Improving the safety of WWER nuclear power plants: Focus on technical assistance in Central and Eastern Europe

At national and regional levels, nuclear specialists are working through IAEA-supported projects to upgrade plant safety levels

by Wiktor Zyszkowski

Energy balance in Central and Eastern Europe is based to a substantial degree on the use of nuclear energy. Nuclear's share of electricity production stands at about 20% in the Czech Republic, 25% in Ukraine, 32% in Bulgaria, 46% in Hungary, and 49% in the Slovak Republic. Reliable operation of nuclear power plants has been essential for the economic development of these countries.

Nuclear plants based upon Soviet technology, specifically pressurized-water reactors (PWRs) of the type known as WWERs, are dominant in Central and Eastern European countries. From the start, the approach to nuclear safety has been different for these plants, when compared with approaches for Western-designed PWRs. This resulted, in fact, in serious shortcomings of WWERs when compared with international practices. There was and remains a clear need for transfer of knowledge, particularly in the field of nuclear safety, to facilitate access to information on PWRs and related infrastructures. These needs extend to modern tools of safety assessment; quality assurance programmes; highly computerized instrumentation and control systems; and the use of robotics for in-service inspection, for example.

However, the situation should not be generalized. It strongly depends on the specific model of the nuclear power plant. These models start with the old WWER-440/230 (operating in Bulgaria, Slovak Republic and Ukraine), go to the more advanced WWER-440/213 (operating in the Czech Republic, Slovak Republic, Hungary, and Ukraine), and on up to the new generation of WWER-1000/320 (operating in Ukraine and Bulgaria, and being built in the Czech Republic). There is an understanding that a programme for safety improvements and technology transfer is required. However, this was difficult to launch in the past due to political and other constraints in the region. Nuclear specialists in the region were aware of the discrepancies between PWR and WWER technologies and looked for possibilities to improve the situation. In the early 1980s, they asked the IAEA for technical assistance.

This article reports on the IAEA's technical assistance projects that have been initiated over the past years to upgrade the safety levels of WWER-type nuclear plants. It also looks at the work ahead, specifically at activities planned into the mid-1990s.

Launching the projects

From early on, the provision of technical assistance, in particular through the IAEA's technical co-operation programme, represented an important avenue for transferring knowledge and technology. Though possibilities in the early 1980s were limited for WWER-type reactors, they have since expanded. What has emerged is a highly effective mechanism of regional co-operation that has become essential for countries interested in strengthening their national capabilities in the nuclear power sector.

In 1984, under an early regional technical co-operation project, access to the IAEA's computer system was provided. This opened the possibility of using the most advanced thermo-hydraulic computer code at that time. Standard

Mr Zyszkowski is a staff member of the Division of Technical Co-operation Programmes in the IAEA Department of Technical Co-operation.

problem exercises were formulated for calculations on loss-of-coolant accidents that created possibilities for regional co-operation and comparison of results with those obtained by Western specialists. An experimental facility constructed at KFKI, Budapest, was a source of experimental data on which the comparison was based. Bulgaria, the former Czechoslovakia, Hungary, and Poland benefitted from the exercises, as did many other countries in the region.

In 1988 a follow-up project started which focused on safety analyses of the WWER-type reactors. The activity was extended to other fields, including maintenance, radioactive waste management, regulatory infrastructure, and various safety review missions to WWER-type nuclear power plants.

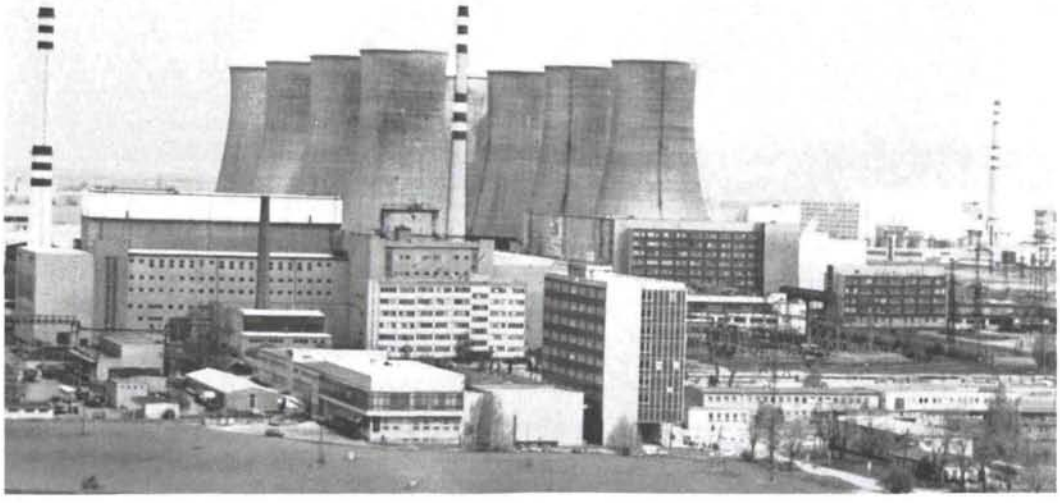
Strengthening national capabilities through regional co-operation

A long-term objective of technical assistance to countries with WWER plants is the strengthening of their national capabilities. This entails helping countries to create an infrastructure for independently evaluating and assessing the plants. Several regional projects have become the main vehicles for this, involving Bulgaria, Czech Republic, Slovak Republic, Hungary, Poland, and Ukraine.

Safety assessment. WWER-type reactors in Central and Eastern European countries have been the subject of criticism as far as overall safety is concerned. Consequently, there is a need for comprehensive assessment and systematic study of their status.

The new WWER-440/213 units incorporate higher structural safety margins in the barriers for preventing radioactive releases that approach Western standards. These units can challenge questions about the extent to which a plant's inherent safety can compensate for certain deficiencies in safety systems. Under an IAEA regional project, an internationally accepted method of assessment using the most advanced computer safety codes is being developed. Related documentation for assessing the actual safety level of the Bohunice nuclear power plant, using the WWER-440/213 as the reference plant, also is being provided.

Specifically, the project focuses on safety reassessment by means of up-to-date methods and techniques for summarizing all available information on the design philosophy; summarizing experimental results supporting the design; evaluating operational results from the point of view of plant performance and safety; establishing accident analysis methodologies for both design basis accidents (DBAs) and severe accidents beyond DBAs; updating DBA analyses as reference analyses for the production of safety reports, operating instructions, and technical specifications (including external events); extending analyses beyond DBA and severe accident situations with special attention to accident management considerations; assessing safety levels and safety margins in the light of new safety requirements; determining priorities for safety enhancement and backfitting (if neces-



The Bohunice nuclear plant in the Slovak Republic.

sary); and providing the scientific and technical basis for decision-making by regulatory organizations.

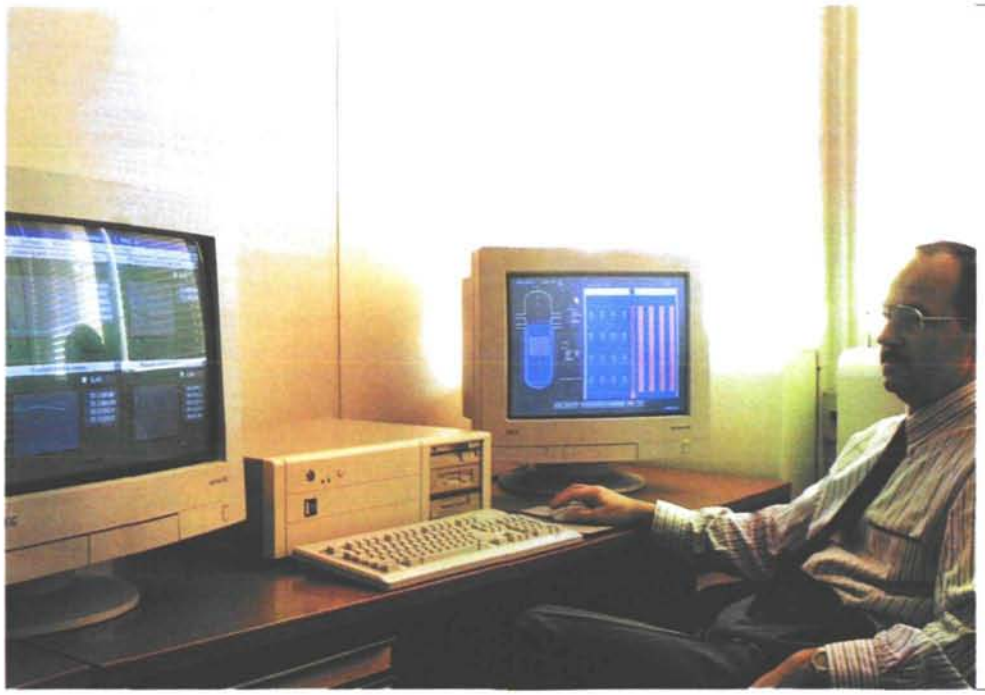
Specific tasks have been formulated and distributed among the participants, which include 19 institutions and more than 100 national specialists. IAEA assistance consists of the provision of computer codes, advanced computer techniques, expertise, and organization of workshops, working groups, and other meetings, as well as co-ordination of the safety assessment activities. Simultaneously, comprehensive national programmes financed from national resources have been launched and benefit from the methodology and results achieved under the regional project.

Despite continuous internal quality assurance, an independent peer review by an internationally recognized specialized organization is a necessary condition for acceptance of the results. Such a review process was started in 1992 and received support from Tractabel in Belgium, Tecnatom in Spain, and the Commission of the European Communities (CEC) in Brussels. The target date for completion is mid-1994. The results will constitute essential guidance on the methodology for preparation of plant-specific safety assessments by national specialists.

One positive example of this regional co-operation is the development of a severe accident simulation trainer for the Bohunice WWER-440/213 plant in the Slovak Republic. It is being developed by an international team of specialists with close co-operation with Risk Management Associates, Inc., in the United States.

Probabilistic safety assessment (PSA). Since the mid-1970s, the probabilistic approach to safety analysis has proved to be an extremely useful complement to the standard, deterministic type of analysis. The approach provides both operators and regulators with additional insights into the safety of nuclear reactors. Consequently, most countries having nuclear power plants have developed a plant-specific PSA for every operating reactor. A broad spectrum of applications that have been demonstrated includes the evaluation/improvement of design and procedures; optimization of technical specifications and maintenance activities; PSA-based regulatory inspection; and assessment of operational experience. Benefits from the use of PSA have also been recognized in all Central and Eastern European countries and large efforts have been made to implement this technique.

A regional programme initiated by the IAEA in 1988 was the first international activity directed towards practical implementation of PSA in countries operating WWER power plants. Initially, the programme was structured to provide training/education of PSA practitioners and to assist in development of generic Level-1 PSA for a WWER reactor. This was supposed to be a basis for development of plant specific Level-1 PSAs at the later stage. Each participating country (including Bulgaria, the former Czechoslovakia, Hungary, and Poland; with the former German Democratic Republic and Soviet Union as observers) was to perform accident sequence modelling for a limited number of initiating events. The Agency provided expertise,



Under an IAEA regional project, a severe accident simulation trainer known as MELSIM is being developed for operators of Russian-designed WWER-440/213 nuclear plants. The trainer is a personal computer-based system that also serves to evaluate accident management strategies and to assess complex interfaces between emergency operating procedures and accident management guidelines. The trainer utilizes several computers working simultaneously on different areas of the simulation. Detailed plant operation displays, portions of which are shown here, are provided on colour monitor screens which show changing plant conditions.

guidance, and co-ordination of the work mainly through a number of workshops centered on selected methodological issues.

The project's main achievement in the first period (1988-91) was the initiation of actual application of PSA methodology for safety assessment of WWER plants. This encompassed adopting and comprehending the methodology for Level-1 PSA and familiarity with computer software. Specialized PSA teams with practical experience now have been consolidated in all participating countries. As a consequence of this IAEA project and growing awareness of nuclear safety issues, comprehensive national PSA programmes were initiated in all countries operating WWER plants. Plant-specific PSA studies are being done or planned for practically every plant in the region. By 1994 PSA Level-1 studies for all types of WWER units (440/230, 440/213 and WWER-1000) will have been completed.

Responding to the new status of national PSA programmes, the emphasis of the IAEA's project is changing. For the period 1993-94 the assistance is centred on advanced PSA methodology; use of PSA results; and assurance of high-quality PSA through independent reviews.

The project has achieved important results, especially in areas of immediate interest. A "data exchange" workshop held at the Paks nuclear plant in Hungary in June 1993, for example, brought together PSA teams and WWER operators from all participating countries. The workshop was used to finalize preparation of a technical document describing data collection activities and providing numerous plant-specific data sets.

A number of previously prepared documents already are being used in PSA projects for WWER reactors. One contains lists of separate generic initiating events specifically developed for the WWER-440 and 1000 models and a unique classification of more than 350 reactor-years of operational experience. Due to different design and operational practices, Western PWR operational experience is generally not appropriate for PSAs on WWERs. The project facilitated collection and analysis of operational experience on all types of WWERs.

Another important area where positive results are visible is PSA reviews. An independent review of ongoing work was performed for the PSAs of the Kozloduy-3 plant in Bulgaria, Bohunice-1 in the Slovak Republic, and Kola in Russia. An end-of-project review for the PSA of Hungary's Paks plant has just been completed.

Significant activities in PSA application are expected in 1994 and beyond. The bulk of activities is expected during 1994 when initial Level-2 PSAs, external analyses, and shutdown risk studies are to be performed. The work will further support PSA applications, which are making significant inroads in countries with WWER plants in areas of regulation and operational safety. At the Dukovany plant in the Czech Republic, a risk monitoring system is being developed for completion in early 1994, and it is expected that PSA will be used for decisions on priorities for backfitting options. Other activities, being considered for implementation after 1994, concern the characterization of the source term (amount of radioactive materials potentially released in an accident) for WWER units, as a basis for efficient accident management and emergency preparedness.

Plant maintenance and service

Maintenance, in-service inspection, and quality assurance are considered the weak points in the management of WWER technology. They have been included in IAEA technical co-operation projects under both regional and national programmes.

The first issue addressed in 1990 was in-service inspection (ISI) of the steam generators at the Kozloduy nuclear power plant. A specialized company from the Institute za Elektroprivredu in Zagreb performed the first eddy-current inspection. The result was a warning that such an inspection must be repeated for other plants. As a consequence, a technical assistance programme was launched in support of efforts undertaken by IAEA Member States operating WWER-type reactors to develop adequate national infrastructures and systems for such inspections. The IAEA has provided assistance through on-the-job training, workshops, and expert services. Emphasis has been on establishment of inspection requirements, basic equipment criteria, and general staffing requirements; evaluation of local capabilities; definition of the implementation approach; building up of basic in-service inspection capability; establishment of quality assurance programmes; and establishment of the in-service inspection programme. Also, through an extrabudgetary contribution from Spain, the technical specifications and basic design of in-service inspection equipment has been provided to the countries participating in this project.

Inspections are directed at particular components including the reactor pressure vessel, steam generators and primary circuit piping, pumps, valves, and pressurizers. Consequently, the project's workshops and on-the-job training

emphasized practical approaches to examination of these components. Inspection techniques for eddy-current testing and other forms of non-destructive testing (ultrasonic methods), as well as steam generator tube plugging, were presented in detail. Additionally, "first-hand" studies were arranged by taking the participants to nuclear power plants during their scheduled maintenance. National projects for Bulgaria and Hungary further contributed to the upgrading of their capabilities for performing inspections of main components for their plants.

As follow-up to the ISI project, the IAEA initiated a regional project centred on plant maintenance and service activities. The project was financed both by the IAEA's regular budget and extrabudgetary contributions form the USA. It resulted in the transfer of knowledge on modern maintenance methods and technology through various avenues. They included technical exchanges, workshops, and a risk-based (PSA) management programme. This programme was designed so that it could be used as the basis for day-to-day operational and maintenance activities at these plants, and for short- and long-term assessment and prioritization of safety-related needs or improvements.

Radioactive waste management

Countries operating WWER-type nuclear power plants have encountered difficulties originating from shortcomings in national strategies and regulations, and in the available technology, in the field of radioactive waste management. One IAEA regional project, launched in 1991, is directed at improving the safety and effectiveness of radioactive waste management practices at WWER plants. Because the accumulated experience and level of development differs from country to country, regional co-operation is recognized as very effective for identifying common problems, sharing experience, and for recommending improvements on waste management that can be considered and implemented.

The list of general issues requiring corrective actions and improvements is as follows:

- legislation in the field of radioactive waste management;
- overproduction of waste at nuclear power plants;
- excessive leakage from equipment;
- build-up of untreated evaporator concentrates;
- inadequate facilities for volume reduction and conditioning; and
- absence of guidance on exemption limits for very low level wastes.

The project's first phase covered activities during 1991-92. Results have been reported in an IAEA technical document, *Radioactive Waste Management of WWER-type Reactors*, issued in 1993. The report identifies waste management problems at power plants with WWER reactors, and describes plans for regional co-operation among countries having WWER-type reactors in operation and for the emulation of good practices being followed at Western nuclear plants.

Basic elements of integrated systems for the safe and efficient management of radioactive wastes also were the topic of a regional training course in Slovakia in 1992. The course was attended by 23 participants from Member States in the region.

The project's next phase, over the 1993-94 period, is directed at two main tasks:

- providing assistance to participating countries in evaluation and improvement of existing legislation of the structure of regulatory bodies, of licensing principles, and of requirements for radioactive waste management at nuclear power plants; and
- performing a comparative evaluation of waste management systems of nuclear plants with WWER-type reactors, as well as providing recommendations for improving these systems. Expertise from countries such as Finland, France, Sweden, the United Kingdom and the United States has been provided from the start of this regional project.

Countries in Central and Eastern Europe operating WWER-type reactors also have asked the IAEA for advice regarding spent-fuel storage, an area of pressing concern. Previously, spent fuel from these countries was returned to the former Soviet Union for reprocessing. However, this solution for all spent fuel requirements can no longer be guaranteed in light of the region's political and economic developments.

National projects and other activities

A number of technical projects have been included in the IAEA's WWER programme which have contributed to improvements in the nuclear energy sector. Essential roles have been played by nuclear plant safety reviews, namely through IAEA services known as Operational Safety Review Teams (OSARTs) and Assessment of Safety Significant Events Teams (ASSETs). All countries with WWER-type reactors have hosted such missions, through which

more knowledge about the plants has been acquired.

In 1991, an OSART mission to Kozloduy in Bulgaria, and subsequent follow-up visits, advised the regulatory body on the operational safety of two units, among other matters. Bulgarian specialists also participated as observers in OSART missions to nuclear plants in Koeberg in South Africa, Grafenrheinfeld in Germany, and Fessenheim in France. OSART and follow-up missions also have gone to Paks in Hungary and Temelin in the Czech Republic. In parallel, a seminar on ASSET methodology was organized for these countries. In Bulgaria a series of ASSET missions dealt with the management of safety significant incidents at the four WWER 440/230 units at the Kozloduy nuclear power station; operational safety performance; training of operators and regulators; assisting plant management to implement ASSET recommendations; and assessing progress in the prevention of incidents. In addition, workshops have been held on the use of the International Nuclear Event Scale (INES), which standardizes the reporting of incidents at nuclear power plants.

These safety missions should be considered not only as a source of information on WWER-type reactors. They also serve as an important mechanism for transferring knowledge on safety culture and modern practices of nuclear plant operations to countries of the region.

Other activities have been arranged to complement regional projects. Designed to address specific national problems, these activities are related to:

- quality assurance and ISI for nuclear power plants (Bulgaria, Czech Republic, Slovak Republic, Hungary, Poland);
- site and seismic safety (Bulgaria, Czech and Slovak Republics);
- nuclear safety and radiation protection (Bulgaria, Hungary, Ukraine);
- radioactive waste management and spent fuel storage technology (Bulgaria, Hungary, Poland);
- management and analysis of severe accidents (Czech and Slovak Republics, Hungary);
- measurements of noise thermometry and burnable absorbers in WWER-type reactors (Bulgaria, Czech and Slovak Republics);
- national training of nuclear specialists (Hungary); and
- strengthening national regulatory capabilities (Czech and Slovak Republics).

While these activites mainly focus on transfer of knowledge, equipment is supplied in some cases. Modern ISI equipment designed and manufactured by Tecnatom in Spain, for example, was made available for the inspection of the reactor pressure vessels in Bulgaria and Hungary. This further opened possibilities for training of specialists on a regional basis. Technology also was provided for the management of radioactive waste at the Kozloduy plant in Bulgaria. This has significiantly contributed to the development of scientifically based release limits which are being implemented now.

These national projects are accompanied by a very comprehensive programme for developing human resources through training in specific subjects of nuclear safety and nuclear engineering. More than 100 scientific fellows from countries in the region have been trained during the last 10 years in fields related to WWERs. Recently consideration has been given to supporting a regional training centre in maintenance. This centre would complement an existing one for nuclear power plant operators.

Complementary efforts

The IAEA's technical assistance programme on WWER-type reactors is part of a wide range of activities being carried out by the IAEA and other organizations in countries of the region in the nuclear power sector. The programme is playing an important complementary role, despite relatively limited financial resources.

In particular, it is:

- contributing to the improvement of nuclear safety in the nuclear power sector in Central and Eastern European countries;
- strengthening and/or developing national capabilities in performing safety analysis and independent safety assessment of each country's nuclear power plants;
- promoting international co-operation between countries having similar circumstances and problems in areas of nuclear power;
- consolidating expertise with respect to the development of human resources;
- transferring knowledge from countries with advanced experience and equipment for nuclear safety (hardware and software) to the region;
- improving communication and the base of worldwide knowledge on WWERs and their safety;
- providing international expertise and advice on particular safety issues; and
- creating a mechanism for international co-operation and channelling the transfer of knowledge and technology to the operators of WWER-type reactors. ❐