

March 12, 1999

FOR: The Commissioners

FROM: William D. Travers /s/
Executive Director for Operations

SUBJECT: STATUS OF NRC RESEARCH CONDUCTED BY THE RUSSIAN RESEARCH CENTER (I.V. KURCHATOV INSTITUTE) AND THE INSTITUTE OF NUCLEAR SAFETY OF THE RUSSIAN ACADEMY OF SCIENCES

PURPOSE:

To inform the Commission of the progress made in 1998 on research sponsored by the NRC at the Russian Research Center (the I.V. Kurchatov Institute) and the Institute of Nuclear Safety of the Russian Academy of Sciences. Also, to inform the Commission of the staff's plan to continue these arrangements in 1999 provided that research results continue to be of value to the NRC and that measurable progress is being made. We will inform the Commission annually of these programs.

SUMMARY:

For the past several years the Russian Research Center and the Russian Academy of Sciences have performed research work for the NRC under bilateral agreements. This work is funded by the Office of Nuclear Regulatory Research and has involved research in code development and assessment, hydrogen combustion experiments, evaluation of high burnup fuel test data, in-vessel debris coolability experiments, evaluation of reactor pressure vessel surveillance capsule data, uncertainty analysis methods and development of concrete containment failure criteria. The results of this work have led to code improvements, expanded data bases and confirmatory research information. This work has also helped the Russians become familiar with USNRC analytical tools, safety issues and Western approaches to safety. It is intended to continue these programs in 1999 at a level comparable to that in 1998. The proposed agreements for the 1999 work are attached to this paper.

BACKGROUND

In SECY-91-375, "Proposed Arrangement with the I.V. Kurchatov Institute for Atomic Energy of the U.S.S.R. on Severe Accident Experiments," SECY-92-015, SECY-93-350, SECY-95-021, SECY-96-036, SECY-97-050, and [SECY-98-049](#) "Status of NRC Research... Sciences," the staff provided descriptions of the NRC research programs being conducted in Russia and recommended to the Commission that continued research cooperation between the NRC and the Russian Research Center (RRC) and the Institute of Nuclear Safety of the Russian Academy of Sciences (RAS) was in the best interest of the NRC. The Commission endorsed the staff recommendation.

Currently, the work being performed for the NRC by the RRC is described in the Implementing Agreement on Severe Accident Research between the USNRC and RRC. A copy of Addendum 2 to this Implementing Agreement describing the work in 1998 was enclosed with SECY-98-049. The 1998 work covered by the Addendum consisted of:

- Completion of development of the BARS 3D reactor neutronics code
- Completion of analysis of high burnup fuel test data and application of that data to developing an irradiated Zr-1%Nb data base

The FY 1998 cost to the NRC for this work specified in the Addendum was \$200K in accordance with the Agreement.

The work being performed for the NRC by RAS is described in the Implementing Agreement on the Development and Application of Nuclear Safety Analysis Codes between the USNRC and the Institute of Nuclear Safety of the Russian Academy of Sciences (RAS). A copy of Addendum 3 to this Implementing Agreement describing the work in 1998 was also enclosed with SECY-98-049. The 1998 work covered by the Addendum consisted of:

- Implementation of improved models in the NRC SCDAP/RELAP severe accident codes

The FY 1998 cost to the NRC for this work was \$20K.

DISCUSSION:

Discussed below is a summary of the work done in 1998 under the Implementing Agreements and our plans for continuing work in 1999. Attached to this paper are a proposed Addendum 3 to the existing Implementing Agreement covering the 1999 work at the RRC and a proposed Addendum 4 to the existing Implementing Agreement with the RAS covering their 1999 work.

WORK AT THE RRC

Work Completed in 1998

Hydrogen Behavior

During 1998, NRC received the RRC report on tests performed during 1997, that were jointly funded by NRC, IPSN (France), and FZK (Germany), with the NRC contribution being one-third of the total. This report provided large scale (500 m3) test results of hydrogen combustion experiments useful for

comparison with small scale results and confirmation of hydrogen ignitor separation criteria.

High Burnup Fuel

From its inception, the work on high-burnup fuel has been coordinated with IPSN (France), who have shared costs equally. Emphasis in 1998 shifted to documentation of test reactor data and related analyses, improvement of mechanical properties measurements with broad application, and continuation of the 3-D neutronic analysis of plant transients. It should be noted that the Russian work is performed on high-burnup VVER cladding (alloy E110) that is very similar to alloy M5, which is currently under NRC review in an application from Framatome Technologies. Further, the plant transient that is being analyzed with 3-D neutronic codes is for a U.S. plant (TMI-1), so results from this work continue to be relevant to NRC activities.

(1) Documentation of IGR reactor test data and related analyses

A large 3-volume document was prepared to summarize the test reactor work and its interpretation, to describe the test procedures and analytical tools, and to record the complete data base. The document will be published by NRC (NUREG/IA-0156), made available on a CD, and entered into the NRC Reactor Safety Data Bank. Final review of the document was completed in December, 1998, and publication is expected in early 1999. This work has shown significant differences in the ductility of Russian alloy E110 compared with Zircaloy-4, which is still prevalent in U.S. plants: highly irradiated Zircaloy-4 is more brittle and therefore more prone to failure at the lower temperatures associated with reactivity transients. Separate reports were also prepared on a Russian-modified version of NRC's FRAP-T6 and IPSN's SCANAIR fuel rod transient codes. Those reports are under review now and will also be published in early 1999.

(2) Measurement of fuel rod cladding mechanical properties

Additional measurements and analysis were performed to try to resolve differences that were observed the previous year in round-robin measurements in the U.S., France, and Russia. These differences were due to differences in test specimen setup and this 3-party effort on defining parameters for ring-tensile tests to represent fuel pellet expansion is pushing the state of the art. Some related tube-burst tests were also performed. Work is continuing on this program, and on NRC's and IPSN's related separate programs, because of the long-term need for such data for analyzing transients involving high-burnup fuel with different cladding alloys being introduced in U.S. reactors.

(3) 3-D neutronic analysis of plant transients

Additional development and validation of the coupled BARS (Russian neutron kinetics code) and RELAP5 (U.S. thermal-hydraulics code) code package were required in 1998. A wide range of benchmarking and validation cases was presented in a paper at NRC's Water Reactor Safety Information Meeting (October 1998) along with results for a rod ejection accident in a VVER-1000 plant. A significant variance in pin-to-pin power was seen in these calculations, which is not seen with codes that calculate power on an assembly basis typical of most Western computer codes. Such variance could be used to enhance best estimate analyses where such analyses are used to demonstrate compliance with acceptance criteria. Work was begun on a 3-way (U.S., France, Russia) code benchmark comparison for rod ejection accidents in a U.S. PWR (TMI-1). This work will continue in 1999.

Work Planned for 1999

[Attachment I](#) to this paper describes the work planned in 1999 at the RRC. This work is summarized below:

High Burn up Fuel

Additional measurements will be made of fuel rod cladding mechanical properties to determine if ring tensile tests adequately represent fuel pellet expansion during reactivity transients, providing a database for the E110 alloy for transient analysis of high-burnup fuel. This work will be used to supplement the database of mechanical properties data being developed at Argonne National Laboratory under NRC sponsorship and will also assist in refining the materials testing techniques to be used in our experimental program related to high burnup fuel.

3-D Reactor Physics

Benchmark comparisons of rod ejection accidents in a U.S. PWR (TMI-1) will be continued and completed, and recommendations will be made regarding the importance of unique features in the Russian code. This work will assist in determining the level of detail to be put in our 3D reactor physics code as well as interpreting results of 3D reactor physics calculations.

WORK AT THE RUSSIAN ACADEMY OF SCIENCES (RAS)

Work Completed in 1998

Model Development for NRC Severe Accident Codes

The RAS has been providing model development and code assessment for NRC's severe accident code, SCDAP/RELAP5. In particular, the RAS has been working on implementation and assessment of improved core degradation models in the code. Specific activities accomplished in 1998 include the implementation and testing of the following four models for the SCDAP/RELAP5 code:

- $\text{UO}_2/\text{Zr}/\text{ZrO}_2$ steam interaction
- fuel/clad candling
- Zr/UO_2 dissolution

- cladding mechanical behavior

Work Planned for 1999

Attachment II to this paper describes the work planned in 1999 at the RAS. This work is summarized below:

Severe Accident Code Consolidation Program

RAS plans to formulate a list of objectives and requirements for a consolidated severe accident code based upon their experience in developing a Russian severe accident code package and work with the NRC codes. The relevant codes will then be assessed in terms of the requirements and, based on this assessment, recommendations regarding a consolidation plan for NRC's severe accident codes will be developed. These recommendations will assist us in formulating requirements and plans for consolidating NRC severe accident codes.

CONCLUSION:

Given the progress to date on the ongoing programs, the expectation that the 1999 work described above can be successfully carried out and the small funding involved, we believe that it is in the best interest of the NRC to continue our agreements with the RRC and the RAS. The proposed Addendum 3 to the Agreement with RRC and the proposed Addendum 4 to the Agreement with the RAS are attached for information. I intend to forward these to the RRC and RAS for signature.

RESOURCES:

The cost to the NRC in FY 1999 of the research summarized above would be \$150K for the RRC and \$80K for the RAS. These costs do not include the cost of travel, which will be paid for by the RRC and RAS. Funds for this research work are in the FY 1999 RES budget.

COORDINATION:

This paper has been coordinated with the Office of the Chief Financial Officer, which has no resource objection, and the Office of the General Counsel, which has no legal objection.

I will continue to keep the Commission informed of progress on the NRC sponsored research at the RRC and the RAS.

William D. Travers
Executive Director for Operations

Contact: T. L. King, RES
415-5790

Attachments: I. Addendum 3 to the Agreement with RRC
II. Addendum 4 to the Agreement with RAS

ATTACHMENT 1

ADDENDUM 3 TO THE IMPLEMENTING AGREEMENT
BETWEEN
THE UNITED STATES NUCLEAR REGULATORY COMMISSION (USNRC)
AND
THE RUSSIAN RESEARCH CENTER (RRC)
FORMERLY THE I.V. KURCHATOV INSTITUTE FOR ATOMIC ENERGY (IAE)
ON SEVERE ACCIDENT RESEARCH

Considering that,

1. In accordance with Article VII, D of the Implementing Agreement on Severe Accident Research between the United States Nuclear Regulatory Commission and the Russian Research Center (hereinafter referred to as the Implementing Agreement), the parties have agreed to this Addendum to the Implementing Agreement.
2. The USNRC and RRC have cooperated in the field of severe accident research under a five year Implementing Agreement signed on February 23, 1996.
3. The RRC has performed extensive research in the area of hydrogen combustion and detonation at conditions representative of severe reactor accident, analysis and examination of high burnup fuel experiments, development of 3-D reactor physics models, measurement of gap conductance representative of severe accident conditions and annealing of reactor pressure vessel steels. The USNRC and RRC are presently cooperating in this research program under Addendum 2 to the original Implementing Agreement.

ARTICLE I - PROGRAM COOPERATION

The cooperative program includes (1) measuring mechanical properties of cladding from high-burnup fuel and evaluating those results for applicability to the analysis of safety transients, and (2) developing and demonstrating a 3-D reactor transient physics code. The NRC program will consist of technical assistance and cash contributions to permit defraying some of the cost of conducting the above described program.

ARTICLE II - SCOPE OF THE ADDENDUM

A. USNRC Scope of Responsibility

The USNRC shall provide over the duration of this Addendum the following specified goods and services related to nuclear reactor safety research.

2. Limited technical assistance and advice will be provided during the conduct of the high-burnup fuel and reactor physics evaluation programs; the extent of such assistance to be mutually agreed to prior to the start of the program.
3. Financial Support - The US NRC will provide to RRC the sum of \$150K in FY99. The funds will be used to defray some of the costs associated with: (1) measurements and analysis of cladding from high-burnup fuel, and (2) development and benchmark calculations with 3-D transient reactor physics codes.

A work plan (Description of Work) acceptable to both sides describing the work items in II.B.1 and II.B.2 should be completed and agreed to within 60 days after signature of this Addendum. Upon USNRC approval of the work plan and receipt of RRC invoices, payments will be made as follows, subject to U.S. Government rules and regulations:

- i. \$75,000 U.S. dollars upon approval of the workplan,
- ii. \$75,000 U.S. dollars in July, 1999, providing that the workplan has been approved by the USNRC.

The cost of this work is to be shared equally between France (IPSN) and the USNRC, with some additional funding expected from internal Russian sources. The cost specified in this Addendum is for the USNRC portion only.

B. RRC Scope of Responsibility

The RRC shall provide over the duration of this Addendum the following specific goods and services:

1. High Burnup Fuel

Work in 1999:

- a. Approximately 24 additional tube burst tests at 20-450C, and approximately 20 additional ring tensile tests (applicable to reactivity-initiated accidents).
- b. Comparison of ring tensile tests with tube burst tests over the range of temperatures applicable to reactivity-initiated accidents.
- c. Conclusions regarding validity of ring tensile test data for reactivity-initiated accident analysis

2. 3-D Reactor Physics

Work in 1999:

- i. Modifications to the BARS and TRIFON codes for temperature non-uniformities (which affect Doppler) and time-dependent nuclide compositions (which affect absorptions)
- ii. Complete the TMI-1 rod ejection benchmark calculations with coupled BARS/RELAP5
- iii. Complete the TMI-1 MSLB benchmark calculations for OECD Standard Problem

3. **Reporting and Meetings** - The RRC will prepare quarterly technical and financial status reports for all programs, and provide final technical reports for each program at the completion of the work described in this Addendum. Periodic technical meetings may be called for by either party to discuss programmatic to technical issues that might arise during the duration of the program described here.

4. **Audit and Record Requirements** - The RRC shall maintain complete accounting records of all funds provided to it by the USNRC under this Addendum in accordance with accounting principles generally accepted in the Russian Federation. The accounting records

shall be maintained for a period of no less than three years after the expiration of this Addendum. The USNRC, or other authorized U.S. Government officials shall have full access to the accounting record for the purposes of financial audit during the period of this Addendum and, after its expiration, for a period of no less than three years.

ARTICLE III. FINAL PROVISIONS

Duration and Termination - The work described in this Addendum shall begin upon signature by the parties and is expected to be completed on or before December 31, 1999. The work described in this Addendum may be terminated by mutual consent or by either party's withdrawing from the present Implementing Agreement after providing the other party written notice 6 months prior to its intended date of withdrawal.

All terms and conditions of the Implementing Agreement will apply to this Addendum. The parties further agree to modify or extend the activities described in this Addendum within the intended scope of this Addendum upon written agreement of its Administrators.

In witness whereof this Agreement has been entered into the day and year last written.

FOR THE UNITED STATES NUCLEAR REGULATORY COMMISSION

BY: _____
WILLIAM D. TRAVERS

TITLE: _____
Executive Director for Operations

DATE: _____

PLACE: Rockville, Maryland, USA

FOR THE RUSSIAN RESEARCH CENTER (RRC), FORMERLY THE I.V. KURCHATOV INSTITUTE OF ATOMIC ENERGY

BY: _____
VLADIMIR ASMOLOV

TITLE: DIRECTOR FOR RESEARCH AND DEVELOPMENT

DATE: _____

PLACE: _____

ATTACHMENT 2

ADDENDUM 4 TO THE IMPLEMENTING
AGREEMENT ON THE DEVELOPMENT AND
APPLICATION OF NUCLEAR SAFETY ANALYSIS CODES
BETWEEN
THE UNITED STATES NUCLEAR REGULATORY COMMISSION (USNRC)
AND
THE NUCLEAR SAFETY INSTITUTE (IBRAE)
OF THE RUSSIAN ACADEMY OF SCIENCES (RAS)

Considering that,

1. In accordance with Article VII.D of the Implementing Agreement on the Development and Application of Nuclear Safety Analysis Codes between the United States Nuclear Regulatory Commission and the Nuclear Safety Institute of the Russian Academy of Sciences (hereafter referred to as the Implementing Agreement), the parties have agreed to this Addendum to the Implementing Agreement.
2. The USNRC and IBRAE/RAS have cooperated in the field of nuclear safety analysis codes under a five year Implementing Agreement signed on January 31, 1995.
3. The IBRAE/RAS has performed extensive research in the areas of model development for NRC severe accident codes, the development of probabilistic risk assessment techniques, the development of containment failure criteria and thermal-hydraulic code model assessment and validation. The USNRC and IBRAE/RAS are presently cooperating in this research program under Addendum 3 to the original Implementing Agreement.

ARTICLE I - PROGRAM COOPERATION

The cooperative program includes (1) implementation of improved models for NRC severe accident codes, (2) thermal-hydraulic code model assessment and validation, (3) application of probabilistic risk assessment techniques, and (4) refinement of containment failure criteria. The USNRC program will

consist of technical assistance and cash contributions to permit defraying some of the cost of conducting the above described program.

ARTICLE II - SCOPE OF THE ADDENDUM

A. USNRC Scope of Responsibility

The USNRC shall provide over the duration of this Addendum the following specified goods and services related to code and analysis research:

1. Limited technical assistance and advice will be provided during the code model and analytical methods development; the extent of such assistance to be mutually agreed to prior to the start of the program.
2. Financial Support - The USNRC will provide to IBRAE/RAS the sum of \$80K in FY99. The IBRAE/RAS will provide a detailed work plan on the research to be conducted and the expected completion dates. The funds will be used to develop suggested requirements and code improvements in support of severe accident code consolidation.

A work plan acceptable to both sides describing the work in item II.B.1 below, should be completed and agreed to within 60 days after signature of this Addendum. Upon NRC approval of the workplan and receipt of an IBRAE/RAS invoice, payment will be made as follows, subject to U.S. government rules and regulations:

- \$80,000 U.S. dollars upon approval of the workplan

B. IBRAE/RAS Scope of Responsibility

The IBRAE/RAS shall provide over the duration of this Addendum the following specific goods and services related to code modeling, analysis methods development and application:

1. **Severe Accident Code Consolidation Program**
 2. Formulate a list of objectives and requirements for consolidating severe accident codes: MELCOR, SCDAP/RELAP, VICTORIA and CONTAIN. This list should address the quality of constituent models and their range of applicability, numerical methods, code architecture, supporting data bases, robustness and maintenance, and verification and validation efforts.
 - ii. Assess the codes in terms of the above requirements and identify the deficiencies in each.
 - iii. Based on the above information develop a consolidation plan, including the selection of models and updates needed to the models, code structure and data bases.

b. **Additional Work**

Subject to availability of funds and agreement between NRC and RAS, additional work related to code consolidation, code development or risk assessment may be added under this Addendum, subject to NRC receipt and approval of a workplan.

3. **Reporting and Meetings**

The IBRAE/RAS will prepare quarterly technical and financial status reports for all programs, and provide final technical reports for each program at the completion of the work described in this Addendum. Either party may call for periodic technical meetings to discuss programmatic or technical issues that might arise during the duration of the program described here.

4. **Audit and Record Requirements**

The IBRAE/RAS shall maintain complete accounting records of all funds provided to it by the USNRC under this Addendum in accordance with accounting principles generally accepted in the Russian Federation. These accounting records shall be maintained for a period of no less than three years after the expiration of this Addendum. The USNRC, or other authorized U.S. government officials shall have full access to the accounting records for the purposes of financial audit during the period of this Addendum and, after its expiration, for a period of no less than three years.

III. FINAL PROVISIONS

Duration and Termination - The work described in this Addendum shall begin upon signature by the parties and is expected to be completed on or before December 31, 1999. The work described in this Addendum may be terminated by mutual consent or by either party's withdrawing from the present Implementing Agreement after providing the other party written notice 6 months prior to its intended date of withdrawal.

All terms and conditions of the Implementing Agreement apply to this Addendum. The parties further agree to modify or extend the activities described in this Addendum within the intended scope of this Addendum upon written agreement of its Administrators.

In witness whereof this Agreement has been entered into the day and year last written.

FOR THE UNITED STATES NUCLEAR REGULATORY COMMISSION

BY: _____

William D. Travers

TITLE: Executive Director for Operations

DATE: _____

PLACE: Rockville, Maryland, USA

FOR THE NUCLEAR SAFETY INSTITUTE OF THE RUSSIAN ACADEMY OF SCIENCES

BY: _____

Leonid A. Bolshov

TITLE: Director, Nuclear Safety Institute, RAS

DATE: _____

PLACE: _____