Nuclear Power Programmes and the Nuclear Fuel Cycle

NUCLEAR POWER PROGRAMMES

The assumption that nuclear fission power would play an important role as an energy source to the end of and beyond this century was certainly included in the background for the programme of the conference. While recent events both on an international level and in some of the participating countries may have caused some to doubt the validity of this assumption, the conference served to reaffirm it and to give a clear definition of the important share of the total energy requirements that must be provided by nuclear power in order to help to stave off energy shortages. The need for nuclear power was made evident in reports from both the industrialized and the developing countries.

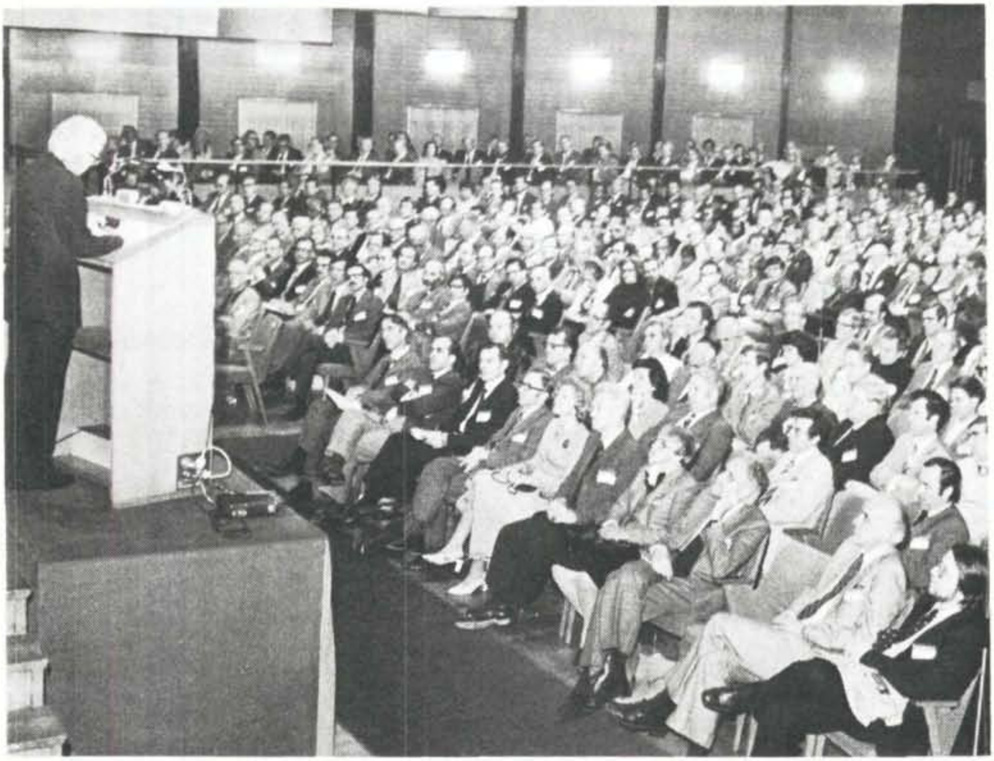
The reduced forecasts for nuclear power and cutbacks in nuclear power programmes must be seen primarily as the result of delays of increases in the demand for energy due to the economic stagnation since 1974. There also have been financing, licensing and public acceptance problems.

Reports from international organizations (Organization for Economic Co-operation and Development, International Energy Agency, Nuclear Energy Agency and Council for Mutual Economic Assistance) stressed the need for viable nuclear power programmes, and national reports from Canada, the Federal Republic of Germany, France, Italy, Japan, the United Kingdom, USSR und USA confirmed the commitment of these countries to strong nuclear power programmes.

It was also of particular interest that several developing countries, among them Brazil, Egypt, India, Iran, Pakistan and Philippines, outlined firm nuclear power programmes and that Brazil stated its intention to achieve independence in the construction of nuclear reactors and in the nuclear fuel cycle within about 15 years.

In most countries, the light-water reactors are likely to provide the basis for nuclear power programmes. The pressurized-water reactors and boiling-water reactors will dominate the market, but they have a technical limitation to their size – the largest units possible are in the 1000 to 1300 MWe range. The USSR is designing a much larger reactor unit: a 2400 MWe graphite-moderated, water-cooled, channel-type reactor. By using modular design and construction, this type of reactor does not have the same inherent size limitation as the light-water reactors.

Canadian reports reviewed experience with the heavy-water reactors of the CANDU type. Four developing countries are also operating or building CANDU type reactors.



The conference's technical sessions and roundtable discussions were held in the Kongresshaus. Shown here is the Europa Saal in the Kongresshaus.

The USA strongly reaffirmed a nuclear programme based on light-water reactors, but its new policy is to delay indefinitely the reprocessing of nuclear fuel and the development of commercial fast-breeder reactors, and to carefully evaluate possible alternative reactor types and fuel cycles. Countries without major indigenous uranium resources but with large nuclear power programmes generally stated national objectives of closing the light-water reactor fuel cycle by reprocessing spent fuel, and five industrialized countries were planning commercial introduction of the liquid-metal-cooled, fast-breeder during the 1990's.

Experience from the three operating fast-breeder demonstration plants (in the 250–350 MWe size range) in USSR, France and UK indicated that the technology has reached a state of maturity and no new major technological problems have appeared. The safety of these fast-breeder reactors was considered to be as good as that of the present generation of thermal reactors. Plans for further demonstration fast-breeder plants are going ahead in the Federal Republic of Germany and Japan. Construction of the first commercial-size plant has started in France, with participation from the Federal Republic of Germany and Italy. The plant is due to be in operation in 1982. Similar plants in the size range 1250–1600 MWe are firmly planned by the UK and USSR.

There was general agreement about the need to ultimately reprocess the spent fuel from the present light-water reactors, although the time scales for reprocessing varied widely and

Ulf Lantzke of the International Energy Agency
and the OECD
reviewed world energy supply and demand.

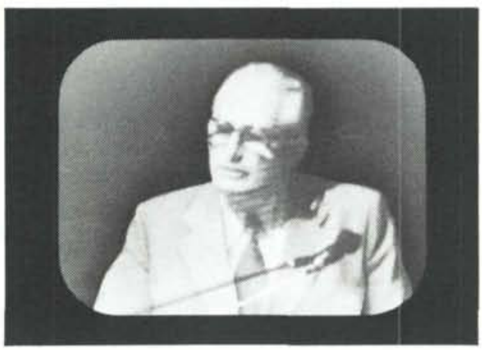
A. Panasenkov of the Council for Mutual Economic Assistance (CMEA), Moscow, described nuclear co-operation among CMEA member countries.

seemingly were dependent on indigenous fuel supplies, and particularly on nuclear fuel resources. In this context it was interesting to note a Canadian report that announced an orderly 20 to 25 year programme to develop and demonstrate the technology of recycling fissile material, including plutonium and thorium, in CANDU reactors.

While plans for light-water reactors and liquid-metal, fast-breeder-reactor programmes were in general firm and optimistic, it appeared that other reactor types were being given less potential in national programmes. A paper from the Federal Republic of Germany reported on the present status of high-temperature reactor development, emphasizing the large investment and long time which would be needed to achieve commercial demonstration of this reactor type and its fuel cycle. The USSR maintains a development effort on a gas-cooled fast-breeder reactor, using dissociating N_2O_4 as the coolant. Other types of breeder reactors did not appear to have large potential within a foreseeable future. A possible, somewhat surprising, exception could be the molten-salt breeder reactor, which was regarded with considerable optimism in one report.

W. Häfele of the International
Institute for Applied Systems Analysis (IIASA),
Laxenburg, Austria,
outlined energy options open to mankind beyond the turn of the century.

André Giraud of the Commissariat à l'Energie Atomique (France) announced the development of a chemical exchange process for uranium enrichment that "practically forbids the production of weapon-grade enriched uranium".



THE NUCLEAR FUEL CYCLE

With respect to the nuclear fuel cycle, the conference clearly demonstrated that there are three necessary conditions for it to be a viable industry. Firstly, a safe and economically sound technology must be available for supply of materials and services for the entire fuel cycle. Secondly, the technology must be in industrial use with sufficient capacity to provide adequate supply for the nuclear power industries' demand. Thirdly, there must be a national as well as a large measure of international agreement on the policies for industrial application of the available technologies.

These three prerequisites are interrelated. The incentive for research on new nuclear fuel technologies is much stronger when they are likely to be applied. The industrial investment of money and manpower in a given technology takes place only when the demand for it can be expected with confidence. A market for a technology can develop only if there is sufficient agreement on policy for its application on a national and international level, hence, international co-operation on nuclear policies is necessary.

Technology

There was a consensus at the conference that a sufficient technological base is already available for the fuel cycle for the types of reactors operating today. As for all technologies, changes are continuously being made. However, these are more in the line of improvements in industrial application rather than development of basically new technologies.

The technology of uranium exploration, mining and processing has advanced more rapidly than for other minerals. It has become more sophisticated, more expensive, and consequently more likely to be in the domain of large organizations. The technology for low-grade uranium ores is being developed in anticipation of the time when uranium prices will make it economic to mine them.

Uranium isotope enrichment is an area where new basic technologies may be of significance. The gaseous diffusion process is now gradually being supplemented by the gaseous ultra-centrifugation process. Additional technologies are under development, such as aerodynamic methods in the Federal Republic of Germany and in South Africa, and the new chemical exchange enrichment process announced during the conference by France. The latter was stated to be economical for production of reactor grade enriched uranium even in plants with relatively small capacities. It was also stated that the chemical exchange process was unable to produce highly enriched uranium with the potential for use in nuclear explosives. Laser isotope separation is at an experimental stage in several countries. The possibility that this process could achieve a very high separation in one step with low energy consumption has neither been confirmed nor disproved.

Fuel fabrication has achieved a high technological level, and failure rates for light-water reactor and heavy-water reactor fuel has been reduced to about 0.03%. Efforts at further reduction of the failure rate are underway and in this there is close co-operation between fuel suppliers and utilities.

Reprocessing of metal nuclear fuel is a technology with more than 25 years of experience. Many thousands of tons of fuel have been reprocessed and this experience provides the basis for reprocessing of oxide and mixed oxide high burn-up fuels. The reprocessing technologies for the two types of fuel are similar except that oxide fuel requires a special head-end of the plant, and that it has a higher content of plutonium and fission products. An industrial scale plant for reprocessing of oxide fuel is in operation in France. One plant is in the late stages of construction in the USA, but its operation will depend on policy decisions. Additional plants are being planned in France, the Federal Republic of Germany, India, Japan and the United Kingdom.

The technology for use of plutonium has been demonstrated in light-water reactors as well as in fast-breeder reactors.

Industrial Application

There was a consensus that for some steps of the nuclear fuel cycle the industrial application of the available technologies is inadequate. This is a result of a lack of decisions on fuel policy rather than a lack of available technology. The mere existence of this situation has an adverse impact on other steps of the nuclear fuel cycle, and reduces the contribution that nuclear power can make to the solution of energy problems.

Regarding the front-end of the fuel cycle, it was widely agreed that a reasonable balance of supply and demand could be achieved over the short term. Problems exist as a result of doubts about nuclear fuel cycle policies; there is little doubt about industrial capabilities.

The potential production of uranium by 1985 was estimated by the Uranium Institute and others at about 75,000 MT, sufficient to meet the requirements for uranium. Programmes to estimate uranium ore potential through detailed examination of geologic provinces, based on recognized criteria favourable for uranium occurrence, are now underway in Canada and the USA. Little has been done elsewhere, but the Nuclear Energy Agency of the Organization for European Co-operation and Development and the International Atomic Energy Agency have recently jointly initiated an International Uranium Resources Evaluation Project to estimate the world's uranium ore potential.

In the field of uranium enrichment, URENCO, EURODIF/COREDIF and the USSR have entered the market, and the USA has recently announced its intention to resume its former role as a major supplier. Adequate capacity to meet demand would then be a question of policy rather than of technological capability. New technologies may be possible, but it is expected that it would take about 15 years for a new enrichment technology to be introduced on a commercial scale.

The industry faces a problem with respect to the reprocessing of the high burn-up oxide and mixed oxide fuels. As a result of delay of policy decisions, economic uncertainties and the technical difficulties of reprocessing these fuels, the present capacity is insufficient. An unexpected back-log of spent fuel has accumulated. Additional storage space is needed, and the back-log is not expected to be worked off until the year 2000.

The economic incentive for recycling of uranium and plutonium will be high because it will reduce the need for natural uranium and uranium enrichment. Plutonium used in breeder reactors offers a large, additional source of primary energy, but reprocessing of spent fuel is an absolute prerequisite. Delay in reprocessing leads to delay of plutonium use and this may create a problem of maintaining the necessary industrial capabilities.

Fuel Cycle Policy

At the conference, it was recognized that the fuel cycle policies and export policies of the supplying countries have profound effects. The mining and export policies of uranium exporting countries decide whether or not the market demand for uranium can be met. The export policies of suppliers of enrichment services influence the economics and choice of reactor type of importing countries.

Few countries have the natural resources and the economic and industrial potential that would enable them to build a complete nuclear fuel cycle industry within their national boundaries. Therefore, there is a special need for international co-operation in all aspects of the nuclear fuel cycle. The USA announced at the conference its intention to explore with other countries the concept of establishing an international fuel cycle evaluation programme and to facilitate the formulation of international nuclear policies and programmes consistent with non-proliferation goals.

Several other countries expressed the view that their lack of energy resources made it necessary for them to continue with reprocessing, and to develop the use of plutonium for breeder reactors as well as recycling plutonium and uranium in thermal reactors. The importance of non-proliferation of nuclear weapons was recognized. This goal could be achieved (i) by exporting countries making their fuel cycle services readily available for importing countries, thus reducing the incentive to acquire independent fuel cycle facilities, (ii) by suitable, reinforced international safeguards, and (iii) by regional fuel cycle centres as studied by the IAEA. Attention was drawn to the non-proliferation experience of existing multinational enrichment and reprocessing companies, and to the fact that use of plutonium in reactors made it unavailable for other purposes.

It was generally agreed that there is need for long-term planning. It was, however, pointed out that long-term planning by either the nuclear fuel cycle industry, utilities, or national authorities would be of limited value if vital fuel services depend on export policies of supplying countries without some guarantee that these policies would not undergo sudden changes. One of the achievements of the conference was that it helped to identify and clarify the issues relating to the nuclear fuel cycle in their technical, national, and international context.

Selected papers:

1. U. Lantzke, "World energy supply and demand and the future of nuclear power". IAEA-CN-36/583.
2. V. Baum, "Energy in the developing countries – prospects and problems". IAEA-CN-36/581.
3. W. Häfele, "Energy options open to mankind beyond the turn of the century". IAEA-CN-36/538.
4. A.M. Petrosyants, "Nuclear power in the USSR and its importance as a source of energy". IAEA-CN-36/590.
5. E.A. Wiggin, "The role of nuclear power in meeting future U.S. energy needs". IAEA-CN-36/396.
6. J.S. Foster and S.H. Russell, "CANDU-Canadian experience and expectations with the heavy-water reactor". IAEA-CN-36/179.

7. A.P. Aleksandrov and N.A. Dollezhal, "Uranium-graphite reactor development in the USSR". IAEA-CN-36/586.
8. R. Holzer and D. Knoedler, "Nuclear fuel in water reactors: manufacturing technology, operating experience and development objectives in the Federal Republic of Germany". IAEA-CN-36/103.
9. H. Albrecht et al., "Behaviour of LWT fuel elements under accident conditions". IAEA-CN-36/124.
10. G.R. Fanjoy and A.S. Bain, "CANDU fuel – fifteen years of power reactor experience". IAEA-CN-36/184.
11. D.O. Pickman and G.H. Inglis, "SGHWR fuel performance, safety and reliability". IAEA-CN-36/63.
12. J. Couture et al., "Design, construction, operation and maintenance of reprocessing plants: experience acquired". IAEA-CN-36/224.
13. W. Schueller et al., "Fuel reprocessing and waste treatment activities at the Karlsruhe Nuclear Research Center". IAEA-CN-36/571.
14. M.A. Demyanovich et al., "Basic problems of fast reactor fuel reprocessing". IAEA-CN-36/318.
15. J. van Dievoet et al., "The utilization of plutonium: present situation and future prospects". IAEA-CN-36/477.
16. G.K. Rossney, "Status and prospects for reprocessing". IAEA-CN-36/56.
17. E.R. Merz, "The thorium fuel cycle". IAEA-CN-36/96.
18. W. Häussermann et al., "Supply and demand estimates for the nuclear fuel cycle". IAEA-CN-36/493.
19. A. Giraud, "The nuclear fuel cycle: encouraging and less encouraging aspects". IAEA-CN-36/220.
20. J. Kostuik, "Industrial and commercial considerations affecting the future supply of uranium". IAEA-CN-36/55.
21. R.W. Manderbach, "Fuel cycle financing, capital requirements and sources of funds". IAEA-CN-36/514.