PROJECT ARRANGEMENT NE-08

among
The Department of Energy of the United States of America,
The Japan Atomic Energy Agency
and
The Central Research Institute of Electric Power Industry
under the
Implementing Arrangement between the Ministry of Economy, Trade and Industry of Japan and the Department of Energy of the United States of America Concerning Cooperation in the Field of Nuclear Energy-Related Research and Development
for
Cooperation on Advanced Reactor Research and Development
(Metal-Fueled Fast Reactor Accident Analysis)

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1. Objective

The Department of Energy of the United States of America (DOE), the Japan Atomic Energy Agency (JAEA) and the Central Research Institute of Electric Power Industry (CRIEPI), collectively hereinafter referred to as the "Participants";

Acting in accordance with Sections 4 and 5 of the "Implementing Arrangement between the Ministry of Economy, Trade and Industry of Japan and the Department of Energy of the United States of America Concerning Cooperation in the Field of Nuclear Energy-Related Research and Development" of May 3, 2013 (hereinafter referred to as the "Implementing Arrangement");

Have decided to undertake a cooperative effort under this Project Arrangement to perform advanced reactor research and development.

2. Scope of Work

The scope of work under this Project Arrangement is as follows:

(1) Metal-Fueled Fast Reactor Accident Analysis
   a. Core Bowing Reactivity Evaluation
   b. Analysis of Core Damage for Metal Fueled Fast Reactors
   c. Mechanistic Source Term Assessments

3. Project Management

3.1 Each Participant is to designate a Project Coordinator and a Principal Technical Contact. The Project Coordinators are to be responsible for detailed management, including technical progress reviews, of the cooperation under this Project Arrangement. The Principal Technical Contacts serve as the points of contact concerning technical details.

3.2 The specific tasks to be conducted are identified in Appendix I and key personnel are identified in Appendix II of this Project Arrangement. Both Appendix I and Appendix II are to be updated as appropriate.

4. Financial Management

All costs resulting from the work carried out under this Project Arrangement are the responsibility of the Participant that incurs them. The ability of the Participants to carry out their specific tasks is subject to the availability of appropriated funds.

5. Intellectual Property

With respect to the protection and distribution of intellectual property rights and other rights of a proprietary nature created or furnished in the course of the cooperative activities under this Project Arrangement and the protection of business-confidential information exchanged under this Project Arrangement, the following paragraphs apply in addition to the paragraphs of the Intellectual Property Annex to the Implementing Arrangement.

5.1 Inventions

For the purpose of this Project Arrangement, "Invention" means any invention made in the course of the cooperative activities under this Project Arrangement which is or may be patentable or otherwise protectable under the laws of Japan, the United States of America, or any third country. In accordance with paragraph 3.B.(iii)(a) of the Intellectual Property Annex to the Implementing Arrangement, the Participants have decided that rights to an Invention made as a result of joint research conducted under this Project Arrangement, and allocation of benefits derived therefrom, are to be provided as follows:

- If an Invention is made solely by a Participant or its contractor, the Participant is to obtain all right, title and interest in and to such Invention in all countries.
- If an Invention is made jointly by (a) two or all of the Participants, (b) contractors of two or all of the Participants, or (c) a Participant(s) and a contractor(s) of the other one or two Participant(s), each Participant is to obtain all right, title and interest in and to such Invention in its own country. Allocation of the right, title and interest between JAEA and CRIEPI is to be settled by consultation between them as necessary. In third countries where two or all of the Participants intend to obtain the right to the Invention, the Participants are to be joint owners of such rights. The Participants may jointly apply to obtain and/or maintain the relevant rights. The Participants are to decide on appropriate cost sharing associated with obtaining and/or maintaining such rights.
- In any country where a Participant which is entitled to obtain the rights therein decides not to obtain such rights and interests, the other two Participants have the right to obtain such rights and interests. In such cases, the other two Participants are to decide on appropriate allocation of the rights and interests between them.
- Each Participant is to have, for its own research and development activities in the area envisaged under this Project Arrangement in its own country during the term of this Project Arrangement, a free right of use of Inventions, whether protected or not by intellectual property rights, owned by the other one or two Participant(s) and resulting from the joint

research performed under this Project Arrangement.

5.2 Copyright

Allocation of rights to an Invention and benefits derived therefrom stipulated in paragraph 5.1 above are to be applied *mutatis mutandis* to disposition of rights to copyrighted works created in the course of the cooperative activities conducted under this Project Arrangement.

6. General Consideration

This Project Arrangement is pursuant to and subject to the Implementing Arrangement, which is, in turn, pursuant to and subject to the arrangement between the Government of Japan and the Government of the United States of America concerning cooperation in the field of nuclear-related research and development, effected by the Exchange of Notes of March 9, 2012.

7. Commencement, Modification, and Discontinuation

7.1. This Project Arrangement is to commence upon signature by all of the Participants, and to continue for a ten (10) year period, unless earlier discontinued in accordance with paragraph 7.2, and may be extended or modified by all of the Participants' mutual written consent, provided that the Implementing Arrangement remains in effect.

7.2. This Project Arrangement may be discontinued at any time by all of the Participants' mutual written consent. Alternatively, it may be discontinued by at least sixty (60) days advance notification in writing from a Participant that wishes to discontinue its participation in this Project Arrangement to the other two Participants.

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APPENDIX I

Description of Tasks for Metal-Fueled Fast Reactor Accident Analysis

1. Outline and Responsibility of Tasks

The purpose of these activities is to contribute to the development of predictive analytical capabilities including in-vessel/ex-vessel event evaluations.

The tasks deal with modeling of Fast Reactor accident conditions including:

- review and mutual understanding of plant dynamic issues during design extension conditions,
- core bowing and radial expansion feedback mechanisms,
- initiating-phase of a severe accident with large-scale fuel failures, and
- mechanistic source term assessments during the accidents with core damage.

The collaborations involve:

- information exchange on physical and numerical models,
- joint research and continued development of simulation tools for specific items of common interests,
- benchmark exercises for accuracy evaluation of computational tools/methods, and
- validation of computational tools and methods by mutually complementary exchange of existing or new experimental data.

The scope of work under the Metal-Fueled Fast Reactor Accident Analysis activity includes:
Task 1: Core Bowing Reactivity Evaluation
Task 2: Analysis of Core Damage for Metal Fueled Fast Reactors
Task 3: Mechanistic Source Term Assessments
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- **Task 1: Core Bowing Reactivity Evaluation**:

In fast spectrum reactors, reactivity feedback due to core radial expansion and bowing can be a significant contribution among all reactivity feedback components. The net negative reactivity feedback at temperatures above the normal operating range is important during the unprotected accidents (anticipated transients without scram) to insure inherently safe response of the reactor. In 1990s, various low-fidelity evaluation methods for core bowing reactivity were developed and applied to a few benchmark problems and core-restraint system designs with mixed success. U.S. and Japan need on development of more mechanistic analytical capabilities that enable higher-fidelity assessments. Within the framework of extended U.S.-Japan bilateral collaboration

(CNWG), decision has been made to conduct the comparative study to demonstrate inherently safe response of fast reactor designs due, in part, to favorable reactivity feedback from core radial expansion and fuel assembly bowing.

The activities under Task 1 involve the following subtasks:

A. Continued development of U.S.' and Japan's core bowing structural analysis codes, and improvement of methods with higher fidelity approaches.
B. Application of these structural analysis capabilities to mutually agreed challenge problems such as the IAEA benchmark, ABR-1000 benchmark, and FFTF-like benchmark for code V&V.
C. Information exchange on development of coupled multi-physics analysis capabilities in application to transient core radial expansion including the thermal- and irradiation-induced creep effects.
D. Recovery of data from the U.S. core restraint test facility for validation. Demonstration of core bowing using instrumented multi-assembly tests to be conducted at CRIEPI.

- **Task 2: Analysis of Core Damage for Metal Fueled Fast Reactors**

Since the fast reactor cores are not in their most reactive configuration under normal operating conditions, managing the accidents that could lead to core damage and molten fuel motion is an important consideration to avoid hypothetical core disruptive accidents. The SAS4A (U.S.) and CANIS and SIMMER (Japan) codes are the analytical tools commonly used for the initiating-phase of a severe accident with large-scale fuel failures. Continued improvement of these analytical capabilities is essential to characterize the metal fuel core damage scenarios and insure that the initial fuel failures do not propagate to a severe core damage accident.

The activities under Task 2 involve the following subtasks:

A. Continued development of U.S. and Japan's codes for analysis of accidents with fuel failures.
B. Analysis of the CAFÉ experiments (Japan) and investigation of metal-fuel and steel-cladding eutectic formation impact using the out-of-pile CAFÉ experiments (U.S.).
C. Exchange and analysis of data from other out-of-pile experiments to investigate metal fuel melting and relocation behavior in a fuel pin bundle, penetration into lower core structure, etc. Analysis of experimental results at Argonne, and modeling of metal fuel melting and relocation by CRIEPI.
D. Numerical analysis to characterize fuel pin failure test conditions based on the past TREAT metal fuel tests. Development of the future metal fuel TREAT test program by U.S.

- **Task 3: Mechanistic Source Term Assessments**

It is anticipated that the advanced non-water-cooled reactors will rely on mechanistic source term (MST) assessments as an integral part of their licensing process. The expectation is that MST

assessments will provide a realistic representation of the potentially reduced offsite consequences associated with a much broader spectrum of accidents (beyond just the LBLOCA for LWRs) through the utilization of best-estimate models and tools. However, the use of an MST analysis as part of licensing will likely require substantial data and a high level of confidence in the radionuclide transport models employed.

This task seeks bilateral information exchange on current status of physical and numerical model development, identification of topics of common interest that are considered as key issues for MST assessments, and sharing of the available experimental data to achieve adequate confidence in source term predictions. Specifically of interest are the capabilities and data required to properly analyze the following phenomena:

- Identification and characterization of radionuclide inventory in a design and the analysis of a spectrum of accidents that could lead to core damage (as addressed in Task 2).
- Release of radionuclides from the failed fuel elements and their interactions with the coolant (compounds formed, solubility, etc.).
- Radionuclide behavior within the coolant (mixing, vaporization, surface effects, plate-out, etc.) and transport of gas/vapor bubbles through the coolant.
- Vaporization/condensation/deposition of radionuclides in the cover gas space, suspension of fission products in cover gas, and their eventual leakage to the containment.
- Vaporization/condensation/deposition/suspension of radionuclides in the containment and their eventual leakage to the environment.

The activities under Task 3 involve the following subtasks:

A. Continued development of U.S.' and Japan's MST analysis codes, and comparison of methods, data, and metal-fuel specific models.
B. Construction of experimental database for V&V and evaluation of the model performances for source term specific phenomena. Improvement of the physical and numerical models through validation of specific phenomena by experimental data from separate effect tests. Consideration of new, joint validation experiments.
C. Benchmark study for mechanistic source term assessments through application of the computational tools/methods.

2. Sites

The tasks will be conducted at:

1. Argonne National Laboratory (ANL) and Sandia National Laboratories (SNL)
2. JAEA's Oarai Research & Development Institute (ORDI) and CRIEPI's Nuclear Technology Research Laboratory

3. Schedule

Tasks		Year (2018-2027)									
		18	19	20	21	22	23	24	25	26	27
Task 1: Core Bowing Reactivity Evaluation	Task 1A	x	x								
	Task 1B	x	x	x							
	Task 1C		x	x	x	x	x	x	x	x	x
	Task 1D	x	x	x	x	x	x	x	x	x	x
Task 2: Analysis of Core Damage for Metal Fueled Fast Reactors	Task 2A	x	x	x	x	x	x	x	x	x	x
	Task 2B		x	x	x	x	x	x	x	x	x
	Task 2C			x	x	x	x	x	x	x	x
	Task 2D		x	x	x	x	x	x	x		
Task 3: Mechanistic Source Term Assessments	Task 3A	x	x								
	Task 3B			x	x	x	x	x	x		
	Task 3C				x	x	x	x	x	x	x

4. **Deliverables**

DOE, JAEA and CRIEPI will produce reports related to the outputs of the tasks.

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APPENDIX II

Key Personnel List

U.S. Department of Energy, National Nuclear Security Administration

1. DOE Headquarters

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2. National Laboratories

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Japan Atomic Energy Agency

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Central Research Institute of Electric Power Industry

1. Nuclear Technology Research Laboratory

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Signed in triplicate.

FOR THE DEPARTMENT OF ENERGY OF THE UNITED STATES OF AMERICA:

Signature: _____
p.p. Sal Golub

Name: John W. Herczeg

Title: Deputy Assistant Secretary for Nuclear Technology Research and Development

Date: 5/24/18

Place: OSAKA, JAPAN

FOR THE JAPAN ATOMIC ENERGY AGENCY:

Signature: _____

Name: Kazumasa Hioki

Title: Director, Office of Strategy and International Affairs

Date: 25 May 2018

Place: Osaka, Japan

FOR THE CENTRAL RESEARCH INSTITUTE OF ELECTRIC POWER INDUSTRY:

Signature: _____

Name: Mamoru Kanatani

Title: General Manager, Planning Group

Date: 14 May 2018

Place: Tokyo, Japan