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ATOM

THE WAGR CONCLUDING EXPERIMENTS CONFORM

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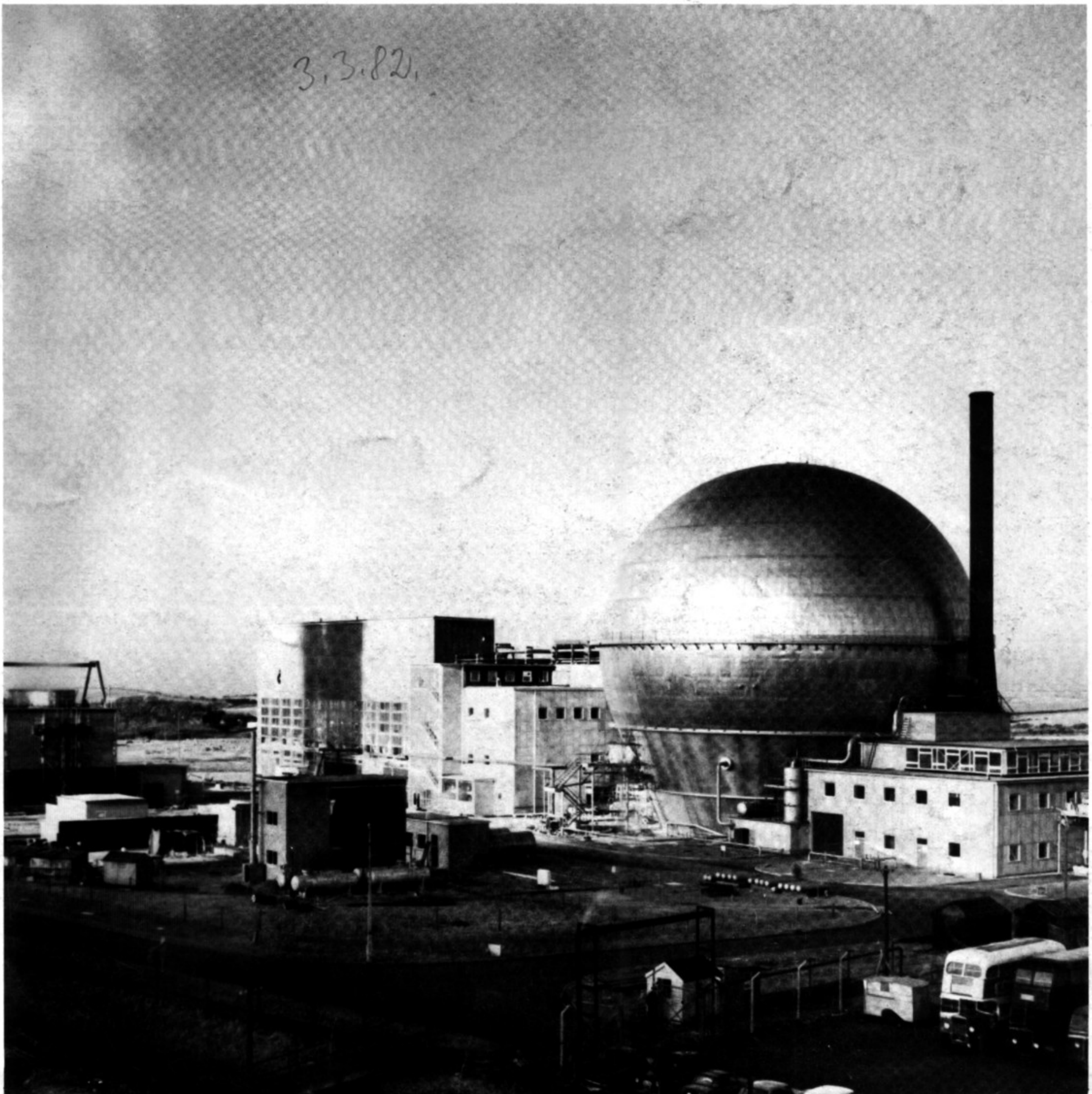

FEBRUARY 1982 NUMBER 304

ATOM contents

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Front cover: An early view of the Windscale Advanced Gas-cooled Reactor, prototype of the commercial units now entering service. In this issue, detail of the "concluding experiments" carried out after the formal shut-down of WAGR in support of the safety cases for the commercial stations

THE WAGR CONCLUDING EXPERIMENTS

The prototype Advanced Gas-cooled Reactor at Windscale—WAGR—first went critical in 1962, and for the following 18 years its operational life as a research and development reactor was very successful. On 3 April 1981 the plant, its work completed, was formally shut down by Sir Francis Tombs and ceased normal power operation. However, early in 1980 the UKAEA, CEGB and SSEB jointly began planning a series of special experiments in WAGR, of which most were to be performed during the few weeks immediately following the formal shutdown. R.E. Mrowicki, C.P. Greef, J.H. Leng and M. Kendal explain

The UKAEA, CEGB and SSEB, in technical and financial collaboration, designed an experimental programme aimed at securing further information to support the Safety Cases of the commercial AGRs operated by the generating boards. Thus, tests were proposed to:

i. examine the behaviour of fuel elements when subjected to temperatures approaching the melting point of the stainless steel fuel pin cladding (about 1 370°C);
ii. check the physical models and computer codes used in fault studies; and
iii. embrace a range of fission product release and transport measurements.

The project, which became known as the WAGR Concluding Experiments, was successfully completed over the period 3 April to 24 June last year.

To be of any subsequent value, some of the experiments had to extend test conditions beyond limits previously encountered in WAGR. As such, a number of safety issues were raised, and the proposed solutions to these problems were subjected to the stringent safety criteria which were adopted throughout the operational life of WAGR. In addition the Nuclear Installations Inspectorate were kept fully informed both during the planning and safety clearance stage and during the execution of the experiments.

The range of experiments within the programme may be summarized as follows.

(a) Four WAGR fuel stringers were subjected to either a flow or power induced temperature transient up to a peak pin clad temperature of about 1 300°C. These experiments were performed in one of the experimental loops installed in WAGR.
(b) The reactor core was subjected to rapid reactivity ramps and flow changes from a variety of initial conditions.
(c) Four fuel stringers, previously discharged from the reactor because of fuel pin failures, were re-irradiated under various conditions and the fission product release was measured. These experiments were performed during the latter months of operation before formal shut-down.
(d) The transport properties of fission product iodine in the form of methyl iodide, together with the behaviour of simulated aerosols, was investigated under different plant conditions.

Mr Mrowicki works for British Nuclear Fuels Ltd at Windscale, and Mr Greef at the CEGB Berkeley Nuclear Laboratories. Messrs Leng and Kendal are at the UKAEA Windscale Nuclear Power Development Laboratories.

A more detailed article describing the experiments is appearing in the *BNES Journal.*

Data acquisition

A fast data collection and display system was essential to monitor those experiments in which rapid changes in power, coolant flow and temperature were involved. The data logger equipment used for a number of years on WAGR, although capable of monitoring two thousand analogue reactor inputs in a cycle time of ninety seconds, was too slow and therefore it was necessary to construct a new much faster system, based on already existing PDP 11/20 computers.

By employing two scan controllers, each driving a maximum of one hundred relays and controlling a pair of digital voltmeters, a logger unit was devised which was capable of scanning four hundred data points at the rate of one hundred points per second. Rapid rates of data collection were required during the core experiments, so reactor data points were limited to 112 so that the desired cycle time of about one second could be achieved. In the loop experiments a different problem arose because of the high temperatures to be measured. There was some doubt concerning both the durability and accuracy of the chromel-alumel, stainless steel sheathed, mineral-insulated thermocouples mounted in the experimental fuel stringers, and so it was arranged for these thermocouples to be monitored for both loop and insulation resistances. Time had to be allowed for the conductors to discharge after each resistance measurement and as a consequence some reduction in scanning time was inevitable. Nevertheless the acceptable cycle time of about two and a half seconds was achieved for the 41 data points used in these experiments. For all experiments double density floppy discs were used to store data for later analysis.

The software provided for the PDP 11/20 was devised to control two main functions. The first, under direct interrupt control, performed the processes of data collection, recording and alarm checking. The second, a BASIC interpreter program, supported two BASIC partitions each driving a display unit, one showing the essential information for operational control of the experiments and the other showing more information of interest to the experimentalists. With this equipment it was possible to provide different displays readily tailored to suit a particular experiment without unacceptable investment in programming effort.

Because many of the experiments could not be repeated, back-up to the computer driven system was included by using a multiplexed digital recording system onto an instrumentation tape recorder, sampling approximately half of the available data points. As this unit was connected directly to the data points and its sampling rate was faster than the computer driven system, it was able to record in finer time steps

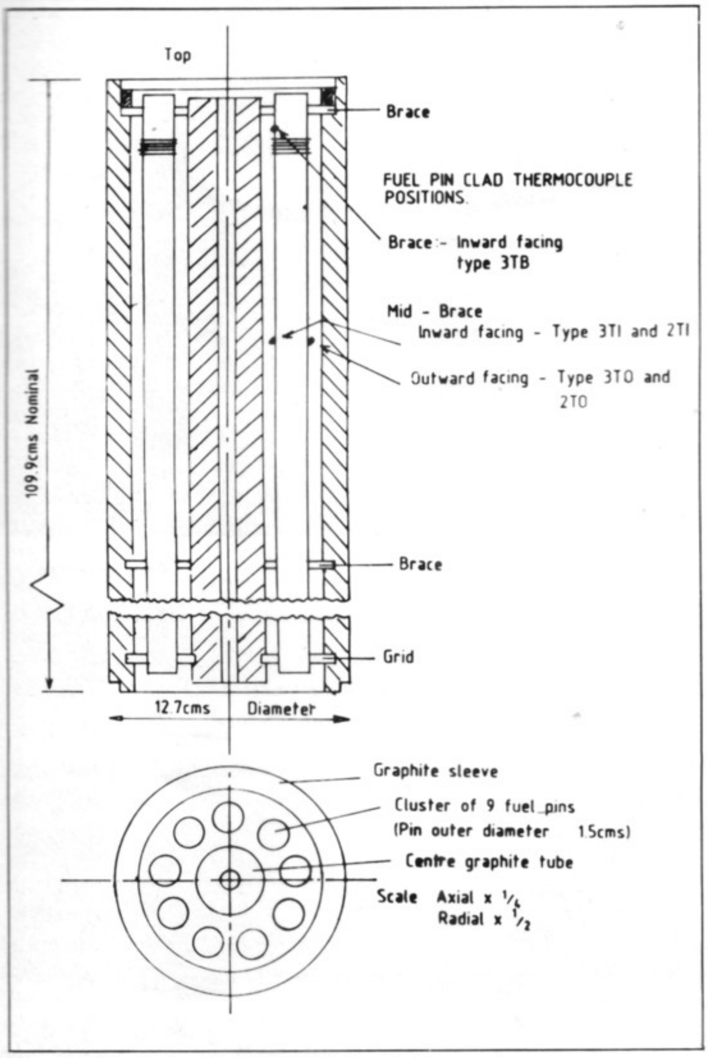


Fig. 1: Sketch of a WAGR fuel element

in addition to providing the redundancy required. Finally a six pen chart recorder was employed to give a display of up to six points of selected data as considered appropriate during each experiment.

High fuel-clad temperature tests

These tests were included in the programme with the objective of supporting the CAGR safety case by adding to the evidence that the fuel pins retain coolable geometry at transient peak can temperatures encountered for the most severe credible CAGR fault transients. The fuel elements used were of current WAGR design consisting of a cluster of nine fuel pins supported in a single ring around a central graphite tube and enclosed within a graphite sleeve (see Fig. 1). The fuel pins consisted of annular fuel pellets of uranium dioxide contained in a stainless steel tube (nominally 1·52 cm diameter and 0·038 cm wall thickness) having a ribbed external surface to improve heat transfer properties. The WAGR fuel element is smaller than the 36 pin CAGR counterpart but the general design and individual pin designs are similar.

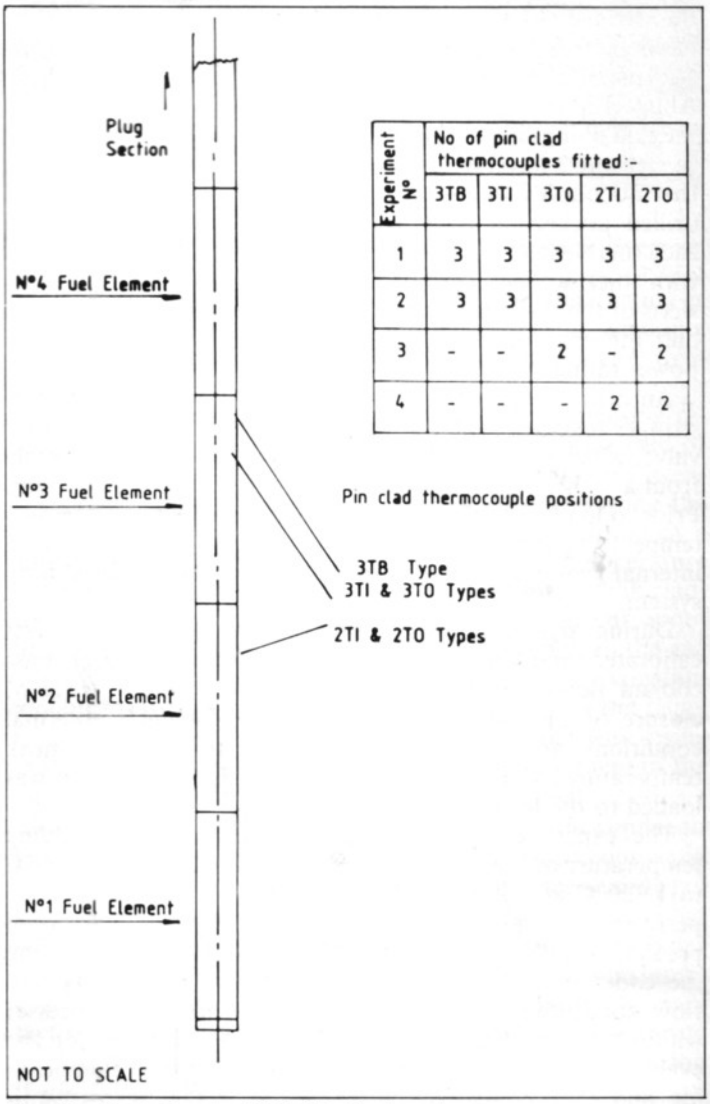
In WAGR a fuel stringer consists of four fuel elements supported on a central tie rod or tube (see Figure 2), which is connected to an upper plug section. This comprises a neutron shield plug, outlet passages for the coolant gas, a gag valve to control coolant flow, a biological shield plug and a closure unit to seal the complete stringer in the reactor primary containment. Four such fuel stringers were tested to a high peak fuel clad temperature in flow or power induced transient, as detailed below.

Experiment 1 was a new purpose built stringer equipped with many thermocouples to measure coolant gas and fuel clad temperatures and containing fuel pins of standard enrichment (3·5 per cent).

Experiment 2 was a similar stringer to Experiment 1 but the fuel pins in element 3 were enriched to 9 per cent to increase the rating, and all fuel was omitted from element 4 to reduce the coolant gas outlet temperature.

Experiments 3 and 4 were stringers which had been irradiated previously in the WAGR core, for other experimental purposes, to burn-ups of 5 000 megawatt-days per tonne and 15 000 MWD/T respectively. Each contained fuel pins of standard WAGR enrichment with a limited number of gas and fuel clad thermocouples. As the purpose of the experiments was to raise peak pin clad temperature to near melting point (about 1 370°C) there was some risk that local melting of the clad could occur and result in significant fission product release. It was decided therefore, to perform the experiments within one of the six loop circuits available on WAGR to minimize the extent of any possible internal contamination of the plant. Each loop utilises a reactor fuel channel containing a separate pressure tube connected to an independent cooling circuit. Thus a loop provided irradiation space which could be operated under different coolant pressures and temperatures from the main core. To minimize the amount of fission product iodine available for release in the event of severe clad failure, total irradiation time of each stringer in the experiments was limited to four full power equivalent hours. The two previously irradiated stringers had been discharged from the reactor earlier in the year to allow the iodine content of the fuel to decay to a very small value before re-irradiation.

To use a loop at very high temperature one difficulty had to be overcome. The coolant gas outlet temperature from a



Experiment N°	No of pin clad thermocouples fitted:-				
	3TB	3TI	3TO	2TI	2TO
1	3	3	3	3	3
2	3	3	3	3	3
3	-	-	2	-	2
4	-	-	-	2	2

Fig. 2: Sketch of a WAGR fuel stringer

WAGR fuel stringer operating at the abnormal peak clad temperature of 1 300°C would be more than 900°C and considerably higher than the maximum (700°C) allowable in a loop to guarantee the integrity of the pressure tube. The problem was solved by introducing a secondary or bypass coolant flow dividing from the main flow through escape holes at the base of the stringer. This flow bypassed the fuel but mixed with and cooled the main stringer flow as it emerged from the stringer gas ports before it impinged on the loop pressure tube. To make this feasible the loop had to be modified to generate sufficient bypass flow from the available pumping capacity. As a consequence, the irradiated liner or partition tube of the loop had to be discharged and replaced by a new tube of larger dimensions. A special remotely operated milling machine was built and developed for the task of increasing the effective dimensions of the loop pressure tube internal features to accept the new larger liner tube.

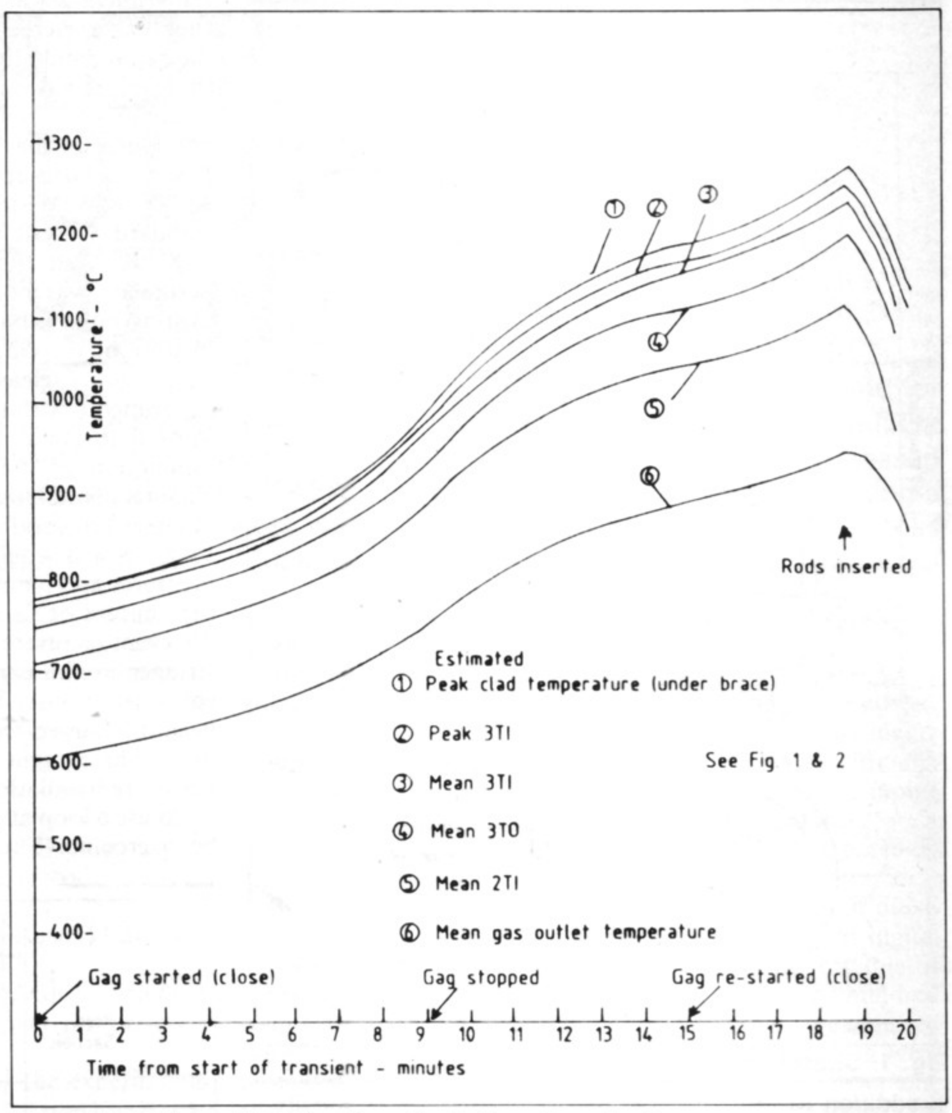


Fig. 3: Experiment No. 1—New fuel, flow transient

Experiment 1

Fifteen thermocouples were installed in this stringer to measure fuel pin clad temperature. Nine of these (three Nicrosil/Nisil and six Chromel/Alumel) were located in element 3 and the remaining six (all Chromel/Alumel) in element 2 (see Fig. 2). The cladding thermocouples were inserted into drilled pockets in three fuel pins, in each fuel element, fitted for the purpose with thick walled cladding (0·178 cm). The external dimensions of the thick wall pins were identical to the standard pins and the enrichment was increased to give the same linear power rating.

An orifice plate coolant flow meter was also fitted to this stringer together with a WAGR gag, or stringer flow control valve, which was mechanised and could be operated remotely from a control point sited in the main reactor control room. Prior to loading in the loop the stringer was tested under low temperature isothermal conditions in a dynamic test rig, the internal geometry of which matched that of the revised loop system.

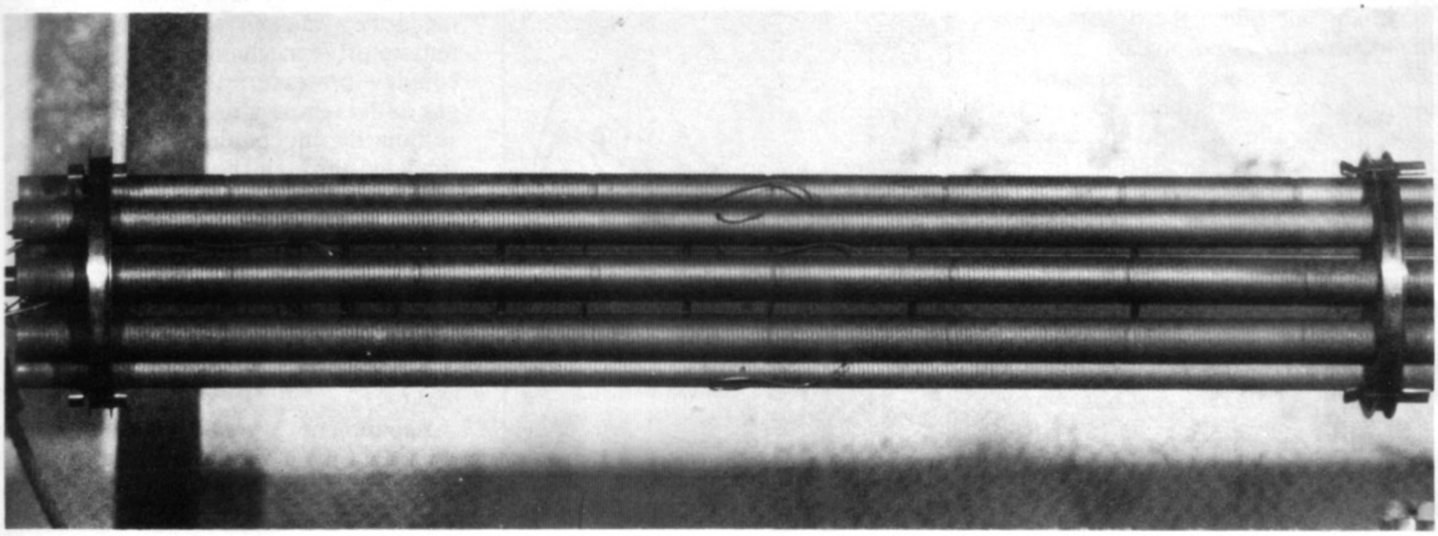
During dynamic testing the stringer flow meter was calibrated and the split between the primary and bypass coolant flows was determined against position or degree of closure of the gag valve. Further testing under isothermal conditions and in "mini" transients to pin clad peak temperatures of about 700°C continued after the stringer was loaded to the loop.

The experimental plan was to raise the peak cladding temperature of the stringer from a normal value of 750-800°C to 1 320°C at full power by reducing the coolant flow. The performance of the stringer in this transient had been predicted by the Berkeley and Windscale laboratories using the codes WELCOME for modelling the loop geometry and flow conditions, HOTSPOT for the heat transfer processes within the fuel pin cluster assembly and HEATRAN for the evaluation of the cladding hot spots caused by end flux peaking and the geometrical disturbances of the braces, anti-stacking grooves and any significant bowing of the fuel pins.

It was found during commissioning that the gag valve tended to continue closing at the higher temperatures when the mechanical drive was switched off because of thermal expansion of the gag shaft. It was decided that the transient would be continuous, would last 18 to 20 minutes, and would be terminated, by insertion of the control rods at fast speed, when peak clad temperature was reached. In this manner the experiment was completed successfully on 8 May.

Large cross-pin temperature gradients (over 100°C) had been predicted at the higher temperatures and there had been some concern that the differential thermal expansion of the cladding so arising might cause significant radial fuel pin bowing relative to the small clearance (6-7 mm) between the pin and the central graphite spine. Should a pin bow sufficiently to touch neighbouring graphite components a local cladding hot spot could occur at the point of contact increasing the clad temperature by a further 100°C or so. Therefore for the first loop experiment the peak target clad temperature of 1 320°C was evaluated on the assumption that a standard fuel pin in element 3 (the hottest region) had bowed to touch the central graphite tube. This assumed temperature was calculated during the transient by the computer using measured cladding temperatures of the thick wall instrumented pins and a model developed during the heat transfer prediction work.

Fig. 3 shows graphs of various temperatures measured during the experiment. All the thermocouples operated successfully during the transient and afterwards on return to normal temperatures. Extra instrumentation had been incorporated into the loop circuit for the high temperature ex-



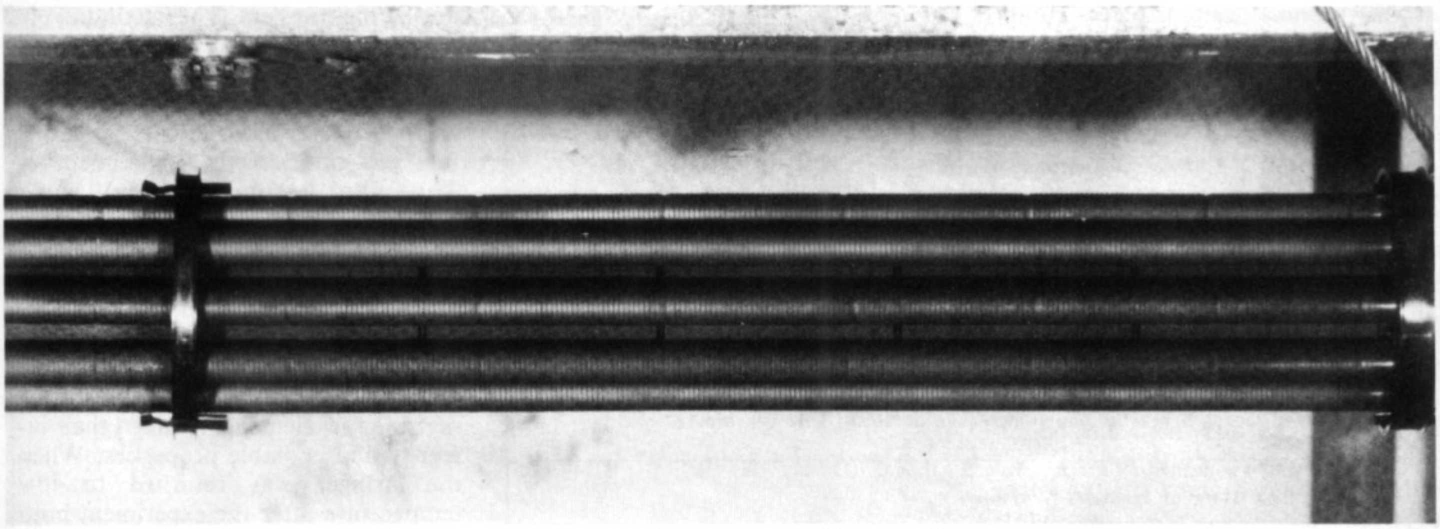


Fig. 4: Fuel elements under PIE

periments to detect and measure any released radioactivity. This includes two sets of burst cartridge detection gear (BCDG) and continuous gamma spectrometry monitoring krypton-89 to assist in the detection of can failure and magnesium-56 as an indication of any clad melting. On safety grounds the criterion for premature termination of the experiment was based on previous experience of fuel failures in the loops, and was set at 1 000 times the normal background BCDG signal. In the event there was no indication of even minor pin failure during the transient.

The programme of the concluding experiments was arranged so that the major part of the core transient experiments would be completed immediately after the first loop experiment. This allowed post irradiation examination (PIE) of the first loop stringer to be completed before proceeding to further high temperature experiments. The results of this PIE showed the fuel elements to be in excellent condition with no evidence of local clad melting, excess oxidation or severe bowing (see Fig. 4). On this basis it was calculated that the maximum cladding temperature reached was probably 1 276°C at a position under a brace on a standard pin in element 3. The highest clad thermocouple reading recorded, on a thick wall pin in element 3, was 1 244°C. The outlet temperature of the coolant gases after mixing of the stringer and bypass flows was comfortably below the limit of 700°C.

Experiment 2

With the knowledge that no severe pin bowing had resulted from the first experiment it was decided that such a phenomenon could be discounted for the second. Whilst the target temperature remained at 1 320°C, this was now attributed to the hot spot calculated to occur on an element 3 standard pin under the upper brace, due to the brace acting as a radiant heat shield. This meant raising the cladding temperature as measured in element 3 some 50°C higher than that of the first experiment.

It was planned to perform the transient by increasing reactor power (as in a reactivity fault) at a constant rate of about 3 MW per minute over a period of approximately twenty minutes, commencing at 30 per cent power. During the transient the coolant gas mass flow was kept constant at a level chosen to achieve the target peak cladding temperature just before full power was reached. The measured peak cladding temperature was expected to rise at the rate of about 40°C per minute. In practice it was necessary to open the gag continuously during the transient to maintain a constant coolant mass flow rate in order to compensate for the rising coolant flow resistance (as gas density decreased with rising temperature) and for the thermal expansion movement of the gag towards the closed position already described.

The preparation and testing for this stringer was similar to that of the first and on 5 June the experiment was completed as planned. The graphs at Fig. 5 show various measured clad temperatures, together with the estimated peak clad temperature, determined during the transient. The latter temperature ultimately reached 1 340°C and the maximum measured clad temperature recorded was 1 290°C. As with the first experiment no thermocouple failures occurred during or after the transient and there was no instrument indication of pin failure. PIE later showed that the fuel elements, like those of the first experiment, remained in excellent condition.

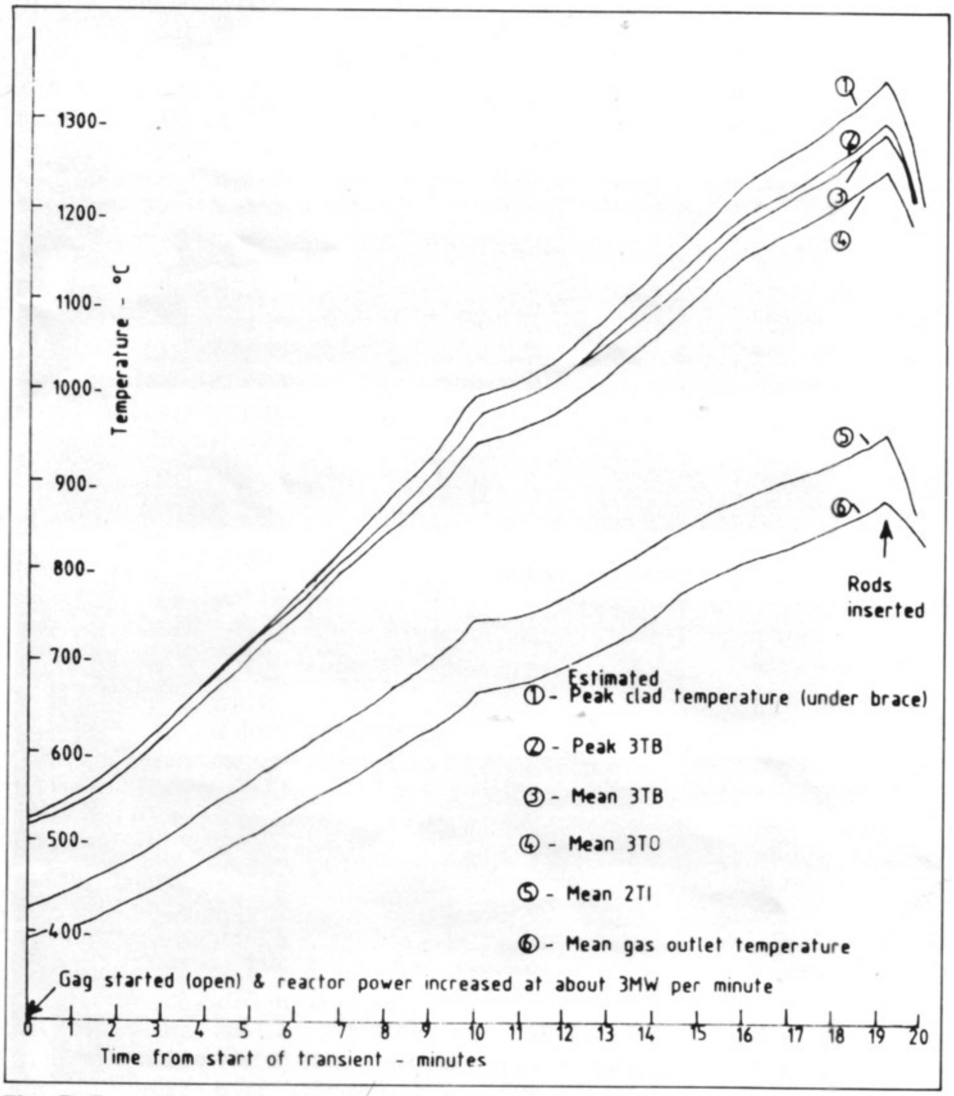


Fig. 5: Experiment No. 2—New fuel, power transient

Experiments 3 and 4

Over the last few years of the reactor's operation a series of experimental stringers had been irradiated to monitor the change in heat transfer coefficient caused by deposition from coolants of various compositions. Each of these stringers had been equipped with four pin cladding thermocouples, mounted by insertion in thick walled pins, as well as thermocouples to measure inlet and outlet gas coolant temperatures. Fortunately two of these stringers having both suitable burn-ups and a full set of serviceable thermocouples were still available, to extend the range of the high temperature experiments to irradiated fuel stringers. The determination of an experimental plan for these stringers provoked considerable discussion. In particular it was clear that the limited number of cladding thermocouples compared with the number available in the previous experiments would cause greater uncertainties in determining the peak clad temperature. Also, whilst no bowing had occurred to the previously unirradiated fuel pins, it was still thought that this remote possibility could not be ruled out for irradiated pins. It was agreed finally that the reasonable decision would be to repeat the first type of experiment on both the irradiated stringers by matching their measured clad temperature to the temperatures attained at corresponding thermocouple positions in the earlier experiment.

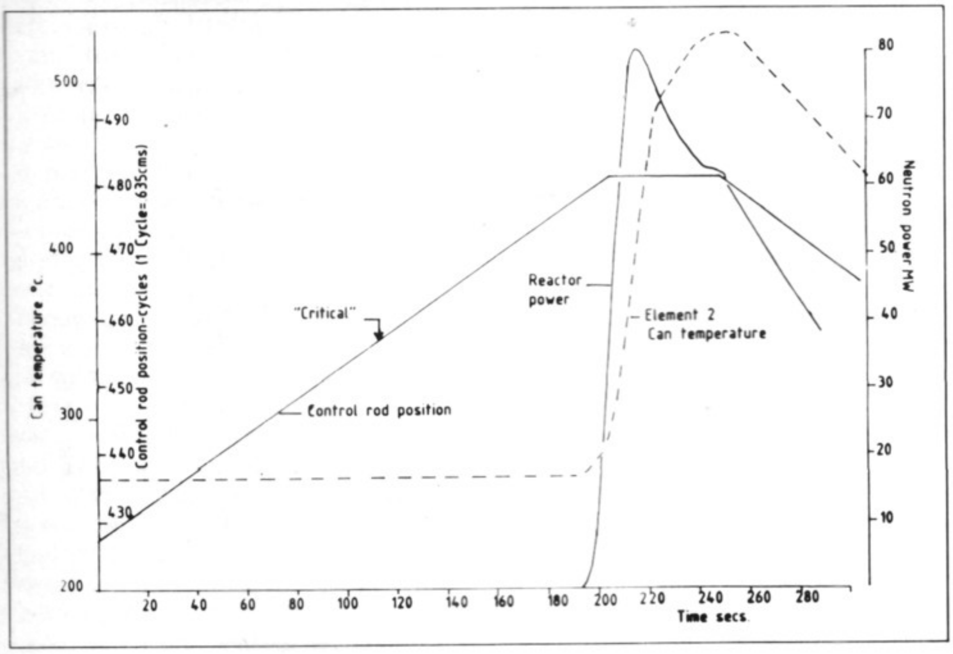
However, before the irradiated stringers could be used for high temperature experiments in the loop, it was necessary to detach the fuel section of each stringer from its original plug section without damaging the thermocouples. This fuel was then attached to the special plug section of one of the earlier high temperature loop stringers carrying a flow-meter, modified gag with remote drive mechanism, and thermocouples to measure the mixed coolant gas outlet temperature. Finally the fuel section thermocouples had to be re-threaded through the new plug, sealed at the closure unit and attached to appropriate connectors. This was a difficult handling task when dealing with irradiated components but was accomplished successfully for both stringers without the loss of any thermocouples, thus making the proposed plan a reality.

Experiment 3 was completed successfully on 12 June in a coolant flow transient lasting twelve minutes. No thermocouple failed and there was no evidence of an increase in BCD signal during the transient. The maximum pin clad measured temperatures reached were 1 192°C (element 3) and 1 082°C (element 2), compared with 1 198°C and 1 076°C reached at corresponding fuel pin positions in Experiment 1. Thus an estimated peak clad temperature on a standard pin (element 3) within the range 1 270-1 280°C was obtained.

The performance of the stringer during and after the transient, as monitored by the clad and coolant gas temperature readings, demonstrated that the fuel elements retained their integrity and coolable properties. When the stringer was returned to low temperature after the experiment both the BCDG and krypton-89 monitor commenced to give a low signal reaching eventually no more than twice background, indicating that a very small clad failure had occurred.

The loop programme was completed by the testing of Experiment 4 on 17 June in a flow transient lasting nineteen minutes. The cladding thermocouples survived the test and gave maximum measured temperatures in element 2 of 1 116°C (outward facing) and 1 110°C (inward facing). These compared with 1 076°C and 1 119°C in like positions in Experiment 1 giving an estimated peak cladding temperature on a standard pin (in element 3) of 1 270°C-1 280°C. The performance of the stringer and the absence of any BCD signal during the experiment again showed that the fuel elements had not undergone any damage due to this high temperature transient. Some time after the completion of the transient a measurable rise in magnesium-56 activity in the loop was noted. This is believed to be due to either deposit or oxide which had spalled off the fuel pins.

During its previous irradiation in the reactor the heat transfer characteristics of this stringer had been monitored by observing cladding and coolant gas temperatures. Appreciable decreases in heat transfer coefficient caused by carbon deposition had been observed on the element 2 pins. The expected heat transfer coefficients were observed in the loop when the stringer was first loaded. Attempts were made to remove the deposit by a short pre-experiment irradiation period at a maximum clad temperature of 800°C (limited to one hour to minimise fission product iodine production) but this was not successful. However it was judged that the deposit would be burnt off during the transient at high cladding temperature and the experiment was planned on that



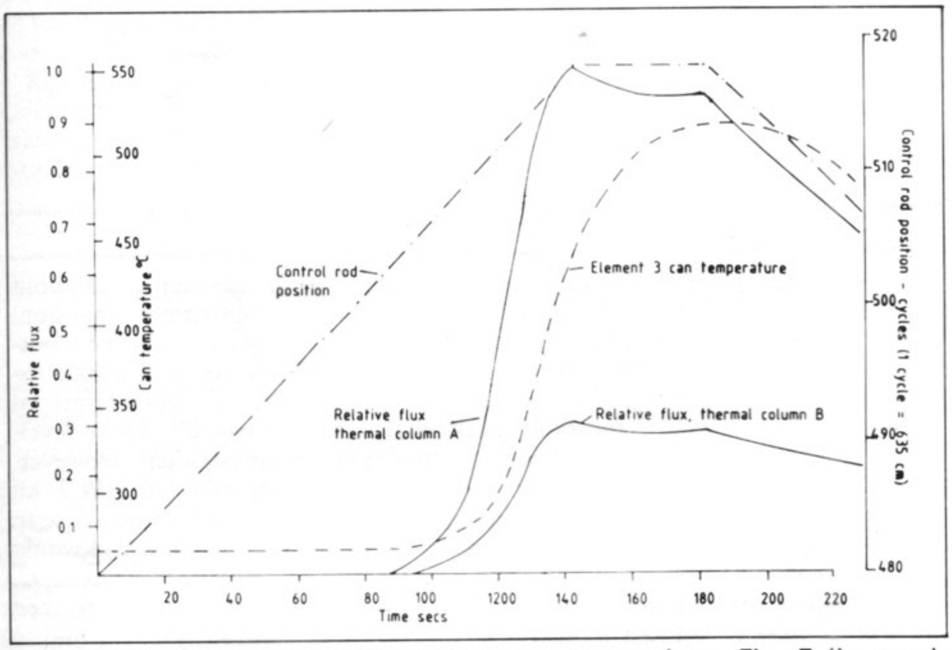


Fig. 6 (top): Subcritical symmetric start-up transient; Fig. 7 (bottom): Asymmetric start-up transient

changes of coolant flow were also performed by tripping the main circulators. As the series of experiments could be performed only once, as wide a range of conditions as possible was covered. In order to monitor possible spatial variations in neutron flux response, especially in the faster transients, extra nuclear instrumentation in the form of nine special ion chambers contained in three non-fuelled stringers were loaded to strategic positions in the reactor core.

As already described arrangements were made for the fast recording and display of all relevant data and CEGB representatives installed equipment to monitor data from one of the heat exchangers. There was a small possibility that the three most severe reactivity ramps could induce some fuel pin failures and therefore these experiments were left to the end of the programme.

Small reactivity perturbation experiment

The aim of these experiments was, mainly, to determine the fuel temperature coefficient for the WAGR core. Twelve such experiments were performed at different power and coolant flow levels, by withdrawing the control rods over a given period of seconds, holding for a further short period and then returning the rods to the initial position. These tests, as did many others later, demonstrated the stabilising effect of the negative temperature feed-back.

Fast start-up experiments

Initially tests were performed in a reactor core having a standard, ie symmetric, radial power distribution, and were intended to simulate a postulated CAGR fast start-up fault. They were initiated by the withdrawal of the control rods at fast speed over a given number of seconds, (ie adding reactivity

basis. Analysis of the experimental data has shown that indeed much of the deposit was removed by the time that peak temperatures in the transient were attained.

Core transients

The CAGR safety case is based upon reactor fault studies employing sophisticated theoretical models, in particular, the programs KINAGRAX and SKARK. There was no direct experimental evidence to validate these calculation techniques in predicting the progress of either the extremely fast or very large amplitude transients appropriate to fault conditions. The objective in WAGR was to perform reactivity and flow excursion experiments of a larger amplitude than was reasonable in an operating CAGR and check the agreement between experimental and predicted results from the CAGR model.

Principally the tests were directed at the dynamic response of the reactor core to positive reactivity changes capable of causing large amplitude ramps, often with rapid rates of change. The majority of the tests consisted of reactivity additions from different initial conditions, imposed by movement of a bank of control rods. Some experiments with large

at 260 mN min^{-1}*, holding the rods withdrawn for another short period and then re-inserting. Thirteen of these experiments were performed, ten commencing from a power level of 50 kW (about 2 mN shut-down); one from 1 kW (about 100 mN shut-down) and two from 200 W (about 540 mN shut-down).

The two plant limitations controlling these experiments were reactor doubling times and heat exchanger performance. The first was determined by the installed instrumentation which limited reactor period to a minimum of two seconds. The second limit involved rapid rates of heat insertion to the heat exchangers causing water expansion in the drums leading to rising levels and consequent risk of water transfer to the superheater section. Drum water level swing therefore was limited to eighteen inches which in practice allowed peak power levels as high as 80 MW which were adequate for testing the reactor codes.

The most severe transient, starting at a power level of 200 W, is shown graphically at Fig 6. The reactor went critical

*The nile is a unit of reactivity, 1N corresponding to a reactivity of 10^{-2}. In indicating reactivity changes it is usual to use the smaller unit, the millinile (mN), equal to a change in reactivity of 10^{-5}.

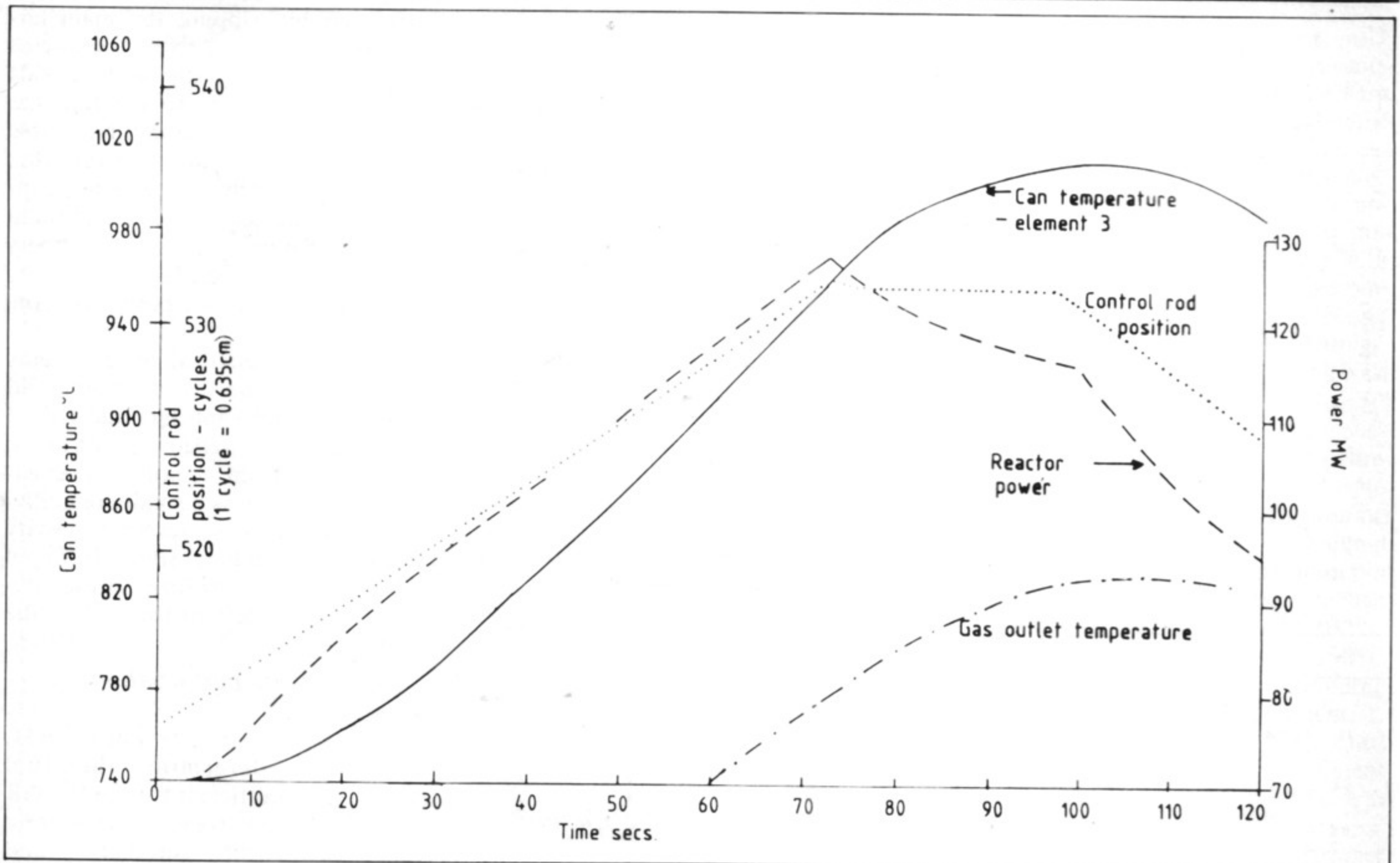


Fig. 8: Reactivity ramp at power

after 115 seconds of rapid rod withdrawal, achieved a minimum doubling time of 2·2 seconds and a clad temperature rate of change of 13°C sec^{-1} before reaching a peak power level of 80 MW. The graph shows clearly the tendency of the reactor to shut itself down as the fuel temperature rises.

To conclude these tests similar transients were performed in a core having a large side to side flux or power gradient (asymmetric core) because such cores pose a more severe test for modelling. The core was made asymmetric by fully inserting five control rods on one side, leaving eight control rods fully out, and operating the remaining five as a bank to give the required reactivity ramp. The latter had a rate of reactivity release at fast rod withdrawal speed of about 160 mN min^{-1}, approximately half that available in the symmetric core tests. Power was distributed in the four quadrants of the asymmetric core in the proportions 35 per cent: 23 per cent: 11 per cent: 31 per cent with individual channel power ratios of up to 6.

Fig 7 illustrates the most severe asymmetric transient which resulted in a minimum doubling time of 5·5 seconds. The graph also shows that the two thermal columns A and B, on opposite sides of the core, whilst having absolute flux levels differing by a factor of three, showed a similar response to the transient in terms of percentage rate of change of flux per minute.

Reactivity ramps at power

In order to demonstrate the validity of the computer codes close to postulated CAGR fault situations, it was necessary for these tests to achieve as high a power and average clad temperature as possible above the normal WAGR operating conditions of 100 MW and 700°C. The criterion limiting the transients arose from the need, on economic grounds, to ensure with a reasonable degree of confidence that only a few (one or two) pins might fail in the transient. This requirement was imposed because on completion of the programme any failed fuel would have to be located, discharged and bottled before storage in the Windscale ponds. Certain calculations indicated that fuel/clad interaction due to thermal expansion, rather than excess internal pressure might prove to be a possible cause of failure in WAGR if the power significantly exceeded 130 MW at an average peak clad temperature of 900°C (absolute peak temperature, 1 040°C). These levels were taken therefore as the limit for the transient. However, the core was first subjected to a transient of 130 MW at an average peak clad temperature of 800°C, when the increased clad strain due to lower thermal expansion of the clad would be more than compensated by higher clad ductility at 800°C. The final test at 130 MW and 900°C could then be performed without imposing any additional strain on the clad due to fuel/clad interaction.

The final transient is graphed at Fig. 8. A full survey for failed fuel in the core, using the reactor BCDG, was made after these experiments with the result that one stringer was detected to contain a failed pin. The history of the stringer suggests that the failure was probably due to excess fission product gas pressure rather than fuel/clad interaction.

Fission product measurements

The fate of fission products released as a result of a small hole developing in the cladding of a fuel pin during normal operation, or released as the result of local clad melting consequent to a fault, is of considerable interest in safety studies. Most of the released material either plates out on cool surfaces within the circuit, is trapped in the filters or is deposited as dust particles at various points around the circuit. Several experiments were performed to improve the accuracy of the data on such effects.

Four fuel stringers previously discharged because they had developed small pin failures were reloaded into the reactor, only one such stringer being in the reactor at any one time. In the case of the first two stringers the caesium release was monitored by mounting steel specimens in the gas stream above the fuel and withdrawing the stringer from time to time to measure the caesium activity on the steel specimens. Iodine release was measured by drawing gas up through the standard burst cartridge detection sampling pipe and through an activated charcoal trap. In these experiments the effect of time and operating temperature on caesium release was measured with time proving to be the dominant parameter.

For the second two stringers a rather more elaborate sampling technique was employed involving specially inserted multiple sample pipes. During the course of an experiment coolant gas was drawn up each pipe in turn, a new pipe being selected for each phase. Finally the pipes were removed for determination of the quantity and distribution of caesium. Throughout these experiments quantitative measurements were made of the radioactive content of the reactor gas by online gamma spectrometry.

If local clad melting should occur in a fault, some of the fission product release would be attached to small particles of clad oxide, so that the rate at which such particles are removed from suspension is of considerable interest. Direct measurements of the rate of decay of released particulate material were performed by injecting labelled particles of known size into the reactor gas circuit and sampling the gas at various times after the injection. Two particle sizes of iron oxide were employed, 2μm and 5μm. It was found that particle half-lives of between one minute at full coolant flow to ten minutes at 15 per cent flow occurred over a range of concentration up to 1 000.

Released iodine is frequently found in the form of methyl iodide and measurements of the decay rate of methyl iodide injected into the reactor circuit were made at a variety of conditions of temperature and flow. These measurements either confirmed previous data used in fault studies or showed currently used data to be somewhat pessimistic.

Conclusions

Two new and two previously irradiated WAGR fuel stringers have been subjected to slow, flow or power induced, transients culminating in a peak pin cladding temperature of about 1 300°C. PIE has shown that the effect of the transients on the new stringers was negligible. Examination of the previously irradiated stringers has not yet been done but their performance, during the transients and return to normal temperatures, demonstrated that they suffered little or no damage from the high temperature exposure. The conclusion is that AGR fuel elements will retain their integrity and coolable geometry should they attain a peak cladding temperature of 1 300°C in a rare accident condition.

A variety of large amplitude reactivity and flow transient experiments have been performed on WAGR without revealing any unexpected effects. The assumptions, methods and data used to predict the results and prepare the safety assessments were able to model the experiments very satisfactorily. Detailed analysis remains to be completed and this will serve to improve the precision of quantification of the uncertainties associated with the theoretical studies.

Further data has been obtained for the release of caesium and iodine fission products from failed fuel pins, together with the plate-out rate of small particles and methyl iodide at various reactor conditions. Such data should prove valuable in refining appropriate aspects of the CAGR safety assessments. □

CONFORM

The well established conventional method for the production of wires, tubes and sections in large quantities is by the reduction of discrete billets by rolling or extrusion. By its nature this is a discontinuous process: but by taking advantage of one of its shortcomings the Advanced Metal Forming Group at the UKAEA laboratory at Springfields have developed a truly continuous extrusion process. Cliff Etherington, research manager, process engineering technology at Springfields, explains

In the early 60s a small team was established at the UKAEA Reactor Fuel Element Laboratories, Springfields (now known as the Springfields Nuclear Laboratories) to investigate novel ways of forming metals with particular reference to the manufacture of fuel elements and fuel element cans. The team was under the leadership of the late Derek Green and concentrated on the development of extrusion processes and, in early years, on hydrostatic extrusion. Considerable progress was made in this field and a significant milestone was reached in the late 60s when a process known as Helical Extrusion[1] was developed, a combined hydrostatic extrusion and mechanical working process which could achieve huge reductions in area in one single operation, producing a small wire section directly from a large billet. By this time the work of the group was aimed entirely at non-nuclear applications being funded by the then Ministry of Technology (now the Department of Industry) under the provisions of the Science and Technology Act of 1965.

The well established conventional method for the production of wires, tubes and sections in large quantities is by the reduction of discrete billets, as in rolling and extrusion. The metals industry has, however, always sought a more continuous means of producing large tonnage products and in the past two decades there has been a significant movement away from casting and working discrete billets to continuous casting techniques by in-line rolling to rod or other section. This development has been particularly rapid in the non-ferrous industry where the bulk of aluminium and copper rod is now made by such routes enabling very large coils—often weighing many tons—to be produced in one continuous length. The introduction of these processes has produced a more reliable feedstock for further working, e.g. into wire and sections for the electrical industry. In parallel with these developments, researchers worldwide, particularly those working in the field of hydrostatic extrusion, have been seeking a truly continuous method of extrusion, such a process would compliment the continuous casting and rolling technique taking the "jumbo" coils of rod and extruding to continuous lengths of finished product in one stage instead of multi-stage drawing or rolling as has been the practice.

The Advanced Metal Forming Group at Springfields were also involved in this search and it was in 1971 that Green conceived the idea for the CONFORM process[2]

The Conform process

In the event, the process derives more from considerations of the shortcomings of conventional extrusion than to the advantages claimed for hydrostatic extrusion! In conventional extrusion, considerable friction exists between the billet and the bore of the container; this friction adds considerably to the extrusion force required of the press and is so significant as to limit the length/diameter ratio of the billet to about 5:1. It is

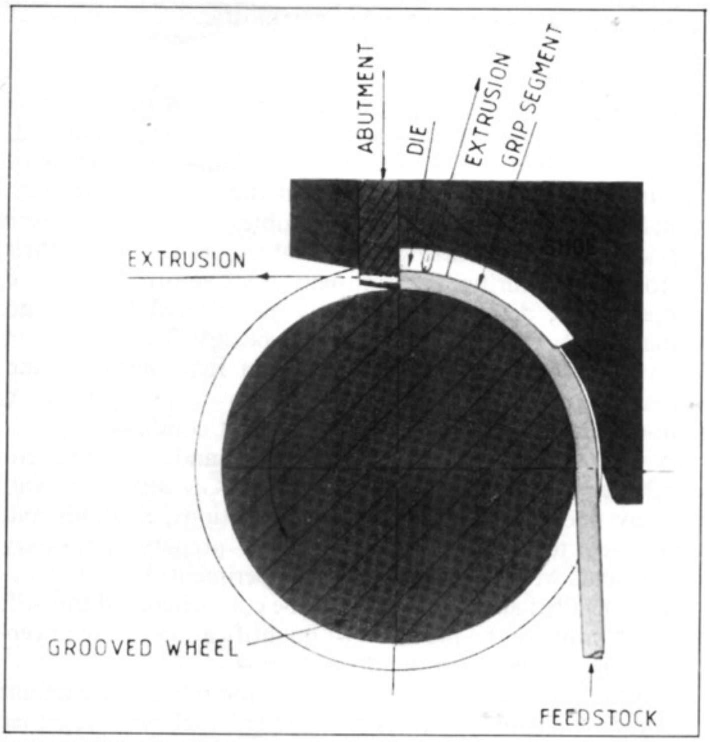


Fig. 1: Schematic arrangement of CONFORM principle

this frictional force which provides the drive in this radically new process. Green realised that billet/container friction could be exploited to provide the driving force in a continuous process, feeding and extruding a continuous metal "billet" via a "continuous" moving container. The continuous container is most simply provided by a rotating wheel having a groove machined around its rim into which the feedstock fits. This open sided container has a closing side formed over part of its circumference by a stationary block of metal, known as the "shoe", which carries the extrusion die and associated tooling (Fig.1). As the wheel rotates, the feedstock is carried round by friction in the groove and is fed up to the abutment, a stationary block of metal sized to fit the cross-section of the groove and thus form the closed end of the extrusion chamber. The driving frictional contact area of the groove is greater than the interacting stationary area of the shoe tooling so there is a net forward force generated on the feedstock. By arranging for sufficient driving length of contact—surprisingly short in the case of most metals—sufficient force can be generated to cause the feedstock to deform plastically to fill the full volume of the groove over a short length in front of the abutment. In this region of plastic flow the bulk compressive stress in the metal rises rapidly to the flow stress required for it to extrude through the die. The die may be positioned almost anywhere in the plastic zone including in the abutment, but is most conveniently situated in a radial position just in front of the abutment. As the wheel continues to rotate, a continuous feed of metal is carried forward into this region of plastic flow and extruded out through the die so that products of almost any length can be made. CONFORM is the first and only commercially successful process which achieves this long sought goal. The rotating wheel groove and stationary shoe tooling form the "continuous" open-ended pressure vessel into which the feedstock enters at atmospheric pressure and is carried over a short distance into a zone of very high pressure, then out again through the die. Pressures may be as high as 10 k bar (70 tons in^{-2}) at the die face with temperatures of up to 500°C.

An additional bonus for CONFORM stems from its use of dry friction as the motivating force in that it can accept feedstock in a wide variety of forms including particulate, e.g. powders and granules, the particles being compressed into a plastic whole before extruding into a homogeneous product through the die. It thus has far reaching potential in the fields of powder metallurgy and waste recycling, these applications having been identified at the outset.

Early developments at Springfields

Initial demonstrations of the process principles were carried out using a linear perspex model with plasticine as the feedstock. This model[3] demonstrated the formation of the grip lengths necessary for the process to operate and was succeeded by the first rotary extruder, a small hand operated table top machine (Fig.2) which is capable of continuously extruding 1.6 mm dia. lead wire from 3.2 mm dia. feed, an extrusion ratio of 4:1. The first motorised extruder (Mk 2A) was successfully commissioned in October 1972 extruding aluminium wire of 1.5 mm dia. from 6.35 mm rod feed—an extrusion ratio of 18:1. This early success was then followed by a demonstration with copper extruding 3 mm dia. wire. In 1973 a second machine of increased power was constructed specifically for investigations with copper which requires greater extrusion pressures than aluminium, the first machine being restricted for use with aluminium and the softer metals. Information from these two machines led in 1974 to the building of a 100 kW CONFORM extruder designed to take standard feed rod 9.5 mm dia., but with numerous improvements making it suitable as a prototype for a production machine. The AEA licensees have subsequently sold some 12 machines based closely on this early design.

A CONFORM machine comprises two basic elements—the rotating wheel and the stationary shoe, the shoe being held in close relationship to the wheel. The whole novelty of the process is contained within the comparatively small volume of the working zone bounded by the shoe tooling and the groove walls. The rotating wheel is carried on a heavy duty shaft mounted in substantial journal bearings to carry the high radial loads developed by the process. Rotational speeds tend to be low, typically not more than 60 rpm on machines currently in production, but torque requirements are high typically 40000 Nm for a 300 mm dia. wheel, so that a high torque, low—but variable—speed drive is required and on the machines at Springfields, hydraulic drives were used for this purpose. Machines currently being supplied to industry tend to be mainly driven by variable speed DC electric motors driving through large reduction gearboxes, although hydraulic drives are also offered as alternatives.

The three machines at Springfields have been extensively modified over the years both in the light of experience and in

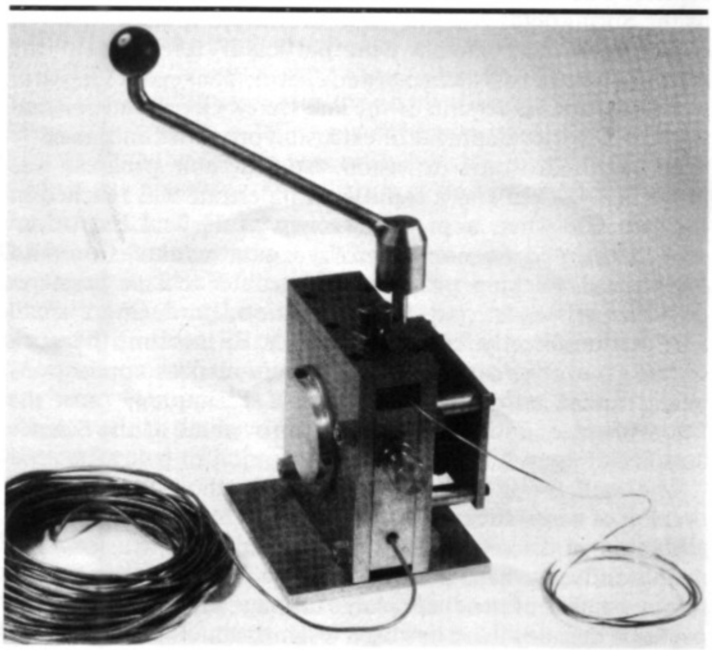


Fig. 2: Lead extruder

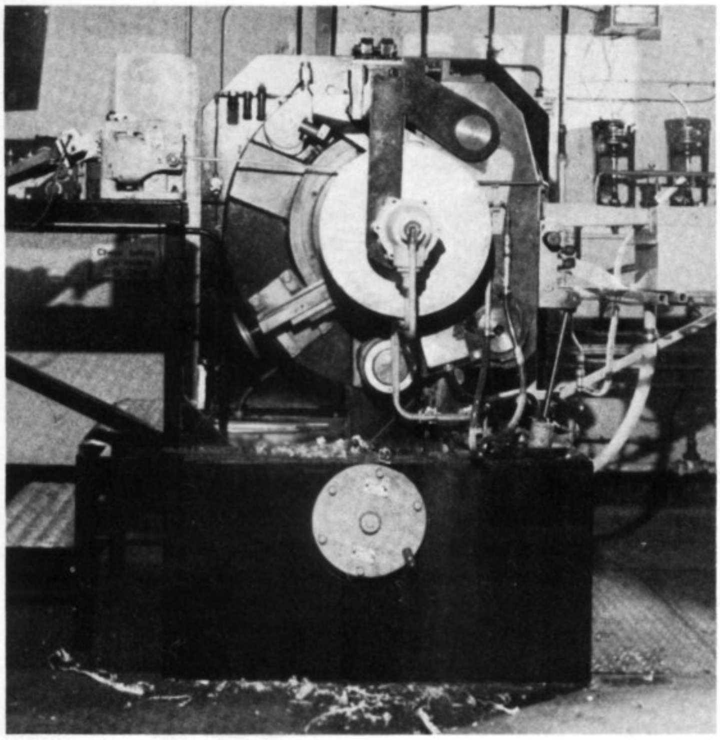


Fig. 3: Mk 2F CONFORM machine

response to the demands made on the process by potential users. Although machines have been built and operated in the laboratory with both vertical and horizontal shafts, currently all three machines are arranged with horizontal shafts to facilitate the feeding of particulates as well as rod feed, particulate feed investigations now being a major aspect of the current development programme. Fig.3 shows a machine modified to accept particulate and rod feed.

The development of CONFORM as a non-nuclear project has been made possible by the granting of funds from the Department of Industry through the Mechanical Engineering and Machine Tools Requirements Board. These funds have been enhanced by earnings from licence fees, royalties on machine sales and work-on-repayment undertaken by the development team for industry. The development is now virtually self-funding from these latter sources.

Licensees and industrial exploitation

The concept was first disclosed to the metals industry in an article published in the Journal of the Institute of Metals in October 1972[3] and although only the hand cranked lead extruder had been operated at that stage, the interest from the non-ferrous section of the industry was immediate—perhaps partly because of the deserved reputation for innovation which Green and the team at Springfields had gained with their earlier work in the extrusion field. It was quickly apparent that the CONFORM process had the potential for a wide range of applications in many areas of the industry and that more would be realised when development and publicity had further demonstrated its capabilities to the industry at large.

It was for this reason that the decision was taken to adopt the policy of licensing machine builders to manufacture and market CONFORM machines rather than attempt to licence each individual user company, the licensees paying a royalty on machine sales. To this end, two UK companies have licences to manufacture in the UK and to sell worldwide. To stimulate the major potential markets of North America and Japan and also to inhibit the development of possible competitive processes in these important areas, a restricted manufacturing licence is held by one American company for manufacture and sales in North and South America and by a Japanese company restricted to sales in the Far and Middle East[4]. However, during the first 5 years of active marketing, UK licensees have sold many machines to the USA and have also competed successfully for sales to Japan thus confirming the soundness of the licensing policy aimed at maintaining the maximum overall benefit to the UK.

In parallel with licensing, an active patenting policy was also adopted and has been maintained covering all the major industrial countries of the world. This has also proved to be sound as many applications and variants are now being proposed mainly by major users with large in-house R&D facilities, but these fall within the scope of the dominant basic patents held by the AEA and so the position of both the AEA and the licensees continues to be protected. Further patentable improvements and applications continue to arise from the development work proceeding at Springfields adding to the substantial patent portfolio held by the Authority.

Process developments

As one would expect with a development of such significance, many of the major non-ferrous metals fabricators around the world have taken delivery of machines, often to conduct in-house investigations to assess its potential for their own particular area of business. This often results in the development of products and production routes not possible before the advent of continuous extrusion, this being especially the case with particulate feeds. In many instances, however, the initial demonstrations have been conducted at Springfields Laboratories as part of work-on-repayment programmes negotiated with the customer and where full confidentiality can be maintained when required. As outlined above, the generic development programme at Springfields concentrated initially on the engineering aspects of designing and developing machines that could be made to operate successfully and from which sufficient information could be obtained to provide the licensees with a reliable Designer's Guide. At the outset, it was felt that on seeing the potential of such a revolutionary process many companies would be eager to buy and do their own pre-production development. However, it was quickly realised that, as with all new technology, something more than just a demonstration of the principles is required before cautious companies foresake existing known technology to take up the novel, no matter how many promises it may seem to offer. As a result, the programme emphasis was changed to concentrate on the development of acceptable industrial products and, in particular, the production of aluminium and copper conductor wire sections, aluminium tubing and simple shapes working principally from rod feeds. It was soon obvious that CONFORM could make an early economic impact in the production of shaped sections rather than round wire where 'generations' of development had already refined wire drawing to a high degree of sophistication making it an exceptionally cheap and efficient process. However, where the conductor shape is other than round, e.g. rectangular strip for transformer or motor windings, and sectored aluminium conductors for heavy current cables, then the ability to produce the finished product in virtually one operation and almost any required length.

An important area of development, pioneered at Springfields, has been the use of what are known as "expansion dies", (Fig. 4) which used technology in the conventional aluminium extrusion field, but required modification and refinement to operate successfully in a continuous extrusion machine. With the development of this technique, it was possible to extend the operating range of CONFORM so that one machine is capable of producing a wide range of products from one size of feedstock, for example, from 9·5 mm aluminium rod feed it has been possible to make products ranging from 1 mm diameter round-wire to a rectangular section of twice the cross-sectional area of the feed rod. This concept of using CONFORM as a metal "pump" to feed metal con-

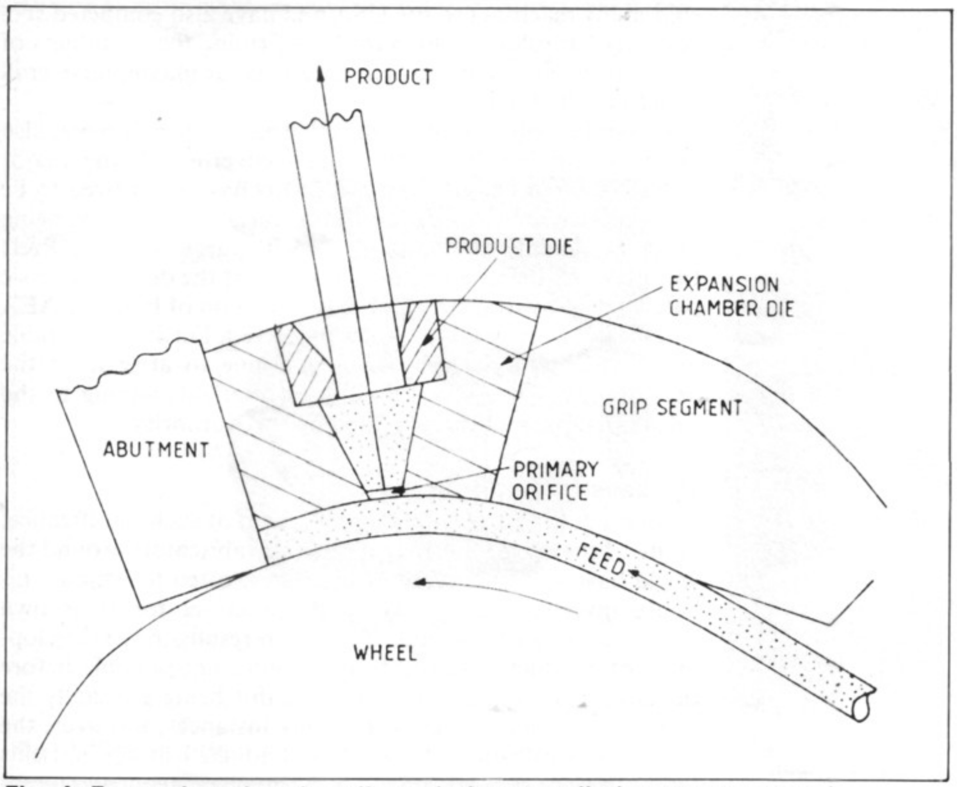


Fig. 4: Expansion chamber die technique applied to CONFORM and

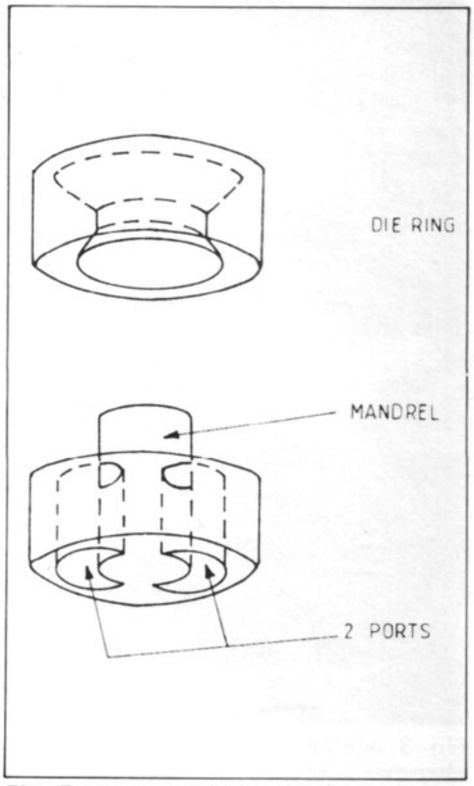


Fig. 5: CONFORM tube die (right)

tinuously into a die chamber from which it will flow in the shape of the required product has vastly enhanced the potential range of applications for the process. It is this technique which has enabled tubes and other hollow sections to be produced by the incorporation into the die of a bridge or "port holes" surrounding a mandrel (Fig. 5). The divided streams of metal reweld in the high pressure zone formed in the gap between the mandrel and the die ring which shapes the outside diameter of the tube. The technique has enabled a wide range of sizes and shapes of hollow sections to be made as can be seen from Fig. 6, including multi-cavity "flat" tubes where the width can be up to three times the diameter of the feed rod.

The use of particulate feed in various forms such as powder or granules—which may be made from primary or recycled "secondary" metal or from granulated clean scrap—offered the opportunity to demonstrate considerable energy and cost savings compared to the conventional non-ferrous metal production routes of billet casting followed by a variety of working processes as mentioned previously. This area of application has become as important as that using solid feed and forms a major part of the current Springfields programme. An added factor in this area is that often the products have enhanced properties over those produced from rod feed. Aluminium powder feeds produce dispersion strengthened products directly, without the need for pressing, sintering and then further working as in normal production routes. Often metal alloys which are difficult to work in the solid form extrude quite readily when used as particulate feed in CONFORM. This is due to the frictional heating which occurs as an inherent part of the process softening the metals and reducing the flow stress to acceptable levels. Granular feeds also facilitate the production of extrusion-clad products, e.g. aluminium coated steel wire conductors. Although ideas for this have been revealed[5] the major CONFORM developments in this area are coming from the potential user companies. Over 50 per cent of machines sold to date have been for applications with particulate feeds.

This variety of applications underlines the inherent flexibility of the CONFORM process, a standard machine with a horizontal shaft can, for example, accept aluminium feeds varying from powders and granules to rod or bar. Wire, solid sections or hollows can be produced from all of these. Even the rod feed does not have to be a precise size or shape for the groove since the process automatically ensures a precise fit where it matters—in the plastic zone established in front of the abutment/die.

Future developments

Despite successes to date there are still many areas and potential applications of the process requiring investigation. One continuing fruitful development area is that of improving wheel and tool life, where abrasive wear and wheel fatigue are possible sources of premature failure, and hence costly breakdowns, and a programme continues at Springfields exploring new materials and designs to combat these problems.

Development to date has concentrated on the extrusion of non-ferrous metals, particularly the high tonnage products in aluminium and copper while ferrous metals remain a major area for future exploitation. Ideas for the extrusion of ferrous and other hard metals have, however, been considered and some of these have been revealed in Research Disclosures[5] and/or patents to protect the concepts. Ideas have also been revealed[6] for using CONFORM for the continuous production of individual components, particularly headed items such as rivets or other components that could not readily be sawn from a continuously produced section. One idea is to introduce a series of recesses, the shape of the desired product, into the base or side wall of the wheel groove, as these pass up to and under the abutment, the metal will be forced to extrude into the cavity. This cavity principle has been demonstrated with a simple bench top model.

To date, licensees have supplied machines of up to 350 kW capacity with a wheel of 400 mm dia., capable of accepting aluminium bar feed up to 40 mm dia. Such a machine is capable of extruding a wide range of heavy architectural sections and is a competitor to the typical 1600 ton standard aluminium extrusion press. The CONFORM machine and associated plant is, however, up to 50 per cent cheaper than the press and its associated plant, saving particularly on the billet pre-heating equipment and hence in overall energy usage. It remains to be seen whether as the process is further developed, more of the major extruders will choose CONFORM

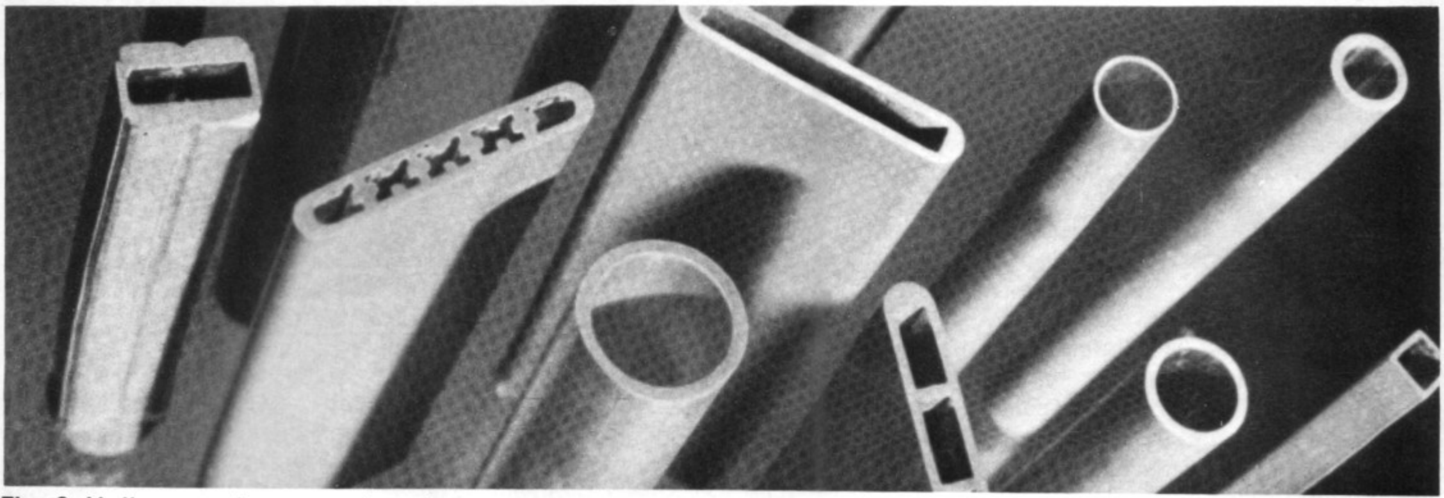


Fig. 6: Hollow section extrusions by CONFORM

machines in place of conventional presses to replace out-dated and worn-out plant. Currently, due to the worldwide recession, there is under utilisation of these heavy capital items, excess capacity being widely available and this has made the task of promoting CONFORM all the more difficult. Nevertheless, many of the more enterprising companies are taking a longer term view and have invested in CONFORM now, working up the application of the technology to a state at which they are now ordering second machines to go straight into production.

Conclusion

The technique has been under active development at Springfields for some nine years. Most of this work has been reported in numerous papers presented by members of the Advanced Metal Forming Group at international conferences[7]. Despite the fact that the first oil crisis—and resulting business recession—occurred in 1973 shortly after its inception CONFORM has consistently attracted worldwide technical interest. Technical and business staff from companies both large and small and from all over the world have visited and continue to visit Springfields Laboratories to view the work, and sales by the licensees are now beginning to reflect the confidence in the viability and eventual acceptance of the process which has consistently been maintained by the development team. Whilst conducting a basic underlying programme of development, it has at the same time been necessary to retain a degree of flexibility in order to respond to market forces. The transfer of new technology from the laboratory to the production floor is a major task and Springfields staff have had to respond to calls for assistance in support of licensees and customers to help launch the process commercially as well as undertake the development of special products to meet potential customers specifications. It is intended that this flexible policy will continue in order to ensure further market penetration and acceptance for the technology.

Continuous extrusion by CONFORM has developed as a spin-off from early nuclear work on hydrostatic extrusion and it is encouraging to note that nuclear applications are now beginning to be seen for the process, particularly in areas of the fuel cycle programme and it will be interesting to see how these develop.

In whatever form CONFORM evolves over future years it can be said with some confidence that friction actuated continuous extrusion, first demonstrated at Springfields in 1972, will become an established metal working process alongside the other recent developments of continuous casting and in-line rolling now used extensively by the non-ferrous industries, and with them will be one of the most significant developments in metal forming to have been made in the past 50 years or so.□

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A PWR for Britain

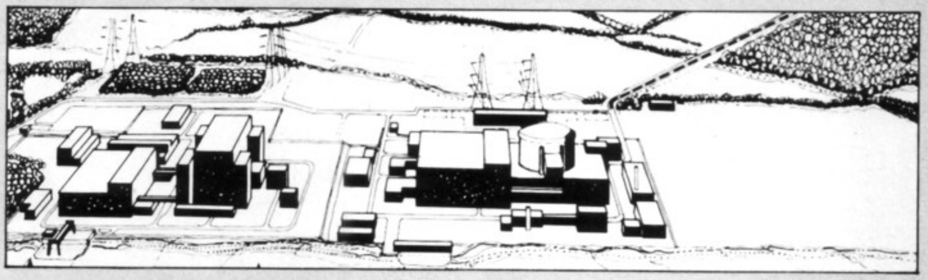
The NNC and CEGB now have a sound and safe design of PWR, which is readily constructable and is backed by a great depth of experience worldwide, Mr J.C.C. Stewart, a director of NNC, said in the 6th Cockcroft Lecture to the BNES in London in December.

"But I believe that we still have a great deal to do in informing the public about nuclear power and the essential need for it on a global scale, and in producing facts to enable the public to form a realistic opinion about its safety," he said. "We should strive to make nuclear power so attractive that the generating boards will not only want to replace old plant, but will also only order nuclear to meet all their future requirements."

One or two points had emerged from the history of the development of the nuclear power programme in Britain, said Mr Stewart. First, constant debate about the relative merits of different systems could be time-consuming, frustrating and destructive. In his view, if there was a sensible economic case for a particular system they should simply go ahead, design it and try it. Secondly, as a family of reactors develops there are bound to be new problems which require solution, as part of an evolutionary process. "Many of us would have liked to have seen an evolutionary progress with the AGR rather than the rapid start which was made with separate designs," he said. "I suggest that we must constantly analyse the performance of existing plant, look at its capital cost as well as demand for power, and adjust our course in the light of all these factors. Lastly, I suggest we should beware of phoney economics."

Mr Stewart suggested that it was outstandingly important to be part of the world technical community. Light-water reactors accounted for 80 per cent of world nuclear capacity, and two-thirds of that was PWR. Eighteen countries were now operating PWRs, five of them in the eastern bloc; the regulatory authorities of those countries had all evaluated the PWR system against their own criteria and had accepted it. All 18 countries had further PWR plant either on order or under construction.

Three of them—France, Spain and Korea—were an object lesson for Britain. None of those countries had any significant fossil fuel resources. In 1990 they would be able to supply



extremely competitive electricity to power their manufacturing industry, their railways and so on. "Their commitment is also such that they will be able to produce the totality of their power stations indigenously, and be able to compete effectively for power stations on the world market."

The current recession had slowed nuclear programmes markedly; but as the world economy picked up ordering would resume. "It is worth noting that the Soviet Union continues to expand its programme," said Mr Stewart. "The perspective of the place of nuclear power, and the PWR in particular, in meeting world energy requirements is that the installed world nuclear capacity is at present 158 000 megawatts—9 per cent of the world output of oil. By 1990 the installed capacity will be about 500 000 megawatts, equivalent to twice the present oil production of Saudi Arabia. With such an achievement there is no need for the industry to make apologies: it is a remarkable achievement to have been made within 30 years.

"In joining the PWR technical community we would become part of a bank of information covering operation, maintenance and methods of improving availability; we would be part of an extensive development programme. For instance, it is possible that the lifetime of PWR fuel will be extended to 40 000 megawatt-days per tonne. . . ." [It is currently about 33 000 MWd/te.—*Ed.*]

The PWR proposed to be built at Sizewell presented both an opportunity and a challenge, he said. The CEGB and NNC had the declared intention of following tried designs; but it was not possible for them to build a 'Chinese copy' of an American plant in the UK for a number of reasons:

- Sizewell B had to satisfy the CEGB and NII safety requirements, which placed special emphasis on redundancy and diversity of safeguard systems;
- any plant built now had to take account of the lessons learned since TMI;
- the high standards of operation and maintenance set by the CEGB had to be capable of being maintained; and
- the plant had to be designed for 50 Hz generation.

"Our first attempt at an overall concept for the power station was naturally governed by our experience of designing gas-cooled reactors. As our understanding of the experience of others increased it became very apparent that the 'first shot' would be difficult to construct and more expensive than was necessary—so the normal processes of design refinement and iteration have taken place."

The design as it stood now would lend itself to tight construction schedules; it would be possible to take many of the detailed drawings straight from the American design (e.g. the drawings for the radioactive waste management building could be readily converted for use in this country); and it retained the benefit to be drawn from previous experience, while meeting fully UK requirements.

With respect to the safety of the plant, Mr Stewart reminded his audience that a wide range of techniques were available for assessing the effectiveness of protection systems, including the probabilistic risk analysis technique developed in the UK. "I make this point because I have always been concerned about the ever-increasing regulatory requirements throughout the world and the additional equipment attendant on them, which may not in my opinion lead to safer plants. I believe it to be more necessary than ever that we exercise judgment in these areas."

The reference design now arrived at, he said, was "solid": it was readily constructable, and he believed it to be safe and good value for money. He estimated that, in round figures and at June 1981 prices, the nuclear island of the plant excluding site, fuel and some other costs would be about £600 million. Associated engineering costs would add about £250 million to that. □

Safeguards explained

To try to correct public misapprehensions about the aims, functions and powers of the safeguards system established by the International Atomic Energy Agency the organisation has published a 38-page booklet* giving a generalised overview of the subject, supplementing the detailed technical literature.

The Agency noted on publication that its safeguards system is unique: it is the first case in recorded history in which countries willingly surrender part of their national sovereignty and allow foreigners to inspect their nuclear installations and verify that the countries are fulfilling their obligations under international treaties and agreements. That the IAEA system applies to such sensitive facilities as nuclear reactors and fuel plants makes the creation and achievements of the system so far all the more remarkable, the Agency said.

The booklet now published is intended to help design engineers and operators of nuclear facilities but, as its technical content is limited, it should also be useful to others who have to deal with nuclear matters—including journalists.

The booklet notes that almost the whole of the world's known nuclear industry outside the nuclear weapon states is under IAEA safeguards. By December 1980, 110 non-nuclear-weapon states were party to the Treaty on the Non-Proliferation of Nuclear Weapons (the NPT) which, *inter alia*, binds these states not to acquire nuclear weapons or other nuclear explosive devices, and to accept IAEA safeguards on all their peaceful nuclear activities with a view to verifying the fulfilment of their obligations. The Agency also applies safeguards in ten other countries under non-NPT agreements.

Safeguards are essentially a technical means of verifying obligations a state has undertaken. According to the booklet, the main political objectives of safeguards are:

- to assure the international community that states are complying with their non-proliferation and other "peaceful use" undertakings;
- to deter the diversion of safeguarded nuclear material to the production of nuclear explosives or for other military purposes; and the misuse of safeguarded facilities for the production of unsafeguarded nuclear material.

The booklet points out that the IAEA has no authority to apply safeguards unless the state concerned requests it, and that safeguards agreements are entered into voluntarily by states. However, those countries party to the NPT are under a legal obligation to conclude safeguards agreements with the IAEA. The deterrent effects of the safeguards system, the booklet warns, depends on the international community responding promptly and vigorously if the IAEA should ever have to "sound the alarm".

The booklet makes clear that no international system of safeguards can physically prevent diversion, that the Agency cannot prevent any party to the NPT withdrawing from the Treaty, and that there can be no question of the IAEA imposing its safeguards on a reluctant state.

The technical objective of safeguards, according to the booklet, is the timely detection of the diversion of significant quantities of nuclear material. A 'significant quantity' is the approximate amount of nuclear material that could be used to manufacture a nuclear explosive device: about 8 kg of plutonium, or 25 kg of highly enriched uranium.

In 1980, the booklet reports, about 6 million surveillance pictures were taken and about 400 000 data entries were made on the Agency's computer. About 200 minor anomalies were detected, all of them were explained satisfactorily upon subsequent appraisal and investigation. The Agency concluded it was reasonable to infer—as in previous years—that all nuclear material under IAEA safeguards had remained in peaceful nuclear activities, or had otherwise been adequately accounted for.

The booklet reviews the way in which safeguards are implemented, and the states' system of accounting for and control of nuclear materials is discussed. Other topics such as nuclear materials accountancy, containment and surveillance, and inspections are covered, and the booklet also describes the structure and organisation of the Agency's Safeguards Department.

An article on the development of the international safeguards system, by A.G. Hamlin of the UKAEA Nuclear Materials Accounting Control Team, appeared in ATOM **274**, August 1979, and is available as a reprint. □

**IAEA Safeguards: An Introduction.* IAEA, Vienna, Austria, 1981; IAEA/SG/INF/3, price 100 Austrian schillings. Copies may be obtained from the IAEA Division of Publications, P.O. Box 100, A-1400 Vienna, Austria.

Four years' work

The National Radiological Protection Board has published a survey of four years' work, from 1977 to 1980, and a review of the organisation's development during its first ten years.

The ten-year review recapitulates briefly the history of the Board's origins and its growth to its present position as an independent organisation devoted to research, advice and services in radiological protection. The four-year survey summarises the work undertaken by the NRPB in relation to the industrial, medical, dental, research and other uses of radiation and to nuclear power in particular. In these four years the NRPB:

- issued more than three million radiation dosemeters as part of a service for measuring and recording the radiation doses received by workers;
- provided advice and assistance, often to cope with unusual problems and following accidents and injuries;
- organised 185 scheduled training courses and numerous courses specially designed for individual clients, and also post-graduate courses for professional health physicists; *cont.*

- acted as agent of the Health and Safety Commission in the inspection of premises;
- contributed to the work of the ICRP, UNSCEAR, IAEA, NEA, EC, IMCO, IEC and other international organisations, and maintained close contact with radiological protection organisations in several countries;
- initiated a system of consultation in relation to the provision of advice on standards;
- published a major review of the radiation doses received by patients from the medical and dental uses of radiation;
- assumed responsibility for the national scheme of measurements of radioactivity in milk;
- measured the exposure of communities in west Cumbria to airborne activity from Sellafield (formerly Windscale);
- analysed the radiological consequences of notional accidental releases from fast breeder reactors;
- developed environmental models to estimate radiation doses to man from the radioactive effluents discharged during the normal operation of nuclear installations;
- evaluated the radiological impacts of the treatment and disposal options for different types of radioactive waste and provided advice on their acceptability.
- carried out extensive and detailed studies of the internal radiation dosimetry of radioactive materials taken into the body, particularly of plutonium and similar materials, and of the naturally occurring gas radon-222 and the products of its radioactive decay;
- introduced and expanded a thermoluminescent dosemeter service and an associated automated dose record keeping service to reduce the labour and administrative complexity of dose record keeping for employers; and
- established the National Registry for Radiation Workers.

Further information is available from the Information Officer, NRPB, Chilton, Didcot, Oxon. OX11 0RQ; tel. Abingdon (0235) 831 600, ext. 410. The survey is available as *The Work of the NRPB 1977-80 and a review of the first 10 years,* HMSO, £4. ISBN 0 85951 160 X. □

Energy R,D&D requires urgency

Unless research, development and demonstration of new energy technologies, well directed and clearly focussed, continues to be conducted with a sense of urgency the projected benefits will not be realised in the 1980s and 90s, the 21-nation International Energy Agency concluded in its most recent review of national programmes.*

The Agency noted a number of trends in the balance of expenditure on various technologies during the past six years:

- conservation R, D&D increased its share of total IEA government budgets from 2·3 per cent in 1974 to 5·0 per cent in 1977, and further to 6·4 per cent in 1980;
- oil and gas R, D&D—where principal effort is in the private sector—increased its share from 2·2 to 3·6 per cent over the same period;
- coal R, D&D went from 5·8 per cent in 1974 to 10 per cent in 1977 and 11·4 per cent in 1980;
- 'conventional' nuclear R, D&D—excluding breeder and fusion work—declined as a proportion of total R&D from 35 per cent in 1974, to 29 per cent in 1977 and to 26 per cent in 1980. "Within this area, it is to be noted that nuclear fuel cycle budgets have remained in the 12-13 per cent range since 1977, and that nuclear supporting technologies (essentially nuclear safety) have declined in percentage terms from 6·1 per cent in 1977 to 4·6 per cent in 1980," said the review.
- Renewable sources of energy increased their share of funding from 1 per cent in 1974 to 7 per cent in 1977, and have continued to increase steadily, receiving more than 13 per cent of total government budgets in 1980;
- fast reactor R,D&D has received a significantly declining share, from 34 per cent in 1974 to 18 per cent in 1980. Fusion's share of total funding has increased from 8 per cent in 1974 to 10 per cent in 1980.

The report concluded that the vulnerability of national economies to oil price increases, supply cutoffs, strains in the balance of payments, unsteady foreign exchange rates, inflation, unemployment and higher interest rates are all having their impact on energy R,D&D in IEA countries. Dr Eric Wills, Director of the IEA Energy, Research, Development and Technology Application Office, said when presenting the report that caution must be exercised in projecting future trends, but 1980 might be a year of transition for IEA governmental funding as some governments reduced funding for research with the role of industry becoming increasingly important. The report found that industry's expenditure on energy R,D&D in all IEA countries might now equal that of governments.

The review concluded that current world energy prices had increased the incentive for industry to develop alternative energy technologies: two-thirds of industrial energy R,D&D effort is focussed on conservation, oil and gas and supporting technologies compared with 20 per cent by IEA governments. Both industry and governments spent 10 per cent on coal R,D&D, and supporting technologies—largely, electricity conversion, and transport—received 19 per cent of industrial expenditure compared with 11 per cent of government expenditure. □

**Energy Research, Development and Demonstration in IEA Countries: 1980 review of national programmes.* 170 pp. OECD/IEA, Paris, 1981. ISBN 92 64 12251 6. Available through HMSO; no price stated.

Science prize

David Fishlock, science editor of the London *Financial Times,* was awarded the $1 500 first prize in the Worthington Pump Award for scientific and technical journalism.

The award, announced by the bureau of the European Union of Science Journalists' Associations in December, was for an article entitled 'Nuclear industry tackles self-control' which appeared in the *Financial Times* in March 1980. The article described the work of the UKAEA power fluidics laboratory at Springfields, and developments in the use of power fluidics in the nuclear and other industries. □

New DG for NEA

The Secretary General of the OECD, Emile van Lennep, announced on 17 December the appointment of Mr. Howard K. Shapar as Director General of the Nuclear Energy Agency, succeeding Mr. Ian Williams, who has retired.

Mr Shapar, who was the executive legal director, senior executive service, of the US Nuclear Regulatory Commission (NRC), took up his duties on 18 January.

The OECD said that in his former position Mr. Shapar's primary task was to give legal and policy advice to the NRC on a wide variety of activities including licensing and regulation of nuclear power reactors and nuclear materials, enforcement, nuclear exports and imports, international agreements, nuclear insurance and indemnity. He was involved in the analysis and preparation of legislation and had extensive contacts with the US

Congress and federal and state governmental agencies.

Mr. Shapar was involved in a number of international nuclear activities, including the activities of the NEA. He was last year elected President of the International Nuclear Law Association; he has also lectured and written extensively on the impact of science and technology, nuclear power and environmental law, international nuclear law and nuclear regulation.

Mr. Shapar was born in Boston Mass., in 1923. Following graduation from the Yale Law School in 1950 he joined the US Atomic Energy Commission. Before taking up his duties at the NRC at its creation, he was assistant general counsel for licensing and regulation at the AEC. □

Landfill leachate symposium

A one-day symposium on the generation, management and disposal of landfill leachate is to be held at AERE Harwell on 19 May.

Leachates, produced by the percolation of water through a decomposing mass of refuse, may contain concentrations of fatty acids, organics and metals which can pose pollution problems. However, such risks can now be minimised by the adoption of new techniques of landfill management, hydrogeological assessment of sites and (as a back-up measure) leachate treatment.

The symposium, which is being organised in conjunction with the Department of the Environment, will review the latest developments and measures available to landfill site operators. Sessions will be devoted to the control of water in flow to landfill sites, the absorptive capacity of landfill refuse, site hydrogeology and leachate quality and control. The symposium will conclude with an examination of the various leachate treatment options and experience in the design and operation of treatment plant in the UK and West Germany.

Formal presentations will be short to encourage a "workshop" atmosphere and full discussion of the key issues. The symposium is aimed at local government waste disposal officers, waste disposal contractors, water authority officials, environmental health inspectors, planners and civil engineers. Attendance will be limited to 200 participants.

The symposium registration fee will be £35 + VAT including preprints, lunch and refreshments. Registration forms may be obtained from Mr. Les Evans, Education and Training Centre, Harwell Laboratory, Didcot, Oxon OX11 0QJ; tel. 0235 24141, ext. 3106. □

Appointments to RWMAC

Mr Michael Heseltine, Secretary of State for the Environment, with the Secretaries of State for Scotland and Wales, announced in December the following appointments and re-appointments to the Radioactive Waste Management Advisory Committee chaired by Sir Denys Wilkinson, FRS, vice-chancellor of Sussex University.

Until August 1985

The Marchioness of Anglesey, CBE, LLD, former member of the Royal Commission on Environmental Pollution*;

Professor B. Funnell, MA, PhD, Professor of Environmental Sciences, University of East Anglia;

Professor J.R. Greening, PhD, DSc, FInstP, FRSE, Professor of Medical Physics, Edinburgh University;

Professor C.K. Rowley, BA, PhD, Professor of Economics, University of Newcastle-upon-Tyne.

Until August 1984

P.N. Adams, National Officer, Electrical, Electronic, Telecommunications and Plumbing Union;

Professor C. Hanson, BSc, PhD, CEng, CChem, FIMechE, FRSC, FIMM, Professor of Chemical Engineering, University of Bradford and member of the Advisory Committee on the Safety of Nuclear Installations*;

L. Lewis, CEng, MIEE, Member of the Institute of Professional Civil Servants;

R.R. Matthews, MA, CEng, FIMechE, FIEE, FIChemE, Director of Health and Safety, Central Electricity Generating Board*;

R.B. Pepper, BSc, MInstP, Member of the Electrical Power Engineers Association.

Until August 1983

Dr D.G. Avery, BSc, PhD, FInstP, Deputy Managing Director, British Nuclear Fuels Ltd;

Dr S.H.U. Bowie, BSc, DSc, FRS, FEng, FRSE, FIMM, FMSA, independent geological consultant, Visiting Professor of Applied Geology, University of Strathclyde;

Dr L.E.J. Roberts, CBE, MA, DPhil, FRSC, member of the UKAEA and Director of the Atomic Energy Research Establishment, Harwell;

Dr R. Scott Russell, CBE, PhD, DSc, FIBiol, former Director, Agricultural Research Council Letcombe Laboratory;

D.R. Smith, MA, CEng, Manager, Technical Department, Thermal Reactor Division, National Nuclear Corporation;

Professor D.R. Williams, PhD, DSc, CChem, FRSC, Professor of Chemistry, University of Wales Institute for Science and Technology, was previously appointed to fill a vacancy for a term ending in December 1983.

*New appointments

The Radioactive Waste Management Advisory Committee was set up in mid-1978 to advise the Secretaries of State for the Environment, Scotland and Wales on the development and implementation of a comprehensive radioactive waste policy. It was formed in response to a recommendation of the Sixth Report of the Royal Commission on Environmental Pollution, *Nuclear Power and the Environment,* published in 1976. □

The present and all the past chairmen of the UKAEA met for lunch in mid-December: from left to right, they are Dr Walter Marshall, CBE, FRS, the present chairman; Sir John Hill, FRS, chairman from 1967 to 1981; Lord Plowden (formerly Sir Edwin Plowden), chairman from 1954 to 1959; Lord Penney (formerly Sir William Penney), chairman from 1964 to 1967; and Lord Sherfield (formerly Sir Roger Makins), chairman from 1960 to 1964.

HSELiNE access widened

The computerised database of references to published information compiled by the Health and Safety Executive (HSE), one of the most up-to-date and comprehensive on the subject in the world, is now available to organisations and individuals in the UK, other countries of the European Communities and some other countries.

The database contains 27 000 references with about another 8 000 being added every year.

The information is held under the name HSELiNE on the computer in Frascati, near Rome, run by the European Space Agency Information Retrieval Service (ESA-IRS). This service is available within the UK from the IRS national centre and marketing outlet, IRS-DIALTECH, run by the Department of Industry and based in Orpington, Kent, where there is a dial-in point (ESANET) to the ESA computer. The information can also be accessed via EURONET, the European telephone data network operated in the UK by British Telecom.

HSELiNE references are drawn from publications of the Health and Safety Commission and Executive, and articles appearing in a wide range of national and international periodicals, books, conference proceedings and legislation in the UK and elsewhere relevant to health and safety at work.

Areas covered reflect the HSE's own wide range of interests—science, general technology, occupational medicine, manufacturing industry and commerce, pollution of the working environment, toxic substances, agriculture, mining, nuclear technology, risk assessment and major hazards. Most documents referenced will be available from the British Library Lending Division, Boston Spa, Wetherby, West Yorkshire; or through normal library channels.

A leaflet about HSELiNE is available free of charge from the library, Health and Safety Executive, Red Hill, Sheffield S3 7HQ; tel. 0742-78141. □

CAMAC seminar

The U.K. CAMAC Association—the U.K. branch of the European CAMAC Association, the official liaison body between the European Standards of Nuclear Electronics organisation, manufacturers and users—is to hold an applications seminar at the Culham Laboratory on 1 April.

The UKCA has a membership of almost 300 drawn from organisations that either use or supply CAMAC equipment. It provides information on ESONE and ECA standards and keeps its members informed of related activities in these fields. The first session of the seminar will concentrate on the use of automatic test equipment, describing the use of CAMAC and other standards in this field; and the second will cover a wider range of applications, both industrial and non-industrial, including the description of an airborne data acquisition system.

Further information may be obtained from A.J. Vickers, Electronics Group, Culham Laboratory, Abingdon, Oxon. OX14 3DB; tel. Abingdon (0235) 21840, ext. 3389. □

Nuclear incidents

The Health and Safety Executive published the third quarterly statement of incidents at nuclear installations in Britain in 1981 on 3 December. The incidents, described in the statement in chronological order, occurred at AERE Harwell, the Sellafield site of BNFL, the UKAEA establishments at Winfrith, Dorset, and Dounreay, Caithness, and the CEGB's nuclear power station at Trawsfynydd, Gwynedd.

- As a result of a routine monitoring check at Sellafield on 6 July a man's protective coverall was found to have been contaminated with radioactivity on the thigh. The man had been working in the Magnox fuel storage and decanning plant engaged in the removal of contaminated equipment from its containment. Preliminary estimates of the level of contamination involved indicated that the man had received a radiation dose to the skin about three times the annual permissible level, and he was withdrawn from radiation work pending the results of further measurements. These confirmed that the dose level had been exceeded, as a consequence of which the man was to remain withdrawn from radiation work until the end of 1981, when he would be able to return to normal duties subject to a restriction on his exposure during the following year.

From investigations it was not possible to identify precisely how the coverall came to be contaminated excessively. Since the incident the procedures for the control and monitoring of operations of the kind being carried out by the man have been reassessed with a view to preventing a recurrence.

- On 21 July some radioactive solution containing americium-241 was spilled in a laboratory in the main radiochemical building at Harwell during its transfer into a waste container prior to disposal at the site's active liquid effluent treatment centre. The amount of radioactivity involved was quite small, all contained within the controlled area, and there was no significant airborne release. Three persons were engaged in work in the vicinity when the spillage occurred, all wearing protective clothing and respiratory protection. The results of tests indicated that none of them had received a detectable intake of activity from the incident. The spillage was cleaned up and the affected area decontaminated.

An investigation into the circumstances of the incident concluded that the spillage had been due to the adoption of an inadequate transfer technique on which appropriate advice had not been sought. To prevent a recurrence action was taken to improve arrangements and techniques employed in handling active liquid waste in the laboratories and to ensure that a safe route for transfer of waste to the treatment centre is established prior to the commencement of work.

- On 28 July routine contamination checks at Winfrith on contractor's equipment which had been used for drilling holes in concrete reactor shielding in two controlled area locations revealed localised areas of radioactive contamination on the drilling rig and associated tools. The contamination, identified as an isotope of cobalt, was removed with some difficulty from the equipment. The results of checks on the hands and clothing of the workers engaged on drilling operations, and the working environment, showed that there had been no personal contamination. The radiation levels involved were very low.

An investigation confirmed that the contamination originated from reactor plant, and indicated that its transfer outside the controlled area had been made possible by insufficient control of the movement of contractor's equipment. Appropriate changes to the procedures concerned were made, and the need for more precision in the completion of the necessary health physics checks stressed.

- A routine radiation monitoring film issued to a worker in the Magnox fuel decanning plant at Sellafield for use during the month of July recorded a radiation dose to the skin slightly in excess of the permissible quarterly level. The man was withdrawn from radiation work pending an investigation into the circumstances of the incident.

- Two workers were found to have received a small amount of radioactive contamination on their hands and overalls at Dounreay on 20 August. The discovery was made during routine contamination checks following maintenance work by the men on a non-radioactive system used for the transfer of non-active liquid into a plant in the fuel reprocessing area. The men were quickly decontaminated and access to the area was restricted until the source of the activity could be determined.

It was found that there was a backfeed of liquid from the plant in question through a faulty non-return valve. The system was subsequently modified to prevent further backfeed leakage by the addition of a syphon break. Other comparable systems elsewhere in the reprocessing area were examined and also modified where necessary.

The two workers concerned were found to have received no measurable radiation dose as a result of the incident.

- In the course of carrying out general maintenance work in an active area at the Dounreay Fast Reactor on 20 August a worker's direct-reading radiation monitor was found to indicate a higher exposure level than expected from the nature and location of the work being performed. Subsequent examination of the man's monthly radiation monitoring film also suggested that a high radiation dose, about twice the annual permissible dose, had been received by him; and he was withdrawn from radiation work.

In the course of an inquiry into the apparent overexposure it was shown that the nature and degree of exposure recorded by the affected man's monitoring film was not consistent with that on those of other workers engaged in work in the same area. It was found that the exposure could only have been caused by prolonged exposure of the film inside the shielding of a source of radiation in the area. The results of blood count, chromosome aberration and whole-body monitoring tests showed no evidence of significant radiation exposure or measurable uptake of radioactivity by the man. The inquiry concluded that the radiation dose recorded by the film was received when it was not being worn by him.

- A small leakage of slightly radioactive water occurred near to the irradiated fuel storage building at Dounreay on 24 August. Water was being pumped from the pond to an active drain when it was found that there was a small leak at the coupling attaching the connecting pipe to the pump. Work was immediately stopped, access to the area was restricted, and decontamination carried out.

The connection for the transfer operation was a temporary one, in use while modifications were being made to the active drain. It was found that the leak had occurred as a result of the coupling in question being insufficiently secured. The temporary structure was removed and a more substantial replacement installed. The leakage did not present a radiation hazard and no one was contaminated.

- A monitoring check on an operator at Sellafield on 2 September indicated that he might have received an intake of plutonium. The man had been engaged in plutonium-contaminated waste bagging operations in a laboratory and was wearing protective equipment. No other personnel were involved. Medical therapy was administered and the man was withdrawn from radiation work pending the results of further bioanalytical measurements. The circumstances of the incident were still being investigated at the time of the report.
- In the course of routine ground monitoring at Trawsfynydd on 15 September some localised patches of radioactive contamination were found within the controlled area fence. Further surveys showed that these patches extended onto gravel on the roadway outside the controlled area. The contamination—predominantly caesium-137—was found to be firmly fixed to the road surface. The area was barriered off and the contaminated material was excavated, packed in sealed bags and sent for disposal at BNFL's Drigg site. An investigation was in progress to determine how this area of the site had come to be contaminated.
- A fitter at Sellafield sustained a wound to the palm of his hand, which was contaminated by radioactivity, on 17 September. The injury occurred while the man was carrying out maintenance on an item within a glove box in the plutonium fuel fabrication plant.

Radioactive material was removed from the site of the wound and medical therapy was administered to the man. He was withdrawn from radiation work pending the results of further bioanalytical measurements. The circumstances of the incident were being investigated.

- A routine monitoring check on an operator at Sellafield on 21 September indicated that he might have received an intake of plutonium. The man had been engaged in plutonium-contaminated waste bagging operations in a laboratory, and had been wearing protective equipment. No other personnel were involved. Medical therapy was administered and the man was withdrawn from radiation work pending the results of further bioanalytical measurement. These revealed that no significant intake had in fact been received and the operator later returned to normal duties.

Copies of the full statement may be obtained from the Public Enquiry Point, Health and Safety Executive, Baynards House, 1 Chepstow Place, London W2 4TF; tel. 01-229 3456. (Stamped addressed envelope please). □

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IN PARLIAMENT

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Spare capacity

26 November 1981

Mr Cryer asked the Secretary of State for Energy what was the current excess of capacity of generating plant in the UK; which stations and with what capacity had been closed in 1981 and were planned to close in 1982; and how many new power stations would generate electricity during 1982 and of which type, nuclear or coal.

Mr Mellor, Parliamentary Under-Secretary of State: I am advised by the CEGB that approximately 4 200 MW of its plant is expected to be surplus to operating requirements during the 1981-82 winter period and is not being kept at full operational readiness; this includes some 3 100 MW of plant proposed for decommissioning in October 1982. I am asking the chairman of the CEGB to write to Mr Cryer about the closure of power stations and new power stations coming into operation.

Project Destiny

26 November 1981

Mr Michael Brown asked the Secretary of State for Defence to make a statement about Project Destiny for the production of highly enriched uranium.

Mr Pattie: Pending the outcome of a programme review, the Ministry of Defence has required British Nuclear Fuels Ltd to slow down work on the Destiny project, for the construction and operation of a centrifuge uranium enrichment plant for the production of fuel for nuclear submarines to the minimum consistent with preserving the option to take the project to completion. This review, which is expected to be completed shortly, is seeking the most cost-effective route for satisfying the requirement for naval nuclear propulsion fuel.

Nuclear-free zones

26 November 1981

Mr Cryer asked the Secretary of State for Transport if he would introduce legislation to prevent the movement of nuclear materials through areas which had been declared nuclear-free zones by local authorities.

Mr Kenneth Clarke: No. The present arrangements are fully adequate for the needs of public safety. The phrase 'nuclear-free zone' appears to have no legal meaning or practical effect, and the declarations by local authorities are political statements rather than effective decisions under their powers.

Dungeness A

27 November 1981

Mr T.H.H. Skeet asked the Secretary of State for Energy to make a statement on the return to power of the Dungeness A nuclear power station.

Mr Nigel Lawson: I am advised by the Nuclear Installations Inspectorate (NII) that it has given formal approval for the resumption of electricity generation from reactor 2 at Dungeness A nuclear power station. This reactor has been shut down since January 1980 following the discovery of weld defects in the bellows units associated with coolant gas ducts at the station as previously reported to the House [17 January 1980, ATOM **281**, p. 83].

The CEGB has carried out a comprehensive programme of inspection and testing for all the gas circuits on reactor 2 and has completed any necessary repairs. They have demonstrated to the NII that the strength of the affected units provides adequate safety margins and that there will be no significant deterioration during operation. The NII is satisfied that the reactor can now be safely returned to power. Reactor 1 continues to be shut down for similar remedial work. Its return to power will also be subject to approval by the NII.

Fire certificates

30 November 1981

Dr John Cunningham asked the Secretary of State for Employment whether he was satisfied with the Health and Safety Executive's fulfilment of statutory duty under the Special Premises Regulations 1976 with respect to the current expansion of British Nuclear Fuels Ltd's operations at Windscale.

Mr Waddington: Applications by British Nuclear Fuels Ltd for fire certificates under the Special Premises Regulations 1976 to cover plants now under construction at Sellafield (formerly Windscale) are being considered with a view to their inclusion on the Sellafield site certificate after the plants have been completed. I am satisfied that the Health and Safety Executive's duties at Sellafield under the regulations are being properly carried out.

Building regulations

30 November 1981

Dr Cunningham asked the Secretary of State for the Environment what discussions his department had had with Copeland borough council about the proposal in Statutory Instrument No. 1338, the Building (Second Amendment) Regulations 1981, to remove all industrial buildings on the BNFL Windscale site from local authority control under the building regulations.

Sir George Young: The second amendment to the building regulations exempts operational buildings erected on any site which is licensed under the Nuclear Installations Act 1965. Windscale is part of such a site. The amendment was made after consultation with the building regulations advisory committee and other interested bodies including the local authority associations.

● Dr Cunningham also asked how many buildings on the Windscale site had been constructed since 1976; how many had been designed to handle nuclear material; and whether all buildings had been subject to building regulations control.

Sir George Young: My department does not have the information available in the form requested but we believe that since 1976 BNFL has made 145 applications for building regulation approval in respect of its Windscale site; 47 of these have related to contractors' buildings and 23 to buildings designed to handle nuclear material. The building regulations make no distinction between buildings designed to handle nuclear material and other buildings.

Fallout

2 December 1981

Mr Skinner asked the Secretary of State for Defence what was the estimated period of time that areas affected by fallout from a nuclear attack on a nuclear power station would be uninhabitable.

Mr Blaker: The length of time during which dangerously high levels of radiation would be present in the vicinity of a nuclear power station which had been attacked with a nuclear weapon would depend upon a number of factors, including the yield of the weapon and the degree of damage caused to the installation.

Plutonium sales

3 December 1981

Mr Rooker asked the Secretary of State for Energy whether his approval was required before the CEGB could sell plutonium to the United States of America.

Mr John Moore: Department of Trade approval is required for the export of plutonium or any other nuclear material. In addition, approval for any plutonium export is required from the Secretary of State for Energy under Section 2(i) of the Nuclear Installations Act 1965, as amended. I also refer Mr Rooker to the answer given to Mr Mudd on 19 October [ATOM **302**, December 1981, p. 325].

Coal equivalence

8 December 1981

Mr Skeet asked the Secretary of State for Energy what was the equivalence in useful fuel in terms of coal of 20 000 tonnes of depleted uranium and 12 tonnes of plutonium used in fast reactors.

Mr Moore: 20 000 tonnes of depleted uranium will, if fissioned in a fast reactor, produce the same amount of electricity as would be produced by burning 40 000 million tonnes of coal. I refer Mr Skeet to the answer given to him on 3 March 1980 for information on the significance of UK plutonium stock [ATOM **283**, May 1980, p. 150].

Waste disposal

8 December 1981

Mr Foulkes asked the Secretary of State for Scotland if he would uphold the decision by Kyle and Carrick district council to refuse permission for test boring at Mullwharchar.

Mr Younger: I am still considering this matter.

● Mr Foulkes also asked to what extent the factor which determined whether deeply buried radioactive waste would be carried back to the environment was the hydraulic gradient of the rock the waste was buried in; whether this was dependent on local topography as well as the particular type of rock; and whether the proposed boring at Mullwharchar, near Loch Doon, would be gathering information on the suitability of granite in general or the suitability of local Mullwharchar granite for the disposal of nuclear waste.

Mr Younger: The hydraulic gradient is one of a number of factors which would determine the rate of movement of constituents from deep buried radioactive waste back to the environment. It is influenced by local topography and by the nature of the particular type of rock but not exclusively controlled by them. The proposed boreholes at Mullwharchar would gather information on the movement of ground water; the results would describe water movement in the area of investigation and aid the interpretation of water movement in crystalline rocks generally.

The proposal is part of a large international study, and carries with it no proposal for disposal of nuclear waste at Mullwharchar or anywhere else.

Sites

8 December 1981

Mr Foulkes asked the Secretary of State for Scotland which sites the South of Scotland Electricity Board and the North of Scotland Hydro-Electric Board had surveyed for the possible development of power stations and which of these sites had proved suitable for the development of a nuclear power station.

Mr Alexander Fletcher: The advance identification of suitable sites in Scotland for future power stations is a matter for the Scottish electricity boards and I am asking the chairmen to write to Mr Foulkes.

● Mr Foulkes also asked what discussions had taken place between the Scottish Office and the SSEB in respect of the acquisition of Hunterston.

Mr Fletcher: The SSEB already owns a substantial area of land on the Hunterston peninsula. I am aware of the board's interest in the acquisition of further land at Hunterston although there have been no detailed discussions between my Department and the Board.

Waste disposal

10 December 1981

Mr Hooley asked the Secretary of State for the Environment if, in the light of the statement by the chairman of the UKAEA, Dr Walter Marshall, that high level radioactive waste should not be buried but should remain accessible for 100 years, he would now direct the Authority to cease all exploratory drilling operations for waste burial.

Mr Giles Shaw: This research programme, which is undertaken on behalf of the environment departments, is kept continuously under review in the light of additional knowledge and advice.

Waste incineration

10 December 1981

Mr Stoddart asked the Secretary of State for the Environment (1) what procedures were in operation to monitor radioactive emissions from the Barnfield Road Depot, Swindon, arising from the burning of radioactive wastes at the depot; (2) what consultations took place before authorisation was given for the burning of radioactive wastes at the depot, and who were consulted; (3) what authorisations he had given for the disposal of radioactive wastes at Wiltshire County Council's refuse disposal unit at Barnfield Road, Swindon.

Mr Giles Shaw: The disposal by burning of low-level radioactive waste at the refuse incineration plant, Barnfield Road, Swindon, by the Wiltshire County Council is authorised under the Radioactive Substances Act 1960. The authorisation is subject to a condition limiting the activity level of the amounts burnt on the premises in any one day. Monitoring is carried out periodically by the Departments radiochemical inspectorate and the Department is satisfied with the position. Before the authorisation was granted the county council was formally consulted and accepted the proposed limitations and conditions. No other body was consulted although a copy of the authorisation was sent subsequently to Thamesdown Borough Council. Roussel Laboratories Ltd is the only undertaking in the county authorised to dispose of radioactive waste to the incinerator.

● Mr Stoddart also asked the Secretary of State if he would list the sites in Wiltshire where authorisation had been given for the disposal of radioactive wastes.

Mr Shaw: The only waste disposal site in Wiltshire authorised for the disposal of radioactive waste is Wiltshire County Council's refuse incineration plant at Barnfield Road, Swindon. There are, of course, other kinds of premises in the county, such as certain industrial sites and hospitals, authorised for radioactive waste disposal. Waste disposed of at these sites are of such low activity that no special measures are required to effect their disposal.

Uranium supply

14 December 1981

Mr Peter Hardy asked the Secretary of State for Energy from which countries the UKAEA and the CEGB received supplies of uranium or enriched uranium; and which countries were the original source of this fuel.

Mr Moore: Uranium supplied to the CEGB comes from Canada and Namibia. No supplies are currently being obtained for R&D purposes by the UK Atomic Energy Authority. Enrichment of uranium owned by the Authority and the CEGB is undertaken by URENCO. The CEGB also has a contract with the Soviet Union for a small proportion of its total contracted supplies of enrichment.

The Windscale incident

15 December 1981

Dr John Cunningham asked the Secretary of State for Energy when he was informed about the incident that occurred at Windscale on 4 October.

Mr Moore [pursuant to his reply of 19 October, ATOM **302**, p. 324]: I have now received the Nuclear Installations Inspectorate's report on the results of their investigations into the circumstances of the release of radioactive iodine from the Sellafield site of BNFL on 4 October 1981. A copy of the full text of the report has been placed in the Library of the House. I informed the House of this incident in the reply given to Dr Cunningham on 19 October.

It has now been estimated that the total iodine-131 released to the atmosphere between 4 and 23 October, when the levels of iodine in milk had declined to normal, was about 8 curies. This, and calculations based on measurements of iodine-131 in milk, confirms the original estimates that the maximum radiation dose which could have been received by a member of the public was a small percentage of the annual limits recommended by the International Commission on Radiological Protection. The actual doses received are likely to have been very much less. I can therefore confirm that this incident caused no significant hazard to public health.

Investigations by both BNFL and CEGB have established that the cause of the release was the processing of six irradiated fuel rods only 27 days after they had been discharged from a reactor at the CEGB's Oldbury nuclear power station. Such fuel is not expected to arrive at the Sellafield fuel storage ponds if it has had less than a 90-day cooling period since being discharged from a nuclear reactor. This period allows radioactive iodine to decay to an acceptably low level. On 7 September seven fuel elements were taken in error from a fuel skip at Oldbury containing newly-discharged fuel and sent in two skips to Sellafield with other fuel identified as adequately cooled after removal from the reactor. The documentation of the two Oldbury skips showed no record of the seven 'short-cooled' fuel rods.

At Sellafield, BNFL relies on the accuracy of the documentation and the fuel from one of the skips, containing six short-cooled rods, was sent for reprocessing in the normal way, but following the detection of abnormal levels of iodine the seventh short-cooled rod was identified in the second skip and retrieved. Before the first stage of processing at Sellafield, fuel rods pass through an installed monitoring device designed as an additional precaution to detect short-cooled fuel. Subsequent checks on this device, which is still in the development stage, showed that although it appeared to be in working order at the time of the incident it was not correctly positioned, and therefore allowed the short-cooled fuel to pass undetected.

The incident revealed shortcomings in the measures adopted by both CEGB and BNFL to ensure that unacceptable releases of radioactivity do not occur in the course of reprocessing. The CEGB have formulated a number of proposals, which the NII endorse, for improving the control of operations at the power stations and which are to be applied, where necessary, at all commercial nuclear power stations. The main purpose of these proposals is to simplify where possible the procedures and instructions for all work in station cooling ponds and to strengthen the existing arrangements for ensuring its effective supervision. In addition the CEGB have proposed the development of further independent technical safeguards to assist with the management of irradiated fuel in cooling ponds, including a monitoring device for recently-discharged fuel for use at power stations.

Immediately following the incident BNFL placed an embargo on the processing of any fuel which could not be proved to be adequately cooled, either by having originated from a reactor which had not been in operation during the previous 100 days, or by having been in the Sellafield ponds for at least 60 days, or by independent gamma spectroscopy for each fuel rod. These checks are additional to the installed monitoring device at Sellafield, which as a result of the incident is now subjected to an increased frequency of testing and functional checks. Whilst these measures are essentially interim arrangements the NII report emphasises that BNFL must continue to store for an additional 60 days any irradiated fuel delivered for processing, irrespective of the evidence of documentary records, until improved methods have been installed for measuring the cooling period of fuel after discharge from the reactor. BNFL will also be required to complete the development of monitoring equipment and to install the optimised system at Sellafield as soon as practicable.

The NII report draws attention to their view that BNFL should have informed the NII, the Radiochemical Inspectorate and the Ministry of Agriculture, Fisheries and Food of the incident before deciding to restart the plant. That is an important finding, and will be taken into account in the review of the procedures for reporting incidents to which I referred in my earlier reply. I fully recognise the concern and anxiety which incidents of this kind cause to the local community, however insignificant they may be in radiological terms. I intend to report further to the House on this matter in due course.

Research options

16 December 1981

Mr Michael Spicer asked the Secretary of State for the Environment whether he had reviewed the research programme into the long-term options for disposing of high-level radioactive waste.

Mr Tom King: The Government has been reviewing the research programme and this review has highlighted the fact that, the longer such waste is stored, the more safely it could be eventually buried, because there would then be less heat to dissipate. For this reason, the Radioactive Waste Management Advisory Committee recommended in their Second Report published earlier this year [ATOM **298**, 203-205] that serious consideration should be given to the desirability of storing high-level waste at the surface in solid form for a period of 50 years and possibly much longer. At the end of that period a decision would be needed whether to continue to store it, or to bury it deep underground, or to use one of the other methods (emplacement on or under the ocean bed) currently under investigation.

The Government have now reviewed the geological element in the research programme for high-level waste in the light of that advice and the conclusions already reached about general feasibility.

The Government has been keeping under review the options for high-level waste, and in particular has been reviewing the progress in other countries as well. The considerable level of research work already completed relates in particular to the factors involved in the emplacement of high-level waste deep underground. The Government's objective has been to establish in principle the feasibility of that potential method of disposal, and now believes that in the light of its review of progress of work overseas that this is now established in principle, and nothing has emerged to indicate that it would be unacceptable.

They have decided that this part of the programme should now be reorientated to confirming the applicability to the UK of the findings from research in other countries. For the time being this will be done by means of desk studies, laboratory work, and the use of data already available. Exploratory drilling will not be needed for this purpose. The Government will look to the Radioactive Waste Management Advisory Committee for advice on the interpretation and implications of work carried out in other countries, as well as on other aspects.

Appropriate provision will be made for the surface storage of vitrified waste. In view of the lengthened timescale and the plans to construct disposal facilities in other countries it is not now intended to construct a demonstration facility for underground disposal in the UK. Instead the UK will follow closely studies involving underground facilities in Sweden, Canada and the USA for granite, in Belgium for clay, and in the USA and Germany for salt.

The reorientation of the research programme does not mean that further geological fieldwork would not be useful, and indeed possibly necessary for decisions that may have to be taken at some future date or if any unexpected difficulty became apparent over storage, but it does not have any present priority. The immediate effect of this decision is that the appeals for planning permission for drilling in the Cheviots will be dismissed, and the other pending appeals and planning applications will be withdrawn.

It will now be possible to concentrate the full priority on the continuing research and implementation in ensuring the safe and acceptable storage of wastes. At the same time priority will be given to making progress towards the early disposal of those wastes with a lower level of radioactivity for which there is no technical advantage in delaying disposal. Research will also continue into the feasibility of the ocean disposal options for high-level waste, which have not yet been established. A White Paper will be published in due course to set out in more detail the current priorities as we see them.

Scottish drilling

16 December 1981

Sir Hector Monro asked the Secretary of State for Scotland to announce his decision on the Loch Doon (Mullwharchar) planning appeal.

Mr. Younger: In the light of the reorientation of the geological research programme for the heat generating wastes referred to in the reply given today by the Minister for Local Government and Environmental Services (Mr. King) and the decision that exploratory drilling will not be needed for this purpose for the time being, I am dismissing the appeal and refusing planning permission. My decision will be issued shortly.

Processed plutonium

17 December 1981

Mr Cook asked the Secretary of State for Energy what was the total amount of plutonium which had been processed in the UK from 1956 to the latest convenient year.

Mr Mellor: As detailed in the replies given to Mr Cook on 6 April and 14 May 1981, approximately 21 tonnes of plutonium have been separated in the UK for civil purposes as a result of reprocessing irradiated fuel. It would not be in the national interest to disclose total plutonium throughput since 1956.

Radiation monitoring

17 December 1981

Mr Gordon Wilson asked the Secretary of State for Energy what facilities and instrumentation were in use to provide regular measurements of external radiation dose-rate, cumulative external radiation dose, and radioiodine concentrations in the air in the vicinity of nuclear facilities.

Mr Mellor: Each operator is required under conditions attached to the nuclear site licence to make suitable and sufficient measurements of (a) ionising radiation, (b) surface contamination, (c) airborne contamination, so far as is necessary to ensure compliance with site licence conditions. In addition, specific requirements for monitoring the environment around nuclear facilities are imposed as conditions of the authorisations of radioactive discharge. Monitoring surveys are regularly carried out by mobile monitoring units stationed at each site. Radioiodine concentrations are regularly monitored through milk sampling.

Emergency precautions

17 December 1981

Mr Donald Stewart asked the Secretary of State for Energy what plans existed for the implementation of (a) sheltering and (b) evacuation of the public in the event of a radiation accident at a nuclear power facility.

Mr Mellor: Each nuclear power station has, as a condition of the nuclear site licence granted by the Health and Safety Executive, a site emergency plan. This plan includes provision for advice to be given to the police on measures to protect the public in the event of an emergency at the site. Such advice could be to take shelter or to evacuate depending on the circumstances of the accident and the prevailing weather conditions.

- Mr Stewart also asked what methods of personal protection would be dispensed for public use in the event of a radiation accident at a nuclear power facility.

Mr Mellor: If as a result of an accident a release of radioactivity was considered likely to affect the public in the vicinity of the site, potassium iodate tablets would be issued by the police on the advice of the operator to the public in the affected area.

- Mr Stewart also asked if residents who live in the vicinity of nuclear facilities were informed periodically of the basis of the emergency response plan which would be implemented and emergency instructions which would be given by the authorities in the event of a radiation accident, and by what means they were kept informed.

Mr Mellor: Information on emergency arrangements at nuclear sites is available to the public through the local liason committees. These committees are organised by the operators, meet regularly, and include a wide representation of local interests, such as district councillors, parish councillors, and farmers unions. Copies of site emergency plans are also available to the public at local libraries.

Instrumentation

17 December 1981

Mr Gordon Wilson asked the Secretary of State for Energy which nuclear facilities were equipped with instrumentation to provide on-site measurements of (a) precipitation, (b) temperature gradients enabling prediction of atmosphere stability class, (c) inversion base height and (d) upper air movements.

Mr Mellor: In the event of an emergency at a nuclear site there are standing arrangements under which the local meteorological office provide to the operator at short notice detailed weather information for his area. Such information would give all the essential data required by the operator to make his assessment of the path and consequences of any release of activity.

Siting evaluations

17 December 1981

Mr Gordon Wilson asked the Secretary of State for Energy what factors his Department took into account when evaluating the suitability of sites for nuclear power facilities.

Mr Mellor: It is for the CEGB in the first instance to investigate and evaluate sites in England and Wales which may be suitable for a nuclear power station. However, before it can construct such a station on a selected site it must first obtain my consent together with deemed planning permission. It will also need a nuclear site licence from the Nuclear Installations Inspectorate of the Health and Safety Executive, which will take siting factors into account in arriving at its licencing decision.

Radioprotective prophylaxes

17 December 1981

Mr Donald Stewart asked the Secretary of State for Social Services what stores of radioprotective prophylaxes were kept for public use in the event of a radiation accident at a nuclear power facility; which prophylaxes they were; and what instructions, if any, his Department had given to public health authorities about the use of these substances.

Mr Geoffrey Finsberg: Stores of potassium iodate tablets are held locally either at the nuclear sites or police stations, hospitals or other appropriate locations near the site. Local arrangements for holding the tablets and for their issue are set out in emergency plans that each nuclear installation maintains as a condition of the nuclear site licence. These plans are prepared in consultation with local health authorities.

● Mr Stewart also asked whether the Secretary of State was satisfied that there were sufficient medical staff trained in the treatment of radiation exposure and injury to be able to deal with a major accident occurring at a nuclear power facility; and what training programmes in 'radiology induced' illnesses existed to provide medical staff able to administer effective treatment to victims of radiation exposure; and how many staff had been trained to deal with such illnesses occurring on a large scale.

Mr Geoffrey Finsberg: Serious radiation exposure and injuries resulting from an accident at a nuclear installation are likely to be restricted to those people working on the site. Operators of installations are required to make contingency arrangements for the treatment of such cases in consultation with the local health authorities. I have no reason to believe that there are difficulties in making such arrangements due to lack of trained staff. Medical training is a matter for the professions concerned.

Safety measures

17 December 1981

Mr Donald Stewart asked the Secretary of State for the Environment if his Department had instructed local authorities to acquire information concerning shielding factors for different types of building that could be designated as shelters in the vicinity of nuclear power facilities.

Mr Giles Shaw: No.

● Mr Gordon Wilson asked the Secretary of State for the Environment what off-site authorities had responsibility for routinely monitoring levels of radiation in the environment surrounding nuclear facilities.

Mr Giles Shaw: The Environment Departments, and in England the Ministry of Agriculture, Fisheries and Food, as the authorising departments under the Radioactive Substances Act 1960, are the off-site authorities which ensure that adequate monitoring of the environment is carried out by the operator of a nuclear site, and also arrange check monitoring. Responsibility for monitoring lies primarily, however, with the site operator.

● Mr Gordon Wilson also asked the Secretary of State for Defence which meteorological forecasting centres were equipped with the necessary instrumentation to facilitate the prediction of plume trajectory and dispersion in the event of a radiation accident at a nuclear power facility.

Mr Wiggin: The Meteorological Office at Bracknell has a computer program for predicting plume trajectory and dispersion in the event of a radiation accident or other release of toxic fumes. Each nuclear facility is equipped with meteorological instrumentation and is linked to the nearest main Meteorological Office. These offices are at Cardiff, London Heathrow airport, Manchester airport, Pitreavie, Prestwick and Upavon. The procedures are practised regularly.

Government borrowing

17 December 1981

Mr Renton asked the Chancellor of the Exchequer what the effect upon Government borrowing would be if the creditors of British Nuclear Fuels Ltd took up any part of the Treasury guarantee of £1·5 billion which the company proposed to borrow from the market.

Mr Brittan: The central Government borrowing requirement would only be affected if and when the guarantee was called, and only to the extent of the payment made by the Government to implement the guarantee.

Plutonium substitution

21 December 1981

Mr Palmer asked the Secretary of State for Energy what conditions he was imposing to prevent British civil plutonium, sold to the United States for peaceful research purposes, being substituted for United States domestic plutonium thus enabling the latter to be cleaned and enriched for military use in contravention of the International Atomic Energy Agency safeguards.

Mr John Moore: I refer Mr Palmer to the answers given to Mr Mudd on 19 October, and to Mr Allaun on 26 October.

RFX

21 December 1981

Mr Dalyell asked the Secretary of State for Energy why he had cancelled the reversed field pinch fusion experiment at Culham.

Mr John Moore: The UKAEA is spending substantial sums on research and development in the nuclear field across a very wide range of important programmes, but funds are not unlimited and the UKAEA is unable to meet the cost of the RFX experiment at Culham within the funds now available for its R&D programme.

"Waste" imports

21 December 1981

Mr Gordon Wilson asked the Secretary of State for Energy how much nuclear waste had been imported from other countries into the UK for reprocessing in each year since 1970; what was the origin, by country, of each year's imports; and for each year, how much of the waste, once reprocessed, was returned to the country of origin.

Mr John Moore: Spent irradiated fuel from foreign nuclear reactors is imported into the UK prior to its reprocessing at BNFL's plant at Sellafield. No radioactive waste separate from irradiated fuel is imported into the UK. Uranium and plutonium are recovered from the fuel and a relatively small volume (in comparison to that of the original fuel) of radioactive waste is separated.

Since 1970 approximately 1 000 tonnes of uranium in the form of irradiated Magnox fuel have been imported from Italy and Japan, and approximately 600 tonnes of uranium in the form of irradiated oxide fuel have been imported from Italy, Japan, the Fed. Rep. of Germany, Switzerland, Canada, Spain, Sweden, the Netherlands and Belgium. All reprocessing contracts concluded by BNFL since 1976 contain an option enabling the company to return this radioactive waste to the customer country.

However, no wastes have yet been returned to these countries because the vitrification plant to convert the highly active liquid wastes into glass blocks has not yet been commissioned. Under the contracts, the wastes may be returned up to 25 years after the spent fuel has been received in this country.