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Joint Nuclear Safety Research Projects Between the U.S. and Russian Federation (RF) International Nuclear Safety Centers (INSCs)*

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JOINT NUCLEAR SAFETY RESEARCH PROJECTS BETWEEN THE U.S. AND RUSSIAN FEDERATION INTERNATIONAL NUCLEAR SAFETY CENTERS

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ABSTRACT

The Russian Federation Ministry for Atomic Energy (MINATOM) and the U. S. Department of Energy (USDOE)formed International Nuclear Safety Centers in October 1995 and July 1996, respectively, to collaborate on nuclear safety research. Since January 1997, the two centers have initiated the following nine joint research projects:

- INSC Web Servers and Databases
- Material Properties Measurement and Assessment
- Coupled Codes: Neutronic, Thermal-Hydraulic, Mechanical, & Other
- Severe Accident Management for Soviet-designed Reactors
- Transient Management and Advanced Control
- Survey of Relevant Nuclear Safety Research Facilities in the Russian Federation
- Computer Code Validation for Transient Analysis of VVER and RBMK Reactors
- Advanced Structural Analysis
- Development of a Nuclear Safety Research and Development Plan for MINATOM

The joint projects were selected on the basis of recommendations from two groups of experts convened by NEA and from evaluations of safety impact, cost, and deployment potential The paper summarizes the projects, including the long-term goals, the implementing strategy and some recent accomplishments for each project.

Introduction

The Russian Federation Ministry for Atomic Energy (MINATOM) and the U. S. Department of Energy (USDOE) signed a joint statement of intent to establish International Centers for Nuclear Safety in the Russian Federation and the United States of America in Vienna in September 1995. USDOE established the U. S. Center (USINSC) at Argonne National Laboratory (ANL) in October 1995. MINATOM established the Russian Center (RINSC) at the Research and Development Institute of Power Engineering (RDIPE) in Moscow in July 1996. The goals of the centers are to:

- Cooperate in the development of technologies associated with nuclear safety in nuclear power engineering.
- Be international centers for the collection of information important for safety and technical improvements in nuclear power engineering.
- Maintain a base for fundamental knowledge needed to design nuclear reactors.

The strategic approach that is being used to accomplish these goals is for the two centers to work together to use the resources and the talents of the scientists associated with the US Center and the Russian Center to do collaborative research to improve the safety of Russian-designed nuclear reactors. The two centers

started conducting joint research and development projects in January 1997. Since that time the following nine joint projects have been initiated:

- INSC Web Servers and Databases
- Material Properties Measurement and Assessment
- Coupled Codes: Neutronic, Thermal-Hydraulic, Mechanical, & Other
- Severe Accident Management for Soviet-designed Reactors
- Transient Management and Advanced Control
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Eight of these projects have completed their first phase; six of these are continuing with active second phases, and the other two are contemplating second phases.

These joint projects was selected after a review of a list of research priorities developed by MINATOM and after a review of NEA studies of nuclear safety research in OECD Countries [1] and safety research needs for Russian-designed Reactors [2]. In addition, it was agreed that the joint projects had to meet the following criteria:

- Identify and select high impact, cost beneficial research programs.
- Utilize (exchange) existing technology and facilities.
- Choose programs with a high safety impact and deployment potential.

Current Joint Projects

INSC Web Servers and Databases

Long-Term Goal: Establish a networking and computer environment that promotes the open exchange of nuclear safety information and supports the joint development of nuclear safety technologies between the USINSC and the RINSC, including the development and maintenance of linked nuclear safety databases at the USINSC and the RINSC.

Implementing Strategy:

1. Develop and maintain Nuclear Safety Databases at the USINSC and the RINSC and link them appropriately. The two databases should be of comparable sophistication and use a common database structure for the storage of data. The databases should have general accessibility from the World Wide Web.
2. Develop and support appropriate telecommunication systems between the USINSC and the RINSC.
3. Develop and support appropriate computing systems at the USINSC and the RINSC to facilitate the conduct of joint research projects between the two centers.

Recent Accomplishments: A WWW site has been created for the RF INSC (www.insc.ru) and data describing one VVER and one RBMK reactor, as well as a list of current RF nuclear regulations have been placed on it. This web site is now used to present the results of the other joint projects.

Coupled Codes: Neutronic, Thermal-Hydraulic, Mechanical, & Other

Long-Term Goal: Improve the fidelity and efficiency of coupled neutronic and thermal-hydraulic codes used for analyzing the dynamic behavior of water cooled reactors (VVER, RBMK, and Western LWRs) and develop additional capabilities, such as mechanical coupling and chemical effects that enhance the

ability to systematically characterize the risks attributable to a wider variety of plant upsets and postulated accidents.

Implementing Strategy:

1. Develop and implement high fidelity and efficient coupled codes using advanced numerical methods and computational resources.
2. Test codes packages and compare results to provide assurances that they accurately model the physical phenomena for which they were developed.
3. Demonstrate the capabilities of codes by using them to analyze realistic benchmark problems and transient measurements obtained in experimental facilities.
4. Develop an archive of benchmark problems that may be accessed electronically by researchers using the WWW.
5. Make code packages available for use in operational safety assessments and in the analysis of potential accident sequences in Russian and Western reactors as well as advanced reactor designs.
6. Demonstrate how the code can be used in activities aimed at improving nuclear power plant efficiency through reduced conservatism in reactor safety evaluations.
7. Enhance the ability of codes to model and analyze severe accidents in which core degradation may have occurred.

Recent Accomplishments: Coupled-code practices in RF and US have been surveyed. Joint meetings have been to identify specific benchmark cases. 3-D coupled benchmark calculations have been performed on VVER and RBMK reactivity insertion accidents. Benchmark data and results will be available on Web site.

Severe Accident Management for Soviet-designed Reactors

Long-Term Goal: Provide the technical basis for reduction of the risk associated with Nuclear Power Plant (NPP) operation through the implementation of severe accident management (SAM) at Russian RBMK and VVER nuclear power plants and foster implementation of severe accident management (SAM) in Russia.

Implementing Strategy:

1. Collaborate in the development of the technical basis for the GAN-mandated SAM program called Management of Beyond Design Accidents (MBDA).
2. Collaborate in the development and validation of generic accident management strategies for RBMK and VVER NPPs.
3. Foster technical progress and cooperation among the various Russian organizations having roles in the Russian MBDA program.
4. Foster contacts and information exchanges between Russian and US experts on the technical bases for severe accident management.
5. Foster regulator and international acceptance of MBDA program elements through joint forums, peer review, and publications.

Recent Accomplishments: Reports on VVER and RBMK technology status in RF and US have been developed. A week-long seminar on SAM practices and technology was held. Possible accident scenarios have been identified. Scoping calculations of SAM scenarios in VVERs and RBMKs are being performed.

Survey of Relevant Nuclear Safety Research Facilities in the Russian Federation

Long-Term Goal: Enhance the knowledge base of Russian facilities, experiments and computer programs that could be used to support the development of nuclear safety technology programs and make

this knowledge available to potential users.

Implementing Strategy:

1. Prepare a compilation of projects and facilities pertinent to safety research and development for Soviet-designed light water reactors.
2. Prepare a compilation of experiments pertinent to safety research and development for Soviet-designed light water reactors.
3. Prepare a compilation of computer codes pertinent to safety research and development for Soviet-designed light water reactors.

Recent Accomplishments: Extensive surveys of RF projects, facilities, experiments and computer codes relative to safety have been conducted. Results are now available on Web site.

Material Properties Measurement and Assessment

Long-Term Goal: Develop a material property database that contains critically assessed thermodynamic, transport and mechanical properties of reactor materials under normal, transient and severe accident conditions. The emphasis of this database will be on materials that are unique to Russian reactors, such as Russian steels, and on materials for which there are unique Russian data or unique Russian measurement techniques. To promote the open exchange of this information, the database will be made available via the World Wide Web.

Implementing Strategy:

1. Perform peer reviews of available thermophysical property data.
2. Reach international agreement on recommendations for thermophysical properties of reactor materials.
3. Participate in the IAEA Collaborative Research Program on Material Properties.
4. Supplement existing information, where necessary, with measurements of thermophysical properties of greatest importance to nuclear safety analysis.
5. Develop analytical techniques to extend the database of thermophysical properties of liquids and liquid mixtures relevant to severe accident to mixture compositions in which experimental data are not available.
6. Develop new material property measurement techniques for high temperatures and chemically reactive mixtures relevant to severe accidents.

Recent Accomplishments: A peer review of high temperature material properties information on UO_2 was conducted, and a survey was made of liquid properties of core materials. Data on irradiated fuel, Zr-Nb mixtures was added to the database. UO_2 /ZrO_2/Fe mixture data are now being examined.

Computer Code Validation for Transient Analysis of VVER and RBMK Reactors

Long-Term Goal: Assess the capability of thermohydraulic analysis computer codes to model generic transient and accident phenomena and behavior in VVER and RBMK reactor types. This assessment will enhance the credibility of INSP-funded Soviet-designed NPP safety analysis projects using these computer codes.

Implementing Strategy:

1. Prepare guidelines for systematic computer code assessment and code configuration control and maintenance for application to VVER and RBMK reactors.
2. Prepare two code assessment plans for application to VVER and RBMK reactors respectively, based on a prioritization of transient phenomena in these reactor types and the test facilities and data available.

3. Assess the RELAP5 system thermohydraulics analysis computer code for its capability to model phenomena characteristic of VVER and RBMK reactors through the analysis of Standard Problems defined on the basis of test facilities and data available.
4. Coordinate VVER code validation activities with those of the OECD NEA Support Group on VVER thermohydraulic code validation matrix development.
5. Ensure the usefulness of the code assessment activities by providing the results and related information to:
   a. organizations using the assessed computer code in International Nuclear Safety Program (INSP)-funded plant safety analyses, and
   b. Concern Rosenergoatom (REA), to support their code certification activities before GAN, the Russian regulatory agency.

Recent Accomplishments: A matrix for RELAP5 validation of VVER and RBMK reactors was developed. Standard problems on both reactor types are being analyzed and the results are being stored on both INSC Databases.

Advanced Structural Analysis

Long-Term Goal: Develop validated three-dimensional structural analysis models and software for the safety evaluation of nuclear power plant structures. Use newly developed structural analysis tools to increase the knowledge base in nuclear structural safety technology.

Implementing Strategy:
1. Develop a database of mechanical properties of key structural materials used in nuclear power plants. The materials shall include steels, metal alloys, concrete, reinforced concrete and prestressed concrete.
2. Develop a database of the geometric characteristics of generic basic NPP structures used in finite element models for safety assessments.
3. Validate US and Russian structural analysis codes by performing simulations of recognized structural behavior experiments.
4. Participate in the NUPEC/NRC Containment Round Robin analysis.
   (NUPEC is the Nuclear Power Engineering Corporation of Japan,
   NRC is Nuclear Regulatory Commission of the United States.)
5. Use US and Russian structural analysis codes to analyze benchmark problems based on generic models of nuclear power plant structures.
6. Incorporate contact, impact and penetration fine element algorithms and shock loading methodologies into US and Russian structural analysis codes.

Recent Accomplishments: Reports on structural analysis techniques in RF and US have been exchanged. Comparative calculations using RF and US codes are being performed. The team is participating in NUPEC/NRC Round Robin containment analysis.

Transient Management and Advanced Control

Long-Term Goal: Develop the technology for new nuclear power plant transient management and advanced control approaches. Increase and exchange knowledge in artificial intelligence technology.

Implementing Strategy:
1. Develop an improved sensor validation software system based on a recurrent neural network technology that is capable of detecting sensor faults under steady state and normal transient operating conditions.
2. Develop expert systems to improve the response of plant staff to off-normal events by the use of technologies for early identification of accident precursors. This would be done by

demonstrating, for example, the portability of the process diagnostic advisor PRODIAG to the VVER-1000 by using it to diagnose simulated component faults in the thermal-hydraulic system of a VVER-1000.

3. Develop expert systems for determining the integrity of the RBMK pressure boundary, such as leak detection systems based on vibroacoustic noise analysis for the identification of possible accident precursors.
4. Develop nonlinear multivariable digital control systems based on emerging artificial intelligence technology, including fuzzy logic and neural networks.

Recent Accomplishments: Surveys of recent R&D in RF and US have been conducted.

Development of a Strategic Nuclear Safety Research and Development Plan for MINATOM

Long-Term Goal: Develop a Strategic Nuclear Safety Research and Development Plan for Russian NPPs. This Plan will include the development and advanced methods and techniques of analysis and database storage for modeling, diagnosis, and assessment of the conditions of systems and components of NPPs, as well as relevant experimental research needs. This Plan will be based on current RINSC and MINATOM research programs as well as the recommendations of international organizations.

Implementing Strategy:

1. Identify and organize a Working Group of representative highly knowledgeable experts.
2. Identify sources of information about the research needs for Russian Designed Reactors.
3. Develop a DRAFT Plan. Review it and achieve consensus within Russia.
4. Obtain international review of the DRAFT Plan.
5. Obtain overall approval of the Plan from MINATOM leadership.

Recent Accomplishments: A comprehensive DRAFT plan for future R&D for MINATOM has been developed.

Conclusions: The start-up phases of nine collaborative research projects have been completed. During the past two years the U.S. has had a senior liaison representative at RINSC half-time to assist in the start-up activities. There have been 28 technical working meetings of several days to one week duration (9 in the U.S. and 19 in Russia) and nine personnel exchanges of two weeks to three months duration. Additional projects are in the planning stages. The participants and sponsors of this partnership believe that this collaboration represents a significant step forward in the open exchange of safety information between the U. S. and Russia.

References:

[1] Nuclear Safety Research in OECD Countries—Report by an NEA Group of Experts OECD Nuclear Energy Agency (NEA) 1994. (ISBN 92-64-14248-7) This document is the report of a senior group of experts headed by Michael Livolant.

[2] Safety Research Needs for Russian-Designed Reactors—Report by an OECD Support Group OECD Nuclear Energy Agency (NEA/CSNI/R(96)12, 1996). This document is the report of a senior group of experts headed by Eric S. Beckjord.