Number 151 / May 1969

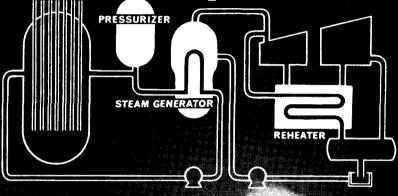


### MONTHLY INFORMATION BULLETIN OF

### THE UNITED KINGDOM ATOMIC ENERGY AUTHORITY

Page	117	Press Releases
	120	In Parliament
	126	The use of radioactive tracers in gas mains
	128	A mobile system for measuring flow in a gas distribution network
	143	Scientific and Technical News Service





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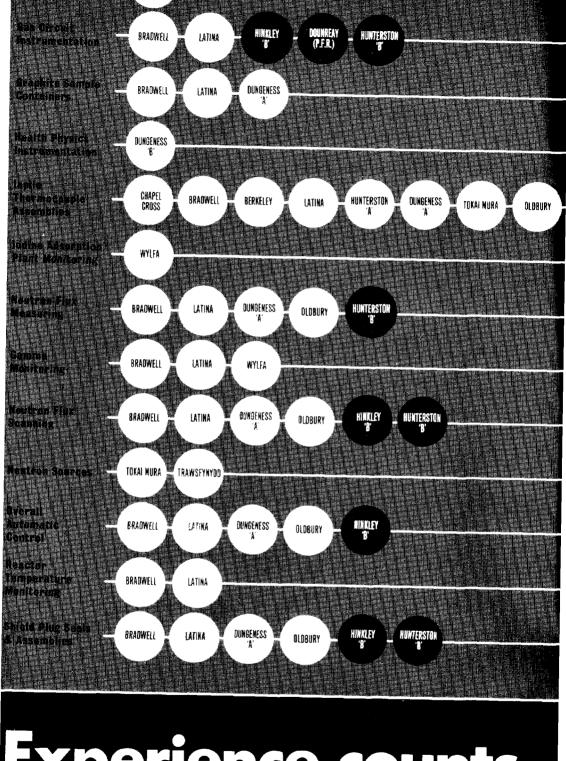
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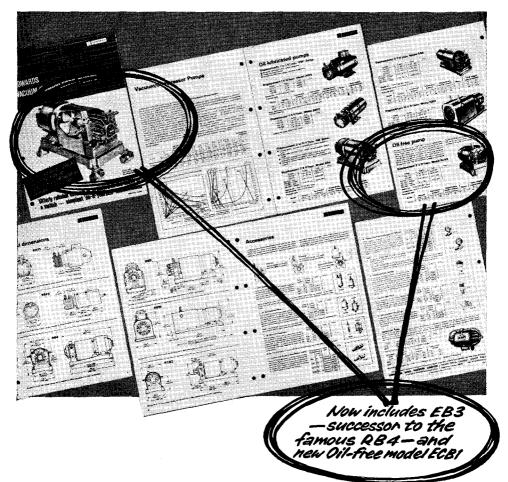
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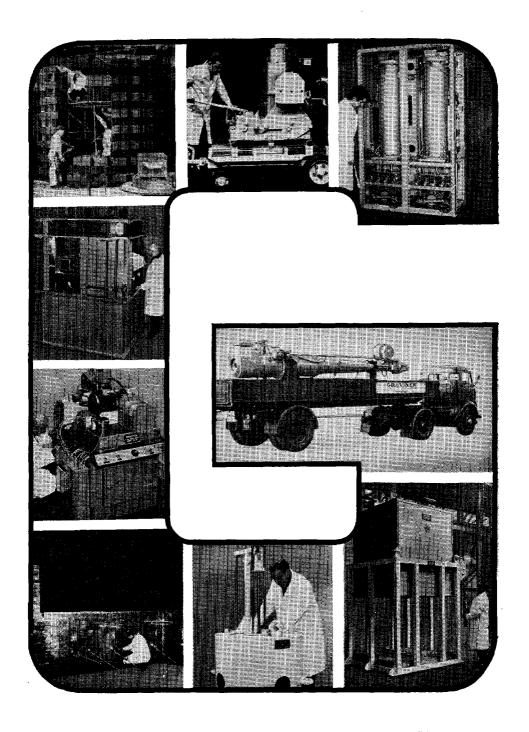


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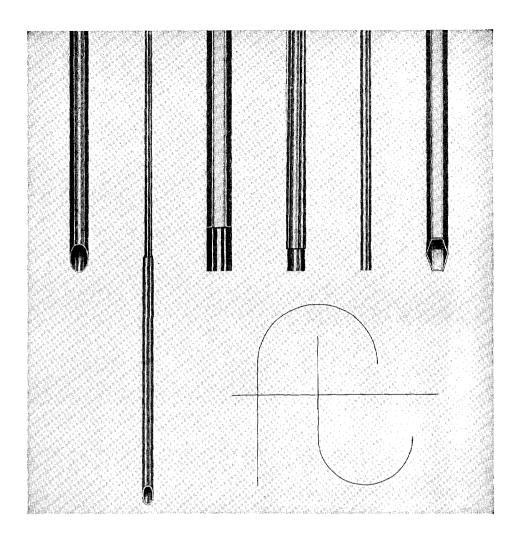
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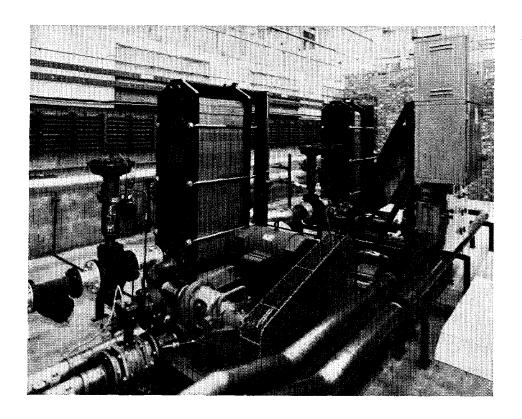
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# **ATOM**

MONTHLY INFORMATION BULLETIN OF THE UNITED KINGDOM ATOMIC ENERGY AUTHORITY

### NUMBER 151

May 1969

### Contents

- P. 117 Press Releases
  - 120 In Parliament
  - 126 The use of radioactive tracers in gas mains
  - 128 A mobile system for measuring flow in a gas distribution network
  - 143 Scientific and Technical News

### ATOM

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### LIKAFA PRESS BELFASES

# Director of Research Group

Dr. W. Marshall is being appointed Director of the Research Group (which includes the Culham Laboratory as well as Harwell). Dr. Marshall will continue to be Director of the Atomic Energy Research Establishment, Harwell.



### Biographical note

Dr. Walter Marshall is 37. He was born and went to school in Cardiff, and took his B.Sc. (1st Class Honours) in Mathematical Physics at Birmingham in 1952. and his Ph.D. in 1954. He joined the Atomic Energy Research Establishment at Harwell in that year and from 1957 to 1959 spent two years in the United States at Berkeley and Harvard before returning to Harwell. In 1960 he was appointed Head of the Theoretical Physics Division at Harwell, and in 1964 he was made a member of the Research Group Management Board. In the same year he was elected a member of the Council of the Institute of Physics and the Physical Society, appointed Kelvin Lecturer of the British Association for the Advancement of Science, and awarded the Maxwell Medal for outstanding contributions to theoretical physics.

On 1st March, 1966, Dr. Marshall was

appointed Deputy Director of the A.E.R.E., Harwell, and on 1st February, 1967, received the additional appointment of Deputy Director of the Research Group. He has had special responsibility for reviewing and reformulating the future programme at Harwell. He was appointed Director of A.E.R.E., Harwell, on 1st April, 1968.

13th March, 1969

# Collaboration with U.S.S.R. on fusion

On 16th March, 1969, five tons of intricate apparatus from the Culham Laboratory of the U.K. Atomic Energy Authority left London Airport by air for Moscow. Four scientists from Culham will use the apparatus to collaborate with Russian scientists in an experiment on a nuclear fusion research device known as TOKAMAK 3 at the Kurchatov Institute of Atomic Energy, Moscow.

Since 1958 there has been a full exchange of information between all countries working in this field and progress has been measured on an international scale. Hitherto these exchanges have been both by visits and in reports; scientists have also been exchanged between some of the U.S.S.R. and U.K. laboratories. The collaboration starting on 16th March is the first investigation in which teams of Russian and British scientists have worked together on an experimental research project in the nuclear energy field.

The research is concerned with the possibilities of producing power from the controlled fusion of the atomic nuclei of light elements such as hydrogen. (Present nuclear power stations produce energy from the fission of atoms of the heavy elements such as uranium.) The method envisaged for achieving fusion power is to confine an extremely hot gas of hydrogen isotopes so that energy is released by thermonuclear reactions between atomic nuclei. The central problem is to find means of isolating the gas at the required density and temperature (about 100 million degrees centigrade) from the walls of its containing vessel for the time required for a net gain of energy from nuclear reactions.

This confinement can probably only be achieved by the use of magnetic fields and one promising form of magnetic confinement system is that known as the "toroidal pinch". ZETA was the first large example of such a system and TOKAMAK 3 is a large modern example of this general class of device.

Results reported by the Russians indicate that TOKAMAK confines the hot gas at temperatures and densities and for times most nearly approaching those required for a fusion reactor. However, interpretation of these results depends on accurate measurements of the temperature and densities of the hot gas and it is on this aspect of the research that Culham Laboratory scientists hope to be able to make a substantial contribution to the experiments, for which they have designed and built the necessary special equipment.

The results of these measurements will be valuable in assessing the relative potential of the various types of nuclear fusion device currently being studied; in particular, our scientists are interested in comparing the performance of this Russian TOKAMAK pinch with different devices at Culham. There are no TOKAMAK type devices elsewhere than in the Kurchatov, so this collaboration will give Culham scientists an opportunity of first-hand experience with these systems without having to build one of their own.

The proposals for collaboration were initiated in discussions between Dr. R. S. Pease, Director of Culham Laboratory, and Academician Artsimovich who is in charge of this work at the Kurchatov Institute.

The Culham scientific team comprises: Dr. N. J. Peacock (Leader), Mr. M. J. Forrest and Mr. P. D. Wilcock. The team are expected to spend about two months in Moscow where they will join Dr. D. C Robinson, who is spending a full year at the Kurchatov Institute.

### Scientific background

TOKAMAK is the generic name for a series of toroidal pinch devices at the Kurchatov Institute.

TOKAMAK 3 is the largest (2 metres major diameter and 20 cm. minor diameter) plasma confinement device in which a toroidal discharge, carrying about 100 kA, is stabilized by a very strong longitudinal magnetic field. The discharge current both heats and confines the plasma. The temperature is believed to be in the range 3 to  $10 \times 10^{8}$  degrees and the

maximum density  $3 \times 10^{13}$  particles per cm<sup>3</sup>, with confinement times of about 1/50 second.

The British team will apply a technique developed by them for a number of Culham experiments. This technique depends on lasers which give out powerful pulsed beams of monochromatic light. The plasma is irradiated with the laser light and the spectrum of the laser photons scattered by the plasma is recorded. specially designed spectrometer with associated electronics analyses this scattered light; from its spectral distribution and intensity the electron temperature and density at any point in the plasma volume can be readily obtained, more accurately than by any other known method.

If controlled fusion can be achieved a new and widely available fuel could supplement or replace fossil fuels and uranium as a source of power.

17th March, 1969

### **Royal Society Fellows**

Dr. Eugen Glueckauf, Deputy Chief Scientist and Head of the Radiochemistry Branch, Chemistry Division, A.E.R.E., Harwell, has been elected a Fellow of the Royal Society. He is distinguished for his work on the theory of chromatography and ion exchange, for their application in the analysis of gases and extraction of rare elements and for his contributions to electrochemistry.

Two former U.K.A.E.A. scientists were also elected Fellows.

Professor P. V. Danckwerts, G.C., M.B.E., formerly Deputy Director of Research and Development, Industrial Group, U.K.A.E.A., from 1954 to 1956, and now Shell Professor of Chemical Engineering at the Department of Chemical Engineering in the University of Cambridge.

Dr. H. M. Finniston, formerly Chief Metallurgist at Harwell and now Deputy Chairman (Technical), British Steel Corporation, London.

### Dr. J. B. Adams

Dr. J. B. Adams, C.M.G., F.R.S., left the Authority at the end of March to take up the appointment of Director of the CERN 300 GeV Project.

On Dr. Adams' departure, Sir Charles Cunningham, the Deputy Chairman of the Authority, became Chairman of the Research Group Board of Management.

# Largest electrodialysis desalination plant

The following statement was issued at a press conference arranged jointly by the Weir Group and the UKAEA on 28th March, 1968.

The Municipality of Benghazi, Libya, has awarded William Boby and Company, a member of the Weir Group, an order for the supply, erection and commissioning of an electrodialysis plant under a contract signed in Benghazi on 26th March. The plant will produce 19,200 cubic metres a day (4.2 million Imperial gallons—5 million U.S. gallons per day) of drinking water from brackish well water.

The contract is worth £890,000. It includes two years maintenance, to follow the handover of the plant in eighteen months time.

This order is a break-through in electrodialysis desalination because the plant is not only some ten times the size of the largest electrodialysis installation at present operating but also the largest single desalination unit of any kind so far ordered anywhere in the world.

Electrodialysis is a form of desalination which is economically ideally suited for the treatment of brackish waters—salt waters of lower salinity than sea-water—to reduce the salinity to a level at which the water is acceptable for drinking.

The duty of the electrodialysis plant to be installed at Benghazi will be to reduce the salinity of the Benghazi water, which is at present around 2,000 parts of total dissolved solids per million, to 650 parts per million. This 650 parts per million compares with London Metropolitan Water Board water of around 350 parts per million. The population of Benghazi. (180,000) are at present drinking the 2,000 p.p.m. water as this is the only water supply available.

The water is pumped from bore holes at Benina, some 20 kilometres from Benghazi.

The increasing rate of pumping from the bore holes, which is becoming necessary to supply the growing population of Benghazi, is liable to lead over the next few years to an increase in the salinity of the water, and the order for the electrodialysis plant is therefore a timely move.

The consultants to the Municipality of Benghazi for this contract were Dr. A. A. Warith and Associates of Cairo.

# Technological co-operation in Europe

The following extracts are taken from the debate on technological co-operation in Europe which took place in the House of Lords on 12th March, 1969.

THE EARL OF BESSBOROUGH: During the past months I have paid visits to Brussels and Germany, to France and Scandinavia. What I have to say first concerns the standing of this country on the Continent, as a result of our Government's attitude to certain European technological projects. I refer particularly to the Government's doubts about the Concorde, to their withdrawal from the ELDO "B" project and to their decision not to contribute to the CERN giant accelerator. Our attitude over ELDO and, perhaps to a lesser extent, over the 300 GeV accelerator have made not only the French in Europe suspicious of our word, but also some of our other partners, too. They cannot understand how, at a time when the British Government were advocating closer co-operation, we should decide partly to withdraw from existing co-operative projects.

I believe that there are possibilities for joint research in desalting water, in boilers. blowers and membranes. We know that we lead in flash distillation plant, but the Americans are catching up, and I think there is a good case for our having European partners in this field. Flash distillation is not the only method of desalting water, as we know. There are various other methods, using membranes, and also the freezing method. The Atomic Energy Authority is conducting research in these methods, but I still think it would be in our long-term advantage to have European partners, when it comes to the export of plant to Europe and the developing countries overseas.

But there are also areas where Government assistance would indubitably be necessary; for example, in economic nuclear-powered container ships, in oceanology, in cosmology and in solar heat applications. In regard to nuclear container ships, I was fortunate last October to be invited by Dr. Stoltenberg, the German Minister for Science, to go on the maiden cruise from Kiel of the "Otto Hahn", which is the German nuclear-

powered ore carrier. Although this ship represents, I think, a considerable progress over the United States ship "Savannah". and although our wealthy German friends may feel that they can build this kind of ship, and perhaps a second one, on their own (with, of course, some assistance so far from EURATOM), I found that some German industrialists felt that this was an area in which the ship-builders and shipping companies in more than one European country should get together in the future: for there seems little doubt that in ten vears or so nuclear container ships carrying meat, say, from Australia and New Zealand to Europe, will certainly prove successful. But research and development costs will continue to be high and I think that we should share them.

The fact is, my Lords, that if European technological co-operation is to advance very far we must all be honest with ourselves about what our best contributions are likely to be and where the other partner or partners are likely to be better. I say this in no idealistic mood but simply because only in this way are we likely to be able to achieve the lead times and sales techniques equalling those of the United States. It is this that will ensure Western Europe, as a group of neighbours in a small world, a prosperous position in the world markets of the 'seventies and the decades of our children.

Above all. I hope that in certain specific areas inter-company co-operation can be developed perhaps on the model of Internuclear, in which firms in this country, T.N.P.G., and firms in Germany, Belgium and Italy have now joined to buildprobably on the Belgian-German frontiera high-temperature gas reactor based on the E.N.E.A. DRAGON at Winfrith. cient as I believe our own advanced gascooled reactors and the steam-generating heavy water reactor are, the fact remains that we have not been conspicuously successful in selling these types abroad; and this sometimes makes me wonder whether in the case of the fast breeder reactor, too, we should not also have European partners. We know that, although our potential partners are not as far ahead as we are in this field, the Germans and the French are also spending very considerable sums on fast breeder development and there must surely be advantages in our combining our efforts by, perhaps,

agreeing to let our own fast breeder prototype at Dounreay become a European reactor. I feel that our prospects of selling new types of reactor in other European countries would be very much more promising if we did so. We have heard a lot of talk of Europeanising Capenhurst. I should be interested to hear the Government's views on Europeanising Dounreay, too.

Lord Chalfont: The next project of particular interest to which I should like to refer is the CERN project—C.E.R.N. being the initial letters of the French title of the European Organisation for Nuclear Research. This was set up in 1954 and its aim was to provide for collaboration among European states in nuclear research. Therefore its object is purely scientific, but it is a successful example of European co-operation; and its technological work, which I am assured by my scientific friends is of a very high order, is carried out in its laboratory at Meyrin in Switzerland. As the noble Earl said, this organisation proposes to build a giant accelerator with a power of 300 GeV. This will be the largest accelerator in the world, and in 1968 the Government announced that they had considered carefully whether or not to participate in this project. Although they recognised the scientific value of it, they were particularly concerned at the effect which taking part in this project might have on the balance of resources between high energy physics, in which, of course, the giant accelerator is an element, and other scientific activities. There is a strong argument advanced by scientists that high energy physics already gets too much of the money allocated to scientific research. We were concerned about this, and also at this time we have to take into account the implications of the devaluation of sterling. We reluctantly came to the conclusion that in the light of other commitments we could not justify expenditure on this very large project.

The question of the gas centrifuge was also raised. As many noble Lords will know, this is a project for collaborating in exploiting the gas centrifuge, which is a method of producing enriched uranium. This is an extremely important scientific development and the Ministers met in November of last year, and again recently, to discuss this project. An agreement on this project will of course have very con-

siderable political significance. This is not necessarily confined to the three countries concerned.

We have some plans afoot in Europe in the field of fast breeder reactors, which the noble Earl mentioned. There is, first of all, as he will know, a top level expert group. It is drawn from the member-nations of the organisation called ENEA, which is the European Nuclear Energy Agency, and this is considering prospects for various types of nuclear reactors known as the fast breeder reactor. On the two specific questions he asked me, the Europeanising-I am using his word although I would not necessarily use it myself-of Capenhurst and Dounreay, I think he will recall that we had discussions last year with several European countries about arrangements for assuring them of supplies of enriched uranium from Capenhurst for their civil reactors, and I think he will see that these ideas are to a great extent, or might well be, now overtaken by the centrifuge collaboration project.

So far as the Dounreay project is concerned, whether we might turn that into a European venture or not, this subject was discussed last year again with the ENEA, the European Nuclear Energy Agency, and the discussions are still going on. So far as Dounreay is concerned, the development has reached a point where its technology is a commercial matter, and it is not a question of Europeanising it in an intergovernmental sense but really of licensing the project; and this we are discussing with a number of our European friends.

Lord Sherfield: It is in the field of atomic energy that we have the only technological community which has so far been brought into existence, EURATOM and its history clearly brings out the difficulties inherent in this type of organisation. Frustrated by nationalistic policies, saddled with an expensive research programme mainly directed to the development of a reactor probably without a commercial future, it gives clear indications of what to avoid in the future.

Happily, atomic energy also provides an example of a successful venture in European technological collaboration, the DRAGON project. It has had the advantage of a specific objective, the development of a reactor prototype with commercial possibilities. It has the further advantage of the

management having been in the hands of a single country. Here I should like to support strongly the views of noble Lords who have advocated this principle of single management as opposed to separate management and separate design and development teams. Admittedly, there were some delays due to the international nature of the project and to the difficulty of awarding and carrying out contracts in a number of countries, but national projects are also subject to delays, and the DRAGON was not greatly out of line in this respect. This project has been notable for its low political content and minimal Government interference. The design has now been taken up by a European industrial consortium, British, German and Swiss, and is being marketed on its economic merits.

My next point, which has a strong bearing on the character of future projects. is the progress now made in this country, the Netherlands and Germany in the development of isotope separation in uranium by the centrifuge method, to which a number of noble Lords have referred. The news that an agreement on the shape of this project has been reached between the three countries is welcome. I do not know whether there has been a technological breakthrough in this most difficult process, and I hope that any temptation on the part of the Press and others to overplay the prospects will be strongly resisted. Atomic energy projects have suffered severely in the past from premature and exaggerated claims of industrial and commercial success.

If this process really now shows promise of being technically feasible and economically viable on an industrial scale, then it may well be more suitable for the satisfaction of European needs for low enriched uranium than an increase in diffusion plant capacity. But I trust it will be left to an industrial consortium or consortia to develop and market the process. I was encouraged by reports in the Press that this is in fact the intention and that there will be one prime contractor to build the plant, and a single marketing organisation. Of course, I realise that there are international implications in this project; notably that there is an inspection problem in relation to the proliferation of nuclear weapons, and that this must be handled between Governments. But otherwise I hope that the project will not be dealt with as a matter of high political significance, but rather as a co-operative industrial and commercial undertaking.

I do not suppose that there is any field in which there is a greater duplication and waste of resources in Europe than in the field of fast reactor technology. The extreme nationalism of the European approach to this subject is the prime cause of this duplication; and in view of the major lead in this field which this country enjoys, we cannot be blamed for it. However, now that the fast reactor is on the verge of commercial exploitation, it seems that a fresh attempt should be made towards some rationalisation of the European effort.

Here, again, I consider that this attempt can best be made at the industrial level. and the first step so far as this country is concerned must surely be to commercialise the work on the Dounreay fast reactor by transferring the responsibility for construction and completion of the prototype to industry. I have therefore noted with some pleasure that there is a proposal to transfer the Atomic Energy Authority fast reactor team to one of the consortia, and I hope that any difficulty there may be in doing this will be resolved as quickly The sooner the Nuclear as possible. Power Group takes charge, the sooner it can explore the possibility of collaboration with other European industry.

This brings me to the question of nuclear Here the Atomic Energy Authority has already taken steps to collaborate with Europe by setting up joint fuel companies in Italy and Germany, with the Italian company making progress. is another field in which it should be possible to operate by means of a European consortium at the industrial level. But a further step needs to be taken in this country before great progress is likely to be made in this direction. This step is to transfer the nuclear fuel operations of the Atomic Energy Authority to a separate company in which, while the Authority may have a substantial holding, it would also take industrial partners who are already involved in the nuclear fuel field, like Rio-Tinto-Zinc and Rolls Royce. This was one of the recommendations of the Select Committee on Science and Technology, and it would be interesting to know what progress is being made in putting this recommendation into effect. Perhaps the Minister may be able to say something about this matter when he comes to reply. There is not much room for delay in this field if we are not once more to be overtaken by an international company based in the United States.

Much is made about the success of CERN as a co-operative venture in the field of higher energy physics, and it has indeed been a success, but it is well known that international collaboration gets easier as the project approximates to pure basic research, and progressively more difficult the nearer you get to industrial and commercial application. The objective of CERN for all the huge sums invested in it and proposed to be invested in its possible successor, is pure research. The same is true of nuclear fusion, a field in which EURATOM can claim some success.

Judging from these precedents, I believe better results are likely to follow in the future by dealing with most large collaborative schemes as industrial and commercial enterprises rather than as political or prestige projects. Nowadays, Governments are so heavily involved in research and development, and indeed in national industrial applications, that it may be impracticable to denationalise such ventures altogether. My belief is that they should be approached on their economic and commercial merit and left as far as possible to the industries in each country to work out. I have no recent information as to how foratom is getting along, but I think that this organisation might serve as an instrument for the kind of European industrial collaboration which is needed in the nuclear field.

I submit that political advantage (at all events, in successful cases there will be substantial political gain) should be treated "fall out" from the technological collaboration, rather than the other way round. It seems that in the past projects have been selected for political reasons and the economic and commercial advantages taken largely on trust. Technological success, as many American examples show, is due more to management than to scientific research, more to practical organisation and proper market research than to political motives: one design team, not two: single management for each project, not a duumvirate or a triumvirate. These are preconditions for success. Official supervision may indeed be necessary where Governmental money is involved, but it should not lead to interference or to an attempt to control management.

Lord Ironside: In the scientific field, it is "big" science that strains national budgets and the co-operative ventures in space and high energy physics are worth reviewing. CERN, which started in the early '50s as a European centre for the study of high energy physics, has matched the United States efforts in this direction and can be regarded as an extension to the facilities of a number of European universities, facilities which any one country would find difficulty in affording and which has given the Treaty countries in Europe the opportunity of making a major contribution to the advancement of fundamental science in the field of particle physics. In the words of the Convention,

"CERN provides for collaboration among European States in nuclear research of a pure scientific and fundamental character and in research essentially related thereto."

Its output is therefore largely in terms of scientific knowledge. Accounts of all work are published and annually it publishes a highly professional report, not the sort of report which could be debated in your Lordships House.

CERN has developed steadily over the years and has recently conceived a number of expensive projects indeed, most of which have attracted the support of the Treaty countries, the latest of whichand most expensive of all—is the 300 GeV accelerator which, if it goes ahead, is to cost £150 million by 1977. Assuming a 9% growth rate in this country of Science Research Council expenditure per year, the experts believe that our contribution, which is around 25%, to the 300 GeV project can be contained within the existing budgets as distributed over the many fields of science. The technical case for the 300 GeV accelerator has been made out and the implications of the proposed United Kingdom involvement have been fully discussed in the White Paper on the subject. As a result, the Government have concluded that we cannot justify participation at present on financial grounds. Unfortunately, nobody has yet thought of a cheaper way of carrying out particle physics studies and the scientific merit of the new accelerator is not in doubt. If we have the money, I believe that this is a pure science investment which is justified subject to safeguards.

But what is going to happen? This is one of the fields where making headway clearly means working above the critical threshold of effort and facilities. If we do not contribute in due course to the 300 GeV accelerator, and the other Treaty countries in consequence decide to abandon the project, then to remain in a viable position in this field of science our national effort would have to be stepped up above the threshold—and probably the CERN contribution anyway—otherwise we shall have to consider the possibility of opting out of the main high energy field and reducing our efforts to fringe work. Will the noble Lord, Lord Chalfont, in his reply be able to give us the Government's present thinking on participation in this particular venture in the CERN programme and, for that matter, their general thinking on the future of CERN? Do the Government feel that the Convention could be renegotiated in any way in order to improve it?

CERN has been one example of how to organise a European scientific centre and keep it going over the years. The ingredients needed for doing this are imaginative programmes and continuity. But there is a grave danger now that a gap could occur after the completion of experiments using the intersecting storage rings. However, there is one other aspect of CERN which has caused some concern to a great many people. It is that contracts gained by British industry for supplying CERN facilities have been few and far between. Reasons have been argued over and over again, but I believe that it is not surprising in view of the fact that CERN have no special mandate to encourage technology and industrial participation, which, incidentally, is in direct contract to ESRO. But I feel that in cases of European co-operative ventures, contracts to industry count as benefits, and if the ground rules are well-conceived British industry can compete as well as any in Europe. One cannot force industry to get contracts with CERN, but I should be interested to hear whether the Government have given further thought to this particular aspect of CERN affairs and what new conclusions they have reached.

### Power costs

13th March, 1969

MR. ASHTON asked the Minister of Power is he will give the latest estimates of the costs of electricity sent out from the power stations listed in Table F of Appendix III to Command Paper No. 3438, and the figure for the coal-fired station at Ratcliffe-on-Soar; and when each of the stations is expected to be in operation.

Mr. Mason: the C.E.G.B.'s latest estimates are as follows:

		(	Generating	Year of
Statio	on		Cost	Commis-
			(d. per	sioning
			unit)*	
Nucle	ar		•	
Dungeness B			0.56	1972
Hinkley Point	В		0.52	1972
Coal-f	ired			
Ratcliffe			0.55	1968
Cottam			0.60	1969
Drax			0.61†	1971
Oil-fi	red		·	
Pembroke (wit	h tax)		0.59	1970
Pembroke (wit	hout ta	ax)	0.48	1970

\* On the assumption of a 30-year life for coal and oil-fired stations, and 25 years for A.G.R. stations.

† On the assumption that the whole 3960 MW station is completed.

### **Fuel supplies**

13th March, 1969

SIR J. EDEN asked the Minister of Power what are his latest estimates of the demand of the nuclear reactor programme for natural and enriched uranium and plutonium in 1970, 1975 and 1980; whether he is satisfied that adequate supplies will be available to meet it; and what is the quantity and value of past and future imports necessary for such a programme.

Mr. Benn: I have been asked to reply.

Estimates for the enriched uranium requirements for the nuclear power programme are about 150 tonnes of lowenriched for 1970 and from 350 tonnes to 550 tonnes in 1975. About 1,700 short tons per annum of natural uranium will also be required for Magnox reactors. The demand for plutonium could be 3 tonnes in 1975; the demand in 1970 will be for research and development purposes only. Requirements for 1980 will depend on how many, and what type of stations are built, but I am satisfied that adequate supplies of enriched uranium and plutonium will be available. All the natural uranium required will be, or has been, imported, but for defence and commercial

reasons details of past and future imports cannot be disclosed.

### Hartlepool costs

18th March, 1969

MR. Woof asked the Minister of Power why it is estimated that electricity from the fourth advanced gas-cooled reactor nuclear power station at Hartlepool will be no cheaper than the estimate given in March, 1968 for the second station in the programme, Hinkley Point B.

Mr. Mason: The reason is that the reduction in costs stemming from design advances has been offset by worse site conditions at Hartlepool than at Hinkley Point and by inflation.

### **Dungeness B costs**

18th March, 1969

MR. Woof asked the Minister of Power what are the latest estimates of the generating and capital costs of the nuclear power station Dungeness B in view of the fact that the first reactor will be 22 months late.

Mr. Freeson: The Central Electricity Generating Board's latest estimate of the construction cost is £83 per kW. The Board's present estimate of the baseload generating cost is 0.56d. per unit.

### Gas centrifuge process

18th March, 1969

MR. BROOKS asked the Minister of Technology if he will make a statement on the effect of the proposed gas centrifuge process for uranium enrichment upon the supply of nuclear fuel during the next decade; and if he is yet in a position to indicate the likely effects of this new technology upon power costs in Great Britain during the 1980s.

Mr. J. P. W. Mallalieu: One of our aims in collaborating with other European countries on the centrifuge process will be to establish a source of enriched uranium which will meet our requirements in the 1970s. and later. It is as yet too early to forecast the effect of enrichment by centrifuge on the cost of power.

### Dounreay

18th March, 1969

MR. HECTOR HUGHES asked the Minister of Technology if he will make a further statement on the present work of Dounreay Experimental Station with special regard to its contribution to Scotland's trade, industry, commerce and employment.

Mr. J. P. W. Mallalieu: Details of the work carried out at the Dounreay Experimental Reactor Establishment were given in the reply to my hon. and learned Friend's Ouestion on 4th December.

In almost every sector, construction of the Authority's prototype fast reactor at Dounreay is proceeding to plan. Difficulties have, however, arisen in the fabrication of the complex steel radiation shield roof, and these have resulted in delay in its delivery. Everything possible is being done to minimise the delay, and construction of the reactor is now expected to be complete by the end of 1971. Providing this date can be held the reactor should be on power by the end of 1972—a total delay of about twelve months.

The difficulty over the radiation shield roof for Dounreay, does not concern the fast reactor system as such. Design study work for the commercial fast reactor has already started and will be unaffected by the delay to the completion of the prototype fast reactor. Although the delay in completion of the P.F.R. will affect the final proving of some components, the timing of the C.F.R. development programme will not be set back by the amount of the P.F.R. delay.

### Amortisation period

25th March, 1969

MR. EADIE asked the Minister of Power why he has agreed to a change in the depreciation period for nuclear power stations from 20 to 25 years; and on what technical evidence he bases this decision for the advanced gas-cooled reactors.

Mr. Mason: Nuclear stations are designed for a 30-year life. Until recently, the C.E.G.B. worked on a 20-year life for purposes of cost comparisons of A.G.R. and conventional stations. It now regards this as unduly cautious and conservative in view of the experience accumulated in the design and engineering of A.G.R.s, and has accordingly changed to 25 years.

### Commercial fast reactor

28th March, 1969

MR. EADIE asked the Minister of Technology when he now expects the first commercial reactor of the Dounreay type to be in operation.

continued on page 148.

### The use of radioactive tracers in gas mains

The following paper by R. W. N. Cameron and M. J. F. Olden of the South Western Gas Board was presented at a Joint meeting of the South Western Section and Wales and Monmouth Section of the Institution of Gas Engineers at Bristol on 15th January, 1969.

The tendency in the gas industry during the past few years to concentrate gas manufacture into fewer but larger units has highlighted the need to pay particular attention to gas characteristics and flow patterns in distribution networks.

At the present time three main types of towns gas are being supplied to consumers:

- (a) mixtures containing principally coal gas and cyclic plant gas;
- (b) gas from high pressure continuous catalytic processes;
- (c) natural gas.

Gases in categories (a) and (b) are normally fully interchangeable as regards calorific value, specific gravity and general combustion characteristics but occasionally disparities occur which require investigation. It is then necessary to be able to determine the location of interfaces between gases from different sources. Furthermore, with the increasing demand for gas there is a need for a more accurate knowledge of gas flow in distribution networks. There are a number of well established methods of estimating gas flow but all have limitations when applied to this type of problem.

The most readily available techniques are those involving the measurement of pressure differential and require the insertion of equipment into the mains under test. Such techniques include orifice plates, Venturi meters and Pitot tubes.

Orifice plates and Pitot tubes are commonly used within the gas industry and even though they are useful means of measuring flow rates, possess inherent limitations when high accuracy is required. An orifice plate must be located with great care in a straight section of pipe without protuberence or any other form of obstruc-

tion which could upset gas flow through the orifice. Orifice plates are not easy to set accurately without the use of specially designed "carriers" and can readily give false readings if the moving gas bears dust or liquid contaminants. Measurements are subject to widely varying accuracy if flow rates or gas compositions change substantially and there is no positive means of identifying gas fronts as they pass the orifice. The orifice plate does not commend itself to general application where only a temporary installation is envisaged. The installation costs are high and serious errors may arise due to the difficulty in locating the equipment in other than flanged pipes. A further objection to the employment of orifice plates is the permanent pressure head loss that occurs. Similar objections can be raised against Venturi meters, the installation costs being even higher, but Pitot tubes involve no pressure loss. It is hardly necessary to remind gas engineers that even after taking due account of the ease with which Pitot tubes are inserted in gas mains, it is difficult to obtain reproducible results. The small and unsteady differential pressure lends itself to approximate velocity estimates only and cannot, under field conditions, be considered as a means for absolute measurement.

Positive displacement meters can provide an accurate measurement of flow rates, an integrated flow and can also be used to identify reverse flow conditions. However, these meters are very expensive and the total cost of installation is far too high for measurements that are not required on a regular basis.

It can be concluded that the use of mechanical means of flow measurement and positive meters are either too expensive, too inconvenient or too inaccurate to be accepted as techniques for occasional flow measurements and the examination of flow patterns in distribution networks.

Tracer methods must also be considered for applications of this type. The use of halogen tracers has been considered but appears to be unsuitable. The method depends upon the ionisation of the compound employed in a detector containing an anode operating at approximately 800°C. The fact that towns gas contains a number of ionisable compounds in small traces led to the conclusion that the "stable" state of the sensitive detection element will be subject to continued "upset" conditions rendering it difficult, if not impossible, to distinguish with certainty the occasions on which halogens are actually passing through the instrument.

A recently described tracer technique involves detection by infra-red absorption and suggests tracer gases which exhibit narrow bands of absorption in the infra-red frequency spectrum. These include carbon monoxide, methane, carbon dioxide, water vapour and nitrous oxide. All these gases are constituents of either reformed gas or coal gas or both, thus limiting the applicability of the method. However, with the advent of direct natural gas distribution infra-red absorption may warrant further investigation<sup>1</sup>.

Any compound that can be detected is worthy of attention and some elementary methods have been examined but without a great deal of success. Leaks in gas mains are, on occasion, pin pointed by employing malodorous compounds such as mercaptans, but there are many situations where it is impossible to increase gas odour sufficiently to detect a change either by direct analysis or the use of human "guinea pigs". Variations in gas density, while possible, involve the introduction of large quantities of tracers and appear to be impracticable. Nevertheless, when two gases possessing significant variations in physical properties meet within a pipe, forming a moving front, it has been possible to identify the front with reasonable rapidity by testing for variations in specific gravity and calorific value. However, such differences in towns gas supplies are not commonplace and, therefore, this technique cannot be relied upon for routine measurement.

The condensable hydrocarbon content of towns gas can be intensified by the injection of light aromatic or paraffinic hydrocarbons but the time taken to carry out analyses reduces the accuracy of determining gas flow rates to a point where tests become almost valueless.

Another method that appeared promising was examined by the Central Laboratories of the South Western Gas Board. This employed gas chromatography and depended on the assumption that no two gases are entirely identical in their trace constituents. Undoubtedly gases originating from differing sources can be identified but the equipment involved and the time lag in obtaining results was against using this method for the examination of gas flow patterns. By a small increase in the presence of a trace hydrocarbon gas, flow rates can be estimated but as a field technique the method was ruled out.

It was at this point the suggestion that radioactive tracers should be used was first considered. The measurement of a change in radioactive level at a fixed point could be made directly if the tracer did not diffuse within the gas creating an attenuated front. Furthermore, reversals in flow direction could be indicated and identified when they occurred as long as the gas movement passed the test points set up. The possibilities of the proposed method appeared to be very encouraging and led to an appraisal of the information that may be gleaned by a technique offering rapid identification of changes in flow conditions.

It is clear that with the very high degree of integration that exists today in the South Western Gas Board distribution system and the considerable distances over which gas is transmitted, virtually any information on the distribution of gas in a complex branched system is likely to be of interest and value.

It is possible to carry out network analysis by employing a computer model and the South Western Gas Board undertake such work. While these exercises are invaluable and, indeed, essential if gas transmission is to be undertaken economically and efficiently, calculations can come to nought if the information used is inaccurate in detail or insufficient. Where gaps in information exist, a practical study of the pipe-lines under examination may prove to be necessary. Excavation is costly, extensive internal inspection impracticable and unlikely to provide all the data required. It is evident upon a study of the continued on page 147

WATKIN, T. D. Tracer Techniques Used in Flow Measurements. Flow Measurement Symposium, Pittsburgh, Penn., U.S.A. ASME. 139 (1966).

# A mobile system for measuring flow in a gas distribution network

The following paper by C. G. Clayton, G. V. Evans, R. Spackman, and J. W. Webb of Wantage Research Laboratory (A.E.R.E.), Wantage, Berkshire, was presented at a Joint Meeting of the South Western Section and Wales and Monmouth Section of the Institution of Gas Engineers at Bristol, 15th January, 1969.

### Introduction

The increasing demand for gas and the introduction of natural gas into existing distribution pipes has generated a need to determine the flow characteristics of distribution networks under conditions of varying supply and demand. Accurate information is required so that reliable analogues can be constructed and the behaviour of systems predicted for any possible flow conditions.

Present practice is to construct analogues from pressure measurements, and from estimated pipe friction factors, in many cases without direct measurement of the gas flows within the network. If direct measurements of gas flow and corresponding measurements of pressure can be made, accurate values for pipe friction factors can be derived and reliable network analogues can be obtained.

Conventional methods of measuring gas flow using pressure-differential devices, such as orifice plates and venturi meters, introduce a pressure loss, are expensive to install and are not easily moved from one location to another. Serious errors can occur in these instruments if condensates are present in the flow.

Turbine meters suffer from the same disadvantages as pressure-differential devices.

Velocity-area methods, using pitot tubes and propeller meters, are tedious to operate and, for accurate measurement, the flow rate and the velocity profile must be constant during the (usually long) period of measurement.

Radioactive isotope methods of flow measurement based on measuring the mean velocity of a tracer introduced into the gas do not suffer from any of the above disadvantages. These methods, which are well established for water flow measurement(1,2), are highly accurate, can be operated without pressure loss, are inexpensive and can be moved easily from one point to another in a pipe network. Measurements can be carried out in several branches of a network from a single injection of the tracer and the time for measurement can be quite short (<1 sec) so that fairly rapid fluctuations as well as slow variations in flow rate can be measured.

Preliminary tests using the radioisotope velocity methods, with krypton-85 as the tracer gas, were carried out on a distribution network in North Devon. They established that these methods can be used to measure gas flows during periods of normal and maximum demand and were capable of being developed for routine use.

The present paper describes the techniques which have been developed subsequently and presents the results obtained when the methods were applied to measure the flow in a medium pressure pipe system. Comparisons between the results obtained using the isotope velocity methods and an orifice meter installed at one end of the pipe are also given.

The use of krypton-85 as the tracer involves negligible radiation risk and is in no way an embarrassment to the simple and rapid operation of these methods. They have been accepted by the Miscellaneous Sources Panel of the Ministry of Housing and Local Government as suitable for frequent use for the purpose of data collection.

### Principle of the velocity methods

A small volume of radioactive gas is injected into the pipe and the transit time between two radiation detectors a fixed distance apart is measured. If the volume of the pipe between the two detectors is known then the volume flow rate of gas can be determined. The mass flow rate can then be derived from the specific gravity of the gas at the mean temperature

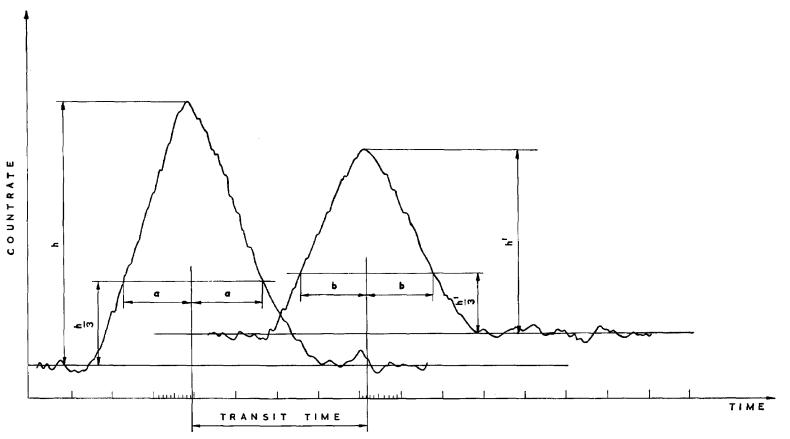


Fig. 1. Typical trace recorded in pulse-velocity method.

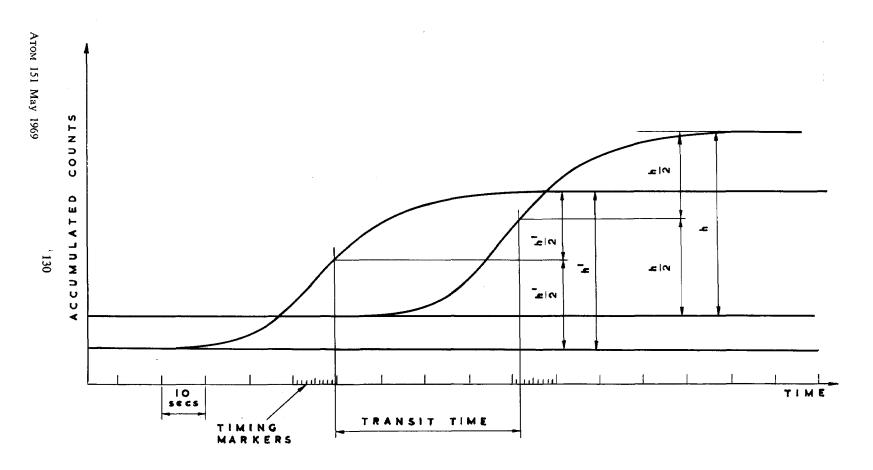


Fig. 2. Typical trace recorded in integrated-pulse-velocity method.

and pressure over the region of measurement.

These methods of flow measurement are applicable at all turbulent flows but the length of pipe between the injector and the first of the two detectors must be sufficiently long for adequate mixing of the injected tracer gas to be established. The separation of the two detectors is not critical and, in practice, can be as short as a few feet.

Under conditions of steady flow these methods have been shown to be accurate to within  $\pm 0.2\%$ <sup>(3)</sup>.

### Pulse-velocity method(1)

The radiation detectors are connected to countrate meters and the signal dis-

played on a suitable recorder. A typical trace is shown in Fig. 1. A simple geometrical construction is used to identify a point on the trace (the point at one half-width and one third amplitude) which is representative of the mean arrival time of the tracer for the purpose of measuring the transit time between the two detectors.

### Integrated-pulse-velocity method(1,4)

The radiation detectors are connected to integrating ratemeters and the signal is displayed on a suitable recorder. In this method the abscissa corresponding to the half-amplitude of the trace is selected as being the characteristic point. A typical trace is shown in Fig. 2.

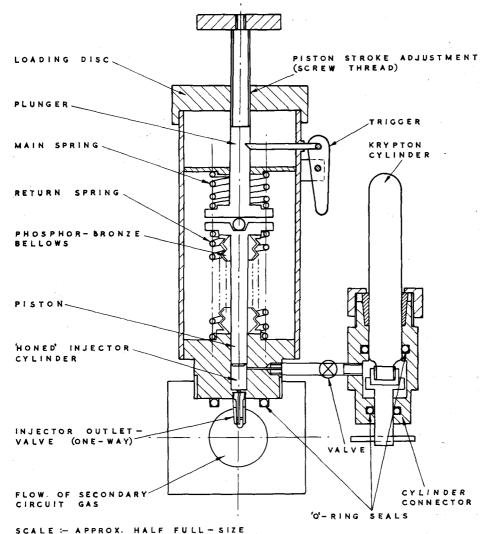


Fig. 3. Gas injector.

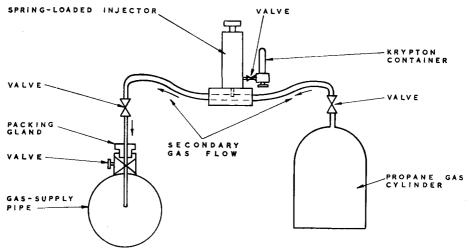


Fig. 4. Diagram of injection arrangement.

For most applications this method has advantages over the pulse velocity method: the characteristic point on the trace can be more easily determined and, for a given injected activity, the statistical error associated with any point on the displayed trace is reduced. A consequence of this latter fact is that small activities of tracer gas can be used.

### Use of krypton-85

Although in principle the velocity methods can be used with any radioactive gas, krypton-85 [half-life 10.6y: emission β-particles 0.67 MeV (99.3%), 0.15 MeV (0.4%), γ-radiation 0.51 MeV (0.4%)] was selected for the present tests as it involves the least radiation risk and at the same time allows a measuring system of adequate sensitivity to be designed. Its long half-life allows it to be stored so that it can be used as and when required.

Because krypton-85 is essentially a  $\beta$ -emitter it is not possible to mount radiation detectors directly on the outer wall of a gas main, as the normal thickness of pipe wall results in total absorption of the  $\beta$ -particles. To overcome this difficulty a sample of the gas is continuously withdrawn from the main and passed through a flow cell constructed from plastic phosphor and being part of a scintillation detector. After the flow cell the gas is passed direct to atmosphere through a flame trap.

## Injection and detection equipment Injection equipment

A diagram of the isotope injector(5) and

an outline of the injection system are shown in Figs. 3 and 4. The isotope injector consists essentially of a cylinder, having a volume that can be varied from zero to 1 ml, and a spring-operated piston. On raising the piston, the cylinder is automatically filled from a separate reservoir which contains the radioactive gas at the required concentration and which initially is at atmospheric pressure.

After operation the piston is retracted by rotating the loading disc, which also acts as a stop to limit the length of piston stroke (and hence the injected-volume) after the trigger is released.

The krypton-85 is not injected directly into the gas main. It is more convenient to use a secondary flow of propane, adjusted to a convenient pressure above that of the gas in the main, and to inject the radioactive tracer into the propane which is supplied from a separate cylinder. The supply of propane can be started shortly before and terminated shortly after injecting the krypton-85. The propane enters the gas main through a 0.5 in. diam. probe terminated at the centre of the pipe.

### Detection equipment

A diagram of the detection system is shown in Fig. 5. The connection from the main to the flow cell (shown in Fig. 6) is through a 0.5 in. diam. pipe and includes a volume flow meter to enable the flow rates through the flow cells at each of the measuring positions to be equalised. This allows a correction for the transit times in the feed-pipes to the flow cells to be mad

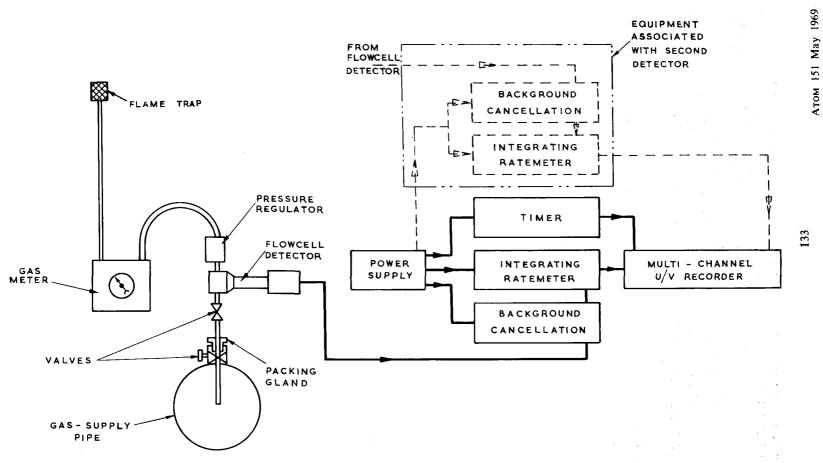


Fig. 5. Diagram of detection apparatus.

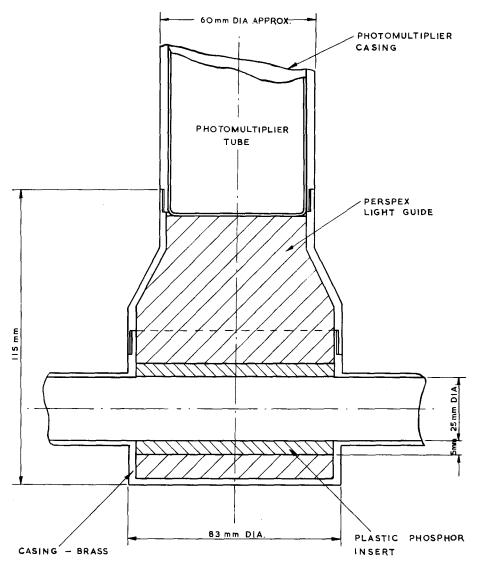


Fig. 6. Diagram of flowcell used in gas flow measurement.

accurately. Adjustment of the flow rate (to 1 ft³/min) is by means of a reducing valve regulated to give an outlet gas pressure of about 6 in. water gauge.

### Gas flow measurements in a distribution pipe

In order to establish the value of the method as a mobile system for rapid installation at selected points in a distribution system and to assess the reliability and accuracy of derived results of flow measurement, tests were carried out on a selected length of 6 in. diam. pipe under normal operating conditions.

Gas is supplied to this pipe from a

production station (at Exeter). The required flow is derived through five compressors which operate independently and are controlled manually so as to maintain a constant pressure at the outlet of the plant.

There was a continuous and varying demand to a separate branch between the production station and injection position. However, there were no branches supplying gas between injection and measuring positions.

The rate at which gas was fed to a gas holder (at Honiton), from the pipe on which the measurements were made, was held constant during the period of the tests. However, due to a varying demand on the supply branch upstream of the injection position, variations in the gas supplied to the test section occurred in an uncontrolled manner, although the pressure of the gas at the beginning of this section was always greater than the pressure of the gas supplied to the gas holder.

The effect of supplying gas to a pipe at a varying rate above that at which it is released is to impose velocity variations along the pipe such that the highest velocity variations occur close to the inlet to the

pipe\*. In the present tests therefore, corresponding velocity variations were expected at the four measuring positions along the pipe.

Measurements of gas flow were made at four positions (each position incorporating two detectors) approximately equally

\*For an ideal gas in a straight pipe without obstruction, the variation in velocity δu over a length L of pipe is approximated by,

$$\delta u = \frac{L}{P} \cdot \frac{dP}{dt}$$

where P is the pressure and dP/dt is the rate of change of pressure in the pipe.

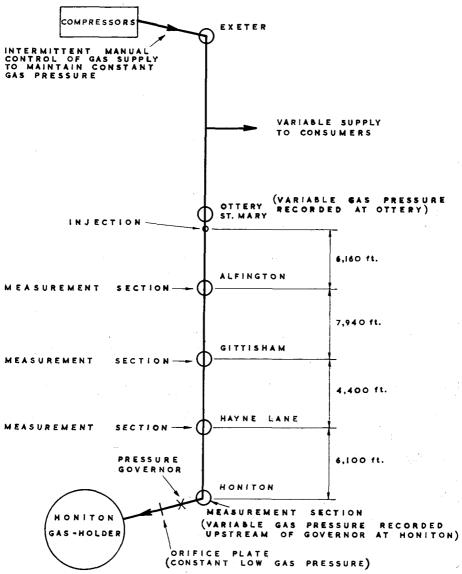


Fig. 7. Gas distribution system showing injection and measuring positions.

spaced over a five-mile section of medium pressure (30 lbf/in.²) distribution pipe. The location of the injection and measuring positions along the pipe (which carried gas from Ottery St. Mary to Honiton in S.W. Devon) is shown in Fig. 7.

The separation of the detectors at the measuring stations varied between 300 ft. and 900 ft. These relatively long separations were used since they coincided with tapping points already installed in the gas main.

To enable an accurate estimate of the separation of the traces to be obtained

from the two detectors at each measuring position, timing pulses at 1 sec intervals (derived from a crystal-controlled oscillator) were also displayed on the recorder charf.

The gas pressure in the main pipe was measured with calibrated Bourdon gauges. The temperature of the gas in the main was measured at one of the detector positions with a thermocouple and found to be within 0.5°F of the ground temperature at the injection point. Ground temperature was therefore used for mass flow determinations.

Table 1—Gas flow rates, pressures and temperature at each measuring station.

Volume between detectors (ft³)		Alfington	Gittisham	Hayne Lane	Honiton		
		123.1	66.1	131.6	169.5		
Day Test		Transit Times (S)					
1st day	A B C D E F G H I	74.6 69.7 72.6 78.4 80.8 80.8 74.4	39.9 42.2 45.0 43.5 — 44.7 43.1 42.7 44.1	78.7 83.6 — 84.1 81.2 82.8 82.8 84.6	110.1 112.9 112.3 112.2 112.7 113.7 113.7 111.8		
Absolute (lbf/in²)	gas pressure	35.7	35.7	35.6	32.7		
	Mean flow rate in pipe (ft <sup>3</sup> /s)		1.53	1.52	1.51		
Day	Day Test		Transit Times (S)				
2nd day	J K L M N O	74.5 75.0 75.7 74.7 79.5	42.0 41.9 42.2 44.1 43.4 42.6	77.2 81.0 79.2 80.4 84.2	106.8 105.7 106.5 105.6 108.2 105.9		
Absolute gas pressure (lbf/in²)		35.0	34.2	33.8	32.7		
Mean flow rate in pipe (ft <sup>3</sup> /s)		1.62	1.55	1.56	1.59		
Day	Test	Transit Times (S)					
2nd day	U	99.2	72.6	148.6 142.5	190.0		
Absolute (lbf/in²) .	gas pressure	35.0	34.2	33.8	32.7		
Mean flow (ft <sup>3</sup> /s)	rate in pipe	1.24	0,91	0.86	0.89		

Gas pressure measurements were not made in each test. The value quoted is an estimate of the mean value over the series of tests. Gas temperature  $= 54^{\circ}F$ .

An orifice-plate meter installed at Honiton close to the final measuring position and on the low-pressure side of a "governor" in the supply to the gasholder, was used to measure the gas flow from the pipe.

### Test procedure

About 2 mCi krypton-85 was injected at 15 min intervals over a period of two hours on each of two days. Altogether 17 injections were made. Velocity measurements were carried out at four selected positions, at Alfington, Gittisham, Hayne Lane and Honiton.

Samples of gas were withdrawn at the governor (at Honiton) and the specific gravity derived by using a Simmance Specific Gravity Bell. The measured flow rates were corrected to the standard conditions of saturated gas (60°F, 30 in. Hg, saturated with water vapour: British Standard 1042, Pt. 1, 1964) according to the equation,

$$Q_{s.c.} = 36.00 (p - p_v) \frac{Q}{KT}$$

where, Q<sub>s.c.</sub> is the flow rate (ft<sup>3</sup>/h) at standard conditions,

Q is the measured flow rate at the conditions in the pipe,

p<sub>v</sub> is the partial pressure (lbf/in.2) of water vapour in the gas,

p is the absolute pressure (lbf/in.2) of gas in the pipe,

K is the Gas Law deviation coefficient (assumed unity),

T is the absolute temperature of the gas (°R).

### Results

The gas flow rates, pressures and temperatures at each measuring section are given in Table 1 and typical recorded traces are exhibited in Fig. 2. The mean value of flow rates at each section, corrected to standard conditions (60°F, 30 in. Hg, saturated with water vapour) and the relative standard deviation of the series of measurements at each measuring section are given in Table 2 together with the flow rates derived from the orifice plate at Honiton. Typical records of the gas pressure variations at Exeter Supply Works and at Honiton are shown in Fig. 8.

Countrate versus time curves obtained using the pulse-velocity method and recorded at each of the measuring positions following a single injection are shown in Fig. 9. An analysis of these curves based on Taylor's dispersion equation shows that the dispersion of the tracer (half-width at half-height) within the pipe is approximately twice that expected theoretically in a straight, smooth pipe of uniform cross-section.

### Discussion of results

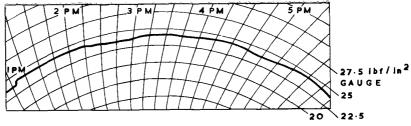
The measured flow rates given in Table 2 decrease as the distance from the injection position to the measurement section increases and this is consistent with the gas flow into the pipe being greater than that at the outflow at Honiton. It corresponds to an increase in the mass of gas stored within the pipe (observed by an increase in pressure) over the period of measurement. It is not possible to correlate the velocity and pressure measurements accurately

Table 2—Mean flow-rates measured by the integrated-pulse-velocity method

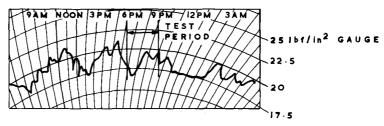
	1st Day		2nd Day		2nd Day	
Measurement Position	Mean volume flow-rate (standard conditions) (ft³/h)	Relative standard deviation (%)	Mean volume flow-rate (standard conditions) (ft³/h)	Relative standard deviation (%)	Mean volume flow-rate (standard conditions) (ft³/h)	Relative standard deviation (%)
Alfington	14120	5.6	13820	2.7	10470	
Gittisham	13420	3.9	12970	1.8	7490	
Hayne Lane	13340	2.5	13000	2.8	7120	_
Honiton	12300	1.5	12980	1.1	7220	
Orifice Plate	12100		12350		7145	_

<sup>1.</sup> Flow-rates are corrected for measured gas flows to flowcell detectors.

<sup>2.</sup> Standard conditions are 60°F, 30 in. Hg, saturated with water vapour.



### (q) PRESSURE MEASUREMENT AT EXETER



### (b) PRESSURE MEASUREMENT AT HONITON

Fig. 8. Typical records of gas pressure variations at Exeter supply works and at Honiton gas holder station.

since the former are spaced in time by the transit period between measuring positions, also inconsistencies in the recorded times on the pressure recorders at Honiton and Ottery St. Mary were observed.

The relative standard deviation of the measured velocities about their mean values was highest at Alfington and gradually reduced to its lowest value at Honiton. These values which are a measure of the flow variations in the pipe caused by the manual control of the compressors supplying the gas at Exeter and the variable amount of gas drawn through the branch pipe, show the extent to which the flow variations are "damped" by pipe friction and volume.

The dispersion of the tracer gas was caused by the turbulent flow and the presence of bends and other pipe fittings in the test pipe. Nevertheless, krypton could be detected easily at about five miles downstream of the injection position and, by extrapolation, it is evident that velocity measurements can be made at distances exceeding ten miles from injection, for similar activities of injected tracer.

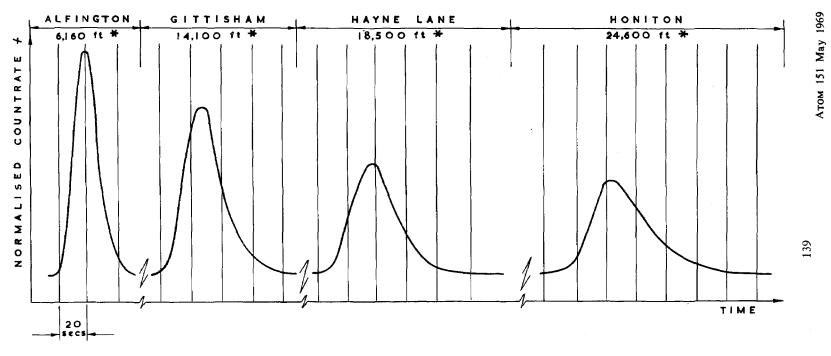
### Health and safety considerations

When a radioactive isotope is used as a tracer in an industrial environment, consideration must be given to the possibility of a radiological hazard arising from ingestion and inhalation and from direct exposure to ionising radiations emitted by the radioactive material.

The conditions governing the safe use of radioactive material in terms of allowable concentrations in air and water and including the metabolism of particular nuclides in specific organs of the body are given in the Recommendations of the International Committee on Radiological Protection<sup>(6)</sup>. These recommendations are incorporated into the Radioactive Substances (Unsealed Sources) Regulations, 1968<sup>(7)</sup> which also include statutory requirements relating to the use of radioactive tracers in industry.

For krypton-85, the highest concentration to which the general public may be exposed continuously for a period of 50 years should not exceed 8.52 μCi/ft³ and this corresponds to a radiation dose to the whole body of 0.5 Rad during each successive period of one year. However, as krypton-85 is an inert gas which does not metabolise in the body, higher concentrations may be experienced for correspondingly shorter periods without an increase in the radiological hazard.

Before the present tests were carried out the radiation dose received by consumers supplied with gas directly from the medium



\* APPROXIMATE DISTANCES FROM INJECTION POINT

+ COUNTRATES CORRECTED FOR DETECTOR SENSITIVITY

Fig. 9. Dispersion of krypton-85 over the test section.

pressure main, and from the gas holder into which the krypton-85 eventually passed, was considered. The radiation dose received by a consumer is represented by the product of the concentration of krypton-85 in the gas and the period of exposure and can be shown to be independent of the method of gas supply, provided the gas is continuously consumed throughout the period when krypton-85 is present.

As the radiation hazard from krypton-85 in unburnt gas is insignificant compared to the explosive or toxic hazard of the gas itself, the presence of krypton-85 in combustion products only need be considered. The combustion products from most gas appliances, especially gas fires, are extracted directly to atmosphere where they are diluted to an insignificant concentration. The highest radiation dose is therefore liable to be received by a consumer who operates open cooking appliances in a poorly ventilated room.

Estimates were therefore made of the radiation dose to a consumer using 100 ft3/hour gas in a room having a volume of 1,000 ft<sup>3</sup> with a ventilation rate of 3 air changes/hour and receiving gas during the complete passage of the tracer. For the tests described in which about 18 mCi krypton-85 were used over a period of 2 hours on each of two days, the corresponding dose was less than one half the recommended maximum dose for continuous exposure when averaged over the period of the tests. If this dose is averaged over a period of one week only, the dose is less than one tenth of the maximum allowed dose. In practice many consumers, especially those supplied from a gas holder, will not use gas during the entire passage of the tracer. In these cases the actual dose measured will be less than that calculated above.

As a result of the experience gained in the tests, it is now possible to reduce the amount of activity required for similar measurements to about one sixth of that used in the present tests, so that future radiation doses could be correspondingly decreased. Higher flow rates would necessarily require an increase in the injected activity, but as the specific activity of krypton-85 in the gas supplied to the consumer would remain the same, the dose to the consumer would be unaltered.

To confirm the negligible radiation risk,

the concentration of krypton-85 in a room containing a gas-jet burner supplied continuously with gas at 2 ft/hour from the Honiton gas holder was measured for one week over the period of the tests. A Geiger counter was used, capable of detecting a concentration of krypton-85 of about 1% of the maximum permissible concentration. No krypton-85 was detected by this equipment indicating that in this situation there was negligible radiological hazard.

Apart from hazards due to ingestion and inhalation, consideration must also be given to the radiation dose arising from exposure to sources of krypton-85 outside the body. In the present techniques exposure of this type occurs only during injection of the tracer. However, as the  $\beta$ -particles are absorbed completely by the walls of all the containers used, only resultant bremsstrahlung and  $\gamma$ -radiation need be considered. The magnitude of the dose from these sources with the activities used can be made negligible and less than 1% of the maximum permissible radiation level.

After consideration of both technical and safety aspects of these methods, their use has been approved by the Miscellaneous Sources Panel of the Ministry of Housing and Local Government for measuring flow rates of gases in distribution pipes for the purposes of data collection.

### Conclusions

- 1. The method described using krypton-85 can be used to measure the flow rates of gas at selected points in a distribution network. It is inexpensive, simple and convenient to operate, and can be moved easily from one position to another so that it is particularly suitable for collecting data for network analysis.
- 2. Measurements can be carried out over several miles of pipeline and flow rates in several branches of a system can be determined by a single injection of the radioactive gas.
- 3. There is negligible radiation hazard from the use of this radioactive gas at the activities required.
- 4. Besides enabling gas velocities to be measured, information on the mass of gas stored within a pipe and the effect of pipe friction on unsteady flows can be derived directly.
- 5. The inadequacy of using a single flowmeter to describe the flow in a long pipe in

which flow velocity fluctuations occur has been clearly demonstrated.

### Acknowledgments

The present tests were arranged and carried out in close collaboration with the South Western Gas Board and the help of Dr. M. J. F. Olden and Mr. R. W. Cameron and Messrs. C. Poole, F. Sanson and F. Tweedle of the Distribution Engineers Department is gratefully acknowledged.

We also wish to thank our colleagues Messrs. M. A. J. Aston and I. S. Boyce for their assistance during the tests.

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- 7. The Ionising Radiations (Unsealed radioactive substances) Regulations 1968, Statutory Instruments No. 780, H.M.S.O. (1968).

### A.E.A. Reports available

THE titles below are a selection from the April, 1969, "U.K.A.E.A. list of publications available to the public". 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 It also lists the published literature. 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.

### **AERE-M 1838**

A Beta-Gamma Counting System for 2000 Series. By K. Witsey. December, 1968. 7 pp. H.M.S.O. 5s.

### **AERE-R 5288**

Remote Handling Services. The Turret Suit. Patent No: 974316. By F. J. May. February, 1969. 18 pp. H.M.S.Ó. 4s.

### AERE-R 5736

Two-phase Two-component Critical Flow in a Venturi. By R. V. Smith, L. B. Cousins and G. F. Hewitt. December, 1968. 44 pp. H.M.S.O. 8s.

### **AERE-R 5809**

Measurement of Liquid Film Flow Rates at 1,000 p.s.i.a. in Upward Steam Water Flow in a vertical Heated Tube. By A. W. Bennett, G. F. Hewitt, H. A. Kearsey, R. K. F. Keeys and R. A. Stinchcombe. January, 1969. 8 pp. H.M.S.O. 2s. 6d.

### **AERE-R 5862**

A Magnetic Tape Transport for Digital Data Logging. By A. Lewis. August, 1968. 27 pp. H.M.S.O. 3s. 6d.

### **AERE-R 5922**

The Plutonium-Uranium-Carbon System. P. E. Potter. October, 1968. 42 pp. H.M.S.O. 5s. 6d.

### AHSB(S) R162

A Survey of Defects in Pressure Vessels Built to High Standards of Construction and its Relevance to Nuclear Primary Circuit Envelopes. By C. A. G. Phillips and R. G. Warwick. 1968. 36 pp. H.M.S.O. 6s.

### AWRE O-2/69

Electric Fields in Flux Compression Devices. By C. S. Speight. February, 1969. 39 pp. H.M.S.O. 5s. 6d.

### AWRE 0-7/69

Charging Choke Design for the Hicup Modulator. By G. M. Ward. February, 1969. 37 pp. H.M.S.O. 5s. 6d.

### AWRE 0-9/69

Temperature Distributions on Conduction-cooled Microcircuit Substrate Surfaces by Relaxation Analysis. By D. J. Dean and J. C. Taylor. February, 1969. 22 pp. H.M.S.O. 3s. 3d.

### TRG Report 1499 (S/X)

A Study of the Fundamentals of Longitudinal Wrinkling in Fuel Element Cans. By S. Bunyaraksh and C. R. Calladine. 1969. 36 pp. H.M.S.O. 9s.

### TRG Report 1743(S)

An Electron Microscope Examination of the Alpha Manganese Precipitate in Mg-Mn Creep Specimens. By D. J. Marsh. 1969. 5 pp. H.M.S.O. 4s.

### TRG Report 1761(R)

Squifid. A Square-Mesh Few-Group Reactor Diffusion Code. By C. W. J. McCallum. 1969. 54 pp. H.M.S.O. 7s. 6d.

### TRG Report 1797(C/X)

Dislocation Atmosphere Formation and Strain-Aging Effects in Niobium. By Z. C. Szkopiak. 1969. 9 pp. H.M.S.O. 2s.

### TRG Report 1801(R)

The Place of the Fast Reactor in Commercial Power Development. By T. N. Marsham. 1969. 7 pp. H.M.S.O. 2s.

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

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

### Reactor Safety

2nd to 27th June

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

### **Radiological Protection**

9th to 13th June

8th to 12th December

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

### Radioisotope Methods in Biochemistry

16th June to 11th July

Intended to give qualified biochemists sufficient background theory and practice in radioactivity and radioisotope techniques to enable them to use radioisotope methods in their work, this course includes lectures on basic physics of radioactivity, radiochemistry and radiation protection. Fee: £160.

### Measurement of Radioactivity

7th to 25th July

Intended for persons having elementary knowledge of radioactivity who need to have theoretical and practical knowledge of a wide variety of counting methods with special reference to their inter-relation, scope and limitations. Visits are made to a research reactor at Harwell, to the Rutherford Laboratory, and to the Package Irradiation Plant and Tritium Counting Laboratory at the Wantage Research Laboratory. Fee: £120.

### **Advanced Optical Microscopy**

14th to 18th July

This course is arranged in conjunction with the Royal Microscopical Society and consists of lectures, demonstrations and practical sessions.

It is for those who already have a knowledge of basic microscopy but wish to develop their use of the microscope for qualitative and quantitative work. Fee: £40.

### Two-Phase Heat Transfer

9th to 13th June

The course should be of particular value to engineers and scientists working in the field.

The subject is approached in a fundamental way and although its application to nuclear reactors problems has some emphasis, the material presented is useful to those requiring a knowledge of the problems inherent in two-phase heat transfer and of current solutions, theories and developments. Fee: £40.

# Pulse Techniques for Nuclear Particle Counting

14th to 18th July

This course for users of nuclear pulse counting equipment has been completely revised during the past year and includes practical work.

The lectures take account of the latest techniques and are given by specialists from Harwell.

Practical work includes instruction in the use of a multi-channel analyser, a single-channel sweep analyser, a total counting system, coincidence counting and logic circuits. Fee: £40.

### Magnet Design

14th to 18th July

This course is suitable for design engineers and scientists with or without experience in the field. Lectures are given by specialists from Harwell, Culham and Rutherford Laboratories, the University of Oxford and industry. Fee: £40.

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

### Dounreay mixer-settler

A mixer-settler of novel design which gives promise of considerable advances in the economic application of industrial solvent extraction processes has been developed by the U.K.A.E.A. at their Dounreay Experimental Reactor Establishment.

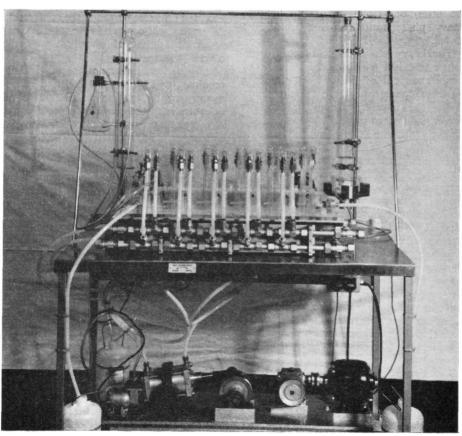
Solvent extraction is a technique widely used in industry for the purification or preparation of pharmaceuticals, petroleum products, nuclear materials such as uranium or plutonium, rare earth metals, the recovery of common metals from low grade sources and the recovery and preparation of organic chemicals.

In solvent extraction the impure material is dissolved, usually in acid solution, and is then shaken or stirred with an immiscible liquid (the solvent) in which the required material has a higher solubility than the impurities. The ratio of required material to impurities transferred to the solvent

will differ according to the materials and conditions involved and may vary from 1000:1 or higher down to a little more than 1:1. But by repeatedly contacting the solution containing the impure material with solvent under the correct conditions all the required materials may be transferred to the solvent, leaving the impurities behind. By varying the conditions the pure product may then be re-extracted from the solvent.

The most economical way to carry out this process is by countercurrent continuous extraction where the solvent and the solution containing impurities flow past each other in specially constructed equipment. This equipment can take various forms. One is a mixer-settler where the two liquids are mixed and then allowed to settle under gravity before being passed counter currently to the next stage.

The Dounreay mixer-settler is a simple laboratory scale equipment which has the advantage over some other types of continuous solvent extraction equipment, such as columns, that the discrete practical



stages can be compared with theoretical stages obtained in standard graphical or computer calculations for solvent extraction processes. It can therefore provide information which is a sound basis for scaling-up.

The design is based on the normal horizontal-type mixer-settler, giving automatic interface control without pumps or tilted boxes. However, to mix the liquids they are alternately sucked in and pumped out through holes in the wall. The holes are linked in a manifold to which an air pulse is supplied by a piston. This eliminates maintenance or problems associated with gear trains or stirrers and the high liquor velocity through the holes prevents blockage with crud and other interfacial deposits. Experience has shown that there is no "carryover" into the pulsing unit.

The maximum throughput depends on the system being used. However, with N-tributyl phosphate in odourless kerosene as the solvent (the light phase) and uranyl nitrate dissolved in nitric acid (the heavy phase) the throughput of the unit is about 3.5 litres/hour (total flow) with light to heavy phase ratios ranging from 30:1 to 1:5.

The heavy phase outlet of the mixersettler unit is a novel feature. The heavy phase runs out of the last settler into a separate compartment; its height determines the interface height in the last settler and is fixed using a vacuum suck-off system which is finely adjustable over wide limits.

The standard construction material for the mixer-settler is Perspex, which, being transparent, is very convenient for experimental work where interface and mixing and settling behaviour may need to be studied. Where liquors are likely to attack Perspex other materials can be used.

Industrial Models Ltd., Hope Works, Wrigley Street, Oldham, Lancs. (telephone: Manchester 633-2131), have been licensed by the A.E.A. to manufacture and sell the equipment and can now offer a complete assembly consisting of mixersettler, pulser vacuum system and pumps mounted on a trolley. The A.E.A. can give advice on settler length, number of stages or flowsheet problems to potential users.

The equipment was shown at the exhibition given by the Solvent Extraction Group of the Society of Chemical Industry

at Imperial College on 27th March, 1969. 19th March, 1969

### Cyclotron conference

An international cyclotron conference organised by A.E.R.E., Harwell, will be held at St. Catherine's College, Oxford, from 17th to 19th September, 1969, inclusive. The conference will cover the design and operating characteristics of AVF cyclotrons and synchrocyclotron conversions and improvements and is sponsored by the International Union of Pure and Applied Physics.

The conference will be followed on 20th September by an optional visit to accelerators at A.E.R.E., Harwell, and at the Rutherford Laboratory of the Science Research Council. In addition an eight day optional tour of European cyclotrons will start from Oxford on 23rd September, finishing in Paris on 1st October. From enquiries received already it is expected that some 150 delegates will attend and it is proposed that up to 50 papers will be accepted for presentation at the conference. All papers will comprise original work not previously published elsewhere and the official language is English.

Informative abstracts of papers will be required by 15th May, 1969, and subsequently copies will be distributed to all delegates with the conference programme. Accepted papers will be required by 1st September, 1969, and it is expected that Proceedings will be published after the conference by Iliffe Books Ltd.

Further information concerning the content of the programme may be obtained from Mr. R. W. McIlroy, Chemistry Division, A.E.R.E., Harwell, Didcot, Berks., England.

Registration literature for the conference and tour is available from Mr. F. K. Pyne, A.E.R.E., Harwell.

This conference on the design and operation of cyclotrons will be followed on 22nd and 23rd September by one on the Use of Cyclotrons in chemistry, metallurgy and biology.

21st March, 1969

# High temperature fluidised bed furnace

The U.K.A.E.A. have licensed W.D.M. Ltd. of Bristol to manufacture high

temperature graphite-resistance-heated furnaces for operation with vacuum, neutral or reducing atmospheres.

This type of furnace has been extensively used by the international DRAGON Project both at A.E.E. Winfrith and under DRAGON contracts with various research and development laboratories in Europe. Sales have also been made to other independent organisations.

This type of furnace has been used mainly in the development and testing of coated particle fuels for high temperature reactors. It is employed, for example, for the reduction sintering of fuel kernels (either under static conditions or in a fluidised bed), for the coating of fuel particles in a fluidised bed with fission product retaining materials, and for the evaluation of coated particle fuels by high temperature annealing at temperatures up to 2200°C.

The furnace comprises essentially a graphite resistance tube heater supported between two water-cooled brass electrodes and located by split graphite collets which accommodate thermal expansion and contraction of the graphite heater tube during operation. The heater assembly is thermally insulated from the outer water-cooled stainless steel furnace vessel by graphite felt. Sighting glasses are provided for using an optical pyrometer to measure the temperature profile of the furnace charge.

Facilities are available, if required, for charging fuel materials via the top flange, and fluidisation, when required (e.g. for vapour phase deposition), is achieved by introducing the fluidisation and process gases via a water-cooled nozzle assembly.

The furnace can be supplied complete with power supply and control facilities, and with a suitable control console for process gases.

Further information is available from W.D.M. Ltd., Western Works, Staple Hill, Bristol. Telephone Bristol 656141.

24th March, 1969

#### The use of cyclotrons

An International Conference on the Use of Cyclotrons in chemistry, metallurgy and biology is being organised by A.E.R.E. Harwell and will be held at St. Catherine's College, Oxford, England, on 22nd and 23rd September, 1969. There will be an optional visit to A.E.R.E. on 24th September, and on 20th September there will

also be a short symposium on the applications of cyclotrons to problems in medicine, to be held at the Hammersmith Hospital, London, W.12.

The topics to be discussed at the Conference will include radiochemistry, isotope production, radiation chemistry, radiation damage, radiation biology, charged particle activation analysis and experimental techniques. Modern cyclotrons and other particle accelerators provide a wide range of particles of different energies which greatly extends the scope of experiments designed to study the interaction of radiation with matter. Chemical effects may change both quantitatively and qualitatively as the density of ionization is altered by changing the nature of the bombarding particles, and the very high dose rates available increase the extent of radiation damage by several orders of magnitude compared with reactor radiation. A much wider range of nuclear reactions may also be studied. It is the aim of the Conference to discuss both the results obtained and the implications for theoretical studies and models of radiation effects.

Up to 30 papers will be accepted for presentation, which must contain original work which has not been published elsewhere. Acceptance of the papers, which must be in English, will be the responsibility of the Organizing Committee, and will be based on informative abstracts which are required by 15th May. Abstracts of the papers selected will be distributed with the Conference programme; the papers themselves are required by 1st September, 1969, for inclusion in the published proceedings, which will also contain a record of the discussions. social programme and visits are being arranged for accompanying wives.

The Conference is preceded by an International Cyclotron Conference on the design and operating characteristics of Azimuthally varying field cyclotrons and synchrocyclotron conversions and improvements, to be held on 17th-20th September, 1969.

Further information regarding the content of the programme may be obtained from Dr. C. B. Amphlett, Chemistry Division, A.E.R.E., Harwell, Didcot, Berks., England. Registration literature is available from Mr. F. K. Pyne, A.E.R.E., Harwell.

31st March, 1969

## Fast reactor irradiation conference

An international conference on fast reactor irradiation testing was organised by the Reactor Group, UKAEA, from 15-17th April, 1969, at Thurso, Caithness.

The conference was opened by the Chairman of the Authority, Dr. J. M. Hill, and had been arranged with the agreement of the IAEA working group on fast reactors.

Over 120 delegates were present, from Austria, Belgium, Czechosolvakia, Denmark, France, Germany, Holland, Italy, Japan, Pakistan, Rumania, S. Africa, Sweden, Switzerland, USA, USSR and UK. In all, some 36 papers were presented.

Fast reactor irradiation testing is of interest because intense irradiation can alter the physical properties of materials and therefore the fuels and structural materials for fast reactors must he irradiated and changes measured. Dounreay Fast Reactor has been used as a test bed for irradiation experiments over the last six years, in addition to producing some 14 MW of electricity. It is also used for "accelerated" tests on thermal reactor materials, lifetime dose equivalents being obtained in about one tenth of the time. For example, lifetime doses have been achieved on AGR graphite samples. The minute dimensional changes in the samples were measured and other tests were carried out to determine changes in the mechanical properties of the material.

The Thurso conference had as its aims:—
To disseminate information on the methods used for irradiations in fast reactors, and the problems involved.

To discuss the problems of standardisation of techniques between different countries.

To discuss future requirements and the adequacy of the present facilities available throughout the world.

The topics covered included the philosophy of fast flux irradiations, irradiation facilities, the design, manufacture and installation of irradiation experiments, the monitoring and interpretation of fast flux data, and further developments of fast flux test facilities.

A social programme was also organised which included a reception by the Caithness civil authorities and there was also a visit to the UKAEA's establishment at Dounreay.

11th April, 1969.

## Summer school in analysis

The Analytical Research and Development Unit, Harwell, is organising, on behalf of the Royal Institute of Chemistry, a Summer School in Nuclear Methods of Trace Element Analysis. It will be held at Harwell from 30th June to 4th July, 1969.

The Summer School is designed for qualified chemists working in such fields as ferrous and non-ferrous metals, refractories, glass, electronics materials, plastics, rubber, chemicals, etc. It aims to provide a working knowledge of the various nuclear techniques for trace element analysis and for the study of surface composition and element Such techniques will include location. thermal and fast neutron activation analycharged particle and gamma-ray activation analysis, autoradiography, mass spectrometric isotopic dilution analysis and the associated use of computers. Participants will also have an opportunity to see some of the other analytical techniques which are currently being employed and developed at Harwell, particularly on the final day when the wider field will be considered to place the nuclear techniques in perspective.

As in previous RIC Summer Schools, emphasis will be placed on small group tuition in which problems arising from the main lectures will be discussed. In addition, participants will have an opportunity to see in operation, and to use themselves, some of the instrumentation relating to the course.

Cost of the course, excluding overnight accommodation is:

Members of RIC £45 Non-members £65

The Analytical Research and Development Unit is a new service for industry intended to help identify, measure or control impurities in industrial materials. The services it offers include research and development work sponsored by one or more firms, measurements based on specialised equipment or techniques and a technical advisory service. The unit forms part of the Harwell Analytical Sciences Division.

Further details of the Summer School are available from: The Education Officer, Royal Institute of Chemistry, 30 Russell Square, London, W.C.1.

15th April, 1969.

## The use of radioactive tracers in gas mains

continued from page 127

full potential offered by radioactive tracers that much information can be gained, in particular flow rates at peak, normal and intermediate loads and the definition of flow direction together with an assessment of the conditions under which reversals occur. From the preceding it is likely that flow patterns in complex networks can be compared readily with theoretical network analysis. Certain side benefits are also evident, and the technique could be adapted to determine interfaces between gases from differing sources or between towns gas/inert gas purging slugs. Measurements can be readily interpreted to identify restrictions causing velocity and/or directional changes and there is reason to believe that the use of radioactive tracers can be adapted to examine gas mixing. layering in gasholders and also to assist in leak detection.

The whole aspect of the use of tracers was considered in detail and field tests organised. From the methods examined and the results obtained it is believed that radioactive tracers offer real possibilities in the determination of gas flows and that a cheap, convenient mobile detection system has been developed.

#### Pressure vessel report

The Ministry of Technology's Committee of Enquiry on Pressure Vessels (Chairman, Mr. R. W. Nichols, Deputy Head of the U.K.A.E.A.'s Reactor Materials Laboratory, Culcheth) has published its report, in two volumes. Volume 1 contains recommendations affecting both the structure and technology of the pressure vessel fabrication industry. An important part of Volume 2 is an economic survey of the U.K. and selected foreign pressure vessel Volume 2 also summarises industries. current research in the U.K. on topics related to pressure vessels and their materials of construction and gives some prediction on future research.

The Ministry of Technology is paying particular attention to the recommendation for the formation of a Pressure Vessel Authority and is asking interested bodies for their comments on this and other recommendations by 1st June, 1969.

The Committee's Report is available from H.M.S.O.

## Electrical methods of machining and forming

The Ministry of Technology has commissioned the U.K.A.E.A. Culham Laboratory to carry out a survey of electrical methods of machining and forming, with the object of assessing the range of profitable applications for these techniques and evaluating the economics of their development for wider use in industry.

The production engineering sector of industry has been using two of these methods, electrical discharge machining and electrochemical machining, for a number of years. Other methods, such as plasma torch and electron beam techniques are beginning to be accepted for some applications, and processes such as laser machining, electromagnetic and electrohydraulic forming, are now emerging from the development stage. Although electrical methods have mostly been applied to overcome limitations of conventional machining, some of the new methods are now competitive in manufacturing processes which do not necessarily require the special advantages of these techniques. The main aim of the survey is to provide the Ministry with the technical and economic information needed to decide what further uses of electrical machining should be promoted.

The survey will be carried out by a team of engineers and scientists from the Culham Laboratory. Enquiries to: D. F. Jephcott, U.K.A.E.A., Culham Laboratory, Abingdon, Berks. Tel: Abingdon 1840 Ext. 535.

#### **Tribology report**

Significant progress was made during 1968 on developments in the field of tribology. Three centres of tribology (at the Universities of Leeds and Swansea and at the U.K.A.E.A. Laboratories, Risley), operating on a commercial basis, were set up as part of a national framework to offer consultancy services to industry for solving tribological problems. The number of orders already placed by industry with these centres indicates that a real need is being met.

Details of this progress are set out in the second annual report of the Ministry of Technology's Committee on Tribology, available from H.M.S.O. at 5s. 6d. a copy.

continued from page 125

Mr. J. P. W. Mallalieu: Preliminary design work for a commercial fast reactor has already started and, subject to a decision by the generating boards as a result of technical and economic evaluation, it is anticipated that a power reactor of this type could come in service by the latter half of the 1970s.

#### Price of uranium

31st March, 1969

MR. ASHTON asked the Minister of Technology what increases he estimates there will be in the price of uranium for power stations in the next five years, in view of the scarcity forecast in the survey made by the European Nuclear Energy Agency and the International Atomic Energy Agency, details of which are in his possession.

Mr. J. P. W. Mallalieu: The Atomic Energy Authority has substantial stocks of uranium which, together with imports under existing contracts, are likely to meet requirements well into the 1970s. No significant increase in the price of uranium for power stations is expected over the next five years.

The high level of exploration work which is being undertaken in various parts of the world should result in sufficient uranium being forthcoming at reasonable prices for the United Kingdom and other nuclear power programmes.

### Hunterston B nuclear power station

1st April, 1969

MR. EADIE asked the Secretary of State for Scotland if he will give estimates of the costs of electricity sent out from Hunterston B nuclear power station on the basis of a 20-year depreciation period, with interest during reconstruction at 8 per cent and including royalties payable to the United Kingdom Atomic Energy Authority.

Mr. Ross: The South of Scotland Electricity Board estimates that on the basis of a 25-year life, with interest at 8 per cent and including the royalty payable to the Atomic Energy Authority on A.G.R. stations of 0.014d. per unit, the cost of electricity sent out from Hunterston B nuclear power station will be 0.51d. per unit; based on a 20-year life the

corresponding unit cost would be 0.53d.

#### Advanced gas centrifuge

2nd April, 1969

MR. MOONMAN asked the Minister of Technology whether, in establishing an intergovernmental committee to supervise collaboration between Great Britain, the Netherlands and West Germany in producing an advanced gas centrifuge for the enrichment of uranium, he will give an assurance that hon. Members will be kept informed of developments on the safeguards of nuclear material, siting of plants and any extension of the work to include other countries.

Mr. Benn: Discussions about this project are still in progress and no decisions have yet been taken by the Governments concerned. However, the functions of the proposed joint committee would comprise inter alia the subjects mentioned and would be dealt with in the intergovernmental agreement which we would conclude with our partners. I shall be keeping the House informed in the usual way.

### Surface materials for radioactive areas

BS 4247—Recommendations for the assessment of surface materials for use in radioactive areas Part 2: 1969 Guide to the selection of materials gives general guidance on the choice of surface materials for use in areas subject to contamination by radioactive substances, the advice being of a kind intended to be helpful to architects, civil engineers and others who may be concerned.

After describing briefly the nature and mechanism of contamination, and defining decontamination, the standard outlines the general properties required of the material. It continues with more specific advice on wear-resistant materials (e.g. for flooring), on surface coatings (paints), and on temporary protective materials (such as strippable coatings). Design requirements are included and the standard ends with a method of classifying materials in terms of the test described in BS 4247 Part 1: 1967. "Method of test for ease of decontamination".

Copies of BS 4247: Part 2: 1969 may be obtained from the BSI Sales Branch at 101/113 Pentonville Road, London N.1. Price 6s. each.

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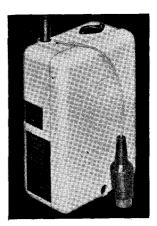
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Co-60 teletherapy unit with uranium shield

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Portable industrial radiography unit with uranium shield Photo by courtesy of Pantatron Ltd.



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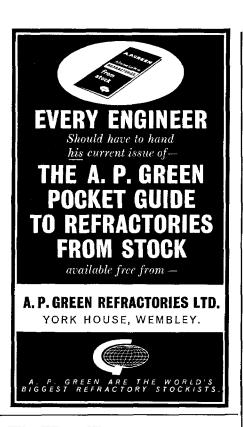
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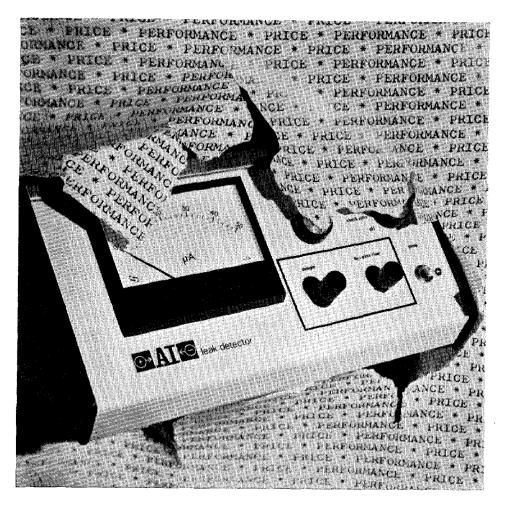
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