# ANNEX I

# Work Plan

## I. Summary Project Information

### 1. Project Title

Examination of VVER Fuel Behavior under Severe Accident Conditions. Quench Stage.

### 2. Project Manager

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Name:** | | Valeri P.Smirnov | | | | | | |
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### 3. Participating Institutions

#### 3.1. Leading Institution

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Short reference:** | | | | | SSC RIAR | | | | | | |
| **Full name:** | | | State Scientific Center Research Institute of Atomic Reactors | | | | | | | | |
| **Street address:** | | | |  | | | | | | | |
| **City:** | Dimitrovgrad-10 | | | | | | | **Region:** | | Uljanovsk | |
| **ZIP:** | *433510* | | | | | | | **Country:** | | | Russia |
| **Name of Signature Authority:** | | | | | | | Alexei F. Grachev | | | | |
| **Title:** | Dr., Professor | | | | | | | **Position:** | | Director of SSC RIAR | |
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| **Governmental Agency:** | | | | | | Ministry for Atomic Energy | | | | | |

#### 3.2. Other Participating Institutions

#### Participant Institution 1

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Short reference:** | | | | | IBRAE | | | | | | |
| **Full name:** | | | Nuclear Safety Institute of Russian Academy of Science | | | | | | | | |
| **Street address:** | | | | B.Tulskaja Street, 52 | | | | | | | |
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#### Participant Institution 2

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Short reference:** | | | | | JSC MSZ | | | | | | |
| **Full name:** | | | Joint Stock Company "MASHINOSTROITELNY ZAVOD" | | | | | | | | |
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### 4. Foreign Collaborators/Partners

#### 4.1. Collaborator 1

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
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#### Collaborator 2

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
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#### Collaborator 3

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#### Collaborator 4

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
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#### 4.2. Partners

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Institution:** | | |  | | | | | | | |
| **Street address:** | | | |  | | | | | | |
| **City:** |  | | | | | **Region/State:** | | | |  |
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| **Project Coordinator:** | | | | |  | | | | | |
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| **Tel.:** |  | | | | | **Fax:** |  | | | |
| **E-mail:** | |  | | | | | | | | |

### 5. Project Duration

36 months

### 6. Project Location and Equipment

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| --- | --- |
| **Institution** | **Location, Facilities and Equipment** |
| **Leading Institution**  **SSC RIAR** | Fuel Element Department. Hot cells and equipment of hot examination laboratory:  testing facility to examine reflood |
| **Participant Institution 1**  **IBRAE** | Computers |
| **Participant Institution 1**  **JSC MSZ** | Technological equipment of the workshops to manufacture fuel rods, absorbing elements and FA construction elements |

## II. Specific Information

### 1. Introduction and Overview

One of the main aspects of reactor safety validation lies in study of the processes in fuel rods under accident conditions to predict and to control accident process, to improve fuel technology and its operation, to reduce consequences or prevent severe accidents.

Currently VVER reactors are the basis for nuclear energy in Russia, Ukraine, Bulgaria, Hungary, Czech, Slovakia and Finland. These reactors operate rather reliably under steady-state and transient conditions. VVER fuel behavior is currently examined under design-basis accident conditions when the cladding remains intact that allows cooling and unloading the core as well as carrying out fuel transportation. However, for the fuel of this type there is lack of data on its behavior under severe accident conditions.

Great uncertainty of the processes of severe accidents, complexity of the problems to describe design element behavior and, hence, large cost and labor expenditures of experiments make almost impossible to carry out necessary work to validate safety by one separate country. Therefore examinations aimed at development of the codes which allow to assure safety of reactor operation are carried out under international cooperation. Particular attention is paid to VVER reactor while carrying out international projects. However, difference in the core design and materials raises the problem for application of examination results and codes aimed mostly at PWR operation safety to VVER reactors.

The purpose of the Project is to find out any possibilities to apply developed data base to describe the VVER core behavior under severe accident conditions carrying out limited number of the experiments which allow to find out if the difference in VVER and PWR designs and materials is significant.

The primary task of the Project is to obtain data on VVER reactors core behavior under severe accident conditions in order to develop physical models and codes applicable to VVER reactors. This task is assumed to be solved as complementary to the QUENCH project in FZK, Karlsruhe. Realization of the same methodical approach will allow comparison of the behavior of VVER and PWR materials and design elements as well as to provide the possibility of application of the same approach to develop the numerical codes and determine safety criteria of these reactors.

Within the frame of the Project it is assumed to carry out the small-scale tests and an integral experiment under quench conditions with VVER material in order to build up a database for model development and verification of codes. The integral fuel bundle experiment will be carried out using non-irradiated materials. The small-scale experiments with irradiated fuel are assumed to be carried out in order to develop the database for irradiated core materials.

The VVER-Quench project "Examination of VVER Fuel behavior under Severe Accident Conditions. Quench Stage" includes the following stages:

**STAGE A**. **Spent ROD-QUENCH**: Study of the spent fuel rod segments behavior under reflood conditions. At this stage the experimental data on spent fuel rod characteristics after reflood will be obtained. Heated up to different temperatures pre-oxidized spent fuel rod simulators will be cooled down by water. Changes in their structure, fragmentation and fission gas release will be examined. Besides, hydrogen generation is planned to be examined.

Project executors: SSC RIAR, Dimitrovgrad. Project co-executors: IBRAE.

**STAGE B**. **Fresh FA-QUENCH:** **Integral experiment of QUENCH type using model bundle with 31 fuel rod simulators under QUENCH conditions.** The result of the work will be the database for VVER bundle behavior under quench conditions, in comparison with available database for PWR bundles..

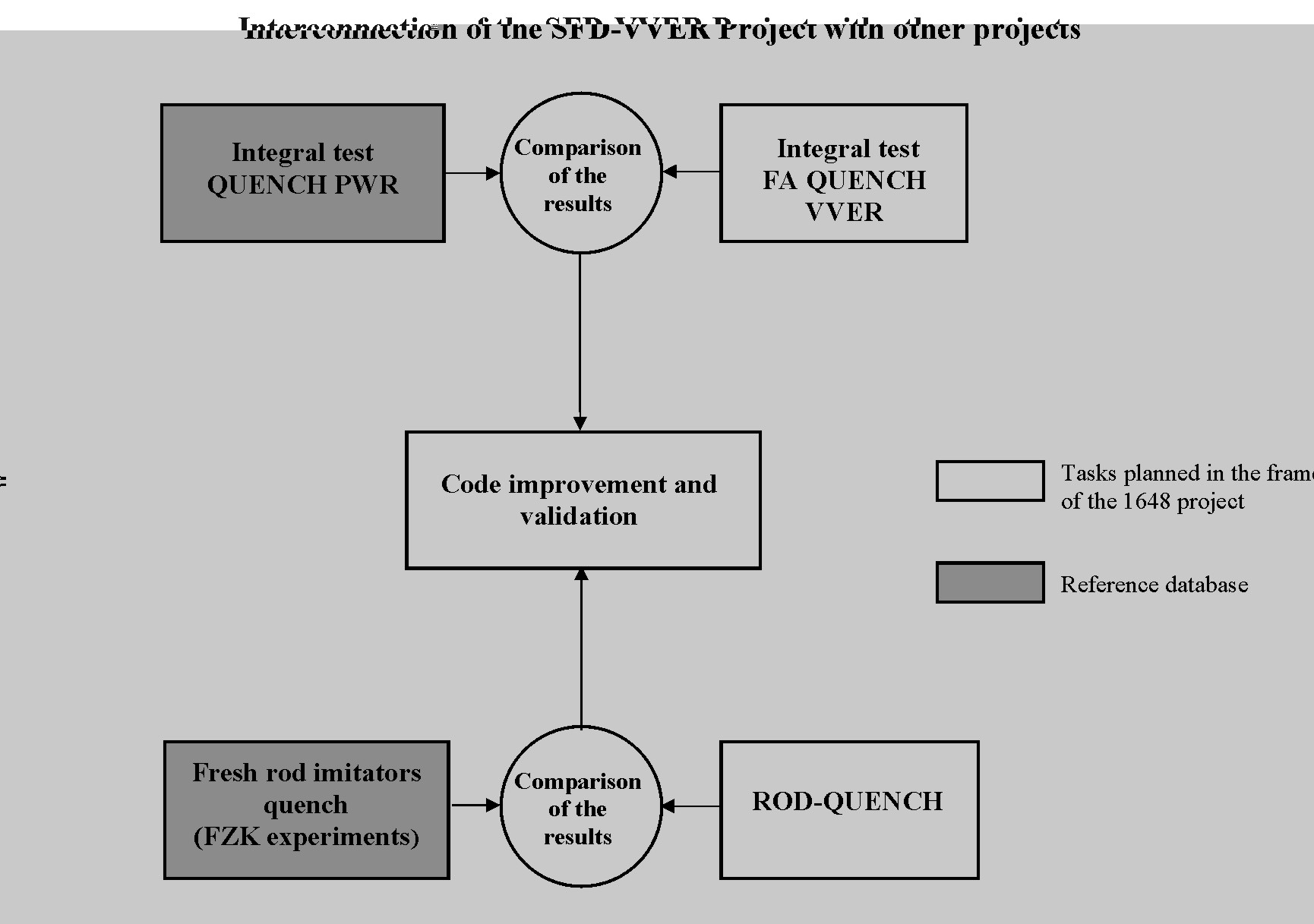
Project executors: JSC "MSZ", Electrostal (delivery of the elements for model FA); Forschungszentrum Karlsruhe, Germany (fitting and equipment of FA simulators, testing at the test facility, post-test examinations); SSC RIAR, Dimitrovgrad, (post-test examinations of model FA); Project co-executors: IBRAE.

**STAGE C**. **FA Quench Model: Development of models and codes to describe VVER core behavior under severe accident conditions (“quench” stage).**

The obtained results will allow to make a conclusion on the behavior of VVER fuel under severe accident conditions during the core reflood and modification and/or adaptation of codes and physical models for PWR fuel behavior to VVER reactor case.

Project executor: IBRAE, Moscow. Project co-executors: SSC RIAR.

**Interconnection of the VVER-Quench Project with other projects**



### 2. Expected Results and Their Application

Project is classified as applied research.

Results of investigations are the creation of experimental data base and development of physical models and modification and/or adaptation of codes, describing VVER fuel rod and fuel assemblies behaviour under severe accident conditions during the core reflood.

The received results will allow to estimate probable consequences of severe accident, to determine means on their reduction and to develop the advanced criteria of core safe operation.

### 3. Meeting ISTC Goals and Objectives

The project gives 19 weapons scientists and engineers an opportunity for redirect of the abilities to peaceful activity;

The work on the project in cooperation with foreign collaborators provides integration of the scientists from Russia into the international scientific community;

The project represents applied research for peaceful purposes directed on increase of nuclear safety in energy production and promotes the solution of national and international problems.

### 4. Scope of Activities

Scope of activities includes fulfillment of three stages. In the frame of the first stage experiments with the irradiated fuel rod fragments should be executed. Second stage consists of execution of experiment with model bundle on the out of pile rig. During the third stage experimental data treatment and making of mathematical models and fragments of computer codes should be done.

##### Interconnection of the tasks within the VVER-Quench Project

#### Task 1

|  |  |  |
| --- | --- | --- |
| **Task description and main milestones** | | **Participating Institutions** |
| **Development of Rod Quench test program**  At this stage the parameters of tests of the irradiated fuel rod fragments are determined: a degree of preliminary oxidation, temperature of tests, speed of cooling. | | 1- SSC RIAR  2- IBRAE |
| **Description of deliverables** | | |
| 1 | Program of tests | |

#### Task 2

|  |  |  |
| --- | --- | --- |
| **Task description and main milestones** | | **Participating Institutions** |
| **Rod Quench testings**  According to the program the tests 18 fragments of the irradiated fuel rods will be carried out | | 1- SSC RIAR |
| **Description of deliverables** | | |
| 1 | Protocols of tests | |

#### Task 3

|  |  |  |
| --- | --- | --- |
| **Task description and main milestones** | | **Participating Institutions** |
| **Post-test examination of Rod Quench**  task includes an estimation of the samples appearance after tests and definition of the following parameters:   1. Microstructures of fuel and cladding 2. Degree of cladding oxidation . 3. Hydrogen release and absorption by cladding. 4. Volatile fission products release | | 1- SSC RIAR |
| **Description of deliverables** | | |
| 1 | Intermediate report | |

#### Task 4

|  |  |  |
| --- | --- | --- |
| **Task description and main milestones** | | **Participating Institutions** |
| **Analysis of Rod Quench experiment results**  Within the framework of the task the next works will be carried out:   1. Creation of experimental data base on materials properties for models and codes 2. Modelling of physical processes and behaviour of oxidized fuel rods at reflood;  * Modelling of the fission products release from fuel at severe accidents during at reflood | | 1- SSC RIAR  2- IBRAE |
| **Description of deliverables** | | |
| 1 | Final report | |

#### Task 5

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| **Task description and main milestones** | | **Participating Institutions** |
| **Development of FA Quench experiment scenario and test program**  At this stage the parameters of model assembly tests are defined: a degree of preliminary oxidation, temperature of tests, speed of cooling. | | 1- IBRAE  2- SSC RIAR |
| **Description of deliverables** | | |
| 1 | The test program | |

#### Task 6

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| --- | --- | --- |
| **Task description and main milestones** | | **Participating Institutions** |
| **Designing and manufacturing assembly components**  Designing and manufacturing of the model test rods and test facility | | 1- JSC MSZ |
| **Description of deliverables** | | |
| 1 | Design documentation | |

#### Task 7

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| **Task description and main milestones** | | **Participating Institutions** |
| **Transportation of the model assembly components**  Transportationof the model assembly components to FZK and transportation of the tested bundle back to RIAR  For experiment with modeling bundle QUENCH-VVER, RIAR provide FZK by the following materials:   * shroud pipe from alloy Zr-1%Nb ø 88/ø79.5 x 1870mm (13.6 kg); * cylindrical procurement from alloy Zr-1%Nb ø85/ø120 x 300mm for manufacturing flanges of the shroud; * 6 rods from Zr-1%Nb alloy ø6 x 2600 mm for manufacturing angular rods; * rods from alloy Zr-1%Nbø 9.13 mm of 1.9 kg in weight (about 4 m) for manufacturing end plugs; * 40 preliminary etched and anodized claddings from pipes ø9.13x7.72 of 2575 mm in the length from Zr-1%Nb alloy; * 8 spacer grids from Zr-1%Nb alloy (each spacer grid contains 37 cells); * 35 pipes from Zr-1%Nb alloy ø5.8/ø4.75 x 1000 mm for angular instrumented rods; * rods of Zr-1%Nb alloy ø9.6mm of 10000 mm in the general length for manufacturing extension pieces of angular rods for instrumentation of the bundle the Material is delivered by pieces of 1500\_2500 mm in length.   Tested part of the bundle consists of fuel rod simulators should be shipped to RIAR for post-test examinations. | | 1- SSC RIAR |
| **Description of deliverables** | | |
| 1 | Acts | |

#### Task 8

|  |  |  |
| --- | --- | --- |
| **Task description and main milestones** | | **Participating Institutions** |
| **FA Quench experiment supervision**  Supervision at experiment preparation and test procedures | | 1- SSC RIAR |
| **Description of deliverables** | | |
| 1 |  | |

#### Task 9

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| --- | --- | --- |
| **Task description and main milestones** | | **Participating Institutions** |
| **FA Quench post-test examination**  The post-test examinations of assembly will be carried outafter its transportation from FZK to RIAR. As a result of examinations the following parameters are determined:   1. Deformation of simulators bundle and character of simulators claddings destruction; 2. Degree of claddings oxidation ; 3. Degree of space grids oxidation ; 4. Degree of shroud oxidation. | | 1- SSC RIAR |
| **Description of deliverables** | | |
| 1 | Intermediate report | |

#### Task 10

|  |  |  |
| --- | --- | --- |
| **Task description and main milestones** | | **Participating Institutions** |
| **Analysis of FA Quench experiment results**  Within the framework of this task the next works will be carried out:   1. Creation of experimental data base on material properties for development of models and codes 2. Modeling of physical processes and behaviour of an oxidized fuel rod bundle at reflood; | | 1- SSC RIAR  2- IBRAE |
| **Description of deliverables** | | |
| 1 | Final report | |

#### Task 11

|  |  |  |
| --- | --- | --- |
| **Task description and main milestones** | | **Participating Institutions** |
| **Development of the requirements to models and codes** | | 1- IBRAE |
| **Description of deliverables** | | |
| 1 | Requirements | |

#### Task 12

|  |  |  |
| --- | --- | --- |
| **Task description and main milestones** | | **Participating Institutions** |
| **Preparation and adaptation of models and codes** | | 1- IBRAE |
| **Description of deliverables** | | |
| 1 | Intermediate report | |

#### Task 13

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| --- | --- | --- |
| **Task description and main milestones** | | **Participating Institutions** |
| **Processing, analysis and modelling of experiments** | | 1- IBRAE |
| **Description of deliverables** | | |
| 1 | Intermediate report | |

#### Task 14

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| --- | --- | --- |
| **Task description and main milestones** | | **Participating Institutions** |
| **Development of codes and their validation** | | 1- IBRAE |
| **Description of deliverables** | | |
| 1 | Intermediate report | |

#### Task 15

|  |  |  |
| --- | --- | --- |
| **Task description and main milestones** | | **Participating Institutions** |
| **Comparison of experiments and calculations** | | 1- IBRAE  2- SSC RIAR |
| **Description of deliverables** | | |
| 1 | Final report | |

### 5. Role of Foreign Collaborators/Partners

FZK participates in preparation of tests and their performance, assessment of the available information on VVER spent fuel which is necessary to test FA elements (fuel rods, spacer grids, guiding tubes, central tube) under severe accident conditions, and validation of the newly developed models and codes. FZK will also support the Project by performing in its laboratories the separate-effect tests with non-irradiated Zr-1%Nb cladding tubes using the same test matrix as proposed for the Stage A of this Project.

IRSN contribute to define and revise the test matrix and test protocol, analyse the results and compare VVER and PWR fuel rod behaviour. Integrate the experimental results and/or models produced by the project in IRSN Severe Accident computer codes.

### 6. Technical Approach and Methodology

**Stage A.** Spent Rod Quench. **Study of VVER spent fuel behavior under Quench conditions**

EXPERIMENT GOAL

To obtain experimental database on high burnup fuel rod behavior under Quench conditions for the further development and specification of models.

EXPERIMENT TASKS

* Evaluation of failure character of preliminary oxidized spent fuel rods during quenching.
* Determination of hydrogen release into gas phase during quenching.
* Determination of gaseous fission product release during quenching.

EXAMINATION OBJECT

* Fuel rod segments of 150 mm long manufactured from VVER spent fuel rods with a burnup of 50-60 MWd/kgU.

EXPERIMENTAL FACILITY

* Maximal temperature is 1700°С.
* Environment is flowing argon or vapor-argon mixture.

TEST SCHEDULE

The experiments will be carried out in four stages:

1. Heating of the simulator in argon flow up to oxidation temperature;

2. Vapor injection and oxidation of a simulator cladding in vapor-argon flow;

3. Heating of the simulator in argon to given temperature;

4. Quench of simulator by rising the water cylinder.

During experiment the hydrogen content and 85Kr activity in the carrier gas is registered in on-line regime.

TESTING REGIME

* Temperature of the pre-oxidation of the specimen is 1300°С.
* Specimen temperature at onset of quenching is from 1400 to 1700°С.
* Water quench rate is 2 cm/s.
* Water temperature is 90°С.

PARAMETERS MEASURED DURING THE EXPERIMENT

* Temperature in the fuel central hole (TC).
* Hydrogen concentration in offgas.
* 85Kr activity in off-gas.

POST-TEST EXAMINATION

* Photo documentation of the specimen appearance.
* Metallography of specimens at three points along the simulator to obtain the following data:
* fuel microstructure;
* Zr - H2O interaction;
* Zr - UO2 interaction;
* Measurement of 85Kr residual activity in fuel.
* Measurement of hydrogen content in the cladding.

RESULTS TO BE PRESENTED

* Microstructure of tested specimens: α-Zr(O), β-Zr, ZrO2 layer thickness of the cladding, size of fuel grains, pores, porosity, Zr -UO2 interaction layer thickness.
* Cladding oxidation.
* Hydrogen release into gas phase and absorption in the cladding.
* 85Kr release.

TEST MATRIX

Temperatures at onset of quenching 1400 – 1700 оС

Number of tests – 18

**Stage B. Fresh FA Quench. Integral experiments of QUENCH type on the model FA with fuel rod simulators. Study of quench regime impact on FR bundle state**

EXPERIMENT GOAL

* Evaluation of quench impact on VVER bundle degradation and hydrogen generation .
* Experimental database for development and validation of physical models and numerical codes for VVER fuel rod behavior.

EXPERIMENT TASKS

* Evaluation of temperature evolution of fuel rod bundle.
* Evaluation of deformation and failure modes of the preliminary oxidized claddings and spacer grids.
* Determination of cladding oxidation during quenching.
* Determination of hydrogen generation during quenching.

EXAMINATION OBJECTS

The experiment is carried out with bundle consisting of 31 VVER fuel rod simulators, arranged in a bundle with the help of standard VVER spacer grid fragments. The model assembly consists of 18 heated and 13 unheated simulators and 6 corner rods. Simulators are manufactured from VVER genuine claddings of Zr-1%Nb alloy and filled with ZrO2 pellets. Corner rods of 6 mm in diameter are manufactured from Zr-1%Nb alloy. Simulators spacing in the bundle is carried out by means of 8 typical VVER spacer grid fragments from Zr-1%Nb alloy, located with the step of 250 mm along the FA. The bundle is settled in Zr-2.5%Nb shroud tube and isolated from the cooling jacket by ZrO2-fiber insulation.

EXPERIMENTAL FACILITY

The experiment will be carried out at the QUENCH facility (FZK).

EXPERIMENT STAGES

The experiment includes the following stages:

* Heating of the bundle up to the temperature 600 °С in inert environment (Ar, 3 К/s).
* Steam supply into the testing facility and bundle heating up to the specified temperature for pre-oxidation.
* Pre-oxidation of simulator claddings in steam at constant temperature.
* Heating up the FA to the desired temperature at onset of quenching
* Bundle reflooding with water.

PARAMETERS MEASURED DURING THE EXPERIMENT

* Temperature evolution of the FA by means of the thermocouples.
* Failure of the unheated rods (time, temperature).
* Continuous hydrogen detection during the whole test.

POST-TEST EXAMINATION

Post-test examinations will be carried out on the cross-sections of the bundle embedded in the epoxy.

RESULTS TO BE PRESENTED

Based on the examination results the following parameters will be determined:

* Deformation of simulator bundle and character of simulator cladding failure.
* Cladding oxidation.
* Spacer grid oxidation.
* Shroud tube oxidation.

TEST SCHEDULE

|  |  |  |
| --- | --- | --- |
| **Stage** | **Contents** | **Results** |
| Development of experiment scenario | Calculated estimation of possible scenarios of LOCA accidents. Experimental parameter options :  1. Temperature of pre-oxidation of FR simulator claddings  2. Temperature of simulator claddings at the onset of quenching  3. Rate of water supply into the test section | Initial parameters of experiment |
| Development of test program and post-test examination | Development of test schedule.  Coordination of bundle design.  Selection of post-test examination methods | Test schedule. Post-test examination program |
| Bundle design and manufacture | Manufacture of the simulators.  Bundle mounting and arrangement in the experimental facility |  |
| Bundle transportation | Transportation of the bundle components from JSC «MSZ» to FZK. Transportation of tested bundle fragments from FZK to RIAR |  |
| Experiment | Bundle test  Filling the bundle with epoxy resin.  Bundle sectioning for post-test examinations | Results of temperature measurements, results on hydrogen generation |
| Post-test examination | Metallography of simulator bundle cross-sections | Data on deformation and character of cladding failure.  Data on oxidation of claddings and shroud tube. |

### Stage C. FA Quench Model

### Improvement of models and codes to describe VVER FA behavior under severe accident conditions without fuel melting ("quench" stage)

The objective of the present specification is calculation and theoretical study of VVER "fresh" and spent fuel element behavior under severe accident conditions when the cladding temperature significantly exceeds 1000оС. Work is carried out on the basis of experimental examination within the frame of 2 experimental parts of the SFD-VVER Project in three main aspects: 1) modeling of physical, chemical and mechanical properties of "fresh" and irradiated materials under severe accident conditions and development of data base on material properties for models and codes; 2) modeling of physical processes and oxidized fuel rod behavior during reflood; 3) modeling of fission product release from the fuel during severe accidents and reflood.

Analysis of fuel rod behavior under severe accident conditions requires data on time-dependent cladding oxidation in the given temperature range since initiation of exothermic reaction of cladding oxidation by steam results in uncontrolled heating of the system up to metal cladding melting and core failure. The same reason at reflood of heated fuel rods may result in uncontrolled rod heating accompanied by hydrogen generation and, consequently, generation of dangerously explosive gas mixtures. Fuel rod mechanical properties determine the initial moment and scenario of the core degradation and the processes of fission product release from fuel pellets after the cladding failure. Thus, to describe all complicated and interconnected phenomena it is necessary to develop detailed physical models of these phenomena followed by model unification in severe accident codes.

The result of the work will be development of data base on VVER fuel rod material properties, development of physical and mathematical models of some phenomena typical for severe accidents, unification of these models and development of numerical code.

Development of physical models and codes will be carried out on the basis of PWR fuel rod behavior models developed in IBRAE (code SVECHA) by means of their further development and generalization to describe VVER materials. The program may be formulated as follows:

1. Examination of material properties under conditions simulating severe accidents:

1. Comparison of the results obtained during examination of "fresh" and spent claddings.
2. Development of physical models of time-dependent high temperature cladding oxidation based on the PWR Zry-4 cladding oxidation model developed in IBRAE.
3. Theoretical processing of the results of Zr-1%Nb "fresh" and spent cladding mechanical properties examination at different temperatures depending on burnup, ECR and hydrogen content.
4. Based on the obtained data further development of cladding mechanical behaviour model developed in IBRAE for PWR Zry-4 claddings and application of modified model to describe examined VVER fuel rods; including in the model a new data base on mechanical properties obtained in the experiments and irradiation impact on these properties.
5. Simulating of hydrogen absorption during the cladding oxidation and description of accumulated hydrogen impact on the mechanical failure of fuel rods under accident conditions.

2. Study of behaviour of spent fuel rod fragments with different degree of cladding oxidation at water reflood depending on heating temperature:

1. Basing on new experiments further development of SVECHA code for physical processes during reflood of fuel rod segments, developed in IBRAE to simulate the tests carried out with PWR "fresh" cladding in FZK (Karlsruhe, Germany). The model includes self-consistent description of the following phenomena:

* *unsteady thermo-hydraulic behavior of steam-water mixture generated during the reflood;*
* *cladding oxidation by generated steam under rapid cooling conditions and large temperature gradient in radial direction;*
* *complicated mechanical behavior of the claddings as a result of phase transition in oxide and metal layers during rapid cooling down and appearance of difference in axial temperature in cooling area; impact of the cladding oxide layer mechanical failure (cracking, spelling) during cooling down on its oxidation rate;*
* *heat exchange with the environment and thermoconductivity inside multi-layer structure of oxidizing cladding.*

1. Modification of the developed code (primary designed to simulate "fresh" fragments of PWR Zry-4 claddings) to describe examined VVER spent cladding materials using new data obtained during preliminary examination of material properties and its application in new simulating experiments in RIAR.

3. Study of unirradiated FA simulator behavior in electrically heated testing facility of FZK (Germany) simulating an accident with reflood:

1. Generalization of earlier developed code for separate fuel rod segment behavior during reflood to describe the bundle, and its application to simulation of new experiments on electrically heated facility of FZK (Germany).

4. Study of the results on fission gas release obtained in the tests with irradiated fuel segments:

1. The detailed workplan with the MFPR code will be defined in close co-operation with IRSN. Modification and development of the MFPR code for radioactive fission product release from the fuel developed in the farmework of the IBRAE-IRSN collaboration to describe similar tests carried out in different laboratories in the world for PWR fuel rods, and describing complicated physical and chemical processes:

* *development of gas porosity inside spent fuel;*
* *migration of fission products from fuel grains to their boundaries and further their release from the fuel through the boundaries between grains;*
* *chemical interaction of volatile and not volatile fission products during their release from the fuel and impact of outer (oxidizing) environment on fission product release rate;*
* *impact of temperature and outer pressure as well as transient temperature regimes on radionuclide behavior in fuel and their release rate from the fuel;*
* *fission products and fuel claddings interaction and further their release from the fuel, etc.*

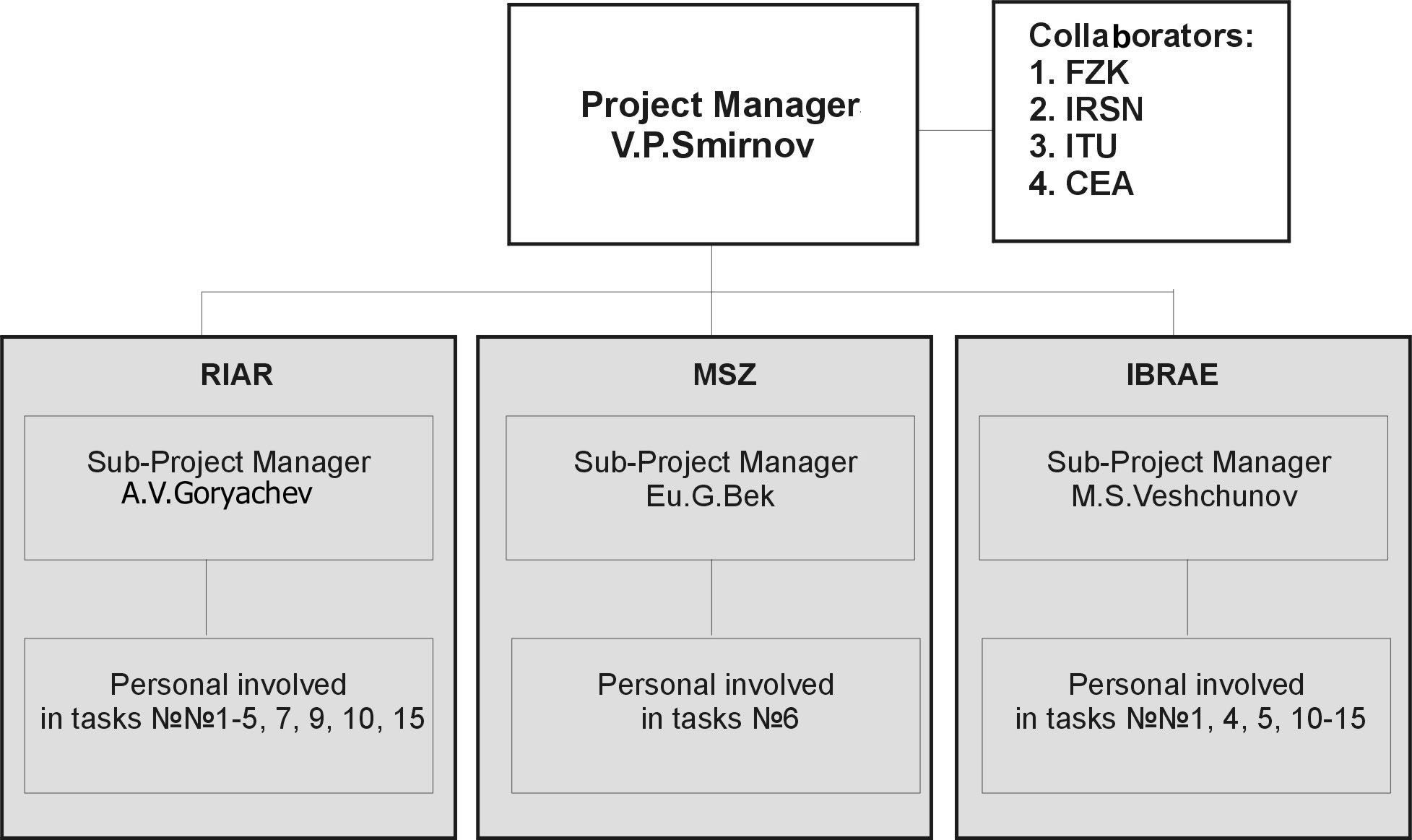
1. Simulation of fission gas release in the new experiments on quenching of rod segments with irradiated fuel performed in RIAR, and application of the developed code to simulation of severe accidents under real conditions.

### 7. Technical Schedule

|  | **Quarter 1** | **Quarter 2** | **Quarter 3** | **Quarter 4** | **Quarter 5** | **Quarter 6** | **Quarter 7** | **Quarter 8** | **Quarter 9** | **Quarter 10** | **Quarter 11** | **Quarter 12** | **Person\* days** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Task 1  Development of Rod Quench test program** | Test program |  |  |  |  |  |  |  |  |  |  |  |  |
| **Person\*days** | **180** |  |  |  |  |  |  |  |  |  |  |  | **180** |
| **Task 2  Rod Quench testings** |  |  |  |  |  | Test protocol |  |  | Test protocol |  |  |  |  |
| **Person\*days** | **101** | **173** | **252** | **229** | **210** | **192** | **161** | **121** | **121** | **118** | **0** | **0** | **1678** |
| **Task 3  Post-test examination of Rod Quench** |  |  |  |  |  |  |  |  |  | Intermediate report |  |  |  |
| **Person\*days** |  |  |  | **65** | **70** | **65** | **65** | **61** | **80** | **76** |  |  | **482** |
| **Task 4  Analysis of Rod Quench experiment results** |  |  |  |  |  |  |  |  | Seminar |  |  | Final report |  |
| **Person\*days** |  |  |  |  | **45** | **41** | **86** | **40** | **127** | **126** | **140** | **152** | **757** |
| **Task 5  Development of FA Quench experiment scenario and test program** |  | Scenario and test program |  |  |  |  |  |  |  |  |  |  |  |
| **Person\*days** | **90** | **70** |  |  |  |  |  |  |  |  |  |  | **160** |
| **Task 6  Designing and manufacturing of the model assembly components** |  |  |  | Design docume ntation |  |  |  |  |  |  |  |  |  |
| **Person\*days** | **124** | **129** | **141** | **197** |  |  |  |  |  |  |  |  | **591** |
| **Task 7  Transportation of the model assembly components** |  |  |  | Act |  |  |  | Act |  |  |  |  |  |
| **Person\*days** |  |  |  | **90** |  |  |  | **90** |  |  |  |  | **180** |
| **Task 8  Supervision FA Quench experiment** |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Person\*days** |  |  |  |  |  |  |  |  |  |  |  |  | **0** |
| **Task 9  FA Quench post-test examination** |  |  |  |  |  |  |  |  |  | Intermediate report |  |  |  |
| **Person\*days** |  |  |  |  |  |  |  | **70** | **76** | **70** |  |  | **216** |
| **Task 10  Analysis of FA Quench experiment results** |  |  |  |  |  |  |  |  |  |  |  | Final report |  |
| **Person\*days** |  |  |  |  |  |  |  |  |  | **43** | **54** | **51** | **148** |
| **Task 11  Development of the requirements to models and codes** |  |  | Requirements |  |  |  |  |  |  |  |  |  |  |
| **Person\*days** |  | **45** | **55** |  |  |  |  |  |  |  |  |  | **100** |
| **Task 12  Preparation and adaptation of models and codes** |  |  | Intermediate report |  |  |  |  |  |  |  |  |  |  |
| **Person\*days** |  | **60** | **86** |  |  |  |  |  |  |  |  |  | **146** |
| **Task 13  Processing, analysis and modeling of experiments** |  |  |  |  |  |  | Intermediate report |  |  |  |  |  |  |
| **Person\*days** |  |  |  | **90** | **90** | **90** | **90** |  |  |  |  |  | **360** |
| **Task 14  Development of codes and their validation** |  |  |  |  |  |  |  |  | Intermediate report |  |  |  |  |
| **Person\*days** |  |  |  | **59** | **58** | **55** | **56** | **96** | **53** | **0** | **0** | **0** | **377** |
| **Task 15  Comparison of experiments and calculations** |  |  |  |  |  |  |  |  |  |  | Seminar | Final report |  |
| **Person\*days** |  |  |  |  |  |  |  |  | **53** | **58** | **76** | **76** | **263** |
| **TOTAL** | **495** | **477** | **534** | **730** | **473** | **443** | **458** | **478** | **510** | **491** | **270** | **279** | **5638** |

#### 8.2. Managerial responsibilities

Diagram of the organizational structure for the project and indicate the relationships among personnel.



### 9. Financial Information

### TABLE 1

#### Estimated Aggregated Expenditures by Recipient

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **Category** | **Quarters 1 & 2** | | **Year 1** | | **Year 2** | | **Year 3** | | **Total** | |
|  |  |  | **(1)** | **(2)** | **(1)** | **(2)** | **(1)** | **(2)** | **(1)** | **(2)** | **(1)** | **(2)** |
| **1** |  | **Grant Payments:** |  |  |  |  |  |  |  |  |  |  |
|  | 1.1 | Category I |  | 15 504 |  | 36 648 |  | 22 396 |  | 18 818 |  | 77 862 |
|  | 1.2 | Category II |  | 8 146 |  | 18 734 |  | 20 410 |  | 17 692 |  | 56 836 |
|  | 1.3 | Category III |  | 700 |  | 1 840 |  | 2 460 |  | 1 940 |  | 6 240 |
|  | 1.4 | Category IV |  | 3 412 |  | 7 142 |  | 7 164 |  | 5 390 |  | 19 696 |
|  |  | *Total Grant Payments* |  | **27 762** | **0** | **64 364** | **0** | **52 430** | **0** | **43 840** | **0** | **160 634** |
| **2** |  | **Equipment:** |  |  |  |  |  |  |  |  |  |  |
|  | 2.1 | Capital Equipment |  |  |  | 34 150 |  |  |  |  |  | 34 150 |
|  | 2.2 | Non-Capital Equipment |  | 5 500 |  | 5 500 |  |  |  |  |  | 5 500 |
|  | 2.3 | Other |  |  |  |  |  |  |  |  |  |  |
|  |  | *Total Equipment* |  | **5 500** | **0** | **39 650** | **0** | **0** | **0** | **0** | **0** | **39 650** |
| **3** |  | Materials/Supplies | **4 746** | **143 669** | **4 746** | **143 669** | **0** | **0** | **0** | **0** | **4 746** | **143 669** |
| **4** |  | **Bank Fees** | **63** | **2 037** | **75** | **2 764** | **25** | **692** | **25** | **635** | **125** | **4 091** |
| **5** |  | **Other Direct Costs:** |  |  |  |  |  |  |  |  |  |  |
|  | 5.1 | Technological Energy |  |  |  |  |  |  |  |  |  |  |
|  | 5.2 | Communications |  |  |  |  |  |  |  |  |  |  |
|  | 5.3 | Subcontracts/Seminars |  |  |  |  |  |  |  |  |  |  |
|  | 5.4 | Other | 0 | 1 500 | 0 | 1 500 | 0 | 1 125 | 0 | 0 | 0 | 2 625 |
|  |  | *Total ODC* | **0** | **1 500** | **0** | **1 500** | **0** | **1 125** | **0** | **0** | **0** | **2 625** |
| **6** |  | Travel: |  |  |  |  |  |  |  |  |  |  |
|  | 6.1 | Internal \*\*\* | 1 100 |  | 2 200 |  | 2 100 |  | 2 100 |  | 6 400 |  |
|  | 6.2 | Outside CIS |  | 8 400 |  | 10 800 |  | 12 000 |  | 13 200 |  | 36 000 |
|  |  | *Total Travel* | **1 100** | **8 400** | **2 200** | **10 800** | **2 100** | **12 000** | **2 100** | **13 200** | **6 400** | **36 000** |
|  |  | **Overhead/Retainage** |  |  |  |  |  |  |  |  | **10 300** |  |
|  |  | ***Subtotals*** | **5 909** | **188 868** | **7 021** | **262 747** | **2 125** | **66 247** | **2 125** | **57 675** | **21 571** | **386 669** |
|  |  | **Totals** | **194 777** | | **269 768** | | **68 372** | | **59 800** | | **408 240** | |

Remarks: \* (1) - Cash flow through Recipient Account

\*\* (2) - Cash flow through ISTC

\*\*\* Include Local and inside CIS travel

### TABLE 1-1

#### Estimated Aggregated Expenditures by Leading Institution: SSC RIAR

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **Category** | **Quarters 1 & 2** | | **Year 1** | | **Year 2** | | **Year 3** | | **Total** | |
|  |  |  | **(1)** | **(2)** | **(1)** | **(2)** | **(1)** | **(2)** | **(1)** | **(2)** | **(1)** | **(2)** |
| **1** |  | **Grant Payments:** |  |  |  |  |  |  |  |  |  |  |
|  | 1.1 | Category I |  | 4 696 |  | 12 360 |  | 16 564 |  | 14 200 |  | 43 124 |
|  | 1.2 | Category II |  | 4 062 |  | 10 610 |  | 13 208 |  | 10 776 |  | 34 594 |
|  | 1.3 | Category III |  | 700 |  | 1 840 |  | 2 460 |  | 1 940 |  | 6 240 |
|  | 1.4 | Category IV |  | 1 920 |  | 4 760 |  | 5 724 |  | 4 628 |  | 15 112 |
|  |  | *Total Grant Payments* | **0** | **11 378** | **0** | **29 570** | **0** | **37 956** | **0** | **31 544** | **0** | **99 070** |
| **2** |  | **Equipment:** |  |  |  |  |  |  |  |  |  |  |
|  | 2.1 | Capital Equipment |  |  |  | 34 150 |  | 0 |  | 0 |  | 34 150 |
|  | 2.2 | Non-Capital Equipment |  | 3 000 |  | 3 000 |  | 0 |  | 0 |  | 3 000 |
|  | 2.3 | Other |  |  |  |  |  |  |  |  |  | 0 |
|  |  | *Total Equipment* | **0** | **3 000** | **0** | **37 150** | **0** | **0** | **0** | **0** | **0** | **37 150** |
| **3** |  | Materials/Supplies | **4 746** | **143 669** | **4 746** | **143 669** | **0** | **0** | **0** | **0** | **4 746** | **143 669** |
| **4** |  | **Bank Fees** | **55** | **1 800** | **60** | **2 300** | **10** | **480** | **10** | **450** | **80** | **3 230** |
| **5** |  | **Other Direct Costs:** |  |  |  |  |  |  |  |  |  |  |
|  | 5.1 | Technological Energy |  |  |  |  |  |  |  |  |  |  |
|  | 5.2 | Communications |  |  |  |  |  |  |  |  |  |  |
|  | 5.3 | Subcontracts/Seminars |  |  |  |  |  |  |  |  |  |  |
|  | 5.4 | Other |  | 1 500 |  | 1 500 |  | 1 125 |  |  |  | 2 625 |
|  |  | *Total ODC* | **0** | **1 500** | **0** | **1 500** | **0** | **1 125** | **0** | **0** | **0** | **2 625** |
| **6** |  | Travel: |  |  |  |  |  |  |  |  |  |  |
|  | 6.1 | Internal \*\*\* | 400 |  | 800 |  | 700 |  | 700 |  | 2 200 |  |
|  | 6.2 | Outside CIS |  | 6 000 |  | 6 000 |  | 7 200 |  | 8 400 |  | 21 600 |
|  |  | *Total Travel* | **400** | **6 000** | **800** | **6 000** | **700** | **7 200** | **700** | **8 400** | **2 200** | **21 600** |
|  |  | **Overhead/Retainage** |  |  |  |  |  |  |  |  | **8 200** |  |
|  |  | ***Subtotals*** | **5 201** | **167 347** | **5 606** | **220 189** | **710** | **46 761** | **710** | **40 394** | **15 226** | **307 344** |
|  |  | **Totals** | **172 548** | | **225 795** | | **47 471** | | **41 104** | | **322 570** | |

Remarks: \* (1) - Cash flow through Recipient Account

\*\* (2) - Cash flow through ISTC

\*\*\* Include Local and inside CIS travel

### TABLE 1-2

#### Estimated Aggregated Expenditures by Participant Institution 1: IBRAE

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **Category** | **Quarters 1 & 2** | | **Year 1** | | **Year 2** | | **Year 3** | | **Total** | |
|  |  |  | **(1)** | **(2)** | **(1)** | **(2)** | **(1)** | **(2)** | **(1)** | **(2)** | **(1)** | **(2)** |
| **1** |  | **Grant Payments:** |  |  |  |  |  |  |  |  |  |  |
|  | 1.1 | Category I |  | 2 884 |  | 5 800 |  | 5 832 |  | 4 618 |  | 16 250 |
|  | 1.2 | Category II |  | 4 084 |  | 8 124 |  | 7 202 |  | 6 916 |  | 22 242 |
|  | 1.3 | Category III |  | 0 |  | 0 |  | 0 |  | 0 |  | 0 |
|  | 1.4 | Category IV |  | 1 492 |  | 2 382 |  | 1 440 |  | 762 |  | 4 584 |
|  |  | *Total Grant Payments* |  | **8 460** |  | **16 306** |  | **14 474** |  | **12 296** |  | **43 076** |
| **2** |  | **Equipment:** |  |  |  |  |  |  |  |  |  |  |
|  | 2.1 | Capital Equipment |  |  |  |  |  |  |  |  |  |  |
|  | 2.2 | Non-Capital Equipment |  | 2 500 |  | 2 500 |  | 0 |  | 0 |  | 2 500 |
|  | 2.3 | Other |  |  |  |  |  |  |  |  |  |  |
|  |  | *Total Equipment* | **0** | **2 500** | **0** | **2 500** | **0** | **0** | **0** | **0** | **0** | **2 500** |
| **3** |  | Materials/Supplies |  | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** |
| **4** |  | **Bank Fees** | **8** | **150** | **15** | **264** | **15** | **212** | **15** | **185** | **45** | **661** |
| **5** |  | **Other Direct Costs:** |  |  |  |  |  |  |  |  |  |  |
|  | 5.1 | Technological Energy |  |  |  |  |  |  |  |  |  |  |
|  | 5.2 | Communications |  |  |  |  |  |  |  |  |  |  |
|  | 5.3 | Subcontracts/Seminars |  |  |  |  |  |  |  |  |  |  |
|  | 5.4 | Other |  |  |  |  |  |  |  |  |  |  |
|  |  | *Total ODC* | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** |
| **6** |  | Travel: |  |  |  |  |  |  |  |  |  |  |
|  | 6.1 | Internal \*\*\* | 700 |  | 1 400 |  | 1 400 |  | 1 400 |  | 4 200 |  |
|  | 6.2 | Outside CIS |  | 2 400 |  | 4 800 |  | 4 800 |  | 4 800 |  | 14 400 |
|  |  | *Total Travel* | **700** | **2 400** | **1 400** | **4 800** | **1 400** | **4 800** | **1 400** | **4 800** | **4 200** | **14 400** |
|  |  | **Overhead/Retainage** |  |  |  |  |  |  |  |  | **1 500** |  |
|  |  | ***Subtotals*** | **708** | **13 510** | **1 415** | **23 870** | **1 415** | **19 486** | **1 415** | **17 281** | **5 745** | **60 637** |
|  |  | **Totals** | **14 218** | | **25 285** | | **20 901** | | **18 696** | | **66 382** | |

Remarks: \* (1) - Cash flow through Recipient Account

\*\* (2) - Cash flow through ISTC

\*\*\* Include Local and inside CIS travel

### TABLE 1-3

#### Estimated Aggregated Expenditures by Participant Institution 2: JSC MSZ

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **Category** | **Quarters 1 & 2** | | **Year 1** | | **Year 2** | | **Year 3** | | **Total** | |
|  |  |  | **(1)** | **(2)** | **(1)** | **(2)** | **(1)** | **(2)** | **(1)** | **(2)** | **(1)** | **(2)** |
| **1** |  | **Grant Payments:** |  |  |  |  |  |  |  |  |  |  |
|  | 1.1 | Category I |  | 7 924 |  | 18 488 |  | 0 |  | 0 |  | 18 488 |
|  | 1.2 | Category II |  | 0 |  | 0 |  | 0 |  | 0 |  | 0 |
|  | 1.3 | Category III |  | 0 |  | 0 |  | 0 |  | 0 |  | 0 |
|  | 1.4 | Category IV |  | 0 |  | 0 |  | 0 |  | 0 |  | 0 |
|  |  | *Total Grant Payments* |  | **7 924** | **0** | **18 488** | **0** | **0** | **0** | **0** | **0** | **18 488** |
| **2** |  | **Equipment:** |  |  |  |  |  |  |  |  |  |  |
|  | 2.1 | Capital Equipment |  |  |  |  |  |  |  |  |  |  |
|  | 2.2 | Non-Capital Equipment |  | 0 |  | 0 |  | 0 |  | 0 |  | 0 |
|  | 2.3 | Other |  |  |  |  |  |  |  |  |  |  |
|  |  | *Total Equipment* |  | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** |
| **3** |  | Materials/Supplies |  | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** |
| **4** |  | **Bank Fees** | **0** | **87** | **0** | **200** | **0** | **0** | **0** | **0** | **0** | **200** |
| **5** |  | **Other Direct Costs:** |  |  |  |  |  |  |  |  |  |  |
|  | 5.1 | Technological Energy |  |  |  |  |  |  |  |  |  |  |
|  | 5.2 | Communications |  |  |  |  |  |  |  |  |  |  |
|  | 5.3 | Subcontracts/Seminars |  |  |  |  |  |  |  |  |  |  |
|  | 5.4 | Other |  |  |  |  |  |  |  |  |  |  |
|  |  | *Total ODC* | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** |
| **6** |  | Travel: |  |  |  |  |  |  |  |  |  |  |
|  | 6.1 | Internal \*\*\* | 0 |  | 0 |  | 0 |  |  |  | 0 |  |
|  | 6.2 | Outside CIS |  | 0 |  | 0 |  |  |  |  |  | 0 |
|  |  | *Total Travel* | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** |
|  |  | **Overhead/Retainage** |  |  |  |  |  |  |  |  | **600** |  |
|  |  | ***Subtotals*** | **0** | **8 011** | **0** | **18 688** | **0** | **0** | **0** | **0** | **600** | **18 688** |
|  |  | **Totals** | **8 011** | | **18 688** | | **0** | | **0** | | **19288** | |

Remarks: \* (1) - Cash flow through Recipient Account

\*\* (2) - Cash flow through ISTC

\*\*\* Include Local and inside CIS travel

### 10. Equipment and Materials Summary

#### 10.1. Equipment Summary

### TABLE 2

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| EQUIPMENT/MATERIALS SUMMARY | | | | | | | |
| **EQUIPMENT SUMMARY**  for Project Agreement #1648.2  To be provided in kind [ X ]  To be purchased by recipient [ ] | | | | | | | |
| The ISTC will normally provide the most appropriate equipment that will perform the functions required; however, if very special reasons are given and explained in detail (Form PR-2E), the purchase of a particular make will be considered. | | | | | | | |
| **Please list items in the order of their priority and put an ‘X’ in the column next to “Item no.” if ISTC form PR-2E, “Data for a Single Equipment Item’, has been completed for a given item and is attached.** | | | | | | | |
| **Item**  **No.** | |  | **DESCRIPTION OF ITEM** | **Date needed (quarter)** | **Qty** | **Unit cost**  **(USD)** | **Amount**  **(USD)** |
| ***Leading Institution: SSC RIAR*** | | | | | | | |
| 1 | |  | Metallographic microscope LEICA DMIRM and High resolution digital camera for microscopyLeica DC300, including custom tax | 4 | 1 | 34150 | 34150 |
| 2 | |  | Computer Pentium IV 2400 MHz, Gigabyte 8PE667 Ultra2, 256 M DDR (2700), 60 G Seagate, CD-RW Philips 16×48×48, GeForce 4 MX440 64 M, SyncMaster 753df. | 1 | 1 | 870 | 870 |
| 3 | |  | Power supply and readout module PR4000A-S2V1N,  Dealer MKS Instruments France S.A. | 1 | 1 | 1230 | 1230 |
| 4 | |  | Mass flow controller 179AX-13CS3BV,  Dealer MKS Instruments France S.A. | 1 | 1 | 900 | 900 |
| **Subtotal:** | | | | | | | **37150** |
| ***Participant Institution 1: IBRAE*** | | | | | | | |
| 5 | |  | Computers Pentium IV 2600 MHz, Gigabyte 8PE667 Ultra2, 512 M DDR, 60 G Seagate, CD-R Teac 52-x, GeForce 4 MX440 64 M, 17” NEC FE791SB (0.25, Mitsubishi SuperBright DIAMONDTRON,1024x768@116 Hz). | 1 | 2 | 1000 | 2000 |
| 6 | |  | Copier Canon PC890 | 1 | 1 | 500 | 500 |
| **Subtotal:** | | | | | | | **2500** |
| **Estimated TOTAL COST:** | | | | | | | **39650** |

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#### 10.2. Materials Summary

### TABLE 3

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| EQUIPMENT/MATERIALS SUMMARY | | | | | | | |
| **MATERIALS SUMMARY**  for Project Agreement #1648.2  To be provided in kind [ X ]  To be purchased by recipient [ ] | | | | | | | |
| The ISTC will normally provide the most appropriate equipment that will perform the functions required; however, if very special reasons are given and explained in detail (Form PR-2E), the purchase of a particular make will be considered. | | | | | | | |
| **Please list items in the order of their priority and put an ‘X’ in the column next to “Item no.” if ISTC form PR-2E, “Data for a Single Equipment Item’, has been completed for a given item and is attached.** | | | | | | | |
| **Item**  **No.** | |  | **DESCRIPTION OF ITEM** | **Date needed (quarter)** | **Qty** | **Unit cost**  **(USD)** | **Amount**  **(USD)** |
| ***Leading Institution: SSC RIAR*** | | | | | | | |
| 1 | |  | Isolation plain of fuel assembly head Manufacturer: Framatome ANP GmbH, Seligenstädter Str. 100, D-63791 Karlstein, Germany | 2 | 1 | 3900 | 3900 |
| 2 | |  | Al2O3 plate (cooling chamber) Manufacturer: Framatome ANP GmbH, Seligenstädter Str. 100, D-63791 Karlstein, Germany | 2 | 1 | 4500 | 4500 |
| 3 | |  | Thermal protection shield Manufacturer:Framatome ANP GmbH, Seligenstädter Str. 100, D-63791 Karlstein, Germany | 2 | 1 | 4500 | 4500 |
| 4 | |  | Seal plate of fuel assembly base Manufacturer: Framatome ANP GmbH, Seligenstädter Str. 100, D-63791 Karlstein, Germany | 2 | 1 | 8600 | 8600 |
| 5 | |  | Seal plate of cooling chamber Manufacturer: Framatome ANP GmbH, Seligenstädter Str. 100, D-63791 Karlstein, Germany | 2 | 1 | 8600 | 8600 |
| 6 | |  | Power supply Manufacturer: Framatome ANP GmbH, Seligenstädter Str. 100, D-63791 Karlstein, Germany | 2 | 1 | 8000 | 8000 |
| 7 | |  | Tungsten heater Manufacturer: Metallwerk Plansee Vertriebs GmbH, Schützenstr. 29, D-72574 Bad Urach, Germany | 2 | 22 | 95 | 2090 |
| 8 | |  | Copper electrodes with sliding contacts Manufacturer:Multi-Contact Deutschland GmbH, Postfach 1606, D-79551, Weil am Rhein, Germany | 2 | 40 | 70 | 2800 |
| 9 | |  | Molybdenum electrodes Manufacturer: Wolfram Industrie GmbH, Postfach 1948, D-83269 Traunstein, Germany | 2 | 40 | 46.5 | 1860 |
| 10 | |  | Coating of electrodes with ZrO2 layer Sulzer Metco AG, Rigackerstr. 16, CH-5610, Switzerland | 2 | 40 | 125 | 5000 |
| 11 | |  | Sleeve of boron nitride Manufacturer: HENZE GmbH, Heisingerstr. 12, D-87437 Kempten, Germany | 2 | 42 | 9 | 378 |
| 12 | |  | W/Re high temperature thermocouples Manufacturer: GAMER Lasertechnik, Vichystr. 10, D-76646 Bruchsal, Germany | 2 | 55 | 1240 | 68200 |
| 13 | |  | Fiber heat insulation Manufacturer: Thermal Ceramics Deutschland GmbH, Borsigstr. 4-6, D-21465 Reinbek, Germany | 2 | 1 | 12599 | 12599 |
| 14 | |  | NiCr/Ni thermocouples Manufacturer: GAMER Lasertechnik, Vichystr. 10, D-76646 Bruchsal, Germany | 2 | 44 | 47.5 | 2090 |
| 15 | |  | Flow sensor Burkert 8030 (423 913 D) Dealer "Aldis" plc, Moscow | 1 | 1 | 325 | 325 |
| 16 | |  | Fitting Burkert S030 (424 022 C)  Dealer "Aldis" plc, Moscow | 1 | 1 | 295 | 295 |
| 17 | |  | PI-controller; Burkert 8623-2 (143 569 B)  Dealer "Aldis" plc, Moscow | 1 | 1 | 616 | 616 |
| 18 | |  | Connector M12 with 5.0m cable (4 wire) Burkert (918 038 T)  Dealer "Aldis" plc, Moscow | 1 | 1 | 50 | 50 |
| 19 | |  | Connector M8 with 2.0 m cable (3 wire) Burkert (918 039 U)  Dealer "Aldis" plc, Moscow | 1 | 2 | 40 | 80 |
| 20 | |  | Flow Solenoid Control Valve Burkert 6223 (134 230 S)  Dealer "Aldis" plc, Moscow | 1 | 1 | 210 | 210 |
| 21 | |  | Solenoid Valve, Burkert 6213 (141 163 S),  Dealer "Aldis" plc, Moscow | 1 | 1 | 240 | 240 |
| 22 | |  | Solenoid Valve Burkert 256 (018 452 U), Dealer "Aldis" plc, Moscow | 1 | 1 | 360 | 360 |
| 23 | |  | Solenoid Valve 6013 (125 317 L)  Dealer "Aldis" plc, Moscow | 1 | 5 | 76 | 380 |
| 24 | |  | Fitting S001 Burkert (438 199 Z) Dealer "Aldis" plc, Moscow | 1 | 3 | 287 | 861 |
| 25 | |  | Pressure-transmitter Burkert 8320 (429 956 W),  Dealer "Aldis" plc, Moscow | 1 | 3 | 334 | 1002 |
| 26 | |  | Voltage controller ТРН-1-160  Dealer «Promspezenergo», Moscow | 1 | 3 | 344 | 1032 |
| 27 | |  | Voltage controller ТРН-1-40.  Dealer «Promspezenergo», Moscow | 1 | 2 | 192 | 384 |
| 28 | |  | Relay actuator card Advantech PCI-1761  Dealer "Prosoft" plc, Moscow | 1 | 1 | 150 | 150 |
| 29 | |  | Analog output card Advantech PCI-1723 dealer "Prosoft" plc Moscow | 1 | 2 | 605 | 1210 |
| 30 | |  | Multifunction DAS card Advantech PCI-1716 Dealer "Prosoft" plc Moscow | 1 | 2 | 1012 | 2024 |
| 31 | |  | Step motor ДШР65-0.16-1,8Д04 УХЛ4.  Dealer "Firm Mikmar" plc, S-Peterburg | 1 | 2 | 666.5 | 1333 |
| **Subtotal:** | | | | | | | **143669** |
| **Estimated TOTAL COST:** | | | | | | | **143669** |

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### TABLE 3-1

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| EQUIPMENT/MATERIALS SUMMARY | | | | | | | |
| **MATERIALS SUMMARY**  for Project Agreement #1648.2  To be provided in kind [ ]  To be purchased by recipient [ X ] | | | | | | | |
| The ISTC will normally provide the most appropriate equipment that will perform the functions required; however, if very special reasons are given and explained in detail (Form PR-2E), the purchase of a particular make will be considered. | | | | | | | |
| **Please list items in the order of their priority and put an ‘X’ in the column next to “Item no.” if ISTC form PR-2E, “Data for a Single Equipment Item’, has been completed for a given item and is attached.** | | | | | | | |
| **Item**  **No.** | |  | **DESCRIPTION OF ITEM** | **Date needed (quarter)** | **Qty** | **Unit cost**  **(USD)** | **Amount**  **(USD)** |
| ***Leading Institution: SSC RIAR*** | | | | | | | |
| 1 | |  | Heat-resistant ceramic tube Outer diameter=28 mm, ∅24 mm, Length=700 mm,  Dealer JSC "ESOZM", Ekaterinburg | 1 | 30 | 40 | 1200 |
| 2 | |  | Heat-resistant ceramic tube Outer diameter=17 mm, ∅14 mm, Length=700 mm,  Dealer JSC " ESOZM ", Ekaterinburg | 1 | 30 | 17 | 510 |
| 3 | |  | High-temperature tubular heater, tungsten,  ∅37×1.5 mm, Length – 350 мм  Dealer ГП "OZTM@TS", Moscow | 1 | 3 | 223 | 669 |
| 4 | |  | Sheet molybdenum, thickness – 0.5 mm, width – 0.5 m Dealer ГП " OZTM@TS ", Moscow | 1 | 3 | 102 | 306 |
| 5 | |  | Heat-resistant sheet compounded rubber, thickness – 5‑6±0.2mm, 300×300 mm, (ИПР-1285),  Dealer JSC "UralRTI", Ekaterinburg | 1 | 5 | 97 | 485 |
| 6 | |  | Tantalum rod. ∅6 mm, Dealer "Chemical- metallurgy company "Metallokomplect" plc, Podolsk | 1 | 2 | 188 | 376 |
| 7 | |  | Tantalum rod. ∅10 mm, Dealer "Chemical- metallurgy company "Metallokomplect" plc, Podolsk | 1 | 2 | 530 | 1060 |
| 8 | |  | Cable type 2C 1179/PR4000, length 5 m, Dealer MKS Instruments France S.A. | 1 | 1 | 140 | 140 |
| **Subtotal:** | | | | | | | **4746** |
| **Estimated TOTAL COST:** | | | | | | | **4746** |

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Materials listed in the table 3-1 (items 1-14) should be additionally purchased and delivered to FZK for installation assembling. All materials listed in the items 1-14 of table 3-1 are consumable and will be spend or seriously damaged during the experiment. For the audition purpose the delivering of the purchased materials to FZK should be confirmed by the act signed by the Project manager and representative of collaborator from FZK. After experiment completed the same persons should sign the act of materials consumption and writing off.