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|  | PROJECT PROPOSAL | #3831 |

## I. Summary Project Information

### 1. Project Title and Taxonomy

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| **Full title:** | Development and experiments at large-scale installation for heating and retention of corium**.** | | |
| **Short title:** | Heating and Retention of Corium | | |
| **Technology area:** | | FIR-NSS | |
| **Category of technology development:** | | | Basic research, Applied research |
| **Key words:** | | | Core, large-scale experiment |

### 2. Project Manager

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| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Name:** | | Kondrashenko, Aleksey Valerievich | | | | | | |
| **Title:** | Cand. Sc. (Phys.-Math.) | | | | **Position:** | | Head of Laboratory | |
| **Street address:** | | | | 37, Mir Street, RFNC-VNIIEF | | | | |
| **City:** | Sarov | | | | **Region:** | | Nizhni Novgorod | |
| **ZIP:** | 607190 | | | | **Country:** | | | Russia |
| **Tel.:** | 7 83130 45974 | | | | **Fax:** | 7 83130 45772 | | |
| **E-mail:** | | | kondrashenko@vniief.ru | | | | | |

### 3. Participating Institutions

#### 3.1. Leading Institution

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Short reference:** | | | | | | RFNC-VNIIEF | | | | | | |
| **Full name:** | | | | | | Federal State Unitary Enterprise Russian Federal Nuclear Center – All-Russia Scientific and Research Institute for Experimental Physics | | | | | | |
| **Street address:** | | | | | 37, Mir Street | | | | | | | |
| **City:** | Sarov | | | | | | | **Region:** | | | Nizhni Novgorod | |
| **ZIP:** | | 607190 | | | | | | **Country:** | | | Russia | |
| **Name of Signature Authority:** | | | | | | | | | Rogachev, Vladimir Grigorievich | | | |
| **Title:** | | Ph.D. | | | | | | **Position:** | | | | Deputy Director of RFNC-VNIIEF |
| **Tel.:** | | | 7 831 304 53 73 | | | | | **Fax:** | | 7 831 305 38 08 | | |
| **E-mail:** | | | | rvg@dc.vniief.ru. | | | | | | | | |
| **Governmental Agency:** | | | | | | | Federal Agency for Atomic Energy | | | | | |

#### 3.2. Other Participating Institutions

#### Participating Institution 1

|  |  |  |  |  |  |  |  |  |  |  |  |
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| **Short reference:** | | | | | IVTAN | | | | | | |
| **Full name:** | | | Joint Institute for High Temperatures of Russian Academy of Sciences | | | | | | | | |
| **Street address:** | | | | 13/19, Izhorskaya Street | | | | | | | |
| **City:** | Moscow | | | | | | | **Region:** | |  | |
| **ZIP:** | 125412 | | | | | | | **Country:** | | | Russian Federation |
| **Name of Signature Authority:** | | | | | | | Zeigarnik, Vladimir Albertovich | | | | |
| **Title:** | Doctor Sci. | | | | | | | **Position:** | | Deputy Director | |
| **Tel.:** | 7 495 4858345 | | | | | | | **Fax:** | 7 495 4859922 | | |
| **E-mail:** | | efremov@ihed.ras.ru | | | | | | | | | |
| **Governmental Agency:** | | | | | | Russian Academy of Sciences | | | | | |
| **Sub-manager:** | | | | Funtikov Aleksandr Iosifovich | | | | | | | |
| **Title:** | Doctor Sci. | | | | | | | **Position:** | | Head of Laboratory | |
| **Tel.:** | 7 495 4841622 | | | | | | | **Fax:** | 7 495 4857990 | | |
| **E-mail:** | | funtikov @ihed.ras.ru | | | | | | | | | |

### 4. Foreign Collaborators/Partners

#### 4.1. Collaborators

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Institution:** | | | | CEA | | | | | | |
| **Street address:** | | | | | Batiment 121 | | | | | |
| **City:** | Gif-sur-Yvette Cedex | | | | | **Region/State:** | | | |  |
| **ZIP:** | F-91191 | | | | | **Country:** | | | France | |
| **Person:** | | | Chistophe Journeau | | | | | | | |
| **Title:** | |  | | | | **Position:** | |  | | |
| **Tel.:** | +33 442 25 4121 | | | | | **Fax:** | +33 442 25 7788 | | | |
| **E-mail:** | | | christophe.journeau@cea.fr | | | | | | | |

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| **Institution:** | | | | EDF | | | | | | |
| **Street address:** | | | | | 12-14 avenue Dutrievoz | | | | | |
| **City:** | Villeurbanne Cedex | | | | | **Region/State:** | | | |  |
| **ZIP:** | 69628 | | | | | **Country:** | | | France | |
| **Person:** | | | K.Atkhen | | | | | | | |
| **Title:** | |  | | | | **Position:** | |  | | |
| **Tel.:** | +33 1 04 72 82 77 77 | | | | | **Fax:** | +33 1 04 72 82 70 00 | | | |
| **E-mail:** | | |  | | | | | | | |

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Institution:** | | | | | JRC-ITU | | | | | | |
| **Street address:** | | | | | | P.O.Box 2340 | | | | | |
| **City:** | Karlsruhe | | | | | | **Region/State:** | | | |  |
| **ZIP:** | | 76125 | | | | | **Country:** | | Germany | | |
| **Person:** | | | P.D.Bottomley | | | | | | | | |
| **Title:** | |  | | | | | **Position:** | | |  | |
| **Tel.:** | | | +49 7247 95 1364 | | | | **Fax:** | +49 7247 95 1593 | | | |
| **E-mail:** | | | | bottomley@itu.fzk.de | | | | | | | |

#### 4.2. Partners

no

### 5. Project Duration

18 months

### 6. Project Location and Equipment

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| **Institution** | **Location, Facilities and Equipment** |
| **Leading Institution** | Sarov, Nizhni Novgorod Region. The Project works will be performed at the test site “Osnovnaya”, in building 64 room 20, building 97 rooms 201, 202; at test site 3, bunker 1; at test site 19, and in rooms of the laboratory building of SarPTI in 6 Alexandrovich Street.  RFNC-VNIIEF disposes stands to conduct experimental study on materials and constructions behavior at high temperatures.  The mathematical modeling of melt behavior and melt interaction with constructional materials of a catcher will be conducted in RFNC-VNIIEF computer center using available mathematical codes and 1D-3D programs. |
| **Participant Institution 1** | Moscow, Izhorskaya Str., 13/19. ÎVÊ building (rooms 2,4,12,14, 20), Ê-6À building (rooms 303, 422), CÎÎ building (rooms 303, 310), L1 building (rooms 307, 332, 408). Press. Furnace. Laser heating installation; installations for XP analysis, probe microanalysis and scanning electronic microscopy; computers. |

### 7. Total Project Effort

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| **Total number of participants** | 180 |
| **Number of weapon scientists and engineers** | 84 |
| **Total project effort (person\*days)** | 18639 |
| **Total project effort of weapon scientists and engineers (person\*days)** | 12976 |

### 8. Financial Information

#### 8.1. Estimated Project Costs

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| **Estimated total cost of the project (US $)** | 727649 |
| *Including:* |  |
| **Payments to Individual Participants** | 438290 |
| **Equipment** | 74480 |
| **Materials** | 94000 |
| **Other Direct Costs** | 41500 |
| **Travel** | 22000 |
| **Overhead** | 57379 |

#### 8.2. Funding Sources

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| --- | --- |
| **Estimated total cost of the project (US $)** | 727649 |
| *Financial Sources:* |  |
| **Requested from the ISTC** | 727649 |
| **Other financial source 1** | 0 |
| *Non-Financial Sources:* |  |
| **Non-financial source 1** | 0 |

### 9. Summary of the project

The main goal of the Project is the experimental and computational verification of the technology for the localization and retention of reactor core melt (corium) at a large-scale installation during a severe accident at a nuclear power plant (NPP).

To experimentally test melt behavior, melt interaction with concrete at a severe accident at NPP it is planned to develop a large-scale installation that is to heat and retain melt of materials of reactor core EPR along with the complex of diagnostic and measuring equipment. To obtain the adequate results of the research of the melt interaction with concrete, the installation should have the following characteristics: melt volume -150 L, melt mass ~1200-1300 kg, melt temperature –~2500-3000С ?C, heat fluxes towards walls and a bottom of a catcher ~100 kw/m2 , melt retention time –1-2 hours. It is planned to manufacture a large-scale catcher with a concrete bottom and walls. The characteristics meet the requirements of a catcher designed for the melt localization and retention. The melt mass is about 200 tons, hence, we have chosen the installation with heating of the mass of ~1200-1300 kg reasoning on the necessity to model a real catcher rather adequately taking into account the scope of experiments.

The peculiarity of the Project is a new technology for the core melt heating and retention, which is similar to the nuclear reactor core melt. The technology has been developed by RFNC-VNIIEF. Special pyrotechnic substances will be used to heat the melt and reach the melt parameters required. To retain the necessary melt temperature in the process of experiment with the melt, some gas(-fired) burners will burn, which use a propane-butane mixture or hydrogen.

An urgent problem is to extend the results of model experiments to the real catchers. The role of a geometrical factor and melt dynamics along with the distribution of the components of the mixture of the melt can be analyzed by means of computational modeling of the processes of heat- and- mass transfer along with physical and chemical conversions in the catcher. Theoretical analysis will be based on the following scenario of accident development.

The reactor core melt at a given temperature pours entirely into the catcher. The homogenous (but stratified) or non-homogenous (in a random way) distribution of the metallic and oxidation components of the melt will be considered as the primary distribution of the melt material.

Then, as a result of volumetric energy release due to radioactive fuel decay, endo- and exothermal chemical reactions, melting and solution of concrete along with heat removal through the walls of the catcher, some temperature distribution sets in the melt. At the same time, melt components concentrations distribution takes place due to the processes of diffusion and convective mixing.

Within the framework of the Project it is necessary to conduct a lot of design-theoretical research work along with the performance of complex and expensive experimental research. RFNC-VNIIEF disposes high-skilled specialists in the field of the design-theoretical and computer simulation of fissile materials multi-component melts flows. RFNC-VNIIEF specialists have developed: the physical and mathematical and computer models of heat and mass transfer in various media, melts included; the models of melt interaction with different materials; the data base on the thermal and physical properties of melts and materials; 1D,2D, 3D computer programs to calculate heat and mass transfer for multi-component systems in complex geometries, thermal hydraulics taking into account phase transformations and chemical reactions.

Within the framework of the Project it is planned to develop the large-scale installation for core melt heating and retention, which is similar to the nuclear reactor core melt, with characteristics described above. It is planned to conduct experiments on the interaction of the melt with concrete at the large-scale experimental installation. It is planned to develop, perform calibration methodical tests and check measuring equipment complex capacity for work for diagnostics of melt temperatures, thermal fields in concrete. It is planned to use metallographic techniques and electron microscopy for analyzing an ingot of a sow melt. It is planned to develop computational models for calculating thermal fields in melt and concrete, melt parameters, interaction of melt with concrete**.**

The main specific feature of the suggested Projects in comparison with other works in this field is the larger mass of the melt (~1200-1300 kg) and pyrotechnic technology of melt heating and retention.

Reactor core melt materials similar to reactor core melt (EPR) are planned to contain (mass. %): 40-50% ZrO2; 50-60% Fe.

The results achieved during the Project implementation can be used to develop promising NPP safety systems for severe accidents conditions.

During the Project implementation, 84 developers of nuclear weapon will be partly involved into the activity unconnected with military programs.

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## II. Detailed Project Information

### 1. Introduction and Overview

The main goal of the Project is the experimental and computational verification of the technology for the localization and retention of reactor core melt (corium) at a large-scale installation during a severe accident at a nuclear power plant (NPP).

An urgent problem is to develop catchers, operating and designed NPPs, to be used to localize and retain the core melt if it spreads beyond a reactor in the case of a severe accident. The catcher should provide melt localization, cooling and retention for an unlimited time, along with saving containment structure and environment.

The catcher can mitigate the consequences of a terrorist act at NPP similar to the one on September 11, 2001 in the USA.

At present, there is no operational PWR with a catcher. The use of the catcher is extremely important for reactors with the electrical power of about 1000 MW. In Russia, 7 of 13 PWRs are the reactors of PWR-1000 type. All NPP designers realize the necessity of reactors equipped with the catchers. Nowadays the different schemes of the external catchers are worked over both for the NPPs under design and operational ones. In Russia, the NPP engineering designs for China and India have been developed [1]. In EC countries, the EPR with the external catcher has been designed [2-4].

It should be noted that localization scenarios for PWR-type reactors operating at present differ from localization scenarios for prospective reactors, in particular, for EPR. The main difference is that in the operational reactors it is practically impossible to provide the melt spreading over a considerable area after it outlets from a reactor vessel. Therefore, it will be entirely accumulated in a reactor concrete vault. Hence, the melt cooling conditions in the operational reactors and reactors under design will significantly differ. However, some matters about melt behavior, melt interaction with concrete when designing the catcher are general and principal for both the operational NPPs and NPPs under design.

The absence of exact information about such important parameters as the moment and duration of corium outlet from the reactor vessel, corium components (for instance, the amount of unoxidized Zr) and temperature, the geometry of vessel destruction, etc. pose significant problems when one realizes localization systems in practice. Hence, experimental work connected with the studies at large-scale laboratory installations is of great scientific and practical interest.

To experimentally test melt behavior, melt interaction with concrete at a severe accident at NPP it is planned to develop a large-scale installation that is to heat and retain melt of materials of EPR reactor core along with the complex of diagnostic and measuring equipment. To obtain the adequate results of the research of the melt interaction with concrete, the installation should have the following characteristics: melt volume -150 L, melt mass ~1200-1300 kg, melt temperature –~2500-3000С ?C, thermal fluxes towards walls and a bottom of a catcher ~100 kw/m2 , melt retention time –1-2 hours. It is planned to manufacture a large-scale catcher with a concrete bottom and walls. The characteristics meet the requirements of a catcher designed for the melt localization and retention. The melt mass is about 200 tons, hence, we have chosen the installation with heating of the mass of ~1200-1300 kg reasoning on the necessity to model a real catcher rather adequately taking into account the scope of experiments.

At present, for this purpose installations are used that are based on microwave heating (installations with cold crucible, in particular) and self-propagating high temperature synthesis. These installations make it possible to reach the temperatures given. But the installations with cold crucible do not allow heating the given amount of material, and the installations based on the high temperature synthesis don’t allow retaining the melt during the given period of time

The peculiarity of the Project is a new technology for the core melt heating and retention, which is similar to the nuclear reactor core melt. The technology has been developed by RFNC-VNIIEF. Special pyrotechnic substances will be used to heat the melt and reach the melt parameters required. To retain the necessary melt temperature in the process ofexperimentwith the melt, gas(-fired) burners will burn, which use a propane-butane mixture or hydrogen.

An urgent problem is to extend the results of model experiments to the real catchers. The role of a geometrical factor and melt dynamics along with the distribution of the components of the melt mixture can be analyzed by means of computational modeling of the processes of heat- and- mass transfer along with physical and chemical conversions in the catcher. The analysis will be based on the following scenario of accident development.

The reactor core melt at a given temperature pours entirely into the catcher. The homogenous (but stratified) or non-homogenous (in a random way) distribution of the metallic and oxidation components of the melt will be considered as the primary distribution of the melt material.

Then, as a result of volumetric energy release due to radioactive fuel decay, endo- and exothermal chemical reactions, melting and solution of concrete along with heat removal through the walls of the catcher, some temperature distribution sets in the melt. At the same time, melt components concentrations distribution takes place due to the processes of diffusion and convective mixing.

Within the framework of the Project it is necessary to conduct a lot of design-theoretical research work along with the performance of complex and expensive experimental research. RFNC-VNIIEF disposes high-skilled specialists in the field of the design-theoretical and computer simulation of fissile materials multi-component melts flows. RFNC-VNIIEF specialists have developed: the physical and mathematical and computer models of heat and mass transfer in various media, melts included; the models of melt interaction with different materials; the data base on the thermal and physical properties of melts and materials; 1D, 2D, 3D computer programs to calculate heat and mass transfer for multi-component systems in complex geometries, thermal hydraulics with regard to phase transformations and chemical reactions.

The main tasks of the Project are:

Task 1 To develop the large-scale installation for heating and retention of reactor core melt with characteristics: melt volume ~150 L, melt mass ~1200-1300 kg, melt temperature ~2500-3000C, heat fluxes towards walls and a bottom of a catcher ~100 kw/m2, melt retention time 1-2 hours. Performance of experiments. A large-scale catcher will be manufactured and mounted with a concrete bottom and walls. The experiments will be conducted to study melt behavior and melt interaction with concrete.

Task 2. To develop the complex of measuring equipment for the diagnosis of melt temperatures, thermal fields in concrete. Calibration and methodical tests will be conducted and measuring equipment complex capacity for work will be checked. The developed complex will be applied to diagnose experiments using the large-scale installation.

Task 3. To develop physical and mathematical and computer models for calculations of thermal fields in melt and concrete, calculations of melt parameters, melt interaction with concrete. Assessments of calculations will be performed for heating melt and concrete. Calculations of melt parameters and melt interaction with concrete will be made.

The main specific feature of the suggested Projects in comparison with other works in this field is the larger mass of the melt (~1200-1300 kg) and pyrotechnic technology of melt heating and retention.

Reactor core melt materials similar to reactor core melt (EPR) are planned to contain (mass. %): 40-50% ZrO2; 50-60% Fe.

IVTAN and RFNC-VNIIEF joint efforts allow one to expect the successful completion of the given Project and obtain a lot of unique experimental and calculation information, which will be useful for specialists in the field of melt retention at severe accidents at NPPs.

The results obtained during the Project implementation can be used for the development of promising safety systems for NPPs at severe accidents.

The participants of the Project have publications and presented reports at international conferences on the subject of the Project [5- 10].

References

1. Kutkhevich I.V., Bezlepkin V.V., Granovsky V.S., etc. Concept of Corium Melt Localization at the Out-of-Vessel Stage of Beyond the Design Basis Accident on PWR-1000 at NPP., Teploenergetika (Thermal Energy), ¹ 9, pp.2-43, 2001
2. M. Fischer Main features of the EPR melt retention concept, OECD Workshop on Ex-Vessel Debris Coolability, Karlsruhe, Germany, 15-18 November 1999.
3. Nie M. Application of sacrificial concrete for the retention and conditioning of molten corium in the EPR core melt retention concept, OECD Workshop on Ex-Vessel Debris Coolability, Karlsruhe, Germany, 15-18 November 1999.
4. Hellmann S. et al., Physico-Chemical and Material Aspects of the Core Melt Retention Concept of the EPR, OECD Workshop on Ex-Vessel Debris Coolability, Karlsruhe, Germany, 15-18 November 1999.
5. Ìineev V.N., Koren’kov V.V., T’unyaev Yu.N., Role of NPP Shielding Barriers at Internal and External Attacks. Atomnaya Energiya (Atomic Energy), 1990, v.69, issue 68.
6. Ìineev V.N. Performance of Russian Nuclear Power-Plant under Internal Explosion und External Terrorism Act Accidents. In Proceedings of the Workshop on Severe Accident Research in Japan (SARJ-95) Dec. 4-6, 1995.
7. Akopov F.A., Akopyan A.A., Barykin B.M., Belmaz N.O., Borovkova L.B.,BorodinaT.I.,Valyano G.E., Vlassov A.S., Lukin E.S., Mineev V.N., Chernyshov //G.P. Resistance of zirconia refractories to the iron oxide melt.// OECD Workshop on Ex-Vessel. Debris Coolability, Karlsruhe, Germany, November 15-18, 1999.
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10. Ogorodnikov V.A., Ivanov A.G., Erunov S.V., Luchinin V.I., Khokhlov A.A., Akopov F.A., Mineev V.N., Chernyshev G.P.// Shock-wave deformation and fracture of ZrO2 ceramics having various fractions structure and porosity.//European high pressure research group (EHPRG) Meeting 2000, Kloster Banz, Germany, Aug.31-Sept.3, 2000.

### 2. Expected Results and Their Application

The following results of the Project implementation are expected:

1. The large-scale installation will be developed for heating and retention of reactor core melt with characteristics: melt volume ~150 L, melt mass ~1200-1300 kg, melt temperature ~2500-3000C, heat fluxes towards walls and a bottom of a catcher ~100 kw/m2, melt retention time 1-2 hours. The large-scale installation will be manufactured and mounted with a concrete bottom and walls. The experiments will be conducted to study melt behavior and melt interaction with concrete.
2. The complex of measuring equipment will be developed for the diagnosis of melt temperatures, thermal fields in concrete. Calibration and methodical tests will be conducted and measuring equipment complex capacity for work will be checked. The developed complex will be applied to diagnose experiments using the large-scale installation.
3. Physical and mathematical and computer models will be developed for calculations of thermal fields in melt and concrete, calculations of melt parameters, melt interaction with concrete. Calculated assessments will be performed for heating melt and concrete. Calculations of parameters of melt and interaction of melt with concrete will be made**.**

The given Project implementation will make it possible to study large-scale processes of the interaction of corium with concrete, and to strengthen an existing multi-barrier security system of NPP with the reactors of PWR type.

2. Expected Results and Their Application

In the course of the fulfillment of the work the results will be achieved, which can be used to assess the resistance of structural units, including space beneath a reactor, to the effect of melt of a material of nuclear reactor core melt (corium) in the case of a hypothetical severe accident bringing about melt-through of reactor body (casing). The study of thermal and physical processes and mechanical processes of melt interaction will enable us to recommend a choice of the most promising materials and optimization of their composition when developing catchers for the melt for the NPP under design and check and improve the available computation programs (codes) of melt interaction with materials as well.

2.1. Sustainability Implementation Plan

2.1.1. Results to be promoted

Development of a method and a technology for conducting a large-scale experiment in order to study the interaction of corium melt with materials of NPP structural units. Checking of resistance of refractory materials and concretes applied for constructing NPP.

2.1.2. Uniqueness of results

Performance of a large-scale experiment under the conditions similar to the real ones to a maximum extent. Modeling of corium composition.

2.1.3. Demand for results

Determination of resistance of existing NPP in the case of a hypothetical severe accident, leading to melt-through of reactor body (casing). Assessment of aftereffects of propagation of radioactivity if it spreads beyond NPP during a severe accident.

2.1.4. Expected income

Organization of work on setup and performance of additional experiments to check resistance of NPP design elements (melt catchers, reactor body etc.) will make it possible to create a testing center producing a profit.

2.1.5. IPR situation

The question is settled with regard to the recognition of a technique for creating the heating of great masses of melt by means of invention.

2.1.6. Additional developments

Suggested ISTC Project implementation and participation in international conferences and exhibitions will enable materials under development to meet the international level of requirements for NPP (Nuclear Power Plant) design and assessments of NPP resistance\stability during severe accidents.

2.1.7. Plan of implementation

Copyright licensing.

2.1.8. Additional licenses or permits

Patenting in the USA and European Community.

2.1.9. Business network

There are business contacts with Hydropress and Atomenergoproject.

### 3. Meeting ISTC Goals and Objectives

During the Project implementation, 84 developers of nuclear weapon technologies (from 180 participants of the Project) will be involved into the activity unconnected with military programs. The efforts of the weapon developers are 12976 man-days, that is ~70 % of the total efforts.

The Project implementation will support the development of applied research and technologies in the field of the safety control of nuclear and chemical industries.

The results achieved during the given Project implementation can help the enterprises producing military products to go on to the industrial production of civil products.

The Project implementation will contribute to the international collaboration on the systems designed to provide nuclear power engineering safety.

### 4. Scope of Activities

#### Task1. Development of the large-scale installation for heating and retention of reactor core melt with characteristics: melt volume ~150 L, melt mass ~1200-1300 kg, melt temperature ~2500-3000C, heat fluxes towards walls and a bottom of a catcher ~100 kw/m2, melt retention time 1-2 hours. The performance of the experiments. Period of implementation: 1-6 quarters.

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| **Task description and main milestones** | | **Participating Institutions** |
| **1. To manufacture units, to mount a catcher and a system for throwing pyrotechnic briquettes into melt.**  **2. To develop the manufacturing technique for pyrotechnic briquettes.**  **3. To mount a measuring complex for diagnosing melt temperatures, thermal fields and catcher elements.**  **4. To test and perfect technology of melt heating and melt temperature retention.**  **5. To conduct the large-scale experiments on study of melt behavior and melt interaction with concrete.**  **6. To analyze the results of the experiments.**  **7. To develop technology of fragmentation and waste recovery of experiments.** | | 1 – RFNC-VNIIEF  2 - IVTAN |
| **Description of deliverables** | | |
| 1 | Manufacturing of units, mounting of a catcher and a measuring complex. Conduction and analysis of large-scale experiments on melt behavior and melt interaction with catcher materials. (Report on items 1-6; 6 quarter). | |
| 2 | Manufacturing of units, mounting of a catcher and a measuring complex. Analysis of experimental results. (Report on items1,6; 6 quarter). | |

#### Task2. Development of the measuring equipment complex for the diagnosis of melt temperatures, thermal fields in concrete. Period of implementation: 1-6 quarters.

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| **Task description and main milestones** | | **Participating Institutions** |
| **1. To test and perfect an optical-electronic system for measuring temperatures with the wide spectrum of radiation on the basis of highly sensitive thermal resistors, thermal elements and thermopairs. To develop optical and electronic systems for measuring temperatures with the direct measurement of a signal on a radiation receiver with a limited spectrum sector based on photodiodes.**  **2. To develop 4-channel optical pyrometer for measuring temperatures in the range of 1500÷3500 Ê. To develop the design documentation on optical input, the principal electric scheme of the amplifier of a signal on a photoreceiver and a power supply unit.**  **3. To develop the design documentation on radiation receivers models, their production and preparation for conducting methodical tests.**  **4. To conduct the calibration and methodical tests and to check the measuring equipment complex capacity for work. The complex is to diagnose the melt temperatures, thermal fields in concrete. Test results analysis.**  **5. To adjust the constructions of the model devices for the measuring optical system that provides the effective registration of the melt temperatures, thermal fields in concrete.** | | 1 - RFNC-VNIIEF |
| **Description of deliverables** | | |
| 1 | Development of the measuring equipment complex and conduction of the calibration tests on measuring melt temperature and thermal fields. (Report on 1-5 units; 6 quarter). | |

#### Task 3. Development of the physical and mathematical and computer models for calculating thermal fields in melt and concrete, melt parameters, melt interaction with concrete. Period of implementaiton:1-6 quarters.

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| --- | --- | --- |
| **Task description and main milestones** | | **Participating Institutions** |
| 1. **To choose experimental and computational data on the physical and chemical properties of the structural materials of the catcher.** 2. **To develop the physical and mathematical model of the heat transfer in the melt.** 3. **To develop computational methods and a computer program for calculating the heat transfer in the melt.** 4. **To develop the physical and mathematical model for the melt interaction with the structural materials of the catcher and heat transfer in the catcher.** 5. **To develop computational methods and a computer program for calculating the melt interaction with the structural materials of the catcher and heat transfer in the catcher.** | | 1 – RFNC-VNIIEF  2 - IVTAN |
| **Description of deliverables** | | |
| 1 | Development of the computational models and computer programs for calculating the heat transfer in the melt. Development of the computational models and computer programs for calculating the melt interaction with the structural materials and the heat transfer in the catcher. (Report on 2-5 items; 6 quarter). | |
| 2 | Choice of the thermal physical parameters of the structural materials and the development of the heat transfer models. (Report on 1-2 items; 6 quarter). | |

### 5. Role of Foreign Collaborators/Partners

The role of collaborators will be the following:

1. participate in project site visits arranged by ISTC;
2. help in organizing Project personnel visits to the collaborators;
3. review all Project documents and reports;
4. conduct regular reviews of the progress of the work throughout the Project effort;
5. provide recommendations on the implementation and direction of the work to ensure that the Project goals as set out in the work plan are met;
6. provide any information about the articles published and conferences on the subject of the Project;
7. edit the final report to ensure that the tasks were fulfilled properly and that a quality of their decision is high.

A supervisory committee including Project personnel and collaborators will be organized to contact with the collaborators constantly.

### 6. Technical Approach and Methodology

Within the work over the Project in RFNC-VNIIEF we are going to install the large-scale installation for melt heating and retention, which is similar to the nuclear reactor core melt, with the system of temperature diagnosis. We are going to conduct computational and experimental research at the installation that heats and retains the melt similar to the real nuclear reactor core melt.

The physical and mathematical and computer models for calculating the melt behavior, melt interaction with concrete, thermal fields in catcher designs will be developed in RFNC-VNIIEF and IVTAN. Calculating assessments will be performed for heating various elements of a catcher design. Calculations of parameters of melt and melt interaction with concrete will be made**.**

At the numerical realization of the physical and mathematical models developed there will be applied the explicit methods of solving the given systems of equations, implicit methods and the methods of classification on physical processes along with the combinations of all the methods above. The methods will be realized in 1D, 2D and 3D programs designed to make calculations on standard PC.

The work will be implemented taking into account the results obtained to date both in Russia and abroad.

### 7. Technical Schedule

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Quarter 1** | **Quarter 2** | **Quarter 3** | **Quarter 4** | **Quarter 5** | **Quarter 6** | **Person\*days** |
| **Task 1** |  |  |  |  |  | 2 Reports |  |
| **Subtask 1** |  |  |  |  |  |  |  |
| **Subtask 2** |  |  |  |  |  |  |  |
| **Person\*days** | **1373** | **1373** | **1374** | **1374** | **1374** | **1374** | **8242** |
| **Task 2** |  |  |  |  |  | Report |  |
| **Person\*days** | **529** | **529** | **529** | **529** | **529** | **530** | **3175** |
| **Task 3** |  |  |  |  |  | 2 Reports |  |
| **Person\*days** | **1203** | **1203** | **1204** | **1204** | **1204** | **1204** | **7222** |
| **TOTAL** | **3105** | **3105** | **3107** | **3107** | **3107** | **3108** | **18639** |