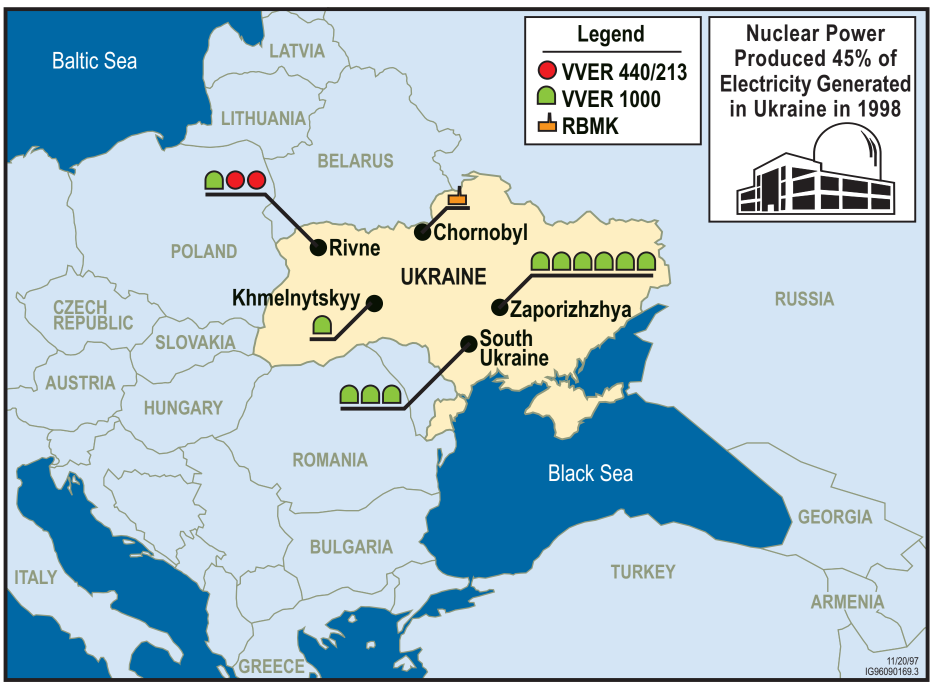
4.0 Ukraine

Reactor Types in Ukraine

- One RBMK-1000
- Two VVER-440/213s
- Eleven VVER-1000s

Ukraine has 14 operating nuclear power reactors at five plants. Together, these reactors produced 45 percent of the electricity generated in Ukraine in 1998. All five plants work with the United States in cooperative safety efforts. Except for one RBMK at Chornobyl, Ukraine's reactors follow the VVER design. Appendix A describes the designs, and Appendix B lists the reactors.

U.S. specialists work closely with Ukrainian organizations responsible for the design, construction, operation, and regulation of nuclear power plants. Appendix E lists these organizations. A U.S. office in Kyiv provides administrative, technical, and contractual support for the cooperative safety efforts.



The Ukrainian Nuclear Power Plants Participating in the Cooperative Effort to Improve Nuclear Safety

Key Accomplishments

4.1.1 Personnel Training

- With U.S. support, Ukraine has successfully established a nuclear training center at the Khmelnytskyy plant.
- Instructors at the Khmelnytskyy training center have developed and conducted 12 courses.
- The U.S.-trained instructors from Khmelnytskyy are training instructors at Rivne, South Ukraine, and Zaporizhzhya.
- Staff at the Khmelnytskyy training center have begun incorporating simulator equipment into selected training courses.
- Chornobyl instructors also have worked with U.S. experts to improve training.

4.1 Increasing the Safety of Day-to-Day Operations

Management and Operational Safety Projects

Management and operational safety projects increase the ability of plant personnel to operate reactors safely. In Ukraine, these projects are organized into the following areas:

- Personnel Training (Section 4.1.1)
- Simulator Development (4.1.2)
- Configuration Management (4.1.3)
- Event Reporting and Analysis (4.1.4)
- Quality Assurance (4.1.5)
- Operational Safety Infrastructure (4.1.6)
- Safety Maintenance Technologies (4.1.7)
- Reliability Database (4.1.8)
- Nondestructive Examination (4.1.9)
- Conduct of Operations (4.1.10)
- Operator Exchanges (4.1.11)
- Emergency Operating Instructions (4.1.12).

4.1.1 Personnel Training

Well-trained, safety-conscious workers are essential for the safe operation of a nuclear power plant. Under the Soviet system, reactor personnel often worked in isolation from their counterparts at other plants and from the international nuclear community, hindering the exchange of information, skills, and lessons learned. Training was not formalized.

The United States and Ukraine have established a nuclear training center at the Khmelnytskyy plant. Khmelnytskyy instructors have worked with U.S. and Ukrainian specialists to expand the training program, teaching instructors at other plants to improve their training processes.

► **Activities Completed**

Establishment of the Khmelnytskyy Training Center. Beginning in 1993, Khmelnytskyy instructors received extensive courses in the Systematic Approach to Training, a methodology adopted at all U.S. nuclear power plants after the 1979 accident at Three Mile Island. The approach provides a standard framework for identifying training needs, analyzing jobs and their specific tasks, developing course materials based on these analyses, and using teaching methods that combine classroom instruction with hands-on equipment use.

Training specialists from U.S.-based General Physics Corporation and Brookhaven National Laboratory worked closely with the Khmelnytskyy instructors, enabling them to adopt the methods of the Systematic Approach to Training, design training programs, and develop and conduct eight pilot training courses in operations and maintenance. Courses covered job-specific tasks, equipment maintenance, and supervision and management.

Khmelnytskyy instructors presented the first operations and maintenance training course in April 1994 and the eighth in June 1997.

U.S. and Khmelnytskyy trainers also developed four general courses: an introduction to the Systematic Approach to Training, general employee safety, the organizational safety culture, and instructor training. Khmelnytskyy instructors presented the first of these courses in February 1994 and the fourth in December 1997.

As part of the program development, U.S. and Ukrainian training specialists worked together to improve methodologies for evaluating training programs and documenting lessons learned. The United States provided basic equipment for the Khmelnytskyy training center, such as computers, software, and copiers. The United States also supplied specialized equipment for the pilot courses, such as soldering stations and a refueling-machine simulator.

Expansion of the Training Program. After successfully establishing the training center at Khmelnytskyy, U.S. and Ukrainian specialists worked together to train instructors at three other plants in Ukraine—Rivne, South Ukraine, and Zaporizhzhya. Since September 1997, a team of experts from Khmelnytskyy, the United States, and the Engineering and Technical Center for the Training of Nuclear Industry Personnel in Kyiv visited each plant three times to prepare instructors and to develop a pilot training course on the Systematic Approach to Training.

In October 1997, the United States provided computers, software, and copiers for the course development work at Rivne, South Ukraine, Zaporizhzhya, and the Engineering Technical Center.

With on-site support from the team of experts, instructors at each plant presented a pilot course in 1998. Rivne's course in April covered the calibration and repair of pressure transmitters. Zaporizhzhya instructors presented a course in May for chemical operators. South Ukraine's June course covered the repair of integrated circuit boards. (Table D.2 in Appendix D shows the status of training program development in Ukraine.)

"One year experience of simulator operation in 1998 as a major training tool demonstrated the high quality of this equipment. The simulator was used for initial and continuous training of more than 60 senior operators of the plant.

[Also,] development of the modern Personnel Training System based on SAT (Systematic Approach to Training) has special significance for us.

We would like to use this opportunity to express our gratitude to the Government of the United States of America for great and timely support in development of the Full-Scope Simulator and Personnel Training System. We are looking forward to successful cooperation in the area of improving personnel training at Khmelnytskyy nuclear power plant."

—Nikolay Dudchenko
Director General of Khmelnytskyy nuclear power plant

Management and Supervisory Training. In December 1998, a U.S. training expert presented a course on management and supervisory skills for Khmelnytskyy's mid- and upper-level managers.

Training Improvements at Chornobyl. In a related effort, U.S. specialists have worked with instructors at the Chornobyl plant to develop courses based on the Systematic Approach to Training. The instructors presented courses in 1997 for radiation protection technicians and control room operators. The United States provided basic and course-specific equipment for use in training development. In December 1998, a U.S. training expert presented a course on management and supervisory skills for Chornobyl's mid- and upper-level managers.

To support improved training at Chornobyl, the United States has supplied computers, copiers, and other basic training equipment for instructors at the Slavutych Laboratory for International Research and Technology. The laboratory is the primary technical branch of the International Chornobyl Center for Nuclear Safety, Radioactive Waste and Radioecology, which is addressing environmental, health, and safety issues created by the 1986 disaster at Chornobyl. (For details about the center and the Slavutych Laboratory, see Section 5.3.)

► Work in Progress

Additional Expansion of the Training Program. In a second phase of the expanded training program, a team of experts from the United States, the Khmelnytskyy training center, and the Engineering Technical Center are working with instructors at Rivne, South Ukraine, and Zaporizhzhya to develop and present a second pilot course. In October 1998, the expert team conducted the first of two, two-week-long workshops in which instructors are developing a course for unit shift supervisors. The course is based on training materials developed for use at Khmelnytskyy.

Also in October, U.S. experts conducted an information exchange in Kyiv on the U.S. process for training and qualifying reactor operators. Participating were staff from the Engineering Technical Center and each Ukrainian plant.

Simulator Training. U.S. and host-country specialists are developing simulators for training control room operators in Ukraine. (For details, see Section 4.1.2.) Simulators operate at Khmelnytskyy, Chornobyl, and Zaporizhzhya. Simulators will begin operating at South Ukraine in 1999 and at Rivne in 2001.

With support from U.S. personnel, staff from the Khmelnytskyy training center are incorporating simulator equipment into some of their training courses. The goal is to ensure a comprehensive, integrated approach to classroom, on-the-job, and simulator training. U.S. and Khmelnytskyy specialists also are developing detailed exercise guides for simulator training. In an October 1998 seminar in Kyiv, U.S. and Ukrainian specialists exchanged information on the use and management of full-scope training simulators.

4.1.2 Simulator Development

A nuclear power plant simulator is an effective, efficient training tool used widely in the international nuclear industry. Its computer programs mimic plant conditions, giving control room operators practice in responding to routine and emergency situations.

Two types of simulators are used in training. A *full-scope simulator* provides hands-on training by replicating the control room of a nuclear power plant. A computer links an instructor station with a full-size physical replica of the control panels. As reactor operators manipulate controls, the simulator responds by displaying the changes in conditions that would occur in the plant. The instructor can select the initial plant state, introduce malfunctions and failures, freeze the exercise, and provide retrospective viewing.

An *analytical simulator* uses computer monitor screens instead of replicated control panels. The computer's graphic displays represent plant systems. Operators practice responding to various conditions by entering computer commands.

U.S., Ukrainian, and Russian organizations are working together to develop control room simulators for Soviet-designed nuclear power plants. Each simulator, whether full-scope or analytical, must be designed to replicate the configuration and behavior of each particular reactor. (Table D.2 in Appendix D summarizes the status of simulator development activities in Ukraine.)

The Khmelnytskyy full-scope simulator began operating in December 1997. An ongoing upgrade of the system will be completed in 1999.

► Activities Completed

Khmelnytskyy Unit 1. The first full-scope training simulator developed with U.S. support for a Soviet-designed nuclear power plant began operating in December 1997 at the Khmelnytskyy plant. U.S. contractor GSE Power Systems, Inc., developed this simulator with support from LAKROM, a Russian subcontractor.

Key Accomplishments

4.1.2 Simulator Development

- Control room operators at Khmelnytskyy and Chornobyl are training on simulators developed with U.S. support.
- U.S. personnel have delivered hardware, software, and training for a full-scope simulator for South Ukraine Unit 3.
- U.S., Ukrainian, and Russian experts are collaborating on the development of full-scope simulators for Rivne Unit 3 and South Ukraine Unit 1.
- In 1996, with U.S. support, Ukraine established the Engineering Technical Center in Kyiv to develop and maintain control room simulators.

Energoatom is a private utility responsible for Ukraine's nuclear power plants. It was organized in 1997 to perform work for which Derzhkomatom previously was responsible.

Derzhkomatom was the Ukrainian State Committee on Nuclear Power Utilization.

Chornobyl Unit 3. GSE produced an analytical simulator for the Chornobyl plant, which became ready for use in February 1998.

Capability Development. Staff from the Khmelnytskyy plant and Energoatom received on-the-job training in simulator technology from March 1995 to March 1996. Ukraine built on the expertise acquired through this training to establish the Engineering Technical Center. The center's objective is to develop and maintain control room simulators for plants throughout Ukraine. In January 1997, the United States delivered hardware and software for a computer complex at the center.

U.S. instructors delivered a three-week training course at Zaporizhzhya in March 1997 on the maintenance of simulator hardware and software. At the Zaporizhzhya plant in August 1997, U.S. instructors provided a course on the effective use of training simulators. Simulator training specialists from Khmelnytskyy and Zaporizhzhya participated, along with Engineering Technical Center personnel.

Simulator instructors from all five Ukrainian plants participated in a December 1998 course on the development and presentation of simulator training materials. Specialists from U.S.-based Sonalysts, Inc., presented the course, which included classroom instruction and extensive use of the full-scope simulator at Khmelnytskyy. As part of the course, teams of Ukrainian instructors developed training scenarios, then observed and critiqued the scenarios as trained operators ran them on the Khmelnytskyy simulator.

► Work in Progress

South Ukraine Unit 3. GSE has delivered hardware and software for a full-scope simulator for South Ukraine Unit 3. In May and June 1997, GSE staff presented a training course in operation, maintenance, and application of the simulator. The project will be completed in 1999.

Zaporizhzhya Unit 5. The United States is providing hardware and software to upgrade a full-scope simulator at Zaporizhzhya Unit 5. The upgrades will be completed in 1999.

Rivne Unit 3 and Unit 2, South Ukraine Unit 2, and Zaporizhzhya Unit 1. GSE, LAKROM, and the Engineering Technical Center will collaborate on full-scope simulators for Riven Unit 3 and Unit 2, South Ukraine Unit 1, and Zaporizhzhya Unit 1. Completion of these projects is scheduled for 2001 and 2002.

Integration of Safety Parameter Display Systems. U.S. and host-country specialists are developing safety parameter display systems for Soviet-designed plants (see Section 4.2.1). The systems give control room operators crucial information about plant conditions during emergency operations. To improve operator training, simulated safety parameter display systems will be integrated into training simulators for Ukrainian reactors. The simulators for Khmelnytskyy Unit 1 and Zaporizhzhya Unit 5 will receive this upgrade in 1999. As control room simulators for other Ukrainian reactors are designed and completed, simulated safety parameter display systems will be included.

4.1.3 Configuration Management

A configuration management system ensures that a plant's physical configuration is in keeping with its safety design basis—the foundation for overall plant safety. Configuration management also ensures that plant drawings and documents are updated consistently to portray the plant's physical configuration accurately. (For details, see box: *Configuration Management Maintains a Match of Design, Documents, and Plant Layout*.)

With support from U.S. personnel, Zaporizhzhya specialists are creating a configuration management system for the plant.

► Activities Completed

In 1997, U.S. contractor Stone & Webster Engineering Corporation provided configuration management training for key Zaporizhzhya managers. The managers visited a U.S. nuclear power plant to observe the use of configuration management databases. Earlier in 1997, Stone & Webster staff conducted a detailed assessment of the plant and made recommendations for establishing the configuration management system.

Configuration Management Maintains a Match of Design, Documents, and Plant Layout

When workers upgrade the design of a nuclear power plant or modify operational procedures, they must make sure the changes are in keeping with the plant's "safety design basis." For example, a new pump must move the amount of water set by the plant's design requirements. Workers then must update the plant drawings and documents to include the new pump.

This important safety process is called configuration management. By verifying that a plant's physical configuration meets its design basis, configuration management ensures that safety equipment functions as designed to preclude or mitigate accidents. By making sure a plant's documentation is up to date, configuration management assures operators that the drawings and documents they use to make operating decisions are accurate.

Inadequate configuration management could lead, for example, to a valve being replaced with an improper spare that fails during an accident or an operator turning off the wrong pump during a crisis because his operational drawing is inaccurate.

In the former Soviet Union, nuclear power plant personnel did not maintain configuration management. Design modifications, repairs, and operational changes did not always conform to the plant's safety design basis, and workers did not update plant drawings and documents consistently.

The United States is supporting configuration management projects at Ukraine's Zaporizhzhya plant, Russia's Novovoronezh plant, Bulgaria's Kozloduy plant, and Lithuania's Ignalina plant.

Key Accomplishments

4.1.5 Quality Assurance

- With U.S. support, Ukrainian specialists have developed a national industry standard for quality assurance.
- Ukrainian specialists are developing improved quality assurance procedures to implement at Ukraine's nuclear power plants.

A root cause analysis identifies the cause or causes contributing to an error or equipment failure and determines corrective actions to prevent recurrence. The analysis examines a range of contributors, such as maintenance, plant procedures, management, and human decision-making.

During 1998, plant personnel developed two preliminary databases, one for registering equipment and the other for documenting procedures.

► **Work in Progress**

Early in 1999, the United States will ship computers for use in the configuration management project at Zaporizhzhya.

4.1.4 Event Reporting and Analysis

With U.S. support, Ukrainian specialists are developing a process for the systematic investigation of abnormal events at Ukrainian nuclear power plants. Called event reporting and analysis, this process calls for determining the cause of events, identifying appropriate corrective actions, and sending written reports to other plants, enabling managers there to take preventive action.

Zaporizhzhya is Ukraine's pilot plant for developing an event reporting and analysis system. Plant staff are working with Energoatom and two Ukrainian contractors, Novator Kyiv and the Crimea Scientific and Engineering Research Center, to develop the process. U.S. contractor Conger & Elsea is providing technical support.

► **Activities Completed**

In May 1997, 12 staff members from Ukrainian plants participated in training on event reporting and analysis.

In December 1998, the Ukrainian team completed the development of procedures for event investigations and the performance of root cause analyses. Zaporizhzhya personnel began implementing the procedures. The procedures incorporate revisions based on comments from personnel at other Ukrainian plants.

► **Work in Progress**

In 1999, U.S. specialists will work with the Ukrainian team to train staff at Zaporizhzhya and to develop a system for reporting abnormal events and their causes to other Ukrainian plants.

4.1.5 Quality Assurance

With U.S. support, Ukrainian specialists have developed a national industry standard for quality assurance along with a general quality manual, and they are developing improved quality assurance procedures. Energoatom and Ukraine's nuclear power plants will work to implement the standard, manual, and procedures as they are completed.

► **Activities Completed**

U.S. specialists have worked extensively with staff at Chornobyl to improve the plant's quality assurance procedures. Chornobyl personnel visited a U.S. nuclear power plant in October and December 1995 to observe the use of internationally recognized procedures. In October 1996, Chornobyl staff attended a course on U.S. principles and practices in quality assurance. In December 1996, U.S. and Chornobyl specialists conducted an audit of quality assurance practices at the plant. In July 1997, 21 Chornobyl staff members attended a workshop on quality assurance procedures for post-maintenance testing. In October 1997, U.S. instructors presented workshops on proactive maintenance and quality assurance procedures for on-line maintenance.

U.S. instructors presented quality assurance workshops in January and August 1997. In November 1997, U.S. instructors trained a Ukrainian quality assurance auditing team that includes 23 staff members from Energoatom and four Ukrainian plants—Chornobyl, Rivne, South Ukraine, and Zaporizhzhya.

In February 1998, a Ukrainian team completed the final version of a national industry standard for quality assurance that is based on the standards of the International Atomic Energy Agency. Energoatom has forwarded it to governmental organizations for acceptance.

Also in February, U.S. instructors presented a workshop on quality assurance assessment techniques. Personnel from each Ukrainian plant participated, along with personnel from Energoatom and the Main State Inspectorate for Supervision of Nuclear and Radiation Safety.

A U.S.-Ukrainian team presented a workshop in July 1998 on document control and records management. Participants compared practices at U.S. and Ukrainian plants and agreed on plans for developing improved procedures in Ukraine. Representatives from Energoatom and four Ukrainian plants—Chornobyl, Rivne, South Ukraine, and Zaporizhzhya—participated.

► Work in Progress

With U.S. support, Ukrainian specialists are developing pilot procedures for document control, records management, and quality assurance assessments. Plant personnel will use the pilot procedures to develop site-specific procedures for implementation at their plants.

4.1.6 Operational Safety Infrastructure

A U.S.-Ukrainian team is identifying ways to improve Energoatom's support for safe and reliable operations at nuclear power plants. The team includes experts from the Pacific Northwest National Laboratory, U.S. contractor Scientech, Ukrainian contractors, Energoatom, and the Nuclear Power Plant Operational Support Institute. The team also is developing a plan for how the Operational Support Institute will work to increase the capabilities available to Energoatom.

Ukraine established the Operational Support Institute in 1997 to provide technical and project management assistance to Energoatom. The Institute's initial efforts focus on quality assurance, risk-based inspection techniques, and the development of a performance indicators program.

Key Accomplishments

4.1.7 Safety Maintenance Technologies

- The United States has supplied up-to-date tools and training for maintenance workers at Chornobyl—including equipment to detect faults in electrical systems that could lead to equipment failure, fire, and loss of power.
- Maintenance technicians at Chornobyl now use modern pipe lathe/weld-preparation machines, valve-seat resurfacing equipment, and vibration monitoring and shaft alignment systems that improve the quality of repairs.
- With U.S. funding, workers refurbished and equipped three rooms at Chornobyl for training maintenance technicians.

► Activities Completed

With support from Scientech and the Pacific Northwest National Laboratory, the Operational Support Institute has outlined a multi-year plan of capability development activities. They will complete the plan in early 1999.

The Operational Support Institute also coordinated Ukraine's efforts in support of the July 1998 workshop on document control and records management (see Section 4.1.5).

► Work in Progress

In 1999, U.S. and Ukrainian specialists will conduct a workshop on developing procedures and a database for a performance indicators program. Ukrainian personnel will use the program to monitor the safety and reliability of Ukrainian plants.

Personnel from the Operational Support Institute are coordinating the development of standards for document control. They also are creating a database structure for document control at Energoatom.

In a related project, personnel at the South Ukraine plant are developing a pilot program for risk-based inspection. (For details, see Section 4.1.9.)

4.1.7 Safety Maintenance Technologies

Chornobyl Unit 3 is an RBMK reactor. The United States is working to reduce equipment malfunctions at RBMKs by supplying up-to-date tools and training for maintenance workers. RBMKs also operate at Lithuania's Ignalina plant and Russia's Kursk, Leningrad, and Smolensk plants.

► Activities Completed

Pipe Lathe/Weld-Preparation Machines. The United States supplied a pipe lathe/weld-preparation machine to Chornobyl and the other RBMK sites in 1996. Workers use these machines to cut pipes precisely and prepare them for welding. This improves weld integrity, reducing the risk of leaks that could cause loss of cooling water to the reactor core. Prior to receiving this equipment, workers cut pipes by hand.

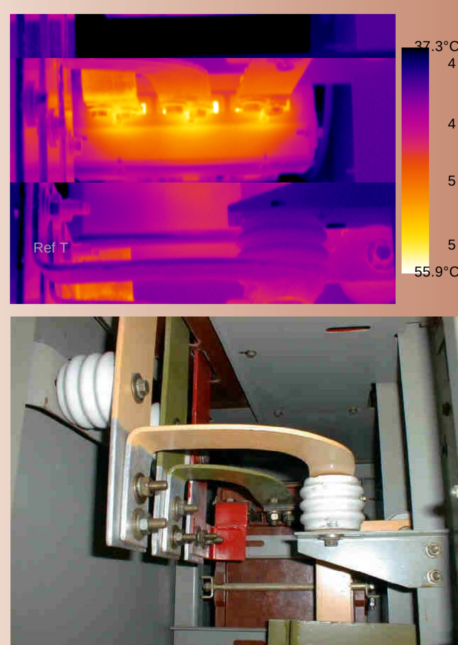
Early in 1997, the United States provided a second pipe lathe/weld-preparation machine to Chornobyl. In late 1997, the United States provided three additional machines in response to an urgent request from Chornobyl managers. During a Unit 3 maintenance shutdown in summer 1997, technicians had discovered faulty and deteriorating welds in cooling system components, a problem that could lead to a loss-of-coolant accident. The Ukrainian Nuclear Regulatory Administration called for complete inspection and repair of the welds before restarting the reactor. Through U.S.-Ukrainian cooperation, Chornobyl received the new machines within five weeks of the managers' request. Maintenance workers used the machines to repair more than 300 cracks. The reactor returned to operation in May 1998.

Valve-Seat Resurfacing Equipment. The United States delivered valve-seat resurfacing equipment to Chornobyl and the other RBMK sites in August 1997, and U.S. specialists trained workers in its use. The equipment enables technicians to repair leaking valves without having to remove them from piping systems. This increases the accuracy of repairs, reduces maintenance time, and maintains the integrity of pipes, reducing the risk of leaks that could lead to loss of cooling water to the reactor core.

Vibration Monitoring and Shaft Alignment Systems. In October 1997, technicians at all RBMK sites received training in the use of vibration monitoring and shaft alignment equipment. Chornobyl received the equipment just in time for major cooling system repairs. Workers use the equipment to detect and correct imbalance and shaft misalignment in rotating machinery, such as pumps, motors, and turbines. For example, each RBMK reactor has 2,000 high-speed pumps, some of which supply cooling water to the reactor core. When a pump is misaligned or out of balance, its bearings and seals can fail, possibly leading to a loss of cooling water to the reactor core.

Technicians use a U.S.-supplied infrared thermography unit to detect hot spots in electrical systems before equipment fails.

Insulation Analysis Equipment. The United States delivered insulation analysis equipment to Chornobyl in June 1998 and trained plant personnel in its operation. Workers use insulation analysis equipment to detect breakdown of the insulation inside the plant's main generators and around high-voltage lines and equipment, such as the transmission lines between site transformers and the main generators. Detecting and correcting insulation breakdown can prevent loss of electrical power to key reactor systems. A risk analysis at Ignalina indicated that loss of electrical power is the trigger most likely to lead to severe accidents at RBMK reactors. For example, loss of electrical power could shut down the reactor's cooling pumps, leading to rapid overheating of the reactor core.



The infrared camera clearly shows hot spots in this electrical junction (top) that are not visible otherwise (bottom). The equipment is being used at the Chornobyl plant.

Infrared Thermography Equipment. In September 1998, Chornobyl received a U.S.-supplied infrared thermography unit. Technicians use this equipment to detect hot spots in electrical systems, identifying hazards that could lead to equipment failure and loss of power.

U.S. specialists worked with plant personnel in October 1998 to conduct a baseline thermographic imaging survey of safety-grade electrical equipment and the electrical buses that connect safety equipment to the power source. The survey simultaneously trained technicians and identified wiring, insulation, and electrical connections that need repair. With U.S. funding, workers will perform the necessary repairs early in 1999.

Training Facilities. With U.S. funding, workers in 1997 refurbished and equipped three maintenance training rooms at Chornobyl. The site previously lacked adequate facilities for training maintenance workers.

Key Accomplishments

4.1.8 Reliability Database

- ◆ Ukrainian specialists have completed the design of a reliability database for the country's VVER reactors.
- ◆ The Ukrainian contractor INIT has completed a software quality assurance plan for database development and use.
- ◆ The United States has provided computers and will provide telecommunications equipment to make the central database accessible to Ukraine's nuclear power plants.
- ◆ Ukrainian specialists have participated in workshops on collecting reliability data for nuclear power plant components.

INIT is a joint venture between INIT in Kyiv and the Rochester Institute of Technology in Rochester, New York.

VNIIAES is the Russian Institute for Nuclear Power Plant Operations.

4.1.8 Reliability Database

With U.S. support, Ukrainian specialists are developing a reliability database for the country's VVER reactors. The database will store maintenance and operational data regarding components of the reactors' mechanical, electrical, and instrumentation systems that are essential to safety. This information will be available to all nuclear power plants in Ukraine.

The reliability database will improve access to maintenance information, enabling Ukrainian nuclear power plants to improve their preventive maintenance programs. The database also will provide key information for performing the probabilistic risk analyses, technical basis calculations, and root cause analyses required in plant safety assessments. Energoatom will maintain the database as a central, interactive, and constantly updated repository of information.

To develop the database, specialists from Energoatom and the Ukrainian Ministry of Energy are working with U.S. experts from the Pacific Northwest National Laboratory. The primary contractor for the project is INIT.

To facilitate the sharing of information, the structure of the database is compatible with major reliability databases. The Institute of Nuclear Power Operations maintains a database called EPIX for U.S. commercial nuclear power plants. The Institute is affiliated with the World Association of Nuclear Operators, which through its Moscow Center made the EPIX structure available to Ukrainian specialists.

The structure of the Ukrainian database also is compatible with the generic reliability database maintained by the International Atomic Energy Agency and with the reliability database under development in Russia. (For details on the Russian database, see Section 6.1.5.)

► Activities Completed

In March 1998, the database development center in Kyiv received U.S.-provided computers and software for creating the database.

In May 1998, specialists from Energoatom, Pacific Northwest National Laboratory, and Science Applications International Corporation presented a workshop on collecting reliability data. Personnel working on the Ukrainian and Russian databases participated, including staff from Ukrainian and Russian plants, INIT, and VNIIAES. Representatives of the organizations involved in the workshop have formed an advisory group to meet periodically. The group's objective is to ensure consistency in data collection and reporting methods.

In June 1998, INIT completed a software quality assurance plan to be used in the development and operation of Ukraine's reliability database.

In November 1998, Ukrainian software engineers completed the design of the database structure. The United States delivered computer equipment for the three pilot plants that initially will have electronic access to the database: Khmelnytskyy, Rivne, and South Ukraine.

In December 1998, Ukrainian specialists defined the list of equipment to be controlled.

► **Work in Progress**

Early in 1999, Ukrainian specialists will complete the construction of the database structure and define the procedures and standards for data collection. The United States will provide telecommunications equipment to establish electronic connections between the plants and the database. The United States also will provide a computer server to Energoatom and computer networks to the pilot plants, enabling the plants to access and contribute to the database.

Ukrainian specialists will populate the database with information on the reliability of safety-related components at VVER reactors in the host countries of Central and Eastern Europe as well as Ukraine. The project will be complete in December 2002.

4.1.9 Nondestructive Examination

The United States is supplying equipment for finding flaws in pipes and steam generator tubes before they create problems. Technicians use ultrasonic, x-ray, and eddy-current equipment for nondestructive examination, which enables them to evaluate pipes for tiny flaws and cracks without cutting the pipes open. (For details, see box: *Equipment Finds Pipe Flaws Before They Cause Problems*.)

Experts examine an ultrasonic calibration standard. Ultrasonic equipment is used to find flaws in pipes and welds before they become cracks or leaks.

► **Activities Completed**

Technology Transfer. In March 1997, the United States delivered state-of-the-art manual ultrasonic inspection systems to the five nuclear power plants in Ukraine. Also in March, inspection personnel from each plant attended a six-day training course at the Khmelnytskyy plant, led by U.S. instructors. These milestones occurred within four months after the signing of the initial project protocol.

To inspect the integrity of steam generator tubes, Ukrainian plants previously contracted for costly foreign inspection services or used pressure tests that did not permit detection of individual leaking tubes. In February 1998, the United States delivered eddy-current equipment to Energoatom to enable Ukrainian plants to conduct their own remote inspections of steam generator tubes. The Croatian company INETEC assembled the equipment and provided training in its use.

Key Accomplishments

4.1.9 Nondestructive Examination

- Zaporizhzhya workers have used U.S.-supplied eddy-current equipment to inspect the integrity of 1,500 steam generator tubes at the plant's Unit 6 reactor.
- Using U.S.-supplied ultrasonic inspection systems, technicians at the South Ukraine plant replaced defective turbine blades after they discovered unacceptable cracks.
- With U.S. support, Energoatom and the National University of Ukraine have established a central training and certification facility for nondestructive examination. U.S. and Ukrainian experts are developing a process for certifying technicians as nondestructive examination specialists.
- Staff at the South Ukraine plant are developing procedures for risk-based inspection of pipes essential to safety.

Equipment Finds Pipe Flaws Before They Cause Problems

Preventing leaks and ruptures in pipes is a crucial task in nuclear plant maintenance. Hundreds of meters of pipes carry cooling water to the reactor, keeping the nuclear fuel in a safe temperature range. If a leak or rupture interrupts the water flow, high temperatures can damage the reactor core, which may lead to the release of radioactive material.

Maintenance workers must find flaws in pipes before they develop into cracks. These inspections must take place without cutting open the pipes and with minimum interruption to plant operations.

To accomplish this, workers use several types of equipment—including ultrasonic, x-ray, and eddy-current equipment—in a process called nondestructive examination. For example, a technician can determine whether a pipe is sound by moving an ultrasonic search unit around the pipe and interpreting the instrument's signals.

In addition to inspecting pipes, workers must examine hundreds of meters of steam generator tubing. Because these tubes carry radioactive water, workers must use remotely operated equipment. Remote equipment also is used to check the integrity of the reactor pressure vessel that houses the nuclear fuel core.

Nuclear power plants in Ukraine and Russia have lacked adequate equipment for nondestructive examination. U.S. deliveries of such equipment paid off quickly in Ukraine. In July 1997, technicians at the South Ukraine nuclear power plant replaced defective turbine blades after their new ultrasonic inspection equipment revealed unacceptable cracks.

Inspections and Training. In March 1998, technicians from Zaporizhzhya and INETEC completed an inspection of 1,500 steam generator tubes at the Unit 6 reactor. Zaporizhzhya technicians will examine the tubes in a second reactor in early 1999.

In April 1998, specialists from the Pacific Northwest National Laboratory conducted a two-week workshop at Khmelnytskyy on ultrasonic examination of pipes fabricated from austenitic steel. Representatives from all five Ukrainian plants participated. Welds in austenitic steel can be subject to cracking caused by a combination of stress and corrosion, which occurred at Chornobyl Unit 3 and resulted in an extended shutdown (April 1997 to May 1998) to identify and repair cracks.

The United States is supporting increased training in nondestructive examination. With U.S. support, Energoatom and the National University of Ukraine have established a central training and certification facility for nondestructive examination. In 1998, workers renovated the facility's classrooms and administrative offices in Kyiv. U.S. and Ukrainian experts are developing a process for certifying technicians as nondestructive examination specialists. The requirements will conform to international standards.

Risk-Based Inspection. In a related project, U.S. specialists have worked with Energoatom and the Nuclear Power Plant Operational Support Institute to begin a pilot study in the use of risk-based inspection techniques. These techniques use risk as a basis for setting inspection priorities. Workers examine more frequently the components that pose the highest risk of causing core damage, loss of containment, or radiological harm outside the plant. Risk-based inspection examines the structural integrity of systems and components to ensure that they remain serviceable.

Personnel at the project's pilot plant, South Ukraine, received training in risk-based inspection techniques in October 1997. Representatives from Rivne and Zaporizhzhya also participated.

► **Work in Progress**

Risk-Based Inspection. South Ukraine staff are developing procedures for risk-based inspection. They will determine which piping systems are most important to safety, then determine which segments of pipe pose the greatest risk of causing loss of cooling water to the reactor core. Maintenance staff then will examine more frequently the structural integrity of those segments of pipe. This approach will enable maintenance workers to address risk more effectively while using fewer resources.

Training. To support nondestructive examination projects in 1999, U.S. specialists will conduct additional training classes in the use of ultrasonic equipment.

Technology Transfer. The United States will supply an eddy-current manipulator that will double the speed at which steam generator tubes can be examined.

4.1.10 Conduct of Operations

Historically, much of the daily business of operating nuclear power plants in the former Soviet Union was based on the knowledge and experience of individual operators, which could vary from person to person and plant to plant. To improve the safety culture in Ukrainian plants, U.S. and Ukrainian specialists developed formal written procedures. Improved procedures prescribe specific actions all workers must follow for routine operations.

In 1993, a working group began developing written conduct of operations procedures for Ukrainian plants. The group was composed of representatives from host plants, nuclear energy agencies in Ukraine, U.S. industry, the Institute of Nuclear Power Operations, and the U.S. Department of Energy.

► **Activities Completed**

By 1996, the working group had drafted 16 standard guidelines for preparing procedures for improved management and operational controls. The specialists based the procedures on the "Good Practices Standards" of the Institute of Nuclear Power Operations and on information from U.S. experts. In December 1996, the World Association of Nuclear Operators began monitoring progress in implementing the procedures at Soviet-designed reactors. The group also facilitates communication among the plants about lessons learned.

Zaporizhzhya is Ukraine's pilot plant for developing plant-specific procedures based on the standard guidelines. Zaporizhzhya has developed and is using 12 plant-specific procedures. Once procedures are developed and tested, Energoatom makes any necessary modifications to the standard guidelines and distributes them to other plants for use in developing their own procedures. Energoatom has approved and issued 15 of the 16 final guidelines to other Ukrainian plants.

The working group has identified eight additional operational procedures in need of guidelines and in 1998 drafted two of them.

Chornobyl. In January and October 1997, U.S. specialists provided training in implementing conduct of operations procedures at Chornobyl Unit 3. The courses covered equipment status control, procedures for isolating equipment during maintenance, and performance of tests before returning the equipment to service. In December 1997, the United States delivered an engraver to make labels for essential safety equipment at Chornobyl, particularly the valves and switches involved in carrying out emergency operating instructions. At that time, much of the plant's equipment was unlabeled, increasing the risk of operator error. Delivery of the engraver completed U.S. contributions to the project.

4.1.11 Operator Exchanges

In the former Soviet Union, nuclear power plant personnel had few opportunities to learn from their counterparts in other nations. To improve the cross-cultural sharing of information, the Institute of Nuclear Power Operations and the World Association of Nuclear Operators began sponsoring operator exchanges in 1989. The exchanges enabled Ukrainian personnel to observe firsthand the U.S. approaches to safe operations and then adapt these practices at their own plants. Most visits focused on training, conduct of operations, and symptom-based emergency operating instructions.

From 1995 to 1997, the U.S. Department of Energy funded additional exchanges. During that time, 42 staff members from three Ukrainian plants visited six U.S. nuclear power plants to observe and discuss safe reactor operations. The Institute of Nuclear Power Operations evaluated the benefits of these visits and found that visitors adapted at their own plants policies and procedures they had observed at U.S. plants. Managers of Ukraine's Zaporizhzhya plant, for example, added an additional reactor operator to each shift to monitor the status of key plant conditions.

The operator exchanges concluded in March 1997. Personnel from Soviet-designed plants continue to visit U.S. plants as part of training for specific safety projects.

4.1.12 Emergency Operating Instructions

During an emergency, nuclear power plant operators must stabilize the reactor quickly to prevent damage to the reactor core and the release of radioactive materials. Symptom-based instructions for rapid response were developed in the United States after the 1979 accident at Three Mile Island.

Previously, operators could not respond immediately to abnormal conditions. They first had to determine the cause of an emergency—such as a leak in a steam generator tube. They then followed procedures designed to correct that specific problem and contain its consequences. These procedures, still used at most Soviet-designed reactors, are called *event-based* emergency operating instructions.

Symptom-based instructions, now used at all U.S. plants and many others around the world, enable operators to respond to emergencies without first determining the cause. These instructions specify responses to emergency "symptoms"—crucial changes in plant parameters, such as reactor pressure, water level, or temperature. Operators can stabilize the reactor quickly by responding to these symptoms. The time saved can prevent disaster.

Symptom-based instructions also tell operators which actions to take first when two or more problems occur simultaneously. This increases the operators' ability to resolve the problems before core damage occurs.

Host-country specialists are adapting symptom-based emergency operating instructions for use at Soviet-designed reactors. A multi-country working group is assigned to each of the four major types of Soviet-designed reactors—the RBMK and the three VVER models. These groups are working with staff from nine reactors that serve as pilot sites.

Personnel from U.S. national laboratories, U.S. utilities, the Institute of Nuclear Power Operations, and the World Association of Nuclear Operators provided training in the methodology for developing the symptom-based instructions. In December 1996, the World Association of Nuclear Operators assumed responsibility for providing review and guidance to host-country experts.

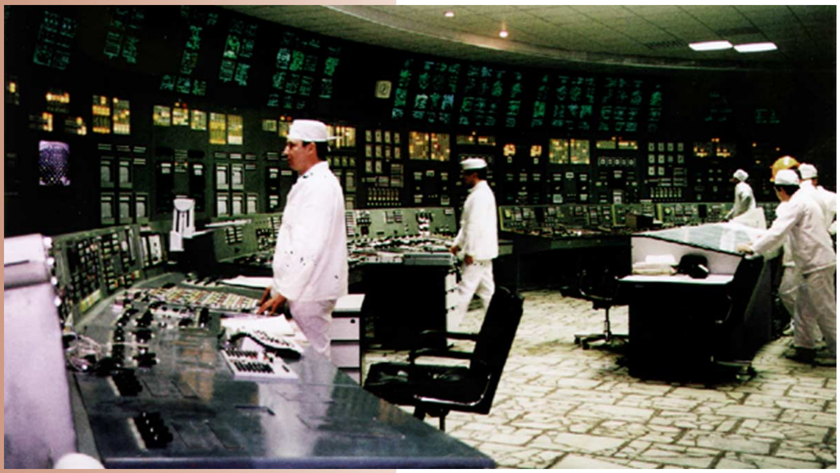
U.S. experts also are providing training to enable host-country specialists to analyze symptom-based emergency operating instructions. Analysts use computer simulations of accident scenarios to test the instructions, ensuring that they will mitigate the consequences of an accident.

Sergei Chuba (left), emergency operating instruction training manager at Chornobyl nuclear power plant, and Vladimir Zaitsev, also of Chornobyl, discuss emergency operating instructions during a training session at the Slavutych Laboratory.

Key Accomplishments

4.1.12 Emergency Operating Instructions

- The Chornobyl plant has implemented a complete set of symptom-based emergency operating instructions.
- Specialists at Zaporizhzhya and Rivne have drafted complete sets of instructions for their reactors.
- U.S. experts completed the transfer of skills for developing symptom-based emergency operating instructions to pilot plants in Ukraine, Russia, and Central and Eastern Europe.



In March 1998, Nikolai Sovorov (right foreground), control room supervisor, directs use of new symptom-based emergency operating instructions during a drill in the Unit 3 control room of the Chornobyl nuclear power plant.

► Activities Completed

In March 1998, Chornobyl Unit 3 implemented a complete set of symptom-based emergency operating instructions for its RBMK reactor, the first such procedures to be instituted in Ukraine. Zaporizhzhya has drafted a complete set for its VVER-1000 reactors, and Rivne has drafted a complete set for its VVER-440/213 reactors. Before these instructions are implemented, analysts must test them to ensure that they will mitigate the consequences of an accident.

In June 1998, U.S. instructors provided training on technical basis calculations for analyzing emergency operating instructions. Participating were personnel from the Rivne and Zaporizhzhya plants, the Ukrainian subcontractor Energorisk, Ltd., and the group of analysts conducting an in-depth safety assessment at Zaporizhzhya. Specialists from Bulgaria also participated.

► Work in Progress

To test the emergency operating instructions, host-country analysts will use computer models developed in in-depth safety assessment projects. (For details, see Section 4.3.1.) Ukrainian specialists at the plants are using RELAP5, a U.S.-developed code, to create a computer model of each reactor's thermal-hydraulic system. They then will use the code to simulate the most severe accident scenarios and predict the effects of operators' use of the emergency operating instructions.

The personnel assigned to analyze the emergency operating instructions for Zaporizhzhya and Rivne will use the RELAP5 models to determine whether the instructions will work as intended to mitigate accidents. This process is called validation. The analysts now are drafting accident scenarios to use in the computer simulations.

4.2 Upgrading Safety Systems

Engineering and Technology Projects

U.S. and Ukrainian specialists are developing systems for giving plant operators crucial, up-to-the-minute information needed to correct abnormal conditions and to respond to accidents. The United States also is transferring equipment, training, and procedures to improve the operation of safety systems and reduce the risk of fires at Ukrainian plants.

The following section describes these improvements at Ukrainian plants. Table D.2 in Appendix D summarizes the projects.

4.2.1 Safety Parameter Display Systems

When an abnormal event occurs at a nuclear power plant, safe resolution requires rapid, effective response. U.S. and Ukrainian specialists are developing safety parameter display systems to quickly give control room operators the information they need in emergencies.

Specialists at U.S. nuclear power plants developed safety parameter display systems after the 1979 nuclear accident at Three Mile Island. That accident underscored the need for better information systems in reactor control rooms.

A safety parameter display system collects and displays critical safety information at workstations in the control room and other locations in the plant. Information on the status of key conditions, such as reactor core cooling and radioactive material confinement, is displayed in a clear format on a computer screen. The system enables operators to assess plant conditions rapidly and take quick corrective actions.

The United States is working with specialists in Ukraine and Russia to develop safety parameter display systems for Soviet-designed nuclear power plants. Response time can be crucial in an emergency, and the new systems are fast, taking less than five seconds for calculations that would have taken 15 minutes on older computers at the plants. U.S. and host-country experts also are developing symptom-based emergency operating instructions (see Section 4.1.12). When a safety parameter display system indicates abnormal conditions, the emergency operating instructions specify the actions to take.

► Activities Completed

In 1998, workers installed safety parameter display systems at four Ukrainian reactors—Chornobyl Unit 3, Khmelnytskyy Unit 1, South Ukraine Unit 1, and Zaporizhzhya Unit 5. U.S., Ukrainian, and Russian specialists collaborated to produce the systems.

RDIPE and Westinghouse Electric Company designed the system for Chornobyl Unit 3, an RBMK reactor. Westinghouse manufactured the components, which were assembled by Westron, a joint venture of Westinghouse and Hartron, a Ukrainian company. U.S.-based Parsons Power coordinated the project.

Westinghouse personnel are working with Ukrainian specialists to design systems for the 11 VVER-1000 reactors in Ukraine. These include six reactors at Zaporizhzhya, three at South Ukraine, and one each at Khmelnytskyy and Rivne. The first three were installed in 1998. Westinghouse is manufacturing the components, and Westron is assembling them. U.S.-based Burns & Roe is coordinating the projects.

Key Accomplishments

4.2.1 Safety Parameter Display Systems

- Workers have installed safety parameter display systems at four Ukrainian reactors—Chornobyl Unit 3, Khmelnytskyy Unit 1, South Ukraine Unit 1, and Zaporizhzhya Unit 5.
- The United States has provided Ukraine with a developmental unit for planning, designing, and testing displays. It is located at the State Scientific and Technical Center in Kyiv.
- Designers have begun work on display systems for Rivne Unit 3, South Ukraine Unit 2, and Zaporizhzhya Unit 3. These systems will be installed in 1999.

Heorhiy Balakan, shift supervisor (standing), and Stepan Stoykov, senior reactor operator. Plant operating staff check values of critical safety parameters at South Ukraine Unit 1. Values are displayed on two safety parameter display system computer monitors in the reactor's main control room.

RDIPE, the Research and Development Institute of Power Engineering, is the Russian designer of RBMK reactors.

Aleksandr Priamikov, senior reactor operator (left), and Valeriy Gonchar, reactor operator, check safety parameters on a display system at South Ukraine Unit 1. The system began operating in June 1998.

Chornobyl Unit 3. Plant workers installed the Chornobyl Unit 3 system during an abbreviated outage in December 1998. They will complete acceptance tests in early 1999 while the plant is operating.

Khmelnytskyy Unit 1. Engineers installed a safety parameter display system at Khmelnytskyy Unit 1 in July 1998. Early in 1999, specialists will finish expanding the system's capabilities and will conduct site acceptance tests. Upon successful completion of the tests, the system will be operational.

South Ukraine Unit 1. South Ukraine Unit 1 received a system a year ahead of schedule. Control room operators began using the system in June 1998, after it passed site acceptance tests and was licensed by state inspectors. Final expansion of capabilities will be completed early in 1999, during the plant's next outage.

Zaporizhzhya Unit 5. Plant workers installed a system at Zaporizhzhya Unit 5 in August 1998. Early in 1999, specialists will finish expanding the system's capabilities and will conduct site acceptance tests. Upon successful completion of the tests, the system will be operational.

Developmental Unit. Westinghouse has provided Ukraine with a developmental safety parameter display unit for training control room operators and for planning, designing, and testing systems. The developmental unit began operating in Kyiv in June 1998 at the State Scientific and Technical Center.

► Work in Progress

Designers have begun work on systems for Rivne Unit 3, South Ukraine Unit 2, and Zaporizhzhya Unit 3. These systems will be installed in 1999. The plants will use the developmental unit in Kyiv to modify the systems according to the requirements of specific plants.

Three more of the 11 Ukrainian VVER-1000 reactors will receive safety parameter display systems in 2000, and the remaining two in 2001.

4.2.2 Safe-Shutdown Analysis

A safe-shutdown analysis identifies the most dangerous fire risks at a nuclear power plant. It concentrates on areas where fire could damage the safety systems needed to shut down a reactor safely.

A nuclear power plant relies on standby safety systems to control the reactor during an emergency. For example, if the nuclear fuel begins to overheat, an emergency core cooling pump will send cooling water to the reactor core. If fire damages an essential safety system, however, operators may be unable to shut down the reactor safely. The result could be damage to the reactor core and the release of radioactive material.

To ensure safe shutdown in the event of a fire, international standards call for fire zones and backup safety systems. Each fire zone has barriers to prevent the spread of fire to other zones of the plant. Each essential safety system has a backup system located in a different fire zone. If fire damages one safety system, such as the emergency core cooling pump, a backup pump can be used for cooling while operators shut down the plant.

Soviet-designed nuclear power plants, however, were not designed with the concept of fire zones to prevent the failure of backup safety systems. For example, an emergency core cooling pump and its backup pump might be in the same fire zone or have power cables located in the same zone. A fire in that zone could disable both pumps. The results could be overheated nuclear fuel and the release of radioactive material.

U.S. and Ukrainian specialists are initiating a safe-shutdown analysis at Zaporizhzhya Unit 5. Personnel from Kyiv Institute Energoproekt will perform the analysis, with technical support and training by U.S. experts.

► Activities Completed

In November 1996, U.S., host-country, and international specialists completed the *Reactor Core Protection Evaluation Methodologies for Fires at RBMK and VVER Nuclear Power Plants*. The document defines methodologies for performing safe-shutdown analyses at the two principal models of Soviet-designed reactors, RBMK and VVER. The text is published in English and Russian, and the methodologies have been endorsed by Russian, Ukrainian, and international experts.

In December 1996, managers from Ukrainian plants received training in the development of plant regulations based on the safe-shutdown methodologies.

In November 1998, Burns & Roe specialists led an initial meeting and training session in Kyiv. In December, they provided detailed training in the use of the safe-shutdown methodology.

► Work in Progress

In 1999, the United States will provide a computer program, REVEAL_W2, for use in the safe-shutdown analysis. The program develops a model of the plant that shows the fire zones and, within each zone, the safety systems and cables for electricity, instrumentation, and control. Looking at each zone in turn, the program assumes that a fire has disabled the safety systems within that zone. The program then determines whether backup systems in other fire zones could perform the functions necessary to shut down the plant safely. If not, analysts identify the necessary changes, such as moving equipment or rerouting cables. U.S. contractor Scientech markets the software, and experts from Brookhaven National Laboratory and the University of Maryland adapted it for use at Soviet-designed reactors.

The United States will provide electrical circuit tracer kits to determine the paths of concealed electrical cables. U.S. specialists will provide further training in use of the safe-shutdown methodologies.

Key Accomplishments

4.2.3 Fire Protection

- At Chornobyl Unit 3, workers have installed a fire-resistant coating on the turbine hall's structural steel to prevent a collapse of the roof during a major fire.
- The United States has supplied Chornobyl and Zaporizhzhya with fire-retardant sealants to coat electrical cables and seal the room-to-room penetrations through which the cables pass.
- Chornobyl and Zaporizhzhya have received fire suppression equipment and protection gear for firefighters.
- The Ukrainian company Askenn Concern has installed about one-third of the 250 fire doors provided to Chornobyl and 125 doors provided to Zaporizhzhya.

During a tour, Chornobyl Unit 3 staff show one of the new metal fire doors to U.S. Congressional staffer Madelyn Creedon of the Senate Armed Services Committee.

The project is scheduled for completion in 2001. The completed analysis will include prioritized recommendations for plant upgrades, so the most urgent and cost-effective changes can be implemented first.

In a related project, U.S. personnel are supporting Ukrainian personnel in a probabilistic risk analysis at Zaporizhzhya Unit 5 (see Section 4.3.1). U.S. and Ukrainian specialists will coordinate the two projects.

4.2.3 Fire Protection

A fire at a nuclear power plant can be catastrophic to the plant, the workers, and the public. Besides endangering personnel, a fire can damage plant safety systems, leaving operators unable to shut down the reactor safely. The result could be damage to the reactor core and the release of radioactive material. The United States is providing Ukrainian plants with materials and equipment that improve their ability to prevent, detect, contain, and suppress fires.

In 1992, Western visitors to Soviet-designed plants found unprotected electrical circuits, conducting wire sprayed with flammable insulating material, and fire doors that fit poorly and were made of wood. The United States is supplying materials to prevent the occurrence and the spread of fires.

Unlike U.S. nuclear power plants, which rely on multiple automatic alarm and protection systems to detect and suppress fire, Soviet-designed plants rely on large brigades of dedicated fire personnel. These brigades need to be able to detect fires reliably and alert staff immediately. They also must have the equipment to fight fires effectively. To meet these needs, the United States is supplying basic equipment for detecting and controlling fires.

► Activities Completed

Structural Steel Coating. In July 1998, workers finished installing a fire-resistant coating material on the structural steel in the Chornobyl Unit 3 turbine hall. In the event of a major fire, the coating will help maintain the integrity of the steel and prevent a collapse of the roof. A 1991 fire in Chornobyl's Unit 2 turbine hall caused the roof to collapse.

Fire Doors. U.S. specialists worked with a Ukrainian company, Askenn Concern, to develop expertise in manufacturing fire doors that meet international standards. Askenn has manufactured 250 doors for Chornobyl and 125 for Zaporizhzhya. Askenn has completed the installation of approximately one-third of the doors.

Fire-Protection Materials. The United States has supplied Zaporizhzhya and Chornobyl with fire-retardant sealant to coat electrical cables and seal the room-to-room penetrations through which the cables pass. U.S. specialists trained workers to apply the sealants.

Fire Suppression Equipment. In 1995, Zaporizhzhya received variable-spray hose nozzles. In 1997, Chornobyl received 19 variable-spray hose nozzles.

Personnel Protection Gear. Zaporizhzhya received 50 sets of fire-brigade gear in 1995. Chornobyl received 90 sets of protective gear in 1997.

During the spring of 1998, workers applied a fire-resistant coating to the structural steel in the Chornobyl Unit 3 turbine building. As shown in this photo, all of the equipment and the floor of the building were covered with plastic while the material was applied. The coating (which is white and can be seen in this photo) is to prevent damage from a fire that could result in failure of the roof—as was the case in the 1991 fire in the Chornobyl Unit 2 turbine building.

► **Work in Progress**

In 1999, workers at Zaporizhzhya will install a sprinkler system, a fire detection and alarm system, and penetration sealants. Workers at Chornobyl will install a fire detection and alarm system in 1999. Early in 1999, the United States will deliver to Chornobyl 30 breathing units for firefighters and an air compressor for filling the breathing units' air bottles. The United States also will deliver 500 fire extinguishers, 20 portable fire-brigade radios, and a radio base station.

4.3 Conducting In-Depth Safety Assessments

Plant Safety Assessment Projects

At a nuclear power plant, experts conduct in-depth safety assessments to determine the most significant risks and set priorities for safety upgrades. Assessments typically involve two kinds of risk analysis methods: probabilistic and deterministic. (For a description of these analyses, see box: *In-Depth Assessments Identify Safety Needs*.)

4.3.1 Plant-Specific Safety Assessments

U.S. experts are working with Ukrainian experts to conduct in-depth safety assessments at four plants in Ukraine: Khmelnytskyy, Rivne, South Ukraine, and Zaporizhzhya. U.S. support includes the transfer of computer codes for performing risk analyses, training in the use of the codes, guidance in conducting the assessments, and review of the work performed by plant specialists. When the assessments are completed, Ukrainian specialists will have a technical basis for identifying which factors at the plant contribute most to radiological risk. They also will have a technical basis for determining the most effective safety upgrades.

Key Accomplishments

4.3.1 Plant-Specific Safety Assessments

- With U.S. support, Ukrainian specialists have completed a probabilistic risk assessment at South Ukraine Unit 1. A design-basis accident analysis is under way.
- Ukrainian specialists have completed the documentation and assessment of previous analysis work at Rivne and Zaporizhzhya.
- The United States has provided computer hardware and software for in-depth safety assessments at Khmelnytskyy, Rivne, South Ukraine, and Zaporizhzhya.

In-Depth Assessments Identify Safety Needs

At a nuclear power plant, experts conduct in-depth safety assessments to determine the most significant risks and set priorities for safety upgrades. The assessments provide the technical information necessary to make sound operational improvements. They also provide the needed documentation for obtaining an operating license from a nuclear regulatory agency.

U.S. experts are working with Ukrainian and Russian experts to conduct safety assessments at four plants in Ukraine and four in Russia. The United States also is providing computer codes and technical support to improve the assessment capabilities of specialists at these plants and at Soviet-designed plants in Bulgaria, the Czech Republic, Hungary, Lithuania, Slovakia, and Kazakhstan.

The safety assessments under way in Ukraine and Russia involve two kinds of analyses: probabilistic and deterministic.

The probabilistic analysis

- Creates a computer model of all important plant systems.
- Identifies the events that could lead to an accident. These initiating events may occur outside the plant, such as an electrical outage, or inside, such as a leak in the reactor cooling system.
- Creates computer models of what could happen after each initiating event. These accident scenarios predict the progression of emergency conditions, examining all possible combinations of human mistakes and failures of plant components.
- Estimates the probability of each scenario occurring and the probability of that scenario leading to damage of the reactor core.
- May include analysis of the effectiveness of plant systems for confining radioactive materials.

A deterministic analysis

- Examines the design and configuration of a particular plant to determine the plant's safety margin—its ability to handle emergency conditions without damage to the reactor core.
- Defines the safety margin for the accidents analyzed. For example, if a particular scenario would allow the reactor core to reach a peak fuel temperature of 1,000 degrees Celsius, and the maximum safe fuel temperature is 1,200 degrees, analysts conclude the plant has a 200-degree safety margin during that scenario.

Experts use computer codes to calculate the safety margins for each accident scenario. An essential code for safety assessments is RELAP5, which was developed jointly by the U.S. Department of Energy and the U.S. Nuclear Regulatory Commission for thermal-hydraulic analyses of nuclear plants. The United States is supplying RELAP5 to Ukrainian and Russian plants and to technical support organizations.

To use RELAP5, analysts enter data about a nuclear power plant, creating a computer representation of its reactor core, reactor pressure vessel, piping, and steam generators. In other words, they create a computer model of the plant's thermal-hydraulic system. The RELAP5 code then performs calculations that predict the progression of various emergencies involving the thermal-hydraulic system and the temperatures in the reactor core.

The United States is working with host-country experts to ensure that RELAP5 and other U.S.-developed safety analysis codes will perform properly at Soviet-designed plants.

The use of RELAP5 and other computer codes is part of the training in safety analysis methodologies given by U.S. contractors to host-country specialists. The contractors also work with the specialists at their plants to develop computer models and perform analyses. When these tasks are accomplished, the host-country specialists will assess the safety of their reactors, determine the most significant risks, and identify the most effective safety upgrades.

Khmelnytskyy. In June 1998, Khmelnytskyy staff and Ukrainian subcontractor Kyiv Institute Energoproekt began working with U.S. specialists to define the scope for an in-depth safety assessment of Khmelnytskyy Unit 1. In the first two technical tasks, specialists from Argonne National Laboratory and U.S. contractor Science Applications International Corporation will work with Ukrainian staff to develop project guidelines and begin data collection.

In July 1998, a Ukrainian contractor installed U.S.-provided computers and software at Khmelnytskyy, including a local area network. The computer system enables plant specialists to use U.S.-developed safety analysis codes, including the RELAP5 thermal-hydraulics code and the ORIGEN code. Analysts use ORIGEN to estimate the amount of radioactive materials that would be released from the reactor fuel under hypothetical accident conditions. The Oak Ridge Radiation Safety Information Computational Center has transferred ORIGEN to Khmelnytskyy, Rivne, Kyiv Energoproekt, and Ukrainian subcontractor Energorisk, Ltd.

Rivne. Plant staff are conducting an in-depth safety assessment of Rivne Unit 1, with support from Argonne National Laboratory, U.S. contractor Scientech, and Energorisk.

In March 1998, a Ukrainian contractor installed U.S.-provided computers and software at Rivne, including a local area network. The computer system enables plant specialists to use modern safety analysis codes, including RELAP5 and ORIGEN.

Rivne and Energorisk specialists completed the project guidelines in June 1998. In July 1998, with support from U.S. experts, the specialists began a design-basis accident analysis.

In September 1998, the Ukrainian specialists completed the documentation and assessment of probabilistic risk analysis work previously done for Rivne Unit 1 by Energorisk and plant specialists. The specialists began updating and completing the thermal-hydraulics data and using the data to create a RELAP5 model of the reactor's thermal-hydraulic system. They will use this model to simulate the reactor response during accident scenarios. In a related project, Energorisk and plant analysts will perform simulations to support the use of symptom-based emergency operating instructions at Rivne. (For details on the validation of emergency operating instructions, see Section 4.1.12.)

Igor Krivolapov (seated) of the Zaporizhzhya nuclear power plant uses a computer code to predict heat flow characteristics in reactor operating situations. Assisting him is Carl Enderlin of the U.S. Department of Energy's Pacific Northwest National Laboratory. Experts are using thermal-hydraulics codes to identify and evaluate risks at Ukrainian nuclear power plants.

South Ukraine. With U.S. support, Ukrainian specialists in 1998 completed a probabilistic risk assessment that addresses abnormal events originating within the plant. The specialists also completed most of the data collection and analysis tasks for a deterministic safety analysis and began a design-basis accident analysis.

Key Accomplishments

4.3.2 Transfer of Safety Assessment Capabilities

- Ukrainian specialists have participated in four, four-week training sessions for using the RELAP5 thermal-hydraulics code for plant safety analyses.
- Ukrainian specialists have participated in a course on the use of the SAPHIRE risk analysis code.
- Ukrainian specialists have participated in U.S.-sponsored international forums and workshops for exchanging information on in-depth safety assessments of Soviet-designed reactors.

Energorisk is performing the in-depth safety assessment of South Ukraine's Unit 1 reactor, with support from plant staff, technical guidance from Scientech, and project coordination from Argonne National Laboratory.

During 1998, Ukrainian specialists completed major tasks for the probabilistic risk assessment. In July, they completed the validation and verification of a RELAP5 thermal-hydraulics model of the plant. They completed the success criteria analysis in September. In November, they completed the accident sequence analysis, the systems analysis, and the final risk quantification. They also issued a final report evaluating the results of the analysis.

During 1998, the Ukrainian specialists completed most data collection and analysis tasks for the probabilistic and deterministic analyses. They completed the nuclear steam system database in January, the plant system descriptions in March, the abnormal events database in April, the component reliability database in July, and the containment database in September.

In July 1998, the Ukrainian specialists began a design-basis accident analysis. They also began a limited-scope assessment of external events and internal hazards, such as fire and flood, that could cause accidents leading to damage of the reactor core.

The in-depth safety assessment of South Ukraine Unit 1 is scheduled for completion in April 2000.

Zaporizhzhya. With U.S. support, Ukrainian specialists are conducting an in-depth safety assessment of Zaporizhzhya Unit 5.

Plant specialists are working with personnel from three Ukrainian companies—Energorisk, Joint Stock Enterprise, and NOVATOR. Scientech and its Ukrainian subsidiary, TAI, Inc., are providing technical support, and Argonne National Laboratory is coordinating the project.

Early in 1998, the United States provided computer equipment for the assessment work. Scientech experts trained Ukrainian personnel in the methodology for conducting a probabilistic risk analysis.

During 1998, Ukrainian specialists completed the documentation of safety assessment work previously conducted at Zaporizhzhya. In August, they began collecting and analyzing data. In September, they completed the development of project guidelines for a probabilistic risk analysis that addresses abnormal events originating within the plant.

The specialists are developing a RELAP5 thermal-hydraulic model of the plant for a deterministic safety analysis.

4.3.2 Transfer of Safety Assessment Capabilities

The United States is working with Ukrainian specialists to develop in-country expertise in conducting plant safety assessments.

► Activities Completed

Code Training. Ukrainian specialists participated in three four-week training sessions on the RELAP5 computer code during 1997. Hands-on exercises illustrated the use of the code for performing thermal-hydraulic analyses of VVER reactors. Experts from Argonne National Laboratory and the Idaho National Engineering and Environmental Laboratory led the sessions.

In May 1998, Ukrainian specialists completed a fourth four-week training session on the RELAP5 thermal-hydraulics code. Personnel from all plants participated, along with specialists from Ukrainian organizations that will conduct peer reviews of the in-depth safety assessments under way at Ukrainian plants. In November 1998, Ukrainian specialists participated in a course in Kyiv on probabilistic risk analyses and the use of the SAPHIRE risk analysis code.

The United States provided courses in technical English during 1997 and 1998 for personnel from Ukrainian plants and technical organizations associated with Energoatom.

Information Exchanges. The United States has sponsored international forums and workshops for exchanging information on in-depth safety assessments at Soviet-designed reactors. The International Atomic Energy Agency and the Swedish International Project on Nuclear Safety have provided support.

Three forums have taken place, focusing on analytical methods and computational tools for conducting assessments. The first forum was in September 1996 in Obninsk, Russia. Representatives of 10 Soviet-designed nuclear power plants were among the 75 specialists attending from around the world.

The second forum was in September 1997 in Obninsk. The forum accomplished its primary objective: providing a context for communicating the results of safety analysis programs under way at Soviet-designed reactors. Host-country plant staff demonstrated a high level of interest through their participation, presentation of papers, and request for continued focus on safety assessment issues in future information exchanges. Some 100 participants from 12 countries attended, including staff from 10 Soviet-designed plants; regulators from Ukraine, Russia, Bulgaria, Hungary, and Slovakia; and staff from host-country technical support organizations.

The third information exchange took place in Obninsk in October 1998, with about 60 papers presented on safety analysis at Soviet-designed reactors. Some 110 people participated from Ukraine, Russia, Armenia, Bulgaria, Lithuania, Slovakia, Germany, Romania, Sweden, and the United States. Cooperating organizations included the U.S. Department of Energy, Russia's Institute of Physics and Power Engineering, the International Atomic Energy

Agency, the Nuclear Energy Agency of the Organization for Economic Cooperation and Development, the Swedish International Project on Nuclear Safety, and Germany's Kernforschungszentrum Rossendorf.

Two smaller workshops have focused on probabilistic safety analyses at VVER reactors. The first workshop, held in November 1996 in the Czech Republic, enabled participants to discuss such issues as loss-of-coolant accident frequencies and component reliability data. The participants—from Ukraine, Russia, the Czech Republic, Hungary, and Slovakia—requested a follow-up session.

The follow-up session, held in April 1997 in Bratislava, Slovakia, focused on improving a generic methodology for structuring and collecting data for plant-specific risk analyses. Participants came from Ukraine, Russia, the Czech Republic, Hungary, Slovakia, Romania, Holland, and Spain.

4.3.3 Validation and Verification of Computer Codes for Safety Analysis

When analysts use RELAP5 and other computer codes in safety analyses, they must make sure the codes accurately represent and predict the configuration and behavior of the reactor being analyzed. In a process called validation, analysts check the codes against test data. These data are produced by experimental facilities designed to simulate the behavior of a specific type of reactor. In a process called verification, analysts use the safety analysis codes to develop plant models and accident scenarios, then check the models and scenarios against data from actual reactors.

U.S. analysts are working with Ukrainian analysts to validate the RELAP5 and NESTLE codes for application to VVER reactors.

► **Work in Progress**

Analysis of RELAP5. U.S. analysts are working with Ukrainian analysts from the Sevastopol Institute and National Kyiv University to conduct a limited analysis of the RELAP5 code for application to VVER reactors. RELAP5 is a U.S.-developed thermal-hydraulics code. Results of the analysis will be compared to similar analyses under way at the U.S. and Russian International Nuclear Safety Centers.

Validation of NESTLE. U.S. analysts are working with Ukrainian analysts from the Nuclear Power Plant Operational Support Institute to develop analysis models for the NESTLE code for use at VVER reactors. NESTLE is a U.S.-developed neutron-kinetics code. The analysts will use the code in conjunction with the RELAP5 code. The coupled codes will be capable of generating a three-dimensional computer model of the thermal-hydraulic and neutron-kinetic characteristics of the core of a VVER reactor.

4.4 Working Safely with Spent Nuclear Fuel

Fuel Cycle Safety Projects

Before the breakup of the Soviet Union, Ukrainian nuclear power plants shipped their spent fuel to Russia for reprocessing. Now Ukraine is working to develop in-country systems for managing spent fuel. The United States has supported these efforts in two areas: the establishment of a dry-cask storage system for the Zaporizhzhya plant and assessment and data collection for developing spent-fuel management systems.

4.4.1 Zaporizhzhya Dry-Cask Storage

The six-reactor Zaporizhzhya plant has needed more capacity for storing spent fuel. Its storage pools are nearly full. The United States has worked with Zaporizhzhya to establish a dry-cask storage system—a safe and cost-effective alternative to storage pools.

► **Activities Completed**

In 1995 and 1996, U.S. experts provided instruction in the safe use and monitoring of dry-cask systems. U.S. and Ukrainian specialists worked together to develop cask-system operating procedures tailored to specific conditions at Zaporizhzhya. The United States transferred U.S.-developed computer codes for storage system calculations to the Ministry of Environmental Protection and Nuclear Safety of Ukraine, the country's nuclear regulatory agency.

The spent-fuel dry-cask storage project is enlarging the storage capacity at the Zaporizhzhya nuclear power plant. Workers are shown erecting the ventilated concrete cask (left), near a cask after removal of concrete forms (middle), and attaching the approval flag after acceptance of the first cask in May 1998 (right).

Key Accomplishments

4.4 Working Safely with Spent Nuclear Fuel

- The United States has worked with Ukraine to establish a dry-cask storage system at Zaporizhzhya.
- To develop the dry-cask storage system at Zaporizhzhya, the United States delivered a self-propelled cask transporter, components for building the first three concrete casks, and baskets to hold 24 spent-fuel assemblies inside each cask.
- U.S. experts provided instruction in the safe use and monitoring of dry-cask systems and trained Zaporizhzhya personnel to manufacture the storage casks. Ukraine's nuclear regulatory agency acquired the capability to use U.S.-developed computer codes for storage system calculations.
- With U.S. support, Ukrainian specialists are developing a nationwide plan for managing the spent fuel from the country's five nuclear power plants. Ukrainian specialists have completed an inventory of existing and projected volumes of spent fuel and entered the information in a database.
- Ukrainian specialists have completed an assessment of the regulatory procedures for licensing spent-fuel storage systems in Ukraine.

The Slavutych Laboratory for International Research and Technology is the primary technical branch of the International Chornobyl Center for Nuclear Safety, Radioactive Waste and Radioecology.

In 1996, U.S. contractor Duke Engineering & Services delivered cask liners, rebar, and forms for building the first three concrete casks. Zaporizhzhya personnel successfully poured the first three casks in May, June, and July 1998 and have the capability of manufacturing 12 additional storage casks per year.

Each concrete cask is designed to be filled with 24 spent-fuel assemblies, backfilled with inert helium gas, and welded shut. The casks provide both gamma and neutron shielding and have a minimum life of 40 years.

Sierra Nuclear Corporation developed steel baskets designed to hold the 24 spent-fuel assemblies inside the casks. By July 1998, the plant had received three baskets, completing the U.S. contributions to the dry-cask storage system. Ukrainian personnel will manufacture additional baskets.

To move each filled cask through the plant to a concrete storage pad, Duke delivered a self-propelled cask transporter in 1996. The diesel-powered unit is based on commercially available heavy lift-and-haul transporters. It has a U-shaped frame and platform and a track-propulsion system that straddles and hydraulically lifts each cask. J&R Engineering of Mukwongo, Wisconsin, built the transporter, under contract to Duke and Sierra Nuclear Corporation.

► Work in Progress

In 1999, Zaporizhzhya will begin using the dry-cask storage system and then will be self-sufficient in managing its spent fuel.

4.4.2 Spent-Fuel Management System

U.S. experts are supporting Ukrainian efforts to develop a nationwide plan for managing the spent fuel from the country's five nuclear power plants. Ukrainian experts at the Slavutych Laboratory for International Research and Technology are leading the project. Personnel from Energoatom and the Ukrainian Nuclear Regulatory Administration are providing technical information on the status of Ukraine's spent fuel.

► Activities Completed

In July 1998, Ukrainian specialists completed an inventory of existing and projected volumes of spent nuclear fuel. They entered the information in a database created with support from staff at the Pacific Northwest National Laboratory.

In September 1998, Ukrainian specialists completed an assessment of the regulatory procedures for licensing spent-fuel storage systems in Ukraine. In November 1998, the Ukrainian project leader for spent-fuel management participated in an International Atomic Energy Agency symposium on spent-fuel management.

► **Work in Progress**

Ukrainian specialists are evaluating options for storage, transportation, and disposal of spent nuclear fuel. In 1999, they will determine the most effective strategies for managing the fuel.

4.5 Developing an Institutional and Regulatory Framework

Nuclear Safety Institutional and Regulatory Framework Projects

U.S. and Ukrainian experts are working to develop a strong institutional framework for regulating Soviet-designed nuclear power plants. The objective is to ensure nuclear safety by promoting a strong, independent body with the capabilities to regulate, oversee, and license nuclear activities.

U.S. efforts also promote host-country adherence to international nuclear safety treaties and liability conventions. Effective exchange of nuclear information and technology requires such adherence, consistent with internationally recognized safety, environmental, and health standards.

4.5.1 Capability Enhancement for Ukrainian Regulators

In October 1997, representatives from the United States and Ukraine's Nuclear Regulatory Authority agreed to work together in developing a strong, independent nuclear regulatory infrastructure in Ukraine.

► **Activities Completed**

In August 1998, 10 Ukrainian regulators participated in a workshop on project management in Kyiv. With U.S. support, a contract was put in place for translating U.S. nuclear safety standards and regulatory documents. Personnel from Ukraine's State Scientific and Technical Center (SSTC) hire the translators and do quality checks on the work.

► **Work in Progress**

U.S. analysts will work with Ukrainian analysts to validate two safety analysis codes for spent-fuel storage. Such codes are used to ensure that spent-fuel storage designs will not permit a nuclear chain reaction to occur or permit overheating, which can cause a breach in the fuel cladding that surrounds the fuel and holds it in place. Analysts will validate the SCALE and ORIGEN codes for application to the types of fuel used in Soviet-designed RBMK and VVER reactors. The validation process ensures that a computer code accurately represents and predicts the physical phenomena and event sequences that characterize a specific type of nuclear fuel.

Key Accomplishments

4.5 Developing an Institutional and Regulatory Framework

- Ukrainian specialists have completed the final draft of regulations and guidelines for verifying and validating emergency operating instructions for Ukraine's VVER reactors.
- U.S. personnel have provided extensive training for regulatory personnel responsible for reviewing and approving emergency operating instructions.
- Ukrainian regulators participated in a workshop on project management.

In 1998, U.S. specialists began working with staff at the Nuclear Regulatory Administration to modernize the agency's computer system. U.S. specialists have analyzed the organization's computer resources and examined the flow of information. They will work with their Ukrainian counterparts to determine appropriate software to improve the flow of information and optimize the use of computer systems.

U.S. and Ukrainian specialists have exchanged glossaries of technical terms. They will translate the terms and agree on standardized terminology for nuclear safety regulatory work.

4.5.2 Regulations for Emergency Operating Instructions

With U.S. training and technical support, Ukrainian specialists are establishing regulations for developing, validating, and implementing symptom-based emergency operating instructions. U.S. experts worked with Ukrainian personnel to develop the instructions (see Section 4.1.12).

In 1996 and 1997, U.S. experts provided extensive training for regulatory personnel from Ukraine, Russia, and host countries in Central and Eastern Europe who are responsible for reviewing and approving emergency operating instructions. Workshops in November 1996 and March 1997 provided information on the development, validation, and regulation of the instructions for VVER reactors; the training and licensing of control room operators; and the role of the regulator during the approval process.

The 1996 session was the first time these regulatory personnel, all of whom work with VVER reactors, met to discuss common issues. The workshop took place in the United States. The 1997 workshop, held in Slovakia, included regulators of sites with VVER reactors in Ukraine, Russia, Bulgaria, Hungary, and Slovakia.

SSTC is the Ukrainian State Scientific and Technical Center for Nuclear and Radiation Safety.

At a September 1997 meeting in Kyiv, experts from the Pacific Northwest National Laboratory presented information on the U.S. approach to verification and validation of emergency operating instructions. Attending were representatives from SSTC, Energoatom, the Ukrainian Nuclear Regulatory Administration, the Main State Inspectorate for Supervision on Nuclear and Radiation Safety, and four nuclear power plants—Chornobyl, Khmelnytskyy, Rivne, and Zaporizhzhya.

In February 1998, SSTC specialists completed the final draft of regulations and guidelines for verifying and validating emergency operating instructions for Ukraine's VVER reactors. Energoatom has approved the VVER regulations and forwarded them for certification by Ukraine's Ministry for Environmental Protection and Nuclear Safety.

In August 1998, staff from SSTC completed a series of on-site inspections at Zaporizhzhya, where Ukrainian analysts have begun verifying the plant's emergency operating instructions. SSTC staff observed the validation process and inspected the plant's control room simulator to see whether it accurately simulates the configuration and behavior of the control room's safety system components. The analysts validating the instructions will use the simulator in their verification process.

SSTC staff also are drafting regulations for the verification of emergency operating instructions for Chornobyl's RBMK reactor. In August 1998, SSTC staff participated in a workshop in the United States on "flow-charted" emergency operating instructions and regulations covering such instructions for U.S. boiling-water reactors. Flow-charted emergency operating instructions graphically map the sequence of decisions to be made in an emergency.

4.5.3 Liability Protection

U.S. technical specialists are supporting the U.S. Department of Energy in seeking international approval of a treaty that would channel liability to the responsible operator of a Soviet-designed nuclear facility. Such liability arrangements are customary in the United States and Europe. The treaty also would cap undue liability of contractors in U.S. and foreign courts if a malfunction or accident occurs at a Soviet-designed nuclear facility where U.S. contractors provided services. This Supplementary Funding Convention for Accident Compensation would improve the safety of Soviet-designed nuclear power plants by permitting more extensive use of advanced safety technologies.

The Board of Governors of the International Atomic Energy Agency approved the proposed treaty in April 1997. In June 1997, leaders of the G-7 nations issued a communiqué at their Denver summit on nuclear safety that welcomed the adoption of the proposed treaty.

Diplomats signed the Supplementary Funding Convention in September 1997 at the International Atomic Energy Agency's Diplomatic Conference in Vienna. U.S. Department of Energy Secretary Federico Peña signed on behalf of the United States. Representatives from Ukraine and Lithuania were among others who signed.

U.S. accession to the treaty is not complete until Congress consents. Legislative ratification is required in other countries as well, including Ukraine and Lithuania.

4.6 Special Studies

In 1998, the United States agreed to work with Ukraine on developing methods to increase electrical output and improve physical security at the country's nuclear power plants.

4.6.1 Capacity Factor Improvements

U.S. engineers are working with engineers from Energoatom to determine ways to improve the capacity factor at Ukraine's VVER-1000 reactors. Improving a reactor's capacity factor involves reducing downtime and increasing the reactor's output of electricity.

In December 1998, U.S. specialists trained Energoatom staff to evaluate a plant's design and operations in four respects:

- Determine how plant staff can reduce the length of planned maintenance shutdowns.
- Identify problems with plant components that may cause the reactor to "trip" or shut down automatically because of abnormal conditions.
- Determine how plant staff can shorten the time it takes to bring a reactor back on-line after a trip occurs.
- Examine the plant's design to determine ways for using its thermal energy more efficiently to produce electricity.

U.S. and Energoatom engineers are evaluating the design and operation of Rivne Unit 3 to determine ways to increase its electrical output. The engineers visited Rivne in October and December 1998 to collect data and interview key plant personnel.

In December 1998, engineers from each of Ukraine's 11 VVER-1000 reactors met to discuss capacity factor problems.

In 1999, U.S. engineers will work with engineers from Energoatom and Rivne to identify specific ways to improve the capacity factor at Rivne Unit 3. They will complete the project in June 1999.

Energoatom personnel will apply the methods used at Rivne Unit 3 to determine ways to improve capacity at Ukraine's other VVER-1000 reactors.

4.6.2 Plant Security

In August 1998, U.S. specialists began working with Ukrainian personnel to assess the physical security of Ukrainian nuclear power plants and identify the technology needed to improve security. In December 1998, Pacific Northwest National Laboratory personnel completed a report describing the current state of security and areas targeted for improvement.

The United States is working with two pilot plants, Khmelnytskyy and Rivne, to better control access. Early in 1999, the United States will ship cameras, computers, and software for producing photo-identification badges.