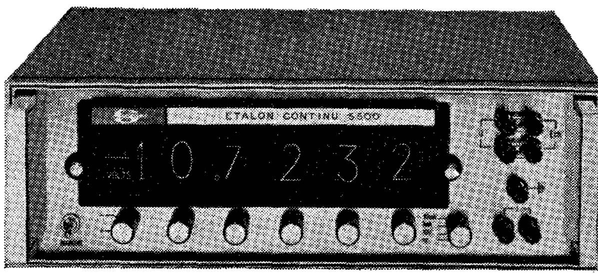

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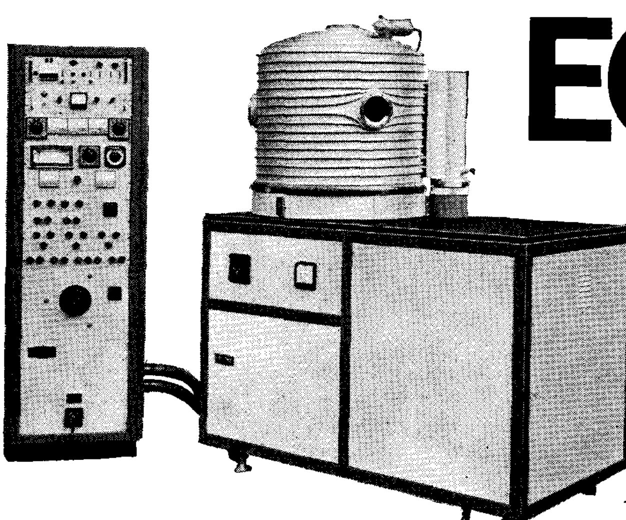

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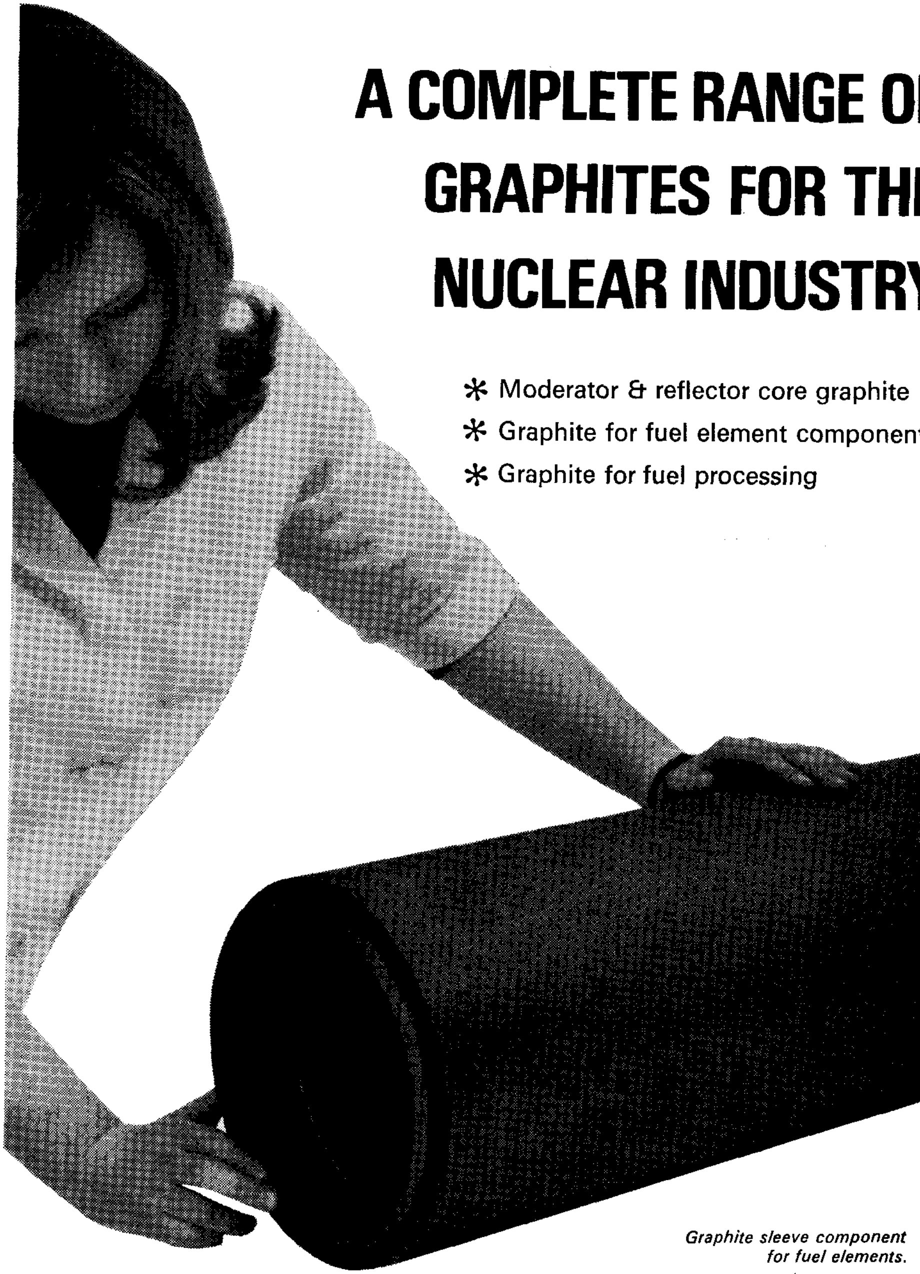

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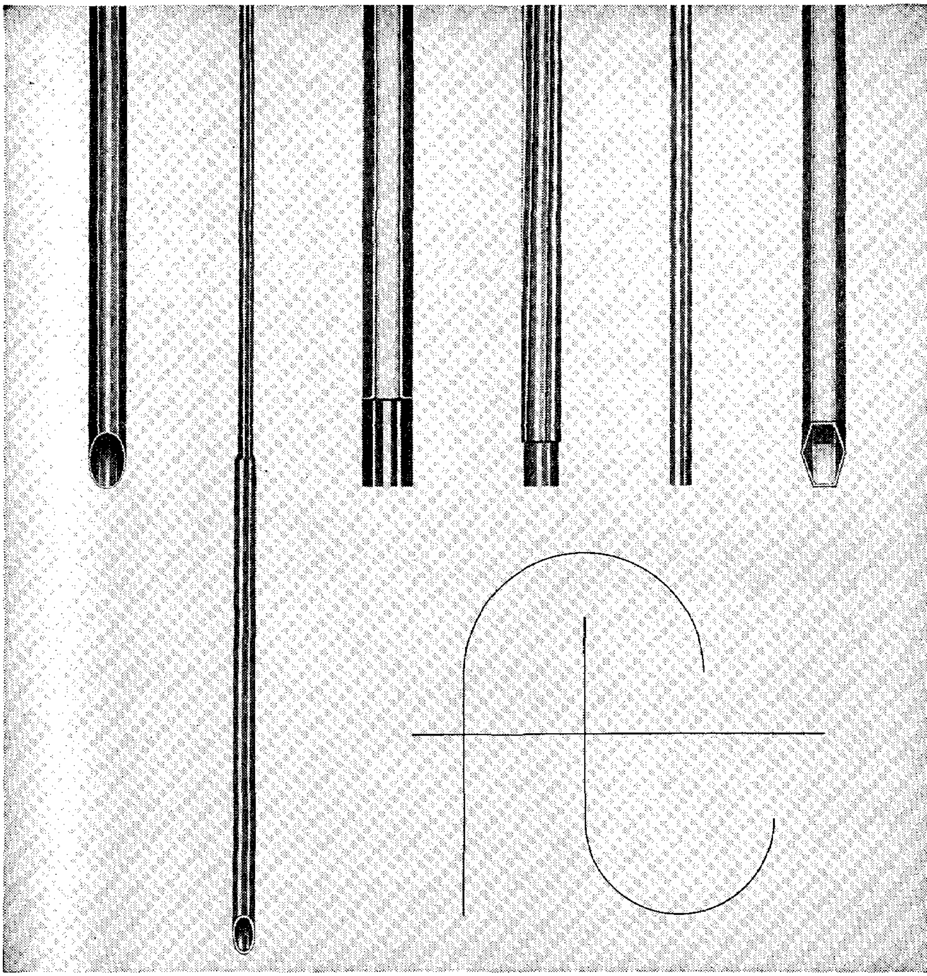

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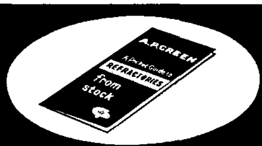

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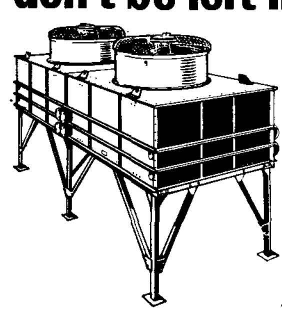

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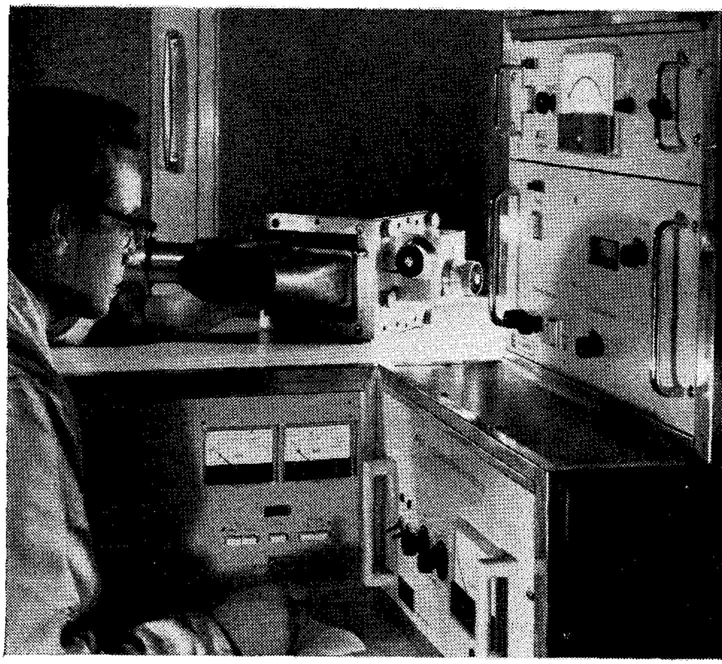

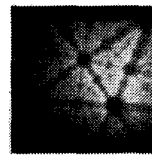

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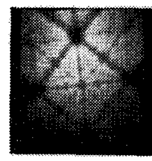

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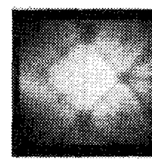

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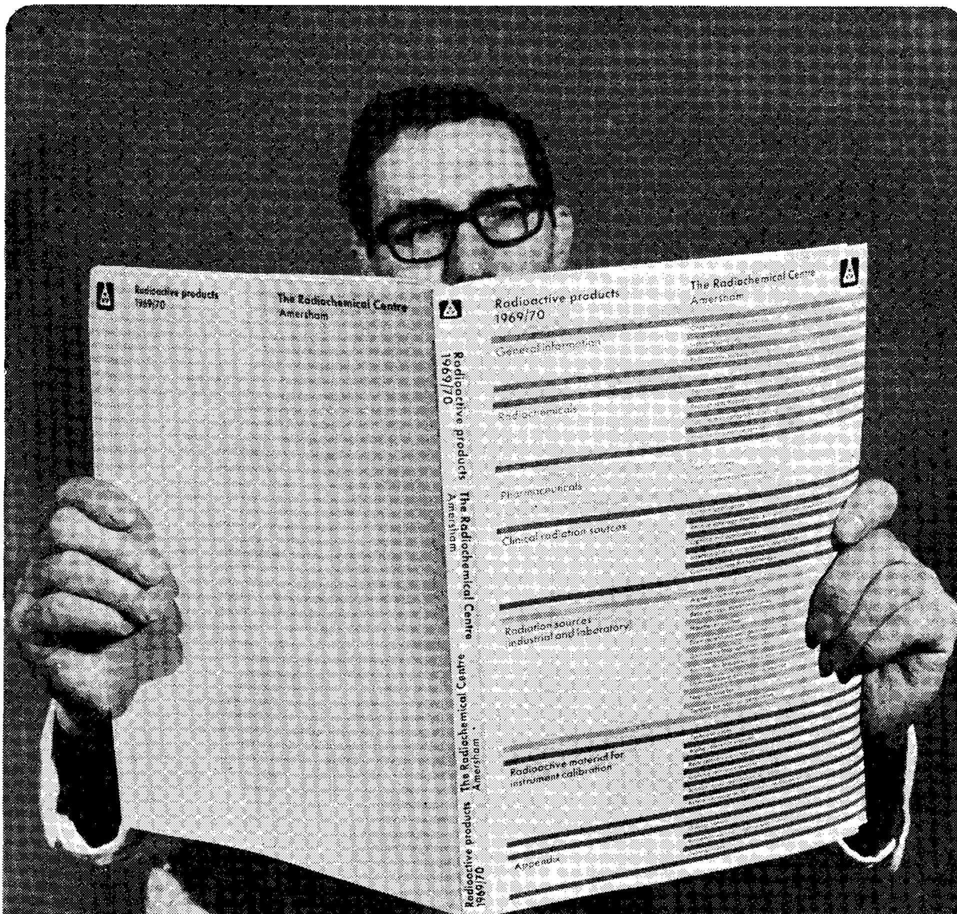

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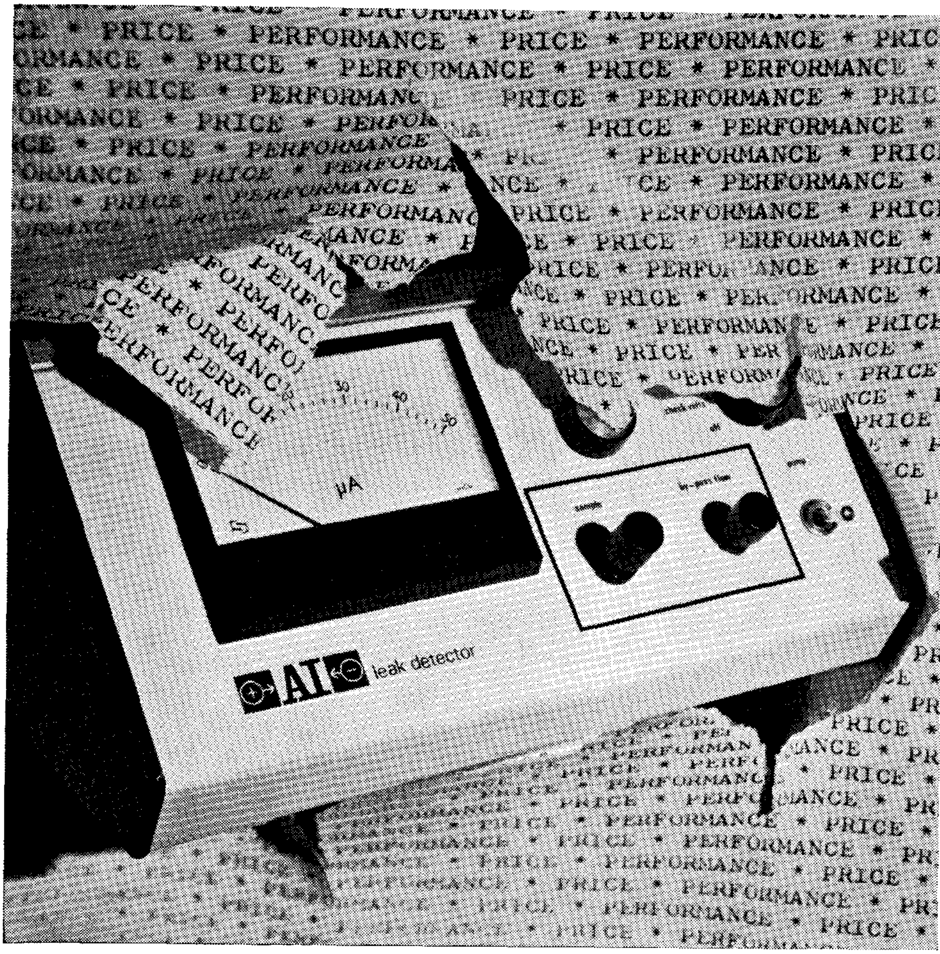

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