SAFETY, EFFICIENCY AND ECONOMY OF NUCLEAR POWER IN USSR

In USSR, where coal, oil and natural gas are abundant, electricity from nuclear sources has to demonstrate its merits in efficiency, economy and safety to be incorporated in the nation's power system. Safety has been proved from the earliest days and several types of reactor have shown that this form of power is competitive. Much attention is being given to the fast reactor for future power generation.

A comprehensive survey of the history of nuclear power development in USSR was given to members of the Agency Staff on 27 February by Dr. I.D. Morokhov, First Deputy Chairman of the State Committee on the Utilization of Atomic Energy, USSR Council of Ministers, and USSR Member of the Agency's Board of Governors.

Dr. Morokhov said that rather than talk briefly about many kinds of work in his country on the peaceful uses of atomic energy he had decided to choose one main aspect, nuclear power, since everyone had seen how much this had developed.

The possibility of obtaining power first drew their attention, and between 1948 and 1950 two atomic stations were designed, both of small power output. One idea, for using a graphite moderator with helium cooling was not put into operation, preference being given to graphite moderating and water cooling. This reactor provided the source of heat for the first nuclear power station which began operation at Obninsk in 1954 with an electrical output of 5 000 kilowatts. It is still in use today, and had a tremendous conceptual importance for power development, not only in USSR.

From the operation of Obninsk it had been possible to draw the following conclusions:

1. Transformation of nuclear energy to electricity was proved to be practical.

2. Atomic power was sufficiently reliable and flexible in operation and fulfilled the requirements for utilization in an electrical network.

3. It was completely safe both for personnel in the plant as well as the surrounding population.

Dr. I.D. Morokhov

In this way they obtained answers to questions of concept and principle. One more question remained — could nuclear power stations be economically viable? Clearly the answers could not be found by relating from technical experience with the first small station to industrial stations of high power. The answers could come only from building large power stations, and this became the second stage.

A number of reactor concepts had by then been put forward, but all had varying degrees of reliability and costs. Thought was given to the use of sodium for cooling, using a loop to avoid contact with radioactivity, but this would have increased the expense. Going to a single loop would have reduced expenditure but created operating complications because of mildly radioactive steam. Carbon dioxide as a coolant had some advantages but would have called for a bigger core, thus increasing construction work and capital expenditure. There were technical ways of increasing temperature and obtaining superheated steam to increase efficiency; this would have meant using stainless steel, which absorbed neutrons. A better balance was obtained with low absorbent aluminium alloys, but this also had disadvantages. High temperatures could be obtained with zirconium, but it was rather expensive. Parameters improved with the use of heavy water, but measures had to be taken to minimise losses of this expensive product.

PREPARING FOR MASS PRODUCTION

What was the final solution to be? It obviously depended on a great deal of study and research. Reactors using sodium and graphite were tried, but had been stopped because they did not have good prospects, a decision confirmed by similar action in USA. A heavy water reactor with gas cooling was found to be somewhat limited. In both cases there were absences of essential advantages compared with other types. They had to prepare for mass production of power stations and had to bear in mind the concept of the fast reactor, in connection with which it was expected that they would cut back on attention to building other types.

USSR had during this phase planned and built large power stations. Among them was the so-called Siberian type at Troitsk, using uranium with light water cooling and graphite as the moderator. The output here exceeded 600 000 kilowatts and it had been operational since 1958. At Beloyarsk a boiling water reactor produced about 100 000 kilowatts, a characteristic feature being the first direct nuclear super-heating of steam. Here it was possible to get steam direct from the reactor to the turbines at a temperature of 500°C and pressures of 90 atmospheres. Such a performance meant that generating equipment mass-produced for conventional power stations could be used. It was also very interesting to find that this system was very reliable from the point of view of radiation, to the extent that it would be possible to locate it in large towns with heavily populated areas. At the end of last year a second block was started up with superheating. This gave 200 000 kilowatts, twice the power of the first, which has now been operating since 1963. In the new station design had been simplified, going from a two-contour to a one-contour scheme, thus reducing costs.

For uranium-graphite reactors development work was going on with two new types, one of them to produce a million kilowatts. This would use saturated steam at a pressure of 70 atmospheres. Super-heating would not be employed, but efficiency compensation came from more effective use of fuel though the use of low-absorbent zirconium alloy. The cost of electric power should be cheaper than from present coal-fired stations.

Work was going on with uranium-graphite reactors to achieve super-critical parameters of steam. The steam with these parameters has higher thermo-physical properties which increase the energy intensity of the fuel and therefore considerably increase the efficiency of the station.

Projects for power stations with outputs of two to four million kilowatts (2 000 — 4 000 megawatts) had been worked out to show that they were going to be competitive with ordinary thermal power stations even in places where fuel was mined. They required a great deal of experimental and research work. Reactors of this type, as well as those using water-water systems were the subject purely of a power approach and were subordinate to the aim of achieving maximum burn-up both of the uranium and of the plutonium formed during operation.

Another approach was the water-water reactor, with a vessel computed for a pressure of 100 or more atmospheres. At the end of 1963, on the River Don, there was put into operation a pressurized water reactor power station with an output of 210 megawatts in a single block. Situated at Novo Voronezh, it was a high power prototype, the aim being to build more like it later on. It had been very reliable in operation. Output has been very consistent — 1 018 000 000 kilowatt hours in 1965, 1 250 000 000 in 1966 and 719 000 000 in the first half of 1967. During this operational time it became clear that the capacity of the station could be raised, without any constructional changes, to 240 megawatts. Construction of a second station, with an output of 365 megawatts electrical was begun very soon afterwards.

"This type of reactor", said the speaker "has been fully acknowledged as the basic source of heat for nuclear power stations for the period 1975-1977".

Construction had started on the third and fourth blocks of the Novo Voronezh type, and it was also being exported to other countries.

As a final comment on water reactors, Dr. Morokhov mentioned that in 1965 they started up a boiling water reactor with an output of 50 megawatts electrical. It was of experimental significance, to be used in the study of boiling under a wide range of pressures. It envisaged direct use of steam in the turbines, which would be an advance in simplification and cheaper power production.

THE SIGNIFICANCE OF FAST REACTORS

It was, however, the study of the fast reactor that the speaker regarded as the main direction of the development of atomic power, because of its tremendous and important properties. In the process of fission of uranium-238 with fast neutrons it was possible to obtain fifteen to twenty per cent more neutrons than in thermal reactors using the uranium fuel. The production coefficient could be 1.4 to 1.7, which meant that an additional 0.4 or 0.7 kg of plutonium could be created for every kilogram used. This was the principal feature and great advantage, that nuclear fuel could be produced in greater quantities than it was burned.

The complexity of the problems required a whole series of experimental reactors. In 1955 the reactor BR-1 started operating at an energy of several tons of k watts. In 1956 came BR-2 at 200 kilowatts. BR-5 followed with a power of 5000 kilowatts, using plutonium oxide fuel and sodium as a coolant. This series of experimental reactors made it possible to carry out a great deal of research. Much information was obtained from BR-5. It was the first to give experience with plutonium, it revealed much of the technology of working with sodium and it achieved a fuel burn-up of 60 000 megawatts days per tonne. Then they started building large power stations with these reactors.

"The resolution of technical problems through studying big power stations with fast reactors, and experience in radiochemical processing of fuel elements makes it possible to consider that the construction of power stations of this type will be implemented during the beginning of the seventies" forecast Dr. Morokhov.

He gave some details of the power station with a fast reactor now being built at Shevchenko to provide 150 megawatts of power in addition to giving steam to a plant for purifying water from the Caspian Sea at the rate of 150 000 tonnes every 24 hours. It thus offered the opportunity both of studying the properties of a reactor of this type as well as the technology of desalting sea water on a large scale.

If design characteristics such as increased core intensity, sodium temperature of 600°C and fuel burn-up of 100 000 megawatt days per tonne could be achieved, the economic characteristics of fast reactors would be quite comparable with conventional thermal plants. Fast reactors could then become the prototype of a series of plants. An experimental reactor, BOR-60, was being built for studies to these ends. It would be a system with great experimental facilities for testing various kinds of fuel element. Many other studies were being made and he drew attention to plans for such reactor plants with capacities of a million kilowatts of electrical energy. A fuel mixture of plutonium and uranium should enable a reproduction coefficient of 1.75 to be obtained, as well as steam temperatures of 580°C, a pressure of 240 atmospheres and fuel burn-up of the order of 100 000 to 150 000 megawatt days per tonne.

USSR occupied a very special position. It had very large reserves of natural fuel and therefore had no problem of lack of such fuels. At the same time distribution of natural fuels was unequal, and this made the production of power in certain areas more expensive. The economic efficiency of nuclear plants would be the principal factor affecting decisions to build them, i.e. the power cost and the unit cost of construction in roubles per kilowatt of installed capacity. One of the main factors in reducing the cost per kilowatt was the construction of larger unit blocks, and was much more important in nuclear than in conventional stations.

After discussing the influence on costs of various factors in both thermal and fast reactors, Dr. Morokhov mentioned that they were now planning to reach a fuel burn-up of 30 000 megawatt days per tonne in thermal nuclear reactors and 100 000 for fast reactors. The main ways to do this were to raise the strength of composition of the materials, to employ ceramic fuels and more resistant construction materials. It was also clear that the higher the efficiency the greater would be the power produced and thus the less the fuel component would figure in the overall costs. According to their calculations, the cost of electricity produced could reach 40 kopeks per kilowatt hour, a figure competitive with conventional power which would enable them to use nuclear power very largely in the national economy of the USSR.

GIANT MACHINE TO STUDY MINUTE PARTICLES

"A great human enterprise that stretches the mind in its conception" was one of the phrases used by Ambassador Henry D. Smyth, US Representative to the Agency and US Member of the Board of Governors, in describing to members of the staff a new "atom smashing" machine to be built by the US National Accelerator Laboratory. Its purpose is to enlarge knowledge of the fundamental laws governing the universe.

Dr. Smyth, who visited the Agency on 28 February to talk about the project, said that he was going to describe a very large machine to study very small objects, a statement more than justified by his supporting statistics. He confessed that he found it very difficult to avoid the purple prose of popular science writers in considering the ways in which atomic particle would be made to travel hundreds of thousand of kilometers in a few seconds or of the effort of synchronising the pulses of nearly a thousand electro-magnets in the operation.