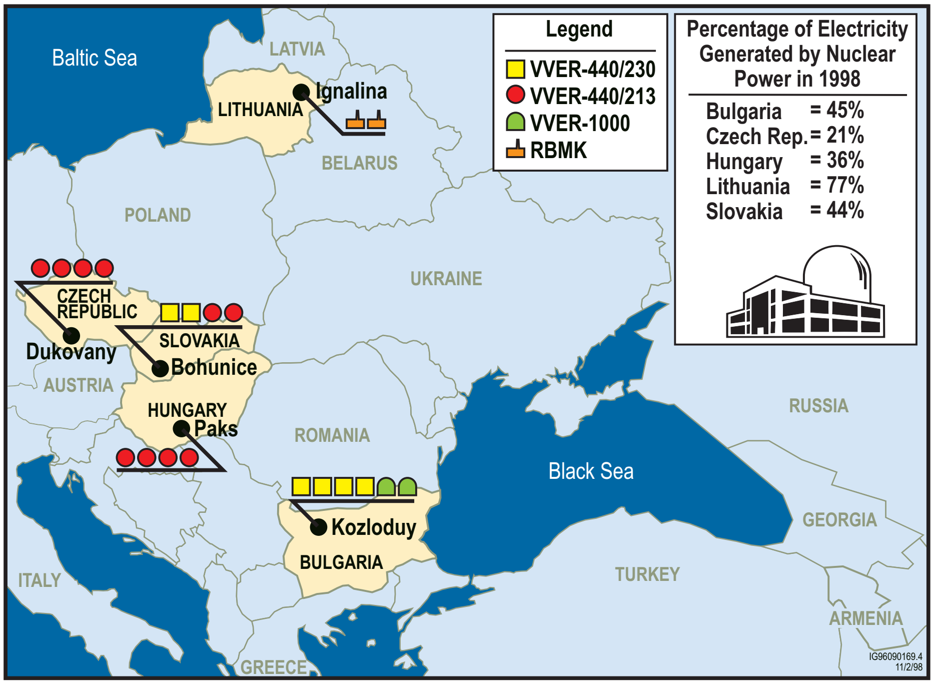
7.0 Central and Eastern Europe

The United States is working with five countries in Central and Eastern Europe to reduce risks at Soviet-designed reactors. Projects are under way at 20 reactors in the following countries:

- **Bulgaria** (Section 7.1)
- **Czech Republic** (Section 7.2)
- **Hungary** (Section 7.3)
- **Lithuania** (Section 7.4)
- **Slovakia** (Section 7.5).

Appendixes A and B provide more details on the plants and the reactor types. Appendix E lists the countries' primary organizations that participate in the cooperative work.

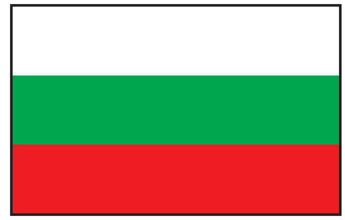


The Central and Eastern European Nuclear Power Plants Participating in the Cooperative Effort to Improve Nuclear Safety

Reactor Types in Central and Eastern Europe

- Two RBMK-1500s
- Six VVER-440/230s
- Ten VVER-440/213s
- Two VVER-1000s

7.1 Bulgaria



Six operating reactors at the Kozloduy nuclear power plant provided 45 percent of the electricity generated in Bulgaria in 1998. Four of the reactors are VVER-440/230s; the others are VVER-1000s.

7.1.1 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*, Section 4.1.3.)

With support from U.S. experts, Kozloduy specialists have created a configuration management system. Kozloduy staff now are implementing the system at two pilot facilities within the plant—the shore pumping station and the common switchyard. These facilities support all six reactors at the plant. The shore pumping station supplies cooling water essential for safety, and the common switchyard supplies emergency power.

In August 1998, the United States delivered thermal-transfer labeling equipment to produce vinyl labels. Affixing permanent labels to a plant's safety-related equipment reduces the risk of operator error and improves status control for the equipment.

In October 1998, the United States delivered computers for use in configuration management, and Risk Engineering, Ltd., a Bulgarian contractor, completed the development of configuration management software. American Technologies, Inc., provided technical support.

By implementing configuration management at the two pilot facilities, Kozloduy personnel are gaining the expertise to use the system throughout the plant. In September 1998, the Kozloduy plant manager announced plans to establish configuration management for all Unit 5 and 6 facilities. The United States completed its contributions to the project in December 1998.

7.1.2 Personnel Training

Specialists from the United States and the Kozloduy training center are working together to improve training for plant personnel.

Key Accomplishments

7.1 Bulgaria

- With U.S. support, specialists at the Kozloduy plant created a configuration management system.
- Kozloduy instructors used the Systematic Approach to Training to develop a course for control room operators.
- Bulgarian specialists drafted a complete set of symptom-based emergency operating instructions for Kozloduy's VVER-1000 reactors.
- The United States delivered computer hardware and software to Kozloduy for use in safety analyses.
- The seismic vulnerability of Kozloduy's essential service-water system and safety-related electrical systems will be upgraded based on U.S. and Bulgarian recommendations.
- Kozloduy workers are using U.S.-provided thermal imaging equipment to identify hazardous hot spots in electrical circuits.

"The management and personnel have accepted the configuration management and are working to complete it. And I can assure you, they are receiving top management support and assistance. Approaching the end of the project, they see the benefits and are working with even more willingness....

At the same time, the management of Electroproduction 2 has declared that they are going to develop and implement configuration management for Units 5 and 6. This implementation is not part of the pilot project [supported by the United States]...The manager of Electroproduction 2, Mr. Mitko Yankov, committed to ensure all necessary human and material resources for the successful completion of the project."

—Krassimir Nikolov
Kozloduy Plant Manager

In May 1996, Kozloduy specialists participated in a course on the Systematic Approach to Training. This 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. Specialists from U.S.-based General Physics Corporation conducted the course.

U.S. training specialists conducted instructor training courses at Kozloduy in February 1997. The United States provided basic materials for the training center in May 1997.

In June 1997, senior managers at the Kozloduy plant participated in a seminar on the Systematic Approach to Training. Seminar leaders described the benefits of the approach and reviewed lessons learned during its use in the United States, Ukraine, and Russia. They also discussed management's role in supporting plant training programs.

With support from General Physics staff, Kozloduy instructors presented a pilot course for control room operators in March 1998.

In 1998, Kozloduy instructors presented a pilot course for control room operators, like the operators shown here in the control room of Unit 1.

In July 1998, a U.S. training expert conducted a two-day course in management and supervisory skills for upper-level managers at Kozloduy. Topics included team management, communication, decision-making, and total quality management. In August 1998, a U.S. expert conducted a course for upper-level managers on organizational safety culture.

In September 1998, U.S. and Kozloduy training specialists surveyed a random sample of plant employees regarding the plant's organizational culture. In November 1998, after analyzing the survey, the U.S. and Kozloduy specialists discussed the results with plant managers. Discussion focused on associations between the survey results and the topics covered in the July and August courses on management and supervisory skills and organizational safety culture.

7.1.3 Emergency Operating Instructions

Bulgarian specialists have drafted a complete set of symptom-based emergency operating instructions for Kozloduy's VVER-440/230 and VVER-1000 reactors.

Emergency operating instructions specify actions reactor operators must take to stabilize the reactor and mitigate the consequences of an abnormal event. Symptom-based instructions enable operators to take action without first having to determine the cause of the problem. The time saved can prevent disaster.

U.S. personnel trained Bulgarian specialists in the methodology for developing symptom-based emergency operating instructions. In December 1996, the World Association of Nuclear Operators began providing review and guidance for developing and implementating these instructions.

U.S. personnel now are providing training and technical support for Bulgarian specialists who have drafted emergency operating instruction scenarios and are conducting in-depth analyses to verify that the emergency operating instructions will work as intended to mitigate accidents.

7.1.4 Safety Analysis Capabilities

The United States is working with inspectors from Kozloduy and the Bulgarian nuclear regulatory authority to improve their ability to perform and review safety analyses at Kozloduy.

Kozloduy analysts are using the RELAP5 computer code to create models of the plant's VVER-440/230 and VVER-1000 reactors. Analysts use RELAP5 to create a computer model of a plant's thermal-hydraulic system, then use the model to simulate severe accident scenarios. They then use the accident simulations to test the emergency operating instructions. The analysts now are developing RELAP5 models, drafting accident scenarios, and beginning the preliminary analysis.

In January 1998, the United States delivered computer hardware and software for use in Kozloduy's safety analyses. In June 1998, U.S. personnel provided training on technical basis calculations. Participating were personnel from Kozloduy, the Bulgarian Academy of Sciences, and contractor Energoproekt. Ukrainian personnel also participated.

In November 1998, Kozloduy specialists began augmenting their quality assurance guidelines for the continued development of RELAP5 models. The specialists also will develop a graphic display of RELAP5 results.

Kozloduy nuclear power plant, Units 5 and 6. The plant is implementing seismic upgrades, based on an assessment by U.S. and Bulgarian specialists.

7.1.5 Safety Analysis Workshops

U.S. and host-country experts are providing a series of workshops to improve the safety analysis capability of nuclear power plants in Central and Eastern Europe. The Kozloduy plant hosted the fourth of these workshops in March 1998. The topic was "Enhancement of Safety Analysis Capability for Nuclear Power Plants, Including Analysis in Support of Emergency Operating Instructions."

7.1.6 Seismic Assessments

In December 1996, U.S. and Bulgarian engineers completed a seismic assessment of the building that houses electrical equipment for reactor Units 5 and 6. The study used a computer model to predict how the building's equipment would respond during earthquakes of various magnitude. The study showed that some structural supports could fail, potentially interrupting electrical service to the reactors or turbine buildings.

The team provided detailed design recommendations to strengthen the structural supports and anchor the equipment. Kozloduy managers have implemented some of these design upgrades and plan to include others in their plant modernization program.

In 1997, U.S. and Bulgarian specialists also performed a detailed seismic assessment of the essential service-water system and spray ponds that provide cooling for safety-related equipment outside the reactor containment areas. The specialists recommended measures to reduce these systems' seismic vulnerability. In September 1998, Kozloduy managers defined the specific seismic upgrades to the service-water system that will be performed as part of their plant modernization program.

Representatives of Risk Engineering, Ltd., U.S.-based Parsons Power Group, and the Pacific Northwest National Laboratory conducted the study in cooperation with Kozloduy plant staff.

7.1.7 Thermal Imaging

In August 1996, the United States delivered thermal imaging equipment to check for hot spots in Kozloduy's electrical and mechanical systems. Some of the Kozloduy reactors had experienced unnecessary trips, or sudden shutdowns, caused by electrical faults. A breakdown of insulation or a faulty contact in a junction box can produce hot spots, overheat the circuits, and cause tripping of equipment.

The thermal imaging equipment provided by the United States identifies hot spots so that electrical repairs can be made before system reliability becomes a problem. U.S.-based Inframetrics conducted hands-on training in the use of the equipment.

Along with the thermal imaging hardware, the United States provided software to analyze the images. To acquire this proprietary software at a reduced price, the United States purchased a one-year membership for Kozloduy in the Nuclear Maintenance Activity Center. The center, a subsidiary of the Electric Power Research Institute in the United States, provides maintenance training for U.S. utilities. Along with the reduced-price software, the membership gave Kozloduy access to an extensive array of cost-free training materials. Experts from the Nuclear Maintenance Activity Center worked with Kozloduy specialists to implement the software.

7.1.8 Fire Safety

The United States delivered fire-safety equipment to Kozloduy in 1994. Included were two fire trucks, firefighting equipment, protective suits, communications equipment, and radiation monitoring dosimeters.

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 Kozloduy plant.

Key Accomplishments

7.2 Czech Republic

- Czech personnel are collecting and analyzing data on the reliability of reactor operator decision-making at the Dukovany plant, and Hungarian specialists are serving as consultants.
- With support from the United States, Czech specialists in 1998 completed a Level 2 probabilistic risk analysis for Dukovany.
- U.S. and Czech specialists developed a plant maintenance database that helps staff predict reactor system performance.

7.1.9 Emergency Power

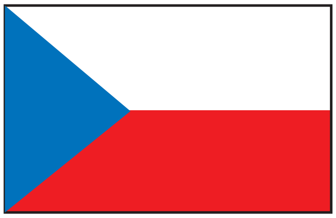
In 1994, the United States provided a 1,000-kilowatt diesel generator to provide backup power for key reactor safety systems.

7.1.10 Conduct of Operations

Soviet-designed plants are developing formal written procedures for improved management and operational controls. In 1993, a working group began drafting guidelines for 16 procedures. The group was composed of representatives from host plants, U.S. industry, the Institute of Nuclear Power Operations, and the U.S. Department of Energy.

Using the guidelines, Kozloduy staff developed and implemented 16 site-specific procedures. The World Association of Nuclear Operators monitors progress in implementing the procedures at Soviet-designed plants and facilitates communication among the plants about lessons learned. The working group now is drafting guidelines to cover eight additional procedures.

7.2 Czech Republic

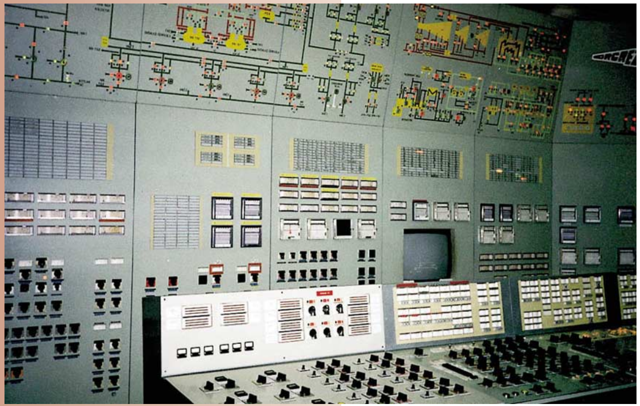


Four operating reactors at the Dukovany nuclear power plant provided 21 percent of the electricity generated in the Czech Republic in 1998. All four reactors are VVER-440/213s.

A **probabilistic risk analysis** identifies events that could lead to damage of the reactor core and calculates the probability of each event's occurrence. The analysis uses computer models of accident scenarios to predict the progression of emergency conditions, examining all possible combinations of human mistakes and failures of plant components.

7.2.1 Human Reliability Analysis

With support from U.S. and Hungarian analysts, Czech analysts are collecting and analyzing data on the reliability of reactor operators' decision-making during full-power operations. To collect the data, staff from Dukovany and the Czech Republic's Nuclear Research Institute are monitoring operators' actions while they train on a full-scope simulator at Slovakia's Trnava training center. During the training, operators respond to event scenarios developed for the plant's probabilistic risk analysis. Czech specialists will analyze and quantify the simulator data and use it to refine the probabilistic analysis. The project began in September 1998 and is scheduled for completion in 1999.



Czech analysts used the full-scope simulator at the Trnava training center in Slovakia to study the reliability of reactor operator decision-making at the Dukovany plant.

With U.S. support, Hungarian analysts completed a similar project at the Paks nuclear power plant in July 1996. Paks and VEIKI, a Hungarian organization, agreed in March 1998 to transfer to the Czech Republic the methodology for studying human reliability. Under the agreement with the Czech Nuclear

Research Institute, VEIKI is serving as project consultant and working with Institute personnel and Dukovany plant staff to modify their methodology and procedures.

7.2.2 Risk Advisory System

With U.S. funding, Scientech staff will train Dukovany staff early in 1999 to use a software-based risk advisory system.

Dukovany nuclear power plant. With U.S. funding, Scientech experts will train Dukovany personnel in 1999 to use a risk advisory software program.

Dukovany staff will use the risk advisory system to evaluate how the unavailability of certain plant components would affect the safety of plant operations. They will be able to determine, for example, the risk the plant would face if a particular cooling-system pump failed or was out of service for maintenance.

Dukovany staff already have created a computer model of the plant's safety-related systems as part of a probabilistic risk analysis. By coupling this model with Scientech's SAFETY MONITOR software, the staff will be able to quantify the risk that would be posed by the unavailability of each component. Maintenance managers will use the results to plan their preventive maintenance programs so that workers monitor more frequently the components that pose the highest risk.

7.2.3 Probabilistic Risk Analyses

In April 1998, U.S. and Czech analysts completed a Level 2 probabilistic risk analysis that evaluated the effectiveness of Dukovany's systems for confining radioactive materials. Czech analysts will determine which containment risks identified by the analysis are most significant and recommend follow-up work.

In December 1994, U.S. and Czech analysts completed a Level 1 probabilistic risk analysis, which identified and quantified the risks of core damage from various accident-initiating events. Dukovany staff modified the plant's operating requirements to reduce the risks identified in the analysis.

Personnel from the Czech Nuclear Research Institute conducted both analyses, with support from Brookhaven National Laboratory and Science Applications International Corporation.

7.2.4 Safety Assessment Information Exchanges

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

Key Accomplishments

7.3 Hungary

- With U.S. support, Hungarian specialists have analyzed the reliability of reactor operator decision-making at the Paks plant. The specialists now are serving as project consultants for a similar project in the Czech Republic.
- U.S. analysts have trained Hungarian analysts to use the GASFLOW code for safety analyses. The specialists now are using the code to analyze the risks of hydrogen buildup in the Paks containment system.
- The United States adapted a computer code for Hungary's use in remodeling Paks' dry-storage system for spent fuel. U.S. experts trained Paks personnel to use the code.
- At the request of Paks managers, U.S. personnel analyzed the ability of the reactor confinement structures to withstand the pressure likely to be created in an accident. They determined that the structures at Paks are adequate. Authorities in the Czech Republic and Slovakia, which also operate VVER-440/213 reactors, have received copies of the report.

Three forums have taken place, focusing on analytical methods and computational tools for conducting assessments. (For details, see Section 6.3.2.)

Two smaller workshops have focused on probabilistic safety analyses at VVER reactors. The Czech Republic hosted the first of these in November 1996. The workshop 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, which took place in April 1997 in Slovakia.

7.2.5 Conduct of Operations

Soviet-designed plants are developing formal written procedures for improved management and operational controls. In 1993, a working group began drafting guidelines for 16 procedures. The group was composed of representatives from host plants, U.S. industry, the Institute of Nuclear Power Operations, and the U.S. Department of Energy.

Using the guidelines, Dukovany staff developed and implemented 16 site-specific procedures. The World Association of Nuclear Operators monitors progress in implementing the procedures at Soviet-designed plants and facilitates communication among the plants about lessons learned. The working group now is drafting guidelines to cover eight additional procedures.

7.2.6 Maintenance Database

In March 1995, a U.S.-Czech team completed a plant maintenance database that includes calculations of the amount of time plant components will be out of operation because of maintenance work. The calculations help staff plan outages and maintenance work and also assist in predicting when the plant will be available to produce power.

7.3 Hungary

Four operating reactors at the Paks nuclear power plant provided 36 percent of the electricity generated in Hungary in 1998. All four reactors are VVER-440/213s.

7.3.1 Human Reliability Analysis

U.S. experts are working with Hungarian specialists to analyze the reliability of reactor operator decision-making at Paks. The specialists will collect and analyze data on operator actions while the reactor is shut down, operating at low power, or being refueled.

With U.S. support, Hungarian specialists completed a previous project in July 1996 that analyzed the reliability of reactor operators' decision-making during full-power operations. That project studied data collected during simulator training. As part of the project, U.S. contractor Scientech provided a bar code reader system that automates the collection of data on the reactor operators' actions. The bar code system enables instructors to enter evaluation codes into a computerized database with speed and accuracy.

VEIKI is the contractor for the current project. With VEIKI's support, Paks personnel in August 1998 defined the methodologies for collecting data and in September 1998 defined the procedures for data collection. In October 1998, U.S. experts trained Paks personnel to use the methodologies and procedures.

VEIKI, or the Institute for Electric Power Research, is a private organization in Hungary.

In 1999, plant personnel will collect, collate, and evaluate the data. The project is scheduled for completion in February 2000. Hungarian personnel will use the data to refine the probabilistic risk analysis for Paks.

In a related project, Paks and VEIKI agreed in March 1998 to transfer to the Czech Republic the methodology for conducting a data collection and analysis of the type completed in Hungary in 1996. Under the agreement with the Czech Nuclear Research Institute, VEIKI is serving as project consultant and working with Institute personnel and Dukovany plant staff to modify their methodology and procedures. The United States is funding the project.

7.3.2 Safety Analysis Capability

Through work with U.S. personnel, two VEIKI analysts have acquired the capability to use the GASFLOW code for safety analysis. In October 1998, they initiated a GASFLOW analysis of the risks of hydrogen buildup in the Paks containment system.

Analysts use GASFLOW to study the chain of events that would create a buildup of hydrogen in a reactor containment system. Hydrogen is created in a nuclear power plant when an abnormal event enables water to come into contact with reactive materials such as zirconium fuel cladding. If hydrogen builds to high concentrations, it can burn or explode.

The Hungarian analysts traveled to Argonne National Laboratory in September 1998 for training in the use of GASFLOW. They returned to compile a set of data from Paks, debug the code and the dataset, and conduct the GASFLOW analysis with support from Argonne analysts. The analysis will provide a technical basis for identifying risks and determining the most effective safety upgrades.

7.3.3 Thermal-Hydraulics Code

Pacific Northwest National Laboratory staff adapted the COBRA-SFS code for use in remodeling Paks' dry-storage system for spent nuclear fuel. The thermal-hydraulics code, developed by Pacific Northwest, predicts temperatures in a dry-storage system.

In December 1996, Pacific Northwest experts trained Paks personnel to use the code. In May 1997, the United States provided the revised code to the Hungary Atomic Energy Commission.

7.3.4 Accident Localization System Improvements

At the request of Paks managers, staff from Argonne National Laboratory analyzed the ability of Paks' confinement structures to withstand the maximum amount of pressure likely to be created in an accident. The worst-case scenario is a "blowdown," which occurs when a large pipe breaks and releases high-pressure steam. When a blowdown involves pipes that carry hot, pressurized reactor cooling water, the released steam will contain radionuclides.

Paks nuclear power plant. Staff from the U.S. Department of Energy's Argonne and Pacific Northwest national laboratories have supported analyses of plant systems.

In each of the four VVER-440/213 reactors at Paks, steam from a blowdown would be channeled through a bubbler condenser system in the confinement area, which consists of 13 levels of water pools inside a tower (see Appendix A, p. A.4). The bubbler condenser is designed to condense the steam and remove or "scrub out" the radionuclides in it, preventing their release into the atmosphere.

The U.S. team used computer codes to analyze VVER-440/213 reactors, defining both the maximum pressure that could be created in a blowdown and the maximum pressure the bubbler condenser system could withstand. The analysis showed that the confinement system is adequate, partly because of additional structural supports at Paks. The team completed its analysis in March 1997 and provided copies to authorities in the Czech Republic and Slovakia, enabling analysts there to evaluate the adequacy of the confinement systems of their VVER-440/213 reactors.

7.3.5 Conduct of Operations

Soviet-designed plants are developing formal written procedures for improved management and operational controls. In 1993, a working group began drafting guidelines for 16 procedures. The group was composed of representatives from host plants, U.S. industry, the Institute of Nuclear Power Operations, and the U.S. Department of Energy.

Using the guidelines, Paks staff developed and implemented 14 site-specific procedures. The World Association of Nuclear Operators monitors progress in implementing the procedures at Soviet-designed plants and facilitates communication among the plants about lessons learned. The working group now is drafting guidelines to cover eight additional procedures.

7.4 Lithuania

Lithuania's Ignalina plant has the world's two largest operating nuclear reactors. The RBMK-1500s each can produce 1,380 megawatts of electricity. Together, they provided 77 percent of the electricity generated in Lithuania in 1998.

7.4.1 Emergency Operating Instructions

Emergency operating instructions specify actions reactor operators must take to stabilize the reactor and mitigate the consequences of an abnormal event. Symptom-based instructions enable operators to take action without first having to determine the cause of the problem. The time saved can prevent disaster.

Ignalina has drafted a complete set of symptom-based instructions and will implement them in 1999. U.S. and Swedish personnel provided technical support for developing the instructions. Staff from the U.S. Department of Energy and the Pacific Northwest National Laboratory are providing technical support for the analysis phase of the project. The World Association of Nuclear Operators provides review and guidance for the development and implementation of the instructions.

7.4.2 Configuration Management

With support from the United States and Sweden, Ignalina personnel have implemented a configuration management system.

A configuration management system ensures that a plant's physical configuration is in keeping with its safety design basis—the safe operating requirements set by the plant's design. Configuration management also ensures that plant drawings and documents are updated consistently to accurately portray the plant's physical configuration. (For details, see box: *Configuration Management Maintains a Match of Design, Documents, and Plant Layout*, Section 4.1.3.)

With support from Stone & Webster Engineering Corporation, Ignalina personnel have created and implemented a configuration management system. Stone & Webster experts provided extensive training and worked with Ignalina staff to upgrade the computer network and develop baseline procedures and databases for controlling equipment and documents. They completed this development phase in February 1997.

U.S. and Swedish personnel have worked with Ignalina staff to complete the implementation of the configuration management system. The United States provided computer hardware and training in September 1997, and

Key Accomplishments

7.4 Lithuania

- Ignalina personnel have created and implemented a configuration management system. U.S. personnel provided extensive training for Ignalina staff. The United States provided computer hardware, and Sweden provided software for the system.
- U.S. and international specialists have trained Ignalina instructors to use the Systematic Approach to Training.
- The United States has supplied up-to-date tools and training for maintenance workers at Ignalina.
- Ignalina technicians are using maintenance equipment provided by the United States, including valve-seat resurfacing equipment, vibration monitoring and shaft alignment systems, and pipe lathe/weld-preparation machines.
- With U.S. funding, workers refurbished and equipped three rooms at Ignalina for training maintenance technicians.
- U.S. experts have produced electronic modules to replace aging modules in Ignalina's control-and-protection system. The experts trained staff at a Lithuanian company to produce additional modules.
- U.S. engineers designed and managed production of a backup control-and-protection system for Ignalina Unit 1. Plant staff installed the system during the 1998 outage. The system meets strict international standards.
- Lithuanian analysts have validated the RELAP5 code for use in safety analyses at Ignalina.
- U.S. analysts have provided training for Lithuanian specialists in the use of safety analysis codes.

Sweden provided the configuration management software. Stone & Webster experts completed the training of Ignalina staff in June 1998. The United States purchased additional personal computers in December 1998 to enable more staff members to use the configuration management software. Delivery of the computers in early 1999 will complete U.S. participation in the project.

7.4.3 Personnel Training

The United States is working with the International Atomic Energy Agency to improve training at Ignalina. In May 1998, eight staff members from Ignalina traveled to the offices of General Physics Corporation in South Carolina, where they completed a four-week course in the Systematic Approach to Training. This methodology 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.

In September 1998, Ignalina instructors participated in the first of two, two-week-long workshops with a U.S. training specialist and a training specialist from the International Atomic Energy Agency. During the workshop, they began developing a pilot training course for control room operators. The Ignalina instructors also will work with the training specialists to develop a pilot course for simulator trainers. They will present both courses in 1999.

7.4.4 Safety Maintenance Technologies

The United States is working to reduce equipment malfunctions at Ignalina's RBMK reactors by supplying up-to-date tools and training for maintenance workers. RBMK reactors also are located at Ukraine's Chornobyl plant and Russia's Kursk, Leningrad, and Smolensk plants.

An RBMK reactor is susceptible to power instabilities. Inadequate maintenance can compound the hazards posed by this design flaw. U.S. specialists have worked with RBMK managers to identify maintenance tools that will provide the fastest improvements in safety.

Pipe Lathe/Weld-Preparation Machines. In 1996, Ignalina made an urgent request for a pipe lathe/weld-preparation machine to repair corroded pipes. The United States delivered the machine within six weeks. Technicians use pipe lathe/weld-preparation 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. Before receiving the equipment, workers cut pipes by hand. In July 1997, the United States shipped four additional pipe lathe/weld-preparation machines to Ignalina.

Valve-Seat Resurfacing Equipment. The United States delivered valve-seat resurfacing equipment to Ignalina in August 1997 and trained plant workers in its use. The equipment enables technicians to accurately repair leaking valves without having to remove them from pipes. This helps maintain the integrity of pipes, reducing the risk of leaks that could lead to a loss-of-coolant accident.

Vibration Monitoring and Shaft Alignment Systems. The United States delivered vibration monitoring and shaft alignment equipment to Ignalina in October 1997 and trained workers to use it. Technicians 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-coolant accident.

Insulation Analysis Equipment. The United States delivered insulation analysis equipment to Ignalina in June 1998 and trained workers to use it. Technicians use the equipment to detect breakdown of the insulation around high-voltage lines and equipment, such as the transmission lines between site transformers and a plant's main generators.

Detecting and correcting insulation breakdown can prevent loss of power to key reactor systems. A risk analysis at Ignalina indicated that loss of 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.

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

7.4.5 Control-and-Protection Systems

U.S. and Ignalina specialists have worked together to increase the reliability of the plant's control-and-protection system. They have improved existing systems and created a completely new backup system. (For details, see box: *Technology Transfer Improves Safety of Ignalina's Control-and-Protection System.*)

Replacement Control Modules. Ignalina managers requested U.S. support in replacing some of the plant's aging control-and-protection system modules. NUS Instruments, a subsidiary of U.S.-based Scientech, designed a replacement module with the same form, fit, and function as the original modules but using modern technology. NUS delivered 100 of the electronic modules in May 1998 after U.S. and plant specialists performed quality assurance testing.

Ron Wright, Pacific Northwest National Laboratory project manager (left); Zoya Voitenko, translator; and Victor Sidnev, Unit 1 project manager; inspect equipment for monitoring pressure in the new control-and-protection system at the Ignalina nuclear power plant.

Scientech and NUS Instruments worked with a Lithuanian company, the Electromagnetic Compatibility Scientific Research Center, to develop the ability to produce additional modules. The U.S. specialists also worked

Technology Transfer Improves Safety of Ignalina's Control-and-Protection System

Nuclear power plants use electronic control-and-protection systems to monitor key reactor conditions, such as pressure, temperature, coolant flow, and neutron flux. If these conditions become abnormal, the control-and-protection system will shut down the reactor automatically.

Plants typically have several "trains"—multiple control-and-protection systems, so that if one train malfunctions, others will be available to monitor and control the plant. Effective maintenance and repair also are essential. To facilitate maintenance, control-and-protection systems often are composed of dozens of electronic modules that can be replaced individually when they malfunction or become worn.

The United States has supported two major improvements to the control-and-protection systems at Ignalina.

First, NUS Instruments, a subsidiary of U.S.-based Scientech, manufactured replacement modules for the existing system. The failure rate of the existing modules was increasing and replacement parts were difficult to obtain. Engineers at a Lithuanian company worked with Scientech and NUS experts to gain the ability to manufacture more modules. The Electromagnetic Compatibility Scientific Research Center delivered the modules in September 1998. The Lithuanian company can now meet future needs for replacement modules at Ignalina and, potentially, at RBMK reactors in Russia and Ukraine.

Second, during the 1998 outage at Ignalina Unit 1, plant workers installed an internationally designed and built backup control-and-protection system. The four-channel system meets strict nuclear standards. In a four-channel control-and-protection system, each channel gets a 'vote' on whether to let the plant operate. If two of the four channels vote to trip the reactor, the reactor is automatically shut down at once. But if one channel is defective and indicates a plant trip, it will not shut down the plant unnecessarily.

The project was an intensive international-team effort, funded by the United States and managed by the Pacific Northwest National Laboratory. Parsons Power provided management and engineering support, The Foxboro Company developed the detailed design of the logic system and supplied special logic cabinets, and Scientech working with the State Institute of Information Technology and the Lithuanian Energy Institute developed the safety review of the system. Ignalina plant staff managed system specifications, quality control, and installation in Ignalina Unit 1.

with the company to establish a quality assurance program. In May 1997, company employees participated in quality assurance training at NUS headquarters in Idaho Falls, Idaho. The company completed production of 200 modules in December 1998.

Backup Control-and-Protection System. During the 1998 outage at Ignalina Unit 1, plant workers installed an internationally designed and built backup control-and-protection system. The Lithuanian Nuclear Power Safety Inspectorate required that a new system be installed before the plant was restarted after the summer outage. An international team had performed a safety analysis of the plant that raised concerns about the existing system. The new system is built to strict international standards. Because it is independent of the original system, which remains in operation, the new system provides an additional measure of safety. With the installation completed in September, the plant was restarted and reached full-power operations in October 1998.

With U.S. support, Ignalina workers will install a backup control-and-protection system in Unit 2 to address the same concerns. Installation is planned for 1999.

7.4.6 Code Validation

STEPAN and NESTLE. Specialists use safety analysis codes to create a computer model of a reactor, simulate accidents, and calculate the reactor's ability to withstand abnormal conditions without damage to the fuel core.

When specialists use safety analysis codes, they must make sure the codes accurately represent and predict the configuration and behavior of the reactor being analyzed. In a process called validation, specialists 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, specialists use the safety analysis codes to develop plant models and accident scenarios, then check the models and scenarios against data from actual reactors.

Swedish and Russian specialists are validating two neutron-kinetics codes for application to RBMK reactors in Lithuania and Russia. Specialists from the Royal Institute of Technology in Sweden are working with Russian specialists from the Kurchatov Institute to validate the STEPAN and NESTLE codes. The specialists will develop benchmark problems in neutron-kinetics for RBMKs. They will analyze the problems using the Russian-developed STEPAN code and the U.S.-developed NESTLE code, then make code-to-code comparisons. The specialists agreed on the scope of the project in September 1998.

RELAP5. With U.S. support, a Lithuanian graduate student at the University of Maryland has partially validated the RELAP5 computer code for use in safety analyses at Ignalina. RELAP5 is used to create a computer model of a particular reactor's thermal-hydraulic system, including the reactor pressure vessel, the primary coolant system, and the steam generator system. The code then uses the computer model to simulate accident scenarios and predict the progression of various emergencies involving the thermal-hydraulic system.

To partially validate the code, the Lithuanian specialist created a RELAP5 model of one of the plant's RBMK reactors. He then checked the model against data from the actual reactor to validate that the code's model and accident simulations accurately represent and predict the physical phenomena and event sequences in Ignalina's reactors. He completed the validation project in June 1998 as part of his graduate thesis.

7.4.7 Safety Analysis Capabilities

The United States is providing computer hardware and training to improve the ability of Lithuanian specialists to perform safety analyses at Ignalina. U.S. experts also have worked with the specialists to create an International Nuclear Safety Center Internet site for Lithuania.

Experts from Argonne National Laboratory are working with personnel from Kaunas University of Technology in Vilnius, Lithuania, and staff from the Ignalina Safety Analysis Group at the Lithuanian Energy Institute.

In February 1998, the United States provided computers to Kaunas for use in safety analyses. In April 1998, two staff members from the Lithuanian Energy Institute completed a week-long workshop on the use of two computer codes for assessing the structural safety of Ignalina's accident localization system. Personnel from Argonne provided training on the NEPTUNE and TEMP-STRESS codes, which were developed at Argonne National Laboratory. Argonne staff provided follow-up training in June 1998.

In 1998, U.S. experts provided training in the use of NESTLE, a neutron-kinetics code, for staff from Kaunas and the Lithuanian Energy Institute.

Specialists at the Institute established an Internet site in 1998 for Lithuania's International Nuclear Safety Center (**http://www.lei.lt/insc/**). The website provides information on the Ignalina nuclear power plant. It also provides access to the handbook for the *Emergency Preparedness Organizations Around the Baltic Sea* and to the *Ignalina RBMK-1500 Source Book*. The Source Book documents the plant's safety systems and describes the way plant components interact during normal and abnormal operating conditions. The Internet site will have a password-protected area for safety research collaborations.

The website is similar to those of the U.S. and Russian International Nuclear Safety Centers. (For more details on the U.S. and Russian Safety Centers, see Section 6.5.2.)

7.4.8 Pressure Tube Analysis

U.S., Lithuanian, and Russian specialists have assessed the potential for the fuel-channel pressure tubes to fail in Ignalina's reactors during an accident. Using the ABAQUS and RELAP5 safety analysis codes, the specialists determined that the risk of pressure tube failure was negligible. They completed their report in June 1998.

Team members included specialists from the Pacific Northwest National Laboratory, U.S.-based Scientech, the Lithuanian Energy Institute, Kaunas Technical University, and Russia's Kurchatov Institute.

7.4.9 Safety Workshops

U.S. and host-country experts are providing a series of workshops to improve the operational safety of nuclear power plants in Central and Eastern Europe. Ignalina hosted the second and third of these workshops. The topic of the April 1996 workshop was "Preventive and Predictive Maintenance in Nuclear Power Plant Operation." The topic of the May 1997 workshop was "Safety Culture in the Operation of Nuclear Power Plants."

7.4.10 Source Book Update

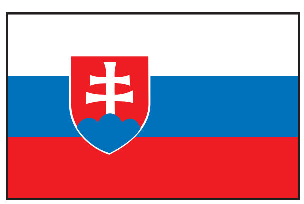
With mentoring support from the University of Maryland, the Lithuanian Energy Institute updated the *Ignalina RBMK-1500 Source Book*. The book documents the plant's reactor and primary safety systems and describes the way plant components interact during normal and abnormal operating conditions. Changes made at Ignalina to improve safety prompted the update, which was completed in April 1998.

7.4.11 Conduct of Operations

Soviet-designed plants are developing formal written procedures for improved management and operational controls. In 1993, a working group began drafting guidelines for 16 procedures. The group was composed of representatives from host plants, U.S. industry, the Institute of Nuclear Power Operations, and the U.S. Department of Energy.

Using the guidelines, Ignalina staff developed and implemented 14 site-specific procedures. Specialists have drafted two more procedures, which await regulatory approval. The World Association of Nuclear Operators monitors progress in implementing the procedures at Soviet-designed plants and facilitates communication among the plants about lessons learned. The working group now is drafting guidelines to cover eight additional procedures.

7.5 Slovakia



Four operating reactors at the Bohunice nuclear power plant provided 44 percent of the electricity generated in Slovakia in 1998. Two of the reactors are VVER-440/230s; the others are VVER-440/213s.

7.5.1 Personnel Training

U.S. training specialists are working with instructors at Slovakia's Trnava training center to improve training programs for nuclear power plant personnel. In July 1997, Trnava instructors traveled to the United States for a four-week course on the Systematic Approach to Training. This methodology provides a standard framework for identifying training needs, analyzing jobs and their specific tasks, developing course materials based on these

Key Accomplishments

7.5 Slovakia

- U.S. personnel have trained instructors at the Trnava training center to use the Systematic Approach to Training. The instructors have conducted a pilot course on instruction skills for Bohunice personnel.
- U.S. and Slovakian specialists have upgraded a personal-computer-based training simulator.
- The United States has provided Slovakian specialists with computer hardware, software, and training to improve their ability to perform safety analyses at Bohunice.
- U.S. and Slovakian specialists have adapted two confinement analysis codes for use at Bohunice's VVER-440/230 reactors. U.S. experts trained Slovakian specialists to use the codes to analyze the effectiveness of proposed upgrades to the reactors' confinement systems.

analyses, and using teaching methods that combine classroom instruction with hands-on equipment use. In August 1997, U.S. training specialists presented a simulator instructor course at Trnava.

U.S. specialists collaborated with VUJE to upgrade a personal-computer-based training simulator at Trnava training center.

With U.S. support, the Trnava staff are using the Systematic Approach to Training to develop courses for personnel at the Bohunice plant. In February 1998, they presented a pilot course on instruction skills. In 1999, U.S. personnel will work with specialists from the Trnava training center and Bohunice to develop a pilot course for the plant's maintenance workers.

U.S. personnel are working with host-country and European Community personnel to upgrade a full-scope training simulator at Trnava. The simulator replicates Bohunice's reactor Units 3 and 4, which are VVER-440/213s. In April 1998, U.S.-based Science Applications International Corporation shipped the new input-output system to Trnava. Staff from VUJE received training in the operation and maintenance of the input-output system. Upgrades are under way for the reactor core and thermal-hydraulic models. The project is scheduled for completion in September 1999.

VUJE is Slovakia's Nuclear Power Plant Research Institute.

U.S. personnel also collaborated with VUJE to upgrade a personal-computer-based training simulator at Trnava. The simulator replicates reactor Units 1 and 2, which are VVER-440/230s. U.S. personnel delivered a user manual for the upgraded simulator in October 1997, completing the project.

7.5.2 Risk Advisory System

The United States has provided Bohunice with a three-year license to use R&R WORKSTATION, a computer analysis code for performing a probabilistic risk analysis. The code includes a software module for use as a risk advisory system. Science Applications International Corporation developed the computer code.

Bohunice staff already have created a computer model of the plant's safety-related systems for use in a probabilistic risk analysis. After training in August 1998, Bohunice staff began incorporating this model into R&R WORKSTATION's risk advisory system.

Bohunice staff will use the risk advisory system to evaluate how the unavailability of certain plant components would affect the safety of plant operations. They will determine, for example, the risk the plant would face if a particular cooling-system pump failed or was out of service for maintenance. They then will use the system to quantify the risk that would be posed by the unavailability of each component. Maintenance managers will use the results to plan their preventive maintenance programs so that workers monitor more frequently the components that pose the highest risk.

7.5.3 Safety Analysis Capabilities

The United States has provided Slovakian specialists with computer hardware, software, and training to improve their ability to perform safety analyses at Bohunice's VVER-440/230 reactors. The Slovakian specialists are analyzing the plant's symptom-based emergency operating instructions to ensure that they will mitigate the consequences of an accident.

> *"I would like to inform you that our system programmer has installed LINUX system as well as PC RELAP5 successfully and we have completed first calculations with RELAP5. Our work with RELAP5 is going on very well. Following our training program we should carry out first representative safety analyses with RELAP5 to the middle of February 1998. Many thanks for your cooperation and support."*
>
> —Jan Husarcek
> Safety Analyst
> Slovak Republic

The United States provided the ADAM computer code for nuclear accident diagnosis, analysis, and management. Energy Research, Inc., a U.S. company, developed the code and trained Slovakian specialists to use it. Staff from Bohunice, VUJE, and the Slovakian nuclear regulatory authority participated in the training.

In November 1998, personnel from the Slovakian nuclear regulatory authority, utilities, and the Nuclear Power Research Institute participated in advanced training on the RELAP5 thermal-hydraulics code.

7.5.4 Confinement Analysis Codes

Bohunice staff are defining ways to upgrade the confinement systems of the plant's two VVER-440/230 reactors. These reactors do not have airtight containment systems. Their confinement structures are less effective than containment systems in preventing the release of radionuclides in an accident. The confinement buildings are not leak-tight and are designed to vent air to the atmosphere when pressure builds up inside, as is likely to occur during an accident.

In 1997, staff from Argonne National Laboratory worked with Slovakian specialists to adapt two confinement analysis codes, NEPTUNE and PACER, for use at VVER-440/230s. In June 1997, Argonne personnel trained Slovakian specialists to use the codes to analyze the effectiveness of proposed upgrades. This completed U.S. contributions to the project.

7.5.5 Information Exchanges

The United States has sponsored international forums and workshops for exchanging information on in-depth plant 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. (For details, see Section 6.3.2.)

Two smaller workshops have focused on probabilistic safety analyses at VVER reactors. Slovakia hosted an April 1997 workshop focused on improving a generic methodology for structuring and collecting data for plant-specific risk analyses. Participants from Russia, Ukraine, the Czech Republic, Hungary, Slovakia, Romania, Holland, and Spain attended.

7.5.6 Safety Workshops

U.S. and host-country instructors are providing a series of workshops to improve the operational safety of nuclear power plants in Central and Eastern Europe. The Trnava training center hosted the first of these in January 1996. The topic was "Safety and Licensing Aspects of Plant Modifications and Engineering Support in the Operation of Nuclear Power Plants." The Slovak Nuclear Regulatory Authority hosted the fifth workshop in September 1998 in Bratislava. The topic was "Optimization of Resource Allocation Effectiveness in Controlling Risk in the Operation of Nuclear Power Plants."

7.5.7 Conduct of Operations

Soviet-designed plants are developing formal written procedures for improved management and operational controls. In 1993, a working group began drafting guidelines for 16 procedures. The group was composed of representatives from host plants, U.S. industry, the Institute of Nuclear Power Operations, and the U.S. Department of Energy.

Using the guidelines, Bohunice staff developed and implemented 16 site-specific procedures. The World Association of Nuclear Operators monitors progress in implementing the procedures at Soviet-designed plants and facilitates communication among the plants about lessons learned. The working group now is drafting guidelines to cover eight additional procedures.