BNL-NUREG-66229
CONF-9810144--

NRC SUPPORT FOR THE KALININ (VVER) PROBABILISTIC RISK ASSESSMENT*

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Abstract

The U.S. Nuclear Regulatory Commission (NRC) and the Federal Nuclear and Radiation Safety Authority of the Russian Federation have been working together since 1994 to carry out a probabilistic risk assessment (PRA) of a VVER-1000 in the Russian Federation. This was a recognition by both parties that this technology has had a profound effect on the discipline of nuclear reactor safety in the West and that the technology should be transferred to others so that it can be applied to Soviet-designed plants. The NRC provided funds from the Agency for International Development and technical support primarily through Brookhaven National Laboratory and its subcontractors. The latter support was carried out through workshops, by documenting the methodology to be used in a set of guides, and through periodic review of the technical activity. The result of this effort to date includes a set of procedure guides, a draft final report on the Level 1 PRA for internal events (excluding internal fires and floods), and progress reports on the fire, flood, and seismic analysis. It is our belief that the type of assistance provided by the NRC has been instrumental in assuring a quality product and transferring important technology for use by regulators and operators of Soviet-designed reactors. After a thorough review, the report will be finalized, lessons learned will be applied in the regulatory and operational regimes in the Russian Federation, and consideration will be given to supporting a containment analysis in order to complete a simplified Level 2 PRA.

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*This work was performed under the auspices of the U.S. Nuclear Regulatory Commission.

Origin of the BETA Project

The Kalinin Probabilistic Risk Assessment (PRA) project was designed to improve reactor safety and regulation in the Russian Federation (R.F.), by enhancing the political and technical position of the regulatory agency in Russia and by building a framework and language to address reactor safety issues. The origins of the project lie in the Lisbon Conference on Assistance to the Nuclear Safety Initiative, held in May 1992, where it was agreed that special efforts should be undertaken to improve the safety of the nuclear power plants designed and built by the former Soviet Union. In the following year, the Gore-Chernomyrdin Commission (GCC) was established to improve technical cooperation between the U.S. and the R.F. The U.S. Nuclear Regulatory Commission (NRC) was to provide support to the GCC in nuclear safety, including support to Gosatomnadzor (GAN), the Federal Nuclear and Radiation Safety Authority of the Russian Federation. A November 1993 Memorandum of Meeting (MoM) between NRC and GAN recorded agreement for NRC and GAN to work together, including provision of support to the R.F. to perform a PRA on a VVER-1000 PWR. This was a recognition by both NRC and GAN that this technology has had a profound effect on the discipline of nuclear reactor safety in the West and that the technology should be transferred to others so that it can be applied to Soviet-designed plants. Unit 1 at the Kalinin Nuclear Power Station (KNPS) was chosen for the PRA, and the effort was carried out under the auspices of GAN with the assistance of several other Russian organizations:

- GAN's Science and Engineering Centre for Nuclear and Radiation Safety (SEC-NRS) - the regulatory agency's semi-independent support organization
- Experimental and Design Office "Gidropress" (EDOGP) - the VVER designer
- Nizhny Novgorod Project Institute "Atomenergoprojekt," (NIAEP) - the architect-engineer
- Kalinin Nuclear Power Station (KNPS)
- Rosenergoatom Consortium - the "owner" of KNPS

The MoM addressed how to manage such a project given the many organizations in the R.F. that would need to cooperate to ensure success. A phased approach was to be used with completion of the work in each phase before initiation of the work in a subsequent phase. The four phases of the PRA at Kalinin Nuclear Power Station (later known as the "BETA Project") were to include:

- Phase I. Project Organization
- Phase II. Training, procedure guide development, and information gathering
- Phase III. System modeling and accident frequency analysis (Level 1 PRA; internal and external events)
- Phase IV. Containment performance and risk assessment (simplified Level 2 PRA)

Phase I Activities

During Phase I, a plan was developed for the PRA, including definitions of tasks, levels of effort, schedules, and products. Two primary documents were developed in the U.S. with these specifications:

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- General Plan for VVER-1000 Probabilistic Risk Assessment
- Detailed Task Descriptions for the VVER-1000 PRA Project

The tasks planned for the PRA are listed in Table 1.

Table 1. PRA Task List

Task	Task Title
III.A	Plant Familiarization and Information Gathering
III.B	Identification and Selection of Site Sources of Radioactive Releases
III.C	Determination and Selection of Plant Operating States
III.D	Definition of Core Damage States or Other Consequences
III.E	Selection and Grouping of Initiating Events
III.F	Functional Analysis and Systems Success Criteria
III.G	Event Sequence Modeling
III.H	System Modeling
III.I	Human Reliability Analysis
III.J	Qualitative Dependence Analysis
III.K	Assessment of the Frequency of Initiating Events
III.L	Assessment of Component Reliability
III.M	Assessment of Common Cause Failure Probabilities
III.O	Initial Quantification of Accident Sequences
III.P	Final Quantification of Accident Sequences
III.R	Interpretation of Results; Importance and Sensitivity Analysis
III.S	Spatial Interactions
III.T	Fire Analysis
III.U	Flood Analysis
III.V	Seismic Analysis
III.W	Documentation

The plan for carrying out the PRA was discussed with the Russian team members at a meeting held in May 1995, at GAN in Moscow and at KNPS. The plan was incorporated into formal Implementing Agreements which delineated the responsibilities of NRC and each of the six Russian organizations participating in the project, including funding, schedules, and deliverables.

These first Agreements defined work to be accomplished during the first year of the BETA Project, including Phase II and the initial work on Phase III, the Level 1 PRA. Subsequent meetings were held in Moscow in August 1996 and May 1997 to negotiate Addenda to the Implementing Agreements for each coming year. The NRC would provide financial support for the PRA with funds from the Agency for International Development and technical support primarily through Brookhaven National Laboratory (BNL) and its subcontractors.

Phase II and Early Phase III Work

Phase II was to provide training, to develop procedure guides for the PRA tasks, and to collect information on the plant. The technical work of the project began with a series of workshops. First was a VVER training program for American members of the BETA team. This was held in the R.F. in December 1995. The PRA workshops for the Russian team members consisted of one 8-week long workshop at BNL at the start of the project, followed by 1-week workshops in Russia approximately every six weeks over a period of one and one-half years. The first workshop took place after the initial plant familiarization and information gathering. It consisted of scheduled seminars to provide training on specific technical issues (e.g., development of event sequence diagrams), independent work by the Russian PRA team with interaction with the U.S. experts as needed, and meetings with the U.S. experts to review work in progress. The followup workshops were on technical subjects that enter into the analysis at later times (e.g., human reliability analysis) and subjects that needed further elucidation (e.g., common cause failure analysis).

The procedure guides complemented the workshops. The first draft of the guides used for the Kalinin PRA were prepared in the U.S., reviewed by the R.F. team and translated into Russian. A final version [1] is to be published to be of assistance to other PRA practitioners, especially those with VVER plants. The procedure guides are limited to accidents involving the reactor core and that occur while the plant is operating at full power. Internal initiating events, including internal fires and floods, are considered as well as seismic events. Guidance is provided for a Level 1, 2, and 3 PRA with the Level 3 PRA guidance limited to offsite consequences.

It was assumed that the team carrying out the PRA would be familiar with the set of guides developed by the International Atomic Energy Agency (IAEA) for carrying out a Level 1 PRA for internal events [2]. The IAEA document represented an internationally acceptable approach. The new guides improve on the existing guides by: (1) taking into account recent work in the field, (2) considering special problems that might be specifically present for the VVER experience, and (3) improving upon the guidance already provided. The idea was not to duplicate the existing guidance found in the IAEA document or the material in other guides that have been produced by the NRC [3, 4]. For subjects not well documented in the open

literature (e.g., the approach taken for human reliability analysis), detailed guidance was given; for tasks where a firm understanding was already well established and documentation freely available (e.g., system modeling), minimal guidance and appropriate references were provided.

Phase III, the carrying out of the Level 1 PRA, began with a two-month workshop held at BNL February-April 1996. A series of seminars on specific PRA tasks were held during the visit to BNL. During this intensive training, great strides in the analysis were accomplished. Unfortunately, after the BETA team's return to Russia, progress continued at a slower pace because the team is widely disbursed and involved in other work.

The product requirements for the Phase III PRA include:

- Databases: component failure rates for all VVER-1000 plants and a KNPS-specific database
- IRRAS computer model representing the KNPS Level 1 PRA
- Documentation on the analysis and results
- RELAP5 model for KNPS Unit 1 with all important plant systems
- Level 1 PRA for the KNPS

A Technical Review Group (TRG) was set up with U.S. experts and Russian team members. TRG sessions were held periodically in Moscow (usually in conjunction with training workshops) to review Russian progress on the analysis. The reports of these meetings provided guidance to the team for continuation of the work.

By fall 1997, all Level 1 internal event tasks (excluding fire and flood events) had been completed except final quantification, uncertainty and sensitivity analysis, and final documentation. A number of problems were identified, and an approach and budget for completing the Level 1 PRA were agreed upon.

An additional task was added in 1997 to come up with an Applications Plan. This plan would include a description of how the results/insights of the PRA will be implemented/disseminated at KNPS and other VVER plants. It was to describe those areas where PRA information can be used to improve the plant operations and safety, how this information will be used, and how it will be communicated to other VVER-1000 plants.

Current Status of Phase III

The draft report of the internal events PRA (excluding fire and flood analysis) was submitted in June 1998, and progress reports on the fire, flood, and seismic analysis were also submitted during the year. Unfortunately, during 1998, funding problems precluded having U.S. experts do a detailed review. A cursory review, however, of the internal events report has recently been completed. That brief review has identified a number of potential problems remaining in the PRA and its documentation and many questions that can only be answered by a detailed review and by discussions with the BETA team.

The most important issues that need to be resolved are whether sump plugging is as important as suggested by the results and whether the analysis of scenarios that were thought to be important in the past, but have now been downgraded, is valid. Of the many specific technical questions that are important is the question of why the diesel generator failure rate is unusually low. While it is possible to cite additional examples of items that are questionable beyond those already identified, it may be unfair to do so as many of the questions may be easily answered and determined not to be significant if discussed with the Russian team.

It is also important to note that the English is difficult to read in many places and much of the text is abbreviated and insufficient to explain to a reviewer what was being done. Although a different style of writing is not unexpected when dealing with a different culture, this is a subject that the U.S. experts have repeatedly emphasized in many discussions with the Russian BETA team.

Concluding Remarks

The efforts described in this paper have brought the completion of the PRA for internal events within sight. It is expected that early in 1999 the review of existing documents will be completed, and the final Level 1 PRA report will be made public. Ongoing work is being done to add results for internal fires and floods and seismic events. It is our belief that the type of assistance provided by the NRC has been instrumental in assuring a quality product and transferring important technology for use by regulators and operators of Soviet-designed reactors. In addition, it is gratifying to observe that the diverse team learned how to surmount technical, political, and cultural barriers to effectively work together. Once Phase III is completed, work is expected to continue in Phase IV, the containment performance assessment needed for a Level 2 PRA.

Acknowledgments

The authors wish to thank their Russian colleagues and acknowledge the roles they have played in organizing, managing, and performing the work described in this paper: A. Matveev, S. Volkovitskii, and M. Mirochnitchenko, GAN; B. Gordon, T. Berg, V. Bredova, E. Zhukova, I. Kouzmina, A. Loubarski, D. Noskov, O. Safronnikova, G. Samokhine, E. Shubeiko and V. Soldatov, SEC-NRS; V. Siriapin, V. Shien, and V. Kydravtsev (deceased), EDOGP; G. Aleshin, E. Mironenko, O. Bogatov, and A. Pestrikov, KNPS; V. Kats, V. Senoedov, S. Petrunina, S. Prihodko, A. Uashkin, L. Eltsova, NIAEP; and V. Khlebtscevich, Rosenergoatom. The authors also wish to express their appreciation to T. King and T. Speis (retired) of the NRC who have provided the leadership and guidance that has made this work possible.

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