E,R

INTERNATIONAL CONFERENCE
ON NUCLEAR POWER AND ITS FUEL CYCLE
SALZBURG, AUSTRIA • 2–13 MAY 1977

INTERNATIONAL ATOMIC ENERGY AGENCY

IAEA-CN-36/6

CO-OPERATION OF THE CMEA MEMBER COUNTRIES IN DEVELOPING POWER REACTORS OF VARIOUS TYPES, INCLUDING SOME ASPECTS OF THEIR NUCLEAR FUEL CYCLES

Prepared by

I.Barbur, A.Barchenkov, W.Hake, L.Molnar, A.Panasenkov, B.Shcherbinin, V.Tolpygo

Secretariat of the Council for Mutual Economic Assistance
Moscow

I. Problems related to the fuel and power complex

Meeting the growing requirements of the national economy of the CMEA member countries for fuel and energy is one of the main problems of the economic, scientific and technical co-operation of these countries over the period up to 1990. This problem is being solved, and will continue to be solved, in accordance with the Comprehensive Programme for the Further Extension and Improvement of Co-operation and the Development of Socialist Economic Integration and subsequently also in accordance with long-term special co-operation programmes of the CMEA member countries, including the programme for meeting economically substantiated requirements of the CMEA member countries for energy, fuel and raw materials for the period up to 1990.

The programmes will provide for rational utilization of natural resources and consolidation of efforts of the CMEA member countries aimed at developing fuel and power sectors, at introducing new, less energy-consuming technological processes, at a speedier construction of atomic power stations, at a broad application of the most efficient and mutually beneficial forms of multilateral and bilateral co-operation.

It is planned to increase the share of solid fuel in the energy balance of the countries concerned on the understanding that the economic efficiency of thermal power stations operating on solid fuels, provided that modern equipment is used and unit capacities are increased, approximates that of stations burning oil and gas.

The forecasts for the development of fuel resources, now under formulation in the CMEA framework and in CMEA member countries, envisage that coal, inspite of its reduced share in the overall fuel-and-energy balance, remains one of the main energy carriers and that coal extraction in absolute volume will be increasing.

Co-operation of the CMEA member countries in the field of oil and gas industries enables on the whole to resolve problems of meeting requirements for oil, gas and oil products. In 1975 deliveries to Bulgaria, Hungary, the GDR and Czechoslovakia from the USSR reached nearly 62 million tons of oil and 14 billion cu m of gas.

As regards a more intensive build-up of capacities for oil and gas extraction in the CMEA member countries, a number of agreements have been signed on multilateral co-operation in geological and geophysical explorations, drilling and development of oil and gas deposits. Possible avenues of co-operation in prospecting for and developing oil and gas deposits located within the limits of marine aquatoria have been examined.

An important role in solving the energy problem will be played by activities aimed at a more efficient utilization of liquid fuel particularly by increasing the degree of oil refining up to 70 per cent. This will make it possible, using the oil resources available, to produce additionally a great number of light oil products and to fill the needs of petrochemistry for motor fuel and raw material without increasing considerably the consumption of oil and oil products.

To solve fuel and energy problems, the CMEA member countries are planning to make a wide use of different forms and methods of co-operation. The role of a comprehensive approach to the solution of large-scale objectives will increase considerably. In solving the fuel problem and first of all the problem of gas and oil, the General Agreement on Co-operation in the

Development of the Orenburg Gas-Condensate Field is a most important integration measure. The Agreement provides for the completion in 1976-1980 of work on exploratory drilling and development of oil fields, the construction by joint efforts of the CMEA member countries of a main pipe-line that will connect the city of Orenburg with the western border of the USSR and will be 2,800 km long. The implementation of this project will enable each of the countries participating in this Agreement to receive 15.5 billion cu m of gas yearly and to create the base for a planned formation of the fuel and raw material balances in the CMEA member countries.

Also, an extensive work is being carried out in the CMEA framework on meeting the requirements for electric energy, the gross output of which in the CMEA member countries in 1975 reached nearly 1,400 billion kwh. Power enginnering is one of the areas, where on the basis of broad co-operation of the countries concerned, international economic, scientific and technical ties are successfully developing and plans for their further intensification are being charted.

The elaboration of a General Scheme for a Long-Term Development of Interconnected Electric Power Systems of the CMEA Member Countries, Including Relevant Co-operation with the Electric Power System of Yugoslavia is an important stage in the development of co-operation among the CMEA member countries in power engineering.

The General Scheme has been drawn up to identify ways for meeting ever growing requirements of the CMEA member countries and Yugoslavia for electric energy over a long-term period, for a fuller use of the economic advantages arising from joint operation of power systems through an increased exchange of electric energy and capacity, realization of inter-system effect and reduction in total spare capacity.

The General Scheme envisages a further improvement of the technical standards of power engineering development on the basis of the construction of large thermal and atomic power stations, power transmission lines of high carrying capacity, a fuller use of fuel and hydropower resources, including low-calorie solid fuels.

When drafting the General Scheme, a technical and economic substantiation of long-term development of interconnected electric power systems (IEPS) has been eleborated, the optimum voltage level for inter-system power transmission has been determined, and matters related to the projected development of atomic power engineering in CMEA member countries have been considered. The General Scheme covers periods of IEPS development up to I980, I985 and I990 and contains data with regard to inter-state power transmission at 750 kV and possible avenues for meeting countries' requirements for electric energy. CMEA member countries put forward proposals concerning the construction by joint efforts of a number of projects in power engineering that are of particular importance for the interconnected power systems, including atomic and pumped-storage hydroelectric power stations.

As follows from the calculations, the inter-system effect from combined schedules of electric power loads and those of spare capacity in the context of the future development of IEPS can produce a saving of 4,600 MW in the installed capacity of power stations in power systems of the participating countries which is equal to a saving of about 400 million transferrable roubles in capital investments into generating capacities up to I990 and is, in fact, a direct economic effect for the countries concerned.

A number of factors such as the enlargement of unit capacity of power blocks and power stations, a more efficient utilization of fuel and the reduction in power losses in electric networks will produce an additional positive influence on the improvement of economic effectiveness of co-operation on the basis of the projected development of IEPS in the countries concerned.

Also, the General Scheme provides for a large-scale development of centralized heat supply from thermal electric power stations for a more rational heat utilization and creation of ecological conditions in cities and industrial centers.

The CMEA member countries plan to increase the installed capacity of heating plants I.8-fold by I990, increasing at the same time unit capacity of heating turbines. It is expected that a wider use will be made of heating plants on the basis of atomic energy.

The tendency of the CMEA member countries towards concentration of power capacity, the development of atomic power engineering, growth in unit capacity of power blocks and electric power stations, the increased capacity exchange, the expediency of mutual reserves and a tendency towards the fullest possible utilization of technical and economic advantages arising from parallel operation of power systems have led to the priority task of transmitting electric power at 750 kV.

Judging from the relevant studies and calculations, the construction of 750 kV inter-system power transmission lines during the period under consideration is the optimum direction to be followed in the context of the development of IEPS.

The 750 kV power transmission line, presently under construction between Vinnitza Zapadnoukrainskaya (USSR) and Albertirsa (Hungary), is the first element of inter-system power lines for the given voltage level.

As envisaged by the General Scheme, the development of 750 kV electric power transmission lines will be accompanied by the construction of 400 kV electric power transmission lines.

To solve a number of problems related to the provision of reliable and efficient parallel operation and management of IEPS as the exchange of capacity grows and new projects in power engineering are put into service, including 750 kV inter-system power transmission lines, it is planned to develop and implement a number of measures including the equipment of control stations with the necessary faccilities and means of control that meet the technical standards of the corresponding stage of development of the interconnected electric power systems. Creation of an automated dispatcher control system and provision of dispatcher stations with progressive means of computer technique will be of great importance.

The development of atomic power engineering plays a prominent role for the solution of the fuel-and-power problem in the CMEA framework. The Council for Mutual Economic Assistance has repeatedly emphasized the importance of an accelerated growth of nuclear power engineering in the CMEA member countries and the neccessity to further enhance co-operation in this field. Closer attention to nuclear power engineering is dictated by the fact that a drastic growth in electric energy production at nuclear power plants (NPP) is provided for in the structure of fuel-and-energy balances of the countries concerned over the years up to 1980 and in preliminary forecasts of their needs for fuel and energy over the years up to 1990. For example, Bulgaria is planning to commission 7,700 MW, Hungary - 5,700 MW, Poland - over 8,000 MW, Czechoslovakia - from 10,000 to 12,000 MW.

Between 1971 and 1975, the aggregate capacity of nuclear power stations in the CMEA member countries went up from 1,100 MW to 7,500 MW. Presently, NPP are in operation in Bulgaria, the GDR, the USSR and Czechoslovakia. Construction of new energy blocks and NPP is under way in these countries. Construction of NPP has been initiated in Hungary, Poland and Romania. A decision has been adopted to build NPP in the Republic of Cuba. In accordance with the five-year economic development plans, the aggregate capacity of NPP in the CMEA member countries is to reach nearly 30,000 MW by the year 1980.

Nuclear power engineering is becoming an economical source of electric energy thanks to the lower costs of the fuel component which makes it possible to offset high capital inputs into the NPP construction. Yet it is known that already now nuclear power plants have reached the required level of reliability and economic efficiency and that they contribute to the environmental improvement.

The growth of nuclear power capacities in the CMEA member countries in 1971-1975 has become possible thanks to serial production of the WWER-440 water-water reactors. Work has been carried out to determine the optimum water operating conditions of nuclear power stations for WWER-440 reactors, to improve their control systems and to ensure their reliable and safe operation.

Thus, energy potential of the CMEA member countries will continue to grow mainly at the expence of solid fuels, hydropower and nuclear power. As regards oil and gas, their increased production will be used to a larger extent for meeting technological needs.

II. Scientific and Technical Co-operation

In connection with the development of nuclear power engineering, the CMEA member countries attach unflagging attention to technical progress in this field, to the development of scientific research. The plan for scientific and technical co-operation in peaceful uses of atomic power in 1971-1975 provided for pursuance of research under II problems and 50 headings. Some 80 state institutes and agencies participated in this work. Special attention was paid to problems of developing water-water reactors of 1,000 MW electric capacity (WWER-1000), of developing energy reactors on fast neutrons, of ensuring proper control of reactors and NPP equipment, and of conducting research on individual links constituting the fuel cycle of nuclear power engineering.

Scientific and technical co-operation carried out through co-ordination of research, joint work, organization of conferences, symposia, exhibitions and mutual consultations has yielded valuable results contributing to the advanced application of nuclear power engineering to the CMEA member countries' national economy.

Instruments and installations created, technological solutions and methodical documentation prepared find direct application in building nuclear power plants, in manufacturing nuclear technology instruments, in reprocessing irradiated fuel, in treatment and burial of radiactive waste. Among these activities mention should be made of an instrument for measuring boron concentration in the heat carrier of the reactor primary circuit, developed in Hungary, of an instrument for determining steam humidity at nuclear power plants and of a system of inter-reactor measurements at the Bruno Leuschner nuclear power plant, both developed in the GDR, of miniature sensors for inter-reactor control of the active zone, developed in Poland, of a 30 MW module steam generator for nuclear power plants operating on fast neutrons, of an electromagnetic step drive of control rods, of a high-speed pump with a capacity of 20,000 cu m/hr for the reactor contour, all made in Czechoslovakia. Work is in progress in Czechoslovakia, Poland and the Soviet Union to improve various types of steam generators for nuclear power plants with reactors of the WWER type.

During the same period, a number of fundamental investigations on physics and hydrodinamics of reactors on fast neutrons have been undertaken in the countries concerned. In recent years, considerable progress has been made in the majority of the CMEA member countries in the development of techniques and programmes for computing reactors on fast neutrons. This led to a notable expansion of reseach in CMEA member countries that gave rise to a further evolvement of co-operation in this field. Co-operation of scientists in conducting research on reactors on fast neutrons was based on joint utilization of physical stands, equipment, computing technology and techniques developed in the CMEA member countries.

Important work on developing new and improving existing programmes and techniques for computing the active zone of reactors on thermal and fast neutrons is performed by the Provisional International Research Collective of Scientists of CMEA Member Countries for Reactor and Physical Investigations on Critical Assembly of WWER, set up in 1972 on recommendation of the CMEA Standing Commission on Peaceful Uses of Atomic Energy in the Central Institute for Physical Investigations of the Hungarian Academy of Sciences (Budapest).

The activities of this collective of scientists yielded the following important results:

- research has been undertaken on micro-parameters in uranium lattices, with water-to-uranium ratio changing within a broad range, on micro-parameters of fuel enrichment and boric acid concentration in the moderator, and on micro-parameters in various uranium lattices;
- reactor codes have been elaborated for processing the results of measurements, experimental techniques have been created and parameters of reactor kinetics have been measured;
- there have been developed instruments to ensure operational safety of reactors of the WWER type.

In the past five-year period, co-operation of the CMEA member countries in the field of research reactors was actively pursued, which made it possible to raise the capacity of these reactors in Hungary, the GDR, Poland, Romania, the Soviet Union, and Czechoslovakia from 2 to 10 MW and to considerably expand their research potentialities.

In this connection mention should be made particularly of a high-flux research reactor "Maria" of 30 MW commissioned in Sverke, Poland. This reactor allows to carry out a broad programme of investigations in the field of solid-state physics, radiative metal studies and nuclear physics.

An important role in scientific and technical co-operation of the CMEA member countries in the framework of the CMEA Standing Commission on Peaceful Uses of Atomic Energy is played by investigations in the field of forecasting the development of atomic power engineering of the CMEA member countries for the period up to 1990 as an integral part of general forecasting of the fuel and power balance.

These investigations are aimed at identification of the optimum ways of developing atomic power engineering in the CMEA member countries on the understanding that:

1) atomic power engineering, as it develops, gradually becomes an important branch of energy production while constituting a large link in the whole system of power engineering with external electric power ties and specific internal ties in the fuel cycle. This characterizes atomic power engineering as an interrelated complex of the CMEA member countries, the maximum possible economic efficiency of which can be attained through a balanced examination of their national nuclear power programmes;

2) large-scale development of atomic power engineering requires considerable inputs of financial, material and labour resources;

3) nuclear power engineering, while comprising a complex of enterprises in the external fuel cycle, is characterized by considerable inertia and a prolonged investment cycle;

4) the availability of several types of reactors that can be used for nuclear power programmes, the differences existing between reactors as to fuel characteristics (thermal and fast) and the varying degree of their readiness for a wide-scale utilization presuppose a number of ways for nuclear power engineering development.

One of the basic tasks of prognosticating in the CMEA framework consisted in comparing indicators of the integrated and the aggregated national systems of nuclear power engineering of the CMEA member countries, in identifying differences between them and in determining the effect and scope of economic integration.

The aggregated system is defined as the sum of energy capacities and requirements for uranium ~~subject to~~ an autonomous development of nuclear power engineering while the integrated system is defined as a joint development of nuclear power engineering subject to integration of links of the external fuel cycle.

To determine the optimum structure of nuclear power engineering, a mathematical model has been elaborated in the CMEA framework, in which a minimum expenditure of natural uranium required for its development was adopted as a criteria for optimization of the structure of the developing nuclear power engineering. The model has 90 restrictions and I80 variables.

This model was used for the study of:

- the relation between requirements for natural uranium for the "all-thermal" hypothesis of development of nuclear power engineering (on thermal reactors only) and of its combined development (on thermal and fast reactors);

- influence of acceleration or deceleration of the revolution of nuclear fuel in the fuel cycle on the structure and requirements for uranium in the aggregated and the integrated systems.

The results of this work have shown that requirements for natural uranium in the net-like system are marginal. Repeated use of plutonium in thermal reactors will allow to reduce the requirements of the system for natural uranium by only I0 per cent. One of the most effective means of solving the fuel problem of nuclear power engineering is through wide-scale utilization of fast breeders. It has been established that the influence of fast breeders on the reduction in the requirements for natural uranium after 5-I0 years since their wide-scale introduction is comparatively small. Basic changes in the structure of national nuclear power systems and consequently in the economy of natural uranium arising from the application of fast breeders are to be expected within I5-20 years, i.e.

approximately by the year 2000. Only then the share of fast breeders in the structure of nuclear power engineering could reach 50 per cent while the economy of natural uranium could account for nearly 30 per cent.

An analysis of the development of the structure of nuclear power engineering has shown that the requirement of the aggregated system of national nuclear power programmes for uranium diminishes slowly (up to 10 per cent) during the first 8-10 years since the possible start of economical fast breeders. This points to the existence of a certain zone of insignificant influence of atomic power on time needed to economically competitive fast breeders. Now, the smaller the system and the slower the growth of nuclear energy capacities particularly that of the share of fast breeders, the wider this zone.

As regards the integrated system, the zone of insignificant influence comprises 6-7 years. Outside of it a delay with a wide-scale introduction of fast breeders results in a considerable increase in the aggregate requirement for natural uranium, for example, by 20 per cent in case of a 10-year delay and by 40-45 per cent in case of a 15-year delay.

The integrated system possessing better possibilities for utilization of plutonium enables to improve considerably the structure of nuclear power engineering and indicators of fuel consumption as compared with the aggregate system. This will make it possible to increase the share of fast breeders in the structure of atomic power engineering by 8-12 per cent and to obtain a corresponding saving of natural uranium over the period under review up to 1990 in the order of 13-14 per cent.

Time required by the fuel to complete the external fuel cycle is very important for the system of nuclear power engineering (T_{ec}). Its influence acquires greater importance for the integrated system in view of the greater amount of plutonium in the cycle as compared with the aggregate system. As T_{ec} increases from 1 year to 2 years, the integral requirement for natural uranium for the whole period goes up 50 per cent. If T_{ec} decreases from 1 year to 0.5 year the requirement for natural uranium is reduced by 20-25 per cent. The share of fast breeders towards the end of the period in the structure of nuclear power engineering will amount to only IO-II per cent, with T_{ec} being equal to 2 years. At the same time, any decrease of T_{ec} from I year to 0.5 year results in a relatively small improvement of the structure. During the first IO years since the possible introduction of fast breeders into the system the influence of the external fuel cycle considerably lessens in view of a relatively small amount of plutonium in the nuclear fuel balance.

All this points to the fact that the reduction of time T_{ec} should be considered as a very important task, the solution of which will result in a considerable improvement of the role of fast reactors in the system of nuclear power engineering and in the economy of natural uranium.

III. Problems Related to the External Fuel Cycle

Co-operation of the CMEA member countries in the field of the external fuel cycle of atomic power engineering is focussed mainly on problems related to radiochemical reprocessing of irradiated fuel, its transportation, reprocessing and disposal of radioactive waste, and is directed at raising the efficiency of atomic power engineering, localization of radioactive waste of the atomic power industry in a limited number of places in the CMEA member countries, and at ensuring the maximum possible radiation safety.

III.I. Reprocessing of the irradiated fuel

The need for radiochemical reprocessing of spent nuclear fuel arises, first of all, from the fact that:

- fuel in the form of fuel rods discharged from the reactor is absolutely unsuitable for burial and its long-term storage entails considerable economic expenditures and technical problems;

- eventually, water-water reactors will be replaced by fast breeders in nuclear engineering. Here, the function of water-water reactors is to accumulate plutonium in order to put into operation the fast breeders and, consequently, its extraction;

- spent fuel discharged from water-water reactor always contains, in addition to plutonium, a certain quantity of unspent U_{235} considerably exceeding its natural content. In case of its re-use in the fuel cycle, the reserves of natural uranium are in fact increased, thus saving expensive separation work.

The scientific and technological co-operation of the CMEA member countries in this area is aimed at optimizing the monitoring systems for reprocessing the irradiated nuclear fuel, at creating the reliable efficient industrial equipment, at developing the methods and control instruments for technological processes and also at creating the optimum radiochemical production.

The problems of determining the content of isotope composition in the spent fuel of nuclear reactors utilizing both the destructive and non-destructive methods constitute a considerable area of co-operation.

As a result of this research carried out by the CMEA member countries under the joint programme, a monitoring system was prepared for treatment of irradiated fuel utilizing butyl phosphate and heavy non-flammable diluent which provides for treatment of fuel rods (wwr -type) with fuel burn-up for about 30 000 MW/days. It is expected that in future research will be aimed at improving and adjusting the diagram to the treatment of fuel from fast breeders with the fuel burn-up for about IO 000 MW/days. One of the major results is the development of a number of instruments which are necessary for instrumentation flow diagram.It includes small-sized pulsation, turbine and centrifugal extractors of various types and dimensions, the screw solvent,etc.

Co-operation of the CMEA member countries is carried out not only in the development of extraction technology (aqueous methods) but also in the development of non-aqeous methods of fluoride technology for recovery. At present an instrumentation-flow diagram is developed for the repocessing of fuel rods according to the fluoride technology which is used for mastering and calculating the optimum version of gas-fluoride technology for the recovery of spent fuel of the fast-neutron reactors (BOR-60).

The technology and instruments have been developed for decanning using the method of thermal opening. The process helps dejacket both the stainless steel cans of fast reactor fuel and zirconium cans of oxide fuel of vver-type reactors. It has been established theoretically and practically that there was no interaction between the stainless steel, uranium dioxide and plutonium dioxide at I500°C. The content of oxides in the stainless steel does not exceed 0.005 weight per cent.

A considerable work has been carried out in the development of methods for control and management of technological processes: control diagram for extractional reprocessing of spent fuel elements of wwr-type; methodology and instruments for radiometric determination of uranium and plutonium; a device for simultaneous determination of uranium and free nitric acid; a system for small volume sampling; neutron method for measuring the level of solutions and accustique method to control the position of surfaces during phase separation in the chemical instruments; neutron equalizers and thermal flow meters operating within the range of I-500 l/h.

Technical and economic research made it possible to determine the optimum capacity of radiochemical plant which equals I500 t U/year and to develop the criteria for its site selection.

III.2. Transportation of spent nuclear fuel

Transportation of spent nuclear fuel is one of the important links of nuclear power engineering fuel cycle, the necessity of which arises from the results of its economic optimization.

The planned scope of the development of nuclear power engineering in the CMEA member countries necessitates the transportation of considerable volume of nuclear fuel from the nuclear power plants to the reprocessing plants. In this connexion, the co-operation of the CMEA member countries in this area is aimed at developing a number of technical problems related to the construction of special transport means and at elaborating international legislative documents covering the transportation.

Under co-operation in this area, the CMEA member countries carried out an extensive research in designing and standardizing the transport means. Special container has been developed for safe transportation of spent nuclear fuel from vver-type reactors. The development of specifications has been completed for spent fuel rods of nuclear power plants operating on vver-440 reactors. These specifications were recommended to the CMEA member countries to be applied as a standard document which is necessary while negotiating the contracts for the delivery of spent fuel rods.

One of the major results of research under co-operation programme, too, is the practical completion of the development of "Regulations on Spent Nuclear Fuel Transportation from Atomic Power Plants of the CMEA Member Countries. Part I - Transportation by Railroad". In 1978 it is planned to complete the second part of the Regulations-Transportation by water.

III.3. Disposing of radioactive waste

The development of efficient and safe methods for disposing radioactive waste formed during the operation of a nuclear power plant is both an important condition for the development of nuclear power engineering and a decisive factor for its development.

The experience of countries with a high level of industrial development indicates that the problem of waste treatment and burial has been dealt with in a practical manner, and there has been no increase in the levels of radioactivity observed either in the immediate environment of nuclear facilities or in the world in general. It is proved, in particular, by the systematic monitoring of radiation safety carried out by the CMEA member countries in the basins of the Danube river, Black and Baltic Seas. Nevertheless, all methods used to deal with radioactive waste have so far been limited essentially to safe storage of the waste rather than final disposal.

A practical approach to the utilization of atomic energy and in particular of nuclear power engineering compels us to develop methods for safe treatment and disposal of radioactive waste right now, so that we have an opportunity to select the most effective and economical methods.

Research on radioactive waste treatment and burial constitutes an important area of co-operation between the CMEA member countries.

For the practical solution of problems of radioactive waste treatment and burial, and also with a view to further enhancement of co-operation, the Commission in 1971 established a Scientific and Technical Co-ordination Board (STCB, KNTS) to deal with treatment and burial of radioactive waste and deactivation of equipment, in which Bulgaria, Czechoslovakia, the German Democratic Republic, the Republic of Cuba, Poland, Romania and the USSR are participants.

The main tasks of the SCTB are to assist in multilateral co-operation, to analyse the state and trends of development in this field, to lay down the main lines of work, to investigate the cost effectiveness of introducing the results of scientific and technical research in practice, to organize exchanges of experience and information.

Co-operation in the years 1971 to 1975 followed the programme for research on the management of liquid, solid and gaseous radioactive waste and the deactivation of contaminated surfaces.

The aim of the programme was to develop and test on an enlarged scale the various methods of treating waste in order to obtain representative data suitable for comparing various systems and devices and, on the basis of this comparison, to select the best systems for treating and burying radioactive waste, and also to prepare a number of documents relating to the methods selected.

Work carried out under the co-operation programme in Bulgaria, Hungary, the German Democratic Republic, Poland, Czechoslovakia and the USSR made it possible, in a short time, to establish the conditions for bituminization (using various types of bitumen) of almost all constituents of the liquid radioactive waste formed during the operation of a nuclear power plant. The research yielded, moreover, a method of selecting the optimum regime in each case for incorporating radioactive waste in bitumen.

The construction and successful testing of periodically operating liquid-waste bituminization facilities using the hot mixture principle made it possible to recommend them for operation at 20 to 60 l/h, and also to work out basic principles for the design of such facilities.

Under this programme a number of practical documents were also prepared, including a list of standard analytical and technico-economic indices for evaluating the efficiency of operating facilities for the treatment of low- and medium-level liquid wastes, criteria for selecting solidification methods in accordance with the properties of the waste and the conditions prevailing at the site of burial, methods for choosing the optimum bituminization regime, and methods for determining safe burial conditions for solidified waste depending on its properties and specific activity.

An important part in the co-operation programme has been assigned to the study of systems for burying radioactive waste of all kinds in geological formations; among the options being considered are the construction of storage chambers in surface horizons, in deep water-saturated strata and in saline formations.

In all three areas, extensive theoretical, laboratory, field and pilot research has been conducted to develop the basic techniques of radioactive waste burial in geological formations. The results of this work have been described in more than 30 papers.

The research yielded data on sorption, migration and diffusion of radioactive elements in soils and aquiferous horizons, and made it possible to assess the compatibility of radioactive wates with stratal rock formations and the water in them; techniques of preparing waste for burial in deep absorbent aquiferous horizons and chemical methods of restoring bore-hole injectivity were developed.

The results of this research are of great practical importance in prognosticating radioisotope dispersal in aquiferous horizons of different mineral composition and in organizing monitoring systems to check on the effects of radioactive waste burial.

The evaluation of temperature fields carried out in connection with the burial of radioactive waste in geological formations is of great theoretical importance, and in many cases where high-level wate is to be buried this evaluation is of decisive importance for selecting a basic method and a technological system.

Schematic diagrams have been drawn of underground chambers for liquid radioactive waste in deep absorbent horizons, taking into account the hydrogeological characteristics of the region and the composition and volume of the waste; also, systematic plans bearing on the design and calculation of equipment for surface and underground storage chambers have been developed.

Research has also been done on the possibility of a pilot project involving radioactive waste burial in a worked-out salt mine. There has been experimental design work on setting up a unified system of tanks and transport containers for low- and medium-level waste.

It can be concluded from the research conducted in connection with plans for the burial of radioactive waste of all kinds in geological formations that the technical foundations for such burial underground are now established.

The main tasks in the programme of work for 1976 to 1980 are to conduct research on the best of the various techniques of treating and burying radioactive waste, and to develop industrial equipment for these techniques.

The main task of the development of nuclear power engineering and its fuel cycle is to construct large complexes which include, on one site, both the groups of nuclear power plants with a total capacity of several million kw and accompanying plants for the reprocessing of nuclear fuel and radioactive waste.

This approach to the development of nuclear power engineering will make it possible to:

- use rationally "ecological capacity" of nuclear power plant siting;

- save costs for transportation of spent nuclear fuel;

- organize the most efficient storage and subsequent burial of radioactive waste;

- develop plant capacities for the reprocessing of spent nuclear fuel which are most efficient from the economic point of view;

- create favourable conditions for the development of interconnected power systems.

IV. Radiation safety

Considering wide development of nuclear power engineering in the CMEA member countries and the necessity for safe human environment during the operation of nuclear power plants, the CMEA member countries attribute much importance to co-operation in radiation safety; this problem has been included into "General Extended Programme of the CMEA Member Countries and Yugoslavia in the Period to 1980 in the Field of Environmental Protection and Improvement and the Related Rational Use of Natural Resources".

The problem of radiation safety is related to the development of nuclear power engineering and to the extended use of radioactive isotopes and ionizing radiation in various fields of science and technology, in industry, in agriculture and medicine. However, research carried out by the CMEA member countries on environmental protection in connection with the development of nuclear power engineering is of utmost importance.

First, attention is paid to engineering and technological measures aimed at providing radiation safety of nuclear power plants as a major factor eliminating the possibility of deterioration of radiation situatuion at the nuclear power plants and in the environment and taking into consideration all regulations on radiation safety standards, and, secondly, attention is paid to monitoring including monitoring of the state of basic metal and nuclear power plant equipment, radiation monitoring of nuclear power plants' personnel and rooms, population and environment, air, water, soil samplings and other types of monitoring.

To co-ordinate research carried out by the CMEA member countries in the area of radiation safety, the CMEA Standing Commission on the Peaceful Uses of Atomic Energy has established a Scientific and Technical Co-ordination Board on Radiation Safety (STCBRS, KNTS-RB) and developed co-operation programme.

Under this programme, the CMEA member countries conduct research in the following major areas:

- environmental radiation monitoring (sampling methods to assess water contamination by radionuclides; recommendations on radiation monitoring in the vicinity of nuclear power plants; recommendations on outer environment monitoring of iodine-131 released into the atmosphere, etc.);

- development of normative and methodological papers on radiation safety to be used at the designing, construction and operation stages of nuclear power plants (recommended basic principles and criteria for selection of construction sites for nuclear facilities; general principles of nuclear power plant safety at the designing, construction and operation stages; radiation protection regulations for various types of concrete and concrete structures, etc.);

- development of technical aspects of radiation safety (standard technological substantiation of safety in the construction and operation of nuclear power plants; development of non-destructive methods for remote control of basic metal, pipe lines, welded joints and nuclear facilities in the process of operation, etc.);

- development of measures aimed at preventing accidents at the nuclear power plants and at eliminating its consequences (classification of emergency situations at the nuclear power plants and methods for assessing emergency factors; regulations concerning environmental protection in case of radiation accidents at the nuclear power plants with water-water reactors and recommendations on basic measures to be carried out following the radiation accident connected with the loss of heat-transfer medium at the nuclear power plants, etc.);

- development of measures aimed at dicreasing personnel irradiation at the nuclear power plants during its normal operation on the basis of experience of nuclear power plant operation (recommendations on decontamination of technological equipment used in nuclear power engineering; development of basic principles on water operating conditions and on methods for purification of radioactive water formed during the operation of nuclear power plants with water-water reactors, etc.).

The normative documents and recommendations prepared by the Commission are used by the CMEA member countries as a basis in carrying out relevant research within the national context.

First International Conference held in September 1975 in Czechoslovakia within the CMEA framework was devoted to the problems of radiation safety in connection with the operation of nuclear power plants. The Conference discussed the following problems: site selection for nuclear power plants; safety planning, technical aspects of environmental protection, evaluation of accident impact, increase of radioactiva wastes, radiation monitoring of the population, exposure to radiation of nuclear power plant's personnel, etc.

The results of this Conference indicate that the measures on radiation safety are more and more dealt with from the economic point of view and that the development of nuclear power engineering entails increased expenditures in order to solve the problems of providing necessary safety during the operation of the nuclear power plants in terms of environmental protection against radioactive contamination.

In the period 1976 to 1980 the CMEA member countries plan to solve a great number of radiation safety problems. At the same time, even now the actual data indicate a high degree of nuclear power plants' safety, their favourable impact on environmental purity. The transfer from the power production using organic fuel to the production using nuclear power leads to considerable dicrease in the levels of environmental contamination by toxique substances.

Joint measures carried out by the CMEA member countries in the area of radiation safety are an important task bacause environmental deterioration may, in particular, have world-wide consequences for many countries, and it will be easier to eliminate or to prevent them by joint efforts of all countries.

V. Role of International Economic Associations

The planned scope of development of nuclear power engineering put forward important tasks before the nuclear mechanical engineering of the CMEA member countries in developing special equipment for nuclear power plants. That's why the governments of the CMEA member countries attribute high importance to this problem. Both in bilateral and multilateral co-operation of the CMEA member countries, these problems are to be solved on the principles of international socialist division of labour using the advantages of international specialization and cooperation of production of nuclear power equipment. Specifically, it is forseen to carry out joint prognosticating and co-operation in co-ordinating plans (beginning from scientific research and experimental design work and co-ordination of plans of production of equipment and the construction of nuclear power plants), relevant measures in the sphere of production (preparation and establishment of facilities which are the result of scientific and technological co-operation; preparation, establishment and operation of international economic associations, organizations and joint ventures), etc.

In recent times several bilateral agreements have been signed between the governments of the USSR, Bulgaria, Hungary, the GDR, Poland and Czechoslovakia on co-operation in the production of equipment for nuclear power plants up to 1980. The agreements provide for manufacturing and delivering to the CMEA member countries reactor assemblies, steam generators and other technological equipment for nuclear power plants with reactors of wwr -440 type. At the same time a programme for maximum possible development of nuclear power mechanical engineering of the CMEA member countries including the questions of cooperation and specialization of production in this area up to 1990 is being worked out now within the CMEA framework.

Under intergovernmental agreements and taking into account the said programme for maximum possible development of nuclear power mechanical engineering up to 1980, the construction is in progress; industrial base of nuclear power mechanical engineering of the CMEA member countries will be further extended to provide for the implementation of the programme for the development of nuclear power engineering. The construction of new plants for the production of special equipment for nuclear power plants and the development of the existing capacities are being carried out now in the USSR, Czechoslovakia and other member countries of CMEA.

International economic association - Interatomenergo - was set up in order to organize cooperation in the production of equipment, to render technical assistance in the construction, putting into operation and reliable utilization of nuclear power plants constructed including the supply of spare parts and repair and assembly operation. One of the important tasks of this Association is the labour division in developing, manufacturing and operating power blocks with the reactors being constructed in the CMEA member countries. At present, Interatomenergo participates in the elaboration of the above-mentioned programme for maximum possible development of nuclear power mechanical engineering.

International economic assiciation - Interatominstrument - was established to meet to a fuller extent the requirements of the countries for instruments and devices in nuclear engineering. In 1975-1976, Service branch offices of the Association were established and began to operate in Bulgaria, Poland and the USSR to service instruments and devices of nuclear engineering which was an important step in the development of economic activities of the Association.

In the first half of 1976 work was completed on co-ordination of mutual deliveries of instruments and devices of nuclear engineering for the period 1976 to 1980. The results of this coordination were reflected in the intergovernmental trade agreements for 1976-1980 signed by the countries participating in Interatominstrument. As a result, in 1980 export of nuclear engineering products will be more than a twofold increase over 1975.

In future, too, the development of co-operation in nuclear power engineering will occupy an important place in the activities of the Council for Mutual Economic Assistance. Favourable prospects in this direction are open in connection with the considerable positive changes in the world situation.

The co-operation between the CMEA and the IAEA will contribute to economic, scientific and technological development of the countries and to the implementation of the provisions of the Final Act of the Conference on Co-operation and Security in Europe laid down in the section entitled "Co-operation in the Field of Economics, of Science and Technology and of the Environment".