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

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The Russian Federation Ministry for Atomic Energy (MINATOM) and the U. S. Department of Energy (USDOE) have formed International Nuclear Safety Centers to collaborate on nuclear safety research. 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. In April 1998 the Russian center became a semi-independent, autonomous organization under MINATOM.

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

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reactors.

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

- INSC Databases. Web Server and Computing Center
- Coupled Codes: Neutronic and Thermal-Hydraulic
- 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
- Properties and Applications of Heavy Liquid Metal Coolants
- Material Properties Measurement and Assessment

Currently, there is activity in eight of these joint projects. Details on each of these joint projects are given below.

INSC Databases, Web Server and Computing Center

Goal: Establish databases of nuclear reactor and nuclear safety information, make the databases available on the Internet, and establish computing capability so that modern nuclear safety computer codes can be run in both the USINSC and the RINSC.

Accomplishments: Databases of reactor and nuclear safety information have been established at both INSCs. These databases are accessible on the Internet at www.insc.anl.gov and www.insc.ru. The database at RINSC is being developed as a module that could be transferred to sites at other countries that wish to establish nuclear safety centers with compatible web sites. In addition, RINSC has established a Computing Center and has installed a SGI Origin 200 computer that has two MIPS 1000 CPUs, 256 MB of main memory and more that 30 GB of disk space; PCs are networked to this computer. The RINSC has been designated by MINATOM to be the center for foreign computer codes used for nuclear safety analysis and a number of nuclear safety analysis applications are installed on the computer. The computer is used for training Russian scientists and engineers on the theory and operation of these codes and the codes are accessed remotely from many institutes in Russia.

Coupled Codes: Neutronic and Thermal-Hydraulic

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.

Accomplishments: The project has contributed several papers to international nuclear conferences. A paper, presented at the 1998 Long Island International Conference on the Physics of

Nuclear Science and Technology, summarized activities performed in the Joint Project and results from VVER-1000 and RBMK benchmark analysis using various INSC codes. Another paper, evaluating the performance of a Russian parallel code on the ANL IBM-SP supercomputer, was presented at the American Nuclear Society (ANS) Annual Conference held in Boston in June 1999. This paper resulted from a Technical Staff Exchange Program on parallel computer research for nuclear reactor safety. A paper discussing INSC code models and results for the OECD/NEA PWR Main Steamline Break Benchmark problem was presented at the 1999 Madrid International Conference on Mathematics and Computations.

Severe Accident Management for Soviet-designed Reactors

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.

Accomplishments: The USINSC has hosted several experts from Russian institutes for training in accident analysis methodology and the adaptation of US accident analysis codes for Soviet-designed reactors. These codes are being used to develop operator actions and plans to deal with a severe accident being better prepared to avoid such an accident as occurred at Chernobyl. We have sponsored two forums in Russia to provide the Russian experts responsible for dealing with such accidents the benefit of the Accident Management planning and training processes that have been required at all US NPP after the TMI-2 accident.

Survey of Relevant Nuclear Safety Research Facilities in the Russian Federation

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.

Accomplishments: A compilation (in English) of projects, facilities, experiment, and computer codes pertinent to safety research and development for Soviet-designed light water reactors (LWRs) has been prepared. A database of Russian research reactors, including fuel characteristics and experimental capabilities, is being prepared

Material Properties Measurement and Assessment

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.

Accomplishments: New measurements have been made for needed properties for which there were no data and for which existing data significantly disagree. An example of such disagreement is

the enthalpy of fusion of zirconium. The value of 225 J/g for the enthalpy of fusion in the MATPRO database for the RELAP code was based on estimations and early Russian measurements. This value disagreed with the only US measurement and a Russian measurement (not in the open literature) that gave values in the range of 140-161 J/g. Under this joint project, 11 measurements of the solid and liquid enthalpy at the melting point were made at the United Institute of High Temperature, Russian Academy of Sciences (IVTAN), which showed that the enthalpy of fusion of zirconium is 153 $\pm$ 4 J/g. A paper on these measurements presented at a European conference will be published in High Temperature-High Pressures. Because no data were available on the zirconium change of density on melting or on the density of liquid zirconium, liquid zirconium densities have been measured at IVTAN using a new experimental technique. A. I. Savvatimski has been invited to present a paper on these measurements at the 14th Symposium on Thermophysical Properties.

A paper describing the database and assessments was presented at an international thermophysical property symposium and published in the International Journal of Thermophysics. The database was also demonstrated at the symposium. All the recommendations, assessments, and new measurements from this joint project are contributions to the IAEA Coordinated Research Program to establish a thermophysical properties database for LWRs and HWRs. Contributed assessments and analysis include thermophysical properties of UO_2, Zircaloy, and Zr-Nb alloys. Zr-Nb alloy property data available in Russia and the US were analyzed by a joint INSC and RINSC collaboration that recommended thermophysical properties of Zr-1%Nb and Zr-2.5%Nb for modification of the MELCOR code for Russian reactors. The analysis of thermophysical properties of UO_2 by the US INSC were peer reviewed by RINSC. Revisions based on the peer review have been made in the INSC database UO_2 recommendations. A paper on the UO_2 property analyses and recommendations is being published in the Journal of Nuclear Materials.

Computer Code Validation for Transient Analysis of VVER and RBMK Reactors

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.

Accomplishments: The project started with an organizational and demonstration stage, in which the transient phenomena of importance to safety in RBMK and VVER reactors were identified and prioritized and two demonstration standard problems, for RBMK and VVER applications respectively, were defined and analyzed. The second stage of the project produced two RELAP5 validation plans for application to RBMK and VVER reactors. The validation plans identify and prioritize a list of standard problems that can be defined, with existing Russian experimental data, to validate the RELAP5 code for application to VVER and RBMK reactors. The current stage of the project consists of the analysis of additional standard problems identified in the validation plans with the highest importance to safety. To date the analysis of two standard problems for each VVER and RBMK reactors has been completed and two additional standard problems are being analyzed. Technical papers on the analysis of the individual standard problems, on the validation plans, and on the overall code validation effort have been presented in international technical conferences in the U.S. and Russia. The U.S. INSC has hosted two long-term personnel exchanges from RINSC related to this project.

Advanced Structural Analysis

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.

Accomplishments: Specialists from the U.S. and Russia are working jointly to develop validated, three-dimensional structural analysis software and models for the evaluation of Russian (VVER, RBMK) and U.S. (LWR) Nuclear Power Plant structures. Three databases have been established. The first contains the mechanical properties for the materials used to construct Russian nuclear power plants. The second contains geometric data that defines the geometries of Russian built plants. The third is for verification and validation of computational code. Both the U. S. and Russian specialist are participating in the International Round Robin Analysis of Containment Structures. Both sides have generated computer models and made significant predictive calculations for the response of the containment under internal pressure. Two researchers from the Russian Federal Nuclear Center (VNIIEF) have participated in a staff exchange in the U.S. and over twenty technical reports have been produced by this joint project.

Transient Management and Advanced Control

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

Accomplishments: A survey of RF R&D work that has been done in sensor validation, system and equipment diagnosis, transient management and advanced control, including work done using artificial intelligence techniques such as expert systems, fuzzy logic, pattern recognition and artificial neural networks has been prepared. The next phase is still the planning stages.

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

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.

Accomplishments: The RINSC has coordinated a "Safety Research Strategic Plan for Russian Nuclear Power Plants" that was reviewed and commented upon by an OECD NEA international team of nuclear safety experts.

Physical Properties of Sodium and Lead

Goal: Examine the safety considerations for several liquid metal coolants and how they may have impacted Russian nuclear plant design and operations in the past, and how they may impact spent nuclear fuel safety and other aspects of the safety of Russian-designed power systems.

Activities: Examine the properties of sodium, lead and similar heavy metal liquid coolants to determine their suitability for use in advanced NPPs and power systems. Develop plans for collaboration on research related to the use of lead bismuth eutectic (LBE) in power systems.

Other Activities

The Computing Center in RINSC has been designated by MINATOM as a repository of Western nuclear safety codes and as a center that should be used by institutes and laboratories throughout Russia for nuclear safety computations. Consequently, RINSC is managing several projects that are sponsored by branches of USDOE other than the branch that sponsored the development of RINSC. Currently two projects are being conducted in this manner. One of the projects is the translation of the Probabilistic Safety Analysis code SAPHIRE, including the documentation, the resource files and the screen shots, into Russian so that Russian scientists can work in their native tongue when they are using this code to analyze Soviet-designed NPPs. Another is to develop computer programming and related support activities in the city of Sarov through the Open Computing Center that was established by the Nuclear Cities Initiative (NCI) Program. Currently, a U.S. company is working with USDOE, USINSC, and RINSC to use Russian computer scientists to enhance selected computer software.

Summary

The USINSC and the RINSC have made the following achievements:

- Joint Research - ten joint nuclear safety projects have been established, 15 technical papers have been presented, and 12 technical papers are currently being prepared.
- Technical Exchange - 54 technical working meetings have been held C 13 in US, 41 in Russia.
- Personnel Exchange - 323 person-days of personnel exchange in the US; 354 person days of personnel exchange in the RF.
- Technology - One of the most significant achievements has been the development of a Computing Center at RINSC. This center is a repository for nuclear safety codes in Russia and it is used as a training center for nuclear safety codes. In addition, other institutes in Russia are now using the codes in the computing center remotely. The center is also providing services to several branches of the USDOE, in addition to the branch that sponsored the development of RINSC.
- The RINSC has been designated by MINATOM to be the center for foreign computer codes used for nuclear safety analysis.
- The RINSC has coordinated the development of a ASafety Research Strategic Plan for Russian Nuclear Power Plants." This plan was reviewed by an OECD NEA international team of nuclear safety experts prior to final approval of the Plan by MINATOM. This was an important part of the effort to have Russia share its research plans with the international nuclear safety community.
- The US and Russian INSCs have been providing support to other institutes in the FSU and are

assisting similar centers that are being developed in Kazakhstan, Lithuania, Ukraine, and Armenia.

The activities of the two INSCs support the improvement of nuclear safety in the Russian Federation in many ways. Some of the most significant support is the following:

- INSC database development supports the joint development and open exchange of nuclear safety data, in particular the results of generic nuclear safety calculations performed to support in-depth plant safety assessments.
- U.S. accident management technology is being used to assist MINATOM organizations in the development of severe accident management guidelines for Russian-designed RBMK and VVER reactors.
- Improved coupled neutronic/thermal hydraulic computer codes are being used to better characterize the risks attributable to a wider variety of plant upsets and postulated accidents in the in-depth safety assessments.
- U. S. computer codes for the transient analysis of design basis accidents are being validated against Russian reactor and experiment data. These codes can then be used in in-depth safety assessments with confidence that their results are valid for RMBKs and VVERs.
- Modern three-dimensional structural analysis software and computer models for seismic, thermal, external and internal shock waves and loadings are being developed for in-depth safety assessments.