# ANNEX I

# Work Plan

## I. Summary Project Information

### 1. Project Title

## Investigation of Corium Melt Interaction with NPP Reactor Vessel Steel

### 2. Project Manager

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### 3. Participating Institutions

#### 3.1. Leading Institution

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| **Short reference:** | | | | | NITI | | | | | | |
| **Full name:** | | | A.P. Alexandrov Research Institute of Technology (NITI) | | | | | | | | |
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| **Name of Signature Authority:** | | | | | | | Mr. Vyacheslav Andreyevich Vasilenko | | | | |
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| **Governmental Agency:** | | | | | | Federal Atomic Energy Agency | | | | | |

#### 3.2. Other Participating Institutions

None

### 4. Foreign Collaborators/Partners

#### 4.1. Collaborators

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| **Institution:** | | | | Forschungzentrum Karlsruhe (FZK), NUCLEAR | | | | | | |
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#### 4.2. Partners

None

### 5. Project Duration

36 months

### 6. Project Location and Equipment

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| --- | --- |
| **Institution** | **Location, Facilities and Equipment** |
| **Leading Institution** | Address of equipment location:  188540, Bldg 12 (assembling hall), Bldg 11 (rooms. 405,406) of LSK «Radon» in Sosnovy Bor, Leningrad Region, Russia.  Equipment:  RASPLAV-2 and RASPLAV-3 experimental installations for the production of different kinds of molten uranium-bearing corium (e.g. suboxidized and oxidized) having temperatures up to 3000ºC, and investigation of its interaction with NPP materials in an inert atmosphere, air and steam (HF generator, induction furnaces, protection and auxiliary technological systems). Data acquisition system, which comprises detectors and sensors for measuring electric parameters of the generator, flow-rate and temperature of the cooling water, temperature of the vessel steel specimen and surface of the molten corium, specimen corrosion depth using ultrasonic sounding, etc. Devices and facilities for physicochemical analyses (mass-spectrometer, X-ray diffractometers and spectrometers, Galakhov microfurnace, chromatograph, etc.). Computers and office equipment |

## II. Specific information

### 1. Introduction and Overview

The main objective of the proposed project is the NPP reactor safety enhancement in case of a severe accident with core degradation and meltdown. Specific subject of the project is the experimental study of physicochemical phenomena occurring at the interaction between a molten corium pool and reactor vessel steel. These studies are carried out for the development and justification of the of the severe accident management concept, mainly, for predicting temperature and stress-and-strain conditions of the reactor vessel. The ISTC #833 METCOR has provided and systematized data on the vessel steel corrosion in the conditions of the melt retention inside the cooled reactor vessel (IVR) for the steady temperature and oxygen potential and the horizontal position of the interaction interface. The IVR concept has been implemented in the medium-capacity NPPs with VVER-440(Loviisa, Finland), in projects AP-600 (Westinghouse, USA), NPPs with VVER-640 (SPb AEP, Russia). At present the concept undergoes further development to be used for large-capacity reactors, including AP-1000 (Westinghouse, USA), BWR-1000 (AREVA ANP GmbH, France-Germany), PWR-1400 (Korea).

A comprehensive analysis of the reactor failure requires the data on the vessel corrosion at its interaction with molten corium in realistic conditions, primarily at higher temperatures of steel, different positions of the interaction interface and changed oxygen potential of the system. It is planned to get these data in the framework of the proposed project, which will use the approach developed and tested in the previous METCOR project. The experimental part of the project is performed on the Rasplav-2 and Rasplav-3 test facilities employing the technique of induction melting in a cold crucible for producing uranium-bearing oxidic and metal-oxidic melts. Rasplav-2 and Rasplav-3 test facilities enable: contact-free power deposition in the melt; experiments in the inert, air and steam atmosphere; no time limit on the continuous interaction studies, and on-line monitoring of corium-steel interaction interface. These experimental facilities have been used in the METCOR, CORPHAD, CIRMAT, CIT, ENTHALPY, ECOSTAR, OECD/MASCA projects, carried out with the participation of the project team, which developed the current project proposal.

Previously the molten corium–vessel steel interaction has been studied by the team of proposed project within the ISTC Project #833 (METCOR). In its experimental program a horizontally-positioned specimen of Russian VVER reactor steel (15Kh2NMFA) was placed on the molten pool bottom, and the melt-steel interaction was studied in the stationary regimes, at which the melt composition, temperature, oxygen potential and specimen temperature on the interaction interface were kept relatively stable.

The implementation of the Work Plan of Project #833, the experimental part of which was completed in December 2005, have produced the following results important for the insight into the influence of physicochemical phenomena on the depth and kinetics of reactor vessel ablation at the IVR:

1. Quantitative characteristics of the vessel steel ablation depth and kinetics at its interaction with molten corium, depending on:

1. Corium oxygen potential sensitive to the composition of melt and above-melt atmosphere. For this purpose coria of the following compositions were produced: fully oxidized oxidic corium UO2/ZrO2 and UO2/ZrO2/FeO(Fe3O4) in an inert (nitrogen, argon) atmosphere, air or steam; suboxidized corium UO2/ZrO2/Zr UO2/ZrO2/Zr/STEEL in argon.
2. Temperatures of steel at the interaction interface, which ranged between 700 oC and 1400 oC.
3. Value of specific heat flux from the corium melt into the steel specimen, which varied between 0.3 MW/m2 and 1.2 MW/m2.

2. The main mechanisms of vessel steel ablation have been determined after the posttest physicochemical and metallographic studies of the microstructure, elemental and phase composition and thermophysical characteristics of the corium ingot, interaction zone between corium and specimen and steel specimen near the interaction zone. It has been found that in case of a fully oxidized melt the mechanism of cooled vessel steel ablation (corrosion) is based on its oxidation, and the main diffusion barrier, which influences the process kinetics, is the FeO layer, which forms on the steel surface. In case of suboxidized oxidic and metal-oxidic molten coria, the main mechanism of the cooled vessel steel ablation is its eutectic melting (dissolution), which goes on until the boundary temperature of ~1090 oC is reached.

3. The determined mechanisms of cooled vessel steel ablation caused by the physicochemical interaction with molten corium have been used for developing approximated correlations for the numeric evaluation of corrosion (ablation) rate and depth.

The produced results enable to predict thermal and mechanical behavior of the reactor vessel bottom during the IVR. The major findings from the preformed investigations have been presented in the following papers and reports:

1. Bechta S.V., Khabensky V.B., Vitol S.A. et al., Experimental Study of Oxidic Corium Interaction with Reactor Vessel Steel Samples // RASPLAV Seminar 2000, Munich, Germany, 14-15 Nov., 2000
2. Bechta S.V., Khabensky V.B., Vitol S.A. et al., Experimental studies of oxidic molten corium-vessel steel interaction // Nucl. Eng. Des., 210 (2001) 193-224
3. Bechta S.V., Khabensky V.B., Granovsky V.S., Krushinov E.V., Vitol S.A., Gusarov V.V., Almjashev V.I., Lopukh D.B., Tromm W., Bottomley D., Fischer M., Cognet G., Kymalainen O., New Experimental Results on the Interaction of Molten Corium with Reactor Vessel Steel // Proceedings of ICAPP’04, Pittsburgh, P.A. USA, June 13-17, 2004, Paper 4114
4. Bechta S.V., Khabensky V.B., Granovsky V.S., Krushinov E.V., Vitol S.A., Gusarov V.V., Almjashev V.I., Mezentseva L.P., Petrov Yu.B., Lopukh D.B., Fischer M., Bottomley D., Tromm W., Barrachin M., Altstadt E., Piluso P., Fichot F., Hellmann S., Defoort F., CORPHAD and METCOR ISTC projects // The first European Review Meeting on Severe Accident Research (ERMSAR-2005), Aix-en-Provence, France, 14-16 November, 2005
5. Bechta S.V., Khabensky V.B., Vitol S.A., Krushinov E.V., Granovsky V.S., Lopukh D.B., Gusarov V.V., Martinov A.P., Martinov V.V., Fieg G., Tromm W., Bottomley D., Tuomisto H., Corrosion of vessel steel during its interaction with molten corium. Part 1: Experimental // Nucl. Eng. Des., 236 (2006) 1810-1829
6. Bechta S.V., Khabensky V.B., Vitol S.A., Krushinov E.V., Granovsky V.S., Lopukh D.B., Gusarov V.V., Martinov A.P., Martinov V.V., Fieg G., Tromm W., Bottomley D., Tuomisto H., Corrosion of vessel steel during its interaction with molten corium. Part 2: Model development // Nucl. Eng. Des., 236 (2006) 1362-1370
7. Bechta S.V., Khabensky V.B., Granovsky V.S., Krushinov E.V., Vitol S.A., Gusarov V.V., Almjashev V.I., Lopukh D.B., Tromm W., Bottomley D., Fischer M., Piluso P., Miassoedov A., Altstadt E., Willschufz H.G., Fichot F., Experimental Study of Interactions Between Suboxidized Corium and Reactor Vessel Steel // Proceedings of ICAPP’06, Reno, NU USA, June 4-6, 2006, Paper 6054.

Still, certain specific features of the corium – reactor vessel interaction remain unclear. Among them:

1. Transients accompanying the steel temperature and oxygen potential growth in the system when the neutral atmosphere is replaced by the oxidizing (steam) atmosphere. They can cause the melt temperature rise, pool structure transformation due to major component repartitioning and corresponding increase of heat fluxes into the vessel (focusing effect).
2. Interactions at vertical orientation of steel specimen surface, in this case the gravity effects could be critical.
3. Behavior of the European reactor vessel steel

Additional studies are important for developing SAM concepts due to the reasons explained below.

**Corium-steel interaction at the melt oxidation transients**

During a severe accident involving the core meltdown the oxidic-metallic pool is formed on the reactor vessel lower head. Pool structure can be generally influenced by the Zr oxidation degree (melt oxygen potential), molten steel mass fraction and uranium to zirconium mass ratio. The U and Zr-bearing molten steel layer can be located in the surface or bottom part of the pool depending on the component partitioning. Beside that, a three-layer structure having an intermediate oxidic layer can be formed.

In comparison to the previous METCOR studies the melt - reactor vessel interaction can be substantially different, if the melt undergoes oxidation caused by the steam (water) on its surface. The melt oxidation is accompanied by additional heat generation, the intensity of which depends on the oxidation kinetics. This causes the melt superheating and increases the thermal and corrosion loads on the vessel. In case of a surface position of the metallic layer, its oxidation leads to the formation of an oxidic crust, which restricts heat evacuation from the top surface and eventually increases the focusing effect. But this crust can also restrict the melt oxidation rate, which influences the situation positively.

Taking into account that phenomena occurring at the pool oxidation are potentially hazardous for the vessel integrity, it is advisable to conduct an experimental study of the steel corrosion kinetics in the realistic conditions.

**Interactions at vertical orientation of steel specimen surface**

During severe accident progression an interaction between suboxidized coria and reactor vessel wall takes place. In reactor conditions, the vertical surface of the vessel is the place where the heat flux from the melt into the vessel wall has the highest density and the oxidic crust has the smallest thickness. As all the METCOR tests with suboxidized corium have shown, a liquefied interaction zone composed of U/Zr/Fe(Cr,Ni)/O forms, which, in accordance with MASCA results, can have a higher density than an oxidic melt.

In comparison to the horizontally positioned vessel steel studied in METCOR, the interaction of suboxidized corium with a vertical vessel steel surface can have substantial differences. When the steel specimen surface is positioned horizontally, the liquid metal interaction zone remains in the surface layer of the vessel steel, while in case of the vertical position the difference in densities can cause the liquid metal flow from the interaction zone down to the molten pool bottom. This can influence both the kinetics and thermal characteristics of the interaction.

**Behavior of the European reactor vessel steel**

The compositions of European reactor vessel steels are different from those of Russian reactors. For example, the European vessel steel 16MND5 has a noticeable difference in the content of Mn, Cr and S, which may influence the strength characteristics and the eutectics temperature of interaction with corium. Calculations using the thermodynamic code CEMINI2+NUCLEA04 for steel 16MND5 have shown that eutectic temperature of corium/steel mixture is ~100 oC lower than that for mixture with 15Kh2NMFA.

The proposed Project foresees experiments, which are aimed at establishing correlations describing European reactor steel corrosion.

The experimental program includes 7 tests; the experimental matrix is given in the table below.

**Experimental Matrix**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| No. | Objective | Experimental conditions | | | Note |
| Composition | Temperature of the specimen/melt surface | Atmosphere |
| 1 | Interaction of molten corium with the vertical surface of a vessel steel specimen | UO2+ZrO2  C 100 | 1400ºC | Ar | Scoping test |
| UO2+ZrO2+Zr C 30 | 1400ºC | Ar | Conditions of Test MC6 with a vertical interaction surface |
| Fe-U-Zr-Cr-Ni-O | 1400ºC | Ar | U- and Zr-enriched metallic fraction of the melt |
| 2 | Transient processes during the corium melt oxidation | UO2+ZrO2+Zr C 30  with a vessel steel specimen | 1400ºC | Ar  steam | 10-hour exposure until the interaction process stabilizes followed by Ar replacement with steam |
| UO2+ZrO2+Zr C 30  without a vessel steel specimen | Melt temperature 2500ºC | Ar  steam | Calorimeter is in contact with melt |
| Fe-U-Zr-Cr-Ni-O  without the specimen | Melt temperature 2500ºC | Ar  steam | U- and Zr-enriched molten steel |
| 3 | Interaction of molten corium with European reactor steel specimens | UO2+ZrO2+Zr C 30 | 1400ºC | Ar | European reactor steel specimens are to be supplied by collaborators. |
| UO2+x+ZrO2 | 1300ºC | Steam |

### 2. Expected Results and Their Application

The Project belongs to the category of applied studies. The main project results will be as follows:

- Physicochemical phenomena which are critical for determining vessel steel ablation in the severe accident conditions.

- Experimental data on the vessel steel corrosion kinetics and depth for the steady state and for oxidation transients.

- Qualitative and quantitative characteristics of the European vessel steel corrosion.

- Correlations for calculating corrosion kinetics in the studied parameter range.

The results will be used for:

- modeling physicochemical phenomena of severe accidents

- code verification

- specifying temperature condition and mechanical behavior of the reactor vessel

- development and justification of different concepts of the core melt localization

2.1. Sustainability Implementation Plan

2.1.1. Results to be promoted

None

2.1.2. Uniqueness of results

The missing data on the influence of physicochemical processes on the interaction of molten corium with the reactor vessel steel for the specified conditions.

2.1.3. Demand for results

The potential users can be research institutions and design engineering firms working in the field of designing and substantiating safety of NPP with VVER, PWR and BWR reactors.

2.1.4. Expected income

Not expected

2.1.5. IPR situation

Governed by the Laws of the Russian Federation and the ISTC standard Project Agreement

2.1.6. Additional developments

Not required

2.1.7. Plan of implementation

Experimental and methodological complex enabling studies with high-temperature uranium-bearing melts.

2.1.8. Additional licenses or permits

Not required

2.1.9. Business network

Not planned

### 3. Meeting ISTC Goals and Objectives

The Project will be implemented within 36 months by 50 participants, of which 23 persons have been previously involved in the development of military technologies.

The full scope of work will be implemented by the A.P. Alexandrov Research Institute of Technology (NITI) of the Russian Atomic Energy Agency.

The current Project will:

1. allow the specialists, previously involved in the development of weapons and military technologies, to redirect their skills to peaceful activities;
2. support applied research performed for peaceful purposes, especially in the fields of environment protection, power production and nuclear safety;
3. contribute to the integration of Russian scientists into the international scientific community and preserve the scientific potential of Russia;
4. support the transition to the market economy satisfying civil needs.

Therefore, the Project meets ISTC goals and objectives completely.

### 4. Scope of Activities

The Project is scheduled for the period of 3 years.

The total funding is 543877.58 USD.

The tasks set in the Project shall be solved by carrying out experimental studies presented in the Experimental Matrix below.

The test succession priorities and experimental specifications will be discussed and approved by collaborators before each test.

According to the Matrix, 5 tasks should be implemented. Their objective is to obtain experimental data on the kinetics of corium melt interaction with vessel steel depending on: the spatial orientation of the interaction surface; non-steady processes of melt oxidation during the change of oxygen potential in the atmosphere; brand of steel used for the European reactor vessels.

Task 1 **–** Modernization, adjustment and preparation of the experimental setup. Fine-tuning of methodologies. Test specification.

Task 2 – Interaction of suboxidized molten corium with vertically positioned vessel steel specimen.

Task 3 – Transient processes at the oxidation of the suboxidized oxidic and metal-oxidic melts when the inert atmosphere (argon) is replaced with steam.

Task 4 – Interaction of molten corium with European vessel steel specimens.

Task 5 – Integrated physicochemical, thermodynamic and thermohydraulic analysis of the completed tests, experimental series and the whole program of experimental and numeric studies. Preparation of deliverables.

Implementation of each task is divided into the following stages of test performance: primary analysis, pre- and posttest calculations, and the integrated analysis of results.

A detailed description of the work is given below, and the required man-days are given in the Technical schedule.

#### Task 1

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| --- | --- | --- |
| **Task description and main milestones** | | **Participating Institutions** |
| In order to conduct experimental series for fulfilling Tasks 2, 3, 4, test facilities Rasplav-2 and Rasplav-3 are modernized, adjusted and prepared for tests; experimental sections are manufactured; the experimental procedure, specimen measurements and analysis methodologies are finalized.  Main stages:   * 1. Adjustment of test facilities to the vertical positioning of the steel specimens and measurement systems, preparation of the test facility, methodologies and procedures for the experimental series of Task 2.   2. Test facility modernization, i.e. design and installation of the system for the replacement of inert atmosphere with steam; and of the measurement system, preparation of the test facility, methodologies and procedures for the experimental series of Task 3.   Manufacturing of experimental devices, preparation of the test facility, methodologies and procedures for the experimental series of Task 4. | | NITI |
| **Description of deliverables** | | |
| 1 | Technical notes in the quarterly reports, a paragraph in the annual report | |
| 2 | Description of methodologies | |

#### Task 2

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| **Task description and main milestones** | | **Participating Institutions** |
| Investigation of the interaction between suboxidized oxidic and metal-oxidic corium with vertically positioned vessel steel specimen in argon at the interface temperature Ts≈1400ºC.  Main stages:  2.1. Completion and primary analysis of the test with C-100 corium (UO2/ZrO2).  2.2. Physicochemical posttest analysis of samples and specimens.  2.3. Completion and primary analysis of the test with C-30 corium (UO2/ZrO2/Zr).  2.4. Physicochemical posttest analysis of samples and specimens.  2.5. Completion and primary analysis of the test with the composition Fe(Cr, Ni)/U/Zr/O.  2.6. Physicochemical posttest analysis of samples and specimens. | | NITI |
| **Description of deliverables** | | |
| 1 | Test records | |
| 2 | Tables with results of physicochemical analyses | |
| 3 | Plots and bar charts | |
| 4 | Technical notes in the quarterly reports | |

#### Task 3

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| **Task description and main milestones** | | **Participating Institutions** |
| Studies of oxidation kinetics of the suboxidized oxidic and metal-oxidic corium during the replacement of the inert atmosphere with steam.  Main stages:  3.1. Completion and primary analysis of the test with molten C30 corium (UO2/ZrO2/Zr) and cooled vessel steel specimen at Ts≈1400ºC on the specimen interaction surface.  3.2. Physicochemical posttest analysis of samples and specimens.  3.3. Completion and primary analysis of the test with molten C30 corium (UO2/ZrO2/Zr) with a bottom calorimeter instead of a steel specimen.  3.4. Physicochemical posttest analysis of samples and specimens.  3.5. Completion and primary analysis of the test with a metal-oxidic melt composed of Fe(Cr, Ni)/U/Zr/O with a bottom calorimeter instead of a steel specimen.  3.6. Physicochemical posttest analysis of samples and specimens. | | NITI |
| **Description of deliverables** | | |
| 1 | Test records | |
| 2 | Tables with results of physicochemical analyses | |
| 3 | Plots and bar charts | |
| 4 | Technical notes in the quarterly reports | |

#### Task 4

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| --- | --- | --- |
| **Task description and main milestones** | | **Participating Institutions** |
| Interaction of molten corium with European vessel steel specimens.  Main stages:  4.1. Completion and primary analysis of the test with molten C30 corium (UO2/ZrO2/Zr) in argon at Ts.≈1400ºC on the specimen interaction surface.  4.2. Physicochemical posttest analysis of samples and specimens.  4.3. Completion and primary analysis of the test with molten C 100 corium (UO2/ZrO2) in steam at Ts.≈1300ºC t on the specimen interaction surface.  4.4. Physicochemical posttest analysis of samples and specimens. | | NITI |
| **Description of deliverables** | | |
| 1 | Test records | |
| 2 | Tables with results of physicochemical analyses | |
| 3 | Plots and bar charts | |
| 4 | Technical notes in the quarterly reports | |

#### Task 5

|  |  |  |
| --- | --- | --- |
| **Task description and main milestones** | | **Participating Institutions** |
| Integrated analysis of stages of all experimental series including: pre- and posttest calculations of the heat distribution in components of the test facility; calculation of the specimen temperature conditions and heat flux into the specimen; detailed physicochemical and metallographic analysis of corium samples, interaction zone and experimental section. Preparation of deliverables.  Main stages:  5.1. Integrated analysis of Task 2.  5.2. Integrated analysis of Task 3.  5.3. Integrated analysis of Task 4.  5.4. Integrated analysis of the whole set of experimental and calculated data of the Project. | | NITI |
| **Description of deliverables** | | |
| 1 | Progress reports on stages of Tasks 2, 3, 4 implementation; annual reports | |
| 2 | Presentations for the meetings with collaborators and CEG-SAM | |
| 3 | Papers and conference presentations | |
| 4 | Final Project report | |

Tasks correlation diagram is given in the figure below.

**Tasks 1 - 5 correlation diagram**

Experimental matrix

Task 1

Task 2

Task 3

Task 4

Task 5

The Experimental Matrix may be updated following discussions of the completed stages of Tasks with collaborators.

### 5. Role of Foreign Collaborators/Partners

This Project envisages the following aspects of cooperation with foreign collaborators:

1. Joint development and modification of the Experimental Matrix in the course of the Project;
2. Efficient information exchange during the Project implementation;
3. Discussion of scientific and technical reports (progress, annual, final) with the aim of modifying experimental methodology, considering the proposed improvements to the physicochemical models of interaction;
4. Cross-check of the Project findings;
5. Conduction of joint meetings and seminars;
6. Joint preparation of presentations and papers.

### 6. Technical Approach and Methodology

The experimental research on the interaction of molten prototypic uranium-bearing corium with vessel steel is performed on the Rasplav-2 and Rasplav-3 test facilities, which have been successfully operated for 15 and 5 years, respectively.

For molten corium production, the facilities employ an original technology of induction melting in the cold crucible (IMCC), which enbles handling of molten prototypic corium heated up to 3300 K.

Presence of a solid phase (lining crust) between the melt and crucible prevents crucible-melt mass transfer, ensures in-crucible melt retention and a high melt purity (at the level of initial components purity). The IMCC method provides contact-free power deposition in the melt.

The Rasplav-2 test facility provides an opportunity of experiments with oxidized and suboxidized oxidic systems, and the Rasplav-3 facility – with metal-oxidic ones. The Rasplav-2 and Rasplav-3 facilities can be used for producing, up to 8 an 2 kg of high-temperature molten corium respectively, in the inert, air or steam atmosphere.

The Rasplav-2 and Rasplav-3 test facilities have a number of advantages for simulating molten corium behaviour during a severe accident. They are as follows:

1. possibility to modify corium melt composition in the course of test;
2. possibility of introducing metals into the melt;
3. considerable melt superheating capability;
4. no test duration limits;
5. universality of melting devices.

Some posttest analyses aimed at studying the interaction mechanisms employ such facilities as the Galakhov microfurnace, high-temperature microscope, derivatographs, and the high-temperature differential thermoanalyzer.

These installations and devices enable the following posttest analyses methods:

1. Visual polythermal analysis (VPA).
2. Visual polythermal analysis in the cold crucible (VPA IMCC).
3. Differential thermal analysis (DTA) and Differential Scanning Calorimetry.
4. Thermal analysis.
5. Galakhov microfurnace (GM).
6. High-temperature microscopy (HTM).

These methods have been tried and tested in the METCOR, CORPHAD, CIRMAT, CIT, ENTHALPY, ECOSTAR, OECD/MASCA projects, in which the current project team has participated.

The following methods are used for physicochemical analysis:

1. Elemental analysis

1. X-ray fluorescence analysis (XRF)
2. Chemical analysis(ChA)
3. Inductively coupled plasma mass spectrometry (ICP MS)
4. Spark source mass spectrometry(SS MS)
5. Phase analysis
6. X-ray diffractionanalysis (XRD)
7. Energy-dispersive X-ray spectrometry(EDX)

3. Metallography and ceramography (Opt M)

1. Optical microscopy
2. Scanning electron microscopy(SEM)

In order to implement the proposed Project, the Rasplav test facilities will be modified in order to conduct tests on the melt interaction with the vertically positioned vessel steel specimen and achieve transient conditions with changed oxygen potential in the above-melt atmosphere.

### 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**  **Subtask 1.1 Subtask 1.2 Subtask 1.3** | Meeting with collabora-tors |  |  |  |  |  |  |  |  |  |  |  |  |
| **Person\*days** | 1800 |  |  |  | 600 |  |  |  | 100 |  |  |  | 2500 |
| **Task 2**  **Subtask 2.1 Subtask 2.2 Subtask 2.3 Subtask 2.4 Subtask 2.5 Subtask 2.6** |  |  |  |  | Meeting with collaborators |  |  |  |  |  |  |  |  |
| **Person\*days** |  | 1300 | 1100 | 1200 | 500 | 400 |  |  |  |  |  |  | 4500 |
| **Task 3**  **Subtask 3.1 Subtask 3.2 Subtask 3.3 Subtask 3.4 Subtask 3.5 Subtask 3.6** |  |  |  |  |  |  |  |  | Meeting with collaborators |  |  |  |  |
| **Person\*days** |  |  |  |  |  | 700 | 400 | 600 | 400 | 500 | 100 |  | 2700 |
| **Task 4**  **Subtask 4.1 Subtask 4.2 Subtask 4.3 Subtask 4.4** |  |  |  |  |  |  |  |  |  |  |  | Meeting with collabora-tors |  |
| **Person\*days** |  |  |  |  |  |  |  |  |  |  | 400 | 500 | 900 |
| **Task 5**  **Subtask 5.1 Subtask 5.2 Subtask 5.3 Subtask 5.4** |  |  |  |  | 1st year report | Paper or conference presentation |  |  | 2nd year report | Paper or conference presentation |  | Final; report. Paper or conference presentation |  |
| **Person\*days** |  | 500 | 710 | 710 | 800 | 600 | 500 | 500 | 300 | 200 | 200 | 188 | 5208 |
| **TOTAL** | 1800 | 1800 | 1810 | 1910 | 1900 | 1700 | 900 | 1100 | 800 | 700 | 700 | 688 | 15808 |

### 8. Personnel Commitments

#### 8.1. Individual participants

### Leading Institution: NITI

#### Category I (weapon scientific and technical personnel)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Name** | **Birth**  **Year** | **Scientific Title** | **Weapon**  **Expertise Ref.** | **Function in project** | **Daily rate**  **(US$)** | **Total days** | **Total grants**  **(US$)** |
| Aniskevich, Yuri N. | 1946 | candidate of sciences | 4.9 | Analysis of experimental data | 34 |  |  |
| Bechta, Sevostian V. | 1961 | doctor of sciences | 4.8 | Manager of experimental Programme | 34 |  |  |
| Blizniuk, Valentina G. | 1950 |  | 4.9 | Chemical analyses | 34 |  |  |
| Borisova, Olga R. | 1970 |  | 4.9 | Book-keeping | 25 |  |  |
| Filippov, Evgeny M. | 1948 | candidate of sciences | 4.9 | Preparation of documentation, organization of meetings | 25 |  |  |
| Granovskaja, Nadezhda P. | 1950 |  | 4.9 | Book-keeping | 34 |  |  |
| Granovsky, Vladimir S. | 1941 | candidate of sciences | 4.9 | Heat transfer calculations | 34 |  |  |
| Gousarov, Victor V. | 1952 | doctor of sc., professor | 4.9 | Thermodynamic calculations and analysis of experimental data | 34 |  |  |
| Kalyago, Elena K. | 1952 | — | 4.9 | Experimental data collection, processing and storage | 34 |  |  |
| Kamensky, Nikolay E. | 1942 |  | 4.9 | Technical services for tests | 30 |  |  |
| Khabensky, Vladimir B. | 1937 | doctor of sc., professor | 4.9 | Manager of Project | 35 |  |  |
| Kirin Gennady S. | 1936 |  | 4.9 | Tests servicing | 25 |  |  |
| Krushinov, Evgeny V. | 1960 | — | 4.3 | Test preparation and conducting | 34 |  |  |
| Koulagin, Igor V. | 1943 | candidate of sciences | 4.7 | Numeric processing of measurement results | 34 |  |  |
| Lopukh, Dmitry B. | 1957 | candidate of sciences | 4.9 | Analysis of experimental data | 34 |  |  |
| Lyssenko, Anatoli V. | 1963 |  | 4.9 | Temperature measurements | 34 |  |  |
| Martynov, Alexandr P. | 1963 |  | 4.9 | Adjustment of high-frequency equipment | 25 |  |  |
| Martynov, Valery V. | 1953 |  | 4.9 | Metallo-and ceramography | 30 |  |  |
| Sabinin, Vladimir V. | 1936 | candidate of sciences | 4.9 | Posttest analyses | 34 |  |  |
| Smirnov Sergey A. | 1957 | candidate of sciences | 4.9 | Hydrodynamic calculations | 34 |  |  |
| Sulatsky Andrey A. | 1961 | candidate of sciences. | 4.9 | Thermophysical modeling | 34 |  |  |
| Vitol, Sergey A. | 1951 | — | 4.9 | Post-test analyses | 34 |  |  |
| **Total:** | | | | | | **7930** | **261480** |

#### Category II (other scientific and technical personnel)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Name** | **Birth**  **Year** | **Scientific Title** | **Function in project** | **Daily rate**  **(US$)** | **Total days** | **Total grants**  **(US$)** |
| Almjashev, Vjacheslav I. | 1972 |  | Thermodynamic analysis, improvement of experimental methodologies | 25 |  |  |
| Beljaeva, Elena M. | 1974 |  | Chemistry analyses | 20 |  |  |
| Bezlepkin Pavel V. | 1959 |  | Experimental facilities maintenance | 25 |  |  |
| Bouligin, Valentin R. | 1967 |  | Servicing of experimental facilities | 25 |  |  |
| Cheremiskin, Vladimir I. | 1953 | candidate of sciences | Processing of experimental results | 25 |  |  |
| Chertkov, Alexdandr A. | 1959 |  | Software for measurements | 25 |  |  |
| Fadeyev Andrey A. | 1959 |  | Dataware | 20 |  |  |
| Gromov Vadim A. | 1981 |  | Experimental facilities maintenance | 25 |  |  |
| Ignatov Alexandr A. | 1950 |  | Dataware | 20 |  |  |
| Kaliagin, Alexandr P. | 1950 |  | Processing of experimental results | 25 |  |  |
| Kirillova Svetlana A. | 1981 |  | Thermodynamic analysis | 20 |  |  |
| Kosarevsky Roman A. | 1982 |  | Physicochemical analyses | 25 |  |  |
| Kotova, Svetlana Ju. | 1967 | candidate of sciences | Physico-chemistry analyses | 25 |  |  |
| Kuchaeva, Sania K. | 1947 |  | Thermodynamic analysis | 25 |  |  |
| Kucherov Yuri I. | 1950 |  | Experimental facilities maintenance | 25 |  |  |
| Peregud, Sergey P. | 1954 |  | Processing of experimental results | 25 |  |  |
| Poldjaeva Inessa Ju. | 1975 |  | Finalization of reports | 20 |  |  |
| Shevchenko, Evgeny V. | 1958 |  | Servicing of experimental facilities | 25 |  |  |
| Shuvalov, Sergey V. | 1960 |  | Translation | 25 |  |  |
| Talalaeva, Tatiana M. | 1955 |  | Translation | 25 |  |  |
| Tolkachev Mochail D. | 1941 |  | Physico-chemistry analyses | 25 |  |  |
| **Total:** | | | | | **7858** | **189750** |

#### Category IV (personnel, who will work less than 10% of project duration)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Number of persons** | **Function in project** | **Daily rate**  **(US$)** | **Total days** | **Total grants**  **(US$)** |
| 2 | Finalization of reports | 20 | 20 | 400 |
| **Total:** | | | **20** | **400** |

#### 8.2. Managerial responsibilities

Project manager

Dr.Sci., Prof.

Vladimir Bentsianovich Khabensky

Task 1 Curator

Evgeny Vladimirovich Krushinov

Task 5 Curator

Dr. Vladimir Semenovich Granovsky

Task 2, 3, 4 Curator

Dr.Sci.

Sevostyan Victorovich Bechta

### 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 |  | 45000 |  | 80000 |  | 101480 |  | 80000 |  | 261480 |
|  | 1.2 | Category II |  | 29000 |  | 57000 |  | 75750 |  | 57000 |  | 189750 |
|  | 1.3 | Category III |  |  |  |  |  |  |  |  |  |  |
|  | 1.4 | Category IV |  |  |  |  |  | 200 |  | 200 |  | 400 |
|  |  | Total Grant Payments |  | **74000** |  | **137000** |  | **177430** |  | **137200** |  | **451630** |
| **2** |  | **Equipment:** |  |  |  |  |  |  |  |  |  |  |
|  | 2.1 | Capital Equipment |  | 20290 |  | 20290 |  |  |  |  |  | 20290 |
|  | 2.2 | Non-Capital Equipment |  | 10050 |  | 15740 |  |  |  | 1600 |  | 17340 |
|  |  | *Total Equipment* |  | **30340** |  | **36030** |  |  |  | **1600** |  | **37630** |
| **3** |  | Materials/Supplies |  | **1130** |  | **6420** |  |  |  |  |  | **6420** |
| **4** |  | **Bank Fees** |  | **1100** |  | **1900** |  | **1900** |  | **1427.58** |  | **5227.58** |
| **5** |  | **Other Direct Costs:** |  |  |  |  |  |  |  |  |  |  |
|  | 5.1 | Technological Energy |  |  |  |  |  |  |  |  |  |  |
|  | 5.2 | Communications |  |  |  |  |  |  |  |  |  |  |
|  | 5.3 | Subcontracts/Seminars |  |  |  | 1000 |  | 2000 |  | 1000 |  | 4000 |
|  | 5.4 | Logistics/Customs |  |  |  |  |  |  |  |  |  |  |
|  | 5.5 | Other |  | 450 |  | 900 |  | 900 |  | 900 |  | 2700 |
|  |  | *Total ODC* |  | **450** |  | **1900** |  | **2900** |  | **1900** |  | **6700** |
| **6** |  | Travel: |  |  |  |  |  |  |  |  |  |  |
|  | 6.1 | Internal \*\*\* |  |  |  |  |  |  |  |  |  |  |
|  | 6.2 | Outside CIS |  | 1800 |  | 4200 |  | 6000 |  | 5500 |  | 15700 |
|  |  | *Total Travel* |  | **1800** |  | **4200** |  | **6000** |  | **5500** |  | **15700** |
|  |  | **Overhead/Retainage** |  |  |  |  |  |  |  |  | 20570 |  |
|  |  | ***Subtotals*** |  | **108820** |  | **187450** |  | **188230** |  | **147627.58** | **20570** | **523307.58** |
|  |  | **Totals** | **108820** | | **187450** | | **188230** | | **147627.58** | | **543877.58** | |

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/MATERIAL SUMMARY | | | | | | | |
| **EQUIPMENT SUMMARY**  for Project Agreement #3592  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: NITI*** | | | | | | | |
| 1 | |  | Chamber electric furnace SNOL 6,7/1300; 1300C, 7l, 200х300х120 mm, 2,4 kW, 35 kg  195009 SPb, Kondratievsky pr., 2, NPK «VARTA»  Tel/Fax: (812) 449 –03-29/ 542-26-40  E-mail: varta-spb@mail.ru | 4 | 1 | 1780 | 1780 |
| 2 | |  | Electronic analytical balance Shimadzu Shimadzu AU220D; Division value: 0.00001 g/0.0001 g; weighing limits: 220g/ 0.001g; balance accuracy rating: according to GOST 24104-2001: I special; weighing cup design: rounded cup with wind protection.  OOO «Vesmaster»; 195279, SPb, shosse Revolyucii , 69- 407  Tel/fax: +7 (812) 334-90-40, www.vesmaster.ru;  E-mail:vesmaster@vesmaster.ru | 2 | 1 | 3890 | 3890 |
| 3 | |  | Agathic mortar (Pulverisette 0);  197110, SPb, ul. Barochnaya, 8-4  Tel/fax: (812) 230-75-53; 237-05-03  E-mail: info(AT)pel.spb.ru; http://pel.spb.ru | 1 | 1 | 2735 | 2735 |
| 4 | |  | Spectrophotometer SF-2000;  SPb, "OKB Spectr", tel. (812) 740-79-16; Lisov Andrey A. | 1 | 1 | 5665 | 5665 |
| 5 | |  | PC (Mb-Server\Xeon5160\Hdd320Gb\RAM4Gb ECC DDR2-800\DVD-RW\ATI X1600\); www.timcompani.ru | 1 | 1 | 3000 | 3000 |
| 6 | |  | PC (Mb P5LD2\ Cel3.46Ghz\ Hdd320GbSeagate\ RAM1Gb \DVD-RW\ATI X1300\mouse\keybord); www.lintec.ru | 1, 2 | 2 | 700 | 1400 |
| 7 | |  | Projector Toshiba TDP-TW95; www.bmk.spb.ru | 1 | 1 | 2200 | 2200 |
| 8 | |  | Notebook Toshiba, www.lintec.ru | 1 | 1 | 1300 | 1300 |
| 9 | |  | Flow meter/regulator LIQU1-FLOW L2/ L2C2 Bronkhorst; 20-1000 g/h; tel: +31 573 458800; fax: +31 573 458877;  e-mail: sales@bronkhorst.com | 1 | 1 | 5000 | 5000 |
| 10 | |  | Camera for the microscope; VAC535 2048\*2048; color  www.evs.ru | 4 | 1 | 2000 | 2000 |
| 11 | |  | PC (Case:INWIN 430W ATX ; motherboard: Asus P5LD2 SE 1945P DDR2 LGA775; CPU: Intel Pentium 4 3.2G 800MHz/2M; RAM: DDR2 2х512 Mb; HDD: 250Gb WD2500KS 16M 7200rpm SATA-II; DVD RW Pioneer DVR-111D; Video: 128M Leadtek WFast PX6600 GeForce 6600 TD; FDD 1’44; monitor Samsung 940N); www.lintec.ru | 9 | 1 | 1600 | 1600 |
| 12 | |  | Grinding globe D70 (Pulverisette 0); 197110, SPb, ul. Barochnaya, 8-4  Tel/fax: (812) 230-75-53; 237-05-03  E-mail: info(AT)pel.spb.ru; http://pel.spb.ru | 1 | 1 | 1110 | 1110 |
| 13 | |  | X-ray tube BKhV17-Pd;  SPb, ZAO Svetlana-Rentgen; tel: (812) 786-59-39 | 4 | 1 | 1155 | 1155 |
| 14 | |  | PC-compatible controller W8731-G (7 expansion slots); www.nnz-ipc.ru | 1 | 2 | 450 | 900 |
| 15 | |  | Module I-8017H | 1 | 4 | 200 | 800 |
| 16 | |  | Module I-87016 | 1 | 1 | 220 | 220 |
| 17 | |  | Module I-87018 | 1 | 3 | 170 | 510 |
| 18 | |  | Module I-8024 | 1 | 1 | 190 | 190 |
| 19 | |  | Module I-8080 | 1 | 2 | 210 | 420 |
| 20 | |  | Monitor 17”, Samsung; www.lintec.ru | 2 | 4 | 250 | 1000 |
| 21 | |  | Fan VR 300-45-3.15 non-corrosive, 1.5kW; ZAO Lissant; SPb, tel.(812)380-14-90, fax (812)527-30-14 | 3 | 1 | 755 | 755 |
| **Subtotal:** | | | | | | | **37630** |
| **Estimated TOTAL COST:** | | | | | | | **37630** |

Form PR-1E of 3/98

#### 10.2. Materials Summary

### TABLE 3

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| EQUIPMENT/MATERIAL SUMMARY | | | | | | | | | | | | | | |
| **MATERIAL SUMMARY**  for Project Agreement #3592  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: NITI*** | | | | | | | | | | | | | | |
| 1 | | |  | | Graphite crucibles for CTR (carbothermic reduction); Dext=13, h=29;  IP Volchematev A.Ju. 454084 Chelyabinsk  tel.(351) 790-82-46 volf\_alex@mail.ru | | 4 | | 100 | | 7.6 | | 760 | |
| 2 | | |  | | Platforms for sensor Setaram WR5; OOO «TECHMA-START», Korenevsky N..L.  tel. (495) 135-96-65; E-mail: asankady@ultra.imet.ac.ru | | 1 | | 3 | | 200 | | 600 | |
| 3 | | |  | | H2 sensor (0-100 % vol);  GUP NKVT "Kristall",198095,SPb,ul.Rosenshteina 28-30, fax: 812 2244802 | | 3 | | 2 | | 50 | | 100 | |
| 4 | | |  | | O2 sensor (0-21 % vol);  GUP NKVT "Kristall",198095,SPb,ul.Rosenshteina 28-30, fax: 812 2244802 | | 3 | | 2 | | 50 | | 100 | |
| 5 | | |  | | Quartz pipes (Dext=30x3, Dext=48x3);  OOO "KVARZ", tel. (49241) 2-18-22 | | 2 | | 10 | | 53 | | 530 | |
| 6 | | |  | | USB-Flash 2 Gb; www.lintec.ru | | 3 | | 8 | | 50 | | 400 | |
| 7 | | |  | | Cartridge С7115А; www.lintec.ru | | 4 | | 4 | | 90 | | 360 | |
| 8 | | |  | | Cartridge for Xerox Е-16; www.lintec.ru | | 4 | | 2 | | 85 | | 170 | |
| 9 | | |  | | Thermocouples (Chromel-Allimel) FEI, Obninsk; tel. (48439) 98791; E-mail: general@ippe.ru | | 3 | | 50 | | 68 | | 3400 | |
| **Subtotal:** | | | | | | | | | | | | | **6420** | |
| **Estimated TOTAL COST:** | | | | | | | | | | | | | **6420** | |

Form PR-1M of 3/98

#### 10.4. Other Direct Costs Summary

### TABLE 4

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| OTHER DIRECT COSTS SUMMARY | | | | | | | | | | | | | |
| **OTHER DIRECT COSTS SUMMARY**  for Project Agreement #3592  To be provided in kind [ X ]  To be purchased by recipient [ ] | | | | | | | | | | | | | |
|  | | | | | | | | | | | | | |
| **Detailed breakdown of Other Directs Costs to include planned activities under items 5.1, 5.2, 5.3, 5.4, 5.5 from Table 1 of the Project Agreement** | | | | | | | | | | | | | |
| **Item**  **No.** | |  | | **DESCRIPTION OF ITEM** | | | **Date needed (quarter)** | | **Qty** | | **Unit cost**  **(USD)** | | **Amount**  **(USD)** |
| ***Leading Institution: NITI*** | | | | | | | | | | | | | |
| 3 | | | 5.3 | | Subcontracts/Seminars | 4, 6, 8, 11 | |  | |  | | 4000 | |
| 5 | | | 5.5 | | Other | 1-12 | |  | |  | | 2700 | |
| **Subtotal:** | | | | | | | | | | | | | **6700** |
| **Estimated TOTAL COST:** | | | | | | | | | | | | | **6700** |

Form PR-1OD of 3/04