Improving Safety at Soviet-Designed Nuclear Power Plants

Status Report

Ten Years of Safety Improvements

2003

Office of International Nuclear Safety and Cooperation

Status Report

Ten Years of Safety Improvements

Office of International Nuclear Safety and Cooperation
U.S. Department of Energy

2003

Foreword

Introduction from Dr. James Turner

I am pleased to report that over the past decade significant strides have been made to improve the safety of Soviet-designed nuclear power plants. From fire protection to operator training, from maintenance practices to safety equipment, together we have been working to reduce the risks of nuclear accidents. Although the first responsibility for safety rests with the host-country operators, nuclear safety will always be an international issue. The effects a major nuclear accident can extend far beyond an individual nation's borders. A serious accident abroad likely would have a significant negative impact on America's energy security since nuclear power currently provides about 20% of our electricity needs.

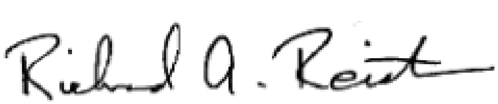
Safety improvements have been accomplished through extensive collaborative efforts with our colleagues in Armenia, Bulgaria, the Czech Republic, Hungary, Kazakhstan, Lithuania, Russia, Slovakia, and Ukraine. Our scientific and technical staff collaborated with these countries to improve the safety of their reactor operations by strengthening the ability of the regulator to perform its oversight function, installing safety equipment and technologies, investing time in safety training, and working diligently to establish an enduring safety culture.

We recognize that nuclear power plants are a major source of electricity and heat in these countries, and that they also provide a major source of employment. Crucial to the success of this program has been our coordination with ministries in these countries and U.S. federal agencies – the Department of State, the Agency for International Development, and the Nuclear Regulatory Commission – to ensure our program understands the larger context within each country and supports broader U.S. interests.

We have seen a considerable change in the attitudes and approaches of plant operators and regulatory bodies, who now support safe nuclear operations much more than before. Despite economic constraints, many nations have invested considerable internal resources to upgrade the plants to improve safety. These improvements now must become self-sustaining, and I believe they will.

I am proud of the international nuclear safety work that has been accomplished by the many individuals from NNSA and DOE, the national laboratories, U.S. and foreign contractors, and the host-country staff who actively support nuclear safety improvements. The following information displays the successes of all those involved.

Sincerely,



Richard A. Reister, Director
Office of International Nuclear Safety
National Nuclear Security Administration
U.S. Department of Energy

This report is organized into two main parts. Part I provides a general overview of the program, the objectives of the program, and a brief discussion regarding the improvements in safety performance at these plants.

Part II provides a summary of activities that have been completed, are in progress, or are planned at each of the Soviet-designed nuclear power plant sites. This information is presented on a reactor-by-reactor basis. Part II is organized by participating country starting with the Central and Eastern European countries, followed by Armenia, Kazakhstan, Russia, and Ukraine.

Contents

Foreword iii

Part I – Program Description 1

Overview 3
- RBMK 3
- VVER-440/230 4
- VVER-440/213 4
- VVER-1000 4

Preface 5
Strategy 5
Goals 7
Selection of Projects 8
International Nuclear Safety Projects 9
- Operational Safety 9
- Simulators and Training 10
- Safety Maintenance 11
- Safety Systems 13
- Safety Assessments 14
- Legal and Regulatory Infrastructure 15

Overview of Program Performance 15
Improvements in Safety 16

Part II – Safety Improvement Projects at Each Plant 19

Central and Eastern European Countries 21
- Bulgaria 23
  - Kozloduy Nuclear Power Plant 25
- Czech Republic 29
  - Dukovany Nuclear Power Plant 31
  - Temelin Nuclear Power Plant 33
- Hungary 35
  - Paks Nuclear Power Plant 37
- Lithuania 39
  - Ignalina Nuclear Power Plant 41
- Slovakia 45
  - Bohunice Nuclear Power Plant 47
  - Mochovce Nuclear Power Plant 49

Armenia 51
Armenia Nuclear Power Plant 53

Kazakhstan 57
Aktau BN-350 Nuclear Power Plant 59

Russian Nuclear Power Plants 61
Balakovo Nuclear Power Plant 63
Beloyarsk Nuclear Power Plant 67
Bilibino Nuclear Power Plant 69
Kalinin Nuclear Power Plant 71
Kola Nuclear Power Plant 73
Kursk Nuclear Power Plant 77
Leningrad Nuclear Power Plant 81
Novovoronezh Nuclear Power Plant 85
Smolensk Nuclear Power Plant 89
Volgodonsk Nuclear Power Plant 93
Russia Legal and Regulatory Capabilities and Other Crosscutting Activities 95

Ukraine 99
Chornobyl Nuclear Power Plant 101
Khmelnytskyy Nuclear Power Plant 105
Rivne Nuclear Power Plant 109
South Ukraine Nuclear Power Plant 113
Zaporizhzhya Nuclear Power Plant 119
Ukraine Legal and Regulatory Capabilities and Other Crosscutting Activities 125

Related Publications 129

Appendix A - Illustrations and Descriptions of Reactor Types at Participating Nuclear Power Plants A.1
Appendix B - Soviet-Designed Nuclear Power Plants in Armenia, Ukraine, Russia, Central and Eastern Europe, and Kazakhstan B.1
Appendix C - Definition of Terms C.1

Figures

1 Number of Minor Safety Events at Soviet-Designed Reactors in Russia and Ukraine 17

2 Nuclear Power Plants in Central and Eastern Europe Participating in the U.S. Program to Improve Nuclear Safety 21

3 Nuclear Power Plant in Armenia Participating in the U.S. Program to Improve Nuclear Safety 51

4 Nuclear Power Plant in Kazakhstan Participating in the U.S. Program to Improve Nuclear Safety 57

5 Nuclear Power Plants in Russia Participating in the U.S. Program to Improve Nuclear Safety 61

6 Safety Events at 30 Soviet-Designed Reactors in Russia from 1992 through 2002 62

7 Nuclear Power Plants in Ukraine Participating in the U.S. Program to Improve Nuclear Safety 99

8 Safety Events at Soviet-Designed Reactors in Ukraine from 1992 through 2002 100

Table

1 Summary of Nuclear Power Plant Reactor Types in Participating Countries 3

Part I – Program Description

Overview

The Soviet-designed Reactor Safety Program has had a direct and substantial impact on improving safe operations of 67 Soviet-designed commercial nuclear power plants in Armenia, Bulgaria, Czech Republic, Hungary, Kazakhstan, Lithuania, Russia, Slovakia, and Ukraine. (See Table 1 below for a summary of the reactor types in each country.) Within the U.S. Department of Energy (DOE), the National Nuclear Security Administration's (NNSA's) Office of International Nuclear Safety and Cooperation has been working steadily with these host countries to improve safe nuclear operations or assist in plant shutdown. Independent international safety reviews have identified significant progress in the Eastern European countries to improve the safety of their nuclear power plants since the early 1990s. In addition, all of the Soviet-designed reactors have shown a major reduction in the frequency of core damage accidents since U.S. assistance to improve safety at these reactors began.

Table 1. Summary of Nuclear Power Plant Reactor Types in Participating Countries

Reactor Type	Russia	Ukraine	Bulgaria	Czech Republic	Hungary	Lithuania	Slovakia	Armenia	Kazakhstan
RBMK	11	2[(a)]				2			
VVER-									
440/230	4		4[(e)]				2	1	
440/213	2	2		4	4		4[(b)]		
1000	8	11	2	2[(c)]					
LWGR-12	4								
BN-600	1								
BN-350									1[(d)]

BN = Breeder reactor.
LWGR = Light-water-cooled, graphite-moderated reactor.
RBMK = Boiling-water, graphite-moderated, pressure-tube reactor.
VVER = Pressurized, light-water-cooled and moderated reactor.
(a) Chornobyl's Unit 3 was shut down on December 15, 2000. Unit 1 was shut down in November 1996.
(b) The two recently completed reactors at the Mochovce site are included in this table; however, no U.S. safety assistance has been provided or planned.
(c) The two reactors recently completed at the Temelin site are included in this table; however, no U.S. safety assistance has been provided or planned.
(d) Kazakhstan shut down its Aktau BN-350 plant in early 1999.
(e) Kozloduy Units 1 and 2 were shut down in December 2002.

International Atomic Energy Agency (IAEA) studies summarized and prioritized hazards at Soviet-designed nuclear plants. Although the program conducts projects in all areas categorized as deficient by IAEA, not every specific IAEA safety issue is addressed with this U.S. program.

The principal safety deficiencies identified by IAEA, by reactor type, are listed as follows:

RBMK

- limited and ineffective accident mitigation systems

- inadequate fire protection systems
- inadequate separation and redundancy of plant safety systems
- inadequate operating and emergency procedures
- inadequate training methods
- inadequate system for monitoring critical safety parameters
- no massive steel/concrete containment structure.

VVER-440/230

- inadequate reactor confinement to accommodate large-pipe breaks
- inadequate emergency core cooling systems
- inadequate fire protection systems
- poor leak-tightness and poor hydrogen mitigation in reactor confinement
- inadequate operating and emergency procedures
- inadequate training methods
- inadequate system for monitoring critical safety parameters.

VVER-440/213

- inadequate fire protection systems
- inadequate separation and redundancy of plant safety systems
- reactor confinement with poor leak-tightness and limited hydrogen mitigation
- inadequate operating and emergency procedures
- inadequate training methods
- inadequate system for monitoring critical safety parameters.

VVER-1000

- inadequate fire protection systems
- inadequate separation and redundancy of plant safety systems
- inadequate operating and emergency procedures
- inadequate training methods
- inadequate system for monitoring critical safety parameters.

The international nuclear community recognizes that a large accident at any one of these Soviet-designed reactors could

- undermine the stability of new democratically elected governments
- place Western investments in the former Soviet Union countries at risk with potential repercussions on international economies
- require billions of dollars in U.S. and international assistance to support recovery efforts
- reduce the continued viability of the nuclear power option throughout the world.

Preface

The current National Nuclear Security Administration (NNSA) program to improve the safety of Soviet-designed reactors in nine host countries is a comprehensive effort to address issues related to training, procedures, equipment, and design. Involvement of the United States in the Soviet civilian nuclear power program began when the chairman of the U.S. Nuclear Regulatory Commission (NRC) and the chairman of the USSR State Committee for the Utilization of Atomic Energy signed the Memorandum of Cooperation in the field of civilian nuclear reactor safety in April 1988.

In May 1992, Secretary of State Baker announced that the United States would work to 1) enhance the operational safety of Soviet-designed reactors, 2) provide for risk-reduction measures for the least-safe plant designs, and 3) enhance the capability of the regulatory organizations. This new project came out of a very modest 1990 U.S. Department of Energy (DOE) activity initiated through the Joint Coordinating Committee on Civilian Nuclear Reactor Safety to improve operational safety at the Novovoronezh nuclear power plant in Russia.

These goals, plus a commitment to support efforts to minimize the remaining time of operation for the least-safe reactor types (RBMK and VVER-440/230), were endorsed later by the G-7 countries at the Munich Summit.

With extensive cooperation from host countries, the approach has been to 1) implement risk reduction through equipment upgrades at the highest-risk reactors; 2) improve operational practices and training at all nuclear power plants; and 3) provide the necessary technology, training, and infrastructure support so that these safety improvements can become self-sustaining, enabling these countries to move forward on a success path to achieve a level of safety comparable to internationally accepted practices. This approach is addressed further in the Strategy section and in the discussion of the six program goals. The program is conducted in a manner consistent with guidance and policies of the U.S. Department of State and the U.S. Agency for International Development (USAID). The program also is performed in collaboration with the NRC. The United States coordinates its safety assistance activities with those of the International Atomic Energy Agency (IAEA), the Nuclear Safety Account at the European Bank for Reconstruction and Development (EBRD), and those of other donors through the G-7 Nuclear Safety Working Group and the European Union's Technical Assistance to the Commonwealth of Independent States (TACIS) Program.

Strategy

International assistance efforts alone cannot resolve the safety deficiencies inherent in these nuclear programs. The goal of external assistance efforts is to help host countries develop their own capability to operate and regulate nuclear power plants more safely. As their economies improve, the host countries will be able to sustain and extend such improvements through their own efforts until they can reach internationally accepted standards in the operation and regulation of their nuclear programs. Therefore, the program strategy is to work with host-country nuclear power plant operators, regulators, and support organizations to provide them the knowledge, technology, equipment, and capability needed to achieve a self-sustaining nuclear safety improvement program.

A substantial element of this strategy is the transfer of manufacturing technologies, training methodologies, and safety assessment capabilities to host countries. Technology transfer methods include information exchanges, technical collaborations, personnel exchanges, licensing of U.S. technologies, and formation of joint U.S./host-country companies.

The relationships established during this program will enable the United States to monitor the host countries' nuclear programs and to respond to future safety problems. This strategy is based on the assumption that economic and an energy market reform has taken hold in the host countries to a level sufficient for them to make substantial investments in nuclear safety in the near future.

Current program activities are divided into six key areas. Improvements are required in each area to improve safety practices in the host countries. The six areas are

- operational safety
- simulators and training
- safety maintenance
- safety systems
- safety assessments
- legal and regulatory capabilities.

The key areas were selected based primarily upon the results of the IAEA studies that summarized and prioritized hazards at Soviet-designed nuclear plants. Although the program conducts projects in all of the areas categorized as deficient by IAEA, not every specific IAEA safety issue is addressed within the U.S. program. Through coordination with other international bodies and the host countries, however, all the IAEA safety issues are being addressed.

During the past few years, in-depth safety assessments have been undertaken for a number of the Soviet-designed reactor types. These assessments have resulted in the identification of additional issues with the design and operation of the plants. Primarily based on priorities determined from probabilistic risk studies for these plants, some additional projects have been identified beyond those that address the IAEA issues.

The selection criteria for projects in the key areas address 1) priority of safety needs, 2) cost-effectiveness, and 3) host-country commitment to ensure sustainability after U.S. support ends. In addition, work is selected in coordination with the host country and other internationally sponsored safety programs to ensure that U.S. projects complement activities undertaken by others.

In the key areas, goals have been achieved largely by following a "pilot plant" approach. Under this approach, one or two pilot or lead plants—or in some cases a group of selected plants—received training, technology, and physical improvements. A sufficient number of pilot plant projects have been completed within each key area to serve as a safety improvement model for all host countries with similar reactor types. As an integral part of each project, technology transfer and training are provided to equip each host country with the means to extend improvements independently. Using their own resources, host countries are expected to capitalize on the momentum established at the pilot plants to extend improvements to other facilities. Where the host-country infrastructure is very limited and the economic conditions preclude independent actions in a timely manner, activities will be extended beyond pilot plants.

NNSA provides support to the U.S. International Nuclear Safety Center (INSC) at Argonne National Laboratory. The U.S. INSC is part of a growing network of organizations dedicated to developing enhanced nuclear safety technology, promoting the open exchange of nuclear safety information among nations, and developing a strong nuclear safety culture worldwide. The U.S. center maintains a nuclear safety database that has 24-hour accessibility through the Internet at www.insc.anl.gov/index.html.

Establishment of a strong, indigenous nuclear safety culture is essential if the task of improving nuclear safety in these countries is to continue once the U.S. program is completed. An underlying purpose of the program, therefore, is to show host-country nuclear plant and regulatory personnel examples of effective nuclear safety practices so they will incorporate and sustain sound safety practices. Through workshops, seminars, and visits to U.S. nuclear plants, host-country personnel learn that a strong nuclear safety culture not only protects plant workers and the public, but also is important to the efficient and financially viable operation of the plant.

Goals

To accomplish its mission of reducing risks at Soviet-designed nuclear power plants and upgrading host-country nuclear safety infrastructure, the program has established goals for each of the six key areas identified above. The goals are

- **Operational Safety -** Implement the basic elements of operational safety consistent with internationally accepted practices.

- **Simulators and Training -** Improve operator training to internationally accepted standards, including the use of plant-specific simulators.

- **Safety Maintenance -** Help establish technically effective maintenance programs that can ensure the reliability of safety-related equipment.

- **Safety Systems -** Reduce the risk of severe accidents by implementing safety system improvements consistent with remaining plant lifetimes.

- **Safety Assessments -** Transfer the capability to conduct in-depth plant safety assessments using internationally accepted methods.

- **Legal and Regulatory Capabilities -** Facilitate host-country implementation of necessary laws and regulatory policies consistent with their international treaty obligations governing the safe use of nuclear power.

Selection of Projects

When the program began, an initial set of projects was selected based on requests for assistance from the operators of Soviet-designed reactors and on input from international nuclear safety organizations that had evaluated these plants and identified safety deficiencies in numerous reviews that followed the 1986 Chornobyl accident. Project selections were based also on U.S. participation on international steering committees established to identify and prioritize key safety issues associated with Soviet-designed nuclear power plants. Further, the United States coordinated the selection of its projects with the members of the G-24 and international financial institutions that also support safety upgrades at Soviet-designed nuclear power plants.

In addition to the above practices, projects are chosen by applying specific selection criteria in two phases. Proposed projects are first screened by program staff to ensure that they will improve the nuclear safety of operating plants, prevent or contain core damage, and apply established technologies. Candidate projects that meet the screening criteria are evaluated in more detail by program staff and host-country experts who apply the following evaluation criteria to determine if the project meets the program mission:

- **Impact on Safety**

  The project is evaluated against available independent safety reviews and risk assessments to verify that it improves safety. Regulatory involvement, technology transfer, sustainability, and the number of plants affected also are factored into the evaluation.

- **Cost-Effectiveness**

  Using a preliminary cost estimate, the project is reviewed in relation to other ongoing projects to determine the comparative investment in safety. Projects are given priority that complement and leverage benefits from other projects, use joint ventures with the host countries, or enhance a host country's capability to undertake its own upgrades.

- **Host-Country Commitment/Sustainability**

  The host-country's desire for the project and willingness to commit funds and personnel are reviewed to verify its ability to sustain the project for the long term. In the case of technical shortcomings, the project must transfer the technology and infrastructure needed for sustainability.

Based upon this evaluation and the availability of resources, priority and schedule are established for the project. This process ensures that projects are consistent with the policies and goals under which U.S. financial support is committed, the needs of the host countries are met, and the required resources are available.

International Nuclear Safety Projects

U.S. nuclear safety support primarily is in the form of joint projects undertaken with host countries. The following project descriptions outline the type of work conducted and its relevance to improving safety at Soviet-designed nuclear power plants.

Operational Safety

Emergency Operating Instructions. Development and implementation of symptom-based emergency operating instructions (EOIs) are under way for nuclear power plants in Bulgaria, Lithuania, Russia, and Ukraine. Emergency operating instructions specify actions operators can take to stabilize a reactor and mitigate the consequences of an abnormal event. Symptom-based instructions enable operators to take such actions immediately, without first having to determine the cause of a problem.

Through information exchange and technology transfer, host-country organizations have acquired the capability to write symptom-based EOIs for their nuclear power plants. Hands-on workshops, classroom sessions, and one-on-one assistance associated with the EOI projects also have provided the necessary training, technical mentoring, equipment and software, and technical assistance needed to help the nuclear power plant staff and their contractors and regulators complete the EOI development and implementation process. These symptom-based instructions have been implemented at only a few plants because of the lack of the technical analysis needed to validate the instructions. Work is under way to assist the plants with the necessary analysis to allow full implementation of these EOIs.

The State Nuclear Regulatory Committee of Ukraine (SNRCU) approved an EOI regulation for Ukraine's nuclear power plants, which will aid in their implementation.

Operator Exchange Program. To improve cross-cultural sharing of operational safety information for operators of Soviet-designed nuclear power plants, the Institute of Nuclear Power Operations (INPO) and the World Association of Nuclear Operators (WANO) facilitated an operator exchange program from 1989 through 1997. This program funded visits to U.S. nuclear power plants by 118 staff members from

11 Russian and Ukrainian plants from 1995-1997. Results are that the visitors have adapted at their own plants policies and procedures they observed at U.S. plants. Staff from Soviet-designed plants continue to visit U.S. plants as part of training and technology transfer for specific safety improvement projects.

Management and Operational Safety Practices. A set of 16 generic management and operational safety practices was developed based on the INPO good practice guidelines for operational safety. The guidelines outlined effective practices for log keeping, shift turnover, procedure writing, control of temporary modifications, equipment labeling, and verbal communications. Host-country nuclear power plants are in various stages of developing and gaining regulatory approval for site-specific guidelines.

Configuration Management. Host-country nuclear power plants are receiving U.S. assistance to help ensure that plant drawings and documents are updated consistently to accurately reflect the plants' actual physical configurations such that they are in keeping with their safety design basis. In-depth knowledge of Soviet reactor design and performance historically resided with design institutes in Moscow. With the breakup of the Soviet Union and resulting changes in host-country political and economic systems, the design institutes have become less and less involved with the nuclear power plants. This is particularly true for Ukrainian plants that have limited ability to pay the institutes for information.

Quality Assurance. The United States is helping host-country specialists establish industry standards for quality assurance (QA) to include development of QA manuals and improved QA procedures. The project helps to improve nuclear safety through seminars and procedure writing workshops, technical exchanges, assessment of existing systems, comparison of these systems to state-of-the-art QA systems, identification of gaps and needs, and implementation of a self-sustaining quality system for the nuclear power plants.

Event Analysis, Reporting, and Lessons Learned. Event analysis and reporting is essential to the effective correction of deficiencies in nuclear power plants both before and following the occurrence of abnormal events. This project will ensure that the cause of an abnormal event is correctly determined through root cause analysis, information is effectively transferred to appropriate personnel in reactor operations/maintenance and the regulatory body, and appropriate corrective measures are identified and implemented at similar nuclear power plants.

Operational Safety Infrastructure. The U.S. safety program established a Ukrainian nuclear safety infrastructure project in 1997 in association with the work of a group of Ukrainian technical support organizations that formed the Operational Support Institute for Nuclear Power Plants (NPP OSI). An infrastructure strategic plan was prepared to outline the necessary capabilities and activities to more fully develop those capabilities that did not exist.

Simulators and Training

Simulator Projects. U.S. and host-country experts have developed computer-based, plant-specific control room simulators for Soviet-designed nuclear power plants that serve as a training tool for reactor operators. Full-scope simulators use full-size physical replicas of actual control room panels, complete with equipment such as switches, controllers, indicators, and recorders. Analytical simulators, which cost much less, use computer screens with graphic displays that imitate plant systems.

U.S. support also includes conducting simulator maintenance courses, developing simulator exercise guides, and training simulator instructors.

Training. Well-trained operators and support staff are essential to the safe operation of nuclear facilities. Training at Soviet-designed reactors historically has been weak, with “on-the-job training” forming the basis for operator qualification. U.S.-supported training projects focus on transferring to Soviet-designed plants the systematic approach to training methodology used at all U.S. nuclear power plants. This approach involves a logical, step-by-step process that identifies the knowledge and skills required for each staff position at a nuclear power plant, establishes training to provide and maintain the necessary knowledge and skills, and obtains feedback to ensure training remains current with plant procedures and practices.

U.S. and host-country experts also are jointly developing pilot training program course material for selected power plant positions that will be taught by plant training staff. Additionally, U.S. experts provide instructor training on classroom, simulator, and on-the-job training techniques, as well as management and supervisory skills training for plant managers.

Safety Maintenance

The United States is working to reduce equipment malfunctions at the Soviet-designed plants by supplying up-to-date tools and training for maintenance workers. Advanced maintenance systems promote safe operations until these plants are shut down.

Nondestructive Examination. Equipment is being supplied to help detect flaws in primary coolant and safety engineered piping systems. Equipment has been provided also to permit inspection of steam generator tubes in host-country VVER nuclear power plants before they create problems. Technicians use ultrasonic, x-ray, and eddy-current equipment for nondestructive examination, which enables them to evaluate flaws in safety-related piping systems without cutting open the pipes. Support also is being provided to transfer risk-based in-service inspection (RBI) technology. RBI technology provides a technical basis for developing an in-service inspection program that focuses the proper inspection methods and inspection intervals on components that pose the highest risk of causing core damage, loss of containment, or radiological harm outside the plant.

In 1997, intergranular stress corrosion cracking (IGSCC) was detected during routine in-service inspections at Leningrad, Kursk, Smolensk (Russia), Ignalina (Lithuania), and Chornobyl (Ukraine) nuclear power plants (all RBMK boiling water reactors). It was the discovery of IGSCC at Chornobyl that drew international attention to a serious degradation issue for RBMK plants. The experience of Western countries that have encountered IGSCC has been that the pipe degradation can be managed with a comprehensive mitigation program and is not a plant life-limiting degradation mechanism. In fact, operating plants that previously experienced IGSCC and have properly implemented the mitigations strategies have had no recurrences.

Assisting operators of RBMK reactors in developing a comprehensive program to manage IGSCC degradation in RBMK reactors improves the safety of Soviet-designed reactors. Particular emphasis is being placed on ensuring the integrity of primary system components and engineered safety systems for safe plant operation. Assistance to RBMK plants is being implemented in two areas. One area of support assists the IAEA's Extra-budgetary program by participating in working group meetings and sponsoring training seminars on in-service inspection and proper techniques for monitoring water quality. A second area of support provides direct technology transfer to Russia for mechanical stress improvement technology. Mechanical stress improvement technology reverses the residual stresses in welds, thus mitigating one of the causal factors for intergranular stress corrosion cracking.

Safety Maintenance Tools. The United States is working with the host-country participants to provide modern tools and equipment to improve the maintenance and monitoring of safety equipment. The following is a brief description of some of the tools and technology provided.

Pipe Lathe/Weld-Preparation Machines. Soviet-designed reactors have been supplied with machines that aid in the repair of corroded piping. Technicians use the pipe lathe/weld-preparation machine to cut pipes precisely and prepare them for welding, which significantly improves weld integrity and reduces the risk of leaks that could cause loss of cooling water to the reactor core.

Valve-Seat Resurfacing Equipment. Equipment has been provided to Soviet-designed nuclear power plants to assist in the repair of leaking valves without having to remove the valves from the pipes. The equipment helps to reduce the risk of leaks that could lead to a loss-of-coolant accident.

Insulation Analysis Equipment. Soviet-designed reactor technicians are using U.S.-supplied equipment to detect and correct the breakdown of the insulation around high-voltage lines and equipment to help prevent loss of power to key reactor systems.

Vibration Monitoring and Shaft Alignment Equipment. State-of-the-art systems are being provided to Soviet-designed nuclear power plants to assist maintenance staff in detecting and correcting misalignment and imbalance in rotating machines, such as pumps, which are critical to safe operation.

Reliability Database. A reliability database is being developed for implementation at plant sites and at the host-country utilities that will aid nuclear power plant operators in cataloging and tracking components (primarily safety related) and failures associated with the components. In addition to developing software tools to track failures, maintenance, and replacement of components, the project involves developing a standardized nomenclature and terminology to describe systems, components, and failures. Information tracked in the database is used for such activities as risk assessments, reliability-centered maintenance, risk-informed operations, root-cause analysis, inventory control, and maintenance and outage planning. The database also will be used to compare information across plants and with the international community.

Safety Systems

Fire Safety. Fire safety projects in host countries are designed to ensure that the basic fire protection equipment at Soviet-designed nuclear power plants is adequate. These plants rely on large brigades of fire fighting personnel who must be able to detect fires reliably, alert staff immediately, and fight fires effectively. To support the fire brigades, the United States supplied basic fire equipment for detecting and controlling fires. Pilot plant projects have been performed at Smolensk (Russia) and Zaporizhzhya (Ukraine) nuclear power plants in which many upgrades have been made as examples of the eventual requirements at all the operating plants. Extensive fire safety upgrades also have been made at the Chornobyl and Armenia plants because of the urgency of the need at those facilities.

It also is essential that in-depth fire hazards analyses be performed to demonstrate the ability of a nuclear plant to shut down safely in a fire, regardless of the location of the fire. Based on Western experience, U.S. fire safety experts developed procedures to be used in evaluating the safe shutdown capability of Soviet-designed nuclear power plants. A pilot study has been completed at Smolensk (an RBMK design). A pilot study is in progress at Zaporizhzhya (a VVER-1000 design).

Based on surveys of fire safety needs at the plants and on the results of fire hazards analyses, comprehensive plans are under development within Russia and Ukraine to complete the process of upgrading fire safety at their plants.

Safety Parameter Display Systems. The United States is collaborating with host countries to develop safety parameter display systems (SPDSs) for Soviet-designed nuclear power plants. SPDSs provide reactor operators with the immediate information they need to control a reactor in the event of a malfunction or an accident. Information on the status of key conditions, such as reactor core cooling and radioactive material confinement, is displayed in a clear format on computer screens. The SPDSs assist the operators in monitoring the important plant parameters such as those associated with the critical safety functions described in the EOIs.

Because of the large number of SPDSs (and advanced instrumentation and control systems) that are being implemented at Ukrainian nuclear power plants, the program has also established an in-country instrumentation and control system maintenance center.

Plant Computer Upgrades. In many Soviet-designed nuclear power plants, plant control and information systems provide unreliable or faulty information to the operators, which could lead to accidents or prevent the operator from taking the correct actions to mitigate an event. For those plants in which SPDSs have been installed, plant computer upgrades can be undertaken inexpensively that rely on much of the input and analyses performed by the SPDS. Recognizing that the VVER-1000 nuclear power plants will be operated for many more years, the U.S. safety program will provide assistance in a pilot plant study to upgrade control and information systems at two units.

Risk-Dominant Design Deficiencies. In-depth safety assessments are being conducted for each type of Soviet-designed nuclear power plant. These safety and risk analyses not only identify plant-specific design vulnerabilities, but they also can be used to draw generic conclusions regarding the risk-dominant contributors for the different reactor types. A review of the results of risk analyses indicates that, for the VVER-1000 nuclear plants, small-pipe break accidents with failure of the emergency core cooling system are dominant contributors to severe fuel damage accidents. Similarly, anticipated transient accidents with failure to scram (automatic reactor shutdown) dominate the risk profiles of the RBMK nuclear power plants.

Safety Assessments

U.S. and host-country experts are conducting safety assessment activities at Soviet-designed nuclear power plants to determine the most significant risks and to establish priorities for safety upgrades.

In-Depth Safety Assessments. Specific to each plant, in-depth safety assessments (ISAs) provide a technical basis for documenting a plant's risk profile to support safe plant operation and to provide justification for proceeding with appropriate safety upgrades. U.S.-supported ISAs are designed to have plant staff lead the projects and subcontract with host-country technical organizations to perform various safety upgrades. U.S. experts provide on-site technical mentoring and project management assistance. The United States also is providing computer codes and technical support to improve the assessment capabilities of specialists at these plants.

Design-Basis Accident Analysis. These analyses are used to establish the design bases for the plant. Design-basis accident (DBA) scenarios are analyzed with deterministic techniques to assess safety margins incorporated into a nuclear power plant's design.

Probabilistic Risk Assessment. The probabilistic risk assessment is a systematic approach to assess the safety of a nuclear power plant in probabilistic terms. Probabilistic risk assessment is an effective tool for identifying design weaknesses.

Safety Analysis Tools and Support. The United States is working with the host country participants to transfer Western safety analysis tools and methodologies. A significant part of this activity is the process of "validating" that the computer codes used in conducting the safety assessments appropriately model the reactors being analyzed.

Russia PSB Test Facility Instrumentation. The project involves identifying the minimum mass flow instrumentation to the PSB test facility required to give the analysts sufficient information for their assessment of safety analysis codes. This project will provide hardware, modify and develop software to interface with the instrumentation, calibrate and test the hardware and software, provide delivery of the instrumentation, and help with acceptance testing. The PSB facility will be used to provide information for the assessment of safety analysis codes related to VVER reactors.

Ukraine VVER Special Transient Analysis. The United States initiated the Ukraine VVER special transient analysis project to provide the systematic evaluation of the adequacy and applicability of the computer codes to the safety assessment of Soviet-designed VVER reactors. This project involves not only transferring technology such as computer codes and methods, but also requires transferring methods to ensure that safety assessment codes and methods are applied correctly.

Information Exchanges. The United States sponsors international forums and workshops for exchanging information on in-depth safety assessments at Soviet-designed reactors. Forums have focused on analytical methods and computational tools for conducting assessments and on comparing probabilistic safety assessments at VVER reactors.

Legal and Regulatory Infrastructure

U.S. support is being provided to assist host countries in the development of strong legal frameworks for regulating Soviet-designed nuclear power plants. The objective is to promote strong, independent regulatory bodies with the capabilities needed to regulate nuclear activities; host-country adherence to international nuclear safety treaties and liability conventions; and protection for U.S. contractors from undue liability in foreign and U.S. courts if a malfunction or accident occurs at a Soviet-designed facility where the U.S. contractor has provided services. U.S. support is coordinated through the U.S. Nuclear Regulatory Commission.

Overview of Program Performance

As previously outlined, the safety efforts have been focused on key technology areas, including: 1) operational safety, 2) simulators and training, 3) safety maintenance, 4) safety systems, 5) safety assessments, and 6) legal and regulatory capabilities. These areas are considered by the international nuclear safety community as essential to safe operation of nuclear power plants.

Although each individual area is critical, a positive synergistic impact results as progress is made in all of these areas at once. Clearly, two overall factors are important to safety: 1) skilled operations staff, provided with the information they need to do the job and trained to handle emergencies; and 2) advanced equipment and techniques that ensure correct operation of the plant safety systems are evaluated and maintained effectively to ensure correct low-risk operations.

Improved operational safety follows from the combined efforts to improve operator performance. These efforts include providing simulators for operators to practice handling emergency scenarios, developing emergency operating instructions that guide operators calmly through emergencies, providing safety parameter display systems that give operators immediate graphical information on the status of plant systems and training the operators on the safety basis for the plants they operate. Together, these efforts provide an operations staff trained to international standards and able to make informed decisions, both during day-to-day operations and under the stress of an emergency situation.

Improving and maintaining the plant safety systems to international standards provides additional assurance that the plant will operate safely. Therefore, efforts to install new safety equipment, improve maintenance, evaluate risks, and prioritize safety upgrades all contribute to improving safety.

Program efforts are aimed primarily at two objectives: improving plant staff capabilities and improving the effectiveness of plant safety systems. In addition to improving operator training and plant safety equipment enhancements, each host country is working to improve its overall nuclear safety infrastructure and safety culture. This includes national organization involvement in the operation and regulation of nuclear power. Efforts to develop the International Nuclear Safety Center in Russia and the Slavutych Laboratory of International Research and Technology in Ukraine directly support the development of a sustainable nuclear safety infrastructure to facilitate continuous improvements in plant safety and the safety culture.

Improvements in Safety

A primary indicator of nuclear plant safety is the frequency of core damage accidents. Prior to the inception of major safety programs such as the Soviet-Designed Reactor Safety Program and similar European Union programs sponsored under TACIS, the average accident occurrence rate at former Soviet Union power plants was 9.8 core-damage accidents per 1000 years of reactor operation. In more than 774 reactor years of operation since the beginning of the safety assistance programs (which were initiated after the 1986 accident in Chornobyl), no accident has resulted in significant core damage.

The recent core damage experience shows that the average current risk is less than 1.3 core damage accidents per 1000 years of reactor operation for all countries with operating Soviet-designed reactors. This demonstrates that almost an order of magnitude reduction in the risk of Soviet-designed reactor operation has been achieved. Further operation may demonstrate that a common Western risk target of 0.1 core damage accidents per 1000 years of operation is achievable for these Soviet-designed reactors.

Because there have been no core damage accidents during the Soviet-Designed Reactor Safety Program, other indicators must be examined to better understand the details of progress made. This is accomplished by considering trends in minor events, which serve as precursors indicating the likelihood of a more severe accident. Minor events show a similar favorable trend since 1992. As depicted in Figure 1, there has been a decrease in the number of events at Soviet-designed nuclear power plants in Russia and Ukraine since the DOE/NNSA program began in 1992. The vast majority of these events are rated as Level 0 Deficiencies on the 7-level International Nuclear Event Scale (INES) and represent quite minor events. The number of events in Russia and Ukraine exceeding INES Level 0 (classified as INES Level 1 Anomalies or INES Level 2 Incidents) also has decreased significantly during this period.

Independent reviews also have assessed the safety of nuclear power plants. In 1999, the Western European Nuclear Regulators Association issued the report, "*Report on Nuclear Safety in EU Applicant Countries.*" The focus of the review was to assess the safety status of the nuclear power plants and the status of the regulatory regime and regulatory body of those Eastern European countries that have expressed interest in joining the European Union including Bulgaria, Czech Republic, Hungary, Lithuania, and Slovakia. The reviews identified significant progress in these countries to improve the safety of their nuclear power plants since the early 1990s.

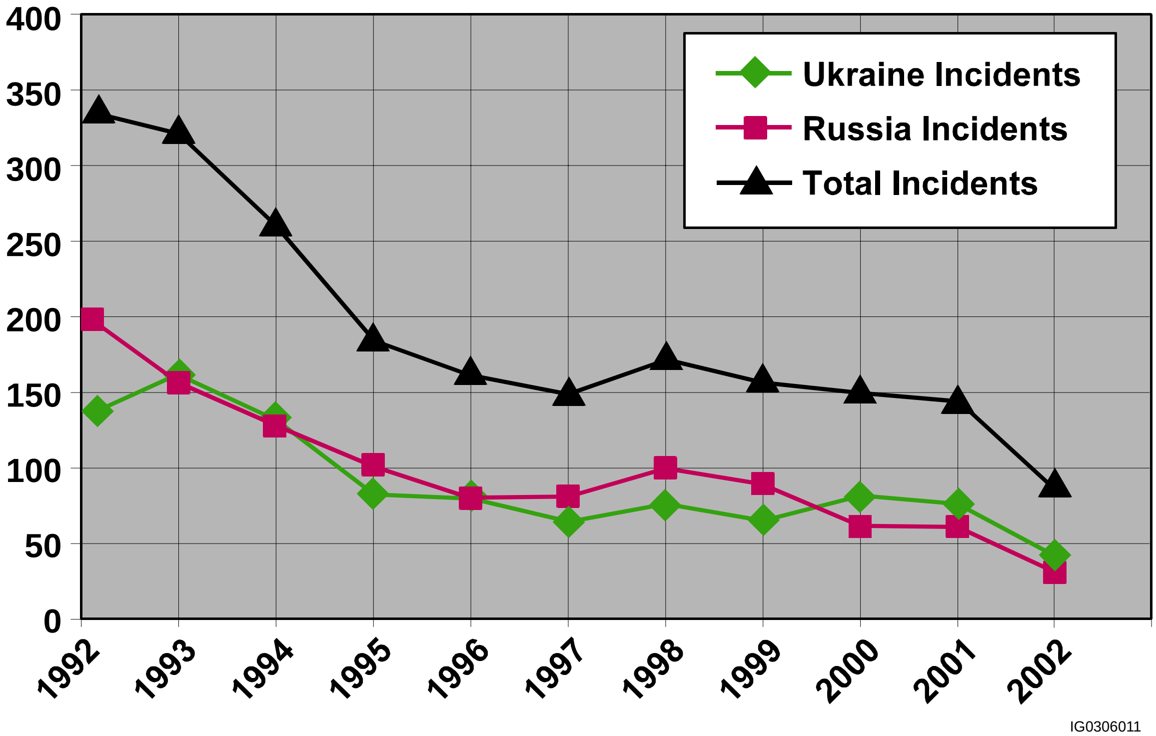


Figure 1. Number of Minor Safety Events at Soviet-Designed Reactors in Russia and Ukraine

In summary, there are clear indications that the U.S. program's efforts, combined with those of the host countries and of other donor countries, are helping to improve the safety of the Soviet-designed reactors. However, continued safety improvement efforts are necessary to ensure safe operating practices and achieve timely phase-out of older plants.

Part II – Safety Improvement Projects at Each Plant

Central and Eastern European Countries

The National Nuclear Security Administration (NNSA) is working with Bulgaria, the Czech Republic, Hungary, Lithuania, and Slovakia to improve safety at Soviet-designed nuclear power plants. Twenty reactors operating in these countries participate in NNSA's cooperative program. The locations and types of reactors at each plant are shown in Figure 2.

This section of the report identifies completed, ongoing, and planned projects in each of these countries through fiscal year 2003.

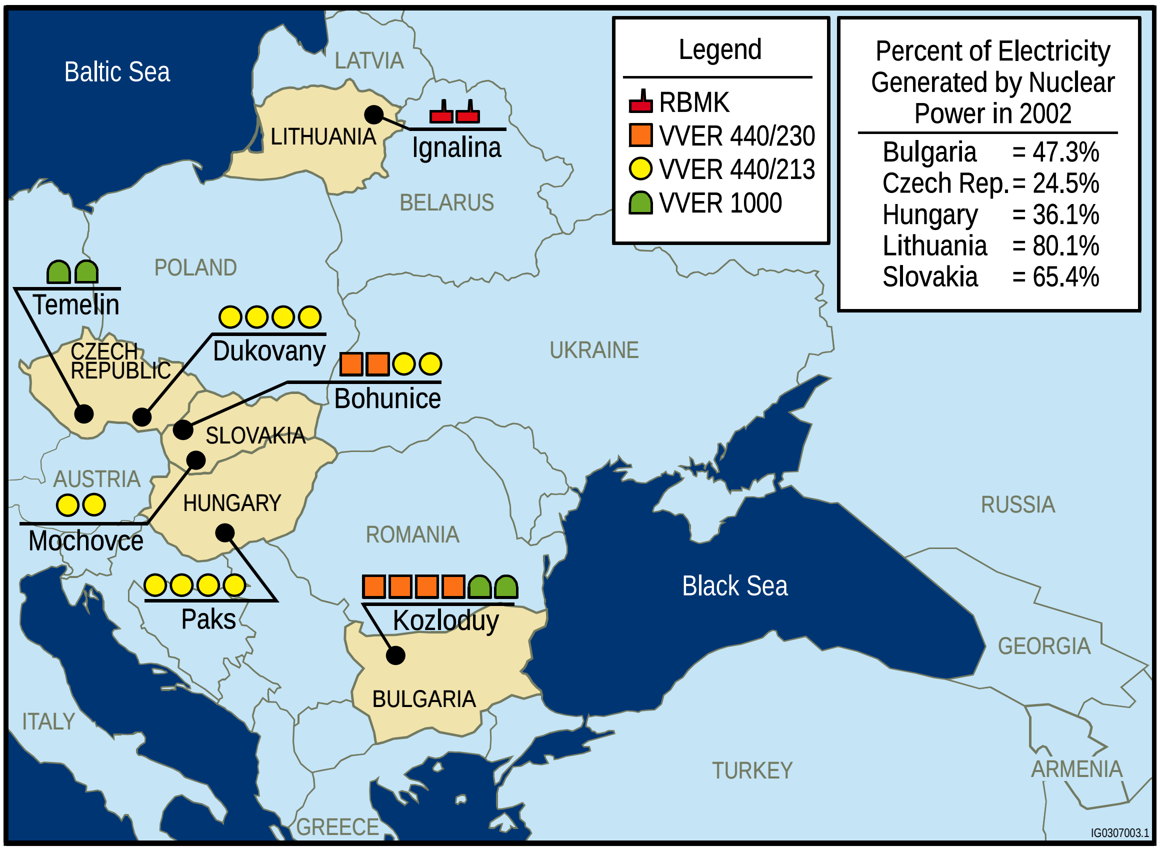


Figure 2. Nuclear Power Plants in Central and Eastern Europe Participating in the U.S. Program to Improve Nuclear Safety (Note: The nuclear power plants listed for Mochovce and Temelin have not received assistance from the U.S. program. These plants were recently completed, and many of the safety improvements implemented at other sites were incorporated into their construction.)

Bulgaria

Bulgaria operates six reactor units at its Kozloduy nuclear power plant (NPP). Units 1 through 4 are VVER-440/230s and Units 5 and 6 are VVER-1000s. Bulgaria agreed to shut down Kozloduy Units 1 and 2 at the end of 2002. In 2002, nuclear power supplied 47.3 percent of the country's electricity. However, that share has often risen to nearly 50 percent because fossil fuel power plants and hydropower plants have not achieved expected outputs.

Safety Status

U.S. National Nuclear Security Administration efforts have improved safety at Kozloduy NPP. This improved nuclear safety is documented independently in the *Report on Nuclear Safety* by the Western European Nuclear Regulators Association (March 1999); the association's findings are summarized in the following subsections.

Nuclear Power Plant Safety

With the completion of further planned safety upgrades, it should be possible to achieve a level of safety for Units 5 and 6 that is in line with reactors of the same vintage in Western Europe.

The short-term upgrading measures implemented at Units 1 through 4 have improved the safety of these units, and further safety improvements are being implemented or planned. However, on the evidence available, the existing and planned safety upgrade programs will not be sufficient to bring these units up to acceptable safety standards in Western Europe for older reactors.

Operational safety at all the units has improved considerably, and staff awareness of safety issues has definitely increased. However, continuous and long-term improvements are necessary to bring the operational safety at the plant up to a level comparable with good practices in Western Europe.

Regulatory Regime and Regulatory Body

During the last seven years, improvements have been made in the capabilities of the Bulgarian nuclear regulatory body (the Committee on the Use of Atomic Energy for Peaceful Purposes – CUAEPP) and in the legislative basis. However, much remains to be done to bring the regulatory regime up to Western European standards. The main needs include the following:

- The budget and salaries for the CUAEPP should be improved to recruit and retain adequate staff, and to obtain independent technical support when needed.

- The number of experienced regulatory staff should be increased.

- Resources should be committed to drafting new legislation and revising existing legislation.

The independence of the CUAEPP from bodies concerned with the promotion of nuclear power should be made explicit.

Kozloduy Nuclear Power Plant

Scope and Status of Activities

Unit	Reactor Model	Net Output	Initial Start	Status
1	VVER-440/230	400 MWe	06/1974	Shut Down 12/2002
2	VVER-440/230	400 MWe	08/1975	Shut Down 12/2002
3	VVER-440/230	400 MWe	12/1980	Operating
4	VVER-440/230	400 MWe	04/1982	Operating
5	VVER-1000	910 MWe	11/1987	Operating
6	VVER-1000	910 MWe	06/1991	Operating

Efforts to improve safety at the Kozloduy nuclear power plant were initiated in 1992 with funds received from the U.S. Agency for International Development. These early efforts, which focused on improving the safety of day-to-day operations and improving the physical conditions at the plant, included projects on developing procedures and practices that improve operational safety (1993-1994); improving fire-fighting capabilities (1992-1993); and upgrading engineered safety systems (1992-1993).

Later efforts include seismic analysis of buildings and systems essential to safe operation of the plant (1995-1998); developing and implementing a configuration management system (1994-1999); supporting development of a training center (1996-2002); and developing and enhancing capabilities for performing plant safety assessments (1994-2002).

Kozloduy Unit 5

Kozloduy Unit 5 Full-Scope Simulator Support. A project to upgrade the Unit 5 full-scope simulator to accommodate recent plant modifications was completed in 2000. Simulator instructor training was provided to the Kozloduy staff. Additional support to modify the simulator instructor station and provide a simulator audio/video system for training was accomplished. This project was completed in early 2002.

Kozloduy-5 Seismic Assessment. In 1996, a seismic assessment was completed of the building that houses electrical equipment for reactor Units 5 and 6. The computer model showed that some structural supports could fail. Some upgrades have occurred to address this problem.

Kozloduy All Units

Bulgaria Emergency Operating Instruction (EOI) Implementation. EOI technology has been transferred to Kozloduy NPP to improve the ability of reactor operators to minimize the effects of abnormal plant transients and multiple failures. Kozloduy plant staff completed their second draft of a full set of EOIs. Technical validation using Bulgarian technical resources is complete for both reactor types, and operational validation and operator training are in progress.

Several other projects are being performed in conjunction with the Kozloduy EOI project. PRONET software was developed to assist the nuclear power plants with the development/clerical/editorial management of the instructions. Kozloduy NPP purchased a full-scope simulator for Units 5 and 6 to improve operator training in the use of EOIs and other operational matters.

Kozloduy Nuclear Plant Safety Analysis Capability. Hardware, software, and training have been provided to support development of an independent and enhanced analytical capability at the Kozloduy plant. Through 2001, the plant staff and supporting organizations have successfully developed the VVER-1000 nuclear plant analyzer, the VVER-440 verification report, and the VVER-440 nuclear plant analyzer.

Future work includes tasks related to the International RELAP User Group and development of the work scope for Probabilistic Risk Assessment (PRA) support. Future code assessment work includes completing a third benchmark analysis and comparative assessments for all three benchmarks.

The United States also will support initiation of Severe Accident Management Guidelines (SAMGs) for the Kozloduy VVER-1000s. This collaboration will build upon a generic SAMG development project with the Russian Minatom International Nuclear Safety Center (RMINSC).

Kozloduy Diesel Generators. A backup emergency diesel generator was delivered to the plant. The generator provides backup power for operation of key safety systems, should an emergency disable both onsite and offsite electrical power sources.

Bulgaria Fire Fighting Equipment. A fire truck, communications equipment, and radiation-monitoring equipment were provided to improve the response capability of the fire brigade.

Bulgaria Management and Operational Safety Practices. Kozloduy NPP used the generic management and operational safety practices guidelines developed by the operational safety-working group to draft 16 site-specific guidelines. These guidelines were approved and implemented in 1997.

Kozloduy Configuration Management Support. A configuration management system developed for the plant was implemented during 1999.

Bulgaria Industry Workshops. A workshop on “Enhancement of Safety Analysis Capability for NPPs” was held at Kozloduy NPP in March 1998.

Kozloduy Training Center Support. The transfer of the Systematic Approach to Training methodology and training materials developed at the Russian Balakovo and Ukrainian Khmelnytskyy training centers is ongoing at the Kozloduy plant. A seminar on the Systematic Approach to Training was held for management personnel to ensure familiarity with and support for the methodology. Pilot courses for shift supervisors, reactor repair technicians, mechanical maintenance personnel, and control room reactor operators were developed and implemented. Basic classroom equipment and course-specific laser-alignment equipment were provided to support training-program development and implementation needs. Initial development of a training course for the operator's use of the drafted symptom-based Emergency Operating Instructions has been completed. Courses on electrical maintenance and on-the-job training were completed in 2001.

Kozloduy Scram Reduction. A thermography camera and specialized training were provided to the Kozloduy NPP staff to assist them in identifying and fixing problems and hot spots in the various electrical connections.

Kozloduy ACE Program Memberships. The fees were paid for two years of membership in a nuclear utility-sponsored advanced containment experiment (ACE) program to improve the plant's safety evaluation capabilities regarding containment performance under postulated accident conditions.

Bulgaria Pipe Analysis Software. This software was provided to Energoproekt, a Bulgarian institution, to enable analyses of Kozloduy reactor systems under operating conditions.

Bulgaria Y2K Support. Bulgarian experts participated in various Y2K Information Exchange and Contingency Planning meetings sponsored by DOE. The meetings included exchange of information between plants concerning their Y2K program efforts as well as seminars about contingency planning.

Czech Republic

The Czech Republic operates four VVER-440/213 units at Dukovany. In 2002, these four reactors provided 24.5 percent of the Czech Republic's electricity.

The Temelin site houses two VVER-1000 units. The first unit was started on October 10, 2000; the second unit undergoing startup in 2002. The instrumentation and control systems for these reactors have been extensively modified.

Safety Status

U.S. National Nuclear Security Administration efforts have improved safety at Dukovany NPP in the Czech Republic. This improved nuclear safety is documented independently in the *Report on Nuclear Safety* by the Western European Nuclear Regulators Association (March 1999); the association's findings are summarized in the following subsections.

Nuclear Power Plant Safety

The overall safety status of Dukovany can be summarized as follows:

- Dukovany NPP appears to be well operated, and the plant safety culture has been continuously improved. Several IAEA missions and cooperation with WANO have contributed substantially to the enhancement of safety; safety assessments are being conducted in a manner similar to Western practices.

- The current level of safety at the plant cannot be assessed fully because of the lack of detailed information. However, subject to a detailed analysis of the fully modified plant and an experimental verification of the containment function, Dukovany NPP should be able to reach a safety level comparable to plants of the same vintage in Western European countries.

Regulatory Regime and Regulatory Body

The Czech Republic has taken the appropriate steps to establish a regulatory regime and regulatory body (the SUJB) according to the principles adopted in Western Europe. Nevertheless, the following improvements still are necessary:

- The budget and salary conditions of the SUJB should be improved to obtain the necessary technical support and retain highly qualified staff.

- The working relationships between the SUJB and other governmental organizations and administrative departments should be clarified. In particular, the organization for emergency preparedness and planning should be tested in a national emergency exercise.

- The SUJB should establish a strong management line to ensure the rapid implementation of the necessary regulations under the Atomic Act.

Dukovany Nuclear Power Plant

Scope and Status of Activities

NNSA projects at Dukovany nuclear power plant include development of improved operating procedures and practices (1992-1994), performance of plant safety assessments (1993-1998), and transfer of capabilities for performing plant safety assessments (1996-1999). Because Dukovany NPP is one of the more advanced nuclear power plants in Eastern Europe, less assistance has been provided than for other Soviet-designed plants.

Unit	Reactor Model	Net Output	Initial Start	Status
1	VVER-440/213	408 MWe	02/1985	Operating
2	VVER-440/213	408 MWe	01/1986	Operating
3	VVER-440/213	408 MWe	10/1986	Operating
4	VVER-440/213	408 MWe	06/1987	Operating

Dukovany All Units

Emergency Operating Instructions (EOIs). Dukovany specialists participated in the VVER-440/213 EOI Working Group, which supported the transfer of the symptom-based emergency procedure methodology. Dukovany specialists decided to develop their EOIs on their own with assistance (a contract) from Westinghouse. These symptom-based emergency procedures are now in use at Dukovany NPP.

Dukovany Safety Analysis Capability. Assistance was provided and technology was transferred in the areas of computing hardware, software, and training to develop an independent, enhanced, analytical capability at the plant and its technical support organization with the intention of improving the plant's safety evaluation capabilities and infrastructure.

Dukovany Risk Advisory System. NNSA sponsored U.S. vendor and host-country support organizations to implement the plant's PRA model in the utilities already-licensed risk advisory system (RAS), which was Safety Monitor™ from Scientech. The software-based RAS is used by Dukovany staff to evaluate how the unavailability of certain plant components affects safety. The project is complete and no future activities are planned.

Dukovany Plant-Specific Database. This database, completed in 1995, is used to support the Dukovany probabilistic risk assessment effort. Using this database, plant staff can predict reactor system performance under various conditions.

Dukovany Level 2 Probabilistic Risk Assessment (PRA) (Phase 1). This Level 2 PRA, completed in 1998, evaluated the effectiveness of Dukovany's systems for confining radioactive materials.

Dukovany Simulator Data Collection and Analysis. With the support from United States and Hungarian analysts, Czech analysts have collected and analyzed data on reliability of operators' decision-making during full-power nuclear power plant operations. To gather the data, staff from Dukovany NPP and the Czech Republic's Nuclear Research Institute monitored operators' actions while they trained on a full-scope simulator at Slovakia's Trnava training center. During the training, operators responded to event scenarios developed for the plant's PRA. The project began in 1998 and was completed in 1999.

Czech Republic Y2K Support. A computer related to emergency response monitoring was replaced. Experts from the Czech Republic participated in various Y2K Information Exchange and Contingency Planning meetings sponsored by DOE.

Temelin Nuclear Power Plant

Scope and Status of Activities

The NNSA has not been involved in the construction or startup of the two VVER-1000 plants at Temelin. However, the instrumentation and control systems for these reactors were modified to conform to accepted international safety practices.

Unit	Reactor Model	Net Output	Initial Start	Status
1	VVER-1000	981 MWe	10/2000	Operating
2	VVER-1000	981 MWe	10/2002	Operating

Hungary

Hungary operates one nuclear power plant at Paks on the Danube River. In 2002, the four VVER-440/213 reactors at Paks produced about 36.1 percent of the country's electricity. The plant's management has recognized the importance of nuclear information exchange and has established several programs to increase the flow of operating experience information to the plant's operators. In addition, the Paks plant has raised its performance level with the help of a new full-scope simulator. The simulator is used to train staff and to test emergency procedures.

Safety Status

U.S. National Nuclear Security Administration efforts have improved safety at Paks NPP. This improved nuclear safety is documented independently in the *Report on Nuclear Safety* by the Western European Nuclear Regulators Association (March 1999); the association's findings are summarized in the following two subsections.

Nuclear Power Plant Safety

The safety characteristics of the Paks units have been evaluated in an in-depth, systematic manner. The basic technical structure of the plant is good from the safety point of view, and the key safety systems are comparable to Western plants of the same vintage. There are no major shortcomings in the present safety systems, but some minor issues remain to be resolved.

Paks containment structures are among the best for this reactor type, and meet their original design targets by providing protection against all sizes of loss-of-coolant accidents. However, their leak-tightness is not as good as the leak-tightness of containments in Western Europe.

Paks has taken actions to mitigate beyond-design-basis accidents and severe accidents. These measures are in compliance with good Western European practice, but additional work is needed to ensure containment integrity following a severe accident.

Periodic safety reviews are conducted similar to Western practices and already have led to an increase in safety.

It is expected that after the implementation of planned safety improvements, which are in the design and preparation phase, the plant will be able to reach a level of safety that compares well with plants of the same vintage in Western European countries.

Regulatory Regime and Regulatory Body

Legislation and other regulations are up to date and compare favorably with the principles applied in Western countries. The Hungarian Atomic Energy Agency (HAEA) also is sufficiently independent from the organizations promoting nuclear energy.

One key issue needs improvement or clarification. To continue to maintain a stable, competent staff, the Hungarian Government should ensure that the salary level of the regulators more closely matches that of the utility.

The HAEA should further develop the role of the site inspection department to avoid undermining the safety responsibilities of the operating organization and to ensure that all operational safety issues are covered sufficiently.

Paks Nuclear Power Plant

Scope and Status of Activities

NNSA participated in efforts at Paks nuclear power plant to improve operational safety of the plant. This involvement included projects such as the development of the operating procedures and practices (1992-1994) and the transfer of capabilities for performing plant safety assessments (1996-1998). The completion of these projects provided necessary means for safe operation of the Hungarian plant and provided an example of the Western safety culture.

Unit	Reactor Model	Net Output	Initial Start	Status
1	VVER-440/213	430 MWe	12/1982	Operating
2	VVER-440/213	433 MWe	08/1984	Operating
3	VVER-440/213	433 MWe	09/1986	Operating
4	VVER-440/213	433 MWe	08/1987	Operating

Paks All Units

Paks VVER-440/213 Emergency Operating Instructions (EOIs). Paks specialists participated in the VVER-440/213 EOI Working Group that transferred the symptom-based emergency procedure methodology. Paks decided to pursue the development of their EOIs on their own. These symptom-based emergency procedures are now in use at Paks NPP.

Paks Nuclear Plant Safety Analysis Capability. In 1998, Hungarian analysts received training in the United States related to GASFLOW, a computer code used in conducting safety analysis. After training, they returned to Hungary and compiled a set of data from Paks and conducted a GASFLOW analysis, which is being used to determine the most effective safety upgrades.

During 2002, Hungarian engineers documented the GASFLOW analyses in a peer-reviewed paper presented at the Tenth International Conference on Nuclear Engineering.

Hungary Human Factors Training and Support. The Western methodology was transferred to the plant to establish a data collection process for human reliability analysis. Once collected and quantified, the data will be used for enhancing the existing probabilistic risk assessment and for root cause analysis data determination.

Hungary Safety Maintenance Center Infrastructure Support. The United States provided technical assistance to Hungary in an effort to improve the maintenance practices at Paks NPP. The primary activity was to provide a two-year membership to the Electric Power Research Institute's Nuclear Maintenance Center.

Paks Accident Localization System Improvements. This activity focused on performing a peer review of the Hungarian assessment of the confinement loadings on a VVER-440/213 reactor due to a large pipe break.

Paks ACE Program Memberships. Hungarian engineers continued membership in the Advanced Containment Experiment program, whose purpose is to investigate containment structure performance under accident conditions.

Code Transfer for Paks NPP Spent Fuel Storage System Analysis. The COBRA-SFS thermal-hydraulics code, developed by Pacific Northwest National Laboratory, was adapted for use in remodeling Pak's dry-storage system for spent nuclear fuel. In 1996, Paks personnel were trained to use the code, and in 1997, a revised code was provided to the Hungarian Atomic Energy Commission.

Hungary Y2K Support. Hungarian experts participated in various Y2K Information Exchange and Contingency Planning meetings sponsored by DOE. The meetings included exchange of information between plants concerning their Y2K program efforts as well as seminars about contingency planning.

Lithuania

Since the breakup of the Soviet Union, Lithuania has relied increasingly on nuclear energy for electricity generation. Lithuania's Ignalina nuclear power plant has the world's two largest operating nuclear reactors—RBMK-1500s that together are designed to produce approximately 3000 MW of electricity. However, safety concerns and public reaction to the Chornobyl accident prompted authorities to limit plant operation to lower power levels of some 2760 MW. In 2002, the Ignalina plant provided 80.1 percent of Lithuania's electricity. Lithuania has committed to shut down Unit 1 by the end of 2004.

Safety Status

U.S. National Nuclear Security Administration efforts have improved safety at Ignalina NPP. This improved nuclear safety is documented independently in the *Report on Nuclear Safety* by the Western European Nuclear Regulators Association (March 1999); the association's findings are summarized in the following two subsections.

Nuclear Power Plant Safety

Much has been achieved in the ongoing safety improvement program. From the independent safety assessments completed so far, it appears that most of the deviations from Western European requirements could be reasonably addressed or compensated for by a continued safety improvement program. However, fundamental weaknesses remain with respect to the type of accidents and transient events that the plant can handle with high reliability and without unacceptable environmental consequences.

In particular, there are ongoing concerns regarding the lack of an adequate containment and the reliability of the reactor shutdown systems. Although it is likely that many of the plant's safety deficiencies could be addressed by means of a further safety improvement program, the lack of an adequate reactor containment remains a major problem that cannot realistically be solved. This design weakness prevents the Ignalina reactors from being able to achieve standards of safety comparable to those required for older reactors in Western Europe.

Much has been achieved with respect to improvements in operational safety and safety management. In addition, the following concerns should be addressed:

- The financial situation of Ignalina NPP should be improved to provide for all of the necessary safety improvement measures required for the remaining plant lifetime.

- The management structure of Ignalina NPP needs further clarification to ensure the necessary quality and safety culture at all levels.

- The internal communication and experience feedback procedures should be improved in parallel with the implementation of the new QA system.

- Accident management strategies and procedures should be evaluated and further developed.

The national technical support infrastructure is improving but will not be sufficient in the near term. For supply and services, Ignalina NPP will remain dependent on foreign companies. In addition, further Western assistance and Russian consultation will be needed for engineering work.

Regulatory Regime and Regulatory Body

The legal and regulatory system in Lithuania has developed substantially over a short period. However, in the following areas, the system needs further improvement:

- The nuclear law should be clearer about the interfaces among different authorities, and the coordination among these authorities needs to be improved.

- The organizational structure of Ignalina NPP should be changed to ensure that the head of the operating organization/utility is authorized under the Board to handle all safety relevant issues and is provided with the means to take full responsibility for safety.

- The resources of the regulator need to be strengthened to enable it to handle all regulatory issues without foreign assistance.

- Technical support and access to nuclear safety research should be strengthened to provide the regulator with an adequate assessment capability.

- The responsibility for auditing and approving vendors and suppliers should rest with the operating organization and not with the regulatory body.

- The work of the resident site inspectors should shift from detailed inspection to a system in which they audit the activities of the licensee.

Ignalina Nuclear Power Plant

Scope and Status of Activities

Unit	Reactor Model	Net Output	Initial Start	Status
1	RBMK-1500	1380 MWe	10/1983	Operating
2	RBMK-1500	1380 MWe	12/1986	Operating

NNSA's work at Ignalina nuclear power plant includes improving safety of day-to-day operations, upgrading critical safety systems, and transferring capability for performing reactor safety assessments. Projects include developing improved operating procedures and practices (1993-1999); developing a configuration management system (1995-1999); providing modern maintenance tools, equipment, and techniques (1995-1998); transferring capabilities for performing plant safety assessments (1995-2003); and providing up-to-date components for the plant's control-and-protection system (1995-2001).

Unit 1

Ignalina Control and Protection System Upgrade. The design, manufacture, and installation of upgrades to the reactor protection system for Unit 1 were completed in 1998. The upgraded systems substantially reduce the risk of anticipated transients without scram (automatic reactor shutdown), which were found to dominate the risk of operation of the units.

Unit 2

Ignalina Safety Parameter Display System. A safety parameter display system project was completed in 2001 for Unit 2. The U.S. organization Data Systems and Solutions is the equipment designer. The scope of the effort is substantially less than for a typical RBMK safety parameter displays system because the input signals are being provided by a new plant computer system that also was provided by Data Systems and Solutions.

Ignalina Control and Protection System DAZ-2. The design, manufacture, and installation of upgrades to the reactor protection system for Unit 2 were completed in 2000. The upgraded systems substantially reduce the risk of anticipated transients without scram (automatic reactor shutdown), which were found to dominate the risk of operation of the units.

Ignalina Safety System Electronic Module Replacement/Upgrade. Modern electronic instrumentation modules were provided to replace outdated modules at Unit 2. The replacement modules were designed by the U.S. organization NUS Instruments, a subsidiary of Scientech. A total of 300 modules were manufactured. NUS manufactured the first 100 modules. NUS trained staff at the Lithuanian Electromagnetic Compatibility Scientific Research Center (EMC) to manufacture the modules with a level of quality assurance consistent with their safety-class application. EMC then manufactured an additional 200 modules. These modules are now in use at the plant.

All Units

Ignalina RBMK Emergency Operating Instructions (EOIs). The Ignalina NPP staff has developed a full set of symptom-based emergency procedures for the plant. All the operators have been trained on the use of these procedures and the procedures are now in use at the plant.

Ignalina Training Technology Transfer. Training technology and materials developed at the Russian Balakovo and Ukrainian Khmelnytskyy training centers are being transferred to the Ignalina plant. Technology transfer is scheduled to be completed in 2003. Pilot courses for Control Room Reactor Operators, Radiation Protection Technicians, and Mechanical Maintenance have been transferred. Training workshops on computer-based training, on-the-job training, and hoisting and rigging are also complete.

Barselina Peer Review – PRA Ignalina RBMK-1500s. A peer review was conducted on the initial phase of the probabilistic risk assessment for the Ignalina plants.

Ignalina Nuclear Plant Safety Analysis Capability. Ignalina NPP in-depth safety assessment work began in May 1995 and focused on improving operational nuclear safety of the plant. With United States assistance, plant staff and supporting organizations received hardware, software, and necessary training that enabled them to develop an independent and enhanced analytical capability.

This analysis capability obtained through training and code technology transfer supports the development of nuclear power plant models to evaluate design changes so that the host-country institutions can perform independent safety assessments in support of the plant operation and the Safety Assessment Report.

During 2001, significant progress was made in the assessment of whether or not pipe vibration in the group distribution header of Ignalina could propagate into a more serious accident. The preliminary analyses indicate that such a propagation of failures is unlikely.

Planned work through 2003 includes completing a structural integrity assessment of the Ignalina steam distribution header, the transfer of technology for the Lithuanian Energy Institute to be able to analyze impact events on buildings and structural members, and the analysis of several Ignalina transients to further validate a RELAP5-3D coupled neutronics/thermo-hydraulics model for the plant.

Experts at the Lithuanian Energy Institute and the Kaunas University of Technology have been trained in the use of the NEPTUNE and TEMP-STRESS code for the assessment of structural integrity of Ignalina systems and components.

Ignalina RBMK Safety Maintenance Technology Transfer and Training. The United States provided up-to-date tools and training for maintenance workers to help reduce equipment malfunctions at Ignalina's RBMK reactors. Types of tools include pipe lathe/weld-preparation machines, valve-seat resurfacing equipment, vibration monitoring and shaft alignment systems, and insulation analysis equipment.

Ignalina NPP DC Power Supply System. A study was conducted to evaluate the safety need for improving the DC power supply. It was decided not to proceed with this activity because of the relatively low safety need and other high-priority activities.

Ignalina Configuration Management Support. A configuration management system was developed and implemented.

Ignalina Industry Workshops. A workshop on "Preventative and Predictive Maintenance in NPP Operation" was held at the Ignalina NPP in April 1996. Another workshop on "Safety Culture in the Operation of Nuclear Power Plants" was held in Visaginas, Lithuania, in May 1997.

Lithuania Commission for Nuclear Safety. NNSA maintains representation on the Lithuanian Commission for Nuclear Safety. The international members of the commission review operation and proposed safety improvements at Ignalina NPP.

Ignalina Communications Network Needs Analysis. A study was performed to determine needed improvements with the communications capabilities (voice and data transfer) for Ignalina NPP during normal and emergency conditions.

Ignalina Source Book. This book has been updated. It documents the plant's reactor and primary safety systems and describes the way plant components interact during normal and abnormal operating conditions.

Ignalina Probabilistic Risk Assessment Program Capability. The Ignalina NPP safety analysis group was provided with software, computer hardware, and training for the Probabilistic Risk Assessment IRRAS program to improve the plant's ability to self-assess risks at its facility.

Ignalina Expert Assistance Positive Void Coefficient. During a workshop in Lithuania, Western specialists shared technical expertise related to a computer code analyses of positive void phenomena.

Ignalina RBMK-1500 RELAP5 Model Development. A deterministic model was developed and verified of the primary systems of the reactor plant capable of calculating selected transients with reactor scram (automatic reactor shutdown). Training in the use of this deterministic model also was provided.

Ignalina Nuclear Plant Analyzer Hardware. Hardware and training required to implement a nuclear plant analyzer were provided. A nuclear plant analyzer allows management and operators to manipulate a deterministic plant model in investigations of "what-if" scenarios for the facility.

Ignalina Pressure Tube Gap Closure. Work was completed to determine if the stresses versus design margins are sufficient to cause failure of an RBMK channel during anticipated operational conditions. This data will assist the plant in better understanding its design basis and associated operational restrictions.

Lithuania Code Validation, CHF Correlations. Code assessment analyses of four Ignalina benchmark problems were completed using the STEPAN and RELAP5-3D codes. A comparative assessment report was prepared documenting the code-to-code comparisons as well as comparisons to Ignalina plant data.

Lithuanian Y2K Support. An Ignalina expert received training in the use of an automated software tool for evaluating source code for Y2K vulnerabilities, and workstation licenses for use at each Unit were provided. The plant used the tool to verify the manual review and testing already completed at the facility. Lithuanian experts also participated in various Y2K Information Exchange and Contingency Planning meetings sponsored by DOE.

Slovakia

Slovakia operates four VVER-440 reactors at Bohunice: Two VVER-440/230s (Units 1 and 2 – V1) and two VVER-440/213s (Units 3 and 4 – V2). In 2002, Bohunice NPP supplied 65.4 percent of Slovakia's electricity. Two VVER-440/213s are located at the Mochovce site. Mochovce Unit 1 was placed in operation in June 1998. Mochovce Unit 2 was placed in operation in December 1999. Since the two reactors at Mochovce have just recently been completed and many safety upgrades were included during construction, no U.S. assistance is planned for the Mochovce plant.

In 1991, the Czechoslovakian government launched a major program to upgrade Bohunice Units 1 and 2. That program was continued under the Slovakian government.

Safety Status

U.S. National Nuclear Security Administration efforts have improved safety at the Bohunice NPP. This improved nuclear safety is documented independently in the *Report on Nuclear Safety* by the Western European Nuclear Regulators Association (March 1999); the association's findings are summarized in the following two subsections.

Nuclear Power Plant Safety

Compared with the original design, the safety of Bohunice Units 1 and 2 has been greatly improved. However, the adequacy of the confinement remains a key issue, and the confinement would probably not mitigate the consequences of large loss-of-coolant accidents and severe accidents consistently with current Western practices for plants of the same vintage.

Due to a lack of information, the current and planned level of safety of Bohunice NPP cannot be fully assessed.

Once the planned improvements are complete, the safety of Mochovce units will be comparable with that of Western plants of the same vintage.

Regulatory Regime and Regulatory Body

The Slovak Republic has taken the appropriate steps to establish a regulatory regime and regulatory body (UJD) according to the principles adopted in Western Europe. Nevertheless, the following improvements are still necessary:

- The relationships need to be clarified between the UJD and the authority in charge of radiological protection.

- The relationships need to be clarified among the different governmental organizations involved in emergency preparedness and planning.

- The budget of the UJD needs to be increased to allow full independent technical assessment capability and to retain expert staff.

The UJD should devote necessary resources and priorities to the continued development of regulations under the Atomic Act and to enhance independent safety assessment capabilities.

Bohunice Nuclear Power Plant

Scope and Status of Activities

Unit	Reactor Model	Net Output	Initial Start	Status
1	VVER-440/230	408 MWe	11/1978	Operating
2	VVER-440/230	408 MWe	03/1980	Operating
3	VVER-440/213	408 MWe	08/1984	Operating
4	VVER-440/213	408 MWe	08/1985	Operating

NNSA's projects at Bohunice nuclear power plant have focused primarily on improving safety of day-to-day operations. Projects include development of improved operating procedures and practices, including enhanced training for personnel, adoption of symptom-based emergency operating instructions (EOIs), and simulator upgrades. A second key area is the development of indigenous capabilities to conduct plant safety assessments (1993-2001). Projects also involve the Trnava Training Center, the training facility for plant workers located in Trnava, Slovakia.

Bohunice Units 1 and 2

VUJE (V-1) Compact Simulator Upgrade. The displays of this V-1 simulator were upgraded in 1996 and 1997.

Bohunice VVER-440/230 Plant Safety Analysis Capability. Assistance was provided and technology transferred in the areas of computing hardware, software, and training to develop an independent, enhanced, analytical capability at the plant and at its technical support organization, with the intent of improving the plant's safety evaluation capabilities and infrastructure.

Bohunice Units 3 and 4

Trnava Training Center (V-2) Full-Scope Simulator Upgrade. This project upgraded the VVER-440/213 multi-functional simulator into a full-scope simulator that models Bohunice Units 3 and 4. This simulator is at the Trnava Training Center, which is operated by VUJE, Slovakia's Nuclear Power Plant Research Institute. U.S. involvement in the upgrade was completed in spring 2002.

Bohunice Risk Advisory System (RAS). NNSA sponsored the acquisition of, and training on, SAIC's R&R Workstation's RAS EOOS module. This software allowed the plant and host-country support organizations to implement the plant's PRA model in the provided RAS. The software-based RAS is used by Bohunice staff to evaluate how the unavailability of certain plant components affects safety. The project is complete and no further activities are planned.

Bohunice All Units and Slovakia Crosscutting

Trnava Training Center Upgrade Support. Work to transfer the Systematic Approach to Training methodology was initiated in 1997. As part of this program, a pilot training program for training instructors was developed and implemented. Instructor skills and simulator-instructor training also were provided for the Trnava Training Center.

Bohunice Emergency Operating Instructions (EOIs). Specialists from Bohunice NPP participated in the VVER-440/213 EOI Working Group that transferred the symptom-based emergency procedure methodology. Bohunice decided to pursue the development of their EOIs on their own (with assistance from Westinghouse). They have currently implemented the EOIs at Units 3 and 4 (V2) and are in the process of developing their EOIs for Units 1 and 2 (V1).

Bohunice Control Systems Upgrade Study. In 1993, DOE supported an assessment of needed upgrades for the Bohunice plant instrumentation and control system.

Slovak ANL Industry Workshops. A workshop on "Safety Licensing Aspects of Modifications and Engineering Support in the Operation of Nuclear Power Plants" was held in Trnava, Slovakia, in January 1996.

Bohunice Safety Parameter Display System (Planning). In 1999, a workshop was held in the United States to develop a joint program with Bohunice NPP to provide a safety parameter display system for Bohunice Unit 3. The U.S. financial contribution would primarily be related to the cost of hardware and system design support. The Slovakians would subsequently purchase the same system for Unit 4 with only minor contribution from the United States. Because of funding limitations, it was decided not to pursue this project.

Slovak Code Transfers (PACER and NEPTUNE). In 1997, two confinement analysis codes (PACER and NEPTUNE) were adapted for use at VVER-440/230s. U.S. staff trained Slovakian specialists in how to use the codes to analyze the effectiveness of proposed upgrades.

Slovakia Y2K Support. Slovakian experts participated in various Y2K Information Exchange and Contingency Planning meetings sponsored by DOE. The meetings included exchange of information between plants concerning their Y2K program efforts as well as seminars about contingency planning.

Mochovce Nuclear Power Plant

Scope and Status of Activities

Mochovce Units 1 and 2, upgraded VVER-440/213 reactors, were started up in June 1998 and December 1999, respectively. Many safety upgrades were incorporated during the construction of these units, so no assistance to Mochovce is planned. However, staff from Mochovce did participate in several of the activities supporting Bohunice NPP.

Unit	Reactor Model	Net Output	Initial Start	Status
1	VVER-440/213	408 MWe	06/1998	Operating
2	VVER-440/213	408 MWe	12/1999	Operating
3	VVER-440/213	-	Under Construction[(a)]	
4	VVER-440/213	-	Under Construction[(a)]	
(a) Completion of construction of Units 3 and 4 is still under consideration.				

Armenia

Armenia NPP is participating in NNSA's cooperative program (Figure 3). In 2002, Armenia Unit 2, the only operating reactor, produced 40.5 percent of the total electricity generated in Armenia. Projects to improve fire safety and upgrade safety systems at the plant are under way with U.S. support.

Figure 3. Nuclear Power Plant in Armenia Participating in the U.S. Program to Improve Nuclear Safety

Summary of Safety Status

The Armenian Nuclear Regulatory Authority (ANRA) is slowly developing its role as an independent nuclear regulator in Armenia. Neither the plant, the regulator, nor the Ministry of Energy foresees the permanent shutdown of Unit 2 for several years, despite earlier government assurances of a 2004 closure. The strong dependence of Armenia on reliable electrical power from the Armenian NPP weakens ANRA's regulatory authority to impose safety requirements. ANRA recently issued guidelines for the development of a Safety Analysis Report to justify the continued operation of Unit 2. The plant has limited resources (expertise, manpower, and finances) to complete such a report and is relying heavily on Western assistance.

The current NNSA program to develop safety assessment capability in Armenia is focused on deterministic analyses of the plant. This represents only a small portion of the Safety Analysis Report effort facing the power plant. The plant also is relying on assistance from the IAEA and the European Union's TACIS program to complete this safety analysis.

Armenia Nuclear Power Plant

Scope and Status of Activities

NNSA's cooperative efforts at Unit 2, the only operating reactor at Armenia NPP, have focused primarily on fire-safety improvements and safety-systems upgrades—two of the most critical safety deficiencies at the plant. Projects associated with these efforts were initiated in late 1996 and are scheduled to be completed during 2005. Projects to address needs in operational safety, safety maintenance, and safety assessment capability were undertaken in 1998. In 1999, a decommissioning planning project was initiated. The U.S. Agency for International Development is providing the funding for the safety work in Armenia.

Unit	Reactor Model	Net Output	Initial Start	Status
1	VVER-440/230	410 MWe	12/1976	Shut Down 1989
2	VVER-440/230	410 MWe	12/1979	Operating

Armenia Unit 2

Armenia Fire Safety Upgrades. The following fire-safety upgrades have been implemented:

- Fire-resistant floor-coating material was provided to replace the plant's original flammable plastic floor covering. In 1998 and 1999, the coating was applied to all areas affecting nuclear safety. U.S.-trained plant personnel carried out the application process.

- 145 fire doors were provided to the plant and installed. The doors were manufactured by the Russian organization Atomremmash in Kursk, Russia.

- An air compressor was provided for charging self-contained breathing-apparatus cylinders for the fire brigade.

A new fire detection and alarm system was installed, programmed, and tested in the plant in 2000. In 2001, automatic actuation of fire-response systems (e.g., spray systems) was transferred to the new system.

Armenia Safety Parameter Display System. A safety parameter display system, designed by Data Systems and Solutions, was installed in 1999. The system is fully operational.

Armenia Nuclear Safety Council. NNSA sponsors participation of a U.S. representative on the Armenian President's Council on Nuclear Safety. The international members of the council review operations and proposed safety improvements of Armenia NPP and advise the Armenian President.

Armenia Safety Analysis Capability. A RELAP5 thermal-hydraulic model was completed and design basis accident analysis calculations carried out with the model. Design documentation for a selected list of safety-relevant systems will be carried out and completed by early 2003. Beyond design basis accident analyses will be completed for the RELAP5 model by the end of 2003. Assistance in selected areas of the development of a Safety Analysis Report by Armenia NPP to conform with guidance from ANRA will be provided during 2002 and 2003. Safety analysis work carried out for Armenia NPP will be coordinated with the IAEA, the (Italian) SOGIN Company, and the (British) SERCO Assurance Company. IAEA is supporting confinement analysis and the other two organizations are supporting a PRA for Armenia NPP.

Armenia Nuclear Service Water System. The United States has provided equipment and supported construction activities to complete a seismic-resistant, spray-pond cooling system to remove heat loads from safety systems. System completion, including tie-in to the plant, integral testing, and commissioning, was completed in 2000. In 2001, a dust-control system was designed and implemented in 2002.

Armenia Auxiliary Feedwater System. Installation and testing of a diesel-driven emergency water supply pumping system to serve as a backup to the emergency feedwater system was completed in 2001.

Armenia Main Steam-Line Isolation Valves. Fast-acting main steam-isolation valves have been provided to mitigate potential steam-line breaks and prevent the possibility of a serious accident involving overcooling and brittle failure of the reactor vessel. The valves were manufactured by Hopkinson Ltd. in England and the valve actuators were manufactured by the U.S. Company Enertech. The valves and automatic actuation system were installed in the plant and tested in 2000.

Armenia Training Equipment and Support. Cooperative efforts with Armenia and the International Atomic Energy Agency to develop a training center and training support were started in 1997 and are expected to be completed by 2005. Training specialists at the Armenia Training Center received training on the Systematic Approach to Training methodology and instructor skills. Transfer of pilot courses for Control Room Reactor Operator, Radiation Protection Technician, and Reactor Equipment Maintenance Shop has been completed. Transfer of the course for the Chemistry Department Shift Supervisor was completed in 2001, as well as implementation of the on-the-job training program. Training has been provided on the use of the simulator in emergency preparedness exercises.

Armenia Piping and Vital Equipment Integrity. The transfer of safety maintenance technology, which was started in 1998, was completed in 2002. Equipment for ultrasonic testing, vibration monitoring, thermographic analysis, pump-shaft alignment, in situ valve repair equipment, and equipment to test for degradation of transformer oil has been provided. Valve-condition monitoring equipment has been provided.

Armenia Turbine Generator and Reversible Motor Generator Upgrades. Four reversible, motor-generator sets are being provided to improve the reliability of emergency AC power in the event of loss of station power. These sets are installed.

Two sets of turbine shaft seals are being provided to reduce the potential for hydrogen leakage and a fire or explosion hazard. The upgrade is being made in response to a safety notice issued by the Russian utility, Rosenergoatom. These sets have been installed.

Armenia Emergency Condenser. The coils of two emergency condensers were replaced in 2001 with stainless-steel coils. The tubes in the original bundles were badly corroded. The condensers are needed to replace makeup water for the steam generators in an accident involving loss-of- heat removal capability.

Armenia Circuit Breakers. Four hundred low-voltage (220-V) circuit breakers were provided to the plant in 2001 to replace unreliable breakers that are a potential source of cable fires.

Armenia Security Systems. Physical security upgrades include an improved access control system for internal and external limited access and vital areas, improved physical barriers, intrusion detection, alarm and surveillance system, and central alarm station. The project will also provide, as necessary, security personnel training in the use of hardware and software, and appropriate procedures. Upgrades are planned to be completed in 2005.

Armenia Safety System Upgrades. It is anticipated that the safety analysis activities will identify some additional safety system upgrades to address specific deficiencies.

Armenia Seismic Upgrades. In 1999, 2000, and 2001, teams of U.S. seismic specialists provided training and participated in seismic walkdowns of Armenia NPP. These walkdowns have identified some deficiencies in the support of vital equipment. Starting in 2004, it is planned to assist the plant in correcting these deficiencies, typically by the addition of seismic bracing.

Armenia Plant Computer Upgrade. The plant control and information system is being upgraded as an extension of the safety parameter display system. The new system was assembled and factory acceptance-tested in 2002 and are to be installed in 2003. Also, in 2003, the in-core monitoring system will be replaced.

Armenia NPP Decommissioning Planning. In 1999, assistance was started for the development of a decommissioning plan.

Armenia Operational Procedures. Assistance has begun to upgrade the existing operational procedures at Armenia NPP. Funding for this project is anticipated through 2005.

Armenia Emergency Response. Technical support and assistance will be provided to improve the emergency planning and response capabilities of the Armenia NPP. Four high-temperature and radiation-resistant suits were provided to the plant in 2001.

Armenia International Nuclear Safety Center. Beginning in late 2001, an Armenia International Nuclear Safety Center (INSC) is being established at the ARMATOM Institute. This center will conduct research and coordinate activities related to Soviet-designed reactors and provide this information to other Armenian and international agencies. Office space has been set aside and personnel have been assigned for this effort, and a capable computer network is in the process of being configured and put into operation to support INSC activities. The establishment of an Internet connection will provide for closer collaboration and information exchange within the country as well as internationally.

Armenia Y2K Support. The most pressing identified Y2K issues at the plant were remediated. This included the in-core monitoring system, plant security system, and the telecommunications system. Armenian experts participated in various Y2K Information Exchange and Contingency Planning meetings sponsored by DOE.

Armenia Project Management. Overall program management services were provided including program planning, financial control, project oversight, development and implementation of infrastructure control systems, procurement assistance, travel logistics, protocols customs support, and performance reporting.

Armenia Regulatory Capabilities

Radioactive Source Control. In 2001, the responsibilities of the Armenian Nuclear Regulatory Administration were extended to include the implementation of a program to control sealed radioactive sources. In 2002 and 2003, the United States is transferring technology and equipment to support this activity.

Kazakhstan

NNSA reactor nonproliferation and nuclear safety efforts in Kazakhstan are related to the BN-350 fast breeder reactor in Aktau. The BN-350 is the country's only nuclear power plant (Figure 4). Most of the energy produced by the Aktau BN-350 plant's reactor was used to operate a desalination plant. An additional 135 MW of electricity was distributed to the Kazakhstan grid. The plant produced plutonium for the former Soviet Union's weapons complex.

Figure 4. Nuclear Power Plant in Kazakhstan Participating in the U.S. Program to Improve Nuclear Safety

Summary of Safety Status

In April 1999, Kazakhstan announced a decision to shut down the plant, and the plant is no longer producing power. U.S. technical and financial assistance is directed toward safely and irreversibly shutting down the plant so it is incapable of producing additional weapons-grade nuclear materials.

Aktau BN-350 Nuclear Power Plant

Scope and Status of Activities

Unit	Reactor Model	Net Output	Initial Start	Status
1	BN-350	135 MWe	07/1973	Shut Down 1999

NNSA involvement in Aktau nonproliferation and nuclear safety activities support the irreversible shutdown of the BN-350 Breeder Reactor. In addition to the NNSA involvement, this work is supported by the European Union through the TACIS program, and by other countries via bilateral agreements with Kazakhstan, as well as host country support. The funding provided by the NNSA supports engineering and technical assistance for the U.S. efforts, and leverages additional funds provided through other sources, such as the International Science and Technology Center (ISTC) and State Department Nonproliferation and Disarmament Fund (NDF).

The work supporting the irreversible shutdown of the BN-350 includes decontaminating and draining the sodium coolant; deactivating the bulk and residual sodium coolant; plant safety modifications, such as fire safety and radiation monitoring upgrades; and assisting in the decommissioning planning efforts.

Aktau BN-350 Unit 1

Aktau Shutdown and Decommissioning. Key accomplishments related to decommissioning include:

- **Decontamination and Draining of the Sodium Coolant.** In 2001, an integrated design team from Kazakhstan and ANL was formed to complete the design of a system to drain the primary and secondary sodium coolant from the reactor. Decontamination and draining should be completed by 2004.

- **Deactivation of the bulk and residual coolant.** In 2001, design work began to develop a system to deactivate the bulk sodium coolant. This system will be operational in 2005. In 2002, design work began to develop a system to deactivate in situ the remaining sodium in the primary system.

- **Development of a Decommissioning Plan.** In 2001, the draft-decommissioning plan was completed. The final decommissioning plan is undergoing international peer review.

- **Fire Protection.** 8.5 metric tons of fire protection equipment was delivered to the BN-350 reactor in 1999.

Kazakhstan Nuclear Technology Safety Center (NTSC). The United States provides necessary computer and management support for the NTSC. The NTSC is currently performing independent safety analyses of the country's nuclear facilities and manages in-country projects for irreversible shutdown of the BN-350, including the NDF project.

Kazakhstan Sources. In 2003, assistance will be provided to help the Kazakhstan specialists implement a program to control sealed radioactive sources.

Kazakhstan Y2K Support. Y2K assistance included inventory and vulnerability assessment of all computer equipment and conversion of the plant information system to a Y2K compliant platform. Kazakhstan experts participated in various Y2K Information Exchange and Contingency Planning meetings sponsored by DOE.

Kazakhstan Project Management. Overall program management services were provided including program planning, financial control, project oversight, development and implementation of infrastructure control systems, procurement assistance, travel logistics, protocols customs support, and performance reporting.

Russian Nuclear Power Plants

In Russia, NNSA is conducting safety projects at 10 nuclear power plants with a total of 30 nuclear reactors. Together, these reactors produce 16 percent of Russia's electricity. The locations of the 10 nuclear power plants in Russia and the type of reactors at each plant are shown in Figure 5.

Figure 5. Nuclear Power Plants in Russia Participating in the U.S. Program to Improve Nuclear Safety

Summary of Safety Status

The U.S. National Nuclear Security Administration (NNSA) efforts through 2002 have improved safety at 30 Soviet-designed nuclear power reactors in Russia. Projects are correcting major safety deficiencies. Equipment, technology, and processes vital to the safe operation of nuclear power plants have been transferred to Soviet-designed nuclear power plants and host-country nuclear organizations. Plant operations and institutional procedures now more closely approach internationally recognized practices.

As shown in Figure 6, one indication of improved nuclear plant safety in Russia is the decreased number of safety events since the program's inception in 1992.

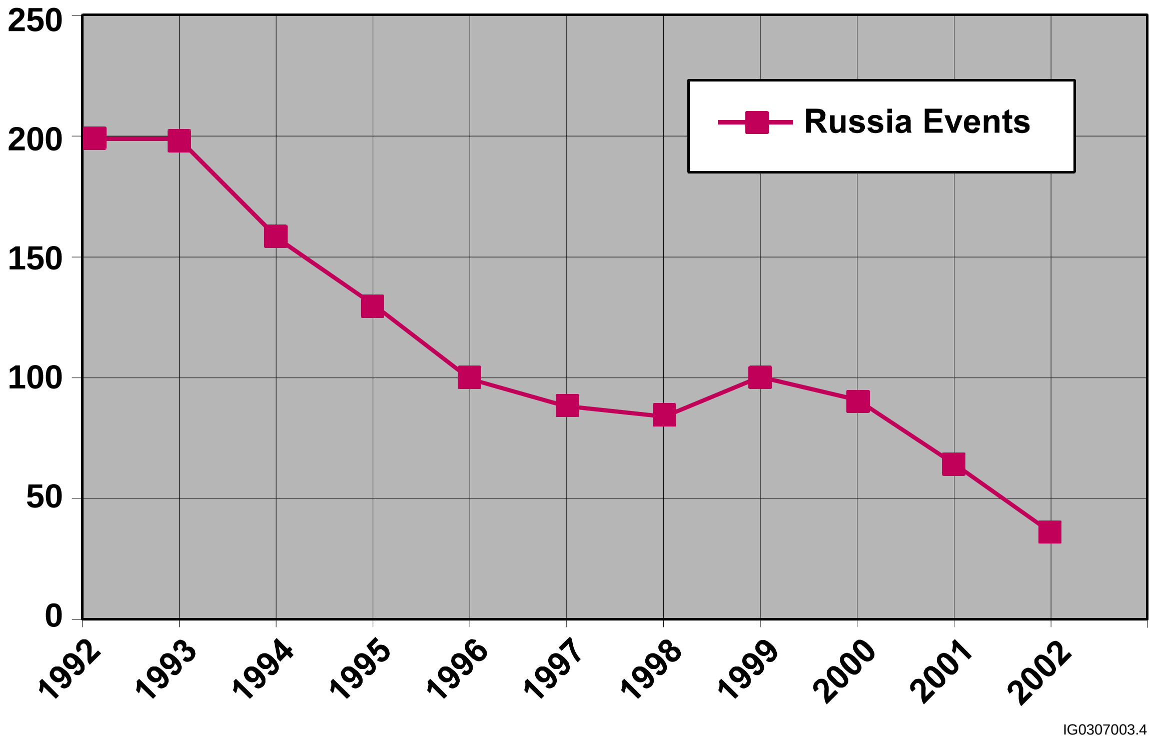


Figure 6. Safety Events at 30 Soviet-Designed Reactors in Russia from 1992 though 2002

During 2002, progress toward achieving program objectives continued. Several long-term projects were completed; other projects are nearing completion, with closeout of all projects expected in 2003. However, three major obstacles continue to impede progress in Russia.

First, the Russian nuclear power plants are still having problems financing their portion of the safety upgrades. For example, the Kalinin NPP was responsible for financing the software portion of the Unit 2 full-scope simulator. However, because the plant had difficulties paying VNIIAES (the Russian simulator developer), the project was delayed.

Second, the Russian nuclear power plants still rely heavily on the design institutes for providing or developing safety information with often-minimal input or interaction with the plants. In addition, the inability for Western organizations or experts to review the details of the analysis and the input parameters makes it difficult to validate the Russian results. An example is the in-depth safety assessment at Novovoronezh Unit 3. The Russian utility Rosenergoatom (REA) has made the decision to use Russian design institutes to perform the analyses with minimal input from the plant.

Third, in early 1999, the United States imposed sanctions against NIKIET, the general designer of the RBMK reactor. Because NIKIET was involved heavily in several DOE safety improvement projects (e.g., in-depth safety assessments, safety parameter display systems), these projects were placed on hold or canceled.

Balakovo Nuclear Power Plant

Scope and Status of Activities

Unit	Reactor Model	Net Output	Initial Start	Status
1	VVER-1000	950 MWe	12/1985	Operating
2	VVER-1000	950 MWe	10/1987	Operating
3	VVER-1000	950 MWe	12/1988	Operating
4	VVER-1000	950 MWe	03/1993	Operating
5	VVER-1000	950 MWe	Construction Suspended	
6	VVER-1000	950 MWe	Construction Suspended	

Operator training is a key factor in improving the safety of day-to-day operations. At the Balakovo nuclear power plant, a major NNSA effort has been to establish the Balakovo Training Center, a fully equipped training facility at which reactor operators from other Russian reactors have been trained in the Systematic Approach to Training methodology (1993-1998). Center specialists have developed job-specific and general safety-related courses for use at the center and at other Russian reactors. Other major projects are focused on developing improved operating procedures and practices (1993-2002) and providing an analytical simulator and upgrading a full-scope simulator to enhance the effectiveness of training (1995-1999).

Balakovo Unit 1

VVER 1000 In-Depth Safety Assessment. An in-depth safety assessment is planned to be provided within the context of the plutonium disposition program.

Balakovo All Units

Russian Training Program Development. To date, more than 3000 nuclear power plant workers have received training at the center. Personnel at the center were trained on the Systematic Approach to Training. Twelve job-specific maintenance and operations courses, plus six courses on general safety topics, were developed and conducted at the center.

Russian Training Program Specific Equipment. Equipment provided to support these courses included motor-current test units, Heathkit electronics training equipment, Pace soldering stations, a reactor-head mock-up, radiation-measurement equipment, flange-bolt-torquing demonstration equipment, chemical-laboratory equipment, and laser-alignment equipment.

Balakovo Training Center Basic Equipment. A fully equipped nuclear power plant training center was established at the Balakovo plant site. Equipment provided included scanners, photocopiers, printers, fax machines, personal computers, office furniture, whiteboards, and overhead projectors and screens.

Russia Special Training Courses. Training, such as the systematic approach to training, was provided to teach instructors. Other courses delivered included general employee training and supervisor training.

Russia Training Technology Transfer. Balakovo staff has helped transfer these courses and capabilities to other Russian nuclear power plants.

Balakovo VVER-1000 Emergency Operating Instructions (EOIs). Balakovo plant staff completed their second draft of a full set of EOIs, and preliminary verification is in progress. Additional analyses are necessary to completely validate the EOIs.

Russia Pronet Software and Training. To facilitate the development and maintenance of EOIs along with other operating procedures, the U.S. provided the Pronet software and training on the use of the software to help modify and maintain procedures up to date.

Balakovo Unit 4 Full-Scope Simulator Upgrade and Analytical Simulator. An analytical simulator with a complete model for Unit 4 was developed for Balakovo in 1999, and its full-scope simulator has been extensively upgraded.

Balakovo Simulator Maintenance Course and Tools. Balakovo NPP developed a full-scope simulator with their own funds but did not have the infrastructure to effectively maintain or modify the simulator. Therefore, the Balakovo training center personnel were provided courses in simulator hardware and software maintenance. The training center also received the necessary equipment to allow them to perform hardware maintenance.

Russia Simulator Training and Engineering Support. The Simulator Training and Engineering Support project will continue to provide spare parts and simulator training through 2003.

DC Power Supply Technology Transfer. Following the successful upgrade of DC power supplies at Kola NPP and Kursk NPP, a study was initiated in fiscal year 1998 to determine the demand for replacement DC batteries at all of the Russian nuclear plants and to evaluate the potential for in-country manufacture of safety-grade batteries. The study indicated that most of the older batteries had been or were in the process of being replaced by Western batteries.

Russia Reliability Database. Balakovo NPP is a pilot plant for the implementing modules to be used at the plants for the collection, use, and sharing of reliability data from all nuclear power plants in Russia.

Installation of the servers, local network, and communications equipment for the Russian reliability database for all Russian nuclear power plants has been completed. Tasks have been assigned for the development of software for data analysis and installation of the reliability database at Balakovo and the other two pilot plants (Kursk and Kola).

Russia Nondestructive Examination. The project, completed in 1999, provided nondestructive examination equipment and associated training to the plant.

Russia VVER Code Assessment. Work continued in the systematic evaluation to assess the adequacy and applicability of computer codes in the safety analysis of VVER reactors. A report is being prepared summarizing the RELAP5 code assessment activity which has occurred over the past several years; this report may identify areas where additional work would be worthwhile in the future years. Other projects provide host-country organizations with computer codes needed to perform in-depth safety assessments. The technology transfer for safety analysis is not complete with code transfer itself, but also requires transfer of the methodology and analytical capability to ensure that the safety analysis codes and methods are applicable and adequate for the plants being analyzed.

Russia Management & Operational Safety Practices. A complete set of guidelines for preparing management and operational control procedures was developed and implemented at the plant in 1995. The guidelines promote safety through improved operating practices. These guidelines have been transferred to other Russian nuclear power plants.

Beloyarsk Nuclear Power Plant

Scope and Status of Activities

At Beloyarsk nuclear power plant, NNSA projects included improving the training of plant managers and operators (1996-1998). Planned U.S. safety assistance at Beloyarsk NPP is complete. Additional safety improvements are anticipated to be done over the next several years primarily by the plant and by support from other countries.

Unit	Reactor Model	Net Output	Initial Start	Status
1	AMB-100	102 MWe	04/1964	Shut Down 06/1981
2	AMB-200	146 MWe	12/1967	Shut Down 01/1989
3	BN-600	560 MWe	04/1981	Operating
4	BN-800	750 MWe	Construction Suspended	

Beloyarsk Unit 3

Russia Training Technology Transfer. The transfer of the Systematic Approach to Training methodology and training materials developed at the Balakovo Training Center was completed at the Beloyarsk plant. Instructors from the plant were trained in the methodology and in instructor skills. A pilot course on sodium pump repair was implemented with assistance from U.S. and Balakovo NPP training specialists. Basic training equipment was provided for the development and support of training materials at the plant. This equipment included computers, software, printers, a photocopier, office furniture, binding machines, whiteboards, overhead projectors, and projector screens.

Bilibino Nuclear Power Plant

Scope and Status of Activities

NNSA is supporting efforts to improve the safety of day-to-day operations at Bilibino nuclear power plant. NNSA projects have been focused primarily on improving training for plant staff (1996-1998); providing an analytical simulator to enhance training effectiveness (1997-2000); providing safety maintenance equipment and technology (1998-2001); and establishing improved communication links with Moscow and with the Alaskan Emergency Response Office.

Unit	Reactor Model	Net Output	Initial Start	Status
1	LWGR	12 MWe	12/1973	Operating
2	LWGR	12 MWe	12/1973	Operating
3	LWGR	12 MWe	12/1975	Operating
4	LWGR	12 MWe	12/1976	Operating

Bilibino All Units

Bilibino Analytical Simulator. An analytical simulator was developed for the unique design of the Bilibino NPP. This project started in 1997 and was completed in 2000. The simulator has been accepted by the regulator and is being used for the training of reactor operators and supervisors.

Bilibino Safety Maintenance Technology Transfer and Training. Maintenance training classes on reactor protective circuit boards were completed. Additional maintenance equipment (thermography, valve repair, vibration monitoring, and laser alignment) and training was provided in 2001. Modifications were made to an existing facility to provide a maintenance-training classroom.

A satellite-based communication system was provided to Bilibino in 1999 to improve communications between the plant, located in an extremely remote area of Russia, and the outside world.

Russia Training Technology Transfer. The Systematic Approach to Training methodology and training materials developed at the Balakovo Training Center have been transferred to the Bilibino plant. Instructors from the plant have been trained in the methodology and in instructor skills. Pilot courses for shift supervisors and instrument and control technicians have been implemented.

Russia Simulator Training and Engineering Support. Simulator exercise guides have been developed for the plant and the training personnel have received instruction in how to effectively use their analytical simulator. The Simulator Training and Engineering Support project will continue to provide spare parts and simulator training through 2003.

Russia Nondestructive Examination. Nondestructive examination equipment and associated training were provided to plant personnel.

Russia Reliability Database. Bilibino NPP was planned to be a follow-on plant for the Russian Reliability Database. However, after review it was decided that the equipment and systems at Bilibino were significantly different than those in use at the RBMK and VVER reactors, thus there would be little benefit in sharing this data.

Alaskan Risk from Russian Reactors. Plant engineers attended a corrosion workshop in Alaska that focused on the unique aspects of corrosion in cold-weather environments. Support is being provided to the University of Alaska to monitor radiation levels and to improve the understanding of the native Alaskans relative to the risks of radiation from Bilibino and other potential sources.

Kalinin Nuclear Power Plant

Scope and Status of Activities

NNSA's efforts at Kalinin nuclear power plant focus primarily on improving the safety of day-to-day operations. Projects include improving the training of plant management and staff (1996-1998) and providing a full-scope simulator to enhance the effectiveness of training (1995-2002).

Unit	Reactor Model	Net Output	Initial Start	Status
1	VVER-1000	950 MWe	04/1984	Operating
2	VVER-1000	950 MWe	11/1986	Operating
3	VVER-1000	950 MWe	Under Construction	
4	VVER-1000	950 MWe	Construction Suspended	

Kalinin All Units

Kalinin Unit 2 Full-Scope Simulator. Key hardware components; including computers, an input/output system, and control panels for the Kalinin Unit 2 VVER-1000 full-scope simulator have been provided. The simulator was assembled, tested, and turned over to the plant in August 2002.

Control System Testing Technology Transfer. Work began in 1999 to develop a facility for testing digital control system modifications for Russian nuclear power plants on the VNIIAES simulator before installing them in operating plants. The prototype system tested in this project is a control system for the special water-purification system at Kalinin NPP. The Russian company Omsk Avtomatika designed and manufactured a new digital control system for one of the modules of the upgraded water purification system. A simulator model was prepared for this system at the VNIIAES facility. The control system was delivered to VNIIAES, assembled, and interfaced with the simulator model of Kalinin's special water-purification system. A series of tests were performed to demonstrate the ability of the new control system to properly control the water purification system. This project, which was completed in 2002, not only demonstrated the practicality of performing simulator validation of digital control systems, but also provided an opportunity for the Russian design organization to obtain experience in the design and manufacture of modern digital control systems.

Russia Nondestructive Examination. The project to provide nondestructive-examination equipment and associated training to the plant was completed during 1997.

Russia Training Technology Transfer. The Systematic Approach to Training methodology and training materials developed at the Balakovo Training Center were transferred to the Kalinin plant. Instructors from the plant were trained in the methodology and instructor skills. Pilot courses on motor-operated valves and laser shaft-alignment were developed and implemented. In conjunction with the laser shaft-alignment course, laser shaft-alignment equipment was provided and is being used for plant operations.

Russia Simulator Training and Engineering Support. The Simulator Training and Engineering Support project will continue to provide spare parts and simulator training through 2003.

Russia Reliability Database. A centralized database for collecting reliability data from the nuclear power plants in Russia has been developed. Kalinin NPP will be a follow-on plant for implementation of modules to be used at the plants for the collection, use, and sharing of this information.

Kalinin Local Crisis Center. The United States assisted in developing specifications and criteria for this local center and provided equipment for its operation.

Kola Nuclear Power Plant

Scope and Status of Activities

NNSA efforts at Kola nuclear power plant are directed primarily toward improving the safety of day-to-day operations and upgrading critical plant safety systems. Projects focus on developing emergency operating instructions (1993-2002), upgrading the confinement system (1993-1996), and providing a full-scope simulator to enhance staff training (1995-2000). Projects also are in place to perform safety assessments and to transfer capabilities for performing plant safety assessments (1995-2002).

Unit	Reactor Model	Net Output	Initial Start	Status
1	VVER-440/230	411 MWe	06/1973	Operating
2	VVER-440/230	411 MWe	11/1974	Operating
3	VVER-440/213	411 MWe	02/1981	Operating
4	VVER-440/213	411 MWe	10/1984	Operating

Kola Unit 2

Kola Confinement Leak Tightness. Confinement isolation upgrades were made at Unit 2 to reduce the release of radioactive material from the plant in the event of an accident. A four-year project to substantially reduce leaks by sealing leak paths has been completed.

Kola Confinement Isolation Valves. Confinement isolation upgrades were made at Unit 2 to reduce the release of radioactive material from the plant in the event of an accident. Confinement isolation valves, which would close in an accident to contain radioactive material, were installed at Unit 2 in 1996.

Kola Post-Accident Radiation Monitors. Post-accident confinement radiation monitors were installed at Unit 2.

Kola Units 1 and 2

Kola Reliable DC Power Supply. The original station batteries at Kola Units 1 and 2 had glass enclosures with open tops. Seismically qualified, direct-current, electrical-power supply systems were installed at these units.

Kola Units 3 and 4

Kola Unit 4 Full-Scope Simulator. A joint U.S./Russian project to develop a full-scope simulator for Kola Unit 4 was completed in 2000.

Kola VVER-440/213 Emergency Operating Instructions (EOIs). EOI technology has been transferred to Kola NPP to improve the ability of reactor operators to minimize the effects of abnormal plant transients and multiple failures. Kola plant staff completed their second draft of a full set of EOIs. Preliminary verification of the EOIs is in progress. Additional analyses are necessary to completely validate the EOIs at Kola. These analyses and subsequent work to implement the EOIs are being performed as a Russian activity.

Russia Simulator Training and Engineering Support. The Kola training staff received training in how to develop simulator exercise guides and have had simulator instructor training. The Simulator Training and Engineering Support project will continue to provide spare parts and simulator training through 2003.

Kola All Units

Kola In-Depth Safety Assessment. The safety-assessment activities at Kola NPP began in July 1995. These projects are designed to support a Level 1 internal-events full-power probabilistic risk assessment for Unit 4 as reference work for other VVER-440/213 units, and a deterministic analysis for Units 1 and 2 to support European Bank for Reconstruction and Development (EBRD) requirements for funding physical upgrades. Both activities are completed.

In 1999, the plant sought Western assistance in preparing a probabilistic risk assessment for Unit 2. That work is being carried out by the Swedish International Project and the NNSA in partnership with Kola NPP.

In 2000, the Swedish International Project completed a peer review for the NNSA-financed Unit 4 probabilistic risk assessment. Through that probabilistic risk assessment, the plant has been able to identify improvements to the facility that would significantly reduce the probability of a major accident.

Russia Training Technology Transfer. The Systematic Approach to Training methodology and training materials developed at the Balakovo Training Center has been transferred to the Kola plant. Instructors from the plant have been trained in the methodology and in instructor skills. Training courses in mechanical maintenance and alignment of rotating equipment have been designed, developed, and implemented. Laser shaft-alignment equipment was provided and integrated into the alignment-training course.

Russia Pronet Software and Training. To facilitate the development and maintenance of the EOIs along with other operating procedures, the U.S. provided the Pronet software and training on the use of the software to help modify and maintain procedures up to date.

Russia Nondestructive Examination. The project to provide nondestructive-examination equipment and associated training to the plant was completed in 1997.

Russia Reliability Database. A centralized database for collecting reliability data from the nuclear power plants in Russia has been developed. Kola NPP is a pilot plant for implementing modules to be used at the plants for the collection, use, and sharing of this information.

Russia VVER Code Assessment. Work continued in the systematic evaluation to assess the adequacy and applicability of computer codes in the safety analysis of VVER reactors. Other projects provide host-country organizations with computer codes needed to perform in-depth safety assessments. The technology transfer for safety analysis is not complete with code transfer itself, but also requires transfer of the methodology and analytical capability to ensure that the safety analysis codes and methods are applicable and adequate for the plants being analyzed.

Kursk Nuclear Power Plant

Scope and Status of Activities

NNSA efforts at Kursk nuclear power plant focus on improving the safety of day-to-day operations and upgrading critical plant safety systems. Projects include providing tools, equipment, and training to improve plant safety maintenance (1995-1999) and upgrading key-engineered safety systems (1993-1999).

Unit	Reactor Model	Net Output	Initial Start	Status
1	RBMK-1000	925 MWe	10/1976	Operating[(a)]
2	RBMK-1000	925 MWe	12/1978	Operating
3	RBMK-1000	925 MWe	08/1983	Operating
4	RBMK-1000	925 MWe	10/1985	Operating
5	RBMK-1000	925 MWe	Under Construction	

(a) Operating under a "trial period" after modernization.

Kursk Unit 1

Kursk In-Depth Safety Assessment. The Kursk Unit 1 in-depth safety assessment was halted in 1999 due to the U.S. sanctions imposed against NIKIET, the general designer of the RBMK reactor. The project will not be restarted. Nevertheless, the NNSA is supporting an IAEA program at Kursk to demonstrate guidelines that they have developed for RBMK safety assessments.

Kursk Unit 2

Kursk Unit 2 Safety Parameter Display System. A safety parameter display system was installed and tested at Unit 2.

Kursk Reliable DC Power Supply. Open-topped, glass batteries were originally used in the plant. Seismically qualified, direct-current, electrical-power supply systems were designed and installed to replace batteries at Unit 2. Non-safety grade batteries also were installed to allow safety and non-safety loads to be separated.

Kursk Unit 3

Kursk Unit 3 Safety Parameter Display System. In 1999, work that had been initiated on an SPDS for Kursk Unit 3 was placed on hold and then cancelled because of sanctions on the Russian design organization NIKIET. Hardware for the system had been manufactured but the system had not been assembled. In 2001, it was decided to use this hardware to complete the Leningrad Unit 3 SPDS.

Kursk All Units

Kursk Piping Integrity. Assistance is being provided (2000-2003) to help develop a comprehensive program to manage intergranular stress corrosion cracking (IGSCC) degradation in RBMK reactors. Particular emphasis will be placed on ensuring the integrity of primary system components and engineered safety systems for safe plant operation. This project involves support in transferring mechanical stress improvement (MSIP) technology, supporting an International Atomic Energy Agency's Extra-budgetary program developed to assist RBMK reactors with IGSCC, and sponsoring training seminars on in-service inspection and proper techniques for monitoring water quality. In 2000, assistance was initiated to help identify and accurately size the cracks associated with intergranular stress corrosion cracking. In 2001, activities were initiated to provide MSIP equipment and technology. This activity also is providing technology transfer for repairing and mitigating the cracks.

Kursk RMBK Safety Maintenance Technology Transfer & Training. State-of-the-art machines to cut pipes in critical safety systems and prepare pipe ends for welding were provided to improve safety maintenance at the plant. Other equipment provided to enhance safety maintenance included valve-seat resurfacing equipment, vibration monitoring and shaft-alignment equipment.

Russia Nondestructive Examination. Portable ultrasonic test equipment and hardness testers were delivered to the plant for detecting flaws in piping and other pressure boundary components. Kursk personnel were trained in the use of the equipment. Training also was provided for the staff to perform periodic recalibration.

Kursk Confinement Leak Tightness. At Kola Units 1 and 2 (VVER 440/230 plants), western sealant materials were used to effectively reduce air leakage from the confinement system. A study was performed to determine whether these Western products could be used to similarly reduce the rate of leakage from an RBMK accident localization system. Because of the very high temperature in some regions of the RBMK confinement system, product development and testing would have been required to obtain an appropriate material. Because one of the guidelines for this program is to transfer Western technology, not to develop materials, an implementation phase was not initiated.

Russia RBMK Emergency Operating Instructions (EOIs) Technical Justification. Draft EOIs were completed for the plant.

Kursk Ultrasonic Test Equipment. Portable and rail-mounted ultrasonic test equipment was provided to the plant for the in-service inspection of piping, elbows, and fittings. Training was provided in the use, maintenance, and calibration of the equipment.

Kursk High-Temperature Clothing. Emergency situations at a plant can require personnel to make emergency repairs, take actions (such as opening or closing a valve manually), or fight fires under conditions of very high temperature, humidity, and airborne radioactivity. Two types of Russian manufactured suits have been provided to each of the Russian nuclear plants. One of the suits, SZO-1, is capable of withstanding very high temperature. The other type of suit, Sukhovey, is more flexible, can accommodate moderate temperature and high humidity conditions, and shields against beta rays.

Kursk Emergency Water Supply. An emergency supply system of cooling water for the reactor coolant was installed and tested.

Kursk New Reactor "Trip." Planning activities were initiated to extend the scope of variables that are monitored to initiate the trip or activation of the reactor protection system. Implementation of an additional activator or parameter was funded by the Russian government as a generic post-Chornobyl upgrade.

Russia Training Technology Transfer. The Systematic Approach to Training methodology and training materials developed at the Balakovo Training Center were transferred to the Kursk plant. Pilot courses on motor-operated valves and laser-shaft alignment were developed and implemented. Instructors from the plant were trained in the methodology and in instructor skills. Basic equipment was provided for the development and support of training materials at the plant. This equipment included computers and a server, software, printers, a photocopier, overhead projectors, and projector screens.

Russia Reliability Database. A centralized database for collecting reliability data from the nuclear power plants in Russia has been developed. Kursk NPP is a pilot plant for implementing modules to be used at the plants for the collection, use, and sharing of this information.

Russia Simulator Training and Engineering Support. The Simulator Training and Engineering Support project will continue to provide spare parts and simulator training through 2003.

Russia RBMK Code Validation. Work continued in the systematic evaluation to assess the adequacy and applicability of computer codes in the safety analysis of RBMK reactors.

Leningrad Nuclear Power Plant

Scope and Status of Activities

NNSA efforts at Leningrad nuclear power plant focus on improving the safety of day-to-day operations and upgrading critical plant safety systems. NNSA projects are in place for developing emergency operating instructions (1998-2003), providing modern safety maintenance tools and techniques (1995-1999), and performing in-depth safety assessments (1996-2003). In addition, a project was completed to provide an improved fire-detection system (1995-2000).

Unit	Reactor Model	Net Output	Initial Start	Status
1	RBMK-1000	925 MWe	09/1973	Operating
2	RBMK-1000	925 MWe	05/1975	Operating
3	RBMK-1000	925 MWe	09/1979	Operating
4	RBMK-1000	925 MWe	12/1980	Operating

Leningrad Unit 1

Leningrad In-Depth Safety Assessment. Following completion of the Unit 2 ISA in 2001, western project participants have agreed to support Leningrad NPP in developing an ISA for Unit 1. U.S. assistance is planned through 2003.

Leningrad Unit 2

Leningrad In-Depth Safety Assessment. The Leningrad NPP Unit 2 In-Depth Safety Assessment (ISA) Project is a multilateral project involving Russia, Finland, Sweden, Great Britain, and the United States. The objective of the project is to assist Leningrad NPP to conduct an ISA, which satisfies Russian regulatory requirements for issuance of a long-term operating license. Specifically, the ISA consists of probabilistic, deterministic, engineering, and institutional studies, which support conclusions regarding plant safety beneficial to assessing future operation. In addition, the project supports an NNSA funding objective to develop Leningrad NPP’s safety infrastructure through the exchange of Western safety assessment technology.

U.S. support includes technical, managerial, administrative, and financial assistance needed to develop the ISA. U.S.-supported technical production areas include the development of 1) documented and plant-specific neutronic and thermal-hydraulic analysis, 2) system design descriptions, 3) an engineering database, 4) plant and component compliance assessments, and 5) safety-concept summary reports. In addition, the U.S. program has provided office and network equipment essential to the ISA project's production, communication, and security.

The Unit 2 ISA was complete June 2001 and the Unit 1 ISA is forecast for completion in 2003.

Leningrad Units 1 and 2

Leningrad Fire Detection System. New fire-detection and alarm systems, manufactured by the Honeywell Corporation, were installed in Units 1 and 2.

Leningrad Units 3 and 4

Russia Simulator Training and Engineering Support. The Simulator Training and Engineering Support project will provide simulator-training support through 2003.

Leningrad Unit 3

Leningrad Unit 3 RBMK Safety Parameter Display System. The Unit 3 system was assembled and tested prior to a hold placed on the project because of sanctions against the Russian design organization NIKIET in 1999. The equipment, which has been in storage since that time, will be retested in the summer of 2003 and will be installed in Unit 3 in the next outage.

Leningrad Unit 4

Leningrad Unit 4 RBMK Safety Parameter Display System. The safety parameter display system for Unit 4 has been assembled at an on-site assembly facility at Leningrad NPP. Factory acceptance testing of the integrated system was completed in March 2003. Installation is in progress and will be completed in 2004.

Leningrad All Units

Leningrad Piping Integrity. Assistance is being provided (2000-2003) to help develop a comprehensive program to manage intergranular stress corrosion cracking (IGSCC) degradation in RBMK reactors. Particular emphasis will be placed on ensuring the integrity of primary system components and engineered safety systems for safe plant operation. This project involves support in transferring mechanical stress improvement (MSIP) technology, supporting an International Atomic Energy Extra-budgetary program developed to assist RBMK reactors with IGSCC, and sponsoring training seminars on in-service inspection and proper techniques for monitoring water quality. In 2000, assistance was initiated to help identify and accurately size the cracks associated with intergranular stress corrosion cracking. In 2001, activities were initiated to provide MSIP equipment and technology. This activity also is providing technology transfer for repairing and mitigating the cracks.

Russia Nondestructive Examination. Portable ultrasonic test equipment and hardness testers were delivered to the plant for detecting flaws in piping and other pressure boundary components.

Leningrad RBMK Safety Maintenance Technology Transfer & Training. The transfer was completed of equipment, technology, and associated training to improve safety maintenance at the plant. Valve-seat resurfacing equipment, a pipe lathe/weld-preparation machine, and vibration-monitoring and a shaft alignment system were provided.

Russian RBMK Emergency Operating Instructions (EOIs) Technical Justification. The symptom-based emergency operating instructions developed for Leningrad NPP require additional analysis to validate their use. These analyses were being performed by NIKIET until 1999. Additional analysis was started in 2002 as part of the ISA project and is expected to be completed in 2003.

Russia Training Technology Transfer. The Systematic Approach to Training methodology and training materials developed at the Balakovo Training Center has been transferred to the Leningrad plant. Instructors from the plant were trained in the methodology and in instructor skills. Basic equipment has been provided for the development and support of training at the plant. This equipment included computers, printers, a scanner, photocopiers, overhead projectors, projector screens, and video equipment. Pilot courses for shift supervisors and control-room reactor operators have been developed and implemented.

Russia Reliability Database. A centralized database for collecting reliability data from the nuclear power plants in Russia has been developed. Leningrad NPP will be a follow-on plant for implementing modules to be used at the plants for the collection, use, and sharing of this information.

Site-Specific Decommissioning Study. A joint study was conducted to develop a general decommissioning plan and cost estimate.

Russia RBMK Code Validation. Work continued in the systematic evaluation to assess the adequacy and applicability of computer codes in the safety analysis of RBMK reactors. A report will be prepared in 2003 summarizing the RELAP5 code assessment activity which has occurred over the past several years; this report may identify areas where additional work would be worthwhile in future years. Other projects provide host-country organizations with computer codes needed to perform in-depth safety assessments. The technology transfer for safety analysis is not complete with code transfer itself, but also requires transfer of the methodology and analytic capabilities to ensure that the safety analysis codes and methods are applicable and adequate for the plants being analyzed.

Novovoronezh Nuclear Power Plant

Scope and Status of Activities

NNSA efforts at Novovoronezh nuclear power plant focus on improving the safety of day-to-day operations and upgrading critical plant safety systems. NNSA projects include providing an analytical simulator to improve reactor operator training (1995-1998), developing and implementing emergency operating instructions (1993-1998), and performing in-depth safety assessments (1996-2002). Other projects include improving key plant safety systems and providing safety parameter display systems.

Unit	Reactor Model	Net Output	Initial Start	Status
1	VVER-210	265 MWe	12/1964	Shut Down 02/1988
2	VVER-365	336 MWe	04/1970	Shut Down 08/1990
3	VVER-440/230	385 MWe	12/1971	Operating
4	VVER-440/230	385 MWe	12/1972	Operating
5	VVER-1000	950 MWe	04/1980	Operating

Novovoronezh Unit 3

Novovoronezh Unit 3 Safety Parameter Display System. The safety parameter display system for Unit 3 became operational in 1998. Modifications will be made to the Unit 3 and 4 systems in 2003 to accommodate major safety system upgrades at these units.

Novovoronezh VVER In-Depth Safety Assessment. Novovoronezh NPP in-depth safety-assessment (ISA) activities focused on Unit 3 began in August 1996. The ISA includes developing system description documentation; a Level 1 internal-event PRA; a limited-scope external event probabilistic risk assessment; a deterministic safety assessment, including design basis accident (DBA) analysis and specific assistance in the preparation of the ISA report.

Through 2000, the plant had accomplished several tasks: A Level 1 internal-events PRA, the external hazards screening, a failure-event database, and system-description documentation. The DBA analysis was cancelled at the halfway point because of the poor support from host-country subcontractors. The Level 1 internal-event PRA model is being modified to account for the many plant upgrades implemented during the scheduled outage in 2001. A limited external-events probabilistic risk assessment model has been developed.

Novovoronezh Unit 4

Novovoronezh Unit 4 Safety Parameter Display System. The safety parameter display system for Unit 4 became operational in 1999. Modifications will be made to the Unit 3 and 4 systems in 2003 to accommodate major safety system upgrades at these units.

Novovoronezh Units 3 and 4

Novovoronezh Unit 3 Analytical Simulator. An analytical simulator was provided for Unit 3. The simulator was declared fully operational in September 1998.

Novovoronezh VVER-440/230 Emergency Operating Instructions (EOIs). Symptom-based EOIs received regulatory approval and were implemented at Unit 3 in 1998. The Novovoronezh plant personnel are in the process of transferring this EOI technology to Unit 4. Additional analyses are necessary to completely validate the EOIs for Unit 4. This analyses and subsequent work to implement the EOIs is being performed as part of a joint U.S.-Russian project. PRONET software was provided to assist Novovoronezh with the development/ clerical/ editorial management of the instructions.

Novovoronezh Emergency Water Supply. A mobile emergency water supply pumping system was delivered to the plant and made operational in 1999. This system would supply water to the steam generators of Units 3 or 4 in case of an abnormal event (such as a seismic event) in which other sources of feedwater are not available.

Russia Simulator Training and Engineering Support. The Simulator Training and Engineering Support project will continue to provide spare parts and simulator training through 2003.

Novovoronezh Post-Accident Confinement Ventilation. A major deficiency of the VVER 440/230 system is the lack of either a containment system or a consequence mitigation system that would decrease the release of radioactive material to the environment in a severe accident. Conceptual designs were investigated to determine the feasibility of backfitting a release mitigation system to the VVER 440/230 plants. Because of the developmental nature of this activity and the expected cost to implement a plant modification, it was decided to focus funds on accident prevention rather than accident mitigation in these plants.

Novovoronezh Unit 5

Novovoronezh Unit 5 Safety Parameter Display System. The safety parameter display system for Unit 5 became operational in 2001.

Novovoronezh VVER In-Depth Safety Assessment. Assistance was provided to Novovoronezh NPP in conducting in-depth safety assessments at Unit 3 (VVER-440/230). Additional assistance was provided to transfer this capability to Unit 5.

Novovoronezh All Units

Russia Training Technology Transfer. The Systematic Approach to Training methodology and training materials developed at the Balakovo Training Center has been transferred to the Novovoronezh plant. Instructors have been trained in the methodology and in instructor skills. Basic equipment was provided for the development and support of training at the plant. This equipment included personal computers, office furniture, overhead projectors, projector screens, and whiteboards. Pilot courses for shift supervisors and control room reactor operators were developed and implemented.

Russia Configuration Management. Efforts to develop a configuration management program for keeping the plant's design basis current and accurate are under way. Following completion of this system at Novovoronezh NPP, the Novovoronezh experts will transfer this capability to other sites in Russia.

Russia Reliability Database. A centralized database for collecting reliability data from the nuclear power plants in Russia has been developed. Novovoronezh NPP will be a follow-on plant for implementing modules to be used at the plants for the collection, use, and sharing of this information.

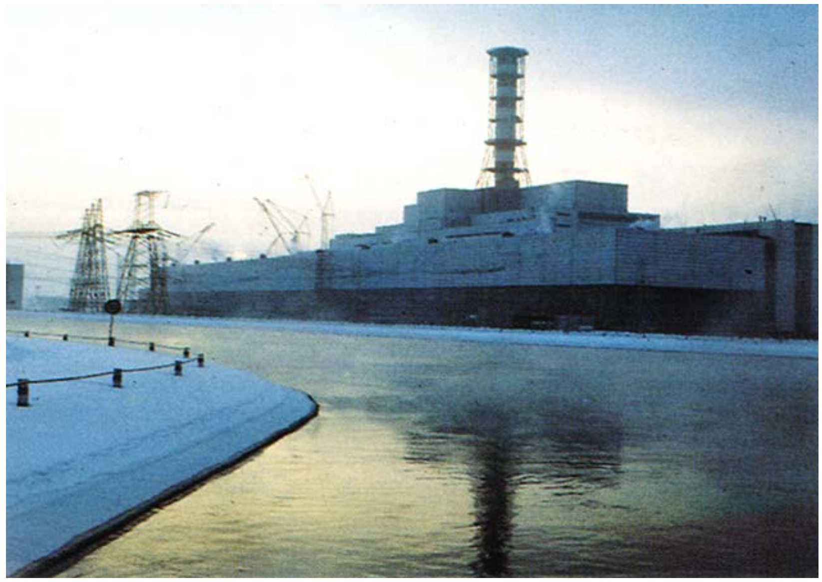
Russia Nondestructive Examination. The project to provide nondestructive examination equipment and associated training to the plant was completed during 1999.

Russia VVER Code Assessment. Work continued in the systematic evaluation to assess the adequacy and applicability of computer codes in the safety analysis of VVER reactors. A report will be prepared summarizing the RELAP5 code assessment activity which has occurred over the past several years; this report may identify areas where additional work would be worthwhile in future years. Other projects provide host-country organizations with computer codes needed to perform in-depth safety assessments. The technology transfer for safety analysis is not complete with code transfer itself, but also requires transfer of the methodology and analytical capabilities to ensure that the safety analysis codes and methods are applicable and adequate for the plants being analyzed.

Russia Circuit Breaker Technology Transfer and Demonstration – Phase II. Subsequent to the success of Phase I in demonstrating the ability to integrate modern Western circuit breakers into Russian NPPs, a project was initiated to enable a Russian organization, Tenzor, to assemble circuit breakers in-country. The parts for the circuit breakers will be manufactured by the U.S. circuit breaker manufacturer, Cutler-Hammer. Tenzor will operate an assembly facility, perform periodic testing as required for nuclear qualification of the circuit breakers, and act as the in-country supplier. The first product line that will be provided by Tenzor is Cutler-Hammer's newest model for low amperage 400 V circuit breakers, which has high flexibility and wide applicability. INSP is funding regulatory reviews in support of certification, the purchase of assembly and test equipment, and the manufacture and certification testing of circuit breaker sample assemblies.

Smolensk Nuclear Power Plant

Scope and Status of Activities



At Smolensk nuclear power plant, NNSA efforts are directed toward improving safety of day-to-day operations and improving critical plant safety systems. Projects include developing emergency operating instructions (1993-1999); providing improved maintenance tools, equipment, and techniques (1995-1999); and improving fire prevention and detection systems (1993-2002).

Unit	Reactor Model	Net Output	Initial Start	Status
1	RBMK-1000	925 MWe	09/1982	Operating
2	RBMK-1000	925 MWe	04/1985	Operating
3	RBMK-1000	925 MWe	12/1989	Operating

Smolensk Unit 3

Smolensk Unit 3 RBMK Safety Parameter Display System. Projects to provide a safety parameter display system for Unit 3 were cancelled because of U.S. sanctions imposed against NIKIET, the general designer of the RBMK reactors. The hardware manufactured for this system is being provided to Leningrad NPP where it will be used to upgrade the plant computers at Units 3 and 4.

Smolensk All Units

Smolensk RBMK Fire Safety Upgrades. Fire doors, fire detectors, fire-protection equipment, and penetration sealant material were provided to improve fire protection. A communication system for the fire brigade also was provided. Design of the fire-detection and alarm system was completed. Installation of this system was completed in 2002.

Smolensk Safe Shutdown Analysis. Analyses of safe shutdown capabilities in the event of fire were completed in 2000. A number of fire-safety vulnerabilities have been identified and prioritized. The final report was issued in 2001.

Russia Plant-Specific Fire Hazard Evaluation Guidelines. Based on U.S. experience in the performance of fire safe shutdown studies, a procedure was developed for performing comparable studies in RBMK and VVER plant designs. The guidelines, "Reactor Core Protection Evaluation Methodology for Fires at RBMK and VVER Nuclear Power Plants, December 1996," underwent extensive review by

U.S., Russian, Ukrainian, and other international organizations before being adopted. Two pilot studies have been undertaken. The Smolensk safe shutdown study was completed in 2001.

Smolensk RBMK Emergency Operating Instructions (EOIs). A complete set of EOIs that promote safety through improved accident-mitigation strategies has been developed. The Russian side performed the necessary analysis to validate the EOIs. Validation and operator training on their use were initiated in 2001, and the EOIs will be implemented in 2003.

Smolensk Piping Integrity. Assistance is being provided to help develop a comprehensive program to manage intergranular stress corrosion cracking (IGSCC) degradation in RBMK reactors. Particular emphasis will be placed on ensuring the integrity of primary system components and engineered safety systems for safe plant operation. This project involves support in transferring mechanical stress improvement (MSIP) technology, supporting an IAEA extra-budgetary program developed to assist RBMK reactors with IGSCC, and sponsoring training seminars on in-service inspection and proper techniques for monitoring water quality. In 2000, assistance was initiated to help identify and accurately size the cracks associated with intergranular stress corrosion cracking. In 2001, activities were initiated to provide MSIP equipment and technology. This activity also is providing technology transfer for repairing and mitigating the cracks.

Russia Nondestructive Examination. Portable ultrasonic test equipment and hardness testers were delivered to the plant for detecting flaws in piping and other pressure boundary components.

Smolensk RBMK Safety Maintenance Technology Transfer and Training. The transfer was completed of equipment, technology, and associated training to improve safety maintenance at the plant. Valve-seat resurfacing equipment, a pipe lathe/weld-preparation machine, and vibration-monitoring and a shaft alignment system were provided.

A thermo-mechanical training loop was installed in 1998 at the Smolensk Training Center. The loop provides hands-on training for maintenance technicians of wide-ranging specialty areas.

Russia Training Technology Transfer. The Systematic Approach to Training methodology and training materials developed at the Balakovo Training Center were transferred. Smolensk plant instructors were trained in the methodology and in instructor skills. Basic equipment was provided for the development and support of training at the plant. This equipment included computers, printers, a scanner, photocopiers, overhead projectors, projector screens, and video equipment. Pilot courses for mechanical maintenance on laser-shaft alignment and for control-room reactor operators were developed and implemented at the plant, and a course for shift supervisors was developed and implemented at the Smolensk Training Center.

Russia Circuit Breaker Technology Transfer and Demonstration – Phase I. Technology has been transferred to allow the use of western circuit breakers in the replacement of obsolete Russian circuit breakers. The program has addressed three general types of circuit breakers: low-amperage, 400 V circuit breakers; high amperage, 400 V circuit breakers; and large 6 kV circuit breakers. Interface racks and drawout assemblies, which provide an interface between the circuit breaker and the plant's electrical panels, have been designed and manufactured by Russian organizations to allow western circuit breakers (6 kV breakers manufactured by ABB and by Merlin Gerin and 400 V breakers manufactured by Merlin Gerin) to be supplied as replacement breakers. Ex-plant tests of the integrated breaker and interface hardware preceded in-plant testing. Subsequent to the certification of these circuit breakers for trial use at Smolensk, nuclear power plants in Russia have placed a number of orders for these circuit breakers. Phase II of this program is being carried out with Novovoronezh as the pilot plant.

Russia Reliability Database. A centralized database for collecting reliability data from the nuclear power plants in Russia has been developed. Smolensk NPP will be a follow-on plant for implementation of modules to be used at the plants for the collection, use, and sharing of this information.

Russia Simulator Training and Engineering Support. The Simulator Training and Engineering Support project will provide simulator-training support through 2003.

Russia RBMK Code Validation. Work continued in the systematic evaluation to assess the adequacy and applicability of computer codes in the safety analysis of RBMK reactors. Other projects provide host-country organizations with computer codes needed to perform in-depth safety assessments. The technology transfer for safety analysis is not complete with code transfer, but also requires transfer of the methodology to ensure that the safety analysis codes and methods are applicable and adequate for the plants being analyzed.

Volgodonsk Nuclear Power Plant

Scope and Status of Activities

The Volgodonsk nuclear power plant commenced operation in March 2001. NNSA efforts at Volgodonsk nuclear power plant through the end of 2001 have focused on supporting the development of a full-scope simulator.

Volgodonsk Unit 1

Volgodonsk Full-Scope Simulator. A joint U.S./Russia project to develop a full-scope simulator was started in December 2000. It is anticipated that this project will be completed in early 2004.

Russia Simulator Training and Engineering Support. This project will continue to provide spare parts and simulator training through 2004.

Unit	Reactor Model	Net Output	Initial Start	Status
1	VVER-10000	950 MWe	01/2001	Operating

Russia Legal and Regulatory Capabilities and Other Crosscutting Activities

Russia International Nuclear Safety Center. A Russian Minatom International Nuclear Safety Center (RMINSC) was established. International Nuclear Safety Centers (INSCs) facilitate the collection and dissemination of nuclear safety and technical improvement information and provide generic research on issues important to the safety of operating reactors. By performing research that is generic to Soviet-designed reactors, the centers provide necessary information to the larger program. In addition, the centers coordinate their activities with other research programs related to Soviet-designed reactors such as those being coordinated by the International Atomic Energy Agency (IAEA), and the Nuclear Energy Agency (NEA) of the Organization for Economic Cooperation and Development (OECD). INSCs are being established in Russia, Lithuania, Ukraine, Armenia, and the United States.

Safety Assessment Activities

International Information Exchange Forum. This annual forum allows for information exchange and the sharing of experience among engineers involved in the safety analysis of Soviet-designed reactors. The forum leverages individual efforts at facilities through sharing and dissemination of results obtained through internationally sponsored projects at Soviet-designed reactors.

IAEA RBMK Accident Analysis Guidelines Demonstration. This project involves testing the feasibility of using Western analysis methodologies at RBMKs, performing some design basis calculations based on these methodologies, and developing a training program for transferring these technologies to operators at RBMK reactors. This activity is also supporting international review of the Russian-developed safety analysis of the Kursk plant.

Russia RELAP Code User Group. State-of-the-art reactor system analysis codes were transferred to host-country organizations, and support was provided in the use of these codes. This project replaces the activities undertaken under the Russian CAMP Membership project.

Russia PSB Test Facility Instrumentation. Assistance was provided to Russia in building and supplying test instruments for an integral test facility representing VVER-1000 reactor systems. The facility will be used to provide information for the assessment of safety analysis codes related to VVER reactors. The conduct and analysis of a series of five tasks in PSB-VVER has been approved as an international program under the OECD-NEA.

Russia Beyond Design Basis Accident Analysis. In 1997, strategies were developed for integrating severe accident analysis in the Plant Safety Evaluation program. Also defined were the specific severe accident analysis to be performed by host-country institutes.

Russia Containment Tension Pre-Stress Analysis. The VVER-1000 pre-stressed reinforced containment system was analyzed under operational and accident conditions for different tension levels of pre-stressed cables. The results were used to provide recommendations to improve operational safety of the containment.

Russia Prioritization of Proposed RBMK Upgrades. In 1994, the wide variety of safety upgrades proposed for RBMK reactors were reviewed and prioritized. A methodology was developed and implemented to evaluate the proposed safety upgrades and to provide a basis for ranking the associated upgrades.

Russia RBMK Code Development. Equipment was provided for the performance of analyses necessary to evaluate RBMK safety and checked the validity of analysis results through the performance of thermo-hydraulic and neutronics code validation benchmark calculations.

Russia CAMP Membership. Membership was funded in the U.S. Nuclear Regulatory Commission's (NRC) international code assessment and maintenance program (CAMP) in order to transfer and provide support for state-of-the-art NRC safety analysis codes to Russian organizations. This project was superseded by the activities undertaken under the Russia RELAP Code User Group project.

Regulatory Activities

Russia Regulatory Capability Enhancement. Training was provided to nuclear safety inspectors in Russia. This training included transferring the methodology for evaluating nuclear safety analysis, quality assurance, fire protection, nuclear criticality safety, and nuclear safety culture.

Russia Probabilistic Risk Assessment Standardization Methodology. Standard methods and analyses were developed for conducting probabilistic safety assessments for Russian nuclear power plants.

Russia MELCOR Validation and Certification. This severe-accident computer code was validated for application to Soviet-designed nuclear power plants.

Russia Regulatory Standards Development. Assistance was provided to the Federal Nuclear and Radiation Safety Authority of Russia (Gosatomnadzor) in the development of regulations and standards to ensure the safety of nuclear facilities in Russia.

Russia Nuclear Safety Institutional Framework. The United States worked with Russian legislators to develop a legislative framework for regulating the safe operation of nuclear facilities in Russia.

Russia Prestressed Containment Stress/Strain Analysis. Plant-specific recommendations, plans, and procedures were developed for improving the operational safety of the Kalinin NPP containment. A regulatory approach also was developed for possible future applications.

General Activities

Russia Operator Exchange Program (WANO). An operator exchange program, which allowed staff from Russian plants to visit and observe operations at U.S. nuclear power plants, has been completed. The program enhanced the capability of plant personnel to develop improved operating safety procedures and practices.

Russia WANO Center. Equipment and support were provided to the World Association of Nuclear Operators (WANO) Center in Moscow. This center provides support and assistance to all the Soviet-designed reactors in the areas of operational safety, conduct of operations, procedures, and training.

Russia Fire Safety EWG Support. Funds were provided for the initial Expert Working Group meetings and for review activities until specific projects were identified.

Russia Safety Systems EWG Support. Funds were provided to support the initial Expert Working Group meetings and initial project activities associated with safety system upgrades. Many of these early activities were later developed into specific projects.

Russia Pressure Vessel Evaluation. Technologies were evaluated for mitigating the effects of radiation-induced embrittlement in reactor pressure vessels.

Russia Valve Manufacturing Technology Transfer. Technology for the manufacture of safety-class valves has been transferred from the U.S. Company Curtiss Wright Flow Control (Target Rock Division) to Russian valve manufacturing organizations. In 2000, Target Rock assisted the Chekhov valve manufacturing company with the design and fabrication of an isolation valve and a relief valve. These valves were tested to enable their certification for use in nuclear power plants in Russia. In 2001, a joint venture called Solenoid Valve Company was formed between Target Rock and the Splav Company for the manufacture of solenoid valves. Solenoid valves are widely used in the U.S. but are not currently used in Russian nuclear plant applications. Assistance has been provided in the development of revisions to Russian standard, in the review of potential nuclear power plant applications, and in the certification of two solenoid valves provided by Target Rock for Leningrad NPP. The INSP is currently funding the manufacture of two four-inch solenoid valves (one to be manufactured at Target Rock and the other to be partially manufactured and assembled at the Splav facility). Certification tests will be performed for 1”, 2”, and 4” valves.

International Activities Support. Several activities were completed to determine what needed to be accomplished. Technical experts were provided to support IAEA activities and reviews.

Russia Alternative Energy Study. This joint study was conducted to evaluate the energy needs and generating capabilities in Russia. This study was conducted for the Energy Policy Committee of the U.S. Russia Joint Commission on Economic and Technological Cooperation.

Russia Emergency Preparedness. Technical support and assistance were provided to Rosenergoatom (REA) and Minatom regarding emergency response capabilities. The activities included demonstrating the capabilities of the NRC's Emergency Response Center and the State of Illinois Nuclear Emergency Response center to several Russian specialists.

Nuclear Material Safety (Texas). A coalition of three Texas universities is receiving support for their work with two Russian universities to develop and implement graduate level degree programs on nuclear material safety.

Environmental Safety Center. In 1999, the establishment of environmental safety centers at the Idaho National Engineering and Environmental Laboratory (INEEL) and Minatom was supported to facilitate an exchange of information related to mitigating the impacts of cold war era nuclear activities on the environment. In fiscal year 2000, U.S. funding from the International Nuclear Safety Program was discontinued after congressional coordination.

Russia Y2K Support. Russian experts participated in various Y2K Information Exchange and Contingency Planning meetings sponsored by DOE. The meetings included exchange of information between plants concerning their Y2K program efforts as well as seminars about contingency planning. The DOE sponsored remediation of the highest priority Y2K vulnerabilities at each of the plants in Russia. In addition, DOE representatives were present in the host-country during the Y2K rollover and were in communication with the DOE's Y2K response center.

Russia Infrastructure Support. A joint review was conducted to determine what improvements were needed to strengthen the nuclear safety infrastructure in Russia.

Ukraine

In Ukraine, NNSA-supported safety projects are planned, under way, or near completion at five nuclear power plants with a total of 14 nuclear reactors. In addition, two units are under construction at Khmelnytskyy and Rivne. Chornobyl's last operating reactor, Unit 3, was shut down on December 15, 2000. The locations of the five nuclear power plants and the type of reactors at each plant are shown in Figure 7. In 2002, Ukraine's nuclear power plants produced 45.7 percent of the country's electricity.

This section of the report identifies NNSA's completed, ongoing, and planned activities at each Ukrainian plant. In this section, projects that apply to all participating nuclear power plants in Ukraine are categorized as "Crosscutting." The U.S. Agency for International Development is providing a significant portion of the funding for the safety work in Ukraine.

Figure 7. Nuclear Power Plants in Ukraine Participating in the U.S. Program to Improve Nuclear Safety

Summary of Safety Status

The U.S. National Nuclear Security Administration (NNSA) efforts through 2002 have improved safety at Soviet-designed nuclear power plants in Ukraine. Projects are correcting major safety deficiencies. Equipment, technology, and processes vital to the safe operation of nuclear power plants have been transferred to the Ukrainian nuclear power plants and support organizations. Plant operations and institutional procedures are approaching internationally recognized practices.

As shown in Figure 8, one indication of improved nuclear plant safety in Ukraine is the decreased number of safety events since the program's inception in 1992.

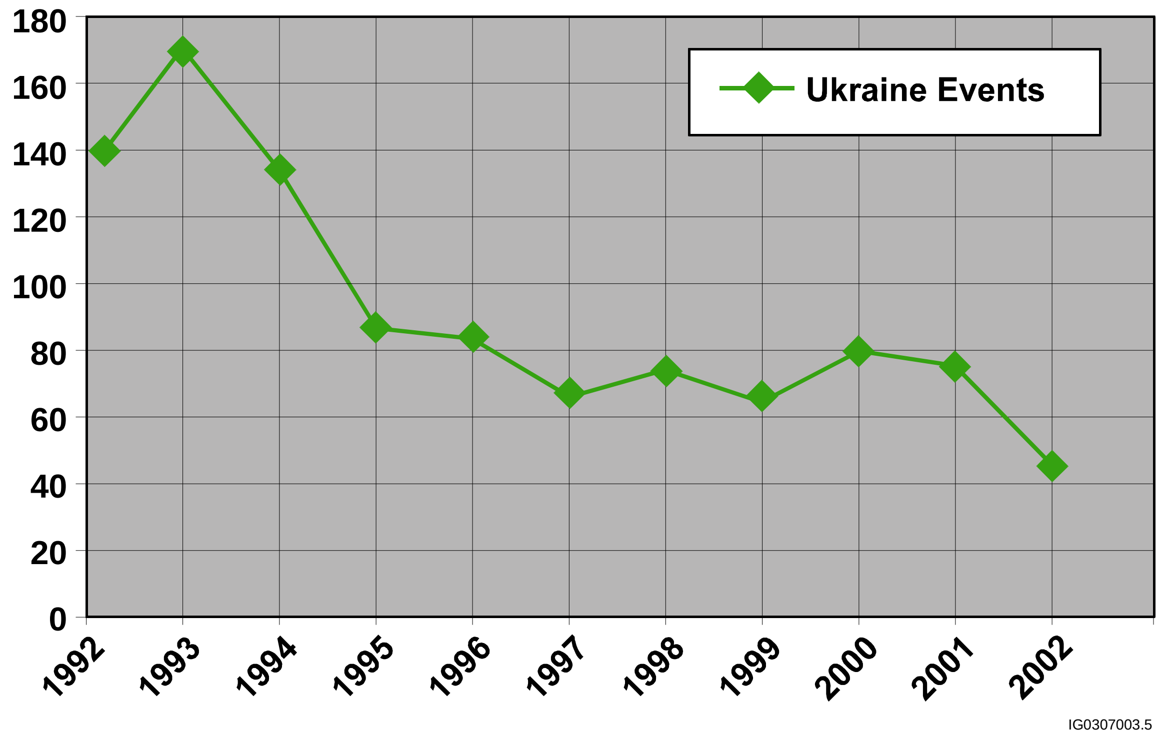


Figure 8. Safety Events at Soviet-Designed Reactors in Ukraine from 1992 through 2002

During 2002, progress toward achieving program objectives continued. Several long-term projects were completed; other projects are nearing completion. However, two interrelated obstacles continue to impede progress in Ukraine.

First, as with Russia, Ukrainian nuclear power plants are having significant problems financing their portion of the safety upgrades. Second, the technical resources are becoming increasingly more limited.

In late 1997, two Ukrainian nuclear power plants defaulted on their responsibilities for completion of three full-scope simulators. A decision was made by DOE to fund and complete each of these three simulator projects.

Ukraine does not have sufficient technically qualified staff to complete the safety assessments of their plants as required by the Ukrainian regulator and international organizations. Because of social and economic conditions in the country, many of the existing native-Russian engineers and specialists are leaving Ukraine for better opportunities in Russia. The NNSA program has been working toward transferring technology and experience to Ukraine to develop a Ukrainian base of technical expertise to support the safe operation of their nuclear plants.

Chornobyl Nuclear Power Plant

Scope and Status of Activities

NNSA efforts at the Chornobyl nuclear power plant covered a broad range of activities. The focus was on improving the safety of day-to-day operations and upgrading critical plant safety systems for the brief remaining operating period. Projects included improving operator training (1995-1999), developing improved operating procedures and practices (1995), developing emergency operating instructions (1995-1998), providing an analytical simulator (1995-1998), providing fire-fighting and fire-prevention material and equipment (1995-2001), and providing a safety parameter display system (1996-1999). NNSA supported negotiations lead to Ukraine's closure of Chornobyl Unit 3 on December 15, 2000.

Unit	Reactor Model	Net Output	Initial Start	Status
1	RBMK-1000	925 MWe	08/1977	Shut Down 11/1996
2	RBMK-1000	950 MWe	05/1979	Shut Down 10/1991
3	RBMK-1000	925 MWe	06/1981	Shut Down 12/2000
4	RBMK-1000	950 MWe	04/1984	Destroyed 04/1986

Chornobyl Unit 3

ChNPP Emergency Operating Instructions (EOIs). Symptom-based EOIs that promote safety through improved accident-mitigation strategies were implemented at Unit 3 in 1998.

ChNPP Unit 3 Safety Parameter Display System (SPDS). A safety parameter display system for Unit 3 was installed and is fully operational. The system was designed with a shutdown protection mode for the period of time after unit closure to the point at which the unit is defueled.

ChNPP Unit 3 Analytical Simulator. An analytical simulator was developed for Chornobyl Unit 3. The simulator was turned over to the nuclear power plant in February 1998 and has been actively used for training of reactor operators.

ChNPP-3 Fire Safety Upgrades. Fire-protection equipment, including protective clothing, hose nozzles, penetration sealant material, and structural steel coating material, was provided. A Ukrainian company, Asken, installed the fire-resistant structural steel coating material. A new fire-detection system, manufactured by Cerberus, has been installed, programmed, and tested.

Technology for manufacturing fire doors was transferred to Asken, which provided 250 fire doors to Unit 3. Installation of the fire doors was completed in 1999.

In response to safety deficiencies identified by a WANO review, additional fire protection equipment, including portable radios and a base station, self-contained breathing-apparatus units, air tanks for existing units, an air compressor, and fire extinguishers were provided in 1999. In 2000, additional fire extinguishers were purchased for the plant. Special training also was provided to the fire-brigade personnel in the use and maintenance of the self-contained breathing-apparatus. In 2001, a foam-spray fire truck was supplied to the onsite fire department.

ChNPP Operator & Safety Maintenance Training Programs. The Systematic Approach to Training methodology and training materials developed at the Khmelnytskyy Training Center were presented to management and training personnel at the Chornobyl plant. Basic equipment was provided for the development and support of training. This equipment included personal computers, AutoCAD workstations, software, printers, scanners, overhead projectors and screens, office furniture, a photocopier, and whiteboards. Instructor-skills training was provided to assist Chornobyl training personnel in improving instruction techniques. Plant-specific radiation protection and control-room operator pilot training courses were developed and implemented.

Chornobyl RBMK Safety Maintenance Technology Transfer &Training. Equipment and training for improving safety maintenance activities have been provided. Safety maintenance equipment included valve-seat resurfacing equipment, pipe lathe/weld preparation machines, vibration monitoring and shaft-alignment equipment, and an electrical fault-detection thermography camera. Training on use of this equipment also was provided.

Ukraine Nondestructive Examination and Safety Maintenance Initiative. Two ultrasonic flaw detectors and two ultrasonic hardness testers were provided to Chornobyl Unit 3. Training also was provided in the equipment’s use.

ChNPP Management and Operational Procedures. A complete set of improved management and operational control procedures that promote safety through improved operating practices was implemented at Unit 3.

ChNPP Quality Assurance (QA) Program. Chornobyl NPP staff participated in various workshops and training programs designed to develop the Ukrainian national standard for QA at nuclear power plants. Staff also participated in a QA training program that officially certified personnel from the various nuclear power plants and Energoatom (Ukraine’s utility organization) as QA auditors. Site-specific procedures for assessments, based on Energoatom guidelines, were developed, and procedures for document control and QA records, including specific procedures for maintenance work planning, were implemented. Chornobyl staff attended workshops for applying quality assurance in planning and execution of maintenance and repair.

Ukraine Event Analysis and Reporting. Chornobyl NPP staff served on the working group monitoring the project developing event-reporting systems, implementing improved procedures/ processes for performing root cause analysis, and implementing lessons learned. Chornobyl NPP staff received root-cause analysis training.

ChNPP Decommissioning Planning. Technical assistance with shutdown and decommissioning activities started in 2000.

Chornobyl All Units

The Chornobyl Center for Nuclear Safety, Radioactive Waste, and Radioecology. Established in 1996, the Chornobyl Center is a cornerstone for developing operational safety programs that support improved and self-sustaining safety cultures at Ukrainian nuclear power plants. The Center conducted its fifth annual conference in September 2001, and celebrated the fifth anniversary of its branch laboratory (Slavutych Laboratory for International Research and Technology) in May 2002. In 2001, the Center participated in projects in Ukraine that support decommissioning of Chornobyl NPP, safety analysis for Rivne NPP, safety analysis for the Chornobyl interim irradiated fuel storage facility, emergency preparedness training for all Ukrainian nuclear sites, development of a radiation protection program for the Chornobyl Shelter, and radioecology research in the Chornobyl exclusion zone. The Center also supported emergency procedure development for Ignalina NPP in Lithuania. The Center continues to develop a state-of-the-art radioecology laboratory and a modern nuclear data facility staffed with engineers trained in Western practices.

Chornobyl Heat Plant. This plant will provide heat to the Chornobyl site so that workers can proceed with decommissioning activities. Heat and steam generated by this natural gas-powered heat plant also will support the liquid radioactive waste processing work. The facility was completed and turned over to Chornobyl NPP in June 2001.

Khmelnytskyy Nuclear Power Plant

Scope and Status of Activities

NNSA's efforts at the Khmelnytskyy nuclear power plant have focused mainly on establishing the Khmelnytskyy Training Center, a fully equipped training facility at which operators from other Ukrainian reactors can be trained in the Systematic Approach to Training methodology (1993-1996). A full-scope simulator to enhance the effectiveness of operator training also was provided as part of this effort.

Other major projects focus on providing a safety parameter display system (1996-1999), supporting in-depth safety assessments (1997-2005), and providing non-destructive examination equipment.

Unit	Reactor Model	Net Output	Initial Start	Status
1	VVER-1000	950 MWe	12/1987	Operating
2	VVER-1000	950 MWe	Under Construction	
3	VVER-1000	950 MWe	Under Construction	
4	VVER-1000	950 MWe	Under Construction	

Khmelnytskyy Unit 1

Khmelnytskyy Unit 1 Full-Scope Simulator. A full-scope simulator was installed at the plant in 1997 and now is in use to train reactor operators and supervisors.

Ukraine VVER SPDS – Khmelnytskyy Unit 1. Installation of a safety parameter display system was completed in 1999. The system is fully operational.

Khmelnytskyy Unit 1 In-Depth Safety Assessment. Khmelnytskyy NPP in-depth safety assessment (ISA) activities are focused on Unit 1. The project is the only active "non-lead" ISA project at this time and serves as the pilot project for this concept. This approach is being implemented to stretch the available funding and the limited availability of Ukrainian trained analysts. The approach for implementing this concept at Khmelnytskyy was the subject of an international peer review, which was completed successfully in 2000. Zaporizhzhya Unit 5 is the lead-plant for this plant type (VVER-1000/320). The scope of this project includes data collection and system documentation, development of the approach of using elements from a lead-plant ISA project to produce a Khmelnytskyy-specific ISA, Level-1 internal-event probabilistic risk assessment, design basis accident (DBA) analysis, and risk-assessment activities addressing internal hazards (that is, internal fires and floods), and external hazards (that is, fire, floods, seismic, and man-made hazards).

With U.S. assistance, Khmelnytskyy personnel have developed detailed project guidelines for performing ISA work. Data collection and system documentation required for performance of the ISA were completed in 2001.

The Khmelnytskyy NPP team has received detailed electronic files documenting the completed Zaporizhzhya Level 1 internal-event probabilistic risk assessment and has begun work on the Khmelnytskyy-specific Level 1 internal-event probabilistic risk assessment. Work also began on the first of the Khmelnytskyy - specific design-basis accident analysis subtasks, as corresponding lead plant work was completed. The first data collection task for internal and external hazards assessment (internal flooding frequencies in Ukrainian VVER plants) was started.

Ukraine Engineering Technology Center. The Engineering and Technical Center for the Training of Nuclear Industry Personnel, established with U.S. support, will provide simulator training and model modification support to Khmelnytskyy and the other plants in Ukraine.

Ukraine Security Systems. The United States is working with Khmelnytskyy as the pilot plant for improving physical security. In 2001, security equipment assembly and installation was completed and finally commissioned by Energoatom in October 2001. Additional upgrades were identified for the reactor building and diesel-generator station. These upgrades include an improved detection, assessment and alarm system, and improved access control and associated training and procedures and were completed in 2002.

Khmelnytskyy All Units

Ukraine Training Program Development. To date more than 3800 nuclear plant workers have received training at this jointly developed training center. Personnel at the center were trained on the Systematic Approach to Training methodology. Eight job specific operations and maintenance courses including all the control room operator positions were developed under this specific project.

Ukraine Training Program Specific Equipment. To complement job-specific maintenance and operations training courses, course-specific equipment was provided. This equipment included soldering stations, a refueling simulator with video simulation capabilities, water-chemistry equipment, and AutoCAD workstations.

Ukraine Training Center Basic Equipment. The Khmelnytskyy Training Center, a fully equipped nuclear power plant training facility, has been established. Basic equipment was provided for the development and support of the training center. This equipment included computers, scanners, printers, photocopiers, fax machines, office furniture, whiteboards, overhead projectors, and projector screens.

Ukraine Special Training Courses. Training, such as the systematic approach to training, was provided to teach instructors. Other courses delivered included general employee training and supervisor training.

Ukraine Training Technology Transfer. The courses and training materials developed at the training center are being transferred to all Ukrainian nuclear power plants. The mechanical maintenance, motor-operated valve repair course developed at the Khmelnytskyy Training Center also has been transferred for use at the Balakovo Training Center in Russia.

Ukraine Simulator Training and Engineering Support. A set of simulator exercise guides (SEGs) was developed during the simulator-development project and has become the model for other VVER-1000 simulator SEGs in Ukraine. A two-week simulator-instructor training course was developed and presented to simulator staff. A configuration management system was upgraded in 2001. Additional simulator training support and some simulator upgrades are planned through 2006.

Ukraine Simulator Integration for SPDS. A safety parameter display system was added to the simulator in 1999.

Ukraine Reliability Database. Khmelnytskyy NPP is the pilot plant for implementing Version 1 of the Ukrainian Reliability Database. This includes development of the database structure and generic interfacing applications. Additional project work will include 1) developing Version 2 of the database for the plants and utility that will allow sharing and analysis of information between plants in Ukraine, 2) developing the protocols for sharing this information with plants in other countries (coordinated through WANO), and 3) cataloging basic event failure probabilities used in existing probabilistic risk assessments at Ukrainian nuclear power plants and generation of new plant-specific values based on information in the database. This information might also be shared with operators of other Soviet-designed reactors via WANO. Full development of the reliability database, which was started in 1998, is scheduled to be completed in 2006.

Ukraine Nondestructive Examination and Safety Maintenance Initiative. Energoatom recognized the need to improve the training and certification practices in Ukraine and agreed to develop a central NDE training and certification facility in April 1998. One of the primary missions of this facility is to conduct NDE training and certification to international standards in Ukraine. Under the NDE activity, Ukraine has developed a certification practice that now meets international standards and is currently training staff from all Ukraine NPPs to international standards. Other activities include providing state-of-the-art equipment to the NPPs, including ultrasonic and eddy current detection equipment. Efforts are under way to fabricate affordable eddy current probes in Ukraine, thus providing a sustainable infrastructure for in-service inspection of steam generators.

Ukraine Operational Safety Infrastructure. A Ukrainian nuclear-safety-infrastructure project initiated by DOE is benefiting Khmelnytskyy NPP in the area of emergency-response communications.

Ukraine Quality Assurance. Khmelnytskyy NPP staff planned and conducted a gap-assessment audit to identify areas needing improvement to be consistent with the national quality assurance standard. NPP staff attended quality assurance training.

Ukraine Event Analysis and Reporting. Khmelnytskyy NPP staff served on the working group monitoring the project developing event-reporting systems, implementing improved procedures/ processes for performing root-cause analysis, and implementing lessons learned. Khmelnytskyy NPP staff received training on root-cause analysis. Program procedures for Khmelnytskyy NPP will be developed, an event reporting program database created and populated, and the necessary computer equipment provided to support program implementation at Khmelnytskyy NPP.

Ukraine Design Basis Documents. Khmelnytskyy is participating in the project to develop design basis documents for VVER-1000 reactors in Ukraine. This project will also establish configuration management processes at Khmelnytskyy.

Transfer of Emergency Operating Instructions (EOIs) to Khmelnytskyy. EOIs improve the ability of reactor operators to minimize the effects of abnormal plant transients and multiple failures are currently being implemented at two pilot plants in Ukraine. After implementation at the pilot VVER-1000 NPP, Zaporizhzhya Unit 5, work will start to develop plant-specific EOIs for the Khmelnytskyy plant.

Emergency Operating Instructions/SPDS Training. Training programs will be developed to provide operators and supervisors with the skills necessary to effectively use safety parameter display systems and symptom based emergency operating instructions. This training program will consist of both classroom and simulator training.

Ukraine Safety Evaluation Codes. Personnel associated with safety assessments were provided with the training and practical experience needed to apply state-of-the-art reactor safety analysis codes to the safety assessment of the nuclear power plant. This project also supports the efforts necessary to assess the adequacy and applicability of computer codes in the safety analysis of VVER reactors.

Rivne Nuclear Power Plant

Scope and Status of Activities

Unit	Reactor Model	Net Output	Initial Start	Status
1	VVER-440/213	361 MWe	12/1980	Operating
2	VVER-440/213	384 MWe	12/1981	Operating
3	VVER-1000	950 MWe	11/1986	Operating
4	VVER-1000	950 MWe	Under Construction	

At Rivne nuclear power plant, NNSA projects include developing EOIs, improving operator training, and performing in-depth safety assessments.

Rivne Unit 1

Rivne Unit 1 In-Depth Safety Assessment. Rivne NPP in-depth safety assessment activities to enhance the operational safety of Unit 1 began in 1997. The Level 1 internal-event probabilistic risk assessment (PRA) is complete, and the design basis accident (DBA) safety margin is in final review. Data collection is underway for use in hazards screening and risk assessments on external hazards (for example, fire, floods, seismic, and man-made hazards) and internal hazards (for example, internal fires, and floods). This includes work to develop a database for internal-flooding frequencies specific to Ukrainian VVER plants. Analysis of these hazards will follow.

Starting in 2001, the Rivne ISA project began thermal-hydraulic analysis activities to support implementation of symptom-based EOIs at Rivne Unit 1. In-Ukraine Peer Review of the Level 1 internal event PRA has begun.

Safety Related Reactor Security. In 1999 an assessment of the safety risks associated with physical security at Ukraine's nuclear power plants was performed. Based on the results of this assessment, NNSA is assisting the Ukrainian plants in upgrading their physical security systems.

Rivne Units 1 and 2

Rivne Unit 2 Full-Scope Simulator. A project to provide a full-scope simulator for Unit 2 started in 1999 and has been completed.

Rivne VVER-440/213 Emergency Operating Instructions (EOIs). EOIs that promote safety through improved accident-mitigation strategies for Units 1 and 2 (VVER-440/213 reactors) have been drafted. Specific analyses are being identified to support the validation of these EOIs. After the analyses are completed, the instructions will be validated, the operators trained, and the instructions implemented.

Emergency Control Panel Simulation. The emergency control panels for Rivne Unit 2 will be simulated and integrated with the simulation model for the Rivne Unit 2 full-scope simulator. This project started in 2002.

Safety Related Reactor Security. In 1999 an assessment of the safety risks associated with physical security at Ukraine's nuclear power plants was performed. Based on the results of this assessment, NNSA is assisting the Ukrainian plants in upgrading their physical security systems.

Rivne Unit 3

Rivne Unit 3 Full-Scope Simulator. A full-scope simulator for Unit 3 has been completed and turned over to the plant in May 2001.

Ukraine VVER SPDS – Rivne Unit 3. A safety parameter display system for Rivne Unit 3 was installed in 2000.

Ukraine Simulator Integration for SPDS. The Unit 3 full-scope simulator was upgraded in 2001 to include an SPDS unit to model the SPDS installed in the plant.

Transfer of Emergency Operating Instructions (EOIs) to Rivne. EOIs for the VVER-1000 reactors are currently being developed at the Zaporizhzhya NPP in Ukraine. After implementation is complete at the pilot NPP, work will start to develop plant-specific EOIs for the Rivne 3 plant.

Safety Related Reactor Security. In 1999, an assessment of the safety risks associated with physical security at Ukraine's nuclear power plants was performed. Based on the results of this assessment, NNSA is assisting the Ukrainian plants in upgrading their physical security systems.

Rivne All Units

Ukraine Training Technology Transfer. The Systematic Approach to Training methodology and training materials developed at the Khmelnytskyy Training Center are being transferred to the Rivne plant. Basic equipment, including a computer with network capabilities and a printer, was provided for the development and support of training. Plant instructors were trained in the methodology and in instructor skills. A pilot training course on instrumentation and control for pressure transmitters has been implemented. To support the course, pressure-calibration equipment has been provided to the plant.

Three additional pilot courses for Control Room Reactor Operators and Unit Shift Supervisors, and Control Room Turbine Operators have been implemented. Future courses for Electrical Shift Supervisors, Instrumentation and Control Supervisors, Turbine Department Shift Supervisors, and

Reactor Department Shift Supervisors are planned to be in place by 2005. Additionally, the development of an on-the-job training program is planned.

Ukraine Operational Safety Infrastructure. A Ukrainian nuclear safety infrastructure project initiated by NNSA is benefiting Rivne NPP in the area of emergency-response communications and assistance with various safety improvement activities.

Ukraine Quality Assurance. Rivne NPP staff participated in various workshops and training programs designed to develop the Ukrainian national standard for QA at nuclear power plants. Staff also participated in a QA training program that officially certified personnel from the various nuclear power plants and Energoatom as QA auditors. Site-specific procedures for assessments, based on Energoatom guidelines, were developed, and procedures for document control and QA records, including specific procedures for maintenance work planning, were implemented. An audit was conducted of reactor-fuel management.

Ukraine Event Analysis and Reporting. Rivne NPP staff served on the working group monitoring the project developing event-reporting systems, implementing improved procedures/processes for performing root-cause analysis, and implementing lessons learned. Rivne NPP staff received training on root-cause analysis. Program procedures for Rivne NPP will be developed, an event reporting program database created and populated, and the necessary computer equipment provided to support program implementation at Rivne NPP.

Ukraine Simulator Training and Engineering Support. The Engineering and Technical Center for the Training of Nuclear Industry Personnel, established with U.S. support, will provide simulator training and model modification support to Rivne in the future. A set of simulator exercise guides has been developed and a two-week simulator instructor training presented to simulator staff for Rivne Unit 3. Simulator exercise guides have been developed for Rivne Unit 2. Updated training materials and simulator updates have also been provided.

Ukraine Pronet Software and Training. To facilitate the development and maintenance of EOIs along with other operating procedures, the United States provided the Pronet software and training on the use of the software to help modify and maintain procedures up to date.

Capacity Factors Improvements. Ukrainian and United States experts jointly studied ways to increase the capacity factor of the Rivne plant. The evaluations at Rivne NPP are anticipated to apply to all 11 VVER-1000 plants in Ukraine. Some recommendations are applicable to Rivne Unit 1 and 2, VVER-440-213 plants. The review identified 52 specific improvements. Overall, the pilot study showed that by increasing plant efficiency at all its nuclear plants to 85%, Ukraine would gain an additional 2400 megawatts of electricity annually. In addition, up to 30% of the power generated is lost because of the poor condition of the power grid and inefficient management of power distribution.

Ukraine Reliability Database. Rivne NPP is the second plant to receive an implementation of Version 1 of the Ukrainian Reliability Database. This primarily includes developing interfacing applications that are consistent with plant-maintenance practices and software tools.

Additional project work will include 1) developing Version 2 of the database for the plants and utility that will allow sharing and analysis of information between plants in Ukraine, 2) developing the data-export filters and event/component classifier mappings to automatically generate information for sharing via an international reliability database, that is, enable sharing of information in the database with plants in other countries (this will likely be coordinated with WANO), and 3) cataloging basic event failure probabilities used in existing probabilistic risk assessments at Ukrainian nuclear power plants and generation of new plant-specific values based on information in the database. This information might also be shared with operators of other Soviet-designed reactors via WANO.

Ukraine Nondestructive Examination and Safety Maintenance Initiative. Energoatom recognized the need to improve the training and certification practices in Ukraine and agreed to develop a central NDE training and certification facility in April 1998. One of the primary missions of this facility is to conduct NDE training and certification to international standards in Ukraine. Under the NDE activity, Ukraine has developed a certification practice that now meets international standards and is currently training staff from all Ukraine NPPs to international standards. Other activities include providing state-of-the-art equipment to the NPPs, including ultrasonic and eddy current detection equipment. Efforts are under way to fabricate affordable eddy current probes in Ukraine, thus providing a sustainable infrastructure for in-service inspection of steam generators.

Emergency Operating Instructions (EOIs)/SPDS Training. Training programs will be developed to provide operators and supervisors with the skills necessary to effectively use safety parameter display systems and symptom based emergency operating instructions. This training program will consist of both classroom and simulator training.

Ukraine Safety Assessment Documentation. Rivne NPP is participating in the project to develop design basis documents for VVER-1000 reactors in Ukraine. This project also will establish configuration management processes at Rivne.

Ukraine Safety Evaluation Codes. Personnel associated with safety assessments were provided with the training and practical experience needed to apply state-of-the-art reactor safety analysis codes to the safety assessment of the nuclear power plant. This project also supports the efforts necessary to assess the adequacy and applicability of the computer codes to the safety assessment of VVER reactors.

South Ukraine Nuclear Power Plant

Scope and Status of Activities

NNSA projects at South Ukraine nuclear power plant have supported developing full-scope simulators to enhance operator training. In addition, in-depth safety assessments are under way, and safety parameter display systems are being provided.

Unit	Reactor Model	Net Output	Initial Start	Status
1	VVER-1000	950 MWe	12/1982	Operating
2	VVER-1000	950 MWe	12/1984	Operating
3	VVER-1000	950 MWe	09/1989	Operating
4	VVER-1000	950 MWe	Cancelled	

South Ukraine Unit 1

South Ukraine-1 In-Depth Safety Assessment. South Ukraine NPP safety-assessment activities for Unit 1 began in 1996. These activities address issues related to safe operation of the plant and point out risk elements of the plant that need improvements. There has been good progress on this project due to the commitment of the host-country organizations and the plant staff as well as to the U.S. assistance. The project team has successfully completed the safety-assessment project guidelines, the development of system descriptions, and the assembly of the nuclear-steam-supply system database, the component-reliability database, the abnormal event database, and the containment database. They also developed all necessary thermal-hydraulic models. The project team also completed a Level 1 internal-event probabilistic risk assessment, which provides insights into the accident situations and initiating events that can lead to possible reactor core damage. The plant also completed a full design basis accident (DBA) analysis that will define the safe-operating envelope for the reactor. An independent peer review of the DBA work is under way.

Other tasks being performed for Unit 1 include a risk assessment due to internal hazards (fire and flooding) as well as due to external-hazards, both man-made and natural-phenomenon hazards. The data collection and hazard screening efforts of these assessments have been completed. As part of the overall safety-assessment activities at the VVER type plants in Ukraine, an effort is in progress to develop a database for internal flooding frequencies specific to VVER plants. In 2002 work commenced on an internal-flooding and limited-fire-hazard assessment. Similarly, the effort to complete the external hazards assessment was started.

Ukraine VVER SPDS – South Ukraine Unit 1. Safety parameter display systems have been provided to all three units. The Unit 1 SPDS was installed in 2000.

Safety Related Reactor Security. In 1999, an assessment of the safety risks associated with physical security at Ukraine's NPPs was performed. Based on the results of this assessment, NNSA is assisting the Ukrainian plants in upgrading their physical security systems. Physical security upgrades will be implemented at each of the units. The scope of the upgrades will include an improved access control system for internal limited access and vital areas, improved interior physical barriers, intrusion detection, an alarm and surveillance system, and a central alarm station. The project will also provide, as necessary, security personnel training in the use of hardware and software, and appropriate procedures.

Emergency Core Cooling Recirculation Pilot Project. Experiments have indicated that the thermal insulation on reactor coolant system piping and vessels in VVER-1000 plants in Ukraine could be damaged and dispersed in a loss-of-coolant accident in a manner that would block the containment sump and prevent emergency coolant from being pumped to the reactor. Under a licensing agreement, the Ukrainian company Askenn will manufacture replacement insulation blankets using the NUKON technology, which is widely used in the United States. Askenn has received training from the U.S. Company PCI and is currently manufacturing samples to obtain certification within Ukraine. The pilot demonstration project involves the replacement of insulation on the reactor coolant system piping of South Ukraine Unit 1

South Ukraine Unit 2

Ukraine VVER SPDS – South Ukraine Unit 2. The SPDS for Unit 2 was installed in 2000.

Safety Related Reactor Security. In 1999 an assessment of the safety risks associated with physical security at Ukraine's NPPs was performed. Based on the results of this assessment, NNSA is assisting the Ukrainian plants in upgrading their physical security systems. Physical security upgrades will be implemented at each of the units. The scope of the upgrades will include an improved access control system for internal limited access and vital areas, improved interior physical barriers, intrusion detection, an alarm and surveillance system, and a central alarm station. The project will also provide, as necessary, security personnel training in the use of hardware and software, and appropriate procedures.

Emergency Core Cooling Recirculation Pilot Project. Experiments have indicated that the thermal insulation on reactor coolant system piping and vessels in VVER-1000 plants in Ukraine could be damaged and dispersed in a loss-of-coolant accident in a manner that would block the containment sump and prevent emergency coolant from being pumped to the reactor. Under a licensing agreement, the Ukrainian company Askenn will manufacture replacement insulation blankets using the NUKON technology, which is widely used in the U.S. Askenn has received training from the U.S. company PCI and is currently manufacturing samples to obtain certification within Ukraine. The pilot demonstration project involves the replacement of insulation on the reactor coolant system piping of South Ukraine Unit 1.

South Ukraine Units 1 and 2

South Ukraine Unit 1 Full-Scope Simulator. A full-scope simulator for South Ukraine Unit 1 was completed and turned over to the plant in June 2001.

Emergency Control Panel Simulator. The emergency control panels for South Ukraine Unit 1 will be simulated and integrated with the simulation model for the South Ukraine Unit 2 full-scope simulator. This is currently planned for funding in 2003.

Transfer of Emergency Operating Instructions (EOIs) to South Ukraine. EOIs improve the ability of reactor operators to minimize the effects of abnormal plant transients and multiple failures are currently being implemented at two pilot plants in Ukraine. South Ukraine NPP has participated in a limited number of EOI seminars and has begun writing their preliminary EOI development, training, and maintenance guidance.

South Ukraine Unit 3

South Ukraine Unit 3 Full-Scope Simulator. A full-scope simulator for South Ukraine Unit 3 was completed in April 2000. The simulator has been fully accepted by the Ukrainian regulator and is being used to train reactor operators and supervisors.

Ukraine VVER SPDS – South Ukraine Unit 3. The SPDS for Unit 3 was installed in 2000.

Ukraine Simulator Integration for SPDS. Installation of a safety parameter display system on the Unit 3 simulator was commenced in 2001.

Transfer of Emergency Operating Instructions (EOIs) to South Ukraine. EOIs improve the ability of reactor operators to minimize the effects of abnormal plant transients and multiple failures is currently being implemented at two pilot plants in Ukraine. South Ukraine NPP has participated in a limited number of EOI seminars and has begun writing their preliminary EOI development, training, and maintenance guidance.

Safety Related Reactor Security. In 1999 an assessment of the safety risks associated with physical security at Ukraine's NPPs was performed. Based on the results of this assessment, NNSA is assisting the Ukrainian plants in upgrading their physical security systems. Physical security upgrades will be implemented at each of the units. The scope of the upgrades will include an improved access control system for internal limited access and vital areas, improved interior physical barriers, intrusion detection, an alarm and surveillance system, and a central alarm station. The project will also provide, as necessary, security personnel training in the use of hardware and software, and appropriate procedures.

South Ukraine All Units

Ukraine Training Technology Transfer. The Systematic Approach to Training methodology is being transferred from the Khmelnytskyy Training Center. A plant-specific training program for instrumentation and control technicians on soldering techniques and integrated circuit repair was developed and implemented. To complement the course, soldering equipment was purchased for the plant. Basic equipment, including a computer with network capabilities and a printer, was provided for the development and support of training.

Three additional pilot training courses for Control Room Reactor Operators, Unit Shift Supervisors, and Control Room Turbine Operators have been implemented. Future courses for Electrical Shift Supervisors, Instrumentation and Control Supervisors, Turbine Department Shift Supervisors, and Reactor Department Shift Supervisors are planned to be in place by 2005. In addition, the development of an on-the-job training program is planned.

Ukraine Operational Safety Infrastructure. A Ukrainian nuclear-safety-infrastructure project initiated by NNSA is benefiting South Ukraine NPP with operational safety improvements.

Ukraine Quality Assurance. South Ukraine NPP staff participated in various workshops and training programs designed to develop the Ukrainian national standard for QA at nuclear power plants. Staff also participated in a QA training program that officially certified personnel from the various nuclear power plants and Energoatom as QA auditors. Site-specific procedures for assessments, based on Energoatom guidelines, were developed, and procedures for document control and QA records, including specific procedures for maintenance work planning, were implemented. An audit of radiological environmental monitoring was conducted.

Ukraine Event Analysis and Reporting. South Ukraine NPP staff was active in the working group monitoring the project for developing event-reporting systems, implementing improved procedures/ processes for performing root cause analysis, and implementing lessons learned. South Ukraine NPP staff received training on root cause analysis. Program procedures for South Ukraine NPP will be developed, an event reporting program database created and populated, and the necessary computer equipment provided to support program implementation at South Ukraine NPP.

Ukraine Reliability Database. South Ukraine NPP is currently implementing Version 1 of the Ukrainian reliability database. This primarily includes developing interfacing applications that are consistent with plant maintenance practices and software tools.

Additional project work will include 1) developing Version 2 of the database for the plants and utility that will allow sharing and analysis of information between plants in Ukraine, 2) developing the protocols for sharing this information with plants in other countries (coordinated through WANO), and 3) cataloging basic event failure probabilities used in existing probabilistic risk assessments at Ukrainian nuclear power plants and generation of new plant-specific values based on information in the Ukrainian reliability database. This information might also be shared with operators of other Soviet-designed reactors via WANO.

Ukraine Nondestructive Examination and Safety Maintenance Initiative. Energoatom recognized the need to improve the training and certification practices in Ukraine and agreed to develop a central NDE training and certification facility in April 1998. One of the primary missions of this facility is to conduct NDE training and certification to international standards in Ukraine. Under the NDE activity, Ukraine has developed a certification practice that now meets international standards and is currently training staff from all Ukraine NPPs to international standards. Other activities include providing state-of-the-art equipment to the NPPs, including ultrasonic and eddy current detection equipment. Efforts are under way to fabricate affordable eddy current probes in Ukraine, thus providing a sustainable infrastructure for in-service inspection of steam generators.

Emergency Operating Instructions/SPDS Training. Training programs will be developed to provide reactor operators and supervisors with the skills necessary to effectively use SPDSs and symptom-based EOIs. This training program will consist of both classroom and simulator training.

Ukraine Safety Assessment Documentation. South Ukraine NPP is participating in the project to develop design basis documents for VVER-1000 reactors in Ukraine. This project also will establish configuration management processes at South Ukraine.

Ukraine Simulator Training and Engineering Support. The Engineering and Technical Center for Training of Nuclear Industry Personnel, established with U.S. support, will provide simulator training and model modification support to South Ukraine in the future. Simulator exercise guides were developed for Units 1 and 3 simulators. In addition, spare parts and other support for the operation of the simulators will be provided.

Ukraine Safety Evaluation Codes. Personnel associated with safety assessments were provided with the training and practical experience needed to apply state-of-the-art reactor safety analysis codes to the safety assessment of the nuclear power plant. This project also supports the efforts necessary to assess the adequacy and applicability of the computer codes to the safety assessment of VVER reactors.

Zaporizhzhya Nuclear Power Plant

Scope and Status of Activities

Unit	Reactor Model	Net Output	Initial Start	Status
1	VVER-1000	950 MWe	11/1984	Operating
2	VVER-1000	950 MWe	06/1985	Operating
3	VVER-1000	950 MWe	12/1986	Operating
4	VVER-1000	950 MWe	12/1987	Operating
5	VVER-1000	950 MWe	06/1989	Operating
6	VVER-1000	950 MWe	10/1995	Operating

NNSA is involved in a wide range of activities at Zaporizhzhya nuclear power plant to help improve operational safety, upgrade critical plant safety systems, complete in-depth safety assessment, and ensure adequate storage facilities for spent nuclear fuel. This work is helping to establish a nuclear safety infrastructure and safety culture at the plant that will result in a sustained safety-improvement program at Zaporizhzhya NPP.

Zaporizhzhya NPP has six VVER-1000 reactors. Since Zaporizhzhya NPP is the largest and the most advanced of the Ukrainian nuclear power plants, the scope of activities includes many pilot projects that will be transferred or are already transferred to other nuclear power plants in the former Soviet Union and Eastern Europe. These projects include activities to improve operational safety (1993-2006), development of simulators and training technology (1996–2006), provision of fire-safety equipment (1993-2001), development of safety parameter display systems (1996-2002), performance of in-depth safety assessment (1996-2005), and provision of a dry-storage system for spent fuel (1994-2001).

Zaporizhzhya Unit 1

Ukraine VVER SPDS. The Unit 1 SPDS was installed in 2001 and is operational. A multi-unit SPDS capability also is being developed to help technical support personnel in the Technical Support Center (which supports all six units) aid control-room operators during an emergency. This capability became operational in 2002.

Safety Related Reactor Security. In 1999, an assessment of the safety risks associated with safety and security at Ukraine's nuclear power plants was performed. Based on the results of this assessment, NNSA is assisting the Ukrainian plants in upgrading their physical security systems. The upgrades to

Zaporizhzhya Unit 1 began in 2001. Currently, the project is focused on the common site-wide security infrastructure upgrade, such as the central alarm station and specific upgrades for Unit 1. Other upgrades include improving the detection, assessment, and alarm systems; improving access control for the internal vital and limited access areas; and providing test and operation training programs and procedures.

Zaporizhzhya Unit 2

Ukraine VVER SPDS. The system has been installed and is in operation at Unit 2.

Safety Related Reactor Security. Upgrades to Zaporizhzhya Unit 2 security systems began in 2001. The design effort is in progress. Plans are to implement upgrades in 2004.

Zaporizhzhya Unit 3

Ukraine VVER SPDS. The system has been installed and is in operation at Unit 3.

VVER Control and Information System. A project will be undertaken at Units 3 and 4 using equipment that interfaces with and shares information with the safety parameter display system. The upgrade to the control and information system will be initiated in 2003.

Safety Related Reactor Security. Upgrades to Zaporizhzhya Unit 3 security systems began in 2002. The design is complete. PNNL is conducting a tender for integrating contractors to implement upgrades at Units 2 – 6. It is planned to complete upgrades in 2003.

Zaporizhzhya Unit 4

Ukraine VVER SPDS. Testing of the Unit 4 system was completed in January 2001.

VVER Control and Information System. A pilot project will be undertaken at Units 3 and 4 using equipment that interfaces with and shares information with the safety parameter display system. The Control and Information System upgrade will be initiated in 2003.

Safety Related Reactor Security. Upgrades to Zaporizhzhya Unit 4 security systems will be implemented in 2004.

Zaporizhzhya Unit 5

Ukraine VVER SPDS. The system has been installed and is in operation at Unit 5.

Zaporizhzhya Unit 5 In-Depth Safety Assessment. Zaporizhzhya NPP safety-assessment activities to improve operational safety are focused on Unit 5. The probabilistic and deterministic analysis will assist in determining the reactor's safety posture. With U.S. assistance, Unit 5 personnel have a detailed understanding of the as-is condition of the plant and its systems important to operation and safety. Plant staff completed a Level 1 internal-event probabilistic risk assessment, which provided insights into the accident situations and initiating events that can lead to possible reactor core damage. In addition, the plant has carried out a large amount of deterministic-accident analyses, and is currently performing the design basis accident (DBA) analyses. These analyses are used to support an understanding of how the reactor and its safety systems will perform under accident conditions and define the safe operating envelope for the reactor.

Also, in place are the information collection and screening of man-made and natural phenomena hazards as well as the screening of the internal fire and flooding hazards. Future safety-assessment work for Zaporizhzhya Unit 5 will include selected detailed analyses and risk assessments for external and internal hazards based on findings of the screening study. Additional deterministic analyses to support the development of the symptom-based emergency operating instructions were started in late 2001.

Zaporizhzhya Safe Shutdown Analysis. A detailed fire-safe shutdown analysis is in progress for Zaporizhzhya NPP Unit 5 (a parallel study in Russia was recently completed for Smolensk Unit 3). The deterministic safe shutdown analysis, including comment incorporation, was completed in December 2001. The probabilistic analysis portion of the project has been combined with the Zaporizhzhya Unit 5 in-depth safety assessment project to perform a fire probabilistic risk assessment (PRA) for the plant. The information and databases developed for the deterministic analysis will be used to perform the fire PRA and parts of the flooding PRA. Proposed corrective actions for the vulnerabilities identified in the deterministic analysis will be developed.

Safety Related Reactor Security. Upgrades to Zaporizhzhya Unit 5 security systems will be implemented in 2004.

Zaporizhzhya Unit 6

Ukraine VVER SPDS. The SPDS for Unit 6 was completed in 2001.

Safety Related Reactor Security. Upgrades to Zaporizhzhya Unit 6 security systems will be completed in 2005.

Zaporizhzhya All Units

Zaporizhzhya VVER-1000 Emergency Operating Instructions (EOIs). EOIs are being transferred to Zaporizhzhya NPP to improve the ability of reactor operators to minimize the effects of abnormal plant transients and multiple failures. Zaporizhzhya Unit 5 has been chosen as the pilot plant for VVER-1000 EOIs in Ukraine. The analysis necessary to technically validate these EOIs is being conducted as part of the in-depth safety assessment being performed for Zaporizhzhya.

Zaporizhzhya Unit 1 Full-Scope Simulator. A full-scope simulator for Zaporizhzhya Unit 1 was completed and turned over to the plant in November 2002.

Zaporizhzhya Unit 3 Full-Scope Simulator. A project for a full-scope simulator for Zaporizhzhya Unit 3 commenced in 2002.

Zaporizhzhya Unit 5 Full-Scope Simulator Upgrade. A full-scope simulator for Zaporizhzhya Unit 5 was developed in the early 1990s. The model had significant deficiencies, and the computer hardware was outdated. This project, completed in 1999, upgraded the simulation models and provided state-of-the-art computer systems.

Zaporizhzhya VVER-1000 V320 Fire Safety Upgrades. One of DOE's first fire-safety projects was a pilot study of basic fire-safety upgrade equipment at Zaporizhzhya NPP. To date, the United States has provided fire-brigade suits (50 sets), self-contained breathing apparatus, fire doors (122 doors), fire-suppression equipment (sprinkler heads, alarms, hose nozzles, and fire-protection system valves), fire detection and alarm equipment, and fire-sealant materials for cable penetrations. All of the fire doors and penetration sealant materials have been installed. Installation of the fire detection and suppression equipment has been completed at all of the units.

Ukraine Training Technology Transfer. Training courses for Chemical Operators, Control Room Reactor Operators and Unit Shift Supervisors, and Control Room Turbine Operators have been implemented. Future courses for Electrical Shift Supervisors, Instrumentation and Control Supervisors, Turbine Department Shift Supervisors, and Reactor Department Shift Supervisors are planned to be in place by 2005. In addition, the development of an on-the-job training program is planned.

Ukraine Nondestructive Examination and Safety Maintenance Initiative. Energoatom recognized the need to improve the training and certification practices in Ukraine and agreed to develop a central NDE training and certification facility in April 1998. One of the primary missions of this facility is to conduct NDE training and certification to international standards in Ukraine. Under the NDE activity, Ukraine has developed a certification practice that now meets international standards and is currently training staff from all Ukraine NPPs to international standards. Other activities include providing state-of-the-art equipment to the NPPs, including ultrasonic and eddy current detection equipment. Efforts are under way to fabricate affordable eddy current probes in Ukraine, thus providing a sustainable infrastructure for in-service inspection of steam generators.

Ukraine Reliability Database. Zaporizhzhya NPP is scheduled to receive a second-generation (Version 2) implementation of the Ukrainian Reliability Database. This includes development of the database structure and generic interfacing applications. These activities require customizing the generic interfacing applications to work with existing data collection systems and work practices at each of the plants.

Additional project work will include 1) developing Version 2 of the database for the plants and utility that will allow sharing and analysis of information between plants in Ukraine, 2) developing the protocols for sharing this information with plants in other countries (coordinated through WANO), and 3) cataloging basic event failure probabilities used in existing probabilistic risk assessments at Ukrainian nuclear power plants and generation of new plant-specific values based on information in the database. This information also might be shared with operators of other Soviet-designed reactors via WANO.

Ukraine Management & Operational Safety Practices. Zaporizhzhya NPP used the generic management and operational safety practices guidelines developed by the operational-safety working group to draft 16 site-specific guidelines that were approved by Energoatom and the Ukrainian regulator and implemented in 1997.

Ukraine Operational Safety Infrastructure. A Ukrainian nuclear-safety-infrastructure project initiated by the U.S. Department of Energy is benefiting Zaporizhzhya NPP in areas of emergency response communications and in developing a computer-aided system for operating procedures associated with reactor startup and shutdown.

Ukraine Quality Assurance. Zaporizhzhya NPP staff participated in various workshops and training programs designed to develop the Ukrainian national standard for QA at nuclear power plants. Staff also participated in a QA training program that officially certified personnel from the various nuclear power plants and Energoatom as QA auditors. Site-specific procedures for assessments, based on Energoatom guidelines, were developed, and procedures for document control and QA records, including specific procedures for maintenance work planning, were implemented.

Ukraine Event Analysis and Reporting. Zaporizhzhya NPP is the pilot plant for a project to develop event-reporting systems, implement improved procedures/processes for performing root cause analysis, and implement lessons learned. Zaporizhzhya NPP staff received training in the United States on operating experience methodology and in Ukraine on root-cause analysis.

Program procedures for Zaporizhzhya NPP were developed, an event reporting program database was created and is being populated, and the necessary computer equipment was provided to support program implementation at Zaporizhzhya NPP. Full pilot implementation at Zaporizhzhya was completed at the end of 2000.

Zaporizhzhya Simulator Maintenance Course and Tools. Zaporizhzhya NPP developed a full-scope simulator with their own funds but did not have the infrastructure to effectively maintain or modify the simulator. Therefore, the Zaporizhzhya training center personnel were provided courses in simulator hardware and software maintenance. The training center also received the necessary equipment to allow them to perform hardware maintenance.

Ukraine Simulator Integration for SPDS. An SPDS was fully integrated into the full-scope simulators for Zaporizhzhya Unit 5 and Unit 1.

Ukraine Simulator Training and Engineering Support. The Engineering and Technical Center for Training of Nuclear Industry Personnel, established with U.S. support, will provide simulator training and model modification support to Zaporizhzhya in the future. Simulator exercise guides will be developed for Units 1, 3, and 5 simulators. In addition, spare parts and other support for the operation of the simulators will be provided.

Emergency Control Room Simulation. The emergency control panels for Zaporizhzhya Unit 1 will be simulated and integrated with the simulation model for the Zaporizhzhya Unit 1 full-scope simulator.

Emergency Operating Instructions (EOIs)/SPDS Training. Training programs will be developed to provide operators and supervisors with the skills necessary to effectively use SPDSs and symptom-based EOIs. This training program will consist of both classroom and simulator training.

Ukraine Pronet Software and Training. PRONET software was developed to assist the nuclear power plants with the development/clerical/ editorial management of the instructions.

Ukraine Fire Hazards Evaluation Training. Following the development of "Reactor Core Protection Evaluation Methodology for Fires at RBMK and VVER Nuclear Power Plants, December 1996," representatives of each of the Ukrainian and Russian nuclear power plant sites were trained in the application of fire hazards evaluation methods to their plants. Pilot fire safe shutdown studies were subsequently undertaken at the Smolensk plant in Russia and at the Zaporizhzhya plant in Ukraine.

Ukraine Safety Control System Upgrade. The need for replacement of instrumentation and control systems at the older VVER and RBMK nuclear power plants has been identified as a critical safety issue in IAEA reviews. In this project, Energoatom reviewed the need to develop in-country capability for the replacement of control modules, similar to the control module replacement project undertaken in Lithuania for Ignalina Nuclear Power Plant. In general, wholesale replacement of instrumentation and control systems will be undertaken as the preferred approach.

Ukraine Safety Assessment Documentation. Zaporizhzhya served as the pilot plant to improve methodologies for control and maintenance of design and safety basis documentation. Equipment was provided to support a planned configuration-management database. Further development of the configuration management system will be done as part of the design basis document project.

Ukraine Dry Cask Spent Fuel Storage System. With U.S. assistance, Ukraine is establishing its first dry cask storage system at Zaporizhzhya NPP. The United States has supported the fabrication of three dry storage cask prototypes, auxiliary equipment, procedures, and training required for transferring the technology to Ukraine. Zaporizhzhya NPP has been responsible for licensing of the system, preparing the storage location, and sustaining the technology transferred to Zaporizhzhya NPP. The NNSA also has provided Zaporizhzhya NPP with assistance in resolving licensing issues with the regulator. The successful loading of the first three casks occurred in August 2001.

Ukraine Safety Evaluation Codes. Personnel associated with safety assessments were provided with the training and practical experience needed to apply state-of-the-art reactor safety analysis codes to the safety assessment of the nuclear power plant. This project also supports the efforts necessary to assess the adequacy and applicability of the computer codes to the safety assessment of VVER reactors.

Ukraine Legal and Regulatory Capabilities and Other Crosscutting Activities

Regulatory Support

Ukraine Regulatory Capability Enhancement. Training and technical assistance were provided to the Ukrainian regulatory organization to help develop a strong independent regulatory infrastructure. The efforts focused on transferring U.S. methodologies in the area of nuclear and radiation safety regulation and needed improvements in the regulatory oversight practices.

Ukraine Emergency Operating Instruction (EOI) Capabilities for Regulators. Assistance was provided to the Ukrainian regulator to help familiarize them with the concept of symptom-based EOIs and to support the development of guidelines for review and acceptance of the EOIs. This activity was completed in 1998.

Ukraine Regulatory Assistance Dry Cask Licensing. Training and analytical tools were provided to the Ukrainian regulators. The regulators used the tools to evaluate compliance of dry-storage systems with safety requirements for nuclear criticality, radiation dose, and maximum fuel temperature.

Convention for Accident Compensation and Legislative Strategy. Support was provided to facilitate the Government of Ukraine to sign the "Supplementary Funding Convention for Accident Compensation" in September 1997 at the International Atomic Energy Agency's Diplomatic Conference in Vienna Austria. This convention channels the liability responsibility to the responsible operators of the plants.

Ukraine Nuclear Safety Institutional Framework. Assistance was provided to the State Nuclear Regulatory Commission of Ukraine to develop and adopt regulations necessary for long-term regulation or nuclear power plants and to address other institutional issues like long-term management of radioactive wastes.

SNRA Communications. A new telephone system was purchased for the Ukraine regulator.

Safety Analysis Support

International Information Exchange Forum. This annual forum allows for information exchange and the sharing of experience among engineers involved in the safety analysis of Soviet-designed reactors. The forum leverages individual efforts at facilities through sharing and dissemination of results obtained through internationally sponsored projects at Soviet-designed reactors. The sixth forum (Forum 6) was held in 2002, in Kyiv, Ukraine. These forums are currently scheduled to continue through 2005.

Ukraine CAMP Membership. Membership was funded in the U.S. Nuclear Regulatory Commission's (NRC) international code assessment and maintenance program (CAMP) to transfer and provide support for state-of-the-art NRC safety analysis codes to Ukrainian organizations. This project was superseded by the activities undertaken under the Ukrainian RELAP Code User Group project.

NEA VVER Support Group on VVER Testing. Program personnel participated in the Nuclear Energy Agency's activities to evaluate the VVER-1000 thermal hydraulic testing facility at Electrogorsk and to evaluate experimental bubbler condenser models.

Technical Training in Ukraine. The nuclear reactor safety infrastructure was developed to enable development of computer code models and transfer of technical information about nuclear safety issues between Ukrainian research institutes and their U.S. counterparts.

IAEA VVER Safety Assessment Review. Program personnel participated in an international technical review of the IAEA document, "Evaluation of Safety Aspects of VVER-440/213 Nuclear Power Plants." The results of the review were documented in a contribution to an IAEA report.

NEA Support Group on VVER Testing & Bubbler Condenser Experiments. Program participation continued in the Nuclear Energy Agency's activities related to the bubbler condenser, PSB experimental programs, and VVER thermal-hydraulic code validation matrix.

NEA Code Validation Matrix Coordination. A code validation matrix was developed through the coordinated efforts of INSP personnel and the Nuclear Energy Agency.

Ukraine RELAP Code User Group. State-of-the-art reactor system analysis codes were transferred to host-country organizations, and support was provided in the use of these codes. This project replaces the activities undertaken under the Ukrainian CAMP Membership project.

General Support

Ukraine Operator Exchange Program (WANO). Through this program, staff from Ukrainian plants visited and observed operations at U.S. nuclear power plants. The program, now completed, enhanced the capability of plant personnel to develop improved operating-safety procedures and practices.

Kharkiv SPDS Maintenance. Because safety parameter display systems have been introduced and plant computer upgrades are planned at each of the VVER-1000 units in Ukraine, the need exists for an in-country capability to service and repair components for these systems. A service center has been established at the Westron facility in Kharkiv for this purpose.

Emergency Core Cooling Recirculation Pilot Project. Experiments have indicated that the thermal insulation on reactor coolant system piping and vessels in VVER-1000 plants in Ukraine could be damaged and dispersed in a loss-of-coolant accident in a manner that would block the containment sump and prevent emergency coolant from being pumped to the reactor. Under a licensing agreement, the

Ukrainian company Askenn will manufacture replacement insulation blankets using the NUKON technology, which is widely used in the United States. Askenn has received training from the U.S. Company PCI and is currently manufacturing samples to obtain certification within Ukraine. The pilot demonstration project involves the replacement of insulation on the reactor coolant system piping of South Ukraine Unit 1.

Ukraine Capacity Factor Improvements. As a follow-up to the capacity factor improvement studies and demonstration at Rivne NPP, the United States is assisting Energoatom in developing specific proposals that Energoatom can use to obtain loans for improvements and upgrades to its nuclear power plants. The objective is to help improve capacity factors and increase revenues at the plants.

Ukraine Fire Safety EWG Support. Funds were provided for the initial Expert Working Group meetings and for review activities until specific projects were identified.

Ukraine Spent Fuel Management Plan. The Chornobyl Center for Nuclear Safety, Radioactive Waste, and Radioecology assessed the need for interim storage and disposal needs for spent nuclear fuel in Ukraine, assessed the regulatory basis for spent fuel management, and determined technologies that are technically and economically viable in Ukraine for spent fuel management. The final report with conclusions and recommendations was submitted to Ukrainian Ministry of Energy and Energoatom in December 1999.

Ukraine Alternative Energy Study. A joint study was conducted to evaluate the energy needs and generating capabilities in Ukraine.

Ukraine Infrastructure Support. A joint review was conducted to determine what improvements were needed to strengthen the nuclear safety support infrastructure in Ukraine.

International Activities Support. Support was provided for general activities, and potential projects were investigated for inclusion in the program.

Ukraine Private Investment Project. Opportunities were examined for U.S. investment partnerships with Ukrainian businesses. The objective was to assist in the establishment of at least one U.S.-Ukraine business partnerships in the energy sector to assist Ukraine in transitioning from a state-dependent economy, particularly to benefit the transition of Slavutych from near exclusive economic dependence on the Chornobyl NPP in preparation for Chornobyl NPP closure.

Chornobyl/Slavutych Event – May 1999. Deputy Secretary of Energy T. J. Glauthier visited organizations and facilities associated with U.S.-supported nuclear safety improvement projects and with economic development activities.

Nuclear Cooperation. In May 1998, the United States and Ukraine signed an Agreement for Cooperation in the Peaceful Uses of Atomic Energy. As a result of this agreement, the Nuclear Fuels Qualification Project began to support the development of Ukraine's technical capabilities in developing nuclear fuel technology and associated nuclear safety and licensing requirements for Ukrainian nuclear power plants

NEA Program Support. Technical and organizational support was provided to the Nuclear Energy Agency for projects and efforts in Ukraine.

Ukraine Y2K Support. Ukrainian experts participated in various Y2K Information Exchange and Contingency Planning meetings sponsored by DOE. The meetings included exchange of information between plants concerning their Y2K program efforts as well as seminars about contingency planning. The DOE sponsored remediation of the highest priority Y2K vulnerabilities at each of the plants in Ukraine. In addition, DOE representatives were present in the host-country during the Y2K rollover and were in communication with the DOE's Y2K response center.

Ukraine Emergency Preparedness and Response Capability. Establishment of an enhanced emergency response program for Ukraine's nuclear facilities continues to receive U.S. support. The program, which to date has focused on enhancing training capabilities, has expanded to include improving emergency plans, procedures and equipment. Plans include establishing an emergency operations center at each of Ukraine's nuclear power plants; putting into place communications systems for data, voice and video connection and transmission; developing emergency plans to ensure response coordination; and conducting emergency response exercises. In addition, a unified emergency response system will be established by connecting the Chornobyl offsite emergency and training center, Energoatom headquarters, and Ukraine's nuclear power plants.

Related Publications

Office of International Nuclear Safety and Cooperation. 2001. *Improving the Safety of Soviet-Designed Nuclear Power Plants: Report to Congress.* U.S. National Nuclear Security Administration, Washington, D.C.

Office of International Nuclear Safety and Cooperation. 2001. *Improving Safety at Soviet-Designed Nuclear Power Plants - Status Report*. U.S. National Nuclear Security Administration, Washington, D.C. (Quarterly Activity Reports [CD-ROM] also available on the Internet at http://insp.pnl.gov.)

Office of International Nuclear Safety and Cooperation. 2000. *Soviet-Designed Nuclear Power Plant Profiles*. U.S. Department of Energy, Washington, D.C.

Office of International Nuclear Safety and Cooperation. 1999. *International Nuclear Safety Information Exchange*. U.S. Department of Energy, Washington, D.C. Available URL: http://insp.pnl.gov/?infoexchange.agenda.

Office of International Nuclear Safety and Cooperation. 1998. *Improving the Safety of Soviet-Designed Nuclear Power Plants - Strategy Document - Rev. 1*. U.S. Department of Energy, Washington, D.C.

Office of International Nuclear Safety and Cooperation. 1998. *Quarterly Report: U.S. Department of Energy Efforts to Upgrade the Safety of Soviet-Designed Reactors in Russia - July through September 1998*. U.S. Department of Energy, Washington, D.C. (Reports for preceding quarters have been issued since 1995.)

Office of International Nuclear Safety and Cooperation. 1998. *Quarterly Report: U.S. Department of Energy Efforts to Upgrade the Safety of Soviet-Designed Reactors in Ukraine - July through September 1998*. U.S. Department of Energy, Washington, D.C. (Reports for preceding quarters have been issued since 1995.)

Office of International Nuclear Safety and Cooperation. 1998. *Changes and Opportunities, Lessons Learned and Successes*. U.S. Department of Energy, Washington, D.C. Available URL: http://insp.pnl.gov/?infoexchange.agenda.

Pacific Northwest National Laboratory. 1997. *Summary of the Contractor Information Exchange Meeting for Improving the Safety of Soviet-Designed Nuclear Power Plants - February 19, 1997.* PNNL-11547, Richland, Washington.

U.S. General Accounting Office (GAO). 2000. Nuclear Safety—Concerns with the Continuing Operation of Soviet-Designed Nuclear Power Reactors.

Appendix A

Illustrations and Descriptions of Reactor Types at Participating Nuclear Power Plants

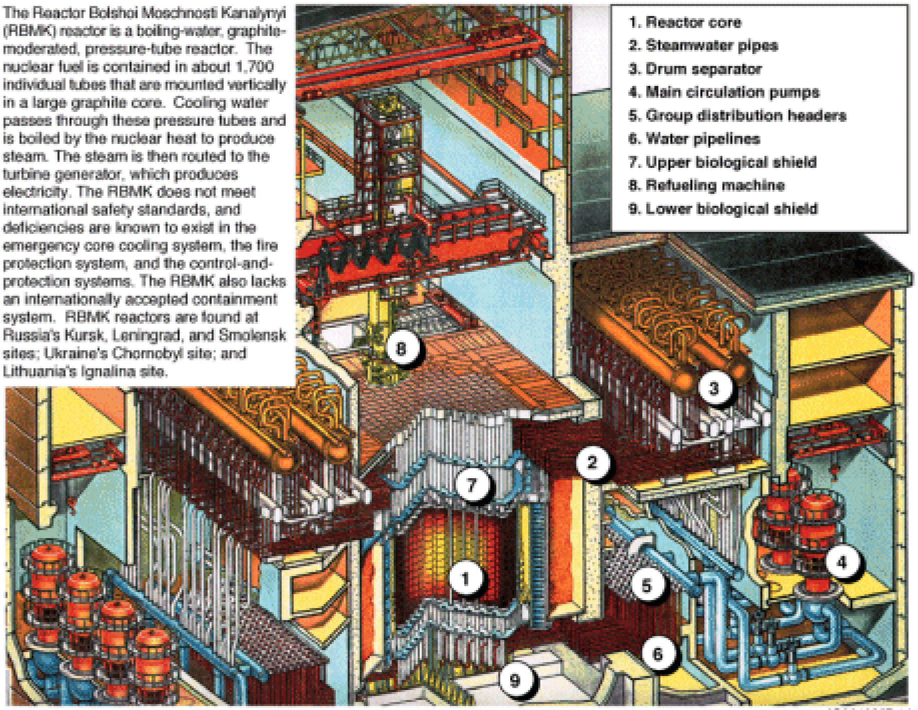
Appendix A

Illustrations and Descriptions of Reactor Types at Participating Nuclear Power Plants

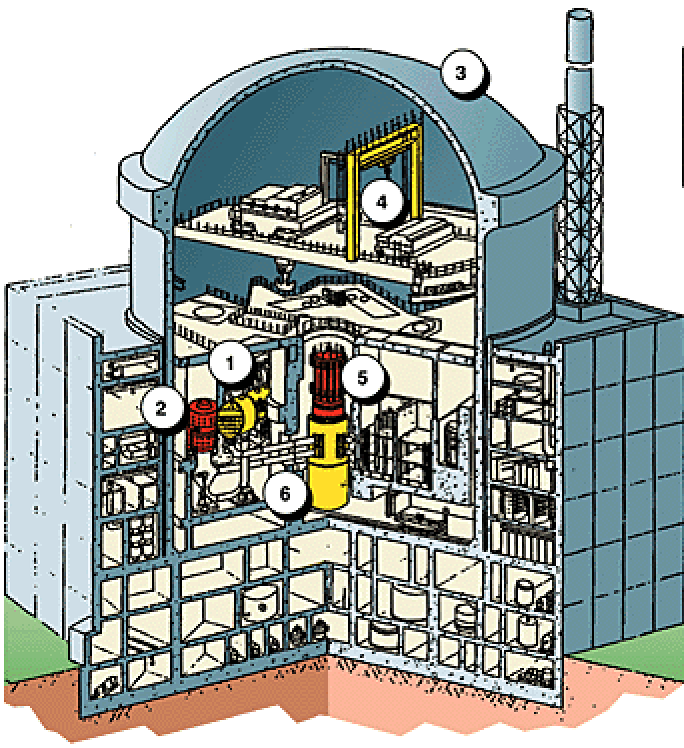
- RBMK Plant Layout
- VVER-1000 Plant Layout
- VVER-440/230 Plant Layout
- VVER-440/213 Plant Layout
- RBMK Reactor Design
- VVER Reactor Design (VVER-440/230)
- BN-600 Reactor Design
- LWGR Reactor Design (Model EGP-6 Channel-Type)

RBMK Plant Layout

The Reactor Bolshoi Moschnosti Kanalnyi (RBMK) reactor is a boiling-water, graphite-moderated, pressure-tube reactor. The nuclear fuel is contained in about 1,700 individual tubes that are mounted vertically in a large graphite core. Cooling water passes through these pressure tubes and is boiled by the nuclear heat to produce steam. The steam is then routed to the turbine generator, which produces electricity. The RBMK does not meet international safety standards, and deficiencies are known to exist in the emergency core cooling system, the fire protection system, and the control-and-protection systems. The RBMK also lacks an internationally accepted containment system. RBMK reactors are found at Russia's Kursk, Leningrad, and Smolensk sites; Ukraine's Chornobyl site; and Lithuania's Ignalina site.



VVER-1000 Plant Layout



The VVER reactor is a pressurized, light-water-cooled and -moderated reactor similar to Western pressurized water reactors (PWRs). There are three predominant models in operation, the VVER-1000 and two versions of the VVER-440.

The VVER-1000 is the largest and newest of the VVERs. This third-generation design produces about 1000 megawatts of electricity and meets most international safety standards. The VVER-1000 employs safety systems common in Western plants, including emergency core cooling systems and a containment structure. The VVER-1000 can be found at the Balakovo, Kalinin, Khmelnytskyy, Kozloduy, Novovoronezh, Rivne, South Ukraine, and Zaporizhzhya sites.

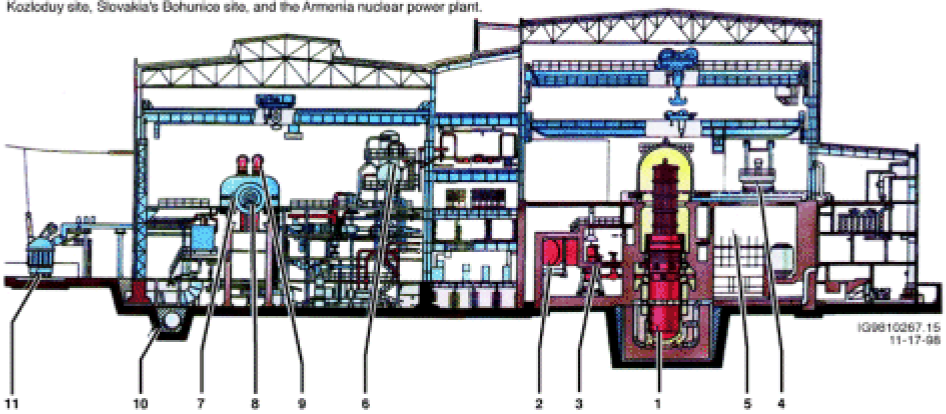
VVER-440 Model 230 Plant Layout

The VVER is a pressurized, light-water-cooled and -moderated reactor similar to Western pressurized water reactors (PWRs). There are three predominant models in operation—the VVER-1000 and two versions of the VVER-440.

The VVER-440/230 was the initial civilian model of the Soviet PWR. It is similar to Western PWRs in that it uses low-enriched uranium oxide fuel, placed in thin metal-clad rods, to generate heat. The fuel rods are cooled by pressurized light water. The steam to run the turbine generator is produced when pressurized, heated water from the reactor is pumped through steam generators where it transfers its heat to a separate secondary coolant.

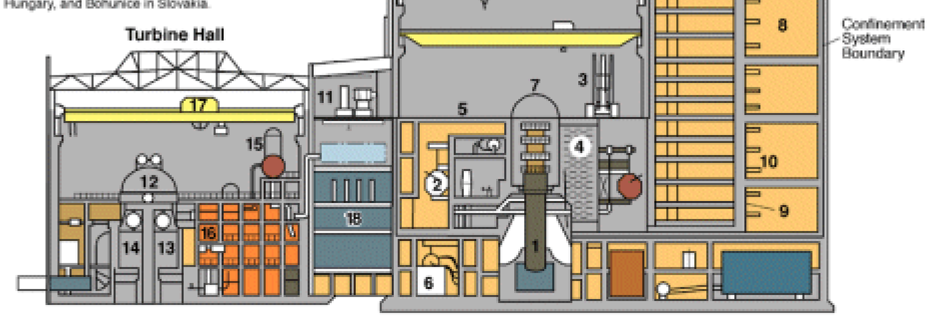
The steam is routed to the turbine generator, which produces about 440 megawatts of electricity. The VVER-440/230, although similar to Western PWRs, lacks a number of safety features, including fire protection systems, emergency core cooling systems, and a strong containment structure. The 440/230 reactor can be found at Russia's Kola and Novovoronezh sites, Bulgaria's Kozloduy site, Slovakia's Bohunice site, and the Armenia nuclear power plant.

1. **Reactor**
2. **Steam generator**
3. **Main circulation pump**
4. **Refueling machine**
5. **Spent fuel cooling pond**
6. **Deaerator**
7. **Steam turbine**
8. **Generator**
9. **Steam pipelines**
10. **Cooling water pipelines**
11. **Transformer**



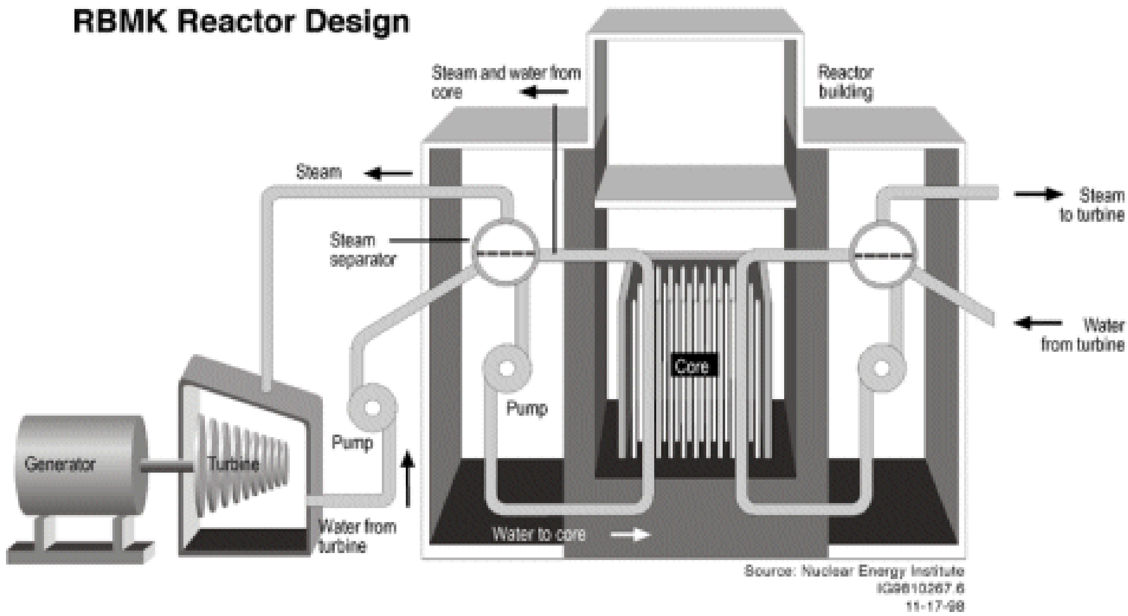
VVER-440/213 Plant Layout

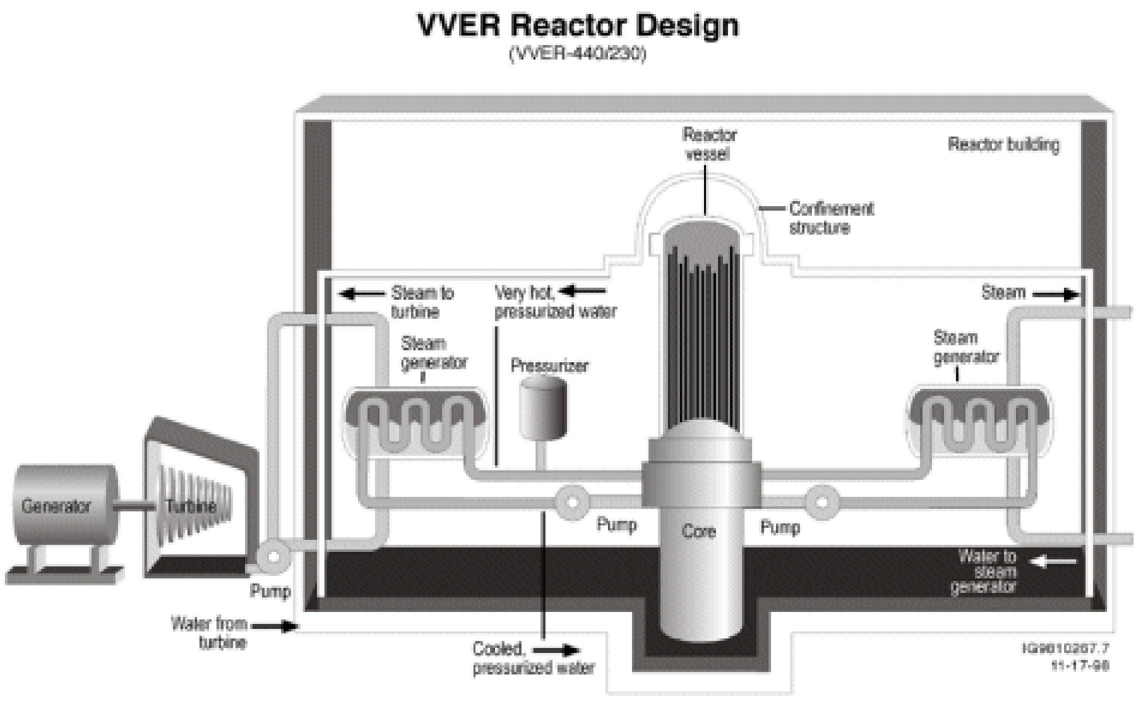
The VVER-440/213, the second-generation VVER design, operates in the same way as the first-generation 230 model (see page A.3), but its design incorporates a few key features that somewhat increase its level of safety. The enhancements include systems for emergency core cooling and auxiliary feedwater, plus a "bubbler condenser" tower that provides some degree of confinement under accident conditions. Other enhancements include a stainless-steel-lined reactor pressure vessel, improved coolant pump, horizontal steam generators (for better heat transfer), and standardized plant components. By international safety standards, however, the fire-protection and electronic control-and protection systems are inadequate. Five plants in five host countries have VVER-440/213 reactors: the Rivne plant in Ukraine, Kola in Russia, Dukovany in the Czech Republic, Paks in Hungary, and Bohunice in Slovakia.



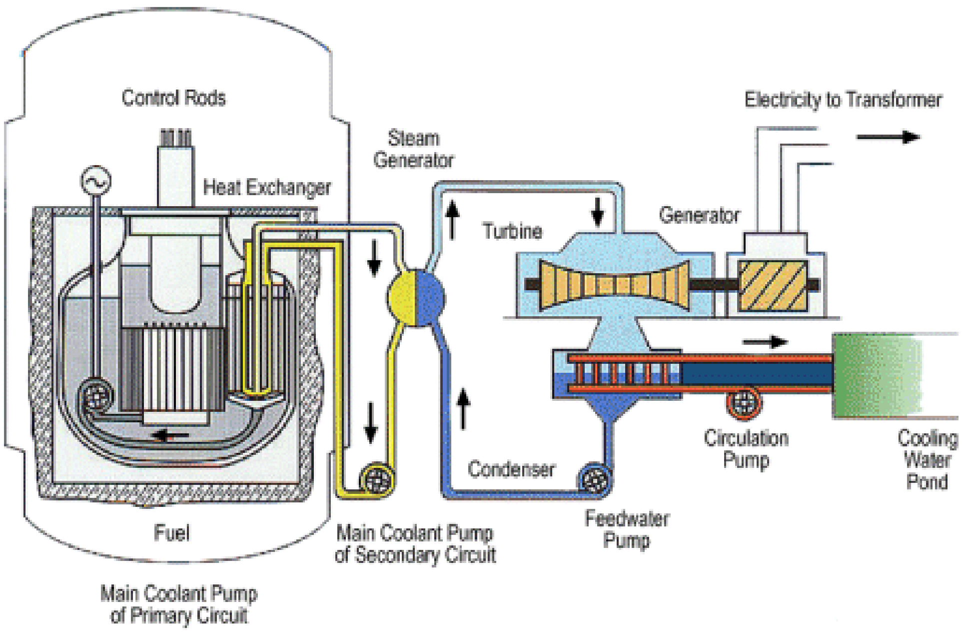
1. **Reactor pressure vessel**
2. **Steam generator**
3. **Refueling machine**
4. **Spent fuel pit**
5. **Confinement system**
6. **Make-up feedwater system**
7. **Protective cover**
8. **Confinement system**
9. **Sparging system**
10. **Check valves**
11. **Intake air unit**
12. **Turbine**
13. **Condenser**
14. **Turbine block**
15. **Feedwater tank with degasifier**
16. **Preheater**
17. **Turbine hall crane**
18. **Electrical instrumentation and control compartments**

IG9810267.16
11-17-98


RBMK Reactor Design
Steam and water from core
Reactor building
Steam
Steam to turbine
Steam separator
Water from turbine
Core
Pump
Generator
Turbine
Pump
Water from turbine
Water to core
Source: Nuclear Energy Institute
IG9810267.6
11-17-98

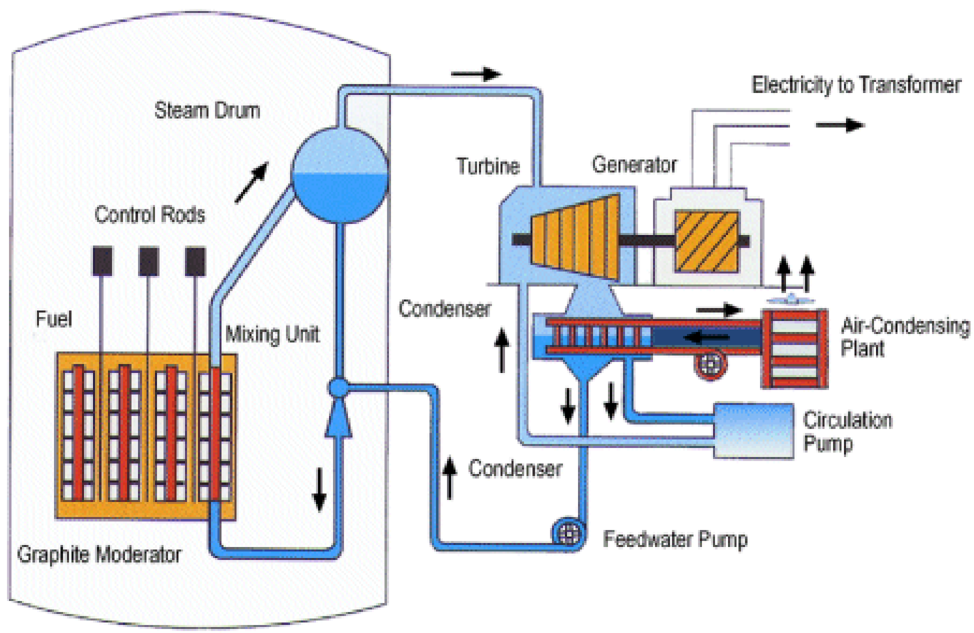

VVER Reactor Design
(VVER-440/230)
Reactor vessel
Reactor building
Confinement structure
Steam to turbine
Very hot, pressurized water
Steam
Steam generator
Pressurizer
Steam generator
Generator
Turbine
Pump
Core
Pump
Pump
Water to steam generator
Water from turbine
Cooled, pressurized water
IG9810267.7
11-17-98

BN-600 Reactor Design



Source: Institute of Physics and Power Engineering, Obninsk, Russia
IG9810267.B
11-17-98

LWGR Reactor Design
(Model EGP-6 Channel-Type)



Source: Institute of Physics and Power Engineering, Obninsk, Russia
IG9810267.C
11-17-98

Appendix B

Soviet-Designed Nuclear Power Plants in Armenia, Ukraine, Russia, Central and Eastern Europe, and Kazakhstan

Appendix B

Soviet-Designed Nuclear Power Plants in Armenia, Ukraine, Russia, Central and Eastern Europe, and Kazakhstan

- Armenia
- Ukraine
- Russia
- Bulgaria
- Czech Republic
- Hungary
- Kazakhstan
- Lithuania
- Slovakia

Key:

BN: Breeder reactor
G-n: Generation of design
LWGR: Light-water-cooled, graphite-moderated reactor
RBMK: Graphite-moderated, boiling-water-cooled channel reactor
VVER: Pressurized water reactor

Armenia		
Plant Name	**Reactor Type**	**Initial Start Date**
Armenia-1	VVER-440 Model 230	1976 (Shut down 1989)
Armenia-2[(a)]	VVER-440 Model 230	1979, 1995 (Shut down from 1989-1994, restarted in 1995)
(a) Actively participates in the cooperative work to improve nuclear safety.		

Ukraine		
Plant Name	**Reactor Type**	**Initial Start Date**
Chornobyl-1	RBMK-1000 (G-1)	1977 (Shut down 1996)
Chornobyl-2	RBMK-1000 (G-1)	1979 (Shut down 1991)
Chornobyl-3[(a)]	RBMK-1000 (G-2)	1981 (Shut down 2000)
Chornobyl-4	RBMK-1000 (G-2)	1984 (Destroyed 1986)

Ukraine (contd)

Plant Name	Reactor Type	Initial Start Date
Khmelnytskyy-1[a]	VVER-1000	1987
Khmelnytskyy-2	VVER-1000	Under construction
Khmelnytskyy-3	VVER-1000	Under construction
Khmelnytskyy-4	VVER-1000	Under construction
Rivne-1[a]	VVER-440 Model 213	1980
Rivne-2[a]	VVER-440 Model 213	1981
Rivne-3[a]	VVER-1000	1986
Rivne-4	VVER-1000	Under construction
South Ukraine-1[a]	VVER-1000	1982
South Ukraine-2[a]	VVER-1000	1984
South Ukraine-3[a]	VVER-1000	1989
South Ukraine-4	VVER-1000	Construction suspended
Zaporizhzhya-1[a]	VVER-1000	1984
Zaporizhzhya-2[a]	VVER-1000	1985
Zaporizhzhya-3[a]	VVER-1000	1986
Zaporizhzhya-4[a]	VVER-1000	1987
Zaporizhzhya-5[a]	VVER-1000	1989
Zaporizhzhya-6[a]	VVER-1000	1995
(a) Actively participates in the cooperative work to improve nuclear safety.		

Russia

Plant Name	Reactor Type	Initial Start Date
Balakovo-1[a]	VVER-1000	1985
Balakovo-2[a]	VVER-1000	1987
Balakovo-3[a]	VVER-1000	1988
Balakovo-4[a]	VVER-1000	1993
Balakovo-5	VVER-1000	Construction suspended
Balakovo-6	VVER-1000	Construction suspended
Beloyarsk-1	LWGR-1000	1964 (Shut down 1983)
Beloyarsk-2	LWGR-1000	1969 (Shut down 1990)
Beloyarsk-3[a]	BN-600	1981
Beloyarsk-4	BN-600	Construction suspended
Bilibino-1[a]	LWGR-12	1973
Bilibino-2[a]	LWGR-12	1973
Bilibino-3[a]	LWGR-12	1975
Bilibino-4[a]	LWGR-12	1976
Kalinin-1[a]	VVER-1000	1984
Kalinin-2[a]	VVER-1000	1986
Kalinin-3	VVER-1000	Under construction
Kalinin-4	VVER-1000	Construction suspended
Kola-1[a]	VVER-440 Model 230	1973

Russia (contd)

Plant Name	Reactor Type	Initial Start Date
Kola-2[a]	VVER-440 Model 230	1974
Kola-3[a]	VVER-440 Model 213	1981
Kola-4[a]	VVER-440 Model 213	1984
Kola-5	VVER-630	Planned
Kola-6	VVER-630	Planned
Kursk-1[a]	RBMK-1000 (G-1)	1976
Kursk-2[a]	RBMK-1000 (G-1)	1978
Kursk-3[a]	RBMK-1000 (G-2)	1983
Kursk-4[a]	RBMK-1000 (G-2)	1985
Kursk-5	RBMK-1000	Under construction
Leningrad-1[a]	RBMK-1000 (G-1)	1973
Leningrad-2[a]	RBMK-1000 (G-1)	1975
Leningrad-3[a]	RBMK-1000 (G-2)	1979
Leningrad-4[a]	RBMK-1000 (G-2)	1980
Novovoronezh-1	VVER-210	1964 (Shut down 1988)
Novovoronezh-2	VVER-365	1970 (Shut down 1990)
Novovoronezh-3[a]	VVER-440 Model 230	1971
Novovoronezh-4[a]	VVER-440 Model 230	1972
Novovoronezh-5[a]	VVER-1000	1980
Novovoronezh-6	VVER-1000	Planned
Novovoronezh-7	VVER-1000	Planned
Rostov-1[a]	VVER-1000	2001
Smolensk-1[a]	RBMK-1000 (G-2)	1982
Smolensk-2[a]	RBMK-1000 (G-2)	1985
Smolensk-3[a]	RBMK-1000 (G-3)	1989
(a) Actively participates in the cooperative work to improve nuclear safety		

Bulgaria

Plant Name	Reactor Type	Initial Start Date
Kozloduy-1[a]	VVER-440 Model 230	Shut down 2002
Kozloduy-2[a]	VVER-440 Model 230	Shut down 2002
Kozloduy-3[a]	VVER-440 Model 230	1980
Kozloduy-4[a]	VVER-440 Model 230	1982
Kozloduy-5[a]	VVER-1000	1987
Kozloduy-6[a]	VVER-1000	1991
(a) Actively participates in the cooperative work to improve nuclear safety.		

Czech Republic

Plant Name	Reactor Type	Initial Start Date
Dukovany-1[(a)]	VVER-440 Model 213	1985
Dukovany-2[(a)]	VVER-440 Model 213	1986
Dukovany-3[(a)]	VVER-440 Model 213	1986
Dukovany-4[(a)]	VVER-440 Model 213	1987
Temelin-1[(a)]	VVER-1000	2000

(a) Actively participates in the cooperative work to improve nuclear safety.

Hungary

Plant Name	Reactor Type	Initial Start Date
Paks-1[(a)]	VVER-440 Model 213	1982
Paks-2[(a)]	VVER-440 Model 213	1984
Paks-3[(a)]	VVER-440 Model 213	1986
Paks-4[(a)]	VVER-440 Model 213	1987

(a) Actively participates in the cooperative work to improve nuclear safety.

Kazakhstan

Plant Name	Reactor Type	Initial Start Date
Aktau[(a)]	BN-350	1973 (Shut down 1999)

(a) Actively participates in the cooperative work to improve nuclear safety.

Lithuania

Plant Name	Reactor Type	Initial Start Date
Ignalina-1[(a)]	RBMK-1500 (G-2)	1983
Ignalina-2[(a)]	RBMK-1500 (G-2)	1986

(a) Actively participates in the cooperative work to improve nuclear safety.

Slovakia

Plant Name	Reactor Type	Initial Start Date
Bohunice-1[(a)]	VVER-440 Model 230	1978
Bohunice-2[(a)]	VVER-440 Model 230	1980
Bohunice-3[(a)]	VVER-440 Model 213	1984
Bohunice-4[(a)]	VVER-440 Model 213	1985
Mochovce-1	VVER-440 Model 213	1998
Mochovce-2	VVER-440 Model 213	1999
Mochovce-3	VVER-440 Model 213	Under construction[(b)]
Mochovce-4	VVER-440 Model 213	Under construction[(b)]

(a) Actively participates in the cooperative work to improve nuclear safety.
(b) It is unlikely that construction of Mochovce Units 3 and 4 will ever be completed.

Appendix C

Definition of Terms

Appendix C

Definition of Terms

ABAQUS. Suite of U.S.-developed engineering analysis software packages used throughout the world to simulate the physical response of structures and solid bodies to load, temperature, contact, impact, and other environmental conditions

ACE. The advanced containment experiments evaluating radiation releases from a nuclear power plant, in the case of an accident.

ADAM. U.S.-developed computer code for nuclear accident diagnosis, analysis, and management.

analysis of emergency operating instructions. A process of using computer simulations of accident scenarios to ensure that a plant's emergency operating instructions will mitigate the consequences of an accident.

Atomenergoproekt. Architect/engineering organization that designed the non-nuclear portions of the Soviet-designed nuclear power plants.

BN. Breeder reactor

BN-350 and BN-600 reactors. These are liquid-metal-cooled, fast breeder reactors.

Blowdown. A blowdown occurs when a pipe carrying hot, pressurized water breaks, causing the leaking water to flash to steam. When a blowdown involves pipes that carry reactor cooling water, the released steam will contain radionuclides.

COBRA-SFS. U.S.-developed computer program, Coolant Boiling in Rod Arrays-Spent-Fuel Storage, used to analyze single-phase gas-cooled spent-fuel storage casks with radiative, convective, and conductive heat transfer.

CONTAIN. Computer code used to model containment response to accident conditions.

configuration management. A process for ensuring that a nuclear power plant's physical configuration and layout meet the safety design basis for the plant and that all design documentation is up to date.

control-and-protection system. An electronic system that monitors 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.

deactivation. A process that follows the permanent shutdown of a reactor, leaving it in a safe storage condition for an indefinite period. Deactivation includes removing the nuclear fuel from the reactor core, draining and drying the primary coolant systems, and shutting off power to some of the electrical and control systems.

decommissioning. The process of safely removing a facility from service followed by reducing residual radioactivity to a level that permits the release of the property for unrestricted use.

dry-cask storage system. A means of storing spent nuclear fuel; it is less costly than storage pools. Concrete casks are filled with 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.

EBRD. European Bank for Reconstruction and Development

Emergency Operating Instructions (EOIs). Set of actions reactor operators must take in an emergency to stabilize the reactor and mitigate consequences of an accident or other abnormal event. *Event-based emergency operating instructions* require operators to identify the cause of a problem, such as loss of power or a leak in a steam-generator tube, before responding. *Symptom-based emergency operating instructions* specify responses to changes in plant parameters, such as reactor pressure, water level, or temperature. By responding to parameter changes, operators can stabilize a reactor without first having to determine the cause of the problem. The time saved can prevent disaster.

Energoatom. Ukrainian organization involved in development of national industry quality assurance standard for nuclear power plants in that country.

G-7 nations. Also known as the Group of 7. Made up of the worlds seven major industrialized countries: Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States. Leaders of the member countries meet periodically to discuss and make decisions regarding a variety of common issues (e.g., economic, political, environmental, security, debt, etc.).

GAN. Gosatomnadzor. Russian organization responsible for regulating the safety of nuclear reactors and fuel cycle enterprises.

GASFLOW. U.S.-developed computer program for analyzing risks of hydrogen buildup in nuclear reactor containment systems.

Gidropress. Russian Design Institute-responsible for VVER reactor design, steam-generator design, and manufacturing, and thermal-hydraulic code development and testing.

GSE. GSE Power Systems Incorporated. U.S. contractor involved in development of full-scope simulators.

IAEA. International Atomic Energy Agency. This agency is the world's central intergovernmental forum for scientific and technical cooperation in the nuclear field. It is also the international inspectorate for the application of nuclear safeguards and verification measures covering civilian nuclear programs.

IBRAE. The Nuclear Safety Institute of the Russian Academy of Sciences

IGSCC. Intergranular stress corrosion cracking

INIT. Information Technologies Incorporated. U.S. contractor involved in development of reliability databases.

INPO. Institute for Nuclear Power Operations

IRL. International Radioecology Laboratory. The IRL, a subsidiary of the International Chornobyl Center in Slavutych, Ukraine, facilititates Ukrainian and international research on the effects of radiation on plants and animals.

In-Depth Safety Assessments (ISAs). ISAs provide the design basis and risk profile to support safe plant operation. The United States also is providing computer codes and technical support to improve the assessment capabilities of specialists at these plants. Host-country regulators use plants' safety assessments as the license basis document in the issuing of long-term operating licenses. **Probabilistic Risk Assessments (PRA)** are used to identify events that would challenge the plant system, to model the progression of an accident, and to estimate system failure probabilities. **Deterministic Risk Analyses (DRA)** use accident scenarios to assess safety margins incorporated into a plant's design.

LWGR reactor. These reactors are graphite-moderated and water-cooled, with no boiling of the cooling water.

MELCOR. U.S.-developed computer program for analyzing severe accidents; used for nuclear power plant safety analyses.

MSC/NASTRAN. U.S.-developed computer program for safety analyses.

Minatom. Ministry of Atomic Energy of the Russian Federation. Russian organization responsible for developing nuclear reactors and for fuel cycle enterprises.

NEPTUNE. U.S.-developed computer program for analyzing the structural safety of nuclear power plant accident localization system.

NESTLE. U.S.-developed computer program for analyzing neutron kinetics.

NIKIET. The Russian designer of RBMK reactors. Also known as RDIPE (Research and Development Institute of Power Engineering) and ENTEK.

NNSA. National Nuclear Security Administration

NSWG. Nuclear Safety Working Group of the G-7 nations (Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States)

Nuclear Energy Agency (NEA). The NEA is a specialized agency within the Organization for Economic Co-operation and Development (OECD), an intergovernmental organization of industrialized countries, based in Paris, France. The mission of the NEA is to assist its Member countries in maintaining and further developing, through international co-operation, the scientific, technological, and legal bases required for the safe, environmentally friendly, and economical use of nuclear energy for peaceful purposes.

nondestructive examination. A process for finding flaws in pipes and steam-generator tubes through the use of ultrasonic, x-ray, and eddy-current equipment.

nuclear plant analyzer. A computer system used to perform safety analyses and calculations. It provides an analytical basis for developing day-to-day operating procedures and emergency operating instructions. The analyzer's thermal-hydraulic and neutronic model of a reactor enables operators to understand and predict the reactor's heat and flow characteristics.

nuclear safety culture. An attitude that stresses safety over all other considerations and is held by staff associated with the design, construction, operation, and regulation of nuclear facilities. It results in design philosophies, construction, and operating practices, and regulatory procedures that set stringent safety goals. Performance is measured against these goals.

nuclear safety infrastructure. The availability of the knowledge, skills, training, tools and equipment, and manufacturing capabilities to design, construct, operate, maintain, and regulate nuclear facilities to established safety levels.

ORIGEN. U.S.-developed safety analysis computer code used to estimate the amount of radioactive materials that would be released from reactor fuel under hypothetical accident conditions.

PACER. U.S.-developed computer program for analysis of reactor confinement systems.

probabilistic and deterministic assessments. Probabilistic assessments are used to identify events that would challenge the plant system, to model the progression of an accident, and to estimate system failure probabilities. Deterministic safety analyses use accident scenarios to assess safety margins incorporated into a plant's design.

RDIPE. Russian Research and Development Institute of Power Engineering. Main designer of RBMK reactors.

REA. Rosenergoatom. The utility of Minatom responsible for operations at all nuclear power plants in Russia except Leningrad NPP, which acts as a separate utility reporting to Minatom.

RELAP5. A thermal-hydraulics code used for safety assessment in the United States. The United States is providing the code and related training to nuclear power plants with Soviet-designed reactors.

REVEAL_W2. U.S.-developed computer program for use in safe-shutdown analyses of nuclear power plants.

RBMK reactors. One of two basic Soviet-designed reactors, the RBMKs are boiling-water, graphite-moderated, pressure-tube reactors. The RBMK design contains deficiencies that include a susceptibility to power instabilities and lack of a modern containment system to prevent release of radionuclides to the environment. The Chornobyl Unit 4 reactor destroyed in the 1986 accident was an RBMK.

root cause analysis. Analysis in which a range of contributors (e.g., management, human decision-making, plant procedures, maintenance) is examined to identify the cause(s) contributing to an error and to determine corrective actions to prevent error recurrence.

R&R WORKSTATION. U.S.-developed computer program for probabilistic risk assessments of nuclear power plants.

SAPHIRE. "Systems Analysis Programs for Hands-on Integrated Reliability Evaluations," a U.S.-developed probabilistic risk and reliability analysis tool.

SCALE. U.S.-developed computer code for analyzing the safety of spent-fuel storage.

SCRAM. A sudden shutting down of a nuclear reactor, usually by dropping safety rods, when a predetermined neutron flux or other dangerous condition occurs.

SSTC. Ukrainian State Scientific and Technical Center

STEPAN. Russian-developed computer program for analyzing neutron kinetics.

STREAM. System for Tracing Remediation, Exposure, Activities, and Materials; management software for decontamination and decommissioning projects at nuclear facilities.

SAFETY MONITOR. U.S.-developed computer software used in modeling a nuclear power plant's safety-related systems as part of a probabilistic risk assessment.

safety parameter display system. Gives plant operators the information they need to control a nuclear plant in the event of an accident. The system automatically displays the status of critical safety functions, such as reactor core cooling, the nuclear chain reaction, and the leak-tightness of the radiation confinement system.

safe-shutdown analysis. A process of identifying the most dangerous fire risks at a nuclear power plant, concentrating on areas where fire could damage the safety systems needed to shut down a reactor safely.

simulators. Computer-based models that replicate nuclear reactor control rooms. *Full-scope simulators* use full-size physical replicas of actual control room panels, complete with equipment such as switches, controllers, indicators, and recorders. *Analytical simulators*, which cost much less, use computer screens with graphic displays that imitate plant systems; operators enter computer commands to "operate" equipment, rather than using switches and controllers as they would in an actual control room or with a full-scope simulator.

systematic approach to training. Provides a standard framework for identifying training needs, developing course materials, and teaching. The approach combines classroom instruction with the use of hands-on equipment, including a full-scope simulator.

TEMP-STRESS. U.S.-developed computer program for analyzing the structural safety of a nuclear power plant's accident localization system.

TACIS Program. Technical Assistance to the Commonwealth of Independent States. The European Union's TACIS Program provides grant finance for the transfer of know-how to twelve countries of the former Soviet Union and Mongolia. The international community adopted a nuclear safety strategy at the G7 summit meeting in Munich, Germany in 1992 in direct support of nuclear safety in Central and Eastern Europe and the New Independent States.

technology transfer. Technology transfer refers not just to the delivery of hardware but to passing on knowledge, processes, and methodologies. The goal is to establish the indigenous safety infrastructure needed for safe operation and maintenance of nuclear plants.

VEIKI. Hungarian Institute for Electric Power Research. Responsible for nuclear power research and development.

VNIIAES. Russian Institute for Nuclear Power Plant Operations. Assists in nuclear power plant start-up, operations, and training; manufactures full-scope and analytical simulators.

VUJE. Slovakian Nuclear Power Plants Research Institute

VVER reactors. These are pressurized, light-water-cooled, and -moderated reactors.

validation and verification. Before using a computer software code for safety analyses of a nuclear power plant, analysts validate the code by checking it against test data. These data are produced by experimental facilities designed to simulate the behavior of a reactor. The analysts verify the code by using it to develop plant models and accident scenarios, then checking the models and scenarios against data from actual reactors.

vibration monitoring and shaft alignment equipment. State-of-the-art systems that enable maintenance staff to detect and correct misalignment and imbalance in rotating machines, such as pumps, which are critical to the safe operation of nuclear power plants.

WANO. World Association of Nuclear Operators.

Improving Safety at Soviet-Designed Nuclear Power Plants

For additional information on the National Nuclear Safety Administration (NNSA) program to improve the nuclear safety of Soviet-designed reactors, visit our website at:
http://insp.pnl.gov

See also the Office of Defense Nuclear Nonproliferation website at:
http://www.nn.doe.gov

For additional copies, contact
Pacific Northwest National Laboratory
International Nuclear Safety Program
Telephone: (509) 372-4108
Fax: (509) 372-4411

Rich Reister
Office of International Nuclear Safety and Cooperation
National Nuclear Safety Administration (NNSA)
19901 Germantown Road
Germantown, MD 20874
U.S.A.
E-mail: richard.reister@nnsa.doe.gov

Pacific Northwest National Laboratory
Operated by Battelle for the
U.S. Department of Energy