for terrestrial thermoelectric generators; $^{238}\text{Pu} (\text{PuO}_2)$ (for units with a long service life) and $^{210}\text{Po}$ (for units which tolerate a reduction of power in the initial period, with its corresponding adjustment throughout its further operation) are widely used for high-power, power-generating facilities.

The complex of work carried out has made it possible to accomplish the commercial production of radioisotope sources for thermal and electric power (Table 4). In particular, in the Soviet Union, more than 200 automatic radiometric stations are operating with radioisotope power supply sources "Beta-S" and "Beta-M," developed in the All-Union Scientific-Research Institute of Radiation Technology, with the inclusion of certain specialized organizations (Fig. 7).

In 1975 at the Scientific-Research Institute of Clinical and Experimental Surgery, Academician B. V. Petrovskii carried out the first operation in vivo of a Soviet radioisotope electrocardiostimulator (pacemaker) in the body of a sick person, suffering from a total transverse blockage of the heart.

The brief and by no means complete review undertaken of the achievements of Soviet researchers in the field of radiation techniques shows that this comparatively new trend has been formed into a large-scale independent branch of nuclear science and technology, without which today further technical progress in the different fields of industry, medicine, agriculture, and also in scientific research would be unthinkable.

COLLABORATION BETWEEN COMECON MEMBERS IN POWER REACTOR DESIGN, INCLUDING SOME ASPECTS OF NUCLEAR FUEL CYCLES

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Fuel and Power Topics

A major purpose of economic and scientific collaboration up to 1990 is to meet the fuel and power requirements of COMECON member-countries. At present this is being handled under the joint program for extending collaboration and development of socialist economic integration, while in the future it will be handled within the framework of long-term programs, including ones designed to meet the needs of member countries for energy, fuel, and raw materials.

There is a tendency for the importance of solid fuel in the energy balance of member countries to increase; coal remains one of the major energy sources, and the scale of coal production will increase. Collaboration between member-countries will meet the main requirements for petroleum, natural gas, and petroleum products; in 1975, deliveries from the USSR to Bulgaria, Hungary, the German Democratic Republic, Poland, and Czechoslovakia reached about 62 million tons of petroleum and 14 billion m$^3$ of gas. Various agreements have been signed on multilateral collaboration in locating and exploiting new petroleum and gas deposits, including offshore ones. An important part will be played by measures for more efficient use of liquid fuel, in particular by increasing the yield from petroleum refining to 70%.

The importance of the multilateral approach to large-scale fuel and energy problems will also increase considerably. The most important integration measure is the agreement on collaboration in exploiting the Orenburg gas-condensate deposit. Under this, joint efforts during 1976-1980 will be devoted to the construction of a pipeline from Orenburg to the western border of the USSR, total length 2800 km. The construction of this will provide member-countries with a further 15.5 billion m$^3$ of gas per year.

The total electrical energy production in member countries in 1975 reached 14,000 billion kW-h. Electrical power is an area in which considerable success has been attained in economic and scientific collaboration, which is to be further extended. An important stage in this is provided by the general scheme for the joint power system in Yugoslavia.
This general scheme has been based on forecasts for the individual power systems, including definition of the optimum voltage level for transfers between systems, development prospects for nuclear power, the design of an interstate transmission system working at 750 kV, and proposals for collaboration on power stations, including large nuclear power stations and pumped-storage stations.

Considerable advantage will come from exploiting the differences between the load curves for the members-countries, which will make available considerable reserve power in these rapidly extending power systems; this may save the installation of about 4600 MW of generating capacity in the member countries, which is equivalent to about 400 million convertible rubles in terms of capital investment in generating output at the 1990 level.

Very extensive use of centralized heat supply from thermal power stations is envisaged in order to ensure more rational use of fuel, with increase in the power supplied by district-heating systems by a factor 1.8 by 1990. In addition, district heating by nuclear power stations will be extended.

Nuclear electricity is playing an increasing part within COMECON; the emphasis on this derives from the fact that the structure of the fuel and power balances of the member-countries up to 1980 must involve a considerable increase in the contribution from nuclear power stations, and the same applies in preliminary forecasts of demands for fuel and energy up to 1990: for the first data, Bulgaria requires 7700 MW, Hungary 5700, Poland over 8000, and Czechoslovakia 10,000 to 12,000.

The total output from nuclear power stations in member-countries rose in 1971-1975 from 1100 to 7500 MW. Nuclear power stations are now operating in Bulgaria, the German Democratic Republic, the USSR, and Czechoslovakia, and further such units are being built in these countries. A start has been made on nuclear power stations in Hungary, Poland, and Rumania. A decision has also been made to build a nuclear power station in Cuba. The total output from nuclear power stations in member countries should be about 30,000 MW by 1980.

This rise in nuclear power in member-countries during 1971-1975 was made possible by the routine production of the VVER-440 reactor type; during that period, researches were performed on optimizing the water parameters in the VVf~R-40, and also on improvement of the monitoring and control systems, as well as on reliability and safety.

The increase in the energy potential of member countries is therefore to come primarily from solid fuel, hydroelectric power, and nuclear energy. To an increasing extent, oil and gas will be redirected to other uses.

Scientific Collaboration

The plan for scientific collaboration in the use of nuclear energy for peaceful purposes for 1971-1975 envisaged joint research and development studies on 11 major problems and 50 topics. About 80 institutes and organizations collaborated. Particular attention was given to the VVER-1000, fast reactors, reactor monitoring and control, and power station equipment, as well as particular links in the fuel cycle.

Techniques, instruments, and systems have been developed, along with the appropriate documentation, for direct use in power stations, which has gone in hand with the production of nuclear-engineering instruments, facilities for reprocessing irradiated fuel, and radioactive-waste processing facilities. In Hungary, an instrument has been developed for measuring the boron level in the heat carrier in the first loops of reactors, while in the German Democratic Republic an instrument has been designed for determining the water content of steam in a nuclear power station, together with systems for making measurements within the reactors at the Bruno Leuschner Nuclear Power Station; Poland has developed small transducers for use within the reactor core, and Czechoslovakia has designed modular steam generators of output 30 MW for fast-reactor power stations, an electromagnetic stepping drive for control rods, and a fast pump of output 20,000 m³/h for reactor loops. In Poland, the USSR, and Czechoslovakia there have been researches on improved designs of steam generators for power stations fitted with VVf~R reactors.

Some major researches have also been performed on the physics and hydrodynamics of fast reactors; considerable advances have been made in research methods and computational programs. The basis has been laid for further extension of collaboration in this area. The cooperation in fast-reactor research is based on joint use of physical facilities, computers, and methods.

Much work has also been done on writing new programs and improving existing ones for calculations on the cores of thermal and fast reactors, which has been carried through by the Temporary International Research Team for research in reactor physics, with critical assemblies of VVf~R type, which was set up in 1972 at the Central Physics Research Institute of the Hungarian Academy of Sciences.