PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

General Discussion

A. D. Evans, J. D. Griffith, B. Saitcevsky, R. Challender, M. Kohler, T. N. Marsham, S. Sawai, K. Q. Bagley, M. F. Troyanov, R. D. Smith and G. Vendryes

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General discussion

A. D. Evans (*BNFL, Risley, U.K.*). I am sceptical about the claim that small reactors (150 MW_e for example) can compete economically with large ones. I have yet to see a convincing demonstration that economics of scale can be beaten.

J. D. Griffith (*DOE, U.S.A.*). Our estimates were made by experienced industrial concerns such as General Electric and Bechtel and in the DOE we have a disciplined estimating system. In my illustrations economies of scale were indicated for both LWRs and coal plants. The same slope applied to modular reactors. The differences lie in cost savings due to safety features, replication and modular, rapid construction (e.g. less than four years) so we feel we can beat economies of scale.

B. Saitcevsky (*Unipede, France*). From a utility viewpoint, I would note that there are important differences affecting cost estimates between European and U.S. conditions. For example, the relative cost of site work is less in Europe and I suspect that the costs for maintenance and operation of small plants have been underestimated.

Turning to Mr Broomfield's paper, I would comment that for Superphénix, we saw our main problem to be overcoming the structural vibrations rather than the barillet leak, even though the latter has cost more. These are also illustrations of the value of constructing and operating full-size plant, allowing true evaluations of practical problems. Finally, I would emphasize the importance of keeping fast reactor fuel cycle costs low. For Superphénix, the utilities have agreed to accept an excess cost for the capital investment, but would be reluctant to pay high costs for the fuel cycle.

R. Challender (*Progressive Engineering Consultants, U.K.*). Could Mr Köhler suggest advantages of the loop type concept to set against pool type reactor advantages, which include a free surface, good maintainability and ability to cope with thermal expansion effects.

M. Köhler (*Interatom, F.R.G.*). The two concepts are, as I said, evenly matched and the final choice depends on the priority given to particular features. For the loop type reactor there are advantages in construction because small components can be shop fabricated and work can proceed in parallel. By contrast, the pool type reactor has a high density of components in the primary vessel. A further advantage for the loop type concept is the potential for eliminating the secondary circuit should very reliable steam generators be developed. However, none of these advantages and disadvantages is decisive and the actual cost of manufacturer's equipment and their capacity is more important.

T. N. Marsham, F.R.S. (*BNFL, Risley, U.K.*). Could Dr Sawai comment on the practicality of ever demonstrating the acceptability of eliminating the secondary circuit even with high-integrity steam generators?

S. Sawai (*Tokyo, Japan*). Plant reliability and manufacturer's capability have improved. Our aim with the development of double-wall steam generators is not to eliminate the secondary

circuit, if this were to be achieved it would be a bonus. Certainly at this stage we are not sure if the safety authorities would ever accept installation of a steam generator in the primary circuit.

K. Q. Bagley (*UKAEA, Risley, U.K.*). Metal fuel has attractive properties, many of which are shared by other advanced fuels such as carbides and nitrides, but the possibility of metal-fuel–clad interaction at temperatures within or just above the normal operating range is a cause for major concern. This uncertainty can only be removed by large-scale irradiation of (U–Pu) alloy fuel pins of realistic design, an undertaking which I understand was scheduled in the Fast Flux Test Facility (FFTF). What impact does the proposal to use the FFTF for the production of ^{238}Pu have on the metal fuel development programme?

All the papers so far have been confined to sodium cooling. Are the alternatives, such as gas cooling, now completely excluded?

J. D. Griffith. We had intended to convert FFTF to metal fuel on economic grounds before the possibility of the ^{238}Pu mission arose. The advantage was that we could fabricate such fuel at INEL Idaho rather than commission the Fuel Manufacture and Evaluation Facility. This would have resulted in a binary, rather than tertiary, alloy fuel being used (three of this type of binary fuel are in FFTF at the moment).

M. F. Troyanov (*Moscow, U.S.S.R.*). I consider that sodium is the only practical coolant for fast reactors. Gas-cooled fast reactor concepts have been extensively studied throughout the world, but no one felt certain about their safety.

M. Köhler. I would add that there is no money left to make such a radical change after some 20 sodium cooled plants have been built.

R. D. Smith (*formerly UKAEA, U.K.*). My comments are on incineration of actinides by recycling through fast reactors. I would like to ask Dr Vendryes which of several possible objectives he considers the most important. A reduction in the stocks of fast reactor fuel can clearly be achieved, but a complex mixture of actinides is produced by repeated recycling, and it is even possible that these might present an increased rather than a decreased biological hazard. The total amount of plutonium present is reduced and its isotopic content altered so as to make it less suitable or useless for weapons thus reducing proliferation concerns. Complete destruction of all the plutonium present is not, however, possible.

G. Vendryes (*CEA, Paris, France*). The aim is to eliminate long-lived α-active elements. The most troublesome nuclides have half-lives in the range 1000–10 000 years, long enough to cause public opinion problems but not long enough to have low specific activity. Examples are ^{239}Pu (24 500 years half-life), ^{240}Pu (6000 years), ^{241}Am (432 years), ^{243}Am (7000 years), ^{245}C (8000 years). In principle it is possible to incinerate these actinides in fast reactors and we need to retain the option to do this in the future to satisfy what may become a public requirement.

K. Q. Bagley. Samples of curium and americium oxide have been irradiated in PFR to determine capture cross sections and yields. Analysis is in progress at Oak Ridge.

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J. D. Griffith. The problems of actinide removal also concern the U.S. We see an argument that it may be more manageable to process irradiated fuel waste in this way rather than accept the risk of long-term storage.

F. J. Barclay (*Energy Consultant, London, U.K.*). The Soviet announcement of concentration of boiling at the fuel pin wire wrap is new. This phenomenon could lead to break-up of the clad due to an uneven temperature distribution, subject to the assumption of failed subassembly instrumentation. Sufficient flow blockage could lead to molten fuel-coolant interaction (MFCI), for which there is no generally accepted theoretical model. Should MFCIs be more extensively investigated, to the point of having a full theoretical model?

M. F. Troyanov. For a long time we have studied heat transfer in subassemblies, including those with distorted geometries. The next problem is to investigate such abnormal circumstances. The role of the wire spacing in influencing boiling is merely an initial idea and we need to develop methods of evaluating boiling phenomena within pin bundles.

A. M. Broomfield (*UKAEA, Risley, U.K.*). I would add that the UKAEA operates the Molten Fuel Test Facility at Winfrith with the aim of studying MFCIs in both water and sodium. Our work to date shows that we do have a well-founded theory and that energy yields are predicted conservatively.

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