NUCLEAR ENERGY IN EASTERN EUROPE

While Communist governments reigned in Eastern Europe, Soviet-designed nuclear energy technology was the order of the day.

The VVER plant design—the Soviet equivalent of the West's pressurized water reactor—was exported to Poland, Czechoslovakia, Hungary, Bulgaria and East Germany.

Principal Strengths and Deficiencies

Three models of the VVER are in operation or under construction in Eastern Europe—the older Model V230 and newer Model V213 of the 440-megawatt design, and a 1000-megawatt model called the VVER-1000.

For an overview of the principal strengths and deficiencies of Soviet-designed plants, see **Soviet Nuclear Power Plant Designs**.

After Chernobyl: Improving Plant Safety

The countries of Eastern Europe, like the USSR itself, produced studies of the VVER that served as the basis for upgrading the plants to improve their level of safe operation. These countries also explored the impact of quality control, preventive maintenance, operator training and sound management on plant safety. Some progress was made in the years after Chernobyl. But with the domino-like collapse of the Communist regimes in Eastern Europe in 1989, nuclear safety activities proliferated.

At the time the Berlin Wall fell in November 1989, 21 VVER units operated in Eastern Europe. With the exception of one 1000-megawatt unit at Kozloduy in Bulgaria, all were 440-megawatt reactors—14 the older Model V230, and six the newer Model V213.

Units in Former East Germany Closed

At the Greifswald plant in former East Germany, the four Model V230 units in operation came under increasing scrutiny after the Chernobyl accident in 1986. West German regulators and the International Atomic Energy Agency cited numerous design and operating problems that compromised safety at Greifswald. Bonn asked Berlin to close two of the units in early 1990. Then, in the wake of German reunification, Bonn closed the two remaining units.

Convinced that backfitting to German safety standards was not economically feasible, the unified German government decided in early 1991 to decommission the four units, close Unit 5, which was undergoing testing at the time, and halt construction on six other units—four VVER-440 Model V213s at Greifswald and two VVER-1000s at Stendal.

Poland Halts Plant Construction

In Poland, the only nuclear plant under construction—consisting of four VVER-440 Model V213 units—was canceled in 1990. The project, plagued by stop-and-start construction because of money shortages, labor strife and public protests, was rejected by Gdansk voters in a spring referendum. The Polish Council of Ministers scrubbed the partially built Zarnowiec plant in September 1990.

Other VVERs Still Operating

The four other countries with VVER units—the Czech Republic, the Slovak Republic, Hungary and Bulgaria—continue to operate them. Although levels of performance and safety vary from plant to plant, all the units have benefited from the exchange of information and experience—among these countries themselves as well as between them and the West.

Fuel Supply and Spent Fuel Disposal

Until its collapse, the Soviet Union provided nuclear fuel for Soviet-designed reactors in Eastern Europe, and took back the spent fuel for reprocessing. But the country's disintegration, together with a 1992 environmental law prohibiting the import of nuclear waste into Russia, disrupted the traditional arrangements. Russia's Ministry of Atomic Energy has chosen to interpret the law as excluding spent fuel that is imported for reprocessing, negotiating new arrangements with the countries of Eastern Europe for fuel supply and reprocessing at market prices and in hard currency.

In September 1995, the Russian government issued a decree stating that all radioactive waste received by Russia must be returned to its country of origin after 20 years. Under this decree, countries shipping spent fuel to Russia would—after 20 years—presumably either have to take back the fuel, if Russia were unable to reprocess it, or accept the waste, if Russia did reprocess the spent fuel.

Russia's new law on nuclear energy, signed by President Yeltsin in November 1995, codifies the Ministry of Atomic Energy's current practice of circumventing existing environmental legislation by defining spent fuel as a raw material. In late December 1995, Yeltsin reportedly vetoed a nuclear waste law approved by both houses of the Russian Parliament that would ban the import of spent fuel by defining it as waste, not a raw material.

In April 1996, the Russian Supreme Court overturned part of a January 1995 presidential decree on importing spent fuel. The court ruled that spent fuel could be imported in the future only if relevant international agreements, approved by environmental experts, had been signed. In essence, the court ruling reinstated some provisions of the radioactive waste law vetoed by Yeltsin.

A Groundswell of Cooperative Efforts

WANO Exchanges. Under the auspices of the World Association of Nuclear Operators, chartered in May 1989, managers or chief engineers from every nuclear plant in Eastern Europe have visited Western plants to observe operating approaches and have hosted visits by personnel from Western plants.

IAEA Missions. Hungary was the first Eastern European country to ask, in 1988, that an International Atomic Energy Agency mission review operational safety practices at its nuclear plant. Since then, at the request of each country, the IAEA has reviewed safety practices, operating history and incident prevention at all operating nuclear plants in Eastern Europe.

VVER Regulators' Association. At the initiative of Bulgaria's regulatory agency, the Association of State Nuclear Regulatory Bodies of Countries Running VVER-Type Reactors was launched in December 1993. The association—which seeks to improve the safety of VVER reactors by cooperating in the development of regulatory policy and safety requirements—held its first meeting in Budapest in May 1994. Representatives of regulatory agencies in Bulgaria, the Czech Republic, Finland, Hungary, Russia, the Slovak Republic and Ukraine attended, as well as observers from the IAEA, the G-24's Nuclear Safety Committee, the U.S. Nuclear Regulatory Commission and Germany's GRS.

Connecting Eastern and Western Grids. The utilities of the Czech Republic, the Slovak Republic, Hungary and Poland created their own grid network—Centrel—in 1992, and in 1993 cut themselves off from the former Soviet network. Centrel's goal is to link up with UCPTE, the West European grid. But before it can do that, it must demonstrate the ability to operate autonomously without compromising customer supply. Integration is expected before the end of the decade.

NUCLEAR ENERGY IN THE CZECH REPUBLIC

The Czech Republic operates four VVER-440 units at Dukovany in south Moravia. Nuclear energy supplies 28.6 percent of the country's electricity; thermal—coal, oil and gas—plants, 68.6 percent, and hydro plants, 2.8 percent.

Nuclear Program and Plans

The Czech Republic, seeking to reduce its reliance on highly polluting brown coal, is working with the U.S. company Westinghouse to upgrade and complete two VVER-1000 units at Temelin. The first Temelin unit is expected to be commissioned in April 1999, with trial operation in March 2000; plans call for fuel loading of the second unit in May 2000 and trial operation in April 2001.

Formulating and Implementing Electricity Policy

Before the breakup of the Czech and Slovak Federal Republic (CSFR), the federal government decided on an energy policy that would continue the country's nuclear program and reduce its reliance on coal.

The Czech government continues to support the use of nuclear energy. It advocates the completion of the Temelin nuclear power plant, the modernization of many coal-fired power plants and the closing of old fossil plants. In a 1994 review, the Organization of Economic Cooperation and Development's International Energy Agency noted that Ceske Energeticke Zavody (CEZ), the Czech utility, is closing the most polluting coal-fired plants and investing $4.5 billion in controlling emissions from the remaining coal-fired plants and in safety and technology improvements to both the Dukovany and Temelin nuclear power plants.

Utility Operations. CEZ is responsible for electricity generation and high-voltage transmission in the Czech Republic, and eight companies are responsible for regional electricity distribution.

Before the breakup of the CSFR, CEZ was state-owned, although the country planned to privatize the utility as part of its move toward a market economy. Now, 32 percent of CEZ stock is publicly owned and 1 percent is held by a restitution fund to compensate people whose property was confiscated under the communist regime, while the remaining 67 percent is held by the Czech government. When privatization is complete, the Czech government will hold a 51-percent share of CEZ equity.

The eight regional distribution companies also are being privatized, with an initial 20-percent stake being offered to foreign utilities or distribution companies. In addition, a 15-percent stake will be offered to the municipalities served by the companies. An additional 15 percent will be auctioned through a citizen coupon voucher scheme. Within the next five years, another 30-percent stake will be offered to foreign companies through financial markets, and the remaining shares will be offered to municipalities.

CEZ has awarded a contract to the U.S. company Westinghouse to supply a plant information system to integrate maintenance, materials and documentation management and operations support for 13 of the country's power plants, nuclear and fossil-fueled.

CEZ reports to the Czech Ministry of Industry and Trade.

In October 1995, the Czech electricity grid was connected to the West European grid network.

Nuclear Energy Oversight

Like its neighbors in Eastern Europe using Soviet-designed nuclear plants, Czechoslovakia had adopted not only the technology but the regulatory model in place in the former U.S.S.R. That meant a single organization—the Atomic Energy Commission (AEC)—promoted nuclear power and regulated nuclear power plant operations.

Reformed Federal Body. In early 1991, the CSFR redefined the AEC's duties, making it responsible for nuclear safety but eliminating any involvement in promoting nuclear power. Within the AEC, the Nuclear Safety Inspectorate (NSI) had sole responsibility for issuing safety regulations.

The NSI staff included 14 resident inspectors at the country's nuclear power plants. Separate Czech and Slovak agencies supported the work of the AEC in such areas as nuclear safety, radiation protection, technical safety and fire protection.

The CSFR also established a national system for collecting, analyzing and disseminating information on safety-significant events at nuclear plants.

New Republic Entity. With the creation of separate Czech and Slovak republics in January 1993, regulatory bodies were established for each republic. The State Office for Nuclear Safety, headed by Jan Stuller, formerly had three technical departments—one for nuclear power plant

components and systems, one for nuclear safety assessment and one for nuclear materials—each with its own director.

Effective July 1, 1995, the Czech government reorganized the State Office for Nuclear Safety, combining the regulation of nuclear safety and radiation protection within the office. The office now has three divisions: one for nuclear safety, one for radiation protection, and one for administration and technical support, each with its own deputy chairman.

The division of nuclear safety has four on-site inspectors at the Dukovany plant and three on-site inspectors at the Temelin plant.

Status of Liability Coverage

The Czech Republic drafted national legislation that includes a provision making the licensee responsible for any nuclear damage resulting from an accident at a nuclear power plant, requiring that the license holder have insurance to cover any damage, and obligating the state to provide compensation for any damage in excess of that covered by the license holder's insurance. The legislation was approved by the Czech cabinet in January 1996, and by the Czech Parliament in December. It went into effect July 1, 1997.

In addition, a nuclear insurance pool was established in the Czech Republic in July 1995. Since then, insurance arrangements for third-party liability have been made for Dukovany, and coverage will soon be arranged for the two Temelin units.

The Czech Republic is a party to the Vienna Convention, which ensures that the responsibility for damage caused by a nuclear accident is channeled to the plant operator. The republic also is a party to the 1988 Joint Protocol on Civil Law Liability and Compensation for Cross-Boundary Damage from Nuclear Accident, which resolves potential conflicts between the Paris Convention—which covers 14 European countries—and the Vienna Convention—which has worldwide coverage.

Fuel Supply and Waste Disposal

Supply of Fuel. Nuclear fuel for the Dukovany plant is supplied by the Russian company Mashinostroyitelniy Zavod Elektrostal. Until 1993, the fuel for the plant was purchased by the Czech company Skodaexport with funds from CEZ. But according to Czech press reports, the Russian company is owed $5.7 million by Skodaexport for 1992 fuel deliveries and has said it intends to sign a contract directly with CEZ for fuel supplies through 1996. Although CEZ has invited tenders for the supply of fuel for Dukovany, any new supplier would need two to three years to develop the production technology. In 1993, the Czech Republic began buying some of the fresh fuel from the shut-down VVER plant at Greifswald in eastern Germany. This fuel gives Dukovany sufficient reserves for one year, but the plant has reportedly begun using it. In 1994, the republic signed an agreement with Russia for the supply of fresh fuel. The contract was renewed in 1996.

Fuel for the Temelin plant is being supplied by Westinghouse as part of the plant's upgrading and completion. The fuel will be manufactured in the United States, with the Czech Republic's Skoda Plzen participating in fuel testing and development.

In December 1995, CEZ signed an agreement with Canada's Cameco Corp. for the supply—beginning in 1998—of uranium hexafluoride produced at Cameco's facilities in Ontario. Uranium hexafluoride must be enriched and then fabricated into nuclear fuel.

The Czech Republic, Russia, Ukraine and Slovakia signed a draft agreement in September 1996 on transporting nuclear materials through Ukraine. Under the agreement, the Czech Republic will supply Russia with uranium concentrate and Russia will send nuclear fuel in return. In 1996, Russia reportedly delivered $23 million worth of fuel to the Czech Republic.

CEZ, together with SEP, has bought some 400 unused fuel assemblies from the closed Greifswald plant in eastern Germany. About 200 of the assemblies will be used at Dukovany.

Spent Fuel Storage and Disposal. Originally, it was agreed that spent fuel from the Dukovany plant would be sent to Russia for disposal. But in 1993, Russia decided to accept spent fuel only for reprocessing, not for disposal. Until the breakup of the Czechoslovak Federal Republic, the Dukovany plant sent its spent fuel to an interim spent fuel storage pool at the Bohunice plant. But in 1993, SEP, the Slovak utility that operates Bohunice, said it was no longer willing to accept Dukovany's spent fuel. In November 1995, the Slovak utility began shipping Dukovany's spent fuel back to the Czech Republic plant. All the spent fuel is expected to be returned by the end of 1997.

To address its storage problem, Dukovany began reracking the fuel assemblies in its spent fuel pools, which will increase capacity by about 90 percent. The plant also took steps to build an on-site interim storage facility for spent fuel, a move that encountered local opposition. Although the Czech Ministry of Environment publicly expressed support for the facility and the Atomic Energy Commission approved the proposal, the licensing process required public discussion and an environmental impact study. An environmental group appealed the granting of a construction permit, but in June 1994, the Czech Economics Ministry upheld the permit, clearing the way for construction to begin.

The 600-metric-ton facility began trial operation in September 1995, when the State Office for Nuclear Safety granted it an initial one-year license. The first of 60 CASTOR casks designed by Germany's Gesellschaft für Nuklear Behälter and manufactured by The Czech company Skoda Plzen were delivered to the plant in January 1996. A full license was issued in January 1997.

CEZ had planned to build a central interim storage facility that could store about 12,500 fuel assemblies from the Dukovany plant and 3,000 fuel assemblies from the Temelin plant. The facility would have to be operational by 2005, when Dukovany's current and planned spent fuel storage capacity will be exhausted. During 1995, CEZ sent tender offers to 16 companies

worldwide, and received expressions of interest from nine, which were asked to submit proposals. Six possible sites were identified for the facility, and a final site was expected to be selected in early 1997, with construction starting soon after the year 2000. The facility would meet the country's radioactive waste storage needs for about 50 years.

In February 1996, CEZ had shortlisted four companies bidding on construction of the facility. The utility—which was considering only technology based on dual-purpose (storage and transportation) casks—will probably not make a final selection until the end of the decade.

But in March 1997, the Czech government decided on a different solution for spent fuel storage, lifting a prohibition on the expansion of the 600-metric-ton interim storage facility at Dukovany and opting for the construction of a new interim storage facility at the Temelin plant. In May, CEZ said that it would ask the companies on its shortlist for a central interim storage facility to propose alternatives for expansion of the interim facility at Dukovany.

The Czech Republic has launched a deep geological repository project, with the country's Nuclear Research Institute in charge. The project calls for national legislation in 1996 as a foundation for the project, with the repository becoming operational in 2035.

Under the country's new atomic law, a levy on the producers of radioactive waste will be used to fund a new state organization—the Radioactive Waste Repositories Management Office—charged with accepting all radioactive waste and organizing its disposal.

Technical/Upgrading Activities

CEZ has awarded several contracts to Western firms for safety-related improvements to both its operating nuclear plant and its plant under construction. For details on specific improvements to its operating plant, see the summary sections on the Dukovany plant.

Under the Communist regime, Czechoslovak equipment manufacturing companies had supplied some of the major components of VVER nuclear plants. Today, most of those companies—formerly state owned—are seeking to privatize, often by selling shares to foreign firms. In a bid to produce equipment that meets Western safety standards, some are exploring joint ventures with Western companies and applying for Western certification.

Skoda Plzen, which makes heavy component sets for VVER reactors, has obtained American Society of Mechanical Engineers (ASME) certification, and Vitkovice, which makes steam generators and pressurizers, has been certified under the ASME code and also meets the French code for generator parts fabrication.

Temelin. Westinghouse, Siemens/KWU, Sweden's Asea Brown Boveri (ABB) and France's Cegelec submitted proposals in 1991 for upgrading the instrumentation and control (I&C) systems at the two Temelin units under construction. In August 1991, CEZ asked Westinghouse and ABB to conduct

parallel preliminary design studies of a replacement I&C system for the original Soviet-designed system.

Also in August 1991, CEZ announced an audit of Temelin 1 and 2. The initial phase of the audit, which was to be completed in about three months, was to examine design analysis, safety analysis, project management, quality assurance, safety levels, licensing aspects, and economics. The audit also was to compare plant codes and operating standards with those at nuclear plants in the West. The results of the audit, to be conducted by Halliburton NUS Corp., would be used to make any modifications considered necessary for plant safety and reliability.

In November 1991, a U.S. company, General Physics International Engineering and Simulation (GPI), and a Czechoslovak simulator manufacturer, Orgrez, were awarded a contract by CEZ to build a full-scope, plant-referenced simulator. GPI will provide software technology as well as computer systems. Temelin nuclear plant personnel will be trained at CEZ training centers.

Temelin Audit. The results of the first phase of the Temelin audit, released in March 1992, said that the plant could meet Western safety standards if CEZ carried out such planned backfits as replacing the I&C system and making provisions for improvements to the Soviet-designed core. In addition, CEZ must make other technical and program improvements, such as conducting a probabilistic safety assessment (PSA). CEZ accepted all the recommendations.

The preliminary results of the second phase of the audit, which covered management and organizational issues, scheduling and costs, indicated that the two units can be upgraded to Western safety standards without significant impact on overall plant costs or schedules, and that the plant can be licensed by the mid-1990s.

In the fall of 1992, CEZ signed letters of intent with Westinghouse to supply both the nuclear fuel for Temelin and the plant's I&C system. CEZ awarded a contract for the PSA, to begin in April 1993, to Halliburton NUS. The results of the PSA were to be used to make decisions on additional proposed design improvements to Temelin.

Financing. On March 10, 1993, the Czech government gave its approval for the completion and commercial operation of the Temelin plant. Citibank and a Belgian bank agreed to lend CEZ $317 million for the project, with the U.S. Export-Import Bank, Belgium's Office National du Decroire and the Czech government guaranteeing the loan. Because of delays, the cost of the project has increased from $2.3 billion to nearly $2.5 billion.

Project Milestones. During 1996, the Czech Republic's State Office for Nuclear Safety—the country's nuclear regulator—reviewed the design changes developed by CEZ and Westinghouse to upgrade the original design to Western standards. It also reviewed Westinghouse's plans to upgrade the I&C system, and CEZ's preliminary and final safety analysis report.

Operating Soviet-Designed Nuclear Power Plants In The Czech Republic

Key

VVER ■

VVER Under Construction □

A consortium led by the U.S. company Science Applications International Corp.—with Britain's Nuclear Electric as the main subcontractor—has won a contract to assess and improve the protection systems software at the plant.

Emergency operating procedures, contracted for in 1993, have been developed and are in place at the plant.

Unit 1's reactor pressure vessel and steam generators were installed in May 1993. Unit 2's pressure vessel and steam generators were installed between August 1995 and November 1995. Westinghouse expects to have Unit 1's I&C system installed and tested by the end of 1998. The Westinghouse-fabricated fuel is scheduled to be loaded in March 1999. At present, civil work on Unit 1 is 95 percent complete, with 75 percent of the technology installed; civil work on Unit 2 is 65 percent complete, with 15 percent of the technology installed.

Plant Operating Practices

The State Office for Nuclear Safety is responsible for reviewing the qualifications and performance of nuclear plant personnel. It oversees staff training, licenses control room operators and administers the work of the State Examination Committee—which tests the qualifications of plant personnel.

Prior to the breakup of the CSFR, there were three training centers for nuclear power plant personnel in the former federal republic, one for skilled workers in the Czech Republic, at Brno, and two in the Slovak Republic, one for skilled workers at Piestany and one for professional employees with university degrees at Trnava. Now, all Czech personnel receive classroom training at Brno and control room operators go to Trnava in the Slovak Republic for simulator training.

Programs consist of initial classroom training, practical training at a nuclear power plant, and examinations. Training programs range from one to 24 months, depending on the position.

Control-room operators receive about 80 weeks of training, which includes 30 weeks in the classroom, 20 weeks of on-the-job training and five weeks of training on the full-scope VVER-440 Model V213 simulator at Trnava. Then, following an examination, the operators receive on-the-job training in a main control room as well as specialized training. After that, they take a state theoretical and practical examination, followed by four to 10 weeks of supervised on-the-job training.

Operators are licensed for two years and must take an examination consisting of written, oral and practical tests for renewal.

International Cooperation/Assistance

After the collapse of its Communist regime, Czechoslovakia became increasingly active in international efforts to improve nuclear power plant safety and operation.

In 1991, the CSFR's deputy minister of economy requested cooperation from the West in all spheres of the country's nuclear power development policies, including upgrading nuclear units to the safety levels of Western Europe.

WANO Membership. The Czech Republic utility CEZ is a member of the World Association of Nuclear Operators' (WANO's) Moscow Center. Under the auspices of WANO, representatives of the Dukovany plant have visited nuclear plants in the West (see individual plant summaries).

Foratom Participation. The Czechoslovak Nuclear Forum, founded in 1990, became an associate of Foratom (the umbrella group for 14 European nuclear industry forums) that same year. In 1991, the forum hosted a Foratom meeting in Prague. There is now a Foratom organization in the Czech Republic, headed by Jiri Benanek.

Utility Partnerships. Under a utility partnership program jointly sponsored by the U.S. Agency for International Development and the U.S. Energy Association (an association of public and private energy-related organizations that represents the United States on the World Energy Council), the Czech utility CEZ is paired with Houston Lighting & Power Co. The partnership involves exchanges of technical and economic information, seminars, and visits by managers to one another's plants.

Separately, CEZ and Germany's Bayernwerk signed a partnership agreement in 1996 between the Temelin plant and Bavaria's Isar 2.

EU Assistance. As part of its program of economic assistance to Eastern Europe—known as PHARE—the European Communities (now the European Union) earmarked 4.5 million ECU ($4.7 million) in 1990 for improvements to Czechoslovak plants and 3.5 million ECU ($3.7 million) in 1991. In 1992, the PHARE nuclear safety program was organized on a regional basis for Central and Eastern Europe, with 20 million ECU ($21.2 million) available for the region. The 1992 funding for the Czech Republic was intended for updating nuclear regulations, improving safety at the VVER-440 Model V213s and VVER-1000s, fuel cycle and waste management activities, and off-site emergency preparedness.

Czech Republic projects funded under the PHARE program include a study of I&C at the Temelin units under construction; a study of I&C replacement at the Dukovany plant; and operator training. Under the PHARE program for 1993, which also provided 20 million ECU ($21.2 million) in funding for the region, an audit of the Dukovany plant was initiated. The audit may result in a proposal for backfitting.

IAEA Training Seminars. Although the International Atomic Energy Agency (IAEA) is known for its inspection missions—including its Assessment of Safety Significant Events Team (ASSET) missions—to nuclear

power plants, the agency also conducts ASSET training seminars at a country's request. The seminars are designed to train operators and regulators in the use of the ASSET methodology to identify safety issues, to assess their consequences and to eliminate the root causes of likely future accidents and incidents.

NEA Membership. In the summer of 1996, the Czech Republic joined the Organization for Economic Cooperation and Development's Nuclear Energy Agency.

Plant Inspections

At the request of the CSFR, the IAEA sent missions to both Dukovany and Temelin. The missions to Dukovany are detailed in the separate summary of that plant.

Temelin Pre-OSART. At the CSFR's request, the agency sent a Pre-Operational Safety Team (Pre-OSART) mission April 23-May 11, 1990, to the two VVER-1000 units under construction at Temelin.

The team evaluated 11 general areas, including project management, civil construction, mechanical and electrical equipment, training, preparation for startup and operations, and radioactive waste management.

The team made several suggestions for improvements, including streamlining the plant's operating organization by separating operating, maintenance and technical support into function groups that cooperate on projects. It also urged that quality assurance be expanded into a comprehensive program in keeping with international standards, and it said that CEZ should be given the necessary tools to help contractors and subcontractors improve industrial safety and housekeeping practices on-site.

Follow-Up Temelin OSART Mission. The CSFR requested a follow-up review to the 1990 mission, which was conducted Feb. 17-21, 1992. The purpose of the review was to evaluate the actions taken in response to the recommendations and suggestions made during the original Pre-OSART mission. The team noted that the Czech utility and plant management were acting on, or had completed, many of the recommendations. But further efforts were needed in some areas, it added, such as: centralization of the Czech utility's nuclear activities; further development and implementation of quality assurance programs; development of a maintenance strategy; and improved implementation of industrial safety requirements.

OSART Safety Review Mission. An IAEA OSART safety review mission visited Temelin March 11-15, 1996, to examine the plant's design and operational safety upgrades, with emphasis on the design upgrades.

Planned Pre-OSART Mission. An IAEA pre-OSART mission plans to visit the Temelin plant in 1998.

DUKOVANY NUCLEAR POWER PLANT

Type: VVER-440 Model V213

Units: Four

Total megawatts (net): 1,560

Location: Dukovany, Moravia, Czech Republic

Dates of initial operation: Unit 1 - August 1985
Unit 2 - September 1986
Unit 3 - May 1987
Unit 4 - December 1987

Principal Strengths and Deficiencies

For an overview of the principal strengths and deficiencies of Soviet-designed plants, see **Soviet Nuclear Power Plant Designs**.

Operating History

Dukovany's operating history has been essentially free of controversy. An International Atomic Energy Agency (IAEA) mission to the plant in 1989 described it as having high availabilities and load factors, with a low—and decreasing—number of unplanned shutdowns. According to the IAEA team, the number of reportable events was within the normal range, and radiation exposure of plant employees was extremely low.

Four events were reported at the plant in 1996, all classified as Level 1—an anomaly—on the International Nuclear Event Scale.

Technical/Upgrading Activities

The Dukovany units are based on the second-generation VVER-440 design and share many of the generic deficiencies common to this design. Plant management and the Czech utility have turned to Western companies for help in upgrading Dukovany in an attempt to address some of these deficiencies.

- Between 1984 and 1986, Germany's Siemens/KWU supplied loose-parts monitoring systems and component-vibration monitoring systems to all four Dukovany units.

- Following an analysis of Dukovany's Soviet-designed instrumentation and control (I&C) system, plant management recommended replacement with a Western-designed system. Siemens/KWU was awarded a contract in 1990 to supply a new I&C system. However, the Czech and Slovak Federal Republic (CSFR) government said in April 1992 that a study of I&C system replacement in VVER-440 Model V213 reactors would be carried out under the European Communities' PHARE program. The study found that extensive I&C refurbishing or replacement was needed at Dukovany, and a contract was signed with the U.K.'s NNC Ltd. in 1993 to provide full technical specification of the I&C system. The replacement itself will be funded by CEZ, which expects to complete the work before the year 2000.

- Also under the PHARE program, NNC Ltd. is leading a consortium that will prepare the data packages needed to develop software for a simulator. The simulator is expected to be supplied by 1998.

- Another PHARE-funded project, expected to begin in early 1996, entails the supply of computer models for severe accidents, training in their use, and a large program of analysis and development of VVER accident management programs.

The Czech Republic's Nuclear Research Institute carried out a probabilistic safety assessment (PSA) of Dukovany in 1993, which indicated areas that needed upgrading. Much of the upgrading work was carried out during the PSA, including extending the scope of the emergency operating procedures and redesigning the emergency power supply system. The PSA was then extended, incorporating equipment qualification, more detailed recognition of human factors, internal flooding and fires. In 1995, the focus was the plant's low-power and shut-down phases. The Institute and plant personnel, together with the U.S. company Science Applications International Corp., have completed the first applications.

A major overhaul of Dukovany Unit 3, including a number of modifications to upgrade operational safety, was completed in 1992. Between 1994 and 1996, the plant plans to evaluate the integrity of all units' primary circulation, steam and feedwater piping. According to plant management, major upgrading of all four units, based on a probability safety assessment, is planned after the year 2000, when Temelin will be in operation. The plant is also carrying out extensive reconstruction of electrical supply and distribution systems, replacing some equipment.

Another major undertaking was the plant's aging control program, aimed at ensuring safe operation over the plant's design lifetime. A basic part of this program entails the systematic monitoring and evaluation of such equipment as the reactor pressure vessel, accident localization system, steam generators, main recirculation pump and turbine generator. The program was audited both internally and externally. The external audit focused on the plant's mechanical systems. It was funded with 1 million ECU ($1.06

million) from the EU's PHARE program, and was completed by the end of 1995.

In cooperation with the U.S. company Westinghouse, Dukovany plant operators have written new emergency operating procedures. Because the four units vary somewhat from one another, each unit has its own documentation. The English version of the procedures was completed in early 1997 and was then translated by the plant. Dukovany awarded a contract to NNC of the United Kingdom to review the plant's emergency operating procedures and provide consultancy services in quality assurance.

In March 1996, CEZ officials said that the utility planned to invest $750 million on a hardware maintenance, backfitting and monitoring program for Dukovany. As a result of the program, the units are expected to be able to operate at least 10 years beyond their design life. The life extension program was launched in 1992 and augmented by the plant audit. A two-part IAEA safety mission in October 1995 supported the life extension program.

According to a CEZ official in March 1996, the utility expected to spend about 1.3 billion Czech crowns ($37.6 million) during the year for upgrades and component replacement. Annual investments for improvements are expected to be 2.5 billion Czech crowns ($72.4 million) in 1997 and 1998, 2 billion Czech crowns ($57.9 million) in 1999 and 2000, and 2 billion Czech crowns by 2003. Through 2005, CEZ expects to spend 20 billion ($579.4 million) for upgrading and life extension at Dukovany, according to the official.

International Exchange/Assistance

WANO Exchanges. Under the auspices of the World Association of Nuclear Operators, Dukovany hosted personnel from the U.S.'s Grand Gulf nuclear plant in 1990, and staff from Dukovany visited the Grand Gulf plant in 1990, the U.S.'s San Onofre plant in March 1992 and Japan's Tsuruga plant in June 1992. Staff from Dukovany visited Russia's Kola plant in March 1996, and hosted staff from Kola the same month.

Dukovany has requested a WANO peer review, which is scheduled for November 1997.

Plant Twinning. The Dukovany plant has been twinned with France's Saint Alban plant, Germany's Obrigheim plant, Hungary's Paks plant and Russia's Kola plant.

IAEA Training Seminar. An IAEA training seminar is scheduled to be held at the Dukovany plant Dec. 3-5, 1996, to review the findings of the October 1996 ASSET peer review mission.

Inspections

OSART Mission. In September 1989, an IAEA Operational Safety Review Team (OSART) mission reviewed safety practices at Dukovany 3.

- It found highly qualified management and a well-trained workforce, aware of health and safety practices. The team called Dukovany's operating history impressive and said exemplary safety practices would be communicated to other plants.

- Among the team's recommendations were limited streamlining of Dukovany's organizational structure and strengthening of the quality-assurance function. In addition, the team recommended an increase in control room personnel and said that operating procedures should be upgraded and expanded.

Follow-Up OSART Mission. After a November 1990 follow-up visit, the team noted that improvements had been made at Dukovany: A new organizational structure was being developed, quality assurance was being improved, and more efficient feedback of operational experience was being organized.

At the same time, the team found areas where little progress had been made: an on-site plant-specific simulator for training control room personnel, recording capability for plant disturbances, and an advanced training facility for firefighters.

OSART Technical Exchange Mission. An IAEA Technical Exchange Mission—part of the OSART program—visited Dukovany Oct. 14-25, 1991, to review the plant's maintenance practices. The team's overall impression was favorable. It noted that the plant's management had made major efforts to develop a modern approach to maintenance, and said that the maintenance policy compared well with those at Western plants. The team also noted that the plant's preventive maintenance program is comprehensive and effectively supports nuclear safety.

The team suggested that plant management make efforts to develop a comprehensive predictive maintenance program to optimize its preventive maintenance program and the cost-effectiveness of maintenance activities. It also suggested that management use critical path analysis in the scheduling and follow-up of refueling outages.

ASSET Mission. An IAEA ASSET mission visited the Dukovany plant Oct. 11-22, 1993, to assess the effectiveness of the plant's policy on incident prevention. The team reviewed 476 events reported between April 1988 and March 1993. Of these, 383 were considered to be of safety relevance; one event was classified as Level 2, 19 were classified as Level 1 and the rest as Level 0. The team observed that the number of reported events rose slightly between 1988 and 1990, but fell in 1991 and again in 1992.

The team identified five pending safety problems:

- diesel generator failures.
- common cause failures owing to lack of protection of electrical equipment.
- deficiencies in and unreliable operation of I&C systems.
- problems with the quality of maintenance procedures and acceptance criteria following testing.
- plant configuration errors following maintenance.

The team noted that electrical system weaknesses such as cable insulation will continue to undermine the reliability of essential electrical supplies until planned improvements are implemented. The team also identified deficiencies in the quality of the procedures, maintenance and testing of 400 kV circuit breakers and their associated protective equipment.

In addition, the team stated that the plant's analysis of events is inconsistent in its thoroughness, and observed that failure to effectively analyze events would undermine the plant's reliability.

Among the team's comments:

- The plant has carried out a significant number of improvements and is to be commended for its progressive attitude, but more needs to be done.
- When investigating events, more attention needs to be paid to procedural aspects.
- CEZ's electrical transmission department and the plant need to develop an interface and a surveillance program to identify deficiencies in investigative procedures.
- The plant is to be commended for its willingness to enlist expert support from external sources.

The team made a number of recommendations to management, including:

- implement plans to replace 6 kV cables and install 400 kV circuit surge suppressors,
- improve means of indication that a diesel generator is not in the normal stand-by mode,
- improve the procedures for investigating unusual events to obtain results more quickly,
- improve quality assurance measures that ensure goods and services provided to the plant are suitable for their intended purpose,
- cooperate with other VVER-440 Model V213 plants to improve the mutual exchange of operating experience, and
- review reporting criteria with the aim of streamlining the level of reporting.

The team noted that many of the recommendations apply to improvements under way at the plant, and suggested a follow-up ASSET mission to Dukovany in 18-24 months. The team also suggested that Dukovany request an ASSET seminar on the INES rating system and ASSET root-cause analysis tailored to the plant's needs.

Safety Review Mission. An IAEA Safety Review Mission visited the Dukovany plant in November 1995 to review the plant modernization program prepared by Dukovany in cooperation with other Czech and

international organizations. The team found that all safety issues identified by the IAEA for the VVER-440 Model V213 had been addressed by the plant with specific safety improvement measures. According to the team, the most important activities planned for the near future include: qualification of safety valves for steam-water flow, and installation of additional relief valves qualified for water flow both on the pressurizer and steam generators.

The team found that issues in the area of component integrity were especially well addressed, and that a considerable amount of work had already been done. According to the team, the measures related to strengthening the bubbler condenser structure needed reconsideration so that weak mechanical points could be strengthened. Dukovany asked the IAEA to send a mission to review the scope of measures aimed at strengthening the bubbler condenser structure.

ASSET Mission. An ASSET peer review mission visited Dukovany Oct. 7-11, 1996, to review the plant's self-assessment of operational safety performance based on ASSET procedures. The team found that the plant's detailed screening of operational events highlighted a few safety problems—in reactor power control, on-site electrical supplies, operating procedures and human factors—that had not yet been completely eliminated. The pending safety problems had been addressed by appropriate corrective actions, however, to eliminate the weaknesses identified in reactor power control and on-sight electrical supplies. The team noted that the plant had prepared an action plan to address the problems, which included appropriate corrective actions to eliminate and prevent recurrence of the problems.

The team also reached several conclusions, among them:

- The plant defense-in-depth hardware provisions made by management appear to have complied with the primary intent: the prevention of incidents and accidents. While software areas—procedure and personnel—had been addressed, however, a more challenging review could have been beneficial.

- The events that had occurred over the three-year period 1993-1995 had highlighted their vulnerability in the areas of communication, procedure adequacy and related adherence.

- Plant safety culture had been developing since the 1993 ASSET visit.

- The plant's technical director was encouraged to require an annual self-assessment of operational safety performance based on the current annual safety report, which should be reviewed at the site or at company level by an independent group.

- An ASSET mission should be scheduled in a few years to peer review the current annual self assessments of Dukovany safety performance.

NUCLEAR ENERGY IN THE SLOVAK REPUBLIC

The Slovak Republic operates four VVER-440 units at Jaslovske Bohunice. Nuclear energy accounted for 49.8 percent of all electricity supplied by the Slovak utility SE in 1996, compared with about 44 percent in 1995. Thermal plants accounted for 30.4 percent of the utility's electricity, and hydro plants for 19.8 percent.

Nuclear Program and Plans

The Slovak Republic has four VVER-440s under construction at Mochovce. To help achieve self-sufficiency in electricity generation, the country is pressing ahead with the completion of two of the four planned Mochovce units. Unit 1 is expected to be completed in 1998, and Unit 2 in 1999.

Formulating and Implementing Electricity Policy

Before the breakup of the Czech and Slovak Federal Republic, the Federal Assembly was considering a draft energy policy that would continue the country's nuclear program and reduce reliance on coal and oil in favor of natural gas and renewable energy sources. The Slovak government has now developed its own energy policy, and continues to support the use of nuclear energy. Without nuclear energy, the country could not meet its commitments for reliable electricity supply, the chairman of the Slovak utility said in May 1997.

Completion of Mochovce. In a policy statement in January 1995, the Slovak government stated it would ensure completion of the construction of units 1 and 2 of the Mochovce nuclear plant. The same month the Slovak Ministry of Economy issued a statement in response to criticism of the Mochovce project by Greenpeace in which it defended the completion of

Mochovce 1 and 2 as the least-cost source of electricity. The ministry also stated that the country planned to complete all four units at Mochovce.

Following a visit to Austria in March 1996, Slovak Premier Meciar told Slovak radio that the country depended on nuclear energy and could not shut down a nuclear plant without having a replacement. He reportedly said that it might be possible to close Bohunice units 1 and 2 by the year 2000.

In April, the premier said that Slovakia intended to complete units 3 and 4 at Mochovce, but with their completion would build no more nuclear power plants. In May, Economics Minister Jozef Ducky said that the country would close Bohunice units 1 and 2 after the Mochovce units had undergone trial runs and a year of commercial operation. Closure could occur by the year 2002, he said.

Utility Operations. Slovenske Elektrarne (SE)—formerly Slovensky Energeticky Podnik (SEP)—the Slovak utility, is responsible for electricity generation and high-voltage transmission in the Slovak Republic. Three companies are responsible for regional electricity distribution.

In September 1994, the Slovak government approved the privatization of SEP—which was state-owned—but the proposed plan did not go into effect, and privatization of the utility is still under discussion.

At a news conference in Bratislava in June 1995, SE management reportedly described the company as being under severe financial pressure, in part because of a heavy debt burden. According to management, SE lacked the resources to replace equipment at generating plants and pay suppliers.

In May 1996, the Slovak government reportedly agreed in principle to raise electricity prices. Prices were raised effective Aug. 1.

SE reports to the Slovak Ministry of Economy.

Nuclear Energy Oversight

Like its neighbors in Eastern Europe using Soviet-designed nuclear plants, the former Czechoslovakia had adopted not only the technology but the regulatory model in place in the former U.S.S.R. That meant a single organization—the Atomic Energy Commission (AEC)—promoted nuclear power and regulated nuclear plant operations. Within the AEC, the Nuclear Safety Inspectorate was responsible for issuing safety regulations.

New Republic Entity. With the creation of separate Czech and Slovak republics in January 1993, regulatory bodies were established for each republic. The Nuclear Regulatory Authority of the Slovak Republic, headed by Jozef Misak, has two sections: a nuclear safety policy section and a nuclear safety evaluation and inspection section. The evaluation and inspection section consists of departments for nuclear safety evaluation, systems and components, nuclear materials and physical protection, decommissioning and radioactive waste. The nuclear safety policy section consists of departments for international cooperation, legal and quality

assurance matters, crisis management and management of the emergency response center, and general administration.

In October 1996, a department of safety analysis was created; it reports directly to the authority's chairman.

The authority has a staff of 80 people, six of whom serve as resident inspectors at Bohunice and Mochovce.

Status of Liability Coverage

The Slovak Republic has drafted national legislation that includes a provision making the license holder responsible for any nuclear damage resulting from an accident at a nuclear power plant. Pending enactment of the legislation, the Slovak government approved a declaration on civil liability for nuclear damage that makes SE liable for damage, with the government providing coverage for any claims. The legislation is expected to be approved by the Slovak Parliament in 1997.

In addition, a nuclear insurance pool for the Slovak Republic's reactors was expected to be established by mid-1996. According to Prime Minister Meciar, the country has allocated 2 billion Slovak crowns ($574.4 million) to cover damages resulting from a nuclear accident.

The Slovak Republic is a party to the Vienna Convention, which ensures that the responsibility for damage caused by a nuclear accident is channeled to the plant operator. The republic is also a party to the 1988 Joint Protocol on Civil Law Liability and Compensation for Cross-Boundary Damage from Nuclear Accident, which resolves potential conflicts between the Paris Convention—which covers 14 European countries—and the Vienna Convention—which has worldwide coverage.

Fuel Supply and Waste Disposal

Supply of Fuel. Nuclear fuel for the Bohunice plant has historically been supplied by Russia, but in 1992 SEP requested bids from other suppliers for fuel for the two VVER-440 Model 213 units at Bohunice and the Model 213 units under construction at Mochovce. It received five bids, one from Russia and the others from Western suppliers that proposed developing the VVER fuel. In March 1994, however, during discussions of Russian assistance to the Slovak Republic for completion of the Mochovce plant, the Russian Minister for External Economic Relations agreed to continue supplying fuel to the Slovak Republic.

SEP, together with the Czech utility CEZ, bought some 400 unused fuel assemblies from the closed Greifswald plant in former East Germany. In the fall of 1992, 111 of the assemblies were shipped to the Bohunice plant.

Under an agreement signed in October 1995, the Slovak Republic will buy nuclear fuel from Russia for the operating life of the Slovak nuclear power plants. Either side can cancel the agreement at any time. In September

1996, Slovak Premier Meciar said that the country would continue to import nuclear fuel from Russia.

Spent Fuel Storage and Disposal. In the past, spent fuel from the Bohunice plant was kept for 10 years in the 600-metric-ton interim storage facility at the plant site and then sent to the former Soviet Union for reprocessing. Until the breakup of the Czechoslovak Federal Republic, the Dukovany plant sent its spent fuel to Bohunice's interim storage facility. But in 1993, the Slovak utility SEP—now SE—said it was no longer willing to accept Dukovany's spent fuel. In July 1995, SE began shipping Dukovany's spent fuel back to the Czech Republic plant, where an interim storage facility had been built and licensed.

During the summer of 1995, Bohunice plant management was attempting to renegotiate its agreement with Russia, and Russia was reportedly reviewing the agreement. According to the Slovak press, Russia's minister of atomic energy said during a December 1995 meeting with the Slovak Republic's economy minister that Russia would take back Bohunice's spent fuel in 1996. The interim storage facility at Bohunice will run out of capacity in 1999, and SE plans to build a long-term storage facility for spent fuel from the Bohunice and Mochovce plants.

In September 1996, a public hearing was held at Bohunice to discuss a project to expand the capacity of the intermediate storage facility for spent fuel and increase the facility's seismic resistance. In addition, the project would extend operation of the facility from 10 years to 50 years.

Technical/Upgrading Activities

SEP, the Slovak utility, awarded several contracts to Western firms for safety-related improvements to both Bohunice and Mochovce. For details on specific improvements, see the summary section on the Bohunice plant.

Mochovce. Between 1988 and 1990, Siemens/KWU supplied loose-parts monitoring systems for all four Mochovce units, as well as component-vibration monitoring systems. SEP announced that it had chosen Siemens/KWU to supply instrumentation and control (I&C) equipment for the four Mochovce units, and by October 1993, I&C equipment furnished by Siemens had been installed in Mochovce units 1 and 2.

Work on Mochovce was halted in 1990 because of lack of funding. In the spring of 1992, safety experts and nuclear engineers from four organizations—Germany's GRS (Institute for Nuclear Safety) and Siemens, and France's IPSN (Institute of Nuclear Protection and Safety) and Framatome—audited Mochovce's design, quality of construction and training needs. The results showed that the plant could be backfitted to meet Western safety standards.

Joint Venture. To find ways of paying for completion of the Mochovce plant to Western safety standards, SEP engaged in discussions with Electricité de France and Germany's Bayernwerk and PreussenElektra. In January 1994, the utility signed an agreement with EdF establishing a joint venture—

EMO—to finish the first two units at Mochovce. EdF owned 51 percent of EMO and SEP, 49 percent. Bayernwerk said it might also join EMO.

SEP—now SE—approached the European Bank for Reconstruction and Development about helping to finance the plant's completion, but both the bank and EdF insisted that any aid for Mochovce be conditional on a commitment by SEP to close units 1 and 2 at the Bohunice plant.

In 1994, Russia offered the Slovak Republic a credit of $450 million for the completion of the Mochovce plant. The Russian government also indicated that it might pay off some of its inherited debt to the Slovak Republic by supplying nuclear plant components.

In October 1994, the Slovak Republic's Nuclear Regulatory Authority reviewed a safety improvement report on Mochovce prepared by EdF with the help of SEP, Framatome and Siemens. In December 1994, the results of several studies were presented to the EBRD at a meeting on the project. One study, a least-cost analysis by the U.S. firm Putnam, Hayes & Bartlett, concluded that completion of the two Mochovce units would cost less than the alternatives analyzed, which included converting Mochovce to a combined-cycle combustion turbine plant, importing more electricity or relying more on combined heat and power production.

A safety analysis by Riskaudit, a Franco-German joint venture, noted that the bubbler condenser—a vapor-suppression confinement structure—had been demonstrated to reliably prevent confinement overpressure in international testing. An environmental impact assessment prepared by the U.K.'s AEA Technology concluded that the two units could be upgraded to be consistent with Western safety requirements and practices.

Project Costs. EMO, the French-Slovak joint venture, estimated the cost of the project at roughly DM 1.452 billion ($778.2 million). The project sponsors sought DM 412.5 million ($221.1 million) from the EBRD and DM 366.3 million ($196.3 million) from Euratom. In early February 1995, following a meeting between Russian Premier Viktor Chernomyrdin and Slovak Premier Vladimir Meciar in Moscow, Slovak officials announced that Russia was interested in helping to complete the Mochovce units.

Project Opposition. Also in February 1995, the European Parliament passed a resolution opposing the completion of the Mochovce units because the project lacked sufficient safety guarantees. The resolution is not binding on either the European Commission or the European Investment Bank.

In early March, Slovak premier Vladimir Meciar said that the country could not comply with two of the EBRD's conditions for a loan for Mochovce—increasing energy prices by 29 percent by the end of March, and shutting down Bohunice units 1 and 2 in 1999-2000, even if the two Mochovce units had not yet come on line. In mid-March, the European Parliament adopted a resolution calling for the EBRD and the European Union (EU) to freeze funds for Mochovce until the plant's economic advantages and safety could be demonstrated. In response, the Slovak Republic asked the EBRD to postpone its vote—planned for late March—on the loan for Mochovce.

Czech Offer. At the end of March, the Czech company Skoda Praha offered to complete the Mochovce plant, including safety improvements, for DM 700 million ($375.2 million)—about 30 percent less than the cost estimated by EMO. In early April, SE asked EdF to renegotiate its bid to lead a consortium to complete the plant.

In September, the Slovak government rejected the EBRD offer to help fund Mochovce's completion, saying the conditions were unacceptable. According to a spokesman of the Slovak Ministry of Economics, the government intended to pursue the offer from Skoda Praha, with financing from two Czech banks ($400 million), the Russian government ($80 million), and other sources, including EdF, the European Commission and commercial banks. Under the Czech offer, the plant could be completed for DM 1 billion ($536 million). The Slovak cabinet instructed the economics minister and the National Bank of Slovakia to develop a financing plan by the end of the year.

At the end of September, SE announced that it had chosen a Czech-Russian team—Skoda Praha and Energoproject of Prague, and Atomenergoeksport and Zarubezhatomenergostroy of Russia—to complete Mochovce. Germany's Siemens and France's Framatome would work with the Russian designers to provide safety upgrades. SE added that it was considering an offer of technical assistance from EdF. SE said it would sign contracts with investors at the beginning of 1996.

At the end of October, the Slovak Republic and Russia signed an agreement that included a provision on the completion of Mochovce. In addition to making a loan of $150 million for completing Unit 1, Russia will supply fuel for the plant and will reprocess the spent fuel. According to Russian atomic energy minister Viktor Mikhaylov, the completion of the second unit would require about $400 million. The Slovak press reported, however, that during a meeting between Mikhaylov and the Slovak Republic's economy minister in December 1995, Mikhaylov said Russia would give the Slovak Republic fuel and labor worth $70 million to defray the trade deficit with the republic that Russia had inherited from the former Soviet Union.

In December 1995, SE and EdF signed an agreement under which EdF would help with project management, quality assurance, scheduling, cost assessment, and the modernization program planned for Mochovce units 1 and 2. SE and the Slovak government were reportedly attempting to arrange for financing that would allow completion of the two units with the help of Czech and Russian engineering firms, with EdF providing technical assistance and France's Framatome and Germany's Siemens working as direct contractors to SE on safety upgrades.

Revised Project Cost. In February 1996, the Slovak economics minister said that SE had initialed contracts for loans of $200 million and DM 200 million ($107.2 million) for Mochovce's completion from two Czech banks. In addition, he said that Skoda Praha would invest 300 million Czech crowns ($8.6 million) and Russia, $150 million ($70 million of that amount reportedly for nuclear fuel, $30 million as a credit for equipment and $50 million as a loan). Funding will also be provided by a German bank, a French bank and two Slovak banks.

According to a March Slovak press agency report, the ministry of economy has put the cost of the project at 26.7 billion Slovak crowns ($766.8 million). Skoda Praha's share of the work is estimated at 10 billion Slovak crowns ($287.2 million). Eucom—a consortium of Siemens and Framatome—will carry out safety-related work at a cost of about 2.8 billion Slovak crowns ($80.4 million). The upgrades will include equipment for accident prevention and control, and for radiation and fire protection, as well as instrumentation and control (I&C) equipment in addition to that already supplied by Siemens. Separately, Siemens delivered a full-scope simulator in the summer of 1995, and it is being used to train the plant's future operators.

Roughly 80 percent of the project cost is earmarked for engineering analyses and other studies to ensure that the units meet new safety requirements established by the Slovak Nuclear Regulatory Authority based on advice from the International Atomic Energy Agency and Riskaudit—the Franco-German joint venture—as well as assessments by the NRA itself. Slovak regulators must approve a final safety analysis report before the units can begin operation.

In March 1996, Slovak officials reportedly said that SE had agreed to pay Russia's Atomenergoeksport $18 million for all relevant design information on the Model V213.

In April, the Slovak government guaranteed loans to SE from Russian, Czech and European banks. Later the same month, SE signed final contracts with project suppliers for the completion of the two units. In June, SE signed a contract with EdF under which the French utility will provide technical assistance at Mochovce.

Completion Schedule. Construction work on Unit 1 was 95 percent complete and engineering work was 85 percent complete in March 1996. Construction work on Unit 2 was 75 percent complete and engineering work, 70 percent complete. According to Slovak Prime Minister Meciar, the target date for completion of Unit 1 is June 1998, with Unit 2 to be completed in March 1999. He said that 800-900 million Slovak crowns ($22.9-25.8 million) of the project's 26.7 billion Slovak crown cost will be used to work on units 3 and 4 while the first two units are being completed. The cost of completing units 3 and 4—which are 40-50 percent complete—is estimated at 40 billion Slovak crowns ($1.14 billion). In November 1996, however, Meciar said that no construction permit had been issued for units 3 and 4.

In June 1997, on-site electricity supply systems were successfully tested for Unit 1, the first in a series of tests leading to reactor start-up.

Plant Operating Practices

Prior to the breakup of the CSFR, there were three training centers for nuclear power plant personnel in the former federal republic, one for skilled workers in the Czech Republic, at Brno, and two in the Slovak Republic—one for skilled workers at Piestany and one for professional employees at Trnava. The Trnava training center has a full-scope VVER-440 Model V213

Operating Soviet-Designed Nuclear Power Plants In The Slovak Republic

Key
VVER ■
VVER Under Construction □

simulator. A second full-scope simulator is operational at the Mochovce plant.

The Slovak Nuclear Regulatory Authority is responsible for reviewing the qualifications and performance of plant operators and other staff, approving training programs, examining licensed personnel and issuing licenses.

Initial training of nuclear plant personnel consists of several phases:

- theoretical training - 22 weeks,
- on-the-job training - 15 weeks,
- simulator training - 5-6 weeks on the full-scope simulator at Trnava,
- certification examination,
- specialized training at place of work - 4-12 weeks,
- licensing examination.

Operators are licensed for two years, and must pass written, oral and practical examinations for license renewal.

International Cooperation/Assistance

After the collapse of its Communist regime, Czechoslovakia became increasingly active in international efforts to raise nuclear power plant safety and operation.

In 1991, the CSFR's deputy minister of economy requested cooperation from the West in all spheres of the country's nuclear power development policies, including upgrading nuclear units to the safety levels of Western Europe.

WANO Membership. The Slovak utility SE is a member of the World Association of Nuclear Operators' (WANO's) Moscow Center. Under the auspices of WANO, representatives of the Bohunice plant have visited nuclear plants in the West (see individual plant summary).

Foratom Participation. The Czechoslovak Nuclear Forum, founded in 1990, became an associate of Foratom (the umbrella group for 14 European nuclear industry forums) that same year. In 1991, the forum hosted a Foratom meeting in Prague. No information is available on the status of the forum since the breakup of the CSFR.

Utility Partnerships. Under a utility partnership program jointly sponsored by the U.S. Agency for International Development and the U.S. Energy Association (an association of public and private energy-related organizations that represents the United States on the World Energy Council), the Slovak utility SEP is paired with Southern Electric International. The partnerships involve exchanges of technical and economic information, seminars, and visits by managers to one another's plants.

EC Assistance. As part of its program of economic assistance to Eastern Europe—PHARE—the European Communities (now the European Union) earmarked 4.5 million European Currency Units (ECU) ($4.7 million) in 1990 for improvements to Czechoslovak plants, 3.5 million ECU ($3.7 million) in

1991 and 20 million ECU ($21.2 million) in 1992. The 1992 funding was intended for updating nuclear regulations, improving safety at the VVER-440 Model V213s and VVER-1000s, fuel cycle and waste management activities, and off-site emergency preparedness.

Projects funded under the PHARE program include a study of I&C replacement at Bohunice 3 and 4; a probabilistic safety assessment (PSA) of Bohunice 1 and 2; and operator training. In addition, the European Nuclear Assistance Consortium, consisting of eight European companies, was awarded a contract under PHARE to carry out engineering safety audits of Bohunice 3 and 4. The project looked for differences in plant conditions between the two units.

Another PHARE-funded project, which was expected to begin in early 1996, entailed the supply of computer models for severe accidents, training in their use, and a large program of analysis and development of VVER accident management programs. PHARE also funded management training for nuclear power plant and regulatory staff.

IAEA Training Seminars. Although the International Atomic Energy Agency (IAEA) is known for its inspection missions—including its Assessment of Safety Significant Events Team (ASSET) missions—to nuclear power plants, the agency also conducts ASSET training seminars at a country's request. The seminars are designed to train operators and regulators in the use of the ASSET methodology to identify safety issues, to assess their consequences and to eliminate the root causes of likely future accidents and incidents.

In February 1992, the IAEA held an ASSET training seminar in Senec near Bratislava in the Slovak Republic. The seminar was attended by 29 people from Czech and Slovak nuclear plants, the country's regulatory agency and its research center.

Included in the seminar were two workshops, one on the International Nuclear Event Scale and one on the application of the ASSET root-cause analysis to operating events at the Bohunice and Dukovany plants.

An ASSET training seminar, planned for Jan. 8-12, 1996, in Bratislava, will provide guidance for the prevention of incidents.

Swiss-Slovak Safety Project. Under an agreement signed in 1996, Switzerland will finance a SF 800,000 ($1.2 million) two-year project aimed at supporting the Slovak Nuclear Regulatory Authority and enhancing nuclear safety in the country. The work will involve training and the establishment of a Slovak group of experts in safety assessment.

Polish-Slovak Nuclear Accord. Poland and Slovakia signed an agreement in September 1996 on timely announcements of nuclear accidents and cooperation in nuclear safety and radiation protection.

Canadian-Slovak Nuclear Cooperation. Canada and Slovakia signed an agreement in October 1996 to cooperate in the peaceful use of nuclear energy. Under the agreement, inspectors from the Slovak Nuclear Regulatory

Authority will receive training at Canada's Atomic Energy Control Board facilities.

Plant Inspections

At the request of the CSFR, the IAEA inspected the Bohunice and Mochovce plants. The IAEA's missions to Bohunice are detailed in the separate summary of that plant.

Mochovce Pre-OSART. The Pre-OSART mission to the Slovak Republic's Mochovce plant took place in January 1993. Following the three-week mission, the team concluded that the plant management intends to improve overall performance and ensure acceptable levels of safety. It noted a commitment to nuclear safety and a willingness to make improvements.

The team identified several commendable features in the plant's program, including: management's commitment to training; design-related activities such as replacement of control room panels and VVER safety improvements; improvements in the use of computers to manage plant programs; and improvements in emergency planning and preparedness.

The team also suggested areas for improvement:

- While acknowledging the plant's new quality assurance program and its use of international experience to improve management and safety programs, the team noted some aspects of existing safety and quality standards that needed to be strengthened, such as issuing a formal policy to provide safety guidance and using a nuclear safety review committee and a self-audit program.

- The team suggested that staffing, training and the preparation and use of procedures all could be improved.

- The team recommended that the plant staff play a stronger, more responsible role in monitoring and controlling the work of contractors and suppliers.

- Finally, the team suggested scheduling in sufficient detail the work that remained to be done at the plant.

BOHUNICE NUCLEAR POWER PLANT

Type: All VVER-440s; Units 1 and 2 are the V230 model; Units 3 and 4 are the V213 model.

Units: Four

Total megawatts (net): 1,632

Location: Jaslovske Bohunice, Slovak Republic

Dates of initial operation: Unit 1 - June 1981
Unit 2 - January 1981
Unit 3 - February 1985
Unit 4 - December 1985

Principal Strengths and Deficiencies

For an overview of the principal strengths and deficiencies of Soviet-designed plants, see **Soviet Nuclear Power Plant Designs**.

Operating History

The Bohunice plant—especially units 1 and 2, older VVER-440 Model V230s—has caused some concern among the public, particularly in neighboring Austria. Although the plant was the subject of a series of programs—first begun in 1984—aimed at improving safety and performance, in 1991 the Czechoslovak government launched a major program to upgrade units 1 and 2.

Technical/Upgrading Activities

The Slovak utility SEP—now SE—has contracted with Western companies for a number of safety-related improvements.

- In 1986, Germany's Siemens/KWU supplied loose-parts monitoring systems and component vibration-monitoring systems for Bohunice 3 and 4.

- In 1990, Siemens/KWU supplied component vibration-monitoring systems to Bohunice 1 and 2, and a year later, delivered leak-monitoring systems for the two units.

- In 1990, the utility commissioned Siemens/KWU to analyze the reactor safety systems at Bohunice 1 and 2. Areas covered included safety-system design, reactor performance under accident conditions, and instrumentation and control technology. In 1997, Siemens began installing its digital reactor protection system at Unit 2. If it performs well during a year of trial operation, SE plans to install the system in Unit 1.

- In June 1991, SEP awarded a contract to a French consortium of Cegelec and Thermatome to supply security systems at Bohunice, including an electronic entry-control system and Thermatome, a site-surveillance system.

- The CSFR government said in April 1992 that a study of instrumentation and control system replacement in VVER-440 Model V213 reactors would be carried out under the European Communities' PHARE program. The study found that extensive I&C refurbishing or replacement was needed at Bohunice units 3 and 4, and a contract was signed with the U.K.'s NNC Ltd. in 1993 to provide full technical specification of the I&C system.

- The U.S. company Westinghouse signed a contract with the Bohunice plant in 1993 to help develop emergency operating procedures. The English-language procedures are now being translated at the plant.

- During the plant's 1996 outage, the United Kingdom's Rolls-Royce and Associates was scheduled to take material samples from the units' reactor pressure vessels to enable the plant to identify the exact properties of welds for safety assessments.

Units 1 and 2. The government's phased safety-related backfit program for units 1 and 2—launched in 1991—consisted of 81 improvements. Under the 2 billion crown ($57.4 million) program, which resulted from an extensive safety assessment by the Czechoslovak Atomic Energy Commission's Nuclear Safety Inspectorate, the reactor pressure vessel at Unit 2 was annealed in February 1993. Based on a decision of the Slovak Nuclear Regulatory Authority, the vessel at Unit 1 was annealed in April of the same year.

In April 1992, the Slovak government reviewed a technical and economic analysis of the units' operation, and requested studies on three options: safety upgrading, conversion of the units to combined cycle, and closure of the units and their replacement with a new combined cycle plant. Studies of the three options concluded that safety upgrading of the units would entail lower capital and operating costs than the other two options. In addition to allowing units 1 and 2 to operate beyond 1995, a major backfitting program would significantly decrease the core melt frequency.

The Slovak regulatory authority asked that the proposed upgrading be reviewed by international experts. In July 1993, the IAEA convened such a meeting. After hearing presentations by Slovak safety authorities and

Bohunice management on safety improvements already made and the options for future major upgrades, the experts agreed that a major safety upgrade was technically feasible and would significantly raise the plant's level of safety. The experts made a number of recommendations on various options to help Slovak authorities make a final decision.

SEP proposed that upgrading be carried out gradually in two phases, during extended refueling outages. In January 1994, the republic's Nuclear Regulatory Authority laid out the conditions that would have to be met so that the two units could be licensed after each refueling. A total of 59 different sets of tasks were to be completed by December 1995, December 1996 and December 1997.

SEP approached both Westinghouse and Siemens about the units' reconstruction and both companies made proposals. SEP divided the project into two phases: basic engineering and implementation. In May 1994, Siemens was awarded the contract for basic engineering; this phase was completed by May 1995. Siemens also reportedly won the 5 billion Slovak crown ($143.6 million) contract for the implementation phase, which will begin in 1998.

Under a European Union-funded contract, the United Kingdom's Electrowatt carried out a comprehensive Level 1 probabilistic safety assessment (PSA) of Unit 1, estimating core damage frequency and identifying major contributors to it. The company evaluated the influence on core damage frequency of various plant and procedural modifications incorporated during the reconstruction of units 1 and 2, and also transferred the PSA methodology to plant staff.

According to Bohunice's manager, units 1 and 2 will have to operate beyond their original planned shutdown dates of 2003 and 2005, respectively, to cover the costs of the upgrading. But only the country's regulatory authority can renew the units' licenses.

In March 1996, an SE official reportedly said that the backfitting work—to be carried out at a cost of about 5.5 billion Slovak crowns ($157.9 million)—would be completed by 1999. The official added that the Level 1 PSA would be used to determine what weaknesses should be addressed first to benefit as much as possible from the upgrades. According to SE officials, the backfitting would allow the two units to operate until 2007.

In April, SE awarded a contract to REKON—a consortium of Siemens and VUJE, the Slovak Nuclear Power Plant Research Institute—for the staged upgrading. The cost of the DM 275 million ($147.4 million) project will be borne by SE. Upgrading work on Unit 2 began in August 1996.

Units 3 and 4. With funding from the European Union's PHARE program, the European Nuclear Assistance Consortium (ENAC)—consisting of eight Western European nuclear design and engineering companies—has carried out an engineering safety evaluation at the plant's two VVER-440 Model 213s. The evaluation identified several areas of concern, including failure of the emergency core cooling system because of sump screen blockage, the adequacy of instrumentation and control systems, and sufficient physical and

functional separation of the unit main and emergency control rooms. ENAC then developed a list of ranked recommendations for the plant.

Bohunice intends to use the ENAC list of recommendations as input to its own decision-making process. Key among the plant's plans is to further improve both the deterministic and probabilistic safety analyses performed by the plant. Bohunice is preparing a prioritized action plan for safety improvements that will cover plant design as well as safety analysis.

International Exchange/Assistance

WANO Exchange Visits. The World Association of Nuclear Operators has sponsored several exchange visits involving the Bohunice plant. The plant has hosted personnel from the following plants:

- Switzerland's Gösgen and Beznau plants (1990),
- United States' Davis-Besse plant (October 1990),
- Germany's Grohnde plant (January 1992),
- Russia's Kola plant (June 1992),
- Japan's Tomari plant (October 1993).

In addition, personnel from Bohunice have visited the following plants:

- Switzerland's Gösgen and Beznau plants (1990),
- United States' Davis-Besse plant (December 1990),
- Japan's Tomari plant (June 1993)
- United States' V.C. Summer plant (December 1996).

Plant Twinning. The Bohunice plant has been twinned with France's Nogent plant and Germany's Grohnde plant.

Simulator Trial. In December 1993, a severe accident simulator developed jointly by the International Atomic Energy Agency (IAEA) and the U.S. company Risk Management Associates entered trial operation at the Bohunice plant's Model V213 reactors. The desktop, personal computer-based simulator is used to train plant operators, but it can also evaluate accident management strategies.

G-24 Assistance. Under the auspices of the G-24 group of industrialized nations, the U.K. government funded a safety assistance training project at Bohunice in March 1996. The project involved training in root cause analysis, human factors and event feedback.

Inspections

In 1990, the Czech and Slovak Federal Republic asked the IAEA to document the special measures that had been taken at Bohunice 1 and 2 to improve plant safety.

Technical Exchange Visit. An IAEA team visited the plant Sept. 3-7, 1990, to review equipment upgrades and modifications, personnel

qualification and surveillance, and to note the effectiveness of each safety measure.

ASSET Mission (Units 1 and 2). A month later, Oct. 1-12, an IAEA Assessment of Safety Significant Events Team (ASSET) mission visited Bohunice in connection with the IAEA's project to assess the adequacy of the VVER-440 Model V230 plants.

The team examined Bohunice's operating history and incident-prevention program and said that plant management deserved credit for the small number of safety-significant events. It noted, however, that the future safe operation of units 1 and 2 would require further efforts.

The IAEA team recommended development of a comprehensive program for the prevention of incidents, including increased surveillance and preventive maintenance. The team also questioned the advisability of continued operation over the long term, given the design and operational deficiencies of the Model V230 units.

Safety Review Mission (Units 1 and 2). As part of the IAEA's VVER-440 Model V230 project, an IAEA Safety Review Mission visited Bohunice-1 and -2. During its April 7-26, 1991, the review team assessed not only basic design deficiencies but plant modifications. The review pinpointed shortcomings in management's identification and correction of nuclear safety issues, deficiencies in fire protection, and incomplete vital operating procedures.

In addition, a seismic safety review mission visited Bohunice to review the plant's ongoing program of seismic upgrading. The team recommended the review of several measures, including the seismic ruggedness of on-site emergency power.

Follow-Up Safety Review Mission (Units 1 and 2). The IAEA carried out a follow-up to its 1991 Safety Review Mission April 27-30, 1992. The team was satisfied with the progress that plant management had made in responding to many of the original mission recommendations. While the team said good progress had generally been made in addressing safety significant issues in the design area, some issues needed more urgent attention, including: the development and implementation of quality assurance programs; the development of operating procedures; the improvement of operating shift staffing; and plant reorganization efforts.

Follow-Up ASSET Mission (Units 1 and 2). An ASSET follow-up mission visited Bohunice units 1 and 2 July 5-9, 1993, to assess the progress made in implementing the recommendations made by the ASSET mission that reviewed the units in 1990.

The team noted that the plant had responded vigorously to the recommendations, reviewing and acting on them with thoroughness.

The team reviewed 223 events that had occurred at the two units between July 1990 and March 1993. Of these, 102 were considered to be safety relevant; 10 were classified as Level 1 on the International Nuclear Event Scale and the rest as Level 0. Most of the Level 1 events were related to

equipment failures, and the team suggested it may be necessary to review the frequency of routine maintenance.

As a result of its analysis of events, the team identified only one safety problem for which it felt corrective actions—both taken and planned—were insufficient: the quality of work preparation and procedural guidance for plant personnel and contractors, which could lead to degradation of safety functions.

To correct this pending safety problem, the team suggested that plant management:

- Carefully revise the procedures related to transferring ownership of equipment from one plant department to another to highlight the operational implications and avoid inappropriate transfer of responsibilities.

- Revise the training of contractor personnel, especially in the plant's safety aspects; end-of-training testing and periodic retesting should be considered.

- Should consider a means to verify compliance of contractor personnel with existing safety procedures.

Final Safety Review Mission (Units 1 and 2). An IAEA team conducted a technical visit to Bohunice units 1 and 2 May 6-8, 1996. The aim of the visit—made in connection with the IAEA's program on safety of Model V230 reactors—was to update information on the status of the implementation of safety improvements and comment on actions taken in response to the IAEA's technical report on Model V230 safety. Of the 60 design issues reviewed by the IAEA team, 57 had been or were being resolved and 3 were being addressed as part of the units' so-called small reconstruction.

The team also evaluated 31 outstanding operational issues in six areas: management, operating procedures, plant operations, maintenance, training and emergency planning. The team found that although satisfactory progress had been made, much work remained to be done in upgrading maintenance working level documents. In addition, management needs to focus attention on implementing the new programs recently put in place at the plant as gradual reconstruction continues. The team encouraged management and staff " to continue their efforts to complete the work necessary to resolve the longer term operational issues, especially those that directly affect the high standards of performance expected by the public and the international community."

OSART Mission (Units 3 and 4). An IAEA Operational Safety Review Team (OSART) mission visited Bohunice Sept. 10-27, 1996. The team found that the plant was taking many initiatives, with the assistance of the international community, to increase nuclear safety. The team identified several areas of good performance:

- The general material condition and cleanliness of the plant is good, and the result of a recent extensive upgrade of plant conditions.

- The plant has sophisticated diagnostic and surveillance systems that are state of the art.
- The radiation and contamination monitoring program outside the radiation controlled area is very comprehensive.
- A continuous monitoring system is installed to monitor the presence of fission products in the primary coolant system.

The team also suggested several improvements:

- The plant should ensure that the program used to investigate events adequately addresses both the root cause and the corrective actions needed to ensure prevention of recurrence.
- The plant should ensure that sufficient resources are devoted as soon as possible to upgrading normal and emergency operating procedures and alarm response procedures.
- The plant should enhance on-site training and emergency planning to improve performance in these areas; this might best be done by an in-depth review of effectiveness.
- Operation management should establish a policy to improve their ability to identify deficiencies and abnormal plant conditions during plant tours.
- The plant should improve industrial safety.

Planned Follow-Up OSART Mission. An IAEA OSART mission is scheduled for Bohunice in 1998.

NUCLEAR ENERGY IN HUNGARY

Hungary operates just one nuclear power plant—four VVER-440 Model V213s at Paks on the Danube River—but it gets nearly 41 percent of its electricity from nuclear energy. Paks, like most of the country's thermal power stations, is part of the network of the Hungarian Power Co. (MVM)—the national utility. Within this network, coal-fired power plants generate about 27 percent of the country's electricity, and oil and gas nearly 30 percent. Self-producers account for the remaining 2 percent.

Nuclear Program and Plans

Before the Communists lost power, Hungary had planned to build two additional units at the Paks site. In 1989, however, MVM canceled its order for the VVER-1000 units from the Soviet Union and expressed an interest in Western-made units for the site.

Among the organizations that approached MVM were a consortium led by Electricité de France, a Soviet-Finnish consortium, Atomic Energy of Canada Ltd., Germany's PreussenElektra and Siemens, and a consortium that included Westinghouse and Bechtel. MVM and Paks plant management were reportedly told that they could talk with Western companies about new nuclear units but could make no contractual arrangements until Hungary's government and parliament agreed on an energy policy.

A long-term energy plan developed by the Ministry of Industry and Trade foresees no construction of a nuclear plant before 2010, but the plan has not yet been approved by Hungary's parliament.

In July 1995, Hungarian trade and energy officials were reported to be negotiating with Westinghouse Corp. on the possible construction of an advanced reactor based on Westinghouse's AP-600 plant.

The Hungarian Atomic Energy Commission initiated the drafting of a new nuclear law in November 1995 that would replace the 1980 law now in force. Under the current law, the Hungarian Atomic Energy Authority is responsible for nuclear safety licensing and, on the basis of such licensing, the Hungarian Atomic Energy Commission issues licenses for the construction, commissioning, operation and decommissioning of nuclear power plants.

The new law grants all licensing authority to the Hungarian Atomic Energy Authority. In addition, the new law addresses the handling of radioactive materials, including the storage and disposal of spent fuel, and requires that the cost of nuclear plant decommissioning and spent fuel disposal be accumulated during the plant's operation. Under the draft law, decommissioning costs would come from the addition of a small charge to electricity rates.

The draft law also spells out the series of licenses required for the construction and commissioning of a nuclear power plant.

Formulating and Implementing Electricity Policy

According to a government official responsible for energy matters, the country's electricity needs can be met during the 1990s with small gas-fired combustion turbines. Hungary will not need new baseload plants—nuclear or coal-fired—until early in the next century.

In 1993, the MVM board of directors mapped out a 10-year electricity generating strategy that included improvements to thermal plants, the construction of natural gas-fired combined-cycle plants and a coal-fired fluidized bed plant, and site studies for a new nuclear plant on the Danube River.

In March 1996, Hungary's Industry and Trade Minister Imre Dunai reportedly said that the country should consider the possibility of building another nuclear power plant, although he denied that there were any plans to do so.

In November 1996, the government announced a 25 percent increase in electricity prices, effective Jan. 1, 1997.

Utility Operations. As the country moves toward a market economy, MVM is being restructured. Responsible for electricity generation, high-voltage transmission and distribution, MVM became a shareholder company Jan. 1, 1992, although the government held all the shares.

In addition to the holding company—MVM Ltd.—the restructured industry consists of eight generating corporations, six regional distribution corporations and one transmission system corporation. In April 1994, the Hungarian parliament adopted a new electricity law, clearing the way for the planned sale of MVM's subsidiaries. According to MVM, up to 100 percent of the non-nuclear electricity production and distribution companies would be

sold, with the government retaining control of the power distribution grid and the Paks nuclear plant.

In September 1995, the government issued a formal tender notice for the sale of up to 24 percent of MVM, and for minority shares in six regional electricity distribution companies and seven electricity generation companies. In December, the government announced that it was selling its six distribution companies and two of its seven generation companies to German, French and Belgian bidders. However, the government chose not to sell MVM at the price that was offered. In August 1996, the Hungarian news agency MTI reported that the government planned to offer 49 percent of MVM shares to investors.

A consortium of three European companies—Germany's Bayernwerk and PreussenElektra, and Electricité de France International—was formed recently with the aim of connecting the Hungarian electricity grid to the Western European grid. Hungary joined UCPTE—the West European grid—on a trial basis in October 1995, and officially joined UCPTE in 1996.

Nuclear Energy Oversight

Until 1991, nuclear safety licensing and inspection were carried out by the State Inspectorate of Energetics and Energy Safety's Nuclear Safety Inspectorate Department. The state inspectorate is part of the Ministry of Industry and Trade, which oversees electricity production and power plant operation.

New Responsibilities. In 1991, Hungary reorganized governmental regulation of nuclear power, making the Nuclear Safety Inspectorate part of the Hungarian Atomic Energy Authority. The authority, which serves as the operating body of the Hungarian Atomic Energy Commission, is responsible for overseeing nuclear safety at operating nuclear power units and for licensing plant operators. The authority employs about 10 resident inspectors at Paks. The industry and trade minister serves as the president of the Hungarian Atomic Energy Commission.

The commission signed an agreement in 1990 with the U.S. Nuclear Regulatory Commission on cooperation and the exchange of information. It is now revising the requirements for nuclear power plant design, manufacture, construction and operation to bring them into line with IAEA recommendations and Western regulations.

Public Safety Measures. In 1987, Hungary's Presidential Council issued a decree amending the country's 1980 Nuclear Power Act to provide protection of the public and environment against ionizing radiation from any source, not just domestic, and to put responsibility for protective measures against radioactive pollution in the hands of the Council of Ministers.

In 1990, the Hungarian government set up a national system for dealing with nuclear events, both domestic and foreign, that affect Hungarian territory. Earlier measures were concentrated only on Paks.

Status of Liability Coverage

Hungary has drafted a new atomic energy law that incorporates the basic principles of the Vienna Convention. The draft law, issued in November 1995, limits liability for nuclear damages and channels it to the licensed operator of the facility at which an accident occurs. The Hungarian Parliament adopted a final version of the law in December 1996.

Under the law, nuclear facility operators must contract for insurance to cover third-party liability obligations. The Paks plant is required to take out an insurance policy for a maximum 20 billion forints ($100 million). According to Paks' general manager, a domestic insurance pool led by Hungaria Biztosito will offer four billion forints' ($20 million) worth of coverage, while an international pool is being organized to cover the remaining 16 billion forints ($80 million). The Hungarian government will provide an additional 15 billion forints ($75 million) in the event of an accident.

The law also stipulated that the construction of new nuclear power plants, the expansion of existing units and the construction of radioactive waste storage facilities are subject to parliamentary approval. In addition, it established a Central Nuclear Fund to finance the construction and operation of radioactive waste storage facilities and nuclear plant decommissioning, and it allowed nuclear power plant privatization.

Hungary is a party to the Vienna Convention, which ensures that the responsibility for damage caused by a nuclear accident is channeled to the plant operator. The country is also a party to the 1988 Joint Protocol on Civil Law Liability and Compensation for Cross-Boundary Damage from Nuclear Accident, which resolves potential conflicts between the Paris Convention—which covers 14 European countries—and the Vienna Convention—which has worldwide coverage.

Fuel Supply and Waste Disposal

Supply of Fuel. In 1993, Hungary signed a two-year contract with Russia's Tekhsnabeksport for the supply of fuel. According to a March 1994 report, Germany had offered to sell 235 slightly irradiated fuel assemblies from the closed Greifswald plant in eastern Germany to Hungary's Paks plant for a nominal DM 1 ($0.53). In January 1996, Greenpeace activists blocked the train tracks from the Greifswald plant to prevent the fuel being transported to Paks. The fuel arrived safely at Paks in mid-February.

Hungary's current contract with Russia for fuel supply runs until 1999. Under new legislation, the Paks plant must create a two-year fuel reserve, and must begin purchasing new fuel in 1996.

In mid-1996, British Nuclear Fuels plc signed a contract with the Finnish utility Imatran Voima Oy and the Paks plant for the design, development, licensing and eventual supply of a new type of fuel assembly for the VVER-440 units at IVO's Loviisa plant and at Paks.

Spent Fuel Storage and Disposal. In the past, spent fuel from the Paks plant was sent to Russia for reprocessing. But after Russia passed legislation in 1992 prohibiting the import of foreign radioactive waste, Ukraine stopped the transit of spent fuel from Hungary for fear it would not be accepted at the Russian-Ukrainian border. In 1993, Russia's President Yeltsin issued a degree saying that Russia would continue to accept spent fuel from those countries that had such an obligation in their fuel supply contracts with the former Soviet Union.

In 1993, Hungary reached agreement with Ukraine and Russia on shipping spent fuel through Ukrainian territory, but a Russian-Hungarian meeting in Moscow in early 1994 failed to resolve the issue of spent fuel acceptance because there was no obligation to accept spent fuel in Hungary's original agreement with the former Soviet Union. However, in March 1994 Russia signed a protocol with Hungary on the acceptance of spent fuel. At the end of 1994, Russia agreed to accept two trainloads of spent fuel from Hungary in 1995. The first train—carrying 55 metric tons of spent fuel—left the Paks plant for Russia in January 1995.

With storage space in its spent fuel pools running low, and future acceptance of spent fuel by Russia uncertain, the Paks plant awarded a contract to GEC Alsthom Engineering Systems in 1992 for the construction of a modular vault dry storage system. The Hungarian Atomic Energy Commission issued a license in February 1995 for the construction of the facility, and construction began a month later. The Hungarian AEC issued an operating license for the facility in February 1997. The Paks plant had earlier said that it would place no spent fuel in the storage facility as long as Russia continues to accept the plant's spent fuel. But in February, a Hungarian Atomic Energy Commission official said that because of transit, financial and legal problems associated with the return of spent fuel to Russia, the plant would begin storing spent fuel in the on-site facility.

However, in July 1997, Russia agreed to continue accepting spent fuel from the Paks plant for three to four more years. This arrangement, according to the Hungarian media, will give Hungary time to make alternative arrangements for the management of its spent fuel.

Atomic Energy of Canada Ltd. is supporting research of a site for a high-level waste repository in the Mecsek mountains.

Technical/Upgrading Activities

After the accident at Chernobyl, Hungarian officials accelerated the modernization of their nuclear units already under way. For details of safety-related improvements, see the separate summary of the Paks plant.

Operating Practices

Training. Operators at the Paks nuclear plant receive between two and three years of classroom and on-the-job training. Operators also must

successfully complete five weeks of simulator training on the plant's full-scope simulator before taking the licensing examination.

Once licensed by the Hungarian Atomic Energy Commission, operators receive a day of refresher training every five weeks and about 80 hours of simulator training every year.

Qualification Upgrading. Following a job and task analysis of control-room operator and field operator positions by the Budapest Technical University in 1991, qualification guidelines for various operator positions are being upgraded.

Maintenance Training. In April 1997, a new maintenance training center opened at the Paks plant. The center includes a dummy VVER-440 Model V213 made of parts—including a pressure vessel, steam generator, main coolant pump and primary system pipes and valves—from reactors never completed in Germany and Poland. The equipment was supplied by the International Atomic Energy Agency. Experts from the IAEA and specialists working under the European Union's PHARE program helped in the adoption of modern training methods, while the United States, Spain and Japan provided direct financial and expert assistance. The center is open to personnel from all countries with operating VVER reactors.

International Cooperation/Assistance

Since the 1986 Chernobyl accident, Hungary has sought nuclear safety expertise from the West. Among Eastern European countries, it has led the way in forging ties with public- and private-sector organizations.

Safety Expertise. The Hungarian Atomic Energy Commission (HAEC) signed an agreement with the U.S. Nuclear Regulatory Commission providing for the exchange of information and cooperation on state supervision of nuclear facilities, analytical safety methods, operational experience, next-generation reactors, life extension, failures and incidents, and treatment and transportation of radioactive waste.

The HAEC also signed an agreement with the French Atomic Energy Commission that covers nuclear safety, radiation protection, radioecology and waste-management research and development.

Technical Services. In 1990, the Paks Nuclear Power Plant Co. and Spain's Tecnatom S.A. began negotiating to establish a joint venture for reactor pressure-vessel inspection services in Eastern Europe. The venture would combine Tecnatom's inspection equipment and expertise with Paks' knowledge of the Soviet-designed VVER-440 pressure vessel.

Foratom Cooperation. Hungary formed a nuclear society in 1990 and indicated its interest in forming a nuclear forum that would permit it to join Foratom, the umbrella group for 14 European nuclear industry forums.

At a joint workshop of the Hungarian and American nuclear societies in April 1991, the groups agreed on a program of cooperation. The workshop itself,

devoted to pressurized water reactor safety, included discussions on reactor safety, probabilistic safety analysis, safety features of new designs, and environmental radiation monitoring in Hungary.

Two months later, Foratom's Working Group on Quality Assurance and the Hungarian AEC's Nuclear Safety Inspectorate sponsored a workshop in Budapest on nuclear quality assurance.

WANO Membership. Hungary is a member of the World Association of Nuclear Operators (WANO), and personnel from the Paks plant have participated in international exchanges sponsored by WANO. Under a new WANO program launched in 1994, experienced operators conduct peer reviews of plant operations. Paks was the first plant visited by a peer review mission under the pilot phase of this program.

Utility Partnerships. Under a utility partnership program jointly sponsored by the U.S. Agency for International Development and the U.S. Energy Association (an association of public and private energy-related organizations that represents the United States on the World Energy Council), the Hungarian utility MVM is paired with the New England Electric System (NEES). The partnership will focus on three main areas: an engineering, operations and managerial information exchange between NEES and MVM; the organization of regional seminars to be conducted in Eastern Europe for other interested parties; and the transfer of technical information gained from the partnership to other Eastern European utilities.

Cooperative Agreements.. In 1993, Hungary and Slovakia signed an agreement on cooperation in the energy industry that included the offer of Hungarian aid in modernizing and enhancing the safety of Slovak nuclear units. The same year, Hungary's Ministry of Industry and Trade signed a technical cooperation agreement with Atomic Energy of Canada Ltd. under which AECL will transfer experience on radioactive waste management and, if requested, would provide information on CANDU reactors.

IAEA Training Seminars. Although the International Atomic Energy Agency is known for its inspection missions—including its Assessment of Safety Significant Events Team (ASSET) missions—to nuclear power plants, the agency also conducts ASSET training seminars at a country's request. The seminars are designed to train operators and regulators in the use of the ASSET methodology to identify safety issues, to assess their consequences and to eliminate the root causes of likely future accidents and incidents.

In September 1990, three lecturers from IAEA's ASSET program conducted a seminar in Budapest on training nuclear operators and regulators in the investigative methodology used by ASSET missions, and to train them in incident prevention. An ASSET seminar was also held June 15-19, 1992, at the Paks plant. It focused on extending the assessment of the safety significance of operational issues to all types of nuclear facilities, and it also covered the root-cause analysis method in preparation for the ASSET mission to the plant scheduled for later that year. An ASSET seminar was held at the Paks plant Dec. 6-7, 1994, and another in Budapest June 13-15, 1995.

U.S. Aid. According to Hungarian officials, U.S. reactor safety assistance to Hungary is winding down, because the Paks plant is considered to meet

Western nuclear safety standards. Since 1991, Hungary has received about $1.5 million, which it has used for scholarships, training, assistance to the country's nuclear safety authority, and analysis of Paks' safety systems.

NEA Membership. In 1996, Hungary became a member of the Organization for Economic Cooperation and Development's Nuclear Energy Agency.

Plant Inspections

Hungary was the first Eastern European country to request an IAEA inspection of its nuclear plant. For details of the inspection, see the separate summary of the Paks plant.

Operating Soviet-Designed Nuclear Power Plants In Hungary

Key

VVER ■

PAKS NUCLEAR POWER PLANT

Type: VVER-440 Model V213

Units: Four

Total megawatts (net): 1,730

Location: Paks, Hungary

Dates of initial operation: Unit 1 - August 1983
Unit 2 - November 1984
Unit 3 - December 1986
Unit 4 - November 1987

Principal Strengths and Deficiencies

For an overview of the principal strengths and deficiencies of Soviet-designed plants, see **Soviet Nuclear Power Plant Designs**.

Operating History

The Paks plant has an essentially untroubled operating history, with a low number of unscheduled outages and reportable events. Between 1990 and 1994, the plant had an average capacity factor of 86.4 percent, and averaged 1 automatic scram per unit year. For 1995, the scram rate was zero. Over this period, the average outage for the plant as a whole lasted 179 days; this figure fell to 136 days in 1995.

Following the detection of several hundred pieces of foreign material in the primary circuit of Unit 2 during planned maintenance in August 1996, three senior maintenance officials of the plant were suspended.

The partial jamming of a control rod in Unit 2 in November 1995, originally classified as Level 0 on the International Nuclear Safety Event scale, was upgraded to Level 2 in light of the subsequent August discovery of the foreign material.

Technical/Upgrading Activities

Before MVM canceled its order in 1989 for two third-generation VVER-1000 units as the fifth and sixth units at the Paks site, it had awarded several contracts to Western companies for assistance in building the units.

- Bechtel Power Corp. won a contract in 1988 to perform project management services for construction of Paks 5 and 6. Bechtel had already assessed management, organization and work flow at the four operating VVER-440 Model V213 units.

- Finland's IVO International Ltd. was awarded a contract in 1988 to deliver project-management systems to the Paks construction project.

- IVO International also signed a technical agreement with Paks management in 1988 under which IVO would participate in the construction and maintenance of the new Paks units.

Plant Upgrades. The Paks plant has also contracted with Western firms for upgrades to the four VVER-440 Model V213 nuclear units. Finland's Nokia Oy was awarded an order for a plant full-scope simulator, and IVO International contracted to provide inspection and quality-control support, as well as safety and construction consulting, for all units at Paks. The simulator was completed in 1987. The plant has raised its performance level with the help of the new simulator, which Paks management uses not only to train staff but also to test emergency procedures. Following such a test in 1990, management made significant improvements to these procedures.

In 1990, Spain's Tecnatom signed a contract with the International Atomic Energy Agency (IAEA) to supply Paks with a system for acquiring and processing data from ultrasonic in-service inspection of pressure vessels and other components. The company carried out a partial inspection of Unit 3's reactor vessel in 1993 that showed the vessel to be in highly satisfactory condition, with no reportable defects in the inspected zones.

In 1992, the Hungarian Atomic Energy Commission launched a study—the Advanced General and New Evaluation of Safety (AGNES) study—of Paks to ensure that the plant meets Western safety standards. Nuclear experts headed by KFKI, the country's leading atomic energy research institute, reevaluated the systems, carried out new design-basis analyses as well as severe accident analyses, and completed a level-1 probabilistic safety assessment. The report on the AGNES study, issued in June 1994, made numerous safety proposals. One major task suggested in the report was upgrading the plant's seismic resistance. Under a Belgian-Hungarian energy agreement signed in May 1993, Belgium will contribute BF 20 million ($660,000) for safety and seismological tests to support safety systems and the construction of a waste storage facility.

Paks' safety enhancement program was reviewed on the basis of the AGNES study recommendations, and new priorities have been established for implementing safety measures. As a result, the training simulator's functions were extended, the steam generators were protected against overpressure in a cold state, diesel generator batteries were upgraded for

earthquake resistance, and fireproof insulation was installed on the turbine hall support pillars.

In 1995, the instrumentation and control (I&C) and electrical panels and cabinets were improved, and the basic design for total separation of the auxiliary feedwater system from the normal and emergency feedwater system was completed. IVO International was awarded a contract to study the management of steam generator primary-to-secondary circuit leaks. IVO designed new clog-proof sumps for the confinement and the test of a prototype was successful. In addition, IVO was contracted to provide consultancy services on emergency procedures and severe accident management. Siemens was awarded a contract to deliver hydrogen recombiners for removing hydrogen generated in the confinement as a result of a severe accident.

The Paks plant spent $9.2 million on safety-related upgrades in 1995.

In September 1996, Siemens won a contract to backfit Paks' reactor protection system. Under the contract, worth nearly DM 40 million ($21.4 million), new computerized instrumentation and control equipment will be installed on the four units between 1999 and 2002. The project was initiated by Paks and defined in discussions between specialists from the plant and Siemens.

Studies, Training. Under a PHARE-funded project, expected to begin in early 1996, Siemens—together with the Czech Republic's Rez and Hungary's VEIKI—will supply computer models for severe accidents, training in their use, and a large program of analysis and development of VVER accident management programs. In addition, the plant has awarded a contract to the United Kingdom's NNC to provide an I&C training course for Paks operators.

Emergency Operating Procedures. In December 1996, the Paks plant began working with the U.S. company Westinghouse to develop emergency operating procedures. The plant is financing the project.

International Exchange/Assistance

WANO Exchange Visits. The World Association of Nuclear Operators (WANO) has coordinated several exchange visits involving the Paks plant. The plant has hosted personnel from the following plants:

- United States' Three Mile Island plant (July 1990),
- United States' Limerick plant (September 1990, July 1991),
- Korea's Kori plant (September 1992).

In addition, personnel from Paks have visited the following plants:

- United States' Three Mile Island plant (April 1990),
- United States' Limerick plant (May 1990),
- Korea's Kori plant (February 1993),
- United States' V.C. Summer plant (December 1996).

Following the successful completion of a series of pilot peer reviews in 1992 and 1993, WANO launched a formal program of voluntary peer reviews of WANO member plants in 1994. Under the program, experienced operators from other plants offer independent observations on plant operations, make recommendations for improvements and identify good practices to share with operators worldwide. The first review in the pilot phase of this program was carried out at the Paks plant in February 1992.

Established Plant Exchanges. In addition to visits under the WANO exchange program, Paks maintains regular contact with several plants: Finland's Loviisa, Russia's Kola, Ukraine's Rovno, the Slovak Republic's Bohunice, the Czech Republic's Dukovany, Germany's Isar 2, and France's Blayais.

Plant Twinning. The Paks plant has been twinned with France's Blayais plant, Germany's Isar 2, and the Limerick and San Onofre plants in the United States.

International Safety Project. In early 1994, Paks launched a four-year safety project to establish a maintenance training center, introduce international training techniques and help to enhance the plant's safety culture. Funding for the $7 million project is provided by the International Atomic Energy Agency (IAEA) ($1.3 million), the U.S. government ($400,000), the European Union's PHARE program ($450,000) and Paks. Construction of the training center started in the summer of 1994 and the center opened in April 1997.

IAEA Training Program. Paks will use the reactor pressure vessel, steam generator and auxiliary equipment from the canceled Zarnowiec VVER-440 Model V213 nuclear plant in Poland in an IAEA training program scheduled to begin in 1996.

NDE Training. In 1996, representatives of Germany's Siemens and the Paks plant began discussions on the establishment of a non-destructive examination (NDE) training center at the plant. The two sides noted that the plant might eventually train operators of Soviet-designed nuclear power plants who want to learn the automated NDE techniques used in the West.

Inspections

Between 1984 and 1987, the Soviet nuclear equipment supplier carried out four reviews of the Paks plant. The aim of the reviews, requested by the plant, was to assess Paks' operation in light of Soviet requirements. Paks widened the scope of successive reviews, inviting not only specialists from the Soviet Union but also from other VVER-440 plants such as Finland's Loviisa

and Czechoslovakia's Bohunice, and comparing the plant's performance with international standards. Hungary was the first Eastern European country to request IAEA inspection of one of its nuclear plants.

OSART Mission. An IAEA Operational Safety Review Team (OSART) mission visited Paks Nov. 14-Dec. 2, 1988, to review operating practices of Unit 3. The team reviewing Unit 3 in 1988 noted several indicators of good performance: The unit's cumulative availability was above 86 percent; the unit had no events requiring the use of redundant safety systems; and unplanned outages during 14 reactor-years of operation numbered 27, extremely low by international comparison. The team found safety performance at a high level and recommended a number of good techniques for worldwide use. The team also suggested improvements to enhance the plant's strong safety record: a strengthened operating organization, six-shift operation, additional independence in quality assurance, on-line chemistry control, and improved industrial safety.

Follow-Up OSART Mission. In 1989, Hungary asked IAEA for a follow-up inspection to review the plant's responses to the recommendations of the 1988 OSART mission. The follow-up team visited the plant Feb. 25-March 1, 1991, and found that of the 140 recommendations and proposals made by the OSART mission, 127 had been carried out or were well under way. The team noted that management-initiated plant modifications and upgraded procedures would help Paks maintain and improve its safety record. The team also noted that management had recognized the importance of nuclear information exchange and had begun several programs to increase the flow of operating experience among plant operators. The team added that Paks' management was committed to operating the plant at the highest possible safety levels. Some areas requiring improvement were mentioned, including the use of personal safety protection, the tagging process and handling human performance problems. The team underscored the progress made in fire protection and in improving operational procedures.

ASSET Mission. Hungary requested an Assessment of Safety Significant Events Team (ASSET) mission to Paks to review operating experience, assess the appropriateness of corrective actions, and exchange views on further enhancing incident prevention. The team, which visited the plant Nov. 2-13, 1992, said that Paks' operational statistics compared well with world averages, and the plant appeared to have entered a period of steady operation since the commissioning of Unit 4 in 1987. The team also found favorable the continuous backfitting of the plant on the basis of intensive exchange of experience with other Model V213 plants.

The team suggested, however, that there was room for improvement in the prevention of incidents. The total number of safety significant events was higher than expected, and the number of events found by surveillance was low compared with the number of events originating from the operational process. But the team did observe an increase in the percentage of events found by surveillance compared with the total number of events, from 5 percent in the 1987-1989 period to 14 percent in the 1990-1992 period.

The team identified three safety issues in its analysis of the plant's reported events: actions by staff that were contrary to written instructions or were carried out in the absence of written instructions; problems in plant operation

associated with the vigilance of personnel and the safety culture; and problems associated with instrumentation and control equipment.

The team concluded that, while many improvements had already been made and others were planned, additional improvement of plant reliability and availability could be achieved by giving full attention to the team's recommendations, concentrating on all aspects of personnel proficiency and procedural guidance. It said a follow-up ASSET mission to the plant in two to three years would be advisable.

Follow-Up ASSET Mission. A follow-up ASSET mission visited the Paks plant March 6-10, 1995. The team noted that since 1992, the plant had carried out several safety upgrading measures, including:

- increasing the reliability of the 6 kV power supply,
- installing a standby uninterruptible power supply system,
- providing steam generator overpressure protection in cold conditions,
- installing an earthquake-detection system,
- installing fireproof doors to the cable rooms,
- increasing the reliability of the high-pressure safety injection pumps, and
- upgrading the plant simulator.

The team reviewed plant events between June 1992 and December 1994. Of 160 events, the team determined that 131 were of safety relevance. Of those, six were classified as Level 1 on the International Nuclear Event Scale, and the remainder, as Level 0. The team noted that the number of safety-significant events was considerably reduced from the number reviewed in the 1992 mission, and the effectiveness of the plant's surveillance program had improved considerably since then.

The team identified several safety problems, and Paks personnel assessed the potential consequences of those problems, including:

- potential for degradation of on-site emergency electrical supply because of failure to start diesel generator,
- operating personnel's noncompliance with written procedures,
- poor maintenance work preparation and implementation,
- potential for degradation of fuel cooling during a loss-of-coolant accident because of essential cooling water valve failures, and
- potential for degradation of reactivity control because of insufficient reliability level of control rod drive low-frequency converters.

The team concluded that the in-house ASSET review carried out by Paks was complete and comprehensive. The team made several recommendations to further enhance the prevention of incidents, including reviewing and evaluating safety culture enhancement practices from plants in other countries and formalizing procedure verification/validation arrangements in plant documentation.

Safety Techniques Inspection. An IAEA team visited the Paks plant in December 1996 to inspect the plant's safety techniques. The inspection, which covered 74 issues, found problems with 17 issues. Three of the 17 required immediate attention—fire risk analysis, the seismic risk of pipe rupture and improvement of covers used during maintenance. Eleven represented longer-term tasks and three were recommendations. The team

said that the resolution of all 17 problems had been started before the inspection, in part because of Paks' management initiative and in part because of findings from an inspection by the country's nuclear regulators.

Other Reviews. In addition to the IAEA reviews, Paks has hosted several other international reviews and inspections.

Operational Safety Review. In 1990, Paks invited an international team of experts to carry out a review similar to that of the IAEA OSART review, but with a limited scope. The review team focused on operation and technical support. Among the team's recommendations: widen the use of the full-scope simulator for preliminary checks of non-routine tests and verification of operating procedures and modify the auxiliary emergency feedwater system to avoid common-cause failures.

IVO Design Review. In 1991, a team of specialists from Finland's IVO carried out a design review of the Paks plant. Using the Loviisa safety report as a reference, the team reviewed the safety features system by system and recommended some safety upgrades. Among them: improve high-pressure emergency core coolant pump reliability, control cooling water temperature for the components that feed the emergency core cooling system heat exchanger, and analyze the possibility of common-cause failures in protection systems.

Hungarian Review. In 1991, Hungarian specialists carried out a review of the plant, including the reactor load, the plant's reporting activity to the Hungarian regulatory body, and plant safety. In their report of the review, the specialists said that plant safety should be upgraded in accordance with current international requirements. This review was one of the initiators of the AGNES study.

WANO Peer Review. In February 1992, the first WANO peer review was carried out at Paks. The review methodology was based on the plant evaluation practice of the U.S. Institute of Nuclear Power Operations. The team identified several strengths at Paks, including good performance indicators, professional control room operation, management commitment to follow best international practices, good training program and excellent housekeeping. The team identified some areas for improvement, including procedure use, safety tagging, shift turnover, overloaded electrical cable trays, and feedback on the use of industrial experience.

NUCLEAR ENERGY IN BULGARIA

Bulgaria operates six units at its Kozloduy nuclear power plant—four VVER-440 Model V230s, and two VVER-1000s.

In 1996, nuclear power supplied 47.5 percent of the electricity produced by the country's utility, the National Electricity Company (NEC). In the past year or two, that share has often risen to 50 percent because of thermal plant inefficiency, fuel shortages and inadequate rainfall for hydropower. Thermal (coal, oil and gas) plants account for about 48 percent of all electricity generated by NEC, and hydro for about 4 percent.

Nuclear Program and Plans

Since the collapse of the Communist regime, the Bulgarian government has cooperated with Western organizations seeking to provide help in upgrading the Kozloduy plant, particularly the older VVER-440 Model V230s.

To meet projected demand—especially if Kozloduy units 1 and 2 are shut down by the end of the decade—the Bulgarian Energy Committee and the state utility have proposed completion of a nuclear plant at Belene, near the town of Svishtov on the Danube River.

Status of Belene Plant. Construction of a VVER-1000 plant was begun at Belene in 1986 but, in light of local protests, the country's economic slowdown and concerns about seismic risks, the Bulgarian government decided in mid-1991 to stop the project. The original project called for construction of two units initially, with another four units to be built at a later date.

In early 1993, however, the general director of Energoproject—a Bulgarian energy research institute—said that officials were considering resuming construction at the Belene site because Bulgaria has no alternative to nuclear energy. Bulgarian and Russian officials met in October 1994 to

discuss cooperating in the completion of the plant. Russia reportedly offered to supply the major equipment for the plant.

In July 1995, Bulgarian radio reported that experts from the International Atomic Energy Agency had visited the Belene site to study its seismic suitability, and reported that there were no seismological hazards.

During talks in November 1995, Russian and Bulgarian officials discussed the possible supply of advanced Russian reactors for Belene as well as the upgrading of the VVER-1000 unit at the site. A Bulgarian official reportedly said that the plant could not be built unless Russian organizations were responsible for construction work and project management. According to an official of Russia's Atomenergoeksport, Russia is prepared to allocate credits for the completion of the Belene plant.

In November 1996, Bulgarian Energy Minister Ovcharov and Russian Atomic Energy Minister Mikhaylov discussed construction of the Belene plant. According to Ovcharov, Russia planned to send experts to Belene to conduct a feasibility study He said an environmental assessment of the site would be required, but this would not be conducted until the project had been finalized and a construction schedule established.

The plant was the subject of considerable public debate in 1997, much of it focused on whether to proceed with construction of the VVER 1000s or to build a newer design. In July, NEC Chairman Konstantin Shushulov said that a thorough seismic study of the site must be carried out before construction could resume. But he questioned the need for an additional generating source in light of the country's declining electricity consumption.

Formulating and Implementing Electricity Policy

Until recently, Bulgaria struggled to meet the country's demand for electricity. With little reserve capacity, it had to impose brownouts and electricity rationing when a power plant was forced off line. Bulgaria has traditionally imported electricity and coal from Ukraine. During the winter of 1994-1995, disruption of coal supplies from Ukraine, which provided the fuel for 1,250 megawatts of Bulgaria's thermal capacity, forced the country to increase its reliance on nuclear energy and hydropower. In a June 1996 interview, the Ukrainian ambassador to Bulgaria said that coal deliveries from Ukraine had been held up in 1995-1996 because Bulgaria still owed Ukraine for coal delivered in 1994.

According to government officials, Bulgaria intended to resolve its electricity supply problems in the near term through a combination of government expenditures and foreign assistance. The country sought to focus on upgrading its thermal and hydroelectric generating plants, improving the safety of Kozloduy and building new gas-fired power plants.

Bulgaria also wants to increase its sale of electricity abroad, exporting power to Turkey and Greece. In mid-1996, Turkey's energy minister said the country had begun talks with Bulgaria on importing electricity to meet an expected shortfall in Turkey later in the year. In September, an NEC official

said that Bulgaria had begun exporting electricity to the Yugoslav Republic. But in July 1997, NEC Chairman Konstantin Shushulov said that while Bulgaria had sufficient electricity for export, it had no foreign customers.

The National Electricity Company planned to invest 70 billion leva ($37.8 million)—some of it from the NEC, the rest from loans by international lending organizations—to carry out several projects in 1997, according to NEC Director General Kozma Kuzmanov. Among them: completing the second stage of a pumped storage plant, installing flue gas desulfurization equipment at one unit of the Maritsa-Iztok thermal power plant, and some safety improvements at Kozloduy units 3 and 4.

Energy Policy Development. In July 1995, the National Assembly's Committee on Power Supply introduced an energy strategy. Under the strategy, which addressed electricity supply to the year 2020, nuclear energy would supply 30-40 percent of the country's electricity, coal would supply 30 percent, natural gas, 12 percent, and hydropower, 7 percent. Bulgaria would import the rest of the electricity it needed. The strategy was never approved by the National Assembly.

In January 1996, the government's Committee on European Integration said that Bulgaria would commit itself to steadily modernizing its nuclear facilities in conformity with European standards. In February, the city council of Svishtov—site of the Belene plant—said it was opposed to the energy strategy because it called for completion of the plant.

Energy Organizations and Personnel. In mid-1996, the government created a Ministry of Energy, and appointed Rumen Ovcharov, formerly deputy chairman of the Energy Committee, as energy minister. According to Ovcharov, one of the ministry's major tasks was to restructure the energy sector.

In July 1996, Kozma Kuzmanov became director general of NEC. The previous director general, Dyanko Dobrev, resigned in September 1995.

Utility Operations. The National Electricity Company is responsible for electricity generation, transmission and distribution. Although there are no immediate plans to privatize the company, it is being restructured to improve the economical generation, transmission and distribution of electricity.

Electricity Pricing. In January 1993, electricity prices for residential customers were increased by 20 percent. But to qualify for a World Bank energy sector loan, the Bulgarian Energy Committee proposed raising prices again in May. Under the proposal, electricity prices for residential users would rise by 50 percent, and those for commercial users, by 5.5 percent. The committee proposed raising rates again on April 1, 1994, this time by 62-67 percent for residential users and anywhere from 28 to 45 percent for industrial users, depending on the dollar value of the Bulgarian leva. The government approved the increases.

In February 1995, Bulgaria's deputy prime minister announced that electricity prices would rise by an average 33 percent on March 1. Industrial customers would see an increase of 28.4 percent, and residential customers, an increase of 47 percent.

In April 1996, the Bulgarian cabinet approved an increase in electricity prices effective May 1. Prices for residential customers were to rise by 37 percent, while prices for industrial and commercial customers were to rise by 55 percent.

In July 1996, the government put in place a formula for revising electricity prices. Under the scheme, prices were revised each month, based on the inflation rate and the lev/dollar exchange rate. With inflation rising and the value of the lev falling against the dollar, in effect electricity prices rose each month under the scheme. In early October, the Commission on Protection of Competition declared the scheme illegal. That same month, Energy Minister Ovcharov said that he had withdrawn his proposal for an energy price rise in November after the country's deputy premier had opposed the pricing scheme.

Nuclear Energy Oversight

The Bulgarian Committee on the Peaceful Use of Atomic Energy, which is chaired by Georgi Kaschiev, has a dual role: It regulates nuclear power plant operations and promotes the peaceful use of nuclear energy. As the chief nuclear regulatory official in the country, Kaschiev is responsible for regulating the operation of the Kozloduy units.

Within the committee is an inspectorate division, which is responsible for establishing safety requirements that all nuclear licensees must meet, verifying that the requirements are met, establishing licensing requirements, processing license applications and issuing licenses. One of the Inspectorate's units—the division of safe operation of nuclear installations—provides on-site inspectors. There are six such inspectors at the Kozloduy plant and the Emergency Response Center.

In April 1995, the committee said it planned to establish a fund for decommissioning Kozloduy.

Yanko Yanev was chairman of the committee until August 1996, when he was replaced by Luchezar Kostov. According to Energy Minister Ovcharov, Yanev was dismissed in connection with agreements on early closure of Kozloduy units 1 and 2 as a condition of a Nuclear Safety Account grant, and on the shutdown of Kozloduy Unit 1 to test its pressure vessel, which Ovcharov said resulted in lost electricity sales. See the Kozloduy plant summary for details.

In March 1997, Kostov was replaced by Vladimir Christov, and four months later, Georgi Kaschiev replaced Christov.

Financial Difficulties

Payment for electricity produced by the Kozloduy plant is received by the National Electric Company, which—because of its own debts—has failed to pass on full payment to the plant.

In June 1995, the Bulgarian government granted a 2 billion leva ($27.8 million) loan to NEC for use at Kozloduy. However, the money was earmarked for NEC's investment program and had to be spent on capital investments. Kozloduy, on the other hand, needed funding to buy fuel and carry out urgent maintenance work.

In May 1996, the NEC said that it would be forced to impose power cuts and rationing starting in the fall if it were unable to collect some of the money owed to it by customers. The heavily indebted company was among those that the government had blocked from drawing bank credit. In September, Energy Minister Ovcharov said that the NEC had received some of the money owed to it. The same month, an NEC official said that the company planned to sign an agreement with a Dutch bank for a $4 million loan.

In July 1996, the Bulgarian cabinet cut the budget for safety work at Kozloduy from 900 million leva ($486,000) to 700 million ($378,000). In November, the plant director reportedly said that some repair and maintenance work was not being completed because Kozloduy lacked funds to buy replacement equipment. In May 1997, he said that the plant needed about $50 million to pay for planned maintenance work and nuclear fuel.

Staff Pay. In the past, Kozloduy had problems attracting and retaining qualified personnel because of low pay levels. In the fall of 1991, however, salaries were raised, which helped to improve plant operation by halting the departure of skilled staff.

In October 1996, a Bulgarian newspaper reported that 13 operators working at Kozloduy units 5 and 6 had threatened to leave unless they received a salary increase. The plant director was said to be negotiating an increase with the government. In February 1997, however, trade unions reportedly demanded wage adjustments for plant staff to compensate for the deteriorating lev/dollar exchange rate.

Status of Liability Coverage

Bulgaria is a party to the Vienna Convention, which ensures that the responsibility for damage caused by a nuclear accident is channeled to the plant operator. The country is also a party to the 1988 Joint Protocol on Civil Law Liability and Compensation for Cross-Boundary Damage from Nuclear Accident, which resolves potential conflicts between the Paris Convention—which covers 14 European countries—and the Vienna Convention—which has worldwide coverage.

Bulgaria enacted national legislation on nuclear energy—the Peaceful Uses of Atomic Energy Act—in August 1995. Under the act, which channels responsibility for damage caused by a nuclear accident to the plant operator,

the operator's liability is set at 15 million Special Drawing Rights (SDR) ($20.2 million). SDRs, based on the rate for a basket of currencies, are used to settle international accounts. If insurance and financial guarantees do not cover claims up to 15 million SDRs, the state will pay the difference to a total of 15 million SDRs. Bulgaria also is taking steps to set up an insurance pool to cover civil liabilities in the event of an accident at a nuclear facility.

Fuel Supply and Waste Disposal

Supply of Fuel. In March 1993, the Bulgarian utility NEC signed a five-year agreement with Russia for the supply of nuclear fuel. NEC has agreed to pay for the fuel in hard currency.

In June 1995, Kozloduy Manager Kozma Kuzmanov said that the plant needed 6 billion leva ($3.2 million) to purchase fuel. By October, Bulgaria had reportedly reached agreement with Russia on the supply of, and payment for, fuel for units 4 and 5. In addition, Ukraine agreed to allow Russian fuel to cross its territory on the way to Bulgaria. The fuel arrived in late October. In late November, Romania briefly detained a ship carrying fuel for Kozloduy Unit 3. The fuel arrived at the plant in early December.

Nuclear fuel intended for Kozloduy Unit 2 was delivered for the first time by air from Russia in June 1996. Previously, the fuel was shipped along the Danube. In August, the NEC had reportedly paid $12 million of the $32 million needed for fuel for Kozloduy Unit 6. The Bulgarian press reported that fuel deliveries for Unit 5 would be delayed because Russia wanted a bank guarantee for the $20 million that NEC owed for the fuel. In October, four separate shipments of fuel for Unit 6—sent by air—arrived at the plant.

In December 1996, Russia's Ministry of Atomic Energy agreed to supply fuel to Bulgaria on credit. To pay for the fuel, Bulgaria reportedly will have to export 2.7 billion kilowatt-hours of electricity to third countries. Bulgaria also signed a contract for the delivery of fuel for units 1 and 2. A four-country agreement was reportedly signed in Moscow on terms for shipping this fuel.

Fuel Transshipment. In November 1994, the Bulgarian Energy Committee announced that Moldova had agreed to allow the transshipment of Russian fresh fuel across its territory to Bulgaria. The committee added that it intended to negotiate with Ukraine on a long-term agreement for the transshipment of nuclear fuel across Ukrainian territory.

In June 1996, the Ukrainian ambassador to Bulgaria said that Ukraine, Russia and Bulgaria had recently signed an agreement on the shipment by rail of Russian nuclear fuel through Ukraine to the Kozloduy plant. He added that rail shipment was impractical at present, however, because Moldova and Romania had not agreed to it. In September, however, Romania approved the transit of fuel through its territory until September 2001.

Spent Fuel Storage and Disposal. Until 1988, spent fuel from the Kozloduy plant was sent to the former Soviet Union for reprocessing under a

bilateral agreement. But with the expiration of the agreement, spent fuel from the plant's four 440-megawatt VVER units was stored on site. The on-site storage facility, which cannot accommodate spent fuel from the plant's two 1000-megawatt VVER units, is expected to exhaust its capacity by the end of 1998.

In 1993, Russia offered to accept spent fuel for reprocessing again, but at a cost of $1,000 per kilogram. In response, Bulgarian Energy Committee officials proposed the construction of a spent fuel storage facility near the Kozloduy plant. Nine companies responded to an international solicitation for a storage facility technology, and NEC is considering proposals from three companies, two in France and one in Spain. In May 1995, NEC chairman Dyanko Dobrev reportedly said that a decision on building a spent fuel storage facility would be made by the end of the year.

In June 1994, Russia agreed to reprocess spent fuel from Kozloduy units 5 and 6, but refused to accept fuel from units 1-4. In March 1995, however, Bulgarian Energy Committee chairman Nikita Shervashidze announced that—following official talks in Moscow—Russia had agreed to continue reprocessing spent fuel from units 1-4.

In February 1996, the NEC asked for bids to build a high-level waste dry-cask storage facility at the Kozloduy plant. The following month, the company said that 10 foreign firms—including the U.S. company Westinghouse, Germany's Siemens, France's Framatome and Russia's Atommasheksport and Izhora—were bidding on the project. However, in October the acting head of Kozloduy said that the project had been halted because of a lack of funding. In November, the director of the Kozloduy plant reportedly said that Russia was providing $100 million in credit for the construction of the facility.

Technical/Upgrading Activities

Between 1991 and 1993, the NEC undertook a comprehensive program for upgrading Kozloduy units 1-4. The program focused first on units 1 and 2, with the aim of restoring them to their original operating condition and improving their reliability and safety. Subsequently, units 3 and 4 were subject to a short-term upgrading effort.

Bulgaria is cooperating with the International Atomic Energy Agency (IAEA), the World Association of Nuclear Operators (WANO) and other international bodies to improve the safety of its nuclear units. For details, see the separate section on the Kozloduy plant.

Operating Practices

Training. Kozloduy has an on-site training center, where classroom instruction is given to operators. The plant has no simulator, but operators are able to train on the full-scope simulator at Russia's Novovoronezh plant. A simulator that can handle up to design-basis accidents is being provided under the EU's PHARE program of economic assistance to Eastern Europe,

and was to have been installed at Kozloduy by the end of 1995. It is based on Kozloduy's Unit 3. NEC has signed a contract with the U.S. firm S3 Technologies for the supply of a full-scope VVER-1000 simulator. S3 is also providing a three-phase simulator program for the plant.

The U.K. government has provided equipment for the training center. In addition, the Bulgarians have drafted emergency operating procedures.

Plant operators and shift supervisors spend 2½ to five years in training and must renew their licenses every five years.

International Cooperation/Assistance

Bulgaria has established ties with such organizations as IAEA and WANO. Under the auspices of WANO, representatives of the Kozloduy plant have visited a nuclear plant in the West (see the Kozloduy plant summary for details).

Bulgaria has also appealed to the countries in the Group of 24—essentially, the members of the Organization for Economic Cooperation and Development—for assistance in improving the safety of the Kozloduy plant.

Through its PHARE program, the European Union (EU) organization earmarked 11.5 million ECU ($12.1 million) in emergency assistance to Bulgaria.

Projects included:

- A study of the country's electrical grid and alternative electricity-supply options.
- A "twinning program" in which the staffs of Kozloduy and nuclear plants in Western Europe would share operating experience; a plant "housekeeping" program; and a special WANO-organized, six-month safety analysis.

EBRD's Nuclear Safety Account. In 1993, the European Bank for Reconstruction and Development (EBRD) agreed to supply 24 million ECU ($25.4 million) to upgrade the Kozloduy plant. See the Kozloduy plant summary for details.

Regulatory Support. A consortium of European safety authorities—led by France's IPSN (Institute of Nuclear Protection and Safety) and including Germany's GRS (Institute for Reactor Safety), the U.K.'s Nuclear Installations Inspectorate and AEA Technology, and Belgium's AIB-Vincotte Nucleaire—is helping the Bulgarian authorities set up a Western-style licensing procedure. Using funding from the EU's PHARE program, the consortium has looked at the legal and regulatory framework in Bulgaria, and the approach to be used by the Bulgarian Committee on the Peaceful Use of Atomic Energy when reviewing requests for the restart of a unit or its continued operation. For example, the committee checked regularly on the

progress in upgrading Unit 2, and issued an operating license when the work was satisfactorily completed.

Under the EU's PHARE program, Bulgaria will also receive a loan of 7 million ECU ($7.4 million) to fund the work of the country's nuclear regulator.

IAEA Training Seminars. Although the IAEA is known for its inspection missions—including its Assessment of Safety Significant Events Team (ASSET) missions—to nuclear power plants, the agency also conducts ASSET training seminars at a country's request. The seminars are designed to train operators and regulators in the use of the ASSET methodology to identify safety issues, to assess their consequences and to eliminate the root causes of likely future accidents and incidents.

In March 1992, an ASSET seminar on prevention of incidents was held in Sofia. The seminar, requested by Bulgaria's Committee on the Peaceful Use of Atomic Energy, was attended by 28 people from Kozloduy, the regulatory agency and two energy research institutes. The purpose of the seminar was to familiarize participants with the ASSET approach to operational safety and the tools used by ASSET missions to identify, rate the significance of, and analyze the root causes of operational safety events.

In September 1992, the IAEA held a second ASSET training seminar at the Kozloduy nuclear power plant at the request of WANO. The seminar was attended by 30 people, including representatives from WANO and the Bulgarian regulatory agency.

Other Cooperative Agreements. In February 1993, Electricité de France (EdF) and NEC signed an agreement under which EdF would increase assistance to both the utility and the Kozloduy plant. EdF would contribute FF 10 million ($1.59 million) for the purchase by NEC of equipment and spare parts for Kozloduy. In addition, EdF—together with the U.K.'s Nuclear Electric—would help Bulgaria get financing from national and international organizations for upgrading the Kozloduy reactors.

Utility Grid Support. According to NEC, Bulgaria planned to complete by 1996 the preliminary work needed to connect the country's electricity grid with that of Western Europe. It has applied to the World Bank for a $93 million loan to help it rebuild the country's energy infrastructure, with some of the money going to the East-West grid link.

Utility Partnerships. Under a utility partnership program jointly sponsored by the U.S. Agency for International Development and the U.S. Energy Association (an association of public and private energy-related organizations that represents the United States on the World Energy Council), NEC is paired with Central Maine Power Co. The partnerships involve exchanges of technical and economic information, seminars, and visits by managers to one another's plants.

Bulgarian-Romanian Agreement. Bulgaria and Romania agreed in April 1996 to exchange technical and operating information on each country's nuclear power plants.

Plant Inspections

Bulgaria has drawn heavily on IAEA expertise in the past year, asking the agency to send inspection teams to Kozloduy and requesting IAEA follow-up to those missions. For details, see the summary of the Kozloduy plant.

Pre-OSART Mission. In 1990, the Bulgarian government asked the IAEA to send a team of experts to Belene, where two VVER-1000 units were under construction.

An IAEA Pre-Operational Safety Review Team (Pre-OSART) mission visited the site July 2-20, 1990, to review construction activities and preparations for plant operation. Among the team's recommendations were:

- Development of a comprehensive quality-assurance program.
- Improvement of management controls and systems.
- Improvement of overall safety attitudes.
- Provision of additional equipment and computer systems.

Operating Soviet-Designed Nuclear Power Plants In Bulgaria

Key

VVER ■

KOZLODUY NUCLEAR POWER PLANT

Type: VVER-440 Model V230 and VVER-1000

Units: Six; units 1-4 are the VVER-440 Model V230, and units 5-6 are VVER-1000s

Total megawatts (net): 3,526

Location: Kozloduy, Bulgaria

Dates of initial operation:
Unit 1 - July 1974
Unit 2 - November 1975
Unit 3 - January 1981
Unit 4 - June 1982
Unit 5 - September 1988
Unit 6 - December 1993

Principal Strengths and Deficiencies

For an overview of the principal strengths and deficiencies of Soviet-designed plants, see **Soviet Nuclear Power Plant Designs**.

Operating History

Kozloduy, which is now run by the National Electric Company, had a troubled operating history in the early 1990s.

Radioactive Contamination. An International Atomic Energy Agency (IAEA) mission in 1990 noted that several serious incidents had occurred, one of which resulted in the radioactive contamination of groundwater on the site.

The mission also found that 217 workers had received excessive exposure to radiation over the plant's operating life. More recently, at least five "hot spots"—areas of radioactive contamination—have been found in the plant.

Poor Physical Condition. A June 1991 IAEA mission found Kozloduy's four VVER-440 units in such poor physical condition, and safety deficiencies so serious, that it recommended they be shut down until improvements were made.

Following the mission, the Bulgarian Committee on the Peaceful Use of Atomic Energy announced that Unit 4 had been shut down for safety-related improvements and that Unit 3—which was being refueled—would remain shut until improvements were made. Unit 4 resumed operation in August 1991 and Unit 3 in November. Unit 1 was shut in September for backfitting, followed by Unit 2 in November.

Plant Events. In August 1996, Bulgarian media reported that two "grave accidents" at Kozloduy had been concealed from the public. The same month, the Bulgarian official responsible for International Nuclear Event Scale reports said that the plant had reported the two events to the Bulgarian nuclear regulator. One involved a leak of radioactive water from the auxiliary building common to units 3 and 4, contaminating ground and wall surfaces. The other involved the disturbance of forced reactor coolant circulation in Unit 5 when it was in cold shutdown. The events—both classified as Level 1 on the INES—were reported to the International Atomic Energy Agency.

Technical/Upgrading Activities

In 1991, Bulgaria requested financing from international lending organizations—the World Bank, the European Bank for Reconstruction and Development—as well as from such bodies as the European Communities to pay for technical improvements by Western companies to the four VVER-440 units at Kozloduy.

In addition, the Bulgarian Energy Committee announced plans to upgrade Kozloduy units 5 and 6.

Technical improvements under way and completed are discussed in the following section.

International Exchange/Assistance

WANO Membership. Kozloduy is a member of the World Association of Nuclear Operators (WANO), and plant representatives hosted a visit by staff of Consumers Power Co.'s Palisades plant May 5-12, 1990. Kozloduy staff, in turn, visited Palisades June 17-24 of that year.

Because of Kozloduy's WANO membership, plant management appealed to the organization for help following the visit of IAEA design and operational safety review teams in early 1991. WANO agreed to help, offering to provide spare parts and equipment from the closed VVER-440 units at Greifswald in eastern Germany.

In November 1995, at the invitation of the Kozloduy plant management, a team of experts from WANO carried out a peer review of units 5 and 6. The review covered such areas as operating practice, maintenance, technical support, radiation protection, training, and organization and management.

IAEA Training Seminar. An IAEA training seminar was scheduled to be held at Kozloduy April 8-10, 1997, to demonstrate the practical use of the ASSET analysis procedures for self-assessment of operational events in advance of the October ASSET peer review mission to the plant.

EC Assistance. In July 1991, the European Communities (EC)—now the European Union—announced that it had earmarked 11.5 million ECU ($12.1 million) through its PHARE program for emergency aid to improve safety at Kozloduy.

The aid focused on three areas:

- The immediate repairs needed to restore the units to their original operating condition.

- A three-year improvement program, starting with a six-month phase consisting of on-site advice by an international team of nuclear engineers to achieve two objectives:

  --evaluate the safety of units 1-4

  --help Bulgarian regulatory authorities function to the IAEA's safety standards and organize safety as EC countries have done.

- "Twinning" Kozloduy with nuclear power plants in EC countries for ongoing exchanges of technical and operating information.

Within a month of the EC announcement, the team of nuclear engineers had arrived at Kozloduy, and by November of that year, units 1 and 2, the two oldest, had been shut down for extensive repairs.

As part of the backfit effort, Germany announced in September 1991 that it was sending $11 million worth of spare parts to Kozloduy from VVER-440s at the closed Greifswald plant.

Electricité de France (EdF) had already agreed in June 1991 to "twin" Kozloduy and EdF's Bugey nuclear plant, making that pairing the first under the emergency aid effort.

As part of the six-month safety review of units 1-4, Bulgaria's Energy Committee and the EC selected firms to carry out the most urgent work, which included assessing the structural integrity of the primary vessel and pipework and the effects of vessel annealing. Among the firms awarded contracts under the EC's 11.5 million ECU PHARE program for Bulgaria were the U.S. company Westinghouse, Empresarios Agrupados of Spain, EdF/Siemens, and Belgatom. A separate contract was awarded to a consortium of Western European nuclear safety expert organizations led by France's IPSN (Institute of Nuclear Protection and Safety).

The consortium, together with WANO, Kozloduy operators and Bulgarian regulators, agreed on a three-year outage management program that would cover plant restoration, equipment requalification, engineering, documentation, operational feedback, formation of a safety committee, and training.

In March 1992, the annealing (a heat-treatment process that can help restore the ductility of metal) of Unit 2's pressure vessel began. Annealing was completed in April. In addition, Western non-destructive testing methods were used to check the condition of the primary circuit, and cracked isolating valves were replaced. Fire-detection equipment was replaced, and fire protection—including fireproof doors and protection for electrical cables—was installed. The EC provided $15 million for improvements to Unit 2, while the Bulgarian government provided $10 million.

Following a full inspection of Kozloduy 2's safety-related systems and equipment by an international consortium and a Bulgarian government commission, the unit was approved for restart in late December 1992. Following a complete check of the primary circuit and analysis of the pressure vessel, Unit 1 was restarted in December 1993.

As part of the upgrading effort, a consortium of Belgatom and Finland's IVO International carried out projects aimed at improving training, operating procedures and documentation at Kozloduy.

According to the Bulgarian regulatory agency, the NEC financed the upgrades for units 1 and 2, and the European Union (EU) financed the upgrades for units 3 and 4.

In July 1996, Bulgaria announced that the EU would provide 7 million ECU ($7.4 million) to improve the safety of Kozloduy. Of this amount, 2 million ECU ($2.1 million) was earmarked for operational safety, 3.4 million ECU ($3.6 million) for near-term improvements to the reactors' design safety, 1 million ECU ($1.06 million) for assistance to the nuclear regulatory agency, and the rest for management and monitoring operational safety.

EBRD's Nuclear Safety Account. In January 1993, members of the G-24's Working Group on Nuclear Safety met at Kozloduy to decide on the next steps in the plant's assistance program. Also in January, Bulgarian officials reported that the European Bank for Reconstruction and Development (EBRD) had agreed to supply 24 million ECU ($25.4 million) to upgrade the Kozloduy plant. The grant was conditional on the earliest possible shutdown of units 1-4.

The Bulgarian government said it intended to shut down units 1 and 2 as soon as upgrading work on either unit 5 or 6 was completed and a pumped storage plant was built, probably by 1997. It added that units 3 and 4 would operate until both units 5 and 6 were upgraded and three district heating cogeneration plants were upgraded, which—given sufficient financing—could be done by 1998.

In June 1994, tenders were invited for a wide range of equipment, most of it intended for units 3 and 4. The U.K.'s Nuclear Electric received a $600,000 grant from the European Union to help the National Electric Company manage the upgrading program.

Under a contract financed by the NSA grant, the French company Sebim supplied pilot-operated safety relief valves for units 1-4. The valves installed on the steam generator circuit of Unit 2 leaked initially, the result of an erroneous piping configuration supplied by NEC, according to Sebim. After

adjustments, they worked properly. As of February 1997, valves had been installed on steam generators and pressurizers at units 1, 2 and 3.

In early October 1995, Bulgarian deputy prime minister Tsochev told the managers of the EBRD's NSA that the government was prepared to place Kozloduy Unit 4 in special shutdown in the spring of 1996 for the installation of safety-related equipment financed by an NSA grant. In September 1996, Energy Minister Ovcharov said that Bulgaria had proposed to the bank that the installation of the equipment be postponed until the March-June 1997 period.

The short-term upgrades were to have been completed by the end of 1997, but because of delays in the program, not all equipment may be installed by then. According to officials from the Bulgarian regulatory authority, upgrades to units 1 and 3 had been completed by February 1997; upgrading work was started on units 2 and 4 in April. As of February, about 18 million ECU ($19 million) of the 24 million ECU grant had been disbursed

Although the NSA grant calls for the earliest possible shutdown of units 1-4, Konstantin Rusinov, chairman of the Energy Committee, said in June 1996 that Bulgaria planned to operate Kozloduy units 1 and 2 until 2004, and units 3 and 4 until 2010 to 2012.

Other Assistance. In 1992, the Bulgarian government requested funding from the World Bank for a review of nuclear safety at Kozloduy. The purpose was not to duplicate the work planned under the EC program, but to indicate what could and should be done at the plant. The review, carried out by EQE International, identified short-term modifications and longer-term improvements to Kozloduy that would enable safety levels at the plant to approach those of nuclear plants in the West.

The EQE International recommendations included four modifications that would significantly enhance safety: adding a segregated, hazard-protected bunker to house all functions needed to shut down the plant; adding fast-acting main steam isolation valves; providing additional protection against hazards such as earthquakes, fires and wind; and providing a filtration system and improving the existing venting capability. According to Bulgaria's chief nuclear regulator, the study demonstrated that the difference in operational risk between units 1-2 and units 3-4 is small and does not justify the early shutdown of units 1 and 2.

EQE Bulgaria was established in 1992 to provide Western seismic and safety analysis expertise to Kozloduy. Among its projects, variously funded by the International Atomic Energy Agency, the World Bank, EQE and Kozloduy itself, are: the seismic qualification of information backup system data recording equipment for units 5 and 6; the design and implementation of seismic upgrades for electrical, instrumentation and control equipment, walls and buildings and the interim spent fuel storage building; a top-level risk study of units 1-4 to analyze safety as initially built and after reconstruction work carried out between 1990 and 1994, and to identify further modifications that could be carried out in the short term; and the evaluation, design and cost-benefit studies of potential safety improvements to units 1-4.

Electricité de France. EdF signed a cooperative agreement with the National Electric Company in 1993 to improve safety at the Kozloduy plant. EdF also contributed FF 10 million ($1.59 million) for equipment and spare parts purchases. The utility is also advising NEC on corporate strategy, fuel supply, training, pricing policy and linking the Bulgarian and Western European grids. In July 1993, the Kozloduy plant asked EdF to help analyze potential improvements to the instrumentation and control systems of units 5 and 6.

In January 1994, EdF agreed to continue its cooperation with NEC aimed at improving the safety of the Kozloduy plant. Under this agreement, EdF would concentrate on upgrading the plant's two VVER-1000 units. The proposed modernization of units 5 and 6—developed by NEC, Energoproject and EdF—was reviewed by an IAEA team in June 1995 during a visit to the Kozloduy plant. The team compared the proposal with an IAEA-developed list of VVER-1000 generic safety concerns, and concluded that the proposal—together with some recommendations from the team itself—would greatly contribute to improved plant safety.

Siemens. Germany's Siemens agreed in 1993 to provide $45 million worth of equipment for Kozloduy's upgrading in exchange for Bulgarian chemical products and exported electricity. NEC, which negotiated the arrangement for Bulgaria, said it was owed several million dollars by Bulgarian chemical manufacturing companies. In June 1995, Siemens said it planned to install a newly developed water and steam leak monitoring system at Kozloduy.

United States. Under the U.S. International Nuclear Safety Program, Kozloduy has received two emergency diesel generators and two fire trucks, one to pump water and one to pump chemical suppressants. In November 1993, Westinghouse won a contract to replace the feedwater control valves on units 5 and 6. The new valves were commissioned on Unit 5 in 1994 and on Unit 6 in 1995. ABB Combustion Engineering, working with Bulgaria's Energoproekt, has completed a study of confinement structures at units 1-4 to assess the technical and economic feasibility of installing a filtered vent system. The study, funded by the U.S. Trade and Development Agency, concluded that vent systems are financially and technically feasible and desirable.

Inetek. Croatia's Inetek has several long-terms contracts with Kozloduy. Under one, the company will carry out eddy current testing of the plant's steam generators until 1999. Depending on the results of testing, it will also carry out tube plugging until 1999. The company will use advanced ultrasonic testing, eddy current testing and visual techniques to carry out in-service inspection of the plant's pressure vessels to the year 2001.

Russia. In December 1995, Russian Deputy Minister of Atomic Energy Viktor Sidorenko reportedly said that Russia was prepared to help Bulgaria develop a modernization program for all six reactors at Kozloduy and, if Bulgaria chose to carry out such a program, to provide support.

In November 1996, Russia agreed to allocate $250 million in credit for modernizing Kozloduy's four VVER 440 Model 230 reactors. An official of the Russian Ministry of Atomic Energy said in February 1997 that Russian specialists had begun installing equipment in units 1 and 4 to improve their

safety. But in April, the Bulgarian press reported that signing of the credit agreement had been postponed.

Unit 1 Restart

Kozloduy's Unit 1—which underwent upgrading in 1992—was shut down in February 1995 for a five-month check of its safety systems. Two European safety institutes—France's IPSN and Germany's GRS—submitted a report to the Bulgarian regulatory authority in mid-September that maintained the resistance of Unit 1's pressure vessel to large thermal shock had not been adequately demonstrated. They recommended that samples be taken from the vessel for examination and analysis before the unit was restarted.

In late September, the ambassadors of the G-7 nations met with Bulgarian Deputy Prime Minister Kiril Tsochev to express their concern about Kozloduy Unit 1. They asked that the unit not be restarted unless the condition of its pressure vessel could be ascertained to the satisfaction of Western safety experts. NEC responded that it could not ensure normal power supplies if any one of the units at Kozloduy did not operate, and the Bulgarian government rejected the G-7 request.

At the end of September, the Committee on the Peaceful Use of Atomic Energy issued a statement noting that all the studies carried out independently by Bulgarian institutes, the Russian designer of Kozloduy and the pressure vessel manufacturer had concluded that the pressure vessel could be operated with sufficient safety margins until the next refueling in March or April 1996.

On Oct. 3, a team of IAEA experts met with representatives from Bulgarian and Russian nuclear bodies as well as IPSN and GRS in an attempt to resolve their differences over Unit 1's restart. At the meeting, the Bulgarian nuclear safety authorities described licensing-related requirements for the unit's restart, consisting of a three-step program of operation: a reduced operating cycle of about six months; a special operating regime to include constant power operation to avoid system transients, revised operating procedures, special operator training, and increased supervisory control; and a comprehensive program to prepare to take samples and/or anneal the reactor pressure vessel after the shortened operating cycle. On Oct. 5, the Bulgarian regulator gave approval for restart.

In mid-October, the European Parliament passed a resolution calling for the immediate shutdown of Unit 1. In response, the chairman of Bulgaria's parliament told the European Parliament that samples from Unit 1's pressure vessel would be analyzed in the spring of 1996.

In December 1995, Bulgarian officials reported that, following a meeting with the Commission of the European Union (EU) in Brussels, the EU would fund the tests on Unit 1's pressure vessel, which could cost up to $500,000. Bulgaria said it could not close the unit for tests before April or May 1996 unless the EU compensated it for electricity losses.

EU, Bulgarian and Russian experts met in January 1996 to discuss the program of tests to be carried out on Unit 1. They agreed that six metal samples would be taken from the vessel for chemical and mechanical analyses. Bulgaria shut down the unit in mid-May. In July, the EU agreed to provide 10 million ECU ($10.6 million) to Bulgaria's energy sector to compensate for the unit's shutdown. Croatia's Inetek, under a subcontract to Westinghouse, was to take metal samples from the mid-vessel weld in August, but problems with the cutting machine—developed by the U.S. company PCI Energy Services under subcontract to Westinghouse—delayed the process until mid-September.

Siemens, together with Russia's Kurchatov Institute and the Bulgarian Academy of Sciences, began analyzing the samples in October. In early December, representatives of the three organizations said that, based on preliminary test results, Unit 1 could be restarted without annealing the pressure vessel.

After an inspection by Bulgarian regulatory authorities, Unit 1 was restarted in mid-January 1997. After the restart, IPSN and GRS—the French and German nuclear safety agencies—issued a statement saying that operation of the unit for more than two years should be conditional on further tests of the pressure vessel. Given the safety deficiencies of the VVER 440 Model 230s, added the agencies, Unit 1 would need major safety improvements if it were to operate for a number of years. In May, however, experts from the IAEA, the European Union, Bulgaria, Germany, Russia, the United Kingdom and the United States met for a workshop in Sofia, and reportedly said that the vessel would be good for another six to seven years of operation.

Upgrading Units 5 and 6

The Bulgarian Energy Committee said in February 1996 that it would seek bids to upgrade the operational and safety reliability of Kozloduy units 5 and 6. In March, the committee said that 14 foreign firms were bidding for the project. A consortium of Germany's Siemens, France's Framatome and a Russian institute put the cost of the project at $250 million, while Westinghouse said it would cost $280-300 million. Russia was also bidding on the project. According to the National Electric Company, the three-year project will be carried out in three stages, with the work done during refueling outages. The German-French-Russian consortium won a $250 million contract for the project. Bulgaria has reportedly applied through the European Commission for a Euratom loan to fund the work. Additional financing will be provided by loans from the consortium members.

The work will focus on long-term cooling of the reactors, radiation and fire protection, instrumentation and control and electrical power supply, and improving operating performance. It will include improvements in the units' seismic stability, the performance of safety and mechanical analyses, the installation of diagnostic equipment, and the improvement of components on the secondary side.

In addition, the Kozloduy plant is funding a four-phase project to upgrade the autonomous radiation control system at units 5 and 6. A U.S. consortium of

Westinghouse and Sorrento Electronics will provide 18 new detectors and 16 new radiation processors. Under the first phase of the project, the central unit and two radiation processors were to be delivered in 1996.

Inspections

The Bulgarian government has requested IAEA inspections of all six operating units at Kozloduy.

OSART Mission (Unit 5). The first IAEA inspection was an Operational Safety Review Team (OSART) mission to Unit 5 Oct. 15-25, 1990. The team focused on several key issues—operations, maintenance and technical support—in what it termed a "mini" OSART and scheduled a full-scope OSART for the following year.

In its review, the team recommended:

- better living and working conditions for plant staff.
- less bureaucratic red tape.
- open exchange of information.
- simple but efficient organization structures.

The team also pointed out that improvements would be difficult to make without the support of the Bulgarian government.

ASSET Mission (Units 1-4). An IAEA Assessment of Safety Significant Events Team (ASSET) mission visited units 1-4 Nov. 7-21, 1990. The team noted a lack of attention to preventing operational events and said that safe operation demanded major improvements by plant management. In particular, the team criticized management's emphasis on production of electricity over operational safety.

The team stressed the seriousness of the situation at Kozloduy and said that Bulgaria must supply the resources needed for the plant's safe and reliable operation. Noting that it could not complete its review because of a lack of information, the team called for another ASSET mission when the necessary information was available.

OSART Mission (Units 1-4). The IAEA OSART mission to Kozloduy units 1-4 during June 3-21, 1991, identified many operational problems, including:

- lack of a safety culture
- poor work practices
- industrial safety hazards
- poor radiological protection
- lack of structured training for operators
- incomplete operating procedures.

The findings were so devastating that the team suggested that continued operation of units 1-4 would be imprudent.

OSART Mission (Unit 5). A month later, July 15-Aug. 2, an OSART mission visited Kozloduy 5. The team said that despite the unit's good operational performance, fundamental changes were needed to break with past practices and establish a safety culture.

ASSET Mission (Units 1-4). An ASSET mission visited Kozloduy June 1-5, 1992, to help plant management implement previous ASSET recommendations on quality control, preventive maintenance, surveillance, root-cause analysis, and repairs and remedies.

The team noted that the plant management had paid proper attention to the recommendations of the 1990 ASSET mission. Some recommendations had been carried out immediately, and others were included in general programs for improving operational safety.

The team observed that plant management was fully dedicated to making technical and organization changes, and was taking full advantage of the international assistance offered for this effort. The team added that the importance of quality assurance and safety culture was understood at the top management level.

Singling out the recommendation on installing fast-acting valves to isolate the main steamlines, the team emphasized that this action should have higher priority than it had been given under the plant's improvement program. The team also noted that while progress had been made in enhancing the safety awareness of maintenance personnel working on safety-related equipment, improvements were still needed to achieve a satisfactory level of safety awareness.

In addition, the team noted that quality assurance was a relatively new concept at the plant, and suggested that while WANO exchanges had improved attitudes toward quality assurance, workshops, seminars and on-the-job training would also help.

Follow-Up OSART Mission (Units 1-4). An OSART follow-up mission visited Kozloduy April 26-30, 1993. The purpose of the mission was to determine the status of actions taken in response to the findings of the 1991 OSART mission to the plant as well as the actions taken in response to the issues identified as part of the IAEA's program on the safety of VVER-440 Model V230 reactors.

The team concluded that the plant had made reasonable progress in responding to the recommendations of the 1991 mission and the more generic issues identified by the IAEA program. Given the significance of the 1991 findings, the team said, the progress represented the fruits of a major effort by, among others, the Bulgarian utility, Kozloduy staff and the Bulgarian regulatory body.

The team noted that about two-thirds of the operational safety issues were moving toward completion. The team identified improvements in:

- management's abilities, attitudes, and knowledge of safety culture principles.
- basic operating procedures.

- safety equipment testing program.
- arrangements to minimize the unavailability of safety equipment.

The team pointed out, however, that a considerable amount of work remained to be done to resolve the issues raised by the 1991 mission. The team urged renewed management drive to ensure that sufficient resources were available to develop and manage the plant's training program, and that plant staff received appropriate training in emergency response when following the recently improved emergency plan.

Follow-Up ASSET Mission (Units 1-4). An ASSET follow-up mission visited Kozloduy Sept. 20-Oct. 1, 1993, to review operating experience, assess the appropriateness of corrective actions, and exchange views on improving the management of incident prevention. The team noted that all 13 recommendations made by the 1992 ASSET mission had received appropriate consideration. Six had been fully addressed and carried out; progress was being made on the other seven.

The team reviewed 93 reported events between December 1990 and May 1993. Of these, 73 were considered by the team to be safety relevant; 14 were classified as Level 1 and the rest, as Level 0.

The team offered several recommendations:

- As the plant organization evolves, management should ensure that each department has a clear definition of its interfaces, responsibilities and resources.

- Departments within the plant should be encouraged to increase the level of shared information.

- Management should consider whether surveillance programs for equipment that has failed should be assessed to determine whether extensive testing is beneficial.

- Management should consider expanding the sharing of information with plants of similar design and origin to include the sharing of critical spare parts when necessary.

The team commended three plant practices:

- Discussion of safe plant operation at the department management level.
- Establishment of significant international contact to promote exchange of safety information.
- Conducting root cause analysis of events on a structured basis.

ASSET Mission (Units 5 and 6). An ASSET mission visited Kozloduy units 5 and 6 Nov. 14-25, 1994. The team reviewed 425 reported events, of which 177 were considered to be of safety relevance. One event was classified as Level 2 on the International Nuclear Event Scale, 31 were classified as Level 1, and the rest as Level 0. The team noted that the number of events per year was declining and the proportion of events discovered by surveillance programs was rising—both positive trends.

The team identified 12 safety problems that had developed over the life of the units, of which six had been resolved. Satisfactory solutions were being implemented for the remaining six.

In its recommendations, the team emphasized further enhancement of the units' surveillance programs and the training of staff.

Safety Review Mission (Units 5 and 6). A Safety Review Mission visited units 5 and 6 June 25-July 1, 1995. The purpose of the mission was to review the safety aspects of the units' modernization program. The review covered plant design and operational safety as proposed in the program. Upgrading measures, which are aimed at improving plant availability, were not reviewed.

Because of variations in the content and descriptions of individual measures in the program, the team could not judge the sufficiency of some proposals. It concluded that a certain number of measures need to be improved, and some measures need to be added to the program. The team recommended that the proposed improvements be examined to ensure that they do not cause adverse effects.

Safety Review Mission (Units 1-4). A Safety Review Mission visited units 1-4 in January 1996 to review progress in implementing safety improvements. Short-term measures had generally been carried out, but implementation of measures requiring major plant reconstruction was limited.

Planned ASSET Mission (Units 5 and 6). An ASSET peer review mission to units 5 and 6 is scheduled for Oct. 6-10, 1997. The mission will review the plant's analysis of events reflecting safety culture issues based on ASSET procedures.

Planned OSART Mission (Units 1-4). An OSART mission to units 1-4 is planned for the third quarter of 1998.