SECY-00-0072

March 24, 2000

FOR: The Commissioners

FROM: William D. Travers /RA/
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 progress made in 1999 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 2000 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 2000 at a level comparable to that in 1999. The proposed agreements for the 2000 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, SECY-98-049, and SECY-99-078, "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 recommendations.

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 3 to this Implementing Agreement describing the work in 1999 was enclosed with SECY-99-078. The work covered by the Addendum consisted of :

- Measuring mechanical properties of cladding from high-burnup fuel and evaluating those results for applicability to the analysis of safety transients
- Developing and demonstrating a 3-D reactor transient physics code

The FY 1999 cost to the NRC for this work specified in the Addendum was $150K 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 4 to this Implementing Agreement describing the work in 1999 was also enclosed with SECY-99-078. The 1999 work covered by the Addendum consisted of:

- Development of a plan for consolidation of severe accident codes

The FY 1999 cost to the NRC for this work was $80K.

DISCUSSION:

Discussed below is a summary of the work done in 1999 under the Implementing Agreements and our plans for continuing work in 2000. Attached to this paper are a proposed Addendum 4 to the existing Implementing Agreement covering the 2000 work at the RRC and a proposed Addendum 5 to the Implementing Agreement with the RAS covering their 2000 work.

WORK AT THE RRC

Work Completed in 1999

High Burnup Fuel

During 1999, the high burnup fuel work consisted of tube burst tests and ring tensile tests on high-burnup VVER cladding under conditions of reactivity accidents. These results provided mechanical properties that are necessary for analysis of reactivity transients and are relevant to a cladding alloy (M5) that is just now being introduced in the U.S. Current results were reported at NRC's Water Reactor Safety Information Meeting in October 1999, and detailed results from earlier work in this program were published in a three-volume report, NUREG/IA-0156, "Data Base on the Behavior of High Burnup Fuel Rods With Zr-1%Nb Cladding and UO_2 Fuel (VVER Type) under Reactivity Accident Conditions," (July 1999). Related developments on analytical codes for fuel rod behavior were published as NUREG/IA-0164, "Modification of the USNRC's FRAP-T6, Fuel Rod Transient Code for High Burnup VVER Fuel," (May 1999), and NUREG/IA-0165, "Modification of ISPN's SCANAIR Fuel Rod Transient Code for High Burnup VVER Fuel," (May 1999).

3-D Reactor Physics

The work on neutronic codes provided a comparison of calculations of a postulated reactivity accident in a U.S. reactor with Russian codes, French codes and American codes. The comparison is significant inasmuch as the Russian code uses different methods and has a completely different origin than the western codes. Excellent agreement is being found, and the current status of this work was presented at the Water Reactor Safety Information Meeting in October 1999.

Work Planned for 2000

Attachment 1 to this paper describes the work planned in 2000 at the RRC. This work is summarized below:

High Burnup Fuel

Axial tensile tests will be performed and compared with previous ring tensile tests and tube burst tests to determine the anisotropy of the cladding on high fuel burnup. Reassessment of existing Russian data on cladding deformation under LOCA conditions will be performed. Combining the results from 2000 for LOCA conditions with the results from 1999 for reactivity insertion accident conditions will provide a broad data base of mechanical properties for the Zr-1%Nb VVER cladding. Additional modifications to the fuel rod transient codes will be made, especially in the area of LOCA analysis, to utilize these data.

3-D Reactor Physics

Sensitivity calculations will be performed with the RELAP-BARS code for the TMI-1 rod-ejection accident that was analyzed in 1999. A rod-ejection accident will also be analyzed starting from 1/3 nominal power to compare with the previous zero-power events that have been analyzed. Results will be compared with those from the PARCS (USA) and CRONOS (France) codes. Improvements will be made in RELAP-BARS to analyze boric acid transport in the primary coolant, and calculations will be performed for a boron-dilution accident in TMI-1.

WORK AT THE RUSSIAN ACADEMY OF SCIENCES (RAS)

Work Completed in 1999

Severe Accident Code Consolidation Program

The RAS effort during FY1999 was focused on preparing a plan for the consolidation of the severe accident computer

programs. This effort is still underway and is expected to be completed later this year. Upon completion, no further work by RAS on severe accident code consolidation is planned.

Work Planned for 2000

Attachment II to this paper describes the work planned in 2000 at the RAS. This work is summarized below:

- Probabilistic Risk Assessment

RAS will assess the variability in PRA results (using a PWR as an example) of uncertainties in parameters not traditionally accounted for in PRA. These include uncertainties in success criteria, human response and passive structure capability due to plant aging. The results will be used to help identify where additional attention should be focused in performing and reviewing PRAs, as well as considering uncertainties in PRA results.

CONCLUSION:

Given the progress to date on the ongoing programs, the expectation that the 2000 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 RAS. The benefits from the research conducted by the RRC and the RAS are discussed in Attachment III. The proposed Addendum 4 to the Agreement with the RRC and the proposed Addendum 5 to the Agreement with the RAS are attached for information. It is noted that the Implementing Agreement with the RRC expires on February 23, 2001; however, the Implementing Agreement with the RAS expired on January 31, 2000. Accordingly, Addendum 5 has also been modified to extend the Implementing Agreement until December 31, 2000. I intend to forward these to the RRC and RAS for signature.

RESOURCES:

The cost to the NRC in FY2000 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 FY2000 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.

/RA/

William D. Travers
Executive Director for Operations

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Attachments:
I. Addendum 4 to the Agreement with RRC
II. Addendum 5 to the Agreement with RAS
III. Benefits from Research Conducted by the Russian Research Center and Russian Academy of Sciences

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ATTACHMENT I

ADDENDUM 4 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

- ARTICLE I - PROGRAM COOPERATION

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 accidents, analysis and examination of high burnup fuel experiments, measurement of gap conductance representative of severe accident conditions and annealing of reactor pressure vessel steels. The USNRC and RRC are currently cooperating in this research program under Addendum 3 of the Implementing Agreement.

ARTICLE I - PROGRAM COOPERATION

The cooperative program includes measuring mechanical properties of cladding from high-burnup fuel and evaluating those results for applicability to the analysis of safety transients. 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:

1. 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.

2. **Financial Support** - The USNRC will provide to RRC the sum of $150K in FY2000. 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. $100K will be designated for the high burnup fuel evaluations and $50K for the reactor physics work.

   A work plan (Description of Work) acceptable to both sides describing the work in items 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 workplan and receipt of RRC invoices, payments will be made as follows, subject to U.S. government rules and regulations:

   - $75,000 U.S. dollars upon approval of the work plan,
   - $75,000 U.S. dollars in July 2000,

The cost of this work is to be shared between France (IPSN) and the USNRC, with some additional funding 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**

   a. Approximately 10 axial tensile tests on Zr-1%Nb E110 cladding (5 unirradiated and 5 irradiated) over a wide temperature range applicable to both RIA and LOCA conditions. Comparison with previous ring tensile tests and tube burst tests to determine isotropy of irradiated and unirradiated E110 cladding.

   b. Reassessment of all available Russian data on mechanical properties, ballooning, burst, and oxidation of E110 cladding under LOCA conditions to provide a data base for code modification and analysis.

   c. Improvement of computer models in FRAP-T (USA) and SCANAIR (France) to incorporate above results on cladding properties.

2. **3-D Reactor Physics**

a. Perform calculations of the TMI-1 rod-ejection accident with varying neutronic and thermal-hydraulic parameters and compare results with those from PARCS (USA) and CRONOS (France).

b. Improve the RELAP-BARS coupling code to consider boric acid transport in the primary coolant and perform calculations of a boron dilution accident at TMI-1. Compare results with those from PARCS and CRONOS.

c. Perform RELAP-BARS calculation of the TMI-1 rod-ejection accident with an initial reactor power of 1/3 of nominal and compare results with those of PARCS and CRONOS.

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 or 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.

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, 2000. 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 II

ADDENDUM 5 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)

- III. FINAL PROVISIONS

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 currently cooperating in this research program under Addendum 4 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 FY2000. 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 an assessment of the variability in risk assessment results due to uncertainties in various parameters.

   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 assessing the contribution of various sources of uncertainty to the variability in risk assessment results.

1. **Probabilistic Risk Assessment Contributors to Uncertainty**

   a. Through the use of sensitivity studies, assess the variability in PRA results from uncertainties not traditionally accounted for in a risk assessment. These would include uncertainties in success criteria, human response time, passive structure capability (due to aging), and others as may be identified in the course of the study. A typical PWR PRA should be used (internal events, full power condition). Variability in the core damage frequency and large early release frequency are the parameters of interest.

   b. The first step should be to develop a work plan identifying the parameters to be varied and whether they should be done singly or in combination.

   c. The second step should be to do the sensitivity analysis and produce a report on the results.

2. **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 periodical 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 - This Addendum extends the duration of the Implementing Agreement to December 31, 2000. The work described in this Addendum shall begin upon signature by the parties and is expected to be completed on or before December 31, 2000. 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 INSTITUTE OF NUCLEAR SAFETY OF THE RUSSIAN ACADEMY OF SCIENCES

BY: _____
Leonid A. Bolshov
TITLE: DIRECTOR, NUCLEAR SAFETY INSTITUTE, RAS
DATE: _____
PLACE: _____

ATTACHMENT III

BENEFITS FROM RESEARCH CONDUCTED BY THE RUSSIAN RESEARCH CENTER AND RUSSIAN ACADEMY OF SCIENCES

Russian Research Center

The cost of this work is leveraged by about 20 as a result of low staff costs and the sharing of costs with the French safety institute, IPSN, and the Russian ministry, MINATOM. Further, large quantities of raw data are brought into this program for assessment from other Russian programs that did not receive NRC support. These programs include (a) testing under reactivity accident conditions in two test reactors, (b) testing under loss-of-coolant conditions in the Impulse Graphite reactor, (c) testing of fresh and irradiated cladding out of pile under loss-of-coolant conditions, and (d) studies of properties of zirconium alloys, especially those with niobium.

Standard Russian VVER cladding is a Zr-1%Nb alloy that is almost identical in composition to the Framatome M5 alloy and

similar to the Westinghouse ZIRLO cladding that are being used in the U.S. High-burnup studies of these alloys have not yet been made in the U.S., and the Russian work gives some insights into the behavior of these cladding types under postulated accident conditions that must be considered in safety analyses.

The first major result from this program was the demonstration that the niobium alloy cladding with its much lower corrosion level behaved much differently than Zircaloy under conditions of a reactivity accident. The failure mechanism was a ductile burst rather than a brittle fracture and it occurred at a significantly higher energy deposition. This demonstrated the importance of the failure mechanism, corrosion level, and alloy type, and it indicates a potential for improved transient behavior of the newer alloys being used in the U.S.

A Russian-French-American round-robin tensile test was performed on Russian cladding tubes to check reproducibility of measurement techniques. This led to state-of-the-art developments of ring-tensile specimen design that will allow testing of small specimens of irradiated material to obtain mechanical properties. These properties are needed to perform analyses that will reduce the number of in-reactor and large integral tests in hot cells to determine damage criteria for new cladding alloys at high burnups.

A recent Russian handbook of zirconium alloy properties was given to the NRC along with permission to pass the information along to the U.S. industry. The NRC had this handbook translated and then gave the original and translated versions to EPRI for distribution to the U.S. industry, subject to cost and copyright arrangements with the publisher.

Information on phase transformations and mechanical properties of Zr-1%Nb alloys generated in this Russian program were used by NRC's reviewer in the review of Framatome's licensing topical report on M5 cladding. These results helped the reviewer perform this review on schedule and issue an approval in 1999.

Models and coding were developed in this program for calculating heat transfer and rewetting in water-filled test capsules where there is no flow over the fuel rod surface. These models were installed in the VVER version developed by the Russians of NRC's FRAP-T6 fuel rod transient code. These models will be imported into NRC's current FRAPTRAN fuel rod transient code, and the models will improve the analysis of data from Japanese tests in stagnant water capsules. Such analysis will help avoid unnecessary conservative biases in interpreting the important data set from Japan.

Excellent agreement between the Russian neutron kinetics code, BARS, and western codes like NRC's PARCS code gives added confidence in all of these codes to predict fuel rod power during transients, and the studies of uncertainties being done in this program will allow more accurate uncertainty estimates thus avoiding unnecessary conservative margin. These codes are used primarily for the postulated reactivity accidents.

Russian Academy of Sciences

The work performed by the RAS has involved analytical modeling of core melt progression, assessment of RELAP against Russian thermal-hydraulic data and PRA methods development.

RAS analytical modeling work led to the development and implementation of four analytical models for NRC's SCDAP/RELAP code. These models address:

- steam/zirconium interactions
- fuel and clad melting
- zirconium and UO_2 dissolution
- cladding mechanical behavior

These analytical models are based more on first principles than the previous models and thus make the code applicable to a wider range of conditions.

RAS thermal-hydraulics work screened and identified unique Russian thermal-hydraulic data of potential use in assessing NRC's RELAP code. This will help focus assessment efforts on the data most relevant to RELAP.

RAS PRA work led to the development of a technique for incorporating uncertainties into a risk assessment at a very detailed level. This method will be used in followon work to assess the sensitivity of PRA results to uncertainties not traditionally included in PRAs (e.g., success criteria uncertainty). Such work will help identify whether or not there are other uncertainties that significantly affect PRA results and should be considered in performing/reviewing a PRA.

RAS has also been developing a report on the desired attributes of a consolidated severe accident code, which will be used to assist severe accident code consolidation work.