NUCLEAR ENERGY IN UKRAINE

Ukraine has a nuclear capacity of about 12,800 megawatts. The country's nuclear units—a total of 15 until Chernobyl 1 closed Nov. 30, 1996—provided 43.8 percent of Ukraine's electricity in 1996, up from 36.7 percent in 1995. During the winter of 1995-1996, nuclear energy produced 41 percent of Ukraine's electricity. Thermal (coal, oil and gas) power stations supply more than 50 percent of Ukraine's electricity, and hydroelectric facilities generate about 5-6 percent.

Total electricity production fell in both 1995 and 1996, but nuclear generation rose. Nuclear output increased by 2 percent in 1995 and by almost 13 percent in 1996.

Nuclear Program and Plans

The Ukrainian government began taking decisive steps toward managing its nuclear power plants shortly after proclamation of Ukraine's independence Aug. 24, 1991.

On Nov. 1, 1991, the Ukrainian Parliament took complete ownership of the nuclear power plants in its territory. Since the Soviet Union's collapse at the end of 1991, Ukrainian authorities have been slowly building their nuclear power economy and their own oversight framework for nuclear power operations. This work has included:

- The formation in 1992 of a state-owned nuclear plant operating organization, Ukratomenergoprom, is a consortium of nuclear power plants and nuclear sector companies.

- The creation by presidential decree in 1993 of the Commission for Nuclear Policy, with responsibility for preparing proposals and recommendations on the development of a national nuclear policy, for analyzing draft legislation on the use of nuclear power, for evaluating the country's nuclear energy development programs against international standards and requirements, and for studying new nuclear energy design and engineering proposals. Viktor Baryakhtar was named chairman. The commission is under the office of the Ukrainian president. In March 1995, President Kuchma issued a decree changing the body's name to the Commission for Nuclear Policy and Environmental Safety, and appointed Valeriy Kukhar as chairman.

- The establishment in 1993 of the State Committee for the Use of Nuclear Power—Derzhkomatom or Goskomatom—which is responsible for the effective management of the country's nuclear energy resources. Goskomatom, which replaced Ukratomenergoprom, is also charged with assessing the prospects for nuclear energy and determining the role that the country's nuclear power plants should play in the country's program for secure energy supplies. In addition, the committee has jurisdiction over nuclear fuel production. Also charged with creating a nuclear operations entity, Goskomatom in May 1995 proposed the creation of Energoatom. In the meantime, Goskomatom served as Ukraine's de facto nuclear operating organization.

  Goskomatom was headed by Mykhaylo Umanets until January 1996, when he was asked to resign by Ukrainian Prime Minister Marchuk. That same month, Goskomatom first deputy chairman Nur Nigmatullin was named acting chairman, and in April, Viktor Chebrov was named chairman. In August, Nigmatullin resigned as first deputy chairman, and in April 1997, Chebrov resigned.

- The formation of Ukraine's own nuclear authority, GANU—the State Committee for Nuclear and Radiation Safety—which became an official state committee in October 1991. In December 1994, however, President Kuchma issued a decree abolishing GANU and the Ministry for Environmental Protection, and merging their functions into the newly created Ministry for Environmental Protection and Nuclear Safety.

- The creation by the Ukrainian Parliament in June 1994 of a Commission on Nuclear Policy and Nuclear Safety, headed by Mykhaylo Pavlovskyy. In January 1995, Pavlovskyy said that the Ukrainian government must develop a 20-year plan for nuclear energy that includes the construction of a new generation of nuclear plants.

- The formation in October 1996 of Energoatom, a state company responsible for selling nuclear-generated electricity as well as procuring fuel, improving nuclear plant safety, and building, backfitting and decommissioning nuclear units.

- The creation in May 1997 of the Ministry of Energy, which includes a State Department of Nuclear Energy, and the abolition of the Ministry of Energy and Electrification and Goskomatom

Chernobyl Backlash. In planning a nuclear program, Ukraine's government faced public opposition to nuclear energy following the 1986 accident at the plant's Unit 4. In response, the Ukrainian Parliament voted in 1990 to impose a moratorium on nuclear plant construction and to close the Chernobyl plant in 1995. In 1991, following a fire in the turbine hall of Unit 2, the Parliament moved the date for Chernobyl's shutdown to 1993.

Replacing Lost Power. As the 1993 deadline grew closer, however, Ukrainian authorities voiced concern that they may have acted too hastily with their decision to close Chernobyl. In April 1993, the chairman of Ukraine's parliamentary standing committee on basic industrial development said the committee intended to ask the Ukrainian cabinet of ministers to lift the moratorium on new plant construction.

The Commission for Nuclear Policy held a public hearing in May 1993 on the issue of lifting the moratorium and extending operation of Chernobyl. After postponing a decision in the summer, the Ukrainian parliament voted in October to continue operating the Chernobyl plant and to lift the moratorium on new plant construction. Parliament cited Ukraine's energy shortage as the reason. The vote cleared the way for completion of three partly-built VVER-1000 units—Zaporozhye 6, Rovno 4 and Khmelnitskiy 2.

Plans for New Capacity. In February 1994, then-President Kravchuk issued a directive calling for the completion by 1999 of five VVER-1000s under construction: Zaporozhye 6, Rovno 4 and Khmelnitskiy 2, 3 and 4.

In July 1994, Leonid Kuchma was elected president, defeating incumbent Kravchuk. President Kuchma has said that Ukraine's entire power sector must be modernized. In March 1995, Kuchma reportedly ordered the Ukrainian finance ministry to allocate 1 trillion karbovantsi to complete Zaporozhye 6 by the end of the year. Zaporozhye 6 is now complete, Rovno 4 is 80 percent complete, Khmelnitskiy 2 is 90 percent complete, Khmelnitskiy 3 is 50 percent complete and Khmelnitskiy 4 is 10 percent complete.

Estimated start-up dates for the reactors under construction are: Khmelnitskiy 2, 1998; Rovno 4, 1999; Khmelnitskiy 3, 1999; and Khmelnitskiy 4, 2000. Funding for completion of Khmelnitskiy 2, estimated at $257 million, and Rovno 4, estimated at $267 million, is expected to come from the state budget and the sale of electricity from the Zaporozhye plant.

In June 1996, Goskomatom Chairman Chebrov said his committee planned an international tender within two years to choose the type of reactor that Ukraine will use in the next generation of nuclear power plants.

Nuclear Operations. In May 1995, Goskomatom proposed the creation of Energoatom—a government-owned holding company that would be responsible for nuclear operations. In addition, the committee called for reform of the nuclear industry, with stock in nuclear plants and uranium enterprises sold to employees and the public.

In April 1996, the Ukrainian Cabinet of Ministers adopted a draft presidential decree creating Energoatom. A month later, the Cabinet approved the reorganization of Ukraine's nuclear energy sector, including the establishment of Energoatom. Under the reorganization, Energoatom would be responsible for coordinating electricity rates with the state rate commission and for selling power in the market. It also would be responsible for procuring fuel, improving nuclear plant safety, organizing training for nuclear plant staff, building and backfitting nuclear units, developing strategies for waste management and decommissioning, and ensuring compliance with international agreements on nuclear safety and liability.

Formation of Energoatom. In October 1996, the Ukrainian government decreed the formation of Energoatom, charging it with improving the nation's electricity supply and enhancing the efficient operation of nuclear power plants. Energoatom is responsible for running all the country's nuclear plants except Chernobyl.

The same month, the Ukrainian cabinet was instructed by the National Security and Defense Council to submit to Ukraine's president proposals for reorganizing the system for controlling the nuclear energy industry, examine the expediency of creating a Ministry of Atomic Energy, and outline programs for developing a domestic nuclear fuel production industry and for managing nuclear waste. The council also authorized Goskomatom to present the cabinet with a draft program for developing Ukraine's nuclear energy complex.

In early April 1997, President Kuchma officially endorsed a March decision of the National Security and Defense Council on energy supplies. In his edict, the president dismissed Viktor Chebrov as chairman of Goskomatom for failing to properly carry out the duties he was charged with.

Parliamentary Resolution. Some of Kuchma's instructions to the Cabinet of Ministers were reflected in a resolution passed by the Ukrainian parliament a week later. In the resolution, parliament called on the government to update its program for nuclear energy development and related safety guidelines. It asked the government to implement a four-point action plan:

- adoption within a month of measures to ensure electricity bills are paid on time
- submission to parliament this year of a "conceptual variant" of the government's nuclear energy development program to the year 2010
- presentation within two months of detailed draft proposals for closing the Chernobyl plant, including financing details and
- inclusion in the draft 1997 budget of financing for maintaining and possibly restarting Chernobyl Unit 2, as well as for maintenance work on the sarcophagus.

New Ministry. In May, President Kuchma reorganized the energy sector, abolishing the Ministry of Energy and Electrification as well as Goskomatom, and creating the Ministry of Energy. He appointed Yuriy Bochkaryev as minister. Within the ministry, Kuchma ordered the formation of a State Department of Nuclear Energy, to be headed by the first deputy minister of energy. Kuchma charged the ministry with the creation of a nuclear fuel cycle and the handling of radioactive waste.

In June, Kuchma appointed Mykola Fridman as first deputy energy minister and head of the State Department of Nuclear Energy. In July, Ukraine's new prime minister, Valeriy Pustovoitenko, appointed Aleksey Sheberstov as energy minister, replacing Bochkaryev.

Operating Performance. In 1996, the average capacity factor for Ukraine's nuclear power plants was 66.9 percent, up from 61.8 percent in 1995. The number of International Nuclear Safety Event reports fell from 85 in 1995 to 82 in 1996. Most of the events were classified as Level 0—having no safety significance—and only one event was classified as Level 2—an incident.

Grid Difficulties. At the end of May 1995, the Ukrainian and Russian electric power grids—separated since November 1993—were reunited. As a result, the risk of grid breakdowns in Ukraine was substantially reduced. While the grids were separated, Ukraine's operating frequency—50 hertz is the operating standard—fell during periods of high demand, increasing the risk of automatic plant shutdowns and possible damage to plant systems. If the frequency were to drop below 49.15 hertz, Ukraine's nuclear plants would automatically shut down.

Russia disconnected the two systems in early December 1995, reconnected them about two weeks later, and disconnected them again in February 1996. The second disconnect occurred after Ukrainian engineers doubled the agreed amount of electricity to be transferred from Russia because of severe winter weather and a drop in thermal plant output caused by a coal miners' strike. Ukraine's operating frequency fell to 49.12 hertz, forcing the six-unit Zaporozhye plant off line.

The two systems remained disconnected throughout 1996. On at least one occasion, the Ukrainian frequency fell to 48.96 hertz—according to a Ukrainian government official—threatening the collapse of the country's electrical system. In January 1997, Goskomatom said that the process of reconnecting the two systems should be accelerated, which would help to reduce the limitations on nuclear units' load and prevent damaging fluctuations in Ukraine's operating frequency. In June 1997, the two systems were reconnected.

Ukraine's unstable operating frequency is reportedly the reason why Turkey and Bulgaria have begun importing more electricity from Russia. The export of Ukrainian electricity to those two countries fell from 593 million kilowatt-hours in 1994 to 123 million kilowatt-hours in 1996.

Electricity Policy. In February 1995, the Ukrainian Prime Minister Vitaliy Masol said that energy rates, including electricity prices, had already been increased by 20 percent, and that by October they would have risen by 60 percent. In July 1997, Ukraine's deputy energy minister said that the country's commission for electricity regulation planned to raise electricity rates by an average of 20 percent—30-32 percent for residential customers and 12 percent for industrial customers—at the end of that month.

In September 1995, Ukraine's energy and electrification minister Aleksey Sheberstov announced plans for the partial privatization of the electric power sector. The process would involve the creation of six power generation companies, four consisting of coal-, gas- and oil-fired plants and two consisting of hydropower plants. Eventually, 49 percent of the shares in these companies would be sold, with the state retaining 51 percent. The government would retain control of electricity transmission and distribution.

In May 1997, Ukraine's law on privatization was amended, excluding nuclear power plants—among other enterprises—from privatization.

Energy Sector Policy. In May 1996, the Ukrainian parliament approved a new fuel and energy program for the period 1996-2010. The program calls for upgrading existing fossil-fuel fired power plants, and building new fossil-fired and nuclear plants. Under the program, fossil-fired plants would generate 50 percent of the country's electricity by the year 2000, while nuclear plants would provide 40 percent and alternative sources, 10 percent.

Nuclear Energy Oversight

Until December 1994, GANU—headed by Nikolay Shteinberg—was responsible for the accounting and control of nuclear materials, certification of nuclear equipment, licensing activities, and organization of radiation monitoring activities. Organizations under its oversight included:

- the general state inspectorate for the supervision of nuclear and radiation safety;
- the scientific and technical center of nuclear and radiation safety; and
- the state center for the quality control of supplies for nuclear power facilities.

In 1992, GANU reportedly launched a safety analysis program for all the country's VVER reactors. The program, due to be completed in 1994, included beyond-design-basis accident analyses, probabilistic safety analyses, operational experience analyses and the development of possible corrective measures for any problems identified.

In December 1994, however, President Kuchma issued a decree creating a Ministry for Environmental Protection and Nuclear Safety. The decree abolished the Ministry for Environmental Protection and GANU, and merged their functions into the newly created ministry. Previously, GANU had been part of the Fuel and Power Board, the government body responsible for Ukrainian energy planning. In January 1995, Kuchma named Yuriy Kostenko to head the new ministry and in February, he named Aleksandr Smyshlyayev—formerly first deputy chairman of GANU—to head the Nuclear Regulatory Administration within the ministry. Smyshlyayev also serves as first deputy minister.

In July 1995, Kostenko said that the ministry planned to begin issuing licenses to organizations operating nuclear power plants, which would help ensure safe operation. In October, a proposal on enforcement measures for license violations was submitted to the Ukrainian cabinet for approval. Under the proposal, the Ministry for Environmental Protection and Nuclear Safety would be authorized to fine nuclear plant licensees for violations of nuclear regulations and the terms of their licenses.

In February 1997, the NRA's State Nuclear Inspectorate introduced a system for licensing nuclear power plant operators. During the first phase of the system, which will last two years, 284 operators will have to be licensed on the basis of applications from plant managers. The licenses will be valid for two years.

In June, Minister Kostenko established an Advisory Council on Nuclear Safety to discuss issues proposed by the ministry or by council members.

Impact of Financial Difficulties

Ukrainian nuclear power plants are seriously short of money. Although electricity rates have been raised, the plants cannot charge enough for their electricity to cover costs. Moreover, nuclear electricity is priced as much as 30 percent below electricity from thermal power plants. In addition, the plants are owed millions of dollars by electricity consumers—especially state-owned enterprises.

In early 1996, nuclear plants were being paid for only 3 percent of the electricity they produced, Goskomatom Chairman Chebrov said in a September 1996 interview. He added that the plants were paid in the form of services for 50 percent of their electricity, and received nothing for the remainder. The situation had improved somewhat by September, with the plants being paid for 10 percent of the electricity produced.

In August 1996, the government reportedly cut off power to about 30 percent of the industrial customers that had not paid their electricity bills. According to an Energy and Electrification Ministry official, electricity consumers countrywide owed the equivalent of $1.1 billion. Beginning October 1996, the government prohibited all power plants from delivering electricity to non-paying customers. It also prohibited debt swaps between plants and their customers. In April 1997, electricity consumer debt was the equivalent of $910 million, according to the Ukrainian press. The same month, the Cabinet of Ministers drafted a resolution on stopping the supply of electricity to energy debtors.

Loss of Staff. The average salary of Ukrainian nuclear plant employees is $300-400 a month. But because of the payment crisis, many of Ukraine's nuclear plants sometimes have been unable to pay their employees at all. For example, as of early February 1997, employees of the Zaporozhye plant had reportedly not been paid in full for a year and a half.

Many of the specialists at Ukrainian plants are Russians, and a number have left to work in Russian nuclear plants where they are paid up to 10 times more than in Ukraine. According to Goskomatom, by mid-1994, Ukrainian plants had lost more than 8,000 highly qualified specialists to Russia. Since then, the situation has improved and staff losses have nearly stopped.

Halted Repair Work. During a press conference in January 1996, Nur Nigmatullin, acting head of Goskomatom, reportedly said that 70 percent of the equipment at the country's nuclear power plants is outdated, and that the industry could not afford to make repairs. He added that four units would be taken out of service for modernization work that might be delayed or halted because of funding difficulties.

In early August 1996, Prime Minister Pavlo Lazarenko was briefed on the nuclear energy plants' preparations for winter. According to a report of the meeting, the plants were owed 141.6 trillion karbovantsi by consumers. As a result, there was no money to pay for nuclear fuel, to buy equipment needed for repairs, or to prepare for winter operation. Units at the South Ukraine, Khmelnitskiy, Zaporozhye and Chernobyl plants had been idled—some for up to two months—because they had no money to complete needed repairs. But repairs were completed and the units were refueled, producing 44.3 billion kilowatt-hours of electricity during the 1996-1997 winter.

In early April 1997, a Goskomatom official reportedly said that the country's nuclear plants could afford to carry out only 30 percent of necessary repair work during the summer. That same month, Minister of Environmental Protection and Nuclear Safety Kostenko said that because of funding problems, nuclear plants had not carried out planned safety improvement work. He said that failure to improve the financial situation could make it impossible to operate the plants. Kostenko also expressed concern about the age of some of the plants' equipment. At the South Ukraine plant, for instance, he said that almost 40 percent of the equipment in units 1 and 2 needs to be replaced.

In July 1997, the Khmelnitskiy plant had reportedly received money to buy fuel, but not to carry out repairs and maintenance work. The plant may also need to replace its steam generators sometime in the next year.

Ukraine depends on foreign suppliers—mainly Russia—for about 70 percent of the spare parts needed at its plants, and does not have sufficient capacity to manufacture these items itself.

Status of Liability Coverage

The Ukrainian Parliament approved the first reading of a draft nuclear energy law in December 1994, and passed the law—which included a provision channeling legal responsibility for a nuclear accident to the operating organization—in April 1995. President Kuchma signed the implementing decree the same month. Parliament subsequently issued a resolution noting that it intended to pass by-laws on how to implement the law, particularly in the area of civil liability for nuclear damage. According to a Ukrainian legal specialist, a by-law on implementing the liability provision cannot be passed until the government estimates the cost of providing liability protection.

In April 1995, parliament approved a decree—seen as a temporary measure—giving the Ukrainian government the right to exempt foreign entities from responsibility for third-party nuclear damage. In September, the Ukrainian cabinet issued resolutions releasing all foreign entities involved in technical support activities, equipment supply and installation, construction, and start-up and shut-down of nuclear facilities in Ukraine from civil liability in the event of a nuclear accident. To obtain liability release, a firm or organization had to submit required documentation to Goskomatom. The committee, and the government, would consider all submissions on a case-by-case basis.

Ukraine 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. But it is not 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.

In late 1993, Ukraine signed an agreement with the U.S. government that covered nuclear safety assistance activities and the provision of liability protection. The Ukrainian government agreed to shield U.S. government contractors from any liability for any future accident. Ukraine has also signed a memorandum of understanding with the European Commission, which provides some protection to the European Union and the contractors and subcontractors working on projects funded by the EU's TACIS program.

Fuel Supply and Waste Disposal

Supply of Fuel. Since the collapse of the Soviet Union, Russia has raised the price of the nuclear fuel it sells to Ukraine by more than 30 times. In addition, fuel deliveries have been disrupted. Fuel purchase is the responsibility of the individual Ukrainian nuclear plants—coordinated by Goskomatom—while the state handles the agreements that set the purchase terms. However, Energoatom—the newly created, state-owned nuclear utility company—has been charged with the centralized purchase of fuel for the country's nuclear plants.

Under the terms of the U.S.-Russian-Ukrainian agreement on nuclear disarmament signed in January 1994, Ukraine was to receive nuclear fuel from Russia in exchange for warheads shipped to Russia.

But in late January 1994, Russia told Ukraine it was halting the delivery of nuclear fuel because Ukraine had not yet ratified the Nuclear Nonproliferation Treaty. While Ukraine's VVER plants had enough fuel to operate for about six months, Chernobyl—the sole RBMK plant—only had enough fuel to operate for several weeks at half power. Shipments to Chernobyl were resumed in late February, supplying the plant with enough fuel to operate units 1 and 3 at full power for several months.

In August 1994, Goskomatom chairman Umanets said that Ukraine had received free of charge only one-third of the fuel owed it under the terms of the U.S.-Russian-Ukrainian agreement. It had to pay in hard currency for the remainder, at a cost of about $300 million annually.

In November 1994, Ukraine ratified the Nuclear Nonproliferation Treaty, and Goskomatom's Umanets said that the supply of fuel from Russia would not be a problem during the 1994-1995 winter. Also in November, Russia's Ministry of Atomic Energy said that the January 1994 agreement under which fuel is delivered to Ukraine was valid for two years, with an automatic extension for five more years, provided Ukraine adhered to full-scope IAEA nuclear safeguards.

According to Goskomatom, by October 1995 Ukrainian nuclear plants had enough fuel for the coming winter season, with the exception of Chernobyl (which only had enough fuel to operate until mid-January) and Rovno. Russia should have shipped 155 fuel assemblies to Ukraine's Chernobyl plant during the first quarter of 1996, but the fuel was not received at the plant until early April. By late June, Chernobyl was again running out of fuel, with units 1 and 3 reduced to 50 percent power. Plant shutdown was averted by an agreement between Goskomatom and TVEL on terms for the delivery of fuel to Ukraine over the next 10 years.

In January 1996, the Ukrainian defense minister announced that Ukraine would continue to receive nuclear fuel from Russia under the U.S.-Russian-Ukrainian agreement on nuclear disarmament. The supply of fuel to Ukraine under the agreement will end in 1997, according to Russia's news agency Interfax.

In February 1997, Ukrainian Prime Minister Pavlo Lazarenko reportedly said that the country's nuclear power plants had enough fuel to operate for six months. But in March, Chernobyl Unit 3 cut output in half to save fuel. The plant last received fuel in July 1996, and owed Russian fuel supplier TVEL more than $3.5 million. Fresh fuel arrived at the plant in early April.

In May 1997, Ukraine and Russia agreed to develop a plan for the delivery and payment of fuel for Ukrainian nuclear plants over the 1997-2000 period.

Ukraine's Nuclear Regulatory Administration said in June that the country's nuclear plants had accumulated enough nuclear fuel for operation during the coming fall and winter.

Domestic Fuel Cycle. The disruption in fuel supply from Russia in 1994 prompted the Parliamentary Committee for Nuclear Policy and Nuclear Safety to recommend the speedy preparation of legislation that would establish a domestic fuel cycle. In addition, Goskomatom chairman Umanets announced that Ukraine planned to ask for bids from foreign companies for equipment to produce its own nuclear fuel. He added that the government had launched a project to convert several industrial enterprises in Ukraine to fuel production facilities. The five-year project would cost about $900 million. Ukraine has uranium deposits, but no facilities for enriching uranium or manufacturing fuel pellets and fuel assemblies.

At an October 1994 meeting of the Ukrainian Cabinet of Ministers, President Kuchma supported the establishment of a nuclear fuel production industry in Ukraine to eliminate the country's dependence on foreign fuel supplies. The cost of creating a Ukrainian nuclear fuel cycle has been estimated at $1 billion over a 10-year period.

Ukraine seeks to meet 40-45 percent of its fuel needs through the establishment of a domestic nuclear fuel cycle. As approved by the Ukrainian government in April 1995, such an undertaking would entail a threefold increase in the domestic mining and milling of uranium, the creation of a conversion facility, the manufacture of intermediate zircaloy products, and the construction of a fuel fabrication plant. The project would not include the development of a uranium enrichment capability. Instead, Ukraine intends to rely on foreign enrichment services.

The government is talking with France's Cogema about developing Ukrainian uranium deposits, and sought international bids for the construction of a facility to fabricate VVER-1000 fuel. Bids were received from four organizations—ABB, Westinghouse, Russia's TVEL, and European VVER Fuels. In early February 1996, Goskomatom announced that Russia had won the tender to build the plant because it offered the lowest price. But before signing a contract, Goskomatom said that Ukraine would insist the Russian government provide guarantees that TVEL would hold to the conditions of its bid. In June, Russia did so.

In July, Mykola Fridman, head of the energy ministry's State Department of Nuclear Energy, reportedly said that only 55 percent of Ukraine's nuclear fuel cycle would be independent, because the other 45 percent of fuel production costs involved enrichment, and Ukraine did not plan to develop its own enrichment facilities in the foreseeable future.

International Fuel Projects. The Ukrainian press reported in January 1996 that Ukraine, Russia and Kazakhstan had agreed to the construction in Russia of a plant to produce fuel for Ukrainian VVER-1000 nuclear plants. According to a Goskomatom official, building the plant in Russia rather than in Ukraine would reduce construction costs threefold. He reportedly said that the money saved would enable Ukraine to continue work on developing its own fuel cycle.

In April 1997, however, the Ukrainian Ministry of Environmental Protection and Nuclear Safety said that the joint venture was "inexpedient." It suggested to President Kuchma that the country continue buying fuel from Russia while working on the construction of its own fuel production facilities. At the time, the president's office had reportedly put the project on hold. But in July, Mykola Fridman, head of the energy ministry's State Department of Nuclear Energy, reportedly said that a draft agreement on the creation of the joint venture was about to be sent to ministries and departments in the participating countries. However, Ukrainian-Russian talks in late July ended only with an agreement to resume discussions at a later date.

In June, Ukraine agreed to cooperate with Great Britain in the production of fuel for Ukrainian nuclear plants. The agreement was reached during a visit to Britain by the heads of the ministries of Energy and Environmental Protection and Nuclear Safety, and Energoatom. The two countries are also expected to cooperate in the reprocessing of nuclear waste.

Spent Fuel Storage and Disposal. In the past, spent fuel from Ukrainian nuclear power plants was sent to Krasnoyarsk in Russia for reprocessing. But in 1992, the Krasnoyarsk local government—in Siberian Russia—refused to allow the Krasnoyarsk nuclear fuel cycle complex to accept Ukrainian spent fuel from VVER-1000 reactors as originally agreed. This refusal posed a major problem for those Ukrainian plants, such as the Zaporozhye complex, which were running out of on-site spent fuel storage space and faced the possible shutdown of some units as a result.

One solution—the construction of additional on-site storage—was pursued by the Zaporozhye plant. The U.S. government provided $300,000 and Duke Engineering Services provided $200,000 for a feasibility study—by Duke Engineering—of building a dry storage facility at the plant. In addition, Ontario Hydro planned to request a Canadian $2.9 million ($2.09 million) government grant to transfer to Ukraine the technology for manufacturing dry storage containers for spent fuel. Ukraine would manufacture the containers for use at the Chernobyl and Rovno nuclear plants. However, the Canadian utility did not bid on the project.

In January 1995, Russian President Yeltsin issued a decree allowing spent fuel from Ukrainian VVER-1000s to be stored at the Krasnoyarsk facility in Russia. In June, Ukraine shipped 144 spent fuel assemblies to Russia from the Zaporozhye and South Ukraine plants. In November, 72 spent fuel assemblies were shipped to Russia from the Khmelnitskiy plant, and in June 1996, some 100 spent fuel assemblies were shipped, resolving on-site storage problems for the next two years. Russia continues to accept spent fuel from Ukrainian VVER-1000 plants.

In June 1995, the Ukrainian parliament passed a law on radioactive waste management. Under the law, several government bodies—among them the Ministry of Environmental Protection and Nuclear Safety, the Ministry of Health, the Ministry of Internal Affairs and the Ministry for Emergency Situations and Protection of the Population Against the Consequences of the Chernobyl Catastrophe—were to be responsible for establishing regulations on radioactive waste management, including the construction of storage and disposal facilities for spent fuel.

The Ukrainian Academy of Sciences, Goskomatom and the State Geological Committee have reportedly identified 12 possible sites for a repository for intermediate and high-level radioactive waste. The repository would be used for all nuclear power plant waste as well as the waste from Chernobyl's decontamination and decommissioning.

In June 1996, the Ukrainian Cabinet of Ministers approved a program for handling radioactive waste up to the year 2005. The Ministry for Emergency Situations and Protection of the Population Against the Consequences of the Chernobyl Catastrophe was charged with implementing the program, with almost all the waste coming from the Chernobyl plant and surrounding area. Under the program, spent fuel from the country's nuclear plants would be stored in on-site pools until 2005, while preparations are made for on-site dry cask storage. Spent fuel loading at the Zaporozhye dry cask storage facility was expected to begin mid-1997, with dry cask facilities at the Khmelnitskiy, Rovno and South Ukraine plants reportedly planned to come on line in 1998.

Chernobyl Shutdown Initiatives

G-7 Action Plan. In early July 1994, the leaders of the G-7 approved a $200 million grant to launch the shutdown of the Chernobyl nuclear power plant. Through the autumn, the G-7 and Kiev discussed the project, and in October the Ukrainian government agreed to shut down Chernobyl provided there was no effect on Ukraine's electricity production. The government made no commitment to a shutdown date, however.

A task force composed of experts from the G-7, the World Bank, the European Bank for Reconstruction and Development, and the Ukrainian government was established to negotiate an implementation plan.

In April 1995, the Ukrainian government stated that early closure of Chernobyl would cost the country $4 billion and was not feasible without a special fund for that purpose. The government proposed that profits from the plant's continued operation be deposited in such a fund. The same month, President Kuchma said that Ukraine would develop a timetable for closing Chernobyl by 2000. Under the timetable, announced in May, Unit 1 would close in 1997 and Unit 3, in 1999. Unit 2, scheduled for restart in 1996, would be decommissioned instead.

At their June 1995 summit meeting, the G-7 leaders congratulated President Kuchma on his commitment to shut down Chernobyl by 2000, reiterated their support for the action plan proposed at the 1994 G-7 meeting, and promised to help Ukraine find the funding needed to compensate for the plant shutdown. But they failed to offer the billions of dollars that Ukraine said were needed to accomplish the shutdown.

Memorandum of Understanding. During the fall of 1995, G-7 and Ukrainian negotiators developed a plan to restructure Ukraine's electric power sector and shut down Chernobyl. In early November, they agreed on a draft memorandum of understanding on Western support for a Chernobyl shutdown.

Ukraine and the G-7 signed the memorandum in December 1995 in Canada, which chaired the G-7 in 1995. Under the agreement, the G-7 would provide $498 million in grants already committed, and $1.809 billion in international and Euratom loans. The loans were intended to fund a program that included the completion of two VVER-1000 units, Khmelnitskiy 2 and Rovno 4, as well as the rehabilitation of thermal and hydropower plants, pumped storage projects and energy efficiency.

The $498 million in grants included $349 million for improving short-term safety at Chernobyl Unit 3 and subsequent decommissioning, $43 million for restructuring the power sector, $102 million for an energy investment program, and $4 million for planning to mitigate the social impact of the plant's shutdown. The cost of final decommissioning as well as rebuilding the sarcophagus over Unit 4 were yet to be determined. The agreement called for decommissioning in the shortest practically achievable time.

MOU Implementation. At the April 1996 Moscow nuclear safety summit meeting of the leaders of the G-7 and Russia, President Kuchma reiterated Ukraine's commitment to close Chernobyl by 2000, and said that the plant's Unit 1 would be shut before the end of the year. Unit 1 was closed Nov. 30.

At a February 1997 meeting, Ukrainian and G-7 officials agreed on a plan for the Chernobyl sarcophagus (see following section), and in April, the two sides reached specific agreement on implementing the MOU. Under the agreement, Ukraine is to receive $900 million in loans and grants by mid-1997. Most of the money will be spent on developing the country's energy market, restructuring its coal industry and modernizing its hydroelectric plants. A grant of $120 million will be used for work at the Chernobyl plant.

At the June 1997 summit meeting of G-7 leaders and Russian President Boris Yeltsin, the G-7 noted that it had made "significant progress" in implementing the MOU. The leaders reaffirmed their commitment to help Ukraine in "mobilizing funds for energy projects to help meet its power needs in 2000 and beyond after Chernobyl's closure." They said that to date, projects totaling more than $1 billion had been agreed.

In late June, the Ukrainian government decreed that—in accordance with the MOU—Chernobyl Unit 1, shut down in November 1996, would be decommissioned without further operation.

Project Funding. In September 1996, the EBRD's Nuclear Safety Account sought bids for a Project Management Unit that would guide the work needed to close Chernobyl. Two months later, the bank offered a 118 million ECU grant ($125 million) for the Chernobyl project. It included 85.8 million ECU ($90.9 million) for the provision of an interim spent fuel storage facility and a liquid radwaste treatment facility, 13.5 million ECU ($14.3 million) for short-term operational safety improvements at Unit 3, and 8.7 million ECU ($9.2 million) for the PMU—project management unit.

In March 1997, the bank awarded the PMU contract to Westinghouse Electric Corp. and its subcontractors, the United Kingdom's National Nuclear Corp. and Ukraine's Kievenergoproyekt. The PMU, which is based at the Chernobyl plant, will be responsible for managing the project over the next six years.

Winners of the tenders for short-term improvements at Unit 3 and for construction of the liquid radwaste treatment facility were to have been announced in July, but now will be announced in the late summer or early fall.

The EBRD and the European Commission have agreed to divide the decommissioning projects between them, with each establishing a PMU to help Ukraine procure facilities and equipment for initial decommissioning of Chernobyl units 1, 2 and 3.

A French-British-German team led by France's SGN-Eurisys Group won a 5 million ECU ($5.3 million) contract—funded by the EC's TACIS program—to serve as an "on-site assistance team." The team will help the Chernobyl plant to develop specifications for facilities and equipment for decommissioning; supervise design and construction of waste treatment and facilities; and plan shutdown and cleanup of units 1, 2 and 3.

Five companies—U.K.'s BNFL Engineering, Japan's Kobe Steel Ltd., U.S.' Morrison Knudsen International, Germany's Nukem Nuklear and France's Technicatome—have teamed up to bid on the NSA- and EC-funded work as well as the Sarcophagus Implementation Project (see below).

Chernobyl Sarcophagus Plan (SIP). In late 1996, the European Commission began a reassessment of the terms of reference for building a new sarcophagus over the destroyed Unit 4 at Chernobyl. It awarded a contract to Germany's Trischler und Partners to prepare the design criteria for a new structure and for stabilizing the existing one.

Trischler directed an international commission of experts, which recommended the extraction of accessible fuel-containing materials from the sarcophagus, leaving the remaining nuclear materials in the structure for several hundred years.

Joint EC/U.S./Ukrainian Study. In November 1996, the European Commission, the United States and Ukraine issued the Trischler-U.S. report on the sarcophagus. It made several recommendations for reducing the probability of the structure's collapse, reducing the consequences of a collapse, and addressing nuclear, worker and environmental safety as well as the structure's long-term stabilization. The G-7 adopted the study recommendations at a meeting in Ukraine in December 1996.

In February 1997, G-7 representatives and Ukrainian officials agreed on a plan to stabilize the structure. The effort, estimated to cost $600 million-$800 million and to be completed by 2005, would not involve fuel removal.

In late April, Ukrainian and G-7 negotiators approved the plan, which consists of 22 tasks within five major areas: reducing the probability of sarcophagus collapse; reducing the consequences of accidental collapse; increasing nuclear safety; increasing worker and environmental safety; and long-term strategy and study of conversion of the sarcophagus to an environmentally safe site.

At its June meeting, the G-7 agreed to set up a multilateral funding mechanism for the Sarcophagus Implementation Plan (SIP), and agreed to contribute $300 million over the life of the project. It asked "concerned governments and other donors" to join in a special pledging conference in the fall to ensure full implementation of the project, estimated to cost $780 million. Ukraine will allocate $100 million for the project.

The EBRD, which will manage the SIP fund, is expected to seek bids on a PMU contract from Western companies in the fall of 1997.

VVER-1000 Completion. Although completion of Khmelnitskiy 2 and Rovno 4 is part of the Ukraine-G-7 MOU, Ukraine's Goskomatom submitted a separate request to the EBRD in early 1996 for funding to complete the two reactors. Sources of financing, in addition to the EBRD, include Euratom—through the European Investment Bank—and major export agencies of the countries involved.

Least-Cost Study. To qualify for funding from the EBRD, the project had to meet the bank's due diligence requirements, including a safety analysis, an environmental assessment, a least-cost analysis and extensive opportunity for public participation. In September 1996, the bank appointed an independent panel to determine whether the completion of the two reactors would be a least-cost electricity option for Ukraine once the Chernobyl plant is closed. An earlier least-cost assessment by Lahmeyer International, which favored completion, was criticized for lack of depth and thoroughness as well as being biased.

In talks with G-7 and EU representatives in December 1996, Ukrainian officials reportedly said that if Ukraine did not receive funding to complete the Khmelnitskiy and Rovno units it could not close Chernobyl by 2000.

The least-cost study—which, because of the very short time frame only analyzed existing data—was completed in early January 1997. The study questioned the economic justification for completing the two reactor units, essentially concluding that it is not the least-cost option. At a meeting later that month, the European Commission and the U.S. government refused to accept the study, however, criticizing the cost estimates used by the panel. In February, the EBRD said it would seek clarification of the panel's assumptions and underlying reasoning, and in March the G-7 asked the bank to propose its own economic analysis of the project.

Loan Decision Delayed. In early June, the bank said it could not make a decision on whether the project is the least-cost option. The G-7 leaders did not consider the project at their June meeting.

At a meeting in late June, the EBRD board of directors made no decision on the completion of the two Ukrainian units. It asked the bank staff to carry out a final analysis of the project. A stage-by-stage implementation of the project in two phases was proposed at the meeting, in which one unit could be completed by 2000. The European Commission has reportedly said it will finance up to 50 percent of the total project.

All other studies needed by the EBRD to make a decision—except for a final report on nuclear safety by Riskaudit—were completed by the end of June. Those studies cover engineering, project costs and procurement issues; a financial analysis of the energy sector and creditworthiness of the borrower; environmental due diligence; and public participation.

In mid-July, Moscow Interfax news agency reported that the EBRD would make a decision in September on whether to finance completion of the two reactors. If the bank approves the loan, an EBRD spokesman reportedly said, Ukraine could start receiving the money early in 1998.

EU Support. In June 1994, the leaders of the European Union said they were willing to provide 100 million ECU ($106 million) in grants over three years from the EU's TACIS program to promote the G-7 plan to shut down Chernobyl and reform Ukraine's energy sector. The EU leaders also offered to raise 400 million ECU ($424 million) through Euratom loans.

In September 1996, the EU signed an aid agreement with Ukraine under the TACIS program that included 22.5 million ECU ($23.8 million) for equipment needed to eliminate radiation at the Chernobyl plant and 9 million ECU ($9.5 million) to complete reactors at the Khmelnitskiy and Rovno plants.

International Chernobyl Replacement Projects. In May 1995, Ukraine and an international consortium agreed to build a thermal power plant to replace the Chernobyl nuclear plant. The consortium, headed by Sweden's Asea Brown Boveri (ABB) and including at least nine companies from eight countries, proposed the construction of a natural gas-fired combined-cycle plant at the Chernobyl plant site.

In June, another consortium—led by Germany's Siemens—proposed replacing Chernobyl's output by modernizing Ukraine's coal-fired plants. Such modernization would provide an additional 2,000 megawatts of capacity, allowing the shutdown of Chernobyl, according to Siemens. In

September 1996, Siemens signed a contract to upgrade Ukraine's coal-fired plants. The project is estimated to cost DM 130 million ($69.6 million), with one-third of the contract work going to Ukrainian companies.

According to a 1996 study by Ukraine's Energoproyekt, Chernobyl could be converted to a coal-fired plant with flue gas desulfurization equipment, a circulating fluidized-bed plant using low-quality coal, or a combined-cycle gas-fired plant. The last option was the cheapest and the quickest to build.

International Cooperation/Assistance

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.

WANO Visits. Under the auspices of the World Association of Nuclear Operators (WANO), personnel from Ukrainian plants have visited a number of nuclear plants in other countries, including the United States, and have hosted visits from staff of U.S. plants and those of other nations.

NRC Working Group Activity. Working groups sponsored by the U.S. Nuclear Regulatory Commission (NRC) have observed on-site environmental and health effects of the Chernobyl accident, fire-management techniques at Zaporozhye, and loss-of-coolant studies at Rovno.

U.S. Government Assistance. Select Ukrainian plants will be the target of "expert groups" involved in the joint U.S.-Russian-Ukrainian effort to focus on improving the various reactor types of the former Soviet Union. The U.S. program also addresses training, risk reduction and the development of regulatory functions (see sections on **NRC Programs**, **DOE Programs**).

International Research Center. In May 1995, an agreement on creating an international center for nuclear research was signed. In September, the Ukrainian government asked the international community to provide technical and financial support for a planned international center to study nuclear accidents. The U.S. government, which plans to give the center $3 million, has proposed three projects for the center—developing telecommunications links with U.S. national laboratories, formulating a strategic plan for spent fuel management, and setting up a database for design calculations and nuclear safety analysis. Italy has reportedly agreed to grant the center $3 million, France and Germany have jointly pledged DM 12 million ($6.4 million), and Japan has expressed interest.

In late April 1996, Ukrainian President Kuchma issued a decree setting up the center, and Ukraine and the United States signed a memorandum of understanding on U.S. participation in and support of the center. In February 1997, U.S. and Ukrainian officials met to promote initial projects and to review facilities in Slavutich proposed for use by the center.

TACIS Assistance. Under the European Union's TACIS (technical assistance to the CIS countries) program, the Zaporozhye, Rovno and South Ukraine plants have received 14 million ECU ($14.8 million) of equipment and spare parts, and the Zaporozhye plant has received 1 million ECU ($1.06 million) of materials for fireproofing girders and columns.

In June 1994 the leaders of the European Union said they were willing to provide 100 million ECU ($106 million) in grants over three years from the TACIS program to promote the G-7 plan to shut down Chernobyl and reform Ukraine's energy sector.

A consortium of three European companies—Electricité de France, Belgium's Tractebel and Finland's IVO International—won a contract in 1995 to help Ukraine complete the construction of units at Khmelnitskiy and Rovno. The 3-million ECU contract, funded under the TACIS program, covered work required to complete the units—installation of project management, creation of a quality assurance program, and finalization of the planned upgrade program, for example—but did not involve construction or main engineering activities. The consortium, together with Ukraine's Goskomatom, sought financing for engineering design, equipment procurement and construction from the EBRD and Euratom. Completion is estimated to take about 30 months and cost about $1 billion.

In May 1996, Kiev Energoproyekt, ENAC (a consortium of West European companies), and the Russian consortium MOKhT signed a contract with the European Commission for safety-related studies under the TACIS program.

Also under the program, Spain's Tecnatom, together with Siemens and EdF, was developing plans for a Ukrainian national training system for nuclear plant staff. The project was to have been completed in June 1996. The same companies also had a contract to develop a plan for creating a regional maintenance training center for power plant personnel. Project completion was expected in December 1996.

In spring 1996, Goskomatom submitted to the European Commission a package of some 30 proposals for improving safety at Ukraine's nuclear plants. It suggested that the projects be considered for financing as part of the EU's TACIS program. In September 1996, the EU signed an aid agreement with Ukraine under the TACIS program that included 22.5 million ECU ($23.8 million) for equipment needed to eliminate radiation at the Chernobyl plant and 9 million ECU ($9.5 million) toward the completion of new reactors at the Khmelnitskiy and Rovno plants.

Under the TACIS programs for 1992 through 1996, the European Union earmarked a total of 87.8 million ECU ($93 million) for maintenance and safety upgrades at Ukrainian nuclear power plants, according to a Moscow Interfax July 1997 report.

Japanese Assistance. In April 1996, a Ukrainian official said that Japan had offered a grant of $25 million to help ensure safety standards at Ukraine's nuclear plants.

British Support. In June 1997, British Energy announced that it had won a £1 million ($1.57 million) contract to provide consulting services to Ukraine's Energoatom for developing and improving its strategic, engineering, safety and human resources systems. The contract, awarded by the British Department of Trade and Industry, is expected to take two years to complete.

Cooperative Agreements/Joint Ventures

French-German Cooperative Agreement. An agreement signed by French and Ukrainian officials in August 1991 solidified a two-year program that focused on the improvement of VVER-440 and -1000 designs. Germany's GRS (Institute for Reactor Safety) and France's IPSN (Institute of Nuclear Protection and Safety) are partners in the effort. An ultimate goal is to develop secure nuclear licensing capability by Ukrainian authorities.

Russian-Ukrainian Nuclear Agreement. In 1993, Ukraine and Russia signed a wide-ranging agreement on economic cooperation and joint research and development in the nuclear power field. The agreement covers the design and construction of power plants and reactor equipment, the nuclear fuel cycle (including spent fuel management), research reactors, operating procedures and staff training, decommissioning, and radiological protection and safety. Under the agreement, the two countries will provide assistance with plant operation, maintenance and spare parts supply, and will also exchange information on incidents.

Ukrainian-Czech Nuclear Cooperation. A Ukrainian nuclear industry delegation met with Czech energy officials in January 1996 to talk about cooperation in the sphere of nuclear power engineering. The two sides proposed that a bilateral agreement on such cooperation be signed. In May 1997, the two countries signed a protocol on cooperation in various fields, including nuclear power engineering. The Czech Republic expressed an interest in helping to modernize Ukraine's nuclear power plants. During a visit to Ukraine by Czech President Vaclav Havel in July, the Ukrainian government offered to repay its debt to the Czech Republic by—among other things—supplying VVER reactor equipment for Czech nuclear power plants.

Ukraine-China Nuclear Agreement. Ukraine's Goskomatom and the Chinese State Nuclear Energy Corp. signed an agreement in March 1996 on the peaceful use of nuclear energy. Under the agreement, the two countries will cooperate in prospecting for and mining uranium ore, conducting research and development on water-cooled reactors, and building and safely operating nuclear power plants.

U.S.-Ukrainian Cooperation. Ukraine and the United States created a bilateral commission in October 1996. One focus of the commission's work will be nuclear power engineering. At a May 1997 meeting, the Ukrainian press reported that Ukrainian President Kuchma and U.S. Vice President Gore agreed to cooperate in improving Ukraine's energy security by, among other things, improving the ability of the country's nuclear power engineering sector to attract investments, improving nuclear safety, and cooperating in the production of nuclear fuel. They also agreed to cooperate in implementing the Memorandum of Understanding on closing Chernobyl.

Joint Ventures. Westinghouse and Ukraine's Khartron Industries agreed in October 1994 to set up a joint venture, Westron, to design, build and install Western-designed instrumentation and control systems for nuclear power plants. In January 1995, the U.S. Trade and Development Agency awarded a $200,000 grant to Westinghouse to help fund feasibility studies on upgrading Ukraine's VVER reactors. Khartron is also setting up a joint venture with ABB Combustion Engineering to manufacture monitoring and diagnostic equipment for Ukraine's nuclear plants.

In April 1996, the U.S. Department of Energy gave permission to Combustion Engineering to transfer advanced instrumentation and control technology to the Ukrainian company P.A. Monolit, set up by an ABB-Monolit joint venture. In February 1997 Ukraine's Energoatomsontrolservis and Croatia's Inetek Ltd. formed a joint venture—Ineteksontrol-Servis—to install monitoring equipment in Ukrainian nuclear plants.

Ukrainian-Lithuanian Cooperation. A Ukrainian delegation to Lithuania in mid-1995 discussed cooperation between the Chernobyl and Ignalina nuclear plants—both RBMKs—in the areas of operational safety and waste management, according to the Lithuanian prime minister.

Ukrainian-Bulgarian Cooperation. Ukrainian and Bulgarian officials met in August 1996 to discuss power sector cooperation. On the agenda was renewal of a contract under which Ukraine exported electricity to Bulgaria. Ukraine indicated that it would accept Bulgarian equipment as partial payment for the electricity.

Ukrainian-Canadian Agreement. Ukraine and Canada signed an agreement on nuclear cooperation in December 1995. In addition, in October 1996, Canada agreed to $600 million worth of trade and investment in Ukraine, including projects aimed at improving safety at the Chernobyl plant and training nuclear regulators in improved inspection and licensing procedures. In February 1997, the two countries approved plans for setting up a Canadian $2.8 million ($2 million) environmental monitoring system for the Chernobyl area.

German-Ukrainian Nuclear Safety Accord. Germany and Ukraine drafted an agreement in November 1996 on nuclear safety cooperation. The agreement, which must be approved by the German government, would focus on training Ukrainian specialists in safety assessments, and on evaluating the safety of the sarcophagus covering Chernobyl's destroyed Unit 4.

Ukrainian-Austrian Agreement. In November 1996, Ukrainian and Austrian officials signed an agreement on nuclear safety cooperation.

Operating Nuclear Power Plants in Ukraine

Plant	Type/Model	# Units	MWe
Chernobyl*	RBMK-1000	1	925
Khmelnitskiy	VVER-1000	1	950
Rovno	VVER-440 Model V213 (two); VVER-1000	3	1,695
South Ukraine	VVER-1000	3	2,850
Zaporozhye	VVER-1000	6	5,700
TOTAL:		14	12,120

*Chernobyl's Unit 4 was destroyed in 1986, Unit 2 was closed following a 1991 turbine generator fire, and Unit 1 was closed Nov. 30, 1996.

CHERNOBYL (CHORNOBYL) NUCLEAR POWER PLANT

Type: RBMK

Units: One operating

Total megawatts (net): 925

Location: Slavutich, Ukraine

Dates of initial operation: Unit 1 - May 1978 (shut down November 1996)
Unit 2 - May 1979 (shut down in 1991)
Unit 3 - June 1982
Unit 4 - April 1984 (destroyed in 1986)

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

Only one of Chernobyl's four units continues to operate. Unit 4 was destroyed by the 1986 accident, Unit 2 has not operated since a fire occurred in its turbine building in October 1991, and Unit 1 was shut down in November 1996. Unit 3 was shut down for maintenance in April 1992. During shutdown, valve problems similar to those that had plagued the Leningrad plant were detected, extending the outage of the unit while all the fuel-channel control valves were replaced.

Plant Incidents. In January 1993, two small fires occurred at the plant, one in a building housing auxiliary electrical equipment, and the other in a ventilation center in Unit 4's sarcophagus. Both fires were classified as Level 0 on the seven-level International Nuclear Event Scale (INES).

In April 1994, two incidents occurred on successive days. One involved a drop in cooling system water levels after a short circuit in a cable as workers were reconnecting Unit 3 to the grid following planned maintenance; it was classified as Level 1 on the INES. The other incident involved the failure of a controlling arm while nuclear fuel was being moved in Unit 1; it was classified as Level 0.

In October 1994, a through-wall crack in the upper part of a fuel channel tract in Unit 3 was classified as Level 1 on the INES.

In January 1995, Unit 3 was scrammed after an operator closed the wrong valve because of an incorrect inscription on a water level sensor. The event was classified as Level 1 on the INES.

Removal of a suspected faulty fuel assembly in Unit 1 in November 1995 resulted in a worker receiving a radiation dose of 5.5 rem, exceeding the 5 rem annual limit. Contamination was spread to several other rooms inside the station, and the source of the radiation—the bottom of the fuel assembly had become loose—was not discovered for ten days. The incident, preliminarily classified Level 1 on the INES, was later classified Level 3 because of the level of contamination involved. Deliberate concealment of the incident's severity was alleged in some reports. Plant director Sergey Parashin received a reprimand for the incident, as did a number of subordinates. The head of the radiation safety section was removed from his post.

During the same period, numerous unconfirmed reports circulated concerning "dangerous developments" at Unit 3. The chief engineer vigorously denied radiation levels around the unit were elevated beyond permissible limits. However, while air purification filters on a station serving Unit 3 and the sarcophagus were being changed on April 24, 1996, radioactive dust was released, resulting in elevated radiation levels within the plant. The incident was classified Level 1 on the INES.

Repair Funding Problems. In July 1997, Unit 3 was shut down for scheduled maintenance and the replacement of 70 fuel channels—about 10 percent of the unit's total. At that time, the plant had funding for only one-quarter of the spare parts and equipment needed for the maintenance work, although it had the replacement fuel channels as well as the equipment needed to carry out the replacement. Unless full funding becomes available, the unit's restart—scheduled for October—could be delayed.

Longer-Term Operation. The pressure tube replacement scheduled for 1997 is part of a project to replace all the pressure tubes that—if implemented—would allow Unit 3 to operate for at least another 10 years, well beyond the date set for its shutdown in the memorandum of understanding signed by the G-7 and Ukraine in 1995.

Unit 2 Restart Plans. In early April 1994, the Ukrainian government approved the restart of Unit 2. A few weeks later, plant management officially applied to the Ukrainian State Committee for Nuclear and Radiation Safety (GANU) to restart Unit 2. In June 1994, GANU adopted a policy on restart that would require plant management to present an annual report of actions planned to increase plant safety. GANU further said it would make a decision on restart only after the unit had been upgraded to meet current safety standards and a technical safety report had been submitted as a basis for licensing. But in December 1994, GANU was abolished, and its functions were assumed by the newly created Ministry for Environmental Protection and Safety of Nuclear Power Utilization.

In April 1995, plant management ordered repairs to be made to Unit 2. By May, one of the unit's turbogenerators had reportedly been repaired, and plans called for the second one to be replaced with a turbogenerator from the unfinished Chernobyl Unit 5.

In October 1995, repair work at the unit had reportedly been suspended because of talks between Ukraine and the G-7 countries about funding Chernobyl's shutdown. In late November, Ukrainian Minister of Environmental Protection and Nuclear Safety Kostenko said that Ukraine had decided not to commission Unit 2 in the first quarter of 1996 as planned. But in April 1997, the Ukrainian parliament passed a resolution asking the government to implement a four-point action plan. One point called for the inclusion in the draft 1997 budget of financing for maintaining and possibly restarting Unit 2.

Unless the unit begins operating in 1997, however, it would not run long enough to pay back the investment in its restart, according to a Ukrainian nuclear expert.

Technical/Upgrading Activities

Ukrainian safety projects completed or under way include fire protection improvements (detection, suppression, actuation logic, instruments, fireproofing, hydrogen removal), development of a quality assurance program, and upgrading of the "Skala" informational computer system to assist operators.

The Chernobyl Accident

The accident at Chernobyl Unit 4 resulted from a combination of design and technical deficiencies and operator error.

In January 1993, the IAEA issued a revised analysis of the Chernobyl accident, attributing the main root cause to the reactor's design and not to operator error. The IAEA's 1986 analysis had cited the operators' actions as the principal cause of the accident.

Reactions to the Accident

In response to the accident, the Soviet government initiated a major backfitting program to upgrade existing RBMK nuclear units, increasing control rod scram speed from 24 seconds to 10-12 seconds, improving core physics and increasing the uranium fuel enrichment from 2 percent to 2.4 percent.

Because of the 1991 Ukrainian parliament vote to close Chernobyl by the end of 1993, however, Ukraine had not carried out many of the upgrading activities undertaken at RBMK plants in Russia and Lithuania. But in March 1995, Ukrainian President Kuchma reportedly said that the country had allocated more than $300 million for Chernobyl safety improvements.

He also said that replacing major components—mainly pressure tubes—could extend the life of operating units by 10 years, and would cost roughly the same as closing the plant.

International Cooperation/Assistance

U.S. Assistance. The U.S. firm S3 Technologies is assisting the Ukrainians in building a control room simulator for Chernobyl. In addition, under the Department of Energy's International Nuclear Safety Program, Unit 3 will receive fire safety upgrades, and U.S. experts are working with plant staff to upgrade operational safety at Chernobyl (see the section on **DOE Programs** for details).

Canadian Aid. Ontario Hydro International will use some of the money in Canada's nuclear safety assistance package to Ukraine to adapt Ontario Hydro's dry storage canisters to accommodate RBMK spent fuel bundles from the Chernobyl plant. The canisters will be manufactured in Ukraine.

European Union Assistance. EU projects completed or underway include fire protection training, provision of an independent alternative shutdown system, and simulator training of Chernobyl personnel at the Smolensk training center to improve normal operating procedures and add more disciplines.

Other Aid. Croatia's Inetek was to deliver to Chernobyl by the end of 1996 first-of-its-kind equipment for in-service inspection of RBMK fuel channels.

NSA Grant. In accordance with the memorandum of understanding signed in December 1995, a project for radwaste management and reactor safety work at Chernobyl—funded by the EBRD's Nuclear Safety Account—got under way in spring 1997. A project management team began operation with an ECU 118 million grant from the bank. Project elements include:

- establishment of an interim spent fuel storage facility;
- a treatment facility for liquid radwaste; and
- short-term operational improvements at Unit 3.

For details, see **Nuclear Energy in Ukraine**, page 174.

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

- Japan's Hamaoka plant (August 1993).

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

- United Kingdom's Dungeness plant (March 1992),
- Japan's Hamaoka plant (November 1992),
- United States' Brunswick plant (October/November 1995),
- United States' Plant Hatch (October 1996).

Plant Twinning. The Chernobyl plant is twinned with Germany's Grohnde plant and with the U.K.'s Dungeness plant.

IAEA Training Seminar. An International Atomic Energy Agency seminar was held at Chernobyl in November 1994. The aim of the seminar—which was attended by IAEA experts, specialists from Ukrainian nuclear plants, and officials from the organizations that manage and regulate those nuclear plants—was to share other countries' plant operating experience and develop a program for improving the safety culture at Chernobyl. A second seminar was held at Chernobyl Oct. 3-5, 1995. The purpose of the seminar was to familiarize plant personnel with the detailed ASSET analysis procedures for plant self-assessment of safety performance in advance of the ASSET peer review mission scheduled for August 1996.

Inspections

ASSET Mission. The IAEA conducted an Assessment of Safety Significant Events Team (ASSET) mission to Chernobyl in June 1992 to investigate root causes of the Unit 2 fire of October 1991. The fire rendered the reactor's emergency feedwater system inoperable. IAEA's goal was to issue generic recommendations and distribute those to other plants.

The team's generic recommendations:

- Check all equipment used for disconnection and isolation of the generator from the grid for proper operation and for acceptance criteria and preventive maintenance.
- Check the capacity of the fire-suppression systems in the turbine hall.
- Check the vulnerability of emergency feedwater systems to common mode failures.
- Check that personnel are aware of the importance of seemingly small deviations, and that operational experience feedback programs pay attention to such small deviations.

The team also made four specific recommendations to Chernobyl management, strongly advising it to implement a "structured management programme" that targets quality control, preventive maintenance, surveillance and the implementation of corrective actions.

In general, the IAEA team reported that it did not receive a clear picture of the Chernobyl organizational structure and accountability for safe operations of the plant. It concluded that the general situation at the plant did not seem to be favorable to Chernobyl's safe operation.

Safety Review Mission. An IAEA mission visited Chernobyl March 7-17, 1994, to review the scope and status of the safety modifications implemented and proposed and to review safety aspects related to operation. The team found "serious safety deficiencies" at the plant, identifying safety shortcomings in four areas: design; inspection; fire protection; and radiological protection.

In the design area, the team found a number of deficiencies in the first-generation Unit 1 and in Unit 2:

- There is poor separation between control and protection systems.
- Main steam lines are located directly above control rooms in units 1, 2.
- Units 1 and 2 lack emergency control rooms.
- The control rooms have no filtered ventilation.
- The emergency core cooling system (ECCS) of units 1 and 2 cannot cope with breaks in pipes whose diameter is greater than 300 millimeters, and there are no dedicated ECCS pumps.
- Pressure relief capability from the reactor cavity is limited to a break in no more than four pressure tubes out of a total of 1,660.
- Units 1 and 2 have no check valves in the group distribution headers to protect against a break in a header or in the pressure header of the main circulation pumps.
- Units 1 and 2 do not have an accident localization system, so radioactive steam is released directly to the atmosphere in case of overpressure in the reactor building.
- Leak rates from hermetic compartments are as high as 40 percent per hour at 40 percent overpressure.
- Lack of redundancy and separation in various parts of the service water system makes the entire system sensitive to possible common mode failures.

The team found the plant's equipment for non-destructive examination of metal components to be out of date. According to the team, defect detection is crucial at units 1 and 2 because the ECCS cannot cope with large pipe breaks.

The team also found "serious deficiencies" in fire protection, especially at Unit 1. Plastic floor coverings in the turbine and reactor buildings can generate toxic smoke or fumes, which could add to the severity of a fire. Also, no systematic analysis has been carried out to determine needed fire prevention and mitigation measures.

The team said "a major and urgent reinforcement of radiation protection measures is necessary." It found serious deficiencies in: training and safety culture of radiation protection personnel, calibration of instruments, individual dosimetry and exposure control, adequacy of procedures, and contamination control.

The team said it was also concerned about the plant's ability to obtain modern equipment and spare parts.

Finally, the team cited the deteriorating condition of the sarcophagus surrounding the destroyed Unit 4, which—if it collapses—would have "serious consequences."

As a result of the mission, the IAEA considered the conditions at Chernobyl so grave that it convened a meeting of international experts and Ukrainian representatives to review the plant's safety situation.

ASSET Mission. An ASSET mission visited Chernobyl April 11-22, 1994. The mission looked at the plant's management policy on safety operation and assessed the plant's performance in preventing incidents.

The team reviewed 243 events reported between January 1989 and December 1993. Of these, 110 were considered to be of safety relevance, with 12 events classified as Level 1 on the International Nuclear Event Scale and two classified as Level 2. The remaining 96 were classified as Level 0.

The team identified nine groups of events:

- pipe and seal leaks,
- cable and electrical supplies,
- instrumentation and control systems,
- essential diesel generators,
- fuel handling,
- operator failures,
- quality of maintenance,
- inadequate training, and
- procedures.

The team said that fuel handling was an area of particular concern, because the fuel route is operated manually and relies on the high proficiency of operators. The team also noted that the frequency of diesel generator failures during the 1992-1993 period was a matter of concern.

The team made a number of recommendations to improve the prevention of events. Among them:

- Improve the maintenance and testing of fast-acting emergency core cooling system gate valves.

- Consider ways to improve cooperation and teamwork between operations and maintenance personnel.

- Ensure that all new or revised criteria for testing equipment be included during the revision of testing procedures.

- As part of a preventive maintenance program, schedule corrective actions as soon as possible after the detection of latent weaknesses.

- Plant management should consider giving further training in root cause analysis and operational feedback.

The team also suggested that plant management consider inviting an ASSET follow-up mission to the plant in two years.

In addition, the team briefly discussed with plant management the implementation of the recommendations made by the 1992 ASSET mission to the plant. Because of a lack of time, only one recommendation—upgrading generator switch control circuits—was reviewed in detail, with plant management providing information on the specific actions taken to upgrade the circuits.

Planned ASSET Mission. An ASSET peer review of the plant's analysis of events reflecting safety-culture issues, previously scheduled for July 1997, is now planned for September 9-15, 1998.

THE CHERNOBYL ACCIDENT AND ITS CONSEQUENCES

Key Facts

- The April 1986 disaster at the Chernobyl nuclear power plant was the product of a severely flawed reactor design. In addition, serious mistakes were made by the plant operators, who violated procedures intended to ensure safe operation of the plant.

- The accident destroyed the reactor in Unit 4, killed 31 people (one immediately and 30 within three months) and contaminated large areas of Belarus (formerly Byelorussia), Ukraine and the Russian Federation. In addition, one person has subsequently died from a confirmed diagnosis of acute radiation syndrome, and three children have died from thyroid cancer. The Chernobyl accident was a unique event, on a scale by itself. It was the only time in the history of commercial nuclear electricity generation that radiation-related fatalities occurred.

- Epidemiological studies have been hampered in the former Soviet Union by a lack of funds, an infrastructure with little or no experience in chronic disease epidemiology, poor communication facilities and an immediate public health problem with many dimensions. Emphasis has been placed on screening rather than on well-designed epidemiological studies. International efforts to organize epidemiological studies have been slowed by some of the same factors, especially the lack of a suitable scientific infrastructure.

- An increased incidence of thyroid cancer among children in areas of Belarus, Ukraine and Russia affected by the Chernobyl accident has been firmly established as a result of screening programs and, in the case of Belarus, an established cancer registry. The findings of most epidemiological studies must be considered interim, say experts, as analysis of the health effects of the accident is an ongoing process.

- The activities undertaken by Belarus and Ukraine in response to the accident—remediation of the environment, evacuation and resettlement, development of noncontaminated food sources and food distribution channels, and public health measures—have overburdened the governments of those countries. International agencies and foreign governments have provided extensive logistic and humanitarian assistance, and the work of the European Commission and World Health Organization in strengthening the epidemiological research infrastructure in Russia, Ukraine and Belarus is laying the basis for major advances in these countries' ability to carry out epidemiological studies of all kinds.

The Accident: What Happened

The accident, which occurred in the early morning of April 26, 1986, resulted from a safety experiment conducted in violation of the plant's technical specifications. Plant operators were testing the ability of plant equipment to provide electrical power when the main source of on-site power was lost. The plant was being run at very low power, without adequate safety precautions. The plant operators took a number of actions that deviated from established safety procedures and led to a dangerous situation. The team in charge of the test had not coordinated the procedure with the personnel responsible for the safety of the nuclear reactor.

Another major cause of the accident was several significant flaws in the design of the plant, which made the reactor potentially unstable and easily susceptible to loss of control in case of operator error. The RBMK design used at Chernobyl has a "positive void coefficient." This means the nuclear chain reaction and power output increases when cooling water is lost. The large value of the "positive void coefficient" caused the uncontrollable power surge that led to Unit 4's destruction. The power surge caused a sudden increase in heat, which ruptured some of the fuel-containing pressure tubes. The hot fuel particles reacted with water and caused a steam explosion, which lifted the 1,000-metric-ton cover off the top of the reactor, rupturing the rest of the 1,660 pressure tubes, causing a second explosion and exposing the reactor core to the environment.

The Chernobyl plant did not have the massive containment structure common to most nuclear power plants elsewhere in the world. Without this protection, radioactive material escaped to the environment. However, because the estimated energy released by the explosions was greater than most containment designs could withstand, it is highly unlikely that a containment structure could have prevented the release of radioactive material at Chernobyl. The crippled Chernobyl reactor is now enclosed in a hurriedly constructed concrete sarcophagus that is weakening over time. Ukraine and the Group of Seven industrialized nations have agreed on a plan to shore up the existing sarcophagus and build a new structure over it.

Contamination, Exposures, Evacuations

Soviet scientists have reported that the Chernobyl Unit 4 reactor contained about 190 metric tons of uranium dioxide fuel and fission products. Estimates of the amount of this material that escaped range from 13 percent to 30 percent.

Contamination from the Chernobyl accident was not evenly spread across the surrounding countryside, but scattered irregularly depending on weather conditions. Reports from Soviet and Western scientists indicate that Belarus received about 60 percent of the contamination that fell on the former Soviet

Union. But a large area in the Russian Federation south of Bryansk was also contaminated, as were parts of northwestern Ukraine.

Short-Term Impact. Twenty-eight people died of acute radiation syndrome shortly after the accident. Another three died from other causes. In addition, one person has subsequently died from a confirmed diagnosis of acute radiation syndrome.

Workers involved in the recovery and cleanup after the accident received high doses of radiation. In most cases, these workers were not equipped with individual dosimeters to measure the amount of radiation received, so experts can only estimate their doses. Also, dosimetric procedures varied. Some workers are thought to have better estimated doses than others.

According to Soviet estimates, between 300,000 and 600,000 people were involved in the cleanup of the 30-kilometer evacuation zone around the reactor, but many of them entered the zone two years after the accident. (Estimates of the number of cleanup workers—workers brought into the area for accident management and recovery work—vary; the World Health Organization, for example, puts the figure at about 800,000.) In the first year after the accident, the number of cleanup workers in the zone was estimated to be 211,000, and these workers received an estimated average dose of 165 millisievert (16.5 rem).

Some children in the contaminated areas were exposed to high thyroid doses (up to 5,000 rad) because of an intake of radioiodine, a relatively short-lived isotope, from contaminated local milk. Several studies have found that the incidence of thyroid cancer among children under the age of 15 in Belarus, Ukraine and Russia has risen sharply (see *World Health Organization*, page 194; *European Commission*, page 198; *Ivanov, Tsyb Studies*, page 202; and *Ukrainian Studies*, page 203). The childhood thyroid cancers that have appeared are of a large and aggressive type, and if detected early, can be treated. Treatment entails surgery followed by iodine-131 therapy for any metastases and then thyroid hormone replacement. Three children have died of the disease, according to the conclusions of an international conference sponsored by the European Commission, the World Health Organization and the International Atomic Energy Agency in April 1996.

Longer-Term Impact. Right after the accident, the main health concern involved radioiodine, with a half-life of eight days. Today, there is concern about contamination of the soil with cesium-137, which has a half-life of about 30 years.

According to reports from Soviet scientists at the First International Conference on the Biological and Radiological Aspects of the Chernobyl Accident (September 1990), fallout levels in the 10-kilometer zone around the plant were as high as 130,000 curies per square kilometer. The so-called “red forest” of pine trees killed by heavy radioactive fallout lies within the 10-kilometer zone.

Soviet authorities started evacuating people from the area around Chernobyl within 36 hours of the accident. By May 1986, about a month later, all those living within a 30-kilometer (18-mile) radius of the plant—about 116,000 people—had been relocated.

According to reports from Soviet scientists, 28,000 square kilometers (10,811 sq.mi.) were contaminated by cesium-137 to levels greater than five curies per square kilometer. Roughly 830,000 people lived in this area. About 10,500 square kilometers (4,054 sq.mi.) were contaminated by cesium-137 to levels greater than 15 curies per square kilometer. Of this total, roughly 2,700 square miles lie in Belarus, 770 square miles in the Russian Federation and 580 square miles in Ukraine. About 250,000 people lived in these areas. These reported data were corroborated by the International Chernobyl Project.

Assessments by Scientific and Medical Organizations

Several international organizations have studied the environmental and health impacts of the Chernobyl accident. Among them are the World Health Organization and the International Red Cross. Some of these organizations' activities and projects are summarized below.

The International Chernobyl Project

The first major assessment of the radiological consequences of the Chernobyl accident, the International Chernobyl Project, was led by an advisory group of international experts organized by a number of agencies, including the Commission of the European Communities, the United Nations Scientific Committee on the Effects of Atomic Radiation, the World Health Organization, the Food and Agriculture Organization, the International Labor Organization, and the International Atomic Energy Agency (IAEA).

The international advisory committee was chaired by Dr. Itsuzo Shigematsu, director of the Radiation Effects Research Foundation in Hiroshima, Japan. The IAEA provided the secretariat for the project. More than 200 experts—in medicine, radiopathology, psychology, epidemiology, radioecology, nutrition, dosimetry and radiation protection—were involved.

The experts were divided into teams, which visited the affected areas around Chernobyl many times, performing medical examinations of the local population, gathering data, and taking samples of soil, water, air and food for further analysis.

Because the purpose of the study was to assess the accident's radiological consequences for the people still living in the contaminated areas, it did not include the cleanup workers. Nor did the project examine what is known as the "forbidden zone" around the damaged reactor.

The report on the project, issued by the IAEA in May 1991, contained conclusions and recommendations with respect to environmental contamination, radiation exposure to the population, health impact and protective measures.

The project experts compared the health of inhabitants from the surveyed contaminated settlements with that of a similar population living in surveyed control settlements where contamination levels are lower but socioeconomic conditions are similar. The teams found significant health disorders in both the contaminated and control settlements, but none was radiation-related.

The experts noted that, as expected, the official Soviet data they examined did not indicate a marked increase in the incidence of leukemia or other cancers. However, several researchers have pointed out that the project's sample size was too small, and the study's time frame too short, to identify an increase in the incidence of tumors with short latent periods, such as leukemia and thyroid cancer. In fact, the project's report noted that "reported absorbed thyroid dose estimates in children are such that there may be a statistically detectable increase in the incidence of thyroid tumours in the future."

World Health Organization Projects

Childhood Thyroid Cancer Studies. In 1992, a team of medical specialists under the auspices of the World Health Organization's (WHO) regional office in Europe visited Minsk to study reports of an increase in the incidence of thyroid cancer in Belarus. The team examined 11 children in Belarus who had been operated on for thyroid cancer and were hospitalized for treatment or evaluation. The team also studied the histological slides of 104 children who had been diagnosed since January 1989 with thyroid cancer, and examined data on the incidence of thyroid cancer in Belarus.

In a letter on its work published in the British science magazine *Nature* in September 1992, the team said that the experience in Belarus suggested that the consequences to the human thyroid of radioactive fallout are much greater than previously thought. The team concluded, "The accident and its impact on Belarus poses a challenge to the international community to help...in promoting research for the understanding of the basic processes underlying the phenomenon. Understanding the consequences of Chernobyl will provide an important basis for preventive action in future."

The same issue of *Nature* carried a letter from medical authorities in Belarus, who reported a "great increase" in cases of thyroid cancer among children, with the greatest increase in the Gomel region, where fallout from Chernobyl was highest. "We believe that the only realistic explanation for the increase...is that it is the direct consequence of the accident at Chernobyl," wrote the authors Vasiliy Kazakov, Yevgeniy Demidchik and Larisa Astakhova.

An October 1992 issue of *Nature* carried two letters on the subject of childhood thyroid cancer in Belarus. In one, from Valerie Beral and Gillian Reeves of the Cancer Epidemiology Unit, Imperial Cancer Research Fund, Radcliffe Infirmary at Oxford, the authors noted there was "little doubt that the number of children reported to have thyroid cancer increased dramatically in radiation-contaminated areas of the Ukraine in 1990 and in Belarus in 1990-1991."

In April 1993, on the seventh anniversary of the Chernobyl accident, WHO issued a statement noting that the public health implications of the accident continued to cause great concern, particularly the rise in the number of thyroid cancer cases among children in Belarus.

International Cooperative Program. The International Program on the Health Effects of the Chernobyl Accident (IPHECA), established under the auspices of WHO in 1991, was a cooperative effort involving Belarus, Russia, Ukraine, WHO and several other countries and organizations. The program's aim was to quantify the effects of the Chernobyl accident on the population, provide recommendations for treatment, and devise more effective programs for managing such incidents in the future.

Under the program, several pilot projects were launched: on thyroid disease, hematologic disease, brain damage in utero, and oral health (in Belarus). The pilot thyroid project, which ran for three years, screened 70,000 children from the contaminated areas of Belarus, Russia and Ukraine to determine the nature of any short-term health effects. The screening identified a very large increase in the incidence of thyroid cancer in the affected countries, according to WHO.

The findings of increased childhood thyroid cancer were reviewed by an international scientific panel and published in a letter in the March 25, 1995, issue of the *British Medical Journal*. The letter, written by scientists from Belarus, Russia, Ukraine and WHO, reported an increased incidence of childhood thyroid cancer between 1991 and 1994 of 96.4 per million in the Gomel region of Belarus, 11.5 per million in five regions in the north of Ukraine, and 10 per million in Russia's Bryansk and Kaluga regions. The authors concluded: "It is notable that in the regions most affected about 2.3 million children were resident at the time of the accident. This led to unprecedented exposure of a population to ionising radiation, which demands an international response."

Report on Health Consequences. These findings, along with those of the other pilot projects, were among the issues discussed at a WHO-sponsored meeting in Geneva in November 1995. The four-day meeting was attended by some 600 scientists, researchers, public health specialists and policymakers from 59 countries. A 38-page summary report of the IPHECA pilot projects and related national programs, *Health Consequences of the Chernobyl Accident*, was released at that time. The comprehensive 800-page report was issued in spring 1996.

Although previously published works in scientific journals had discussed key findings of the studies, the main conclusions were summarized in *Health Consequences*:

- "Psychosocial effects, believed to be unrelated to direct radiation exposure, resulted from the lack of information immediately after the accident, the stress and trauma of compulsory relocation to less contaminated areas, the break in social ties among community members, and the fear that radiation exposure could cause health damage in the future. National registries recorded significant increases in many diseases that are not related to radiation. This is an important health consequence of the Chernobyl accident in view of the size of the population affected and the burden on the health care systems.

- "The Chernobyl accident resulted in a sharp increase in thyroid cancer, especially among children living in the contaminated areas. The total number of thyroid cancer cases reported among children (aged 0-14 at the time of diagnosis) in the three countries in the post-accident period was, by the end of 1994, 565 (333 in Belarus, 24 in the Russian Federation, 208 in Ukraine). An increase in childhood thyroid cancer to about 100 times the pre-accident levels was recorded in the Gomel oblast of Belarus which lay in the direct path of the initial cloud of radioactive fallout.

- "There was no significant increase in the incidence of leukaemia or other blood disorders. This may be expected given the short time frame of this study. However, since the peak in the incidence of blood disorders may occur more than 10 years after the accident, long-term studies of these diseases are needed.

- "Some evidence was found to suggest retarded mental development and deviations in behavioural and emotional reactions in a small group of children exposed to radiation *in utero*. The extent to which radiation may have contributed to such psychological changes cannot be determined because of the absence of individual dosimetry data.

- "The types and distribution of oral diseases observed in the residents of contaminated areas of Belarus were the same as those of the residents of uncontaminated areas."

Follow-Up to International Program. With the completion of the above project, the IPHECA was divided into follow-up programs: the International Thyroid Project, which was initiated in Belarus in 1994; accident recovery workers; dose reconstruction; and guidelines on public health action.

- The International Thyroid Project is addressing the public health implications of the increase in thyroid disease in children, adolescents and adults. The aim of the project is to provide early diagnosis, improved treatment, and mitigation, where feasible, of childhood thyroid cancer. Activities within the project—not all of which have been fully funded—include:

  --improving the efficiency of thyroid hormone testing;
  --monitoring the iodine status and goiter in children and adolescents in Belarus;
  --evaluating the impact of iodine supplementation in preventing thyroid disorders in Belarus;
  --a case control study;
  --a thyroid pathology pilot study;
  --compilation of a registry of thyroid surgeries; and
  --setting up a computer network for physicians.

- WHO was also asked to assist health care systems that provide diagnosis, treatment and rehabilitation of the accident cleanup workers in Russia, Ukraine, and Belarus. That project may also be expanded to include a program that would lay the groundwork for a system to collect data for research.

- On dose reconstruction, the role of the IPHECA would include facilitating international cooperation to encourage use of the best method or methods to achieve accurate retrospective calculations of individual doses.

- The project for guidelines on public health actions would assess lessons learned from Chernobyl and identify what emergency actions should be taken in the event of a nuclear accident and the best approaches for investigating the health consequences in populations.

WHO maintains an inventory of ongoing epidemiological work. The 1995 edition of *Catalogue of Studies on the Human Health Effects of the Chernobyl Accident* includes 84 projects. The inventory consists of three main sections: studies of cleanup workers, studies of thyroid diseases, and registries.

In addition, WHO has set up a separate project, together with a center in St. Petersburg, Russia, to address the problems of the approximately 800,000 cleanup workers. As part of this effort, WHO issued a final draft protocol in 1996 to guide medical institutions in monitoring the workers' health. The aim of the protocol is to accumulate data in a standardized form for those on health registers in Ukraine, Russia, Belarus, the Baltic countries and emigrants in Israel. If funding is available, a data base on the clinical and epidemiological status of 125,000 cleanup workers could be established within five years, according to WHO.

The data base will permit analyses of epidemiological indicators for links between morbidity, disability, psychological effects and mortality, and the doses that each person received during the cleanup operations. The clinical aspect involves relating signs and symptoms that the workers would develop, and the effectiveness of different diagnostic tools, treatment measures and rehabilitation methods.

WHO has begun to maintain an inventory of ongoing epidemiological work. A draft of the inventory, which includes 40 projects, was published in November 1994. The inventory consists of three main sections: studies of cleanup workers, studies of thyroid disease, and registries.

European Union, WHO and IAEA 10th Anniversary Conference

The Commission of the European Union, WHO and the IAEA cosponsored an international conference on the consequences of the Chernobyl accident April 8-12, 1996, in Vienna. More than 700 people attended the conference, which included updates on studies or projects undertaken by the three sponsoring organizations as well as the Organization for Economic Cooperation and Development's Nuclear Energy Agency and organizations in Germany, Japan and the United States.

In addition, one day of the conference was devoted to presentations by experts on clinically observed health effects, thyroid effects, longer term health effects and other health-related effects: psychological consequences, stress and anxiety. At the end of the conference, the meeting's joint secretariat issued highlights of conclusions, including those of the accident's health effects.

- ***Clinically Observed Effects.*** "The Chernobyl accident resulted in a total number of 237 individuals who were suspected of suffering from acute radiation sickness (ARS). Of these, 28 died due to radiation exposure. ...There is little doubt that the ARS patients, also those with severe skin injury, have received the best possible treatment in line with the state of knowledge at the time in the most experienced centre available. The therapy of bone marrow transplantation recommended at the time was of little benefit."

- ***Thyroid Effects***. "Ten years after the Chernobyl accident, the highly significant increase in thyroid cancer in those exposed as children in the three most affected countries [Belarus, Ukraine and Russia] is the only evidence to date of a public health impact of radiation exposure as a result of the accident. ...So far, a very small number of children (three) have died of this disease. Although only short term follow-up data are available at present, these post-Chernobyl papillary thyroid cancers in children, in spite of their aggressiveness, appear to respond favorably to standard therapeutic procedures if appropriately applied."

- ***Longer Term Health Effects.*** "Apart from thyroid cancer, there has been no statistically significant deviation in the incidence rates of other cancers attributable to radiation exposure due to the accident. In particular, to date no consistent attributable increase has been detected in the rate of leukaemia, one of the major concerns of radiation exposure. ...Increases in the frequency of a number of non-specific detrimental health effects other than cancer among exposed populations, particularly among liquidators [cleanup workers], have been reported. ...If real, these increases may be attributable to stress and to anxiety resulting from the accident."

- ***Other Health Related Effects: Psychological Consequences, Stress, Anxiety.*** "There are significant non-radiation-related health disorders and symptoms, such as anxiety, depression and various psychosomatic disorders attributable to mental stress among the population in the region. Psychosocial effects, unrelated to radiation exposure, resulted from the lack of information immediately after the accident, the stress and trauma of compulsory relocation, the breaking of social ties, and the fear that radiation exposure is damaging and could damage their and their children's health in the future. ...The highly politicized handling of the accident's consequences has led to psychosocial effects among the population that are extensive, serious and long-lasting."

European Commission Program

In 1992, the European Commission signed an agreement for international collaboration on the consequences of the Chernobyl accident with representatives of Belarus, Ukraine and the Russian Federation—the Chernobyl Research Program. Under the terms of the agreement, a

Coordination Board staffed with representatives from the three countries and the European Union approves projects and participating institutes.

The aim of the projects, which are partnerships between Eastern and Western research institutions and hospitals, is to improve training for scientists in the former Soviet Union, provide financial support to institutes participating in collaborative projects, introduce new technology and train medical specialists, improve the local infrastructure, and create a regional research facility in Belarus, Ukraine and Russia. The European Commission has provided 20 million ECU ($21.2 million) for the program's operation from its inception through 1995, when the collaborative program came to an end, and EC institutes participating in the program contributed another 5-10 million ECU ($5.3-10.6 million).

The EC has suggested that projects studying the health consequences of the Chernobyl accident evaluate them for both the medium term (1-10 years) and long term (10-50 years), evaluate the consequences for the public and the cleanup workers, and establish international guidelines for treating victims (e.g., children with thyroid cancer).

Three projects evaluating the health consequences of the accident were launched in 1992: biological dosimetry for people irradiated by the accident; epidemiologic investigations, including dose assessment and dose reconstruction; and treatment of accident victims. Three projects were added in 1993: molecular, cellular and biological characterization of childhood thyroid cancer; development of optimal treatment and preventive measures for childhood thyroid cancer; and dose reconstruction and retrospective dosimetry.

Childhood Thyroid Cancer. In 1992, the European Commission published a report by a panel of experts on childhood thyroid cancer. According to the panel, which documented its findings on the occurrence of childhood thyroid cancer in Belarus and northern Ukraine, there was a true increase in the incidence of this cancer in areas around Chernobyl, and intensive screening programs were unlikely to have accounted for much of the increase. The panel concluded that radioactive iodine was the most likely cause of the increase. The panel also noted that affected children were not receiving optimum treatment, despite the efforts of medical authorities in Belarus and Ukraine, because of the lack of adequate surgical and therapeutic facilities.

In 1994, the European Commission's European Office for Humanitarian Aid launched a project to supply specialist equipment and medicines for the diagnosis, treatment and follow-up of children with thyroid cancer in Belarus and Ukraine.

The work sponsored by the European Commission, as well as by the World Health Organization, is helping to provide a foundation for advances in the capability of Russian, Belarusian and Ukrainian researchers to carry out epidemiologic studies of all kinds. The expertise these researchers develop is also likely to prove useful in conducting future clinical trials of therapy.

10th Anniversary Conference. In March 1996, the EU, Russia, Ukraine and Belarus sponsored a conference in Minsk that summed up the results of the Chernobyl Research Program. Under the program, the EU allocated 35 million ECU ($37.1 million) for equipment and training of scientific and medical specialists. Sixteen collaborative projects were carried out over five years, covering such topics as:

- studies of the pathways and transfer of radionuclides into the food chain
- the countermeasures to such transfer, including traditional farming practices of plowing and the use of fertilizers
- the efficiency of a variety of decontamination methods
- epidemiological studies, together with dosimetry measurements—including dose assessment and dose reconstruction techniques—to follow the health of the affected populations
- the medical treatment of accident victims
- the development of a real-time on-line decision support system that could assist the off-site management of any future nuclear accident or any other emergency that might have wide environmental and health consequences, and
- the production of a European atlas of cesium contamination.

A report presented at the conference on a pilot study of 500 cleanup workers in Belarus found an above-average incidence of disease—of the nervous, blood circulation and digestive systems—but an incidence of cancer that was lower than that of the general population.

Other Projects, Studies

U.S. Studies. Under an agreement signed between the United States and the U.S.S.R. in 1988, the National Institutes of Health's National Cancer Institute (NCI) has been working with the governments of Belarus and Ukraine to prepare scientific protocols for thyroid studies in those two countries, and for studies of leukemia, lymphoma and related disorders in Ukraine. To support this work, the U.S. government has sent equipment and supplies to Belarus, and plans to send them to Ukraine. NCI is providing scientific, technical and medical expertise to Belarus and Ukraine for all aspects of the studies. In addition, Belarus and Ukraine are providing candidates for professional training in the United States.

The NCI thyroid studies are long-term (10-20 years or more) and involve the evaluation and medical follow-up of about 15,000 people in Belarus and 50,000 people in Ukraine who were children at the time of the Chernobyl accident.

In May 1994, Belarus and the United States agreed on a scientific protocol for the study of thyroid cancer and other thyroid disease among approximately 15,000 children. In May 1995, Ukraine and the United States agreed on a scientific protocol for the study of thyroid disease, especially cancer, among approximately 50,000 children who lived in areas of Ukraine heavily contaminated as a result of the Chernobyl accident. In both countries, children up to 18 years of age, and those in utero, at the time of the accident will be examined for thyroid disease at least every two years. Some 50,000 children had their thyroids measured for radioactivity during the first few weeks following the accident. The studies, which will be funded by the U.S. government, seek to quantify the thyroid cancer risk due to exposure to radioiodine, particularly iodine-131, and the role of potential cofactors, especially dietary iodine deficiency.

The NCI leukemia and lymphoma studies in Ukraine will involve approximately 88,000 Ukrainian cleanup workers who worked in the Chernobyl area between 1986 and 1990. Using physical and biological dosimetry techniques to reconstruct bone-marrow doses, researchers will study the incidence of leukemia and lymphoma over the next 10-20 years.

International Consortium. Another project is the International Consortium for Research on the Health Effects of Radiation, which has three objectives: to acquire the knowledge needed to determine the health effects of radiation and how best to treat those who have been, or will be, exposed to it; to develop and support a cadre of world-class U.S. and foreign investigators to carry out long-range studies; and to use this knowledge for the treatment of other diseases as appropriate.

The consortium arose out of an agreement between U.S., Russian and Israeli research institutions in 1992 to study the long-term health effects of the Chernobyl accident. In 1993, the U.S. Navy provided funding to launch the consortium's initial research project, which focused on putting into place basic essentials of sound research—such as standardized procedures, training, data management—and then testing the effectiveness of those essentials.

Following two years of pilot and feasibility studies, the consortium initiated a three-year multinational project in 1996 that focused primarily on epidemiological investigations in Belarus, the Bryansk region of Russia, and Israel. The project, which focuses on childhood malignancy, has two phases: to ascertain cancer mortality and prevalence between May 1986 and April 1996, and to identify incident cases occurring between May 1996 and April 1999 among individuals exposed to the Chernobyl accident or migrants from exposed areas to Israel.

Scientists from the former Soviet Union are collaborating with their U.S. counterparts on this research project. Russian scientists from Bryansk, Moscow and Obninsk have partners from the Fred Hutchinson Cancer Research Center in Seattle. Belarusian researchers from Gomel, Minsk and Mogilev are working with U.S. researchers from Connecticut's Bridgeport Hospital and Yale University Medical School. Ukrainian scientists from Kiev are working with scientists from Baylor College of Medicine in Houston. The immigrant study in Israel involves the Hadassah Medical Organization and Carmel Medical Center. Also involved in the project are the Roswell Park Cancer Institute in Buffalo and the National Marrow Donor Program in Minneapolis.

German, Swiss Projects. From mid-May to early October 1991, staff from the Jülich Research Center in Germany conducted a radioactivity measurement campaign in four regions of Russia to provide information on the radiation exposure of the population in those regions as a result of the Chernobyl accident. The staff first measured environmental and food samples to obtain information on external radiation and on the uptake of radioactivity from the diet, and then examined more than 160,000 people, using whole-body measuring equipment. The staff concluded that "the health of this part of the population was not endangered by food or environmental radioactivity."

In the summer of 1991, a team of Swiss specialists from the Paul Scherrer Institute and Ukrainian specialists carried out approximately 3,400 whole-body and 1,000 food measurements in an area about 50 kilometers (31 miles) west of Chernobyl. The specialists found a wide variation in whole-body dose rates. They concluded that higher doses occurred if Ukrainian authority bans on specific foods were not observed. The specialists also found the highest concentrations of cesium-137 in foods from woodland areas, such as berries, mushrooms and wild animals. The project, which was designed to help the Ukrainian authorities carry out such measurements and to inform and educate the population about radiation, continued in 1992.

In 1994, the nuclear expert committee of VDEW, the German power plant association, launched the GAST-Projekt aimed at providing health care and therapy for sick children in Belarus as well as studying the health impacts of the Chernobyl accident. Project scientists will take biological cell measurements to help predict the development of illness and define optimal treatment. The project will also provide training to doctors in Belarus and supply medicine and medical equipment.

Ivanov, Tsyb Studies. In April 1993, two doctors, Yevgeniy Ivanov and Anatoliy Tsyb, reported the results of their studies of the Chernobyl accident's health effects. Ivanov, director of the Scientific-Technical Research Institute of Hematology & Blood Transfusion of the Belarus Ministry of Health, claimed that his research represented the first attempt at a systematic epidemiological study of the accident's effects on the population of Belarus. He said that his research had failed to produce any evidence of increased incidence of leukemia among the population of Belarus. His research did confirm, however, a rising incidence of thyroid cancer among children, mainly in the Gomel region.

Tsyb, director of the Medical Research Radiological Center of the Russian Academy of Medical Sciences and chairman of the Russian Scientific Commission on Radiological Protection, reported that his study of cleanup workers found a 30-percent increase in diseases in this group, compared with a control group, but these diseases did not include leukemia or other diseases normally associated with radiation exposure.

At an IAEA-sponsored conference on radiation and society in October 1994, Tsyb said there is strong evidence that the increase of thyroid cancer in children in Bryansk, Russia, is the result of irradiation. At the conference, Viktor Ivanov—who works with Tsyb—reported excess mortality of 3 percent per 10 millisievert (1 rem) among the registered Russian cleanup workers. He said, however, that the causes of death—psychosomatic diseases, suicides—could not be associated with radiation.

Norwegian Study. In 1994, the Norwegian Radiation Protection Institute released the results of a study of the effects of the Chernobyl accident on Norway's ecosystem. According to the institute, radioactive cesium from the accident could remain in Norway's ecosystem for 10 to 20 years. Norwegian authorities reportedly estimate that 6-7 percent of the cesium released from Chernobyl came down in Norway.

Ukrainian Studies. Anatoliy Prisyazhiuk of the Ukrainian Scientific Center for Radiation Medicine reported data in 1994—published by the center—on the incidence of childhood leukemia, thyroid cancer and other cancers in three districts within 80 kilometers (50 miles) of the Chernobyl plant. According to the center, data for the period from 1981 to 1993 show a decline in the incidence rate for leukemia in children 10 to 14 years old, but an increase in the incidence rate for thyroid cancer in this age group. The three Ukrainian districts—Polesskoye, Nordichiy and Ovruch—were not evacuated after the accident, but according to soil testing they received the heaviest contamination in Ukraine outside the 30-kilometer (18-mile) zone around the Chernobyl plant.

In a letter published in a June 1995 issue of *Nature*, Ukrainian and U.K. researchers reported on the increased incidence of childhood thyroid cancer in Ukraine. The authors—Likhtarev, Sobolev and Kairo of the Scientific Center for Radiation Medicine, Tronko, Bogdanova, Oleinic and Epshtein of the Ukrainian Research Institute of Endocrinology and Metabolism, and Beral of the Imperial Cancer Research Fund, Cancer Epidemiology Unit, Radcliffe Infirmary, Oxford—concluded that "the pattern of thyroid cancer in relation to thyroid dose from ^{131}I suggests that the increase in thyroid cancer in childhood reported in the Ukraine is likely to be a direct consequence of the accident at Chernobyl."

French-Russian Study. France's Institute of Nuclear Protection and Safety and the St. Petersburg Center for Ecological Medicine in Russia agreed in October 1994 to conduct a joint study of the cleanup workers—the civilians and military personnel who participated in the Chernobyl accident cleanup. The two organizations will carry out research in biological dosimetry, which permits an estimation of the dose received by an individual by examining damage to his organism, and in digestive radiobiology, which entails the study of the effects of ionizing radiation on the digestive system.

The official Russian register lists more than 160,000 cleanup workers, most of whom worked within the 30-kilometer "forbidden zone" in the first two years after the accident and received an estimated average radiation dose of 165 millisievert (16.5 rem).

The St. Petersburg center has a Chernobyl registry with data on about 75,000 cleanup workers, and is studying about 14,000 of them. Aleksey Nikiforov, director of the center, is reported as saying that the cleanup workers being treated at the center are ill more often than the general population, suffer from old-age diseases such as arteriosclerosis before the age of 45, and have a much higher incidence of psychological disorders. In addition, the center's doctors are reportedly seeing an increase in solid tumors in the lung, bronchial tubes and stomach. Although the center has observed a higher morbidity (illness) rate among the 14,000 cleanup workers it is studying, it has not observed a higher mortality rate.

French-German-Ukrainian Study. Scientists from Germany, France and Ukraine agreed in July 1997 to study the effects of the Chernobyl accident by validating existing research data on human health and radiation doses and harmonizing the methodologies used. The aim of the project is to draw scientifically based conclusions about the health impacts of the accident and make them public. Under the DM 12 million ($.. million), three-year project, scientists will collaborate in studying the state of the Unit 4 sarcophagus, the ecological consequences of the accident, and the health effects of the accident. Funding will come from the French and German governments, Electricité de France and VDEW, Germany's utility association.

The Health Impact: Some Cautionary Notes

There is no doubt that the Chernobyl accident caused enormous dislocation, stress and anxiety among the people living in the areas touched by the fallout. It has also caused an increase in the incidence of thyroid cancer among children. But radioactive contamination from the accident cannot be blamed for all the illnesses reported. Other factors must be considered:

- Much of the affected population had never received modern, adequate health care. The extensive medical surveillance given these people since the accident may be uncovering medical problems and conditions that have always existed.
- Medical data frequently do not exist for the period before the accident in 1986. As a result, it is difficult to measure the health impact of the Chernobyl accident, because there are often no baseline data to compare with post-accident statistics.
- The latency period for solid cancers—other than leukemia and thyroid cancer—to develop is usually at least 10 years. In spite of lurid reports of thousands of new cancer cases since the accident, there has not been sufficient time to determine the extent of Chernobyl-related cancers. However, several studies have found a sharp increase in the incidence of thyroid cancer among children in areas of Belarus, Ukraine and Russia contaminated as a result of the accident. The thyroid cancer latent period is likely to be shorter in children (5-10 years) than in adults (10-15 years).
- Medical personnel in the region are generally not well trained in radiation science. Consequently, they attribute many illnesses to radiation, when radiation is not the cause.
- There has been an increase—based on historic rates—in cases of high blood pressure, stomach ulcers, anemia and various pulmonary disorders since the accident. Although often attributed to radiation, these illnesses are more likely a result of the tremendous stress imposed on the region's population. Such stress appears to have been exacerbated by alarming and scientifically unfounded reports of the health effects of the accident.

Also contributing to the rise in stress-related illnesses may be the widespread notion among the affected population that alcohol is an effective antidote to the effects of radiation. According to some Western researchers, cleanup workers they have met believe that death is imminent. This sense of doom, coupled with alcoholism and drug abuse among these workers, may be a factor in the reportedly high suicide rate for this group.

- In the longer term, the radiation doses from the accident may lead to an increase in cancers and cancer deaths. The ability to detect future excess cancers, however, will depend on whether groups that received the highest doses and those that received lower doses can be identified and followed up satisfactorily. Unless the mortality registries (and the registries of cancer incidence) and the dose reconstruction exercises are improved substantially, a good correlation between disease and dose is not likely to be achieved.

THE CHERNOBYL SARCOPHAGUS: SEARCHING FOR SOLUTIONS

The explosion of Unit 4 at the Chernobyl nuclear power plant in 1986 left the reactor destroyed, with some 180 metric tons of irradiated fuel exposed to the atmosphere. In an attempt to prevent the escape of additional radiation, the Ukrainians built a concrete sarcophagus over the unit. The sarcophagus, called a *ukrytie*, or shelter, by the Ukrainians, was begun in May 1986 and completed in November of that year.

The sarcophagus was erected in part using remote construction methods—because of the high radiation fields—and without full information on the strength of the original building, which meant that its structural integrity could not be gauged.

Many Sources of Radioactivity

Between 1987 and 1991, Ukrainian and Russian scientists conducted research at the sarcophagus to determine the location and physical state of the irradiated fuel. The scientists found three forms of fuel, widely distributed: core fragments, which had been thrown to the upper floors of the unit by the force of the explosion; a congealed form of vitrified fuel, sand, concrete and metal structures known as Chernobylite; and several metric tons of radioactive dust from one to several microns in size.

In addition to the approximately 180 metric tons of fuel or fuel-containing materials, the scientists identified 64,000 cubic meters of radioactive building materials, 10,000 metric tons of metal structures and 800-1,000 cubic meters of radioactive water in the destroyed unit.

Over this period, the Ukrainians mapped the location of radiation fields within the unit, measured radiation and temperature levels within the sarcophagus, monitored site ground water and nearby rivers, and reinforced internal structures that had been badly damaged by the accident to prevent further failures.

The sarcophagus is not leak tight. Rainwater can enter and radioactive dust can escape.

The Threat of Dust, Collapse

The 10 metric tons of radioactive dust within the sarcophagus represent a major threat to public health and the environment. The fear is that the movement or collapse of an internal structure—like the 1,000-metric ton reactor lid sitting on edge in the mouth of the reactor vessel—could stir up the dust, which could then be propelled into the atmosphere by pressure differences. In 1988, for instance, drilling equipment was accidentally dropped, sending up a thick cloud of dust and forcing the evacuation of the sarcophagus. The Ukrainians have installed a system for sprinkling water to control dust within the structure, and it reportedly works.

Structural Integrity. The high radiation levels within the sarcophagus contribute to the problems with dust and structural integrity. The magma containing molten fuel is disintegrating in the high radiation fields, providing even more radioactive dust. And the reactor's original concrete and other support structures are losing mechanical strength. The Ukrainians have attempted to deal with this problem through structural reinforcements, not always with success.

In one reported case, a load-bearing I-beam rests on a wall without a plate to spread the load. With no margin of safety where the I-beam rests, heavy snow or high winds could overload the wall, causing it and the roof of the sarcophagus to collapse.

At a conference in Ukraine in December 1994, officials reportedly said that one of the weak points in the structure had been repaired and the sarcophagus could operate for another 10 years, provided extensive, additional repair and stabilization activities are completed.

Earthquakes are the greatest concern, and stabilization to resist them is the most difficult problem. An earthquake could topple an internal structure and—in the case of a 1990 earthquake—create new vents in an already cracked structure.

The Ukrainians reportedly admit that it is difficult for them to determine the stability of the structure using traditional monitoring instruments because some 40 percent of the reactor building within the sarcophagus is inaccessible owing to high radiation levels.

Leak Tightness. Water poses problems, too. It causes corrosion, weakening the structure, and it can get into the fuel, posing a possible criticality hazard. There is no evidence of leakage from the sarcophagus into the groundwater. According to a joint Sandia National Laboratory-Ukrainian study, groundwater contamination is not, nor is it expected to be, a major problem.

Rather, contaminated water run-off from the surface of the exclusion zone is likely to be a much worse problem.

Ukrainian authorities had planned to deal with the lack of leak tightness by eliminating about 70,000 square meters (83,720 square yards) of vents in the sarcophagus, but they have postponed the work because of a lack of money.

Fire Risk. Two Ukrainian academicians reported in December 1994 that the possibility of explosion or fire within the sarcophagus is increasing. They said several fires have already occurred, and one—in 1993—burned for several hours and increased the radioactive discharge from the reactor building tenfold. The academicians concluded that a large fire could cause a radioactive release, in the form of fuel dust, on a scale similar to that of the 1986 accident. They urged the development and implementation of an integrated fire detection and suppression system for the sarcophagus.

Criticality. According to an official from GRS—Germany's nuclear safety institute—it is unlikely that a large portion of the mass of fuel inside the destroyed reactor would go critical. But the Chernobylite is apparently starting to be transformed into a water-soluble, pumice-like substance. As particles of this substance are lifted into the air by heat-generated convection currents, the amount of radioactive dust inside the reactor building will increase. Since 1990, the Ukrainians have used a dust suppresser to periodically spray neutron absorbers inside the central hall, where much of the irradiated debris is located.

On four occasions, an increased neutron flux was monitored in the sarcophagus—in June 1990, during heavy rains, in January 1996, when snow was melting, and two incidents in September 1996.

Following the September incidents, an international commission was formed to determine whether the signals activated in the sarcophagus monitoring system were caused by chain reactions in fuel remnants. The commission was unable to determine with certainty the cause of the high neutron flux measurements, but it concluded that they were probably caused by malfunctioning instrumentation, not a nuclear criticality. As a result of the incidents, Chernobyl plant management said it would replace the neutron flux monitoring system in the sarcophagus.

Looking for Solutions

In 1991, the Soviet government initiated a study of the costs, risks, time scales and implications of two options for dealing with the weakened sarcophagus: Build a new, separate structure over the existing sarcophagus or fill the existing sarcophagus with a special concrete.

The Organization for Economic Cooperation and Development's Nuclear Energy Agency (NEA) agreed to provide experts in nuclear safety and waste management to help the Soviet panel evaluate the options.

Second Shelter. In early 1992, the panel concluded that filling the sarcophagus with special concrete was the preferable option, but Moscow admitted that the newly independent Ukraine might not follow its advice. In fact, Ukrainian politicians said that the rapidly weakening structure needed to be either enclosed in a protective shell or, preferably, removed from the site.

In July 1992, the Ukrainian government announced an international competition for the best project to provide a second “shelter” for the destroyed reactor that would last for 100 years or more. The aim is to first contain and then eliminate the destroyed reactor and all radioactive equipment, structures and materials.

The deadline for proposals—originally Dec. 31, 1992—was extended to April 26, 1993. A jury of scientists from Ukraine, Russia, Belarus and the West awarded second prize to a French consortium; there was no first prize.

At a “Sarcophagus Safety-94” meeting held in Ukraine in March 1994, 172 nuclear experts from 12 countries gathered to discuss the deteriorating sarcophagus. Participants also received details of the tendering process for a European Union feasibility study on dealing with the sarcophagus. The study will be funded from the 3 million ECU ($3.78 million) earmarked by the EU’s TACIS program for improving the safety of the sarcophagus.

The same month, following a visit to the Chernobyl plant, a team of experts from the International Atomic Energy Agency (IAEA) noted the “technically confirmed accelerated deterioration of the shelter which, if it collapses, would have serious consequences.”

Alliance Group Study. In August, the EU awarded a 3-million-ECU contract to the Alliance Group to study the feasibility of strengthening the existing sarcophagus and building a new shelter over it. The group, consisting of two U.K. companies, three French companies and a German company, was to review all concepts that were finalists in the 1993 Ukrainian government competition, select an option and carry out a cost and design study within eight months of contract award.

In March 1995, EU officials presented the results of the first phase of the Alliance Group’s feasibility study to Russian, Ukrainian and Western participants. Alliance concluded that the high level of radioactivity inside the existing sarcophagus required the construction of a new shelter over it that is leak tight and would permit the dismantling of the structures beneath it. The new shelter must be built over Unit 3 as well as the destroyed Unit 4, which would require the decommissioning of Unit 3. According to Alliance, the existing sarcophagus is unstable and could collapse under external forces, especially earthquakes. Long-term stabilization of the existing structure is not a feasible option.

The second phase of the study, which included a detailed examination of strengthening the existing sarcophagus, development of a design for the new shelter, identifying requirements for dismantling Unit 4, studying nuclear waste issues, drawing up a project management plan and estimating total cost, was completed in mid-1995. In July, the Alliance Group presented two options: the construction of a new shelter over units 3 and 4, and the construction of a new shelter for Unit 4 alone.

The estimated cost—$1.6 billion—would cover provisional stabilization work on the existing sarcophagus, construction of a new shelter, and project management. The group proposed a two-stage funding system for the project.

EC Reassessment. In late 1996, the European Commission began a reassessment of the terms of reference for construction of a new sarcophagus. It awarded a contract to Riskaudit to help the Ukrainian regulatory agency in defining safety objectives for a new structure and stabilization of the existing structure. It also awarded a contract to Germany's Trischler und Partners to prepare the design criteria for a new structure and for stabilizing the existing one. In addition, Trischler—with U.S. help—was asked to study other options that might cost less than the Alliance Group project.

Trischler directed an international commission of experts, which recommended the extraction of accessible fuel-containing materials from the sarcophagus, leaving the remaining nuclear materials in the structure for several hundred years. They did not support the construction of a new shelter over the existing sarcophagus, as proposed by the Alliance Group.

The commission's recommendation was initially opposed by Ukraine, which wanted to remove the fuel-containing materials as soon as possible. Instead, Ukraine proposed stabilizing the existing structure and extracting the fuel-containing materials over a 10-year period.

Joint EC/U.S./Ukrainian Project (SIP). In November 1996, the European Commission, the United States and Ukraine issued the Trischler-U.S. report on the sarcophagus. It made several recommendations for reducing the probability of the structure's collapse, reducing the consequences of a collapse, and addressing nuclear, worker and environmental safety as well as the structure's long-term stabilization. The G-7 adopted the study recommendations at a meeting in Ukraine in December 1996.

In February 1997, G-7 representatives and Ukrainian officials agreed on the establishment of an $800 million fund to stabilize the sarcophagus. The fund, to be managed by the European Bank for Reconstruction and Development, would be separate from the Nuclear Safety Account administered by the bank. The 10-year project would not involve fuel removal. At the meeting, the U.S. government said it would allocate $27 million to develop technologies to separate and bury the spent fuel in the sarcophagus.

In February and March, the EC-U.S.-Ukrainian group reassembled at Trischler und Partners in Germany to produce a detailed draft Shelter Implementation Plan (SIP). In late April, Ukrainian and G-7 negotiators approved the SIP, which consists of 22 tasks within five major areas: reducing the probability of sarcophagus collapse; reducing the consequences of accidental collapse; increasing nuclear safety; increasing worker and environmental safety; and long-term strategy and study of conversion of the sarcophagus to an environmentally safe site

At its June meeting, the G-7 agreed to set up a multilateral funding mechanism for the SIP, and agreed to contribute $300 million over the life of the project. It asked "concerned governments and other donors" to join in a special pledging conference in the fall to ensure full implementation of the project, estimated to cost $780 million. Ukraine will allocate $100 million for the project.

The European Bank for Reconstruction and Development, which will manage the fund for the SIP, is expected to seek bids on a project management unit contract from Western companies in the fall of 1997.

The United States and the G-7 have stated clearly to Ukraine that they will not pay for the removal and disposal of the Chernobyl fuel at this time. They are committed to evaluate and develop technologies for fuel removal, and to evaluate the optimum time for fuel removal. Early fuel removal—within the next 50 years—is likely to cost billions of dollars and involve large radiation doses to personnel.

The G-7 believes that deferred fuel removal is by far the best option. But Ukraine is advocating early fuel removal—to be paid for by the G-7—based primarily on the fear of recriticality. G-7 technical experts do not think that recriticality is a significant threat. Moreover, some components of the G-7 proposed program (e.g., a better neutron monitoring system) are aimed at establishing even more firmly that recriticality is not a threat.

KHMELNITSKIY (KHMELNYTSKYY) NUCLEAR POWER PLANT

Type: VVER-1000

Units: One (three additional units are under construction)

Total megawatts (net): 950

Location: Neteshin, Ukraine

Date of initial operation: August 1988

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

In March 1992, Unit 1 was shut down to correct a problem with piping and in May and November because of turbine vibrations. In December 1993, it was taken out of service after a hydrogen leak was detected in the cooling system.

Unit 1 was shut down for five days in March 1994 following a fire in the turbine hall that was caused by a short circuit in an electrical cable. The event was classified as Level 1 on the International Nuclear Event Scale. Since 1992, the plant has been unable to ship its spent fuel to Krasnoyarsk in Russia for reprocessing. With storage space decreasing, the plant reracked the spent fuel pool, increasing capacity enough to provide an additional three years of storage.

To obtain spare parts, the plant must sign an agreement with the appropriate Russian supplier. As a result, many of Khmelnitskiy's maintenance activities are now focused on the repair and refurbishment of equipment or on preventive maintenance. According to a Ukrainian news agency report in October 1994, Khmelnitskiy had been forced to suspend repairs because of a lack of funds.

While unit 1 was in cold shutdown during a planned April 1996 outage, a malfunction in the reactor cooling system occurred when a pump switched off due to a pressure drop at the pump inlet. A back-up pump started and then switched off for the same reason. Primary coolant temperatures exceeded operational limits before the problem could be eliminated, reportedly about three hours after it began. The event was preliminarily classified as Level 1 on the INES.

The unit was still in outage in July 1996 when, during preparations for primary circuit hydro-testing, a nitrogen supply pipeline was mistakenly filled with primary coolant. The pipeline, related equipment and the facility supplying the gaseous nitrogen were exposed to radiation measured at 60-100 microRoentgens per hour. No personnel were exposed and there was no off-site release. The event was rated Level 1 on the INES.

Three hours after the incident, a pipe carrying high-pressure steam burst, striking a worker and severely burning him. He later died from the injuries. Conflicting reports called the incident a serious—at least Level 3 on the INES—accident, while others said it was not given an INES rating.

A shipment of fresh VVER fuel reportedly was received from Russia in March 1997, making a planned refueling outage later in the year possible. The shipment was part of the agreement reached between Ukraine and Russia in which Russia would supply nuclear fuel in exchange for nuclear warheads, which Ukraine had already returned as part of a 1994 agreement.

Additional Plans

The Ukrainian Parliament’s 1990 moratorium stopped construction on three other units at the site. In October 1993, the Ukrainian parliament voted to lift the moratorium on new plant construction, citing Ukraine’s energy shortage. In February 1994, then-President Kravchuk issued a directive calling for the completion by 1999 of five VVER-1000s that were under construction, including Khmelnitskiy 2, 3 and 4. Khmelnitskiy 2 is 90 percent complete, Khmelnitskiy 3 is 50 percent complete and Khmelnitskiy 4 is 10 percent complete.

Ukraine has requested a loan from the European Bank for Reconstruction and Development (EBRD) to complete Khmelnitskiy 2 and Rovno 4, another VVER-1000 unit. The bank is expected to decide in September 1997 whether to finance completion of the two reactors. If the bank approves the loan, an EBRD spokesman reportedly said, Ukraine could start receiving the money early in 1998.

Technical/Upgrading Activities

Ukrainian safety projects completed or under way include modification of the control circuitry for turbine valves, modernization of the ventilation systems for the unit control room and emergency control room, reconstruction of the uninterruptible power supply, and development of symptom-oriented emergency operating instructions.

International Exchange/Assistance

WANO Exchange Visits. Under the auspices of the World Association of Nuclear Operators, Khmelnitskiy plant staff have participated in several exchange visits. The plant has hosted personnel from the following plants

- Scotland's Hunterston plant (October 1992),
- Japan's Ohi plant (June 1993),
- United States' Fort Calhoun plant (July 1995, June 1996).

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

- United States' Point Beach plant (April 1992),
- Japan's Ohi plant (November 1992),
- Scotland's Hunterston plant (May 1993, April 1994),
- United States' Fort Calhoun plant (November 1994, February 1996),
- United States' Seabrook plant (June 1996).

Plant Twinning. The Khmelnitskiy plant is twinned with Germany's Philippsburg plant and with Scotland's Hunterston plant.

IAEA Training Seminars. The International Atomic Energy Agency (IAEA) sponsored an ASSET seminar in the town of Neteshin near the Khmelnitskiy plant Sept. 7-11, 1992. The seminar was attended by 27 people representing six nuclear plants as well as regulatory bodies and research institutes. The seminar covered reporting criteria, INES event rating, ASSET root cause analysis, and the Ukrainian incident report system. An ASSET training seminar was also held at Khmelnitskiy Dec. 12-14, 1995. The purpose of the seminar was to familiarize plant personnel with the detailed ASSET analysis procedures for self-assessment in advance of the ASSET peer review mission scheduled for July 1-5, 1996.

U.S. Assistance. Under the U.S. government's nuclear safety assistance program, Khmelnitskiy is to be the site of Ukraine's first nuclear training center. For details on U.S. assistance, see **NRC Programs** and **DOE Programs**.

French Assistance. To upgrade Khmelnitskiy plant training programs (especially for operators), normal and emergency operating procedures, France provided a simulator on workstations.

British Aid. Britain contributed $80,000 for equipment for the full-scale training facility under construction at Khmelnitskiy.

Proposed Joint Venture. France's Framatome and Khmelnitskiy have proposed a joint venture involving equipment repairs to the plant.

Inspections

ASSET Mission. An IAEA ASSET mission visited the Khmelnitskiy plant March 8-19, 1993, to assess the effectiveness of the plant's policy for preventing incidents. The team reviewed 221 events reported between

January 1988 and February 1993. Of these, 89 were safety relevant; 16 were classified as Level 1, one was classified as Level 2 and the rest were classified as Level 0 on the International Nuclear Event Scale (INES).

The team identified 11 safety problems that it considered to be the most significant. Of these, it singled out six as pending safety problems:

- fouling of heat exchangers in the emergency core cooling system
- secondary circuit chemistry problems
- diesel generator failures
- degradation of safety functions owing to circuit breaker failures
- deficiencies in maintenance procedures and acceptance criteria after maintenance
- common cause failures owing to deficiencies in instrumentation and control and electrical equipment.

Among the team's recommendations for improving the prevention of incidents were:

- develop a new procedure for diesel generator maintenance
- improve plant policy and procedures for preventive maintenance and quality control
- develop and encourage the use of feedback mechanisms to improve the quality of procedures and surveillance programs
- monitor personnel proficiency and develop clear guidelines for safety issues
- develop a healthy "no blame" culture at the plant.

The team found a few shortcomings in the manufacturing quality of some equipment that had degraded during operation. But it noted that plant management had taken steps to resolve these problems by paying proper attention to preventive maintenance. The team concluded that some improvements were needed in the quality of maintenance procedures.

The team also concluded that management and staff were dedicated to implementing the plant's policy of preventing incidents. The team suggested a follow-up mission to the plant in about two years.

OSART Mission. An Operational Safety Review Team (OSART) mission visited Khmelnitskiy Oct. 23-Nov. 9, 1995. The team found that the plant is taking initiatives—with the help of the international community—to increase nuclear safety. These initiatives include purchasing a full-scope simulator and upgrading operating procedures. The team noted, however, that plant management is too narrowly focused on meeting the minimum requirements for nuclear safety as set by the Ukrainian regulatory body.

The team identified several areas of good performance, including:

- The staff is well-educated and works hard to ensure basic plant safety.

- The plant has developed a comprehensive vibration measurement and analysis program that applies to all plant systems.

- Partial scope simulators are being developed to train staff in activities outside the main control room.

- The plant fire brigade is well-trained, well-staffed and well-equipped.

The team also made several recommendations:

- Management should establish higher expectations in the area of nuclear safety than the regulations of the Ukrainian nuclear power industry.

- The system of payment for electricity generated by the plant should be improved. The plant has received only about 50 percent of the income due to it for power produced in the past year, and extra care is needed to ensure that adequate funding is available for safety-related issues.

- The quality and use of documentation at the plant needs to be improved.

- Although major plant defects have been identified and a program exists to ensure they are repaired, there are many lower-level defects at the plant. The cumulative effect of these defects could affect plant safety.

- The development and implementation of a quality assurance program should be given high priority.

The team concluded that implementation of its recommendations should result in improvements in many of the plant’s programs, and should thus contribute to the plant’s safe operation.

Safety Review Mission. An IAEA safety review mission visited the Khmelnitskiy plant’s Unit 2 June 10-16, 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. An ASSET peer review mission to Khmelnitskiy, originally scheduled for July 1996, is now planned for October 7-13, 1997. The mission will review the plant’s analysis of events reflecting safety culture issues based on ASSET procedures.

Planned OSART Mission. A follow-up OSART mission to Khmelnitskiy is scheduled for 1998.

ROVNO (RIVNE) NUCLEAR POWER PLANT

Type: VVER-440 Model V213 (Units 1 and 2)
VVER-1000 (Unit 3)

Units: Three (one additional unit is under construction)

Total megawatts (net): 1,695 (Unit 1 - 361; Unit 2 - 384; Unit 3 - 950)

Location: Kuznetsovsk, Ukraine

Dates of initial operation: Unit 1 - September 1981
Unit 2 - July 1982
Unit 3 - May 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

Rovno has experienced problems with steam-generator tube breaks, which have been the subject of a number of international technical exchange activities. Two such breaks reportedly occurred at unit 3 during May 1996. The incidents were rated “0” on the International Nuclear Event Scale (INES), but rumors about a major accident at the station reportedly kept some residents indoors for days.

According to the Russian news agency TASS, computers to aid plant operators were installed at one of Rovno’s nuclear units by the Moscow Research Institute of Instrument-Making in 1992, marking the first use of such a system in a nuclear power plant in the former Soviet Union. The computers will help operators make correct decisions and verify their actions.

Additional Plans

The Ukrainian Parliament's 1990 moratorium stopped construction on a fourth unit at the site. In October 1993, the Ukrainian Parliament voted to lift the moratorium on new plant construction, citing Ukraine's energy shortage. In February 1994, then-President Kravchuk issued a directive calling for the completion by 1999 of five VVER-1000s that were under construction, including Rovno 4. The unit is 80 percent complete.

Ukraine has requested a loan from the European Bank for Reconstruction and Development to complete Rovno 4 and Khmelnitskiy 2, another VVER-1000 unit. The bank is expected to decide in September 1997 whether to finance completion of the two reactors. If the bank approves the loan, an EBRD spokesman reportedly said, Ukraine could start receiving the money early in 1998.

Technical/Upgrading Activities

Ukrainian safety projects completed or under way at units 1 and 2 include replacement of electrical portions of the reactor protection system, upgrading of reactor protection system logic, upgrade of steam generator safety valves, and replacement of unit 2's steam generator collectors.

At unit 3, part length control rods were replaced with full absorber length rods, steam generator safety valves are being replaced, and capacity of the spent fuel storage pool was increased. Replacement of uninterruptible power supply units and accumulator batteries is planned.

International Exchange/Assistance

U.S. Assistance. Rovno's steam generator tube break was reviewed by various international working groups, including Working Group 2 of the U.S./Soviet Joint Coordinating Committee for Civilian Nuclear Reactor Safety. The working group used the Rovno station as the basis for studies of a hypothetical loss-of-coolant scenario and, in turn, compared Rovno's results with a similar study of the South Texas Project in the United States. The U.S. team also used the Rovno plant to study anticipated transients without scram—when plant operators control an abrupt shift in temperature without shutting the plant down.

Rovno's fire-protection techniques were studied by a working group sponsored by the U.S. Nuclear Regulatory Commission as part of an East-West exchange group on fire safety. Working group members assessed the plant's fire-protection standards to determine whether safe shutdowns could be carried out in the event of a fire.

Under the International Nuclear Safety Program, U.S. experts are helping to improve fire protection and operating procedures for units 1 and 2. In addition, operators are being trained in quality assurance in the United States. See **DOE Programs** for details of the program.

Canadian Aid. Ontario Hydro International will use some of the money in Canada's nuclear safety assistance package to Ukraine to adapt Ontario Hydro's dry storage canisters for use at the Rovno plant to store VVER spent fuel assemblies. The canisters will be manufactured in Ukraine.

French Assistance. Electricité de France (EdF) signed a protocol of intent with the Rovno plant in April 1994 under which EdF will provide technical assistance and help open a line of credit with France. The company Coris reportedly provided a simulator to the Rovno station for modeling possible emergency situations.

Help from Germany. The German government announced in September 1994 that it would give Ukraine an electric generator for the Rovno plant's VVER-440 units. The generator was originally built for the now-closed Greifswald plant. Rovno operators have also received training at the Greifswald plant's training center.

In addition, Germany's Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) and the Ministry of Environment and Nuclear Safety have launched a program that will include a safety analysis of all three reactors at the Rovno plant and a complete evaluation of each unit's operating records. In addition, Siemens has a contract to supply loose parts, vibration and acoustic leak monitoring systems to Rovno 3.

EU's TACIS Program. Under the European Union's TACIS program, Rovno will receive about 1.6 million ECU ($1.69 million) of equipment from German companies: equipment for vibration monitoring of coolant pumps, steam generator manipulators and fire protection improvements.

Also under TACIS, Germany's GRS, France's Institute for Nuclear Safety & Protection (IPSN) and EdF are instructing Rovno personnel in the methodology for deterministic and probabilistic safety analysis. Based on an evaluation of plant operations, IPSN and GRS made several recommendations on organizational structure and staff duties as well as suggestions on improving safety-related equipment such as diesel generators and instrumentation and control systems. According to a Russian news agency report in June 1994, EdF will help install fireproof systems and monitor the functioning of the main circulation pumps and the steam generators. France also is said to be providing computer programs and workstations for the plant.

As part of the TACIS aid, the French company Intercontrole is supplying eddy-current inspection equipment for Rovno's steam generators. Intercontrole and Germany's Siemens will help Rovno staff carry out the first two inspections using the equipment.

Other EU Assistance. The EU is also sponsoring efforts to improve instrumentation and controls design, maintainability and availability. A safety parameter display system and reactor coolant pump vibration monitor are being provided. Like the U.S., an EU program is helping Rovno upgrade its quality assurance program to IAEA standards.

Czech Agreement. According to a Ukrainian news agency report in May 1994, the Rovno plant will receive approximately $2 million worth of equipment from the Czech Republic's Skoda company under a barter arrangement. Skoda will receive electricity or goods in return. Among the equipment are spent fuel racks, which have increased storage capacity by 20 percent and provided a solution to spent fuel storage for the next 4-5 years.

WANO Exchange Visits. Under the auspices of the World Association of Nuclear Operators, Rovno plant staff have participated in several exchange visits. The plant has hosted personnel from the following plants:

- India's Madras plant (July 1994),
- United States' Byron plant (November 1994).

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

- India's Kalpakkam plant (October 1992),
- United States' Byron plant (October 1994, June 1995),
- United States' Point Beach plant (September 1995),
- United States' V.C. Summer plant (December 1996).

Plant Twinning. The Rovno plant is twinned with Germany's Mülheim-Kärlich plant and France's Golfech plant.

ASSET Training Seminar. An International Atomic Energy Agency (IAEA) training seminar was held at the Rovno plant March 26-28, 1996, to demonstrate the practical use of the ASSET analysis procedures for self-assessment of operational events.

Inspections

OSART Mission (Unit 3). Rovno was the site of the first OSART (Operational Safety Review Team) mission to the Soviet Union by the IAEA.

The purpose of the Dec. 5-22, 1988, mission was to review operating practices at Unit 3 and allow a technical exchange of experience on pursuing excellence in operational safety.

Among the team's conclusions:

- The plant is safely operated by a dedicated and motivated management team supported by a skilled workforce.

- Safety is given priority consideration.

- Radiation protection and environmental aspects of plant operation meet international standards.

The team offered several recommendations:

- Plant management should be given more responsibility for decision-making by the Ministry of Atomic Power and Industry.

- Equipment design, manufacture, installation, operation and maintenance must be verified by more effective quality assurance activities.

- Plant management should revise training materials, use more modern training aids and train operators on a full-scope simulator.

ASSET Mission (Units 1 and 2). An ASSET mission visited the Rovno plant Nov. 22-Dec. 3, 1993, to review the effectiveness of the plant's policy for incident prevention. The team reviewed a total of 191 events that had occurred at units 1 and 2 between August 1988 and November 1993. Of these, 117 were considered to be safety relevant. Two events were classified as Level 2 on the International Nuclear Event Scale, six were classified as Level 1 and the rest, Level 0.

From its analysis of these events, the team identified 11 types or groups of recurring faults. It then identified six safety problems, singling out three for in-depth analysis:

- frequent failure of diesel generators owing to inadequate maintenance,

- potential for loss of two safety functions—control of reactivity and cooling of fuel—because secondary isolation, safety and dump valves were not closed,

- potential for operation outside the authorized regime because of noncompliance with procedures.

The team noted that the plant had instituted measures to improve the quality and extent of procedures and to systematically analyze and learn from failures. The number of incidents had declined since 1990, which was an indication of the plant's effectiveness in managing safety, the team said. Nonetheless, the team concluded there was room for considerable improvement in the prevention of incidents. The team noted that while high standards of housekeeping existed in some areas of the plant, safe and economic operation could be radically improved in many areas of the plant through available low- or no-cost solutions.

The team made a number of recommendations. Among its suggestions to plant management:

- make maintenance procedures more comprehensive and ensure that operating instructions are amended promptly,

- enhance quality control to ensure independent inspection of valves and pipework prior to installation or reassembly,

- review safety-relevant plant items to identify those at risk from internal or external corrosion, chemical attack or physical damage, and amend the preventive maintenance program to include inspection of the condition of these items,

- enhance the policy for training and authorization of staff to include continual monitoring of staff competence and use the results of this monitoring to modify training programs,

- consider establishing multidiscipline engineering support groups to solve specific problems.

Safety Review Mission (Unit 4). An IAEA safety review mission visited Rovno Oct. 2-12, 1995, to review the modernization program of Unit 4, a VVER-1000 reactor that is under construction. The program was developed on the basis of the operating experience of VVER-1000 reactors and the results of studies by Ukrainian, IAEA and other organizations.

The purpose of the mission was to review the safety aspects of the program and advise on the completeness and adequacy of the safety improvements proposed. The IAEA's draft report on VVER-1000 safety issues and their ranking served as the basis for the review. The review covered plant design and operational safety, but not upgrading measures, which are aimed only at improving plant availability.

The team concluded that the modernization program is well developed and well structured with respect to design issues. Its implementation will make a major contribution to plant safety. But the team noted that the degree of detail for individual measures in the program varies, and most descriptions were not sufficient for an in-depth technical review. The mission thus focused on reviewing the safety issues identified by the IAEA for this type of reactor.

The team found that a number of measures need to be improved, and some measures added, to meet the intent of the IAEA recommendations. The modernization program also covered some safety aspects not included in the IAEA's list of safety issues. Discussions revealed that the implementation of these new safety aspects could further contribute to improved safety. The team suggested, however, that the combined effects of the individual improvements be examined to ensure there would be no adverse effect on plant safety.

Planned ASSET Mission (Units 1 and 2). An ASSET peer review mission to Rovno, originally scheduled for November 1996, is now set for Sept. 24-30, 1997. The mission will review the plant's analysis of events reflecting safety culture issues based on ASSET procedures.

SOUTH UKRAINE NUCLEAR POWER PLANT

Type: VVER-1000

Units: Three

Total megawatts (net): 2,850 (950 per unit)

Location: Yuzhnoukrainsk, Ukraine

Dates of initial operation: Unit 1 - October 1983
Unit 2 - April 1985
Unit 3 - December 1989

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

In 1991, South Ukraine had the highest number of unplanned shutdowns among Ukraine's plants, with 3.33 per unit.

A September 1992 event at the plant was classified as Level 2 on the International Nuclear Event Scale. The event was the result of defective core instrumentation and led to the failure of a steam isolation valve.

After safety systems were shut off in November 1992 to boost power production, officials of GANU—the Ukrainian State Committee on Nuclear and Radiation Safety—wrote to the government calling for the removal of South Ukraine's plant manager, Vladimir Fuks. The committee pointed out that safety violations had increased significantly throughout 1992 and generally cited "unsatisfactory" safety conditions.

Ukratomenergoprom, Ukraine's utility organization, responded, noting that incidents were up because of stricter domestic standards and that the reactors were being operated according to international standards. Ukratomenergoprom officials said there was no reason to change management at the plant.

In the spring of 1993, there were reports that the plant's cooling pipes were furred up because local authorities had forbidden the plant to replace the water in the cooling system and the plant had no suitable filters. The plant was also said to be facing critical shortages of boric acid, chemical resins and chemicals needed for the water system. Repair materials were also reportedly in short supply.

In May 1993, Unit 3 at the plant was shut down following the detection of a hydrogen leak in the plant's turbine cooling system. Earlier in the month, a similar leak at Unit 5 of the Zaporozhye plant in Ukraine had resulted in an explosion and fire in which one worker was killed.

In April 1994, a defect in a steam generator's reactor protection system level controller was discovered on Unit 1 during a routine walkdown. The defect was corrected, but not within the time period stipulated by the technical specifications. This event was classified as Level 2 on the International Nuclear Event Scale. A month later, routine examination of the primary circuit's main gate valve components on Unit 1 revealed corrosion-induced deterioration of the gate valve main joint studs. The deterioration was caused by primary circuit leaks through the gland gasket of the main joint of the gate valves. This event was classified as Level 1 on the INES.

In December 1995, radioactive liquid leaked from a pipe onto the ground at the plant, contaminating a 30-square-meter area. The leak was apparently not discovered until early January. This event was classified as Level 1 on the INES.

An "emergency unloading" of the unit 1 reactor was reportedly necessary in September 1995 because of a breakdown in the purification system of a turbine condenser.

Fuel Purchases, Plant Staffing. The South Ukraine plant reportedly received a Ukrainian bank loan of 300 billion karbovantsi in March 1995 to buy nuclear fuel from Russia. According to plant manager Vladimir Fuks, the plant is owed nearly 6 trillion karbovantsi by electricity consumers.

Fuks said in August 1995 that the plant had no fuel for 1996. He also noted that more than one-third of the plant's equipment had reached the end of its service life. Fuks also said that in 1994 the plant lost a number of staff, including four engineers, six production managers and numerous other skilled workers. He explained that in Russia, salaries were one and a half to two times higher than in Ukraine, but added that the plant had a reserve of personnel.

Technical/Upgrading Activities

According to plant manager Fuks, the South Ukraine plant spent about $5 million on maintenance and backfits in 1994. Up to the beginning of 1995, the plant had spent about $10 million on equipment from abroad, of which $7 million was spent for reactor protection system controls from the Czech firm Skoda.

Ukrainian safety projects completed or underway include upgrading of personnel training rooms, improvement of steam generator level monitoring, installation of hydrogen monitoring and removal systems, and development of symptom-oriented emergency operating instructions.

International Exchange/Assistance

EU Projects. With funding from the European Union, Spain's Tecnatom has supplied a remote primary pipework inspection system, and by the end of 1996, the company provided training, design and specification for reactor pressure vessel and primary circuit inspection.

Other projects include upgrades to the plant's instrumentation and controls to improve their design, maintainability and availability; upgrading primary welding to improve non-destructive testing of the reactor coolant system and reactor vessel; and upgrading steam generator level controls.

Germany assisted South Ukraine in improving physical plant security.

In July 1996, Westinghouse won a TACIS-funded contract to replace the feedwater control system, related transmitters and feedwater control valves on units 1 and 2.

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

- France's Blayais plant (December 1992),
- Brazil's Angra plant (July 1994),
- Switzerland's Gösgen plant (September 1994),
- Spain's Asco plant (September 1994),
- Japan's Takahama plant (October 1994).

In addition, personnel from South Ukraine have visited the following plants:

- United States' Waterford plant (February 1991),
- Brazil's Angra plant (June 1992),
- Spain's Asco plant (November 1993),
- Switzerland's Gösgen plant (March 1994),
- Japan's Takahama plant (December 1994).

Plant Twinning. The South Ukraine plant is twinned with Germany's Grohnde plant.

ASSET Training Seminar. An International Atomic Energy Agency training seminar was held at the South Ukraine plant March 21-25, 1994. The purpose of the seminar was to train operators and regulators in the use of the ASSET—Assessment of Safety Significant Events Team—methodology to identify safety issues, assess their consequences and eliminate the root causes of likely future incidents and accidents. An IAEA training seminar was held at the South Ukraine plant April 10-12, 1996, to demonstrate the practical use of the ASSET analysis procedures for self-assessment of operational events.

Other. Westron, a joint venture between Westinghouse Electric Co. and Hartron, a Ukrainian missile control systems manufacturer, has contracts to upgrade the computer system at the South Ukraine plant. The first phase of a computer information system has been delivered to the plant, and delivery of the final phase was scheduled for mid-1997.

Inspections

ASSET Mission. An ASSET mission visited the South Ukraine plant Jan. 16-27, 1995. The purpose of the mission was to determine the effectiveness of the plant's incident prevention policy. It reviewed all operational events reported by the plant between January 1989 and December 1994. Of 178 events, 98 were found to have safety relevance. Of these 98, six were classified as Level 1, and the remainder as Level 0 on the INES.

The team found that the prevention of safety relevant events varied from unit to unit. While Unit 1 had worsened during the review period, Unit 3 had improved. The team suggested that plant management consider the reasons for the divergent performance of the units, and attempt to bring all units to the performance level of Unit 2.

The team also found considerable variability among the three units with respect to the percentage of events discovered by surveillance. It recommended that plant management consider investigating the reasons for the variability of surveillance performance with a view to bringing surveillance effectiveness to a consistent, high level.

The team also recommended that plant management prepare a report summarizing the problems encountered with emergency power supply cables. The team noted that plants with similar equipment and layout arrangements had not encountered as many problems, and that it would be worthwhile exchanging operating experience. In view of the recurrent cable problems, the team suggested that the plant consider establishing a pro-active policy to detect incipient failures in safety systems.

The team also suggested that plant management consider reviewing the job functions of the personnel in shift operations with a view to enhancing their effectiveness in handling transients through team training and interpersonal communications. In addition, it suggested that plant management consider the advantages that might be gained by adopting symptom-based emergency operation procedures.

The team commended the extensive program of improvements planned by the plant, but it noted that the timely implementation of these improvements might be jeopardized by funding constraints. It strongly urged that funding be made available to the plant. The team also noted the adverse effect of the loss of trained personnel on the plant's safety performance, and strongly urged plant management to continue its efforts to combat the loss of experienced staff.

OSART Safety Review Mission. An OSART safety review mission visited South Ukraine July 8-19, 1996, to identify safety issues related to the VVER-1000 “small series” nuclear power plants. The team noted deficiencies in the physical separation of safety systems. The IAEA will complete the consolidated list of safety issues and their ranking in 1997.

Planned ASSET Mission. An ASSET peer review mission to South Ukraine, formerly scheduled for March 1997, is now planned for July 22-28, 1998. The mission will review the plant’s analysis of events reflecting safety culture issues based on ASSET procedures.

ZAPOROZHYE (ZAPORIZHZHYA) NUCLEAR POWER PLANT

Type: VVER-1000

Units: Six

Total megawatts (net): 5,700 (950 per unit)

Location: Energodar, Ukraine

Dates of initial operation:
Unit 1 - April 1985
Unit 2 - October 1985
Unit 3 - January 1987
Unit 4 - January 1988
Unit 5 - October 1989
Unit 6 - October 1995

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

Zaporozhye's station manager has noted that the plant's steam generators have experienced corrosion problems and may have to be replaced in units 1 and 2, and possibly in units 3, 4 and 5.

In January 1992, a fire extinguisher was accidentally activated in Unit 2; subsequent water damage led to a plant shutdown. The incident was classified as Level 2 on the International Nuclear Event Scale (INES).

In May 1993, while Unit 5 was in a maintenance and refueling outage, hydrogen leaked from a line in the turbine generator cooling system and was ignited by a welder's torch. The explosion and subsequent fire caused the death of one maintenance worker and severely burned a second. There was no damage to equipment in the turbine hall. A state investigating commission reportedly concluded that the accident was caused by a flagrant violation of safety regulations.

Also in May, Unit 2 was shut down after a group of control rods malfunctioned during planned maintenance work. A similar malfunction occurred in Unit 5 before it was shut down for planned maintenance earlier in the month.

In June 1993, a radioactive “hot spot” was discovered near Unit 1. The contamination occurred after water seeped from the reactor building. A drain valve in the reactor’s primary circuit make-up system apparently failed, and water seeped from the floor of one of the rooms of the reactor building onto the roof of the adjacent motor drive building. From there, heavy rains washed it to the ground. The event was classified as Level 2 on the INES.

In January 1994, contaminated primary circuit water entered a compressed air system in Unit 4 because of a valve failure. The contamination affected one room and some piping inside an auxiliary building. The event was classified as Level 2 on the INES.

A leak of borated primary coolant onto the vessel head delayed the restart of unit 2 following maintenance during the spring of 1996. The reported cause of the leak was failure to ensure leak-tightness of a seal between a thermocouple penetration and the lid. The lid and vessel head stud bolts are not made of stainless steel and are vulnerable to attack by the boric acid. A related incident that occurred previously at the South Ukraine plant set a precedent that the state inspection agency need not prove need for a special inspection when potentially vulnerable metal experiences acid attack.

Personnel, Cash Shortages. Plant workers reportedly sent a letter to then-President Kravchuk and the Ukrainian Parliament in May 1993, saying that the entire plant might have to be shut down because of a shortage of skilled personnel. The letter asked for salary increases to bring plant workers up to the level of Russian nuclear plant personnel. According to plant manager Vladimir Bronnikov, the plant lost 427 highly qualified workers in 1993. Bronnikov also said that the plant was paid for only 40 percent of the electricity it delivered in 1993. In addition, the plant was running out of spent fuel storage capacity. Bronnikov reportedly said that without additional storage, the plant might be forced to shut down Unit 1 in 1995, and might have to close two more units in 1996.

According to a Ukrainian news agency report in October 1994, units 2 and 3 at the Zaporozhye plant had run out of fuel and did not have the $300-500 million needed to buy more. The report added that the plant also did not have the money needed to carry out maintenance work. In November 1994, plant manager Bronnikov said that Zaporozhye would use government credit to launch its 1995 engineering plans.

Some plant employees reportedly held a rally in July 1995 to protest delays in the payment of wages. According to a Ukrainian news agency report, Zaporozhye’s management told employees that the plant was owed 12 million rubles by its customers, and thus had insufficient funds to pay wages on a regular basis.

In February 1997, state regulators denied permission for Unit 6—which began operating in December 1995 under a trial license—to begin commercial operation because of the plant’s failure to complete a promised work program. Goskomatom reportedly said that the $2 million program could not be completed because consumers were not paying for the electricity they used.

The committee was expected to seek modification of the work program commitments to break the deadlock.

In March 1997, the Cabinet of Ministers reportedly directed Goskomatom and the Environment and Nuclear Safety Ministry to take all necessary steps to ensure commissioning of Unit 6. The State Acceptance Commission, which had blocked full commercial operation, was said to believe all necessary work for a commercial license could be completed before planned maintenance in 1998. Within a matter of days, however, the commissioning process was divided into three stages, with the commissioning itself expected to be completed before the year 2000.

Plant Performance. Zaporozhye's performance in 1995 was poor, with a capacity factor for the year of 54 percent. In addition, the plant had more malfunctions—35—than any other Ukrainian nuclear plant. Following the unplanned shutdown of Unit 1's reactor in early December 1995, Russia disconnected its power grid from that of Ukraine. The same week, Unit 5 shut down when a steam generator feedwater regulator got stuck.

Zaporozhye station manager Vladimir Bronnikov was dismissed in October 1996, charged with creating a critical energy situation in Ukraine by failing to ensure rapid repair of three disabled reactors at the plant. Grid frequency in the country reportedly fell to a level that required a large number of manufacturing facilities to suspend operations to prevent collapse of the system.

Technical/Upgrading Activities

A number of host country safety projects have taken place at Zaporozhye or are under way. Steam generator safety valves are being replaced. Emergency feedwater lines are being reconstructed to eliminate thermal cycling. The control system on refueling machines is being replaced with an upgraded system.

Physical protection measures being undertaken include installation of television monitoring and infrared detection devices.

Additional Plans

The Ukrainian Parliament's 1990 moratorium stopped construction on a sixth unit at the site. In October 1993, the Ukrainian parliament voted to lift the moratorium on new plant construction, citing Ukraine's energy shortage as the reason. In February 1994, then-President Kravchuk issued a directive calling for the completion by 1999 of five VVER-1000s that were under construction, including Zaporozhye 6. The unit began operation in October 1995.

According to former plant manager Bronnikov, some upgrades could not be incorporated in Unit 6 because of a lack of money and equipment. He also reportedly said that because the plant owed 2.5 billion rubles to Russian scientific and technical institutes, all safety upgrade programs had been halted.

International Exchange/Assistance

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

- United States' Duke Power headquarters (October 1992),
- United States' Catawba plant (November 1993, September 1994).

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

- United States' Catawba plant (October 1992, August 1994),
- Spain's Almaraz plant (November 1992),
- United States' Catawba, McGuire and Oconee plants (August 1993),
- United States' Beaver Valley plant (June 1994),
- United States' Catawba plant (August 1994),
- United States' Diablo Canyon (November 1994),
- United States' Wolf Creek plant (October 1995, October 1996).

Plant Twinning. The Zaporozhye plant is twinned with France's Bugey plant, with Germany's Neckarwestheim plant, and with the Catawba plant in the United States.

U.S. Assistance. Working groups sponsored by the U.S. Nuclear Regulatory Commission (NRC) have explored a wide variety of issues at Zaporozhye, including regulatory inspection practices, fire-protection approaches and internal communications.

In 1993, Duke Engineering & Services (Europe) Inc. signed a contract with Zaporozhye to develop an independent spent fuel storage facility at the plant consisting initially of 14 dry storage casks. The company will provide design, fabrication, project management, technical support and training, licensing support, quality assurance and public outreach support for Zaporozhye. The contract provides for Zaporozhye to build additional casks as needed.

In July 1994, the U.S. Trade and Development Agency sponsored a feasibility study for the project, which also helped Duke Engineering & Services and Zaporozhye in initial planning and project development.

In July 1995, the U.S. Department of Energy agreed to provide financial support to the project through its International Nuclear Safety Program. The DOE contract provides funding for three dry storage casks, a cask transporter and miscellaneous ancillary equipment and engineering services.

Also under the DOE program, basic fire protection equipment, such as sprinkler heads, control panels, self-contained breathing apparatus, and sealants, is being supplied to Zaporozhye.

European Union Assistance. The EU is engaged in instrumentation and control upgrades at Zaporozhye, and has provided spare parts to the plant.

French Assistance. Representatives of Cegelec visited the Zaporozhye plant in February 1997 to discuss a planned physical protection system for the site. The visit followed signing of a financial protocol between France and Ukraine under which France will provide about $1 million to support the site protection system and implement a related technical assistance program. Cegelec will provide the necessary equipment.

Spanish Contract. The Spanish company Tecnatom has been awarded a contract for the supply of nondestructive equipment to the Zaporozhye plant. The equipment, which includes a data acquisition system for reactor pressure vessel inspection, a mechanical and electrical system for reactor vessel closure stud inspection, an automatic pipe inspection system and a containment instrumentation system, was expected to be delivered in early 1996. Zaporozhye was reportedly to pay for the equipment with money raised through barter deals involving uranium.

Croatian Contract. Croatia's Inetek has a contract, running from 1995 to 2000, to carry out eddy current testing of steam generator tubing and tube plugging, and to supply four sets of eddy current testing equipment and one set of plugging equipment.

IAEA Workshop. An IAEA team conducted a workshop at the Zaporozhye plant Oct. 30-Nov. 2, 1995. The purpose of the workshop was to discuss nuclear maintenance practices, especially preventive and predictive maintenance. An earlier mission to Zaporozhye had identified preventive maintenance as an area where significant improvements might be made, and the workshop was arranged as a follow-up. Zaporozhye made presentations on its maintenance programs, and the IAEA team made presentations on maintenance practices in Switzerland and the United States. The IAEA presentations included lessons learned in optimizing maintenance based on industry experience. Fifteen managers from Zaporozhye and six managers from Chernobyl attended the workshop.

Inspections

Safety Review Mission. An International Atomic Energy Agency Safety Review Mission visited Zaporozhye in May 1994 in connection with the IAEA's program on the safety of VVER-1000s. The team identified the main engineered safety features at the plant and pointed out aspects of plant design that reflected international practice.

The team also identified design shortcomings through an examination of operational experience and a comparison with plant design in other countries. Most of the shortcomings—which included fuel assembly structural instability, higher incidence of instrumentation and control system failure, and heat exchanger fouling—were being addressed by the plant.

The team further identified areas in which management and operational safety practices could be improved. It pointed out that some elements of a safety culture were in place at the plant, but a self-critical attitude needed to be encouraged and allowed to develop.

ASSET Mission. An IAEA ASSET mission visited Zaporozhye June 13-24, 1994, to review the plant's management policy on safe operation. The team found that while the frequency of total plant events was comparable to that of other plants visited by ASSET missions, the frequency of safety significant events had increased in the last two years because of the problem of malfunctioning control rods. The team noted that the problem had been recognized and addressed by plant management.

The team reviewed 709 events that were reported between January 1990 and March 1994. Of these, the team found 275 to be safety relevant; nine were classified as Level 2, 15 were classified as Level 1 and the rest, as Level 0 on the INES. The team identified eight safety problems, two of which—potential unreliability of reactivity control because of sticking control rods and unreliability of mechanical components (pumps and valves) in safety-related systems—were determined to be pending because corrective action had not been fully implemented.

The team conducted an in-depth analysis of three events, and noted that in one case its analysis confirmed the analysis done earlier by the plant. The team considered this to be a successful application of the ASSET methodology in event analysis.

Among the team's recommendations to improve the prevention of incidents were:

- maintenance personnel should be trained in the processes and procedures of work on sensitive devices
- operator response procedures for situations involving the failure of automatic control systems should be improved
- management should consider the development of a comprehensive quality assurance program for plant modifications
- the operational feedback program should be reviewed within a year for its effectiveness
- internal reporting criteria should be changed so that non-safety relevant events are reported separately from safety relevant events.

Planned ASSET Mission. An ASSET peer review mission to Zaporozhye was scheduled for May 6-10, 1996. The mission—to review the plant's analysis of events reflecting safety culture issues based on ASSET procedures—has yet to be re-scheduled.