REMOVING THE HEAT FROM FAST REACTOR CORES

Whatever the view about the time when fast breeder reactors will reach the commercial and industrial stage, there is a growing and widespread interest in developing their technology. The reactors are called breeders because they can produce more fissile material than they use in their own cores. As part of an Agency programme related to their technology and economics a symposium on Alkali Metal Coolants — Corrosion Studies and System Operating Experience was held in Vienna from 28 November to 2 December.

More than 100 participants attended from 16 IAEA Member States and EURATOM and the 50 papers presented came from nine countries. In an opening address Professor Ivan Zheludev, Deputy Director General for Technical Operations, spoke of the reasons for the interest in fast reactors. Although there were already reactor systems which could produce competitive power in large plants, it was known that they did not use uranium fuel very efficiently. If the world went on building them, all the available low cost uranium reserves would soon be committed and problems would be created for the future. It was therefore recognized that they should develop systems offering a far better utilization of uranium reserves. As a result many countries were placing great emphasis on the development of fast breeder reactors at an early date. Such reactors would ensure very high utilization of nuclear fuels and would eliminate any concern about their availability to support very large nuclear power programmes around the world.

Based on the experience gained with the Dounreay reactor, the United Kingdom had decided to construct a prototype of 250 megawatts energy to be ready in 1971. The Soviet Union, based upon its experience with BR-5, was constructing a dual-purpose fast reactor for electricity production and water desalination of 1000 thermal megawatts output. In the United States the Enrico Permi and the EBR-II fast breeder reactor had been in operation for some time. Until it encountered some problems recently, the Enrico Fermi plant was approaching full power operation. France was developing the Rapsodie project of 20 thermal megawatts to serve as a basis for the planned Phénix fast breeder reactor.

The symposium was part of the Agency's programme of activities related to fast breeder reactor technology and economics. The problems of plutonium technology were reviewed in the proceedings of the Panel on Plutonium Utilization issued in 1965. A review of fast power reactors was published this year, and plans were being made for a symposium on the Use of Plutonium as a

Reactor Fuel in March 1967, in Brussels and another on Physics and Related Safety Problems later on, with additional activities possible for 1968.

The main topics considered during the coolants programme had been selected by a working group of specialists which met in Vienna last March. They included alkali metal corrosion studies in materials such as stainless steel, nickel base alloys, vanadium alloys, refractory metal alloys; and the problems of decarburization of steels and of changes in mechanical and metallurgical properties of structural materials in alkali metal environment. Sessions were also devoted to experience in the design and operation of alkali metal loops and associated experimental devices; on the detection and control of impurities; and on the behaviour of fission products in sodium systems.

The subjects in general were related to the fact that immense amounts of heat have to be transferred from comparatively small cores in fast reactors in order to use it for generating steam to run the turbines. This produces some problems in heat transfer. The excellent properties of alkali metals make them especially suitable as heat removal agents, but they give rise to questions related to corrosion and the additional effects of irradiation and heat. Systems now operating use sodium for cooling, but other metals have been studied in a number of countries.

Of the fifty papers presented, 20 were from the USA, nine from USSR, six from UK, six from France, four from Germany, two from Belgium and one each from Austria, Czechoslovakia and Netherlands.

At the end of the week there was an informal discussion on topics which had been raised. John R. Weeks (USA) who was chairman for the final afternoon, said that since an IAEA meeting on corrosion of reactor materials four years ago, it was evident that many countries had increased their interest. All the countries with experience of fast reactors had gone beyond the first designs, which were highly conservative, and were looking for techniques that would enable them to take advantage of the high temperature and heat transfer capabilities. There was a search for fuel cladding other than stainless steel. On the whole reports from the operating countries had been generally along the same lines, if not entirely in agreement. Mechanism studies had not as a rule kept up with the proposed uses of fast reactors, but the situation was changing and there had been two interesting papers on mechanisms and overall corrosion problems. There had been great interest in impurities and the USSR had made contributions in this respect. Although the carbon situation had been studied, it seemed to him that more work was needed to clarify the exact mechanism of what was going on. They needed much more information on how detrimental was carbon transfer to the mechanical properties of fuel particles. Many questions had come up as to whether one should use a carbon stabilised with refractory metal cladding, and if so what were the rates at which the carbon would transfer. The effects of corrosion in sodium/water reaction were now beginning to be understood and appreciated. Then there was the question of the relative advantages of simple as against complex circuits for sodium. The original simple circuits had given way to others much more complex, but he had also heard

observations that certain systems were too complex and they wanted something more simple in order to understand and get the data needed. The need for monitoring impurities in sodium and the ways in which meters worked had been discussed, particularly as the result of a big difference between the USSR reports of resistivity meters being more responsive to hydrogen than oxygen compared to previous understanding. This threw some shadow on their use as a permanent monitor for oxygen only. It was most desirable to study the information and perhaps vary existing programmes to obtain greater coordination of overal efforts. There clearly had been a need for such a meeting, and for more of them on these and related technologies. Questions of heat transfer, of components and of mechanisms could receive more attention, and the subject of corrosion alone would justify an entire meeting.

W.L. Chase (USA) suggested that the most important problem was the other end of the heat transfer chain, the steam generator, and that it would be worthy of a special meeting. R. Davies (UK) agreed with this and said he would also like to hear more about work in the sodium/water field.

J.P. Lagowski (USA) thought the subject of carbon and hydrogen in a system planned for a twenty or thirty year life ought to be pursued with greater vigour.

M.N. Ivanowski (USSR) was sure that the data obtained during the week would lead to better orientation and increase the representative nature of the work, and he would like to see more of them in different countries. He also recognized the importance of developing fully reliable steam generators. Problems concerned with heat exchange, high temperatures in the flow and in the walls and various thermodynamic instabilities should be examined. He would like specialists in the various fields to meet and talk about their various subjects, and would hope for a conference within a year on the interaction of sodium and water. He hoped there would be full exchange of information on conferences and other meetings planned in various countries to enable the appropriate papers to be prepared.

C. Tyzack (UK) observed that a lot of people were working on measuring corrosion rates of materials at the highest temperature points in circuits, and it might be that these were not too meaningful unless they were related to the level of things like iron or nickel in the circuit. They needed more work on mass balance and the overall transports in steel circuits. They knew that in a large reactor they were going to get thousands of pounds of corrosion products moving around and he did not think they yet had a clear idea of where these were going to finish up, whether it would be in the cold traps or deposited on cooler surfaces. He also put in a plea for more fundamental thermo-dynamic measurements of heats of formation, of sodium metal oxygen compounds, and more work on detailed models of decarburization and carburization. One topic touched on had been corrosion on the steam water side in the heat exchangers, but there seemed to be very little information on corrosion rates at the very high fluxes at which they were going to work.

A warning note was sounded by L.F. Epstein (USA). They must resist pressure to get quick results, because there were no such things as "quick and dirty" experiments with sodium. They must also, in trying to avoid over complication, be careful not to put things together too carelessly.

B.V. Kulpin (USSR) said that to obtain better knowledge of corrosion of constructional materials in a sodium water flow they must first study fully the kinetics of the interaction of these coolants. If they understood corrosion of construction materials they could prevent ill effects on the heat transfer surface of steam generators.

E. Duncombe (UK) spoke of protective instrumentation. Burst cartridge and core blockage detection, gas entrainment and the onset of sodium water reaction, which came up again in heat exchangers, raised difficult problems which he would like to hear discussed more fully. There was also the subject of vibration and noise. Cavitation effects could be a real problem at all parts of the core. For ordinary process measurements they could not expect more than to ensure that a system was working more or less as expected, with more detailed information coming from sampling and analysis. It might be an expensive method, but it worked.

The possibility of gas turbines being competitive with steam was raised by R.E. English (USA) after noting that sodium temperatures as high as 1500°F (800°C) had been discussed. Duncombe recalled commercial claims for economic gas turbine systems and J.H. de Van (USA) remarked that at Oak Ridge potassium vapour turbines looked very good for a topping cycle in any power reactor at these temperatures. Weeks gave mercury as a good medium.

The question of finding competitive materials for sodium reactors was regarded by the Chairman as of highest importance. While it was certainly desirable that such reactors should be commercial, there were strong feelings that it would be essential to develop materials for containing the fluid and indeed for the complete system.

In closing the symposium, D.G. Hurst, Director of the IAEA Division of Nuclear Power and Reactors, recalled a USSR expert's statement recently that it was now not much more difficult to handle many tons of sodium in a reactor system than it was to handle water. Nevertheless there were still many problems to be solved in fast reactor technology and he was sure their meetings had been useful in discussing some of them.