SECY-97-050

February 27, 1997

FOR: The Commissioners

FROM: L. Joseph Callan /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 1996 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 1997 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 involves 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 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 1997. The proposed agreements for the 1997 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, and SECY-96-036, "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 and the Institute of Nuclear Safety of the Russian Academy of Sciences was in the best interest of the NRC. The Commission endorsed the staff recommendation.

Currently, the work being performed for the NRC by the Russian Research Center is described in the Implementing Agreement on Severe Accident Research between the USNRC and the Russian Research Center (RRC). A copy of the Agreement was enclosed with SECY-96-036. The 1996 work covered by the Agreement consists of:

- Model development, calculations and experiments on hydrogen combustion
- Evaluation of high burnup fuel test data
- Investigation of mechanisms for in-vessel cooling of molten core debris
- Evaluation of reactor pressure vessel surveillance capsule data

The FY 1996 cost to the NRC for this work specified in the Agreement was $500K. In accordance with the Agreement, this was supplemented in August 1996 with another $150K based upon successful demonstration of facility operation to measure gap conductance representative of in-vessel cooling conditions and submittal of an acceptable proposal for a follow on test program.

The work being performed for the NRC by the Institute of Nuclear Safety 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 1 of this implementing arrangement was also enclosed with SECY-96-036. The 1996 work covered by the Addendum consists of:

- Model development and assessment for NRC severe accident codes
- Development of concrete containment failure criteria
- PRA uncertainty analysis methods
- Enhancement of the data base and assessment of NRC thermal-hydraulic codes

The FY 1996 cost to NRC for this work was $350K. In accordance with the Addendum, this was supplemented in August 1996 with another $75K based upon successful development of code models and containment failure criteria and an acceptable proposal for additional work.

DISCUSSION:

Discussed below is a summary of the work done in 1996 under the Implementing Agreements and our plans for continuing work in 1997. Attached to this paper are a proposed Addendum 1 to the existing Implementing Agreement covering the 1997 work at the RRC and a proposed Addendum 2 to the existing agreement with the RAS covering their 1997 work.

WORK AT THE RRC

Work Completed in 1996

- Hydrogen Behavior -

During 1996 the RRC continued to conduct experiments on hydrogen combustion to provide data on the potential for hydrogen detonation by deflagration to detonation transition (DDT). Six tests were conducted in the large scale (480 M^3 volume) RUT facility to investigate the combustion behavior of well mixed hydrogen, air, steam mixtures at elevated temperatures near the expected DDT point. The findings from these experiments are being used to develop a generalized methodology for predicting the possibility of detonations due to DDT in hydrogen, air, steam mixtures. These tests were jointly funded by NRC, IPSN (France), and FZK (Germany) with the U.S. contribution being one-third of the total.

- High Burnup Fuel -

In 1996, additional work was done to understand the data from 13 high-burnup transient tests that were examined in 1995 as part of our investigation of the adequacy of NRC regulatory criteria for reactivity accidents. An evaluation was also performed of similar tests on unirradiated fuel to establish a baseline. Preliminary results were discussed with French and American experts at a mid-year program review workshop in Moscow in June 1996, and those results were documented in an intermediate laboratory report. A paper summarizing recent results was presented at the 24th NRC Water reactor Safety Information Meeting in October 1996, and a written paper was provided for the proceedings. A full-length paper was submitted for publication in the Proceedings of the ANS International Topical Meeting on Light Water Reactor Fuel Performance to be held in March 1997. Key results obtained so far include:

  - Hot-cell measurements of cladding oxide thickness, hydrogen concentration, hydride orientation, and fission gas release provided sufficient information to allow analysis and comparison with the French and Japanese data on reactivity accidents.
  - Mechanical properties measurements show that the strength of irradiated Zr-1%Nb cladding (Russian type) is about the same as that of unirradiated Zircaloy cladding (older PWR type), consistent with the observed failure mechanism in the Russian tests.
  - Ballooning with rupture was the failure mechanism for fresh fuel and irradiated fuel, and the failure threshold for this niobium alloy cladding was about 160 cal/g for both.
  - FRAP-T (NRC code) and SCANAIR (French code) were set up and preliminary calculations were performed for each of the transient tests, contributing additional information for understanding the test data.

- In-vessel Cooling Mechanisms -

During 1996 RRC completed development of a facility to experimentally measure the thermal resistance in an initially water-filled gap between a simulated solid ceramic crust and the reactor vessel (RV) wall. The purpose of these tests is to obtain experimental data on the ability of steam filled gaps between core debris and the reactor vessel wall to remove sufficient heat to maintain RV integrity under high pressure severe accident conditions. In addition, RRC developed an analytical model to predict the experimental results. Initial feasibility tests with a small gap (i.e., less than 0.5mm) were completed in early 1996, and Phase 1 of the test program (linear gaps) was initiated. Results of the tests with a small gap size indicated dry out of the upper part of the test section with some damage to the test section. Further tests will be carried out with larger gap sizes.

- Evaluation of Surveillance Capsule Data -

The project to reevaluate the neutron flux and fluence estimates for the VVER-1000 surveillance capsules was completed with the delivery of the final report detailing the analyses performed and the results of the reevaluation. This project provided a consistent estimate of the flux and fluence values for the surveillance specimens which are located in a complex 3-D irradiation environment at the top of the core in the VVER-1000 designs. The improved flux and fluence estimates will permit better comparisons between the embrittlement trends observed in the surveillance data and data from test reactor irradiations in the U.S. and Russia. Delivery of the final report completes the work on this project. Comparison of the embrittlement trends will be conducted under the auspices of the Joint Coordinating Committee on Civilian Reactor Safety Working Group 3/12 for the Russian VVER-1000 plants, and under the Lisbon Initiative for the Ukrainian VVER-1000 plants.

Work Planned for 1997

Attachment I to this paper describes the work planned in 1997 at the RRC. This work is summarized below:

- Continuation of Hydrogen Behavior Research -

In 1997 experimental work on hydrogen deflagration will continue. This will include additional experiments on hydrogen ignition in the large scale RUT facility with nonuniform initial conditions (e.g., temperature, hydrogen concentration) and experiments with hydrogen injection into an air/steam atmosphere at elevated temperatures. The purpose of this work is to investigate the effects of nonuniform initial conditions on DDT and to investigate hydrogen ignitor separation distance in an environment with air and steam at elevated temperatures. This work will continue with France and Germany in an equal cost sharing arrangement, thus enabling the generation of test data at a lower cost to NRC. The cost shown in Attachment I is the U.S. contribution only.

- Continue Investigation of In-vessel Cooling Mechanisms -

This work is a continuation of the work in 1996 to investigate the potential for water in the reactor vessel to provide enhanced cooling of core debris beyond what is currently modeled. The test apparatus to measure gap conductance in the presence of high pressure water/steam will complete a series of tests with linear gaps. Based upon the results of these tests, future plans will be developed and the remainder of the 1997

work defined.

- High Burnup Fuel -

Additional measurements of materials properties will be performed on the Zr-1%Nb Russian cladding, which has similarities to the niobium alloys now being introduced in the U.S. Work will also be initiated on the analysis of core neutronics for LWRs to take advantage of an extensive underlying Russian technology in this area. The cost of this work is being shared 50-50 with CEA, France. Supplemental funding from RRC is also expected. The cost shown in Attachment I is the U.S. contribution only.

WORK AT THE RUSSIAN ACADEMY OF SCIENCES (RAS)

Work Completed in 1996

- 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 this code. Specific activities accomplished in 1996 include implementation and testing of the following four improved models: (1) UO_2/Zr/steam interactions, (2) candling of fuel rod molten material, (3) mechanical behavior of fuel rod cladding response, and (4) $U0_2$ dissolution kinetics based on diffusion mass transfer equations to account for the appearance and growth of a two-phase boundary region between solid $U0_2$ and liquid U-Zr-0 phases. In addition, the NRC has reviewed and approved implementation of the following two RAS models into SCDAP/RELAP5: (1) Zr - steam oxidation at high temperature, and (2) dissolution of $U0_2$ by molten Zr in an oxidizing atmosphere.

- Development of Concrete Containment Failure Criteria -

The purpose of this work is to develop containment failure criteria applicable to severe accident loads. A model of a prestressed concrete containment was developed and tested against data from a VVER-1000 prestressed containment. Predictions compared well with measured data and a letter report was issued.

- NRC Thermal-Hydraulic Code - Data and Assessment -

In late 1995, work began on RELAP5 code assessments and this work continued through 1996. The objective is to assess the adequacy of the RELAP5 hydrodynamic heat and mass transfer models in low flow regimes and for horizontal tube bundles using Russian experimental data. In effect, this expands the assessment data base for RELAP5 to include data and conditions that were not available in the U.S. and not considered in previous assessments. In addition to code assessment, new models for wall drag and wall heat transfer of two-phase bubble flow at low pressure and low mass fluxes were developed.

Two reports were completed in 1996. The first report, "Wall Drag and Heat Transfer Modules for Two-Phase Non-Equilibrium Flows at Low Pressure and Flowrate," describes the results of work performed to assess and improve the two-phase flow constitutive models of RELAP5 for vertical bubbly flow at low pressure and low flow conditions for:

  - wall shear stress;
  - wall heat transfer (forced convection);
  - interfacial heat transfer (subcooled liquid).

The work has provided data on modeling deficiencies which will be used to improve RELAP5.

The second report, "Assessment of RELAP5/Mod3.2 Heat and Mass Transfer Models for Large Volume with Horizontal Tube Bundles against Russian Experimental Data," assesses the subject RELAP models under two experimental configurations: a "separate effects" experiment where inlet conditions to a horizontal bundle were specified, and an "integral effects" experiment utilizing a model of a VVER steam generator. Both experimental configurations measured void fractions and heat transfer coefficients at relatively high pressure conditions.

The assessments presented in this report are important for the extension of RELAP5 to the analysis of VVER reactors; however, they were found to not be directly applicable to the RELAP5 models to predict the heat transfer and dryout characteristics of a large horizontal tube bundle immersed in low pressure water such as the PRHR heat exchanger of the AP600 design.

Work Planned for 1997

Attachment II to this paper describes the work planned in 1997 at the RAS. This work is summarized below:

- Model Development for NRC Severe Accident Codes -

Work is planned to continue on SCDAP/RELAP model development and assessment. This will include improving existing models, development of new models and comparisons against experimental data. Also, for those models implemented in the code last year, integrated assessment against experimental data will be done to help ensure proper integral functioning of the code. RAS will also perform sensitivity analyses using SCDAP/RELAP to independently assess where, if any, additional model improvement should be undertaken. In addition, RAS is to review the recently completed VICTORIA code (NRC fission product transport code) peer review report (peer review was chaired by BNL and did not involve RAS) and provide recommendations as to how to resolve the identified issues.

- Completion of Development of Concrete Containment Failure Criteria.

This work is a continuation of the 1996 work and will be used to develop a containment fragility curve applicable to the Kalinin VVER-1000 containment. This data will then be used in the PRA being performed on the Kalinin NPP under NRC sponsorship as the Priority 8, Lisbon Initiative. In addition, it is expected that this work will be of general use in assessing any prestressed concrete containment.

- Uncertainty Analysis Methods

A comparison will be made of existing PRA uncertainty analysis methods employed by NRC versus a more detailed uncertainty method developed by RAS, which includes the uncertainty in analytical methods and success criteria. The results will be used to help determine what additional uncertainty methods development would be useful for use in risk-informed regulation. This work was originally planned for 1996 but due to adjustments in defining the work scope, will be performed in 1997 using funds provided in 1996.

- NRC Thermal-Hydraulic Code Data and Assessment

Work will continue in this area to identify and utilize Russian data applicable to passive systems to further assess RELAP5. In particular, work, in 1997 will focus on data and assessments applicable to small break LOCA scenarios.

One additional item of importance pertaining to the work at the RRC and RAS is that the staff is considering an option of using one or both of these organizations to provide independent audit calculations on the safety aspects of the conversion of the 3 remaining Russian production reactors (2 at Tomsk-7 and 1 at Krasnoyarsk-26) to non-plutonium producing reactors, if a safety oversight role is defined for NRC on this activity. Although discussions are still underway with the Departments of Defense and Energy regarding NRC's role in oversight of the safety of the core conversion effort, preliminary informal discussions have been held with representatives of both the RRC and RAS regarding performing such audit calculations. Each organization has capability in this regard because of their experience in applying NRC's accident analysis codes to RBMK reactors (which have some similar design characteristics to the Russian production reactors). In the event such an oversight role is defined for NRC, a separate paper will be prepared which will discuss this subject in more detail. However, to facilitate arranging for and quickly initiating work by the RRC and/or RAS in this area, a task has been added to their proposed agreements for 1997 (Attachments I and II) which would allow funding of this work through our agreement, using funds supplied by the Department of Defense, once a decision is made and a scope and schedule for the work are agreed upon.

CONCLUSION:

Given the progress to date on the ongoing programs and the expectation that the 1997 work described above can be successfully carried out, 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 1 to the Agreement with RRC and the proposed Addendum 2 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 NRC in FY 1997 of the research summarized above would be $400K for the RRC and $520K for the RAS. These costs do not include the cost of travel, which will be paid for by the RRC and RAS or by NRC through invitational travel. Funds for this research work are in the FY 1997 RES budget. Additional funds for any follow on research work or work related to audit calculations in support of our oversight of the core conversion work would be provided separately (note: funds for core conversion work would be provided by the Department of Defense).

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.

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

L. Joseph Callan
Executive Director for Operations

Attachments:
1. Addendum 1 to the Agreement with RRC
2. Addendum 2 to the Agreement with RAS

ATTACHMENT I

ADDENDUM 1 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 (hereafter 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 presently cooperating in this research program under the initial year of the Implementing Agreement.

ARTICLE I - PROGRAM COOPERATION

The cooperative program includes (1) participating in a program to develop a scaling methodology for spontaneous detonations, and other hydrogen related research, (2) evaluating data and analyzing the results of tests in the IGR reactor on high burnup fuel and (3) developing models and performing experiments and assessments for in-vessel debris cooling mechanisms. 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 severe accident research:

1. Limited technical assistance and advice will be provided during the conduct of the hydrogen, high burnup fuel and in-vessel debriscooling test and evaluation programs; the extent of such assistance to be mutually agreed to prior to the start of the program.
2. **Financial Support -** Subject to the availability of funds, the NRC will provide to RRC the sum of $400K in FY97. The RRC will provide a detailed work plan on the research to be conducted and the expected completion dates. The funds will be used to conduct the necessary analyses to define the experiments and to defray some of the costs associated with: (1) conducting and analyzing hydrogen experiments and (2) evaluating high burnup fuel test data. $50K will be designated for analysis of the hydrogen experiments, $200K will be designated for the hydrogen experimental program and $150K will be designated for the high burnup fuel evaluations. Work on the in-vessel cooling mechanisms will proceed utilizing funds provided by NRC in FY96.
   A work plan 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 work plan and receipt of RRC invoices, payments will be made as follows, subject to U.S. government rules and regulations:

   - $200,000 U.S. dollars upon approval of the work plan,
   - $200,000 U.S. dollars in June 1997.

   Subject to availability, additional funds may be provided for the work described in items II.B.3 and II.B.4 below, subject to NRC review and approval of a detailed work plan.

B.RRC Scope of Responsibility

The RRC shall provide over the duration of this Addendum the following specific goods and services related to nuclear reactor severe accident research:

1. **Hydrogen Combustion**
   1. Conduct at least three hydrogen combustion experiments in the RUT facility to better define the conditions for ignitor placement to prevent hydrogen detonation. These experiments will be conducted at a temperature higher than ambient temperature with various concentrations of hydrogen, air and steam present. The exact test conditions will be specified by NRC after review of previously conducted test results and in consultation with the French and Germans who are co-sponsoring this experimental program. Cost for these experiments are to be shared among France-IPSN, Germany-FZK and USNRC, and the cost specified in this Agreement is for the USNRC portion only.
   2. Continue model development and calculations on hydrogen combustion behavior and continue to provide analysis on deflagration to detonation transition (DDT) and spontaneous detonation scaling methodology. In addition, provide assistance to USNRC in the review of technical issues associated with hydrogen combustion on an as requested basis.

2. **High Burnup Fuel** - The RRC is to complete the analysis of IGR test data and to initiate related follow-up studies:
   Work in 1997 is organized in four tasks:

   - complete analysis and assessment of IGR tests using NRC's FRAP-T code;
   - develop plans and initiate measurement of additional material properties for VVER fuel materials with the goal of preparing niobium alloy options in the NRC's MATPRO code;
   - develop best-estimate neutronics code for plant analysis of transients and accidents based on existing Russian Technology, and share neutronic data and analytic methods with NRC experts;
   - describe the combined work of 1996 and 1997 in a single data report suitable for documentation as a NUREG/IA report, and prepare

conference papers and journal articles as appropriate.

The cost of this work is to be shared equally between France (IPSN) and the USNRC. The cost specified in this Agreement is for the USNRC portion only.

3. **Investigate Mechanisms for In-vessel Cooling of Molten Core Debris**
The RRC should continue to experimentally measure the heat transfer gap conductance representative of conditions in the reactor vessel lower head with molten core material and water. Phase 1 testing using plate geometry gaps should be completed (using funds provided by NRC in FY96). Additional funds may be provided for Phase 2 testing (utilizing different gap materials) depending upon the results from Phase 1 and USNRC review and approval of a detailed workplan.

4. **Audit Calculations and Safety Review**
Perform audit calculations and review safety reports on RBMK type reactors. The exact scope, schedule and level of effort for this task will be determined after further discussions between NRC and RRC and development and approval of a detailed work plan.

5. **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.

6. **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. 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.

3. 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, 1997. 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 int ended 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: _____
Hugh L. Thompson, Jr.

TITLE: Acting 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	_____ N. N. Ponomarev-Stepnoi	
TITLE:	Director for Research and Development	TITLE:	Vice President
DATE:	_____	DATE:	_____
PLACE:	_____	PLACE:	_____

ATTACHMENT II

ADDENDUM 2 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 containment failure criteria and thermal-hydraulic code model assessment and validation. The USNRC and IBRAE/RAS are presently cooperating in this research program under the original Agreement.

ARTICLE I - PROGRAM COOPERATION

The cooperative program includes (1) development of improved models for NRC severe accident codes, (2) application of concrete containment failure criteria to the Kalinin Nuclear Power Plant (3) development of methods related to probabilistic risk assessment (PRA) uncertainty analysis and (4) thermal-hydraulic code model assessment and validation. 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. In addition, information related to uncertainty analysis methods currently used by the USNRC will be provided.

2. **Financial Support -** Subject to the availability of funds, the USNRC will provide to IBRAE/RAS the sum of $520K in FY97. 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 the necessary code models and analysis methods and to defray some of the costs associated with: (1) developing and applying models for use in USNRC severe accident codes, (2) application of concrete containment failure criteria, and (3) assessment and validation of thermal-hydraulic code models.
$220K will be designated for the severe accident code model development, $50K will be designated for application of the concrete containment failure criteria and $250K for the assessment and validation of thermal-hydraulic code models. Demonstration of PRA uncertainty analysis methods will be completed using funds previously provided by NRC in FY96. A work plan acceptable to both sides describing the work in items II.B.1a-e, II.B.2, II.B.3 and II.B.4.a should be completed and agreed to within 60 days after signature of this Addendum. Upon NRC approval of the workplan and receipt of IBRAE/RAS invoices, payments will be made as follows, subject to U.S. government rules and regulations:

    - $260,000 U.S. dollars upon approval of the workplan
    - $260,000 U.S. dollars in June 1997

    Subject to availability, additional funds may be provided for the work described below in II.B.1.f, II.B.4.b and II.B.5 subject to NRC review and approval of a detailed work plan.

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 model and analysis methods development and application:

1. **Model Development and Application for NRC Severe Accident Codes**

    a. Implement and assess the following new or improved models to the SCDAP/RELAP code:

    - dissolution of $UO_2/Zr/ZrO_2$ by molten zircalloy
    - improvement of the MATPRO data base in the areas of zircalloy cladding oxidation and hydriding
    - interaction of zircalloy with silver, cadmium and indium

    b. Complete assessment of previous IBRAE/RAS developed SCDAP/RELAP models against the following experimental data to ensure effective code operation and reasonable prediction capability:

    - CORA-5, 13 and 15 tests
    - Phebus tests

- PBF irradiated and fresh fuel tests
- RASPLAV corium and salt tests

c. Initiate development of a rod quenching model for SCDAP/RELAP which includes:

- cladding oxidation model for high cooling rates (i.e., Δ T across the clad)
- mechanical deformation
- transient heat exchange model

d. Assess sensitivity of models in SCDAP/RELAP to determine importance to overall melt progression.

e. Review VICTORIA peer review recommendations and provide assessment of modelling improvements needed.

f. Additional funding for model development and assessment may be provided based on the results of a-e above.

2. **Concrete Containment Failure Criteria**
Apply previously developed failure criteria for a prestressed concrete containment under severe accident loads to the Kalinin NPP. Develop a fragility curve for the Kalinin NPP prestressed concrete containment for use in risk assessment.

3. **PRA Uncertainty Analysis Methods**

Demonstrate an improved probabilistic risk assessment (PRA) uncertainty analysis method by comparison to existing PRA uncertainty analyses.

4. **Thermal-Hydraulic Code Assessment and Validation**

a. Continue work on assessment and validation of RELAP 5 in the areas of low flow regimes and horizontal tube bundles. This shall include assessment against:

- VVER-440 and 1000 steam generator data
- VTI and IVO loop seal clearing experimental data
- vertical pipe flooding experimental data
- fluid thermal stratification data

b. Based upon the results of the work described in 4(a) above, additional funding may be provided to extend the assessment to cover additional data.

5. **Audit Calculations and Safety Review**

Perform audit calculations and review safety reports on RBMK type reactors. The exact scope, schedule and level of effort for this task will be determined after further discussions between NRC and IBRAE/RAS and development and approval of a detailed work plan.

6. **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.

7. **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, 1997. 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: _____
Hugh L. Thompson, Jr.

TITLE: Acting 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: _____