PROJECT ARRANGEMENT NE-01

between
The Department of Energy of the United States of America
and
The Japan Atomic Energy Agency
under the
Implementing Arrangement between the Department of Energy of the United States of America and the Ministry of Education, Culture, Sports, Science and Technology of Japan Concerning Cooperation in the Field of Nuclear Energy-Related Research Development
for
Cooperation on Advanced Reactor Research and Development

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1. Objective

The Department of Energy of the United States of America (DOE) and the Japan Atomic Energy Agency (JAEA), referred to collectively herein as "Participants",

Acting in accordance with Sections 4 and 5 of the "Implementing Arrangement between the Department of Energy of the United States of America and the Ministry of Education, Culture, Sports, Science and Technology of Japan Concerning Cooperation in the Field of Nuclear Energy-Related Research and Development" of January 7, 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) Fast Reactor Materials
(2) Advanced Reactor Modeling and Simulation
(3) Metal Fuel Core

3. Project Management

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

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 will be updated as appropriate.

4. Financial Management

All costs resulting from the work carried out under this Project Arrangement will be 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 will 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, rights to an Invention made as a result of joint research conducted under this Project Arrangement, and allocation of benefits derived therefrom, are provided as follows:

- If an Invention is made solely by a Participant or a contractor (hereinafter referred to as the "Inventor"), the Inventor will obtain all right, title and interest in and to such Invention in all countries.
- If an Invention is made jointly by a Participant/contractor of both Participants, each Participant will obtain all right, title and interest in and to such Invention in its own country. In third countries where both Participants intend to obtain the right to the Invention, the Participants will be joint owners of such rights. The Participants may jointly apply to obtain and/or maintain the relevant rights. The Participants should come to an agreement concerning the costs associated with obtaining and/or maintaining such rights.
- In any country where the Inventor which is entitled to obtain the rights therein decides not to obtain such rights and interests, the other Participant has the right to do so.
- Each Participant will have, in its own country, for its own research and development activities within the scope of work of this Project Arrangement, during the term of this Project Arrangement, a free right of use of Inventions, whether protected or not by intellectual property rights, solely owned by the other Participant 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 will 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 agreement 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

1. This Project Arrangement will enter into effect upon signature by both Participants, continue for a three (3) year period, unless earlier discontinued in accordance with paragraph 7.2, and may be extended or modified by the Participants' mutual written consent, provided that the Implementing Arrangement remains in effect.

2. This Project Arrangement may be discontinued at any time by the Participants' mutual consent in writing. Alternatively, a Participant that wishes to discontinue its participation in this Project Arrangement should endeavor to provide at least sixty (60) days advance notification in writing to the other Participant.

Signed in duplicate.

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

Signature: John E Kelly

Printed Name: John E. Kelly

Title: Deputy Assistant Secretary for Nuclear Reactor Technologies

Date: Nov 1, 2013

FOR THE JAPAN ATOMIC ENERGY AGENCY:

Signature: 青砥紀身

Printed Name: Kazumi Aoto

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APPENDIX I-1

Description of Tasks for Fast Reactor Materials

1. Outline and Responsibility of Tasks

The objective of Fast Reactor Materials activity is to conduct research and development on advanced materials in support of code qualification and codes and standards development required to apply the materials to liquid metal fast reactors. Modified 9Cr-1Mo steel and its associated weldments are the focus of this task. Topics of interest are design allowables and creep-fatigue evaluation methods for 60-year design life, and creep-fatigue design rules for weldments with focus on Type IV cracking. Possibility of collaborative data acquisition will also be pursued.

The scope of work under Fast Reactor Materials activity is as follows:

Task 1: Data Exchange
Task 2: Design Allowables Extended to 60-year Design Life
Task 3: Improvement of Understanding of Creep-Fatigue Interaction and Creep-Fatigue Design Life
Task 4: Improvement of Understanding of Type IV Cracking
Task 5: Improvement of Understanding of Creep-fatigue Interaction and Creep-fatigue Design Life of Weldments

Task 1: Data exchange

The data exchange will be conducted with the following steps.

Step 1: Exchange a list of data obtained by each Participant which could be exchanged within the framework of the bilateral collaboration. The list would include data from tensile tests, creep tests, fatigue tests, creep-fatigue tests, and fracture toughness and crack growth tests of base metal, weld metal, welded joints, and heat-affected zone. Other relevant data would be included as well. The list should identify what kind of information is available for each test (for example, in the case of creep test, it should be identified if creep curve data, creep rupture time, steady state creep rate, time to tertiary creep, etc., are available or not). The list should also contain information on on-going and future test programs.

Step 2: Identify data that can be actually exchanged, maintaining equality based on the list made in Step 1. Set up a future exchange plan based on the planned test programs on both sides.

Step 3: Exchange the data identified in Step 2.

The subtasks include:

- Subtask 1.1. Perform Steps 1 to 3 for base metal.
- Subtask 1.2. Perform Steps 1 to 3 for weld metal and weldment.
- Subtask 1.3. Perform Steps 1 to 3 for additional data.

Task 2: Design allowables extended to 60-year design life

This task involves a joint effort in developing mechanism-based predictive models for data extrapolation is of interest to both sides. The subtasks include:

- Subtask 2.1. Perform thermodynamic and kinetic modeling of microstructural evolution during thermal aging to develop a better understanding of the thermal aging effects for reliable data extrapolation to the 60-year design life. Areas include precipitation and coarsening kinetics and synergistic effects of thermal aging and mechanical loading. Where possible, perform with experimental validation. (DOE/JAEA)[1]
- Subtask 2.2. Develop mechanistic models to correlate microstructural changes with associated mechanical properties during long-term thermal aging. Where possible, perform confirmatory tests of aged Modified 9Cr-1Mo specimens to validate the model. (DOE/JAEA)
- Subtask 2.3. Propose accelerated testing techniques to accurately assess material behavior in relatively short time periods and in simulated reactor operating conditions. These techniques need to be based on improved understanding of thermal aging effects and mechanistic models. (DOE/JAEA)
- Subtask 2.4. Develop a mechanisms-based methodology for constructing long-term (60 years) creep fracture maps that support extension of time-dependent allowable stresses by using analytical methods such as mechanisms-based micromechanical finite element analyses and creep fracture data. (DOE/JAEA)
- Subtask 2.5. Investigate long-term thermal aging effect on fracture toughness. (DOE/JAEA)

Task 3: Improvement of understanding of creep-fatigue interaction and creep-fatigue design life

This task involves a joint effort on the improvement of creep-fatigue design methods. The subtasks include:

- Subtask 3.1. Improvement of bilinear creep-fatigue damage rule.
    - Subtask 3.1.1. Identify stress relaxation data necessary to validate/improve the current creep-fatigue diagram. If they are not available in the database established in Task 1, make a plan of creep-fatigue tests. Where possible, perform creep-fatigue tests at selected

[1] DOE leads the effort

test temperatures and hold times to obtain the stress relaxation data. (JAEA/DOE)[2]

  - Subtask 3.1.2. Analyze creep-fatigue test data to provide proper data for creep-fatigue linear damage rule modeling. If sufficient data are not available in the database established in Task 1, make a plan of creep-fatigue tests. Where possible, perform creep-fatigue tests. (DOE/JAEA)

- Subtask 3.2. Consider other creep-fatigue interaction models. (JAEA/DOE)

- Subtask 3.3. Develop mechanistic predictive models of creep-fatigue interaction that incorporate cyclic softening effects. (DOE/JAEA)

Task 4: Improvement of understanding of Type IV cracking

This task involves a joint effort on improving the understanding of the mechanisms of Type IV crack initiation and growth under creep-fatigue loading. The subtasks include:

- Subtask 4.1. Characterize microstructure of thermally aged or creep-tested weldments. (JAEA/DOE)

- Subtask 4.2. Perform thermodynamic and kinetic modeling of microstructural evolution under dynamic welding processes. Where possible, validate the model experimentally. (DOE/JAEA)

- Subtask 4.3. Mapping of microstructure in the heat-affected-zone and its associated tensile properties to provide valuable information in understanding weldment cracking under mechanical and thermal loading. (DOE/JAEA)

Task 5: Improvement of understanding of creep-fatigue interaction and creep-fatigue design life of weldments

This task involves a joint effort on the improvement of creep-fatigue design rules. The subtasks include:

- Subtask 5.1. Improvement of bilinear creep-fatigue damage rule.

  - Subtask 5.1.1. Analyze creep-fatigue test data at selected test temperatures and hold times to obtain stress relaxation data to validate/improve the current creep-fatigue diagram. If data are not sufficiently available in the database established in Task 1, make a test plan. Where possible, perform tests. (JAEA/DOE)

  - Subtask 5.1.2. Analyze creep-fatigue tests to provide proper data for creep-fatigue linear damage rule modeling. If sufficient data are not available in the database established in Task 1, make a test plan. Where possible, perform tests. (JAEA/DOE)

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[2] JAEA leads the effort

- o Subtask 5.1.3. Analyze inelastic behavior of weldments including stress/strain distribution in base metal, weld metal and heat affected zone under conditions expected in practical applications. (JAEA and DOE[3])

- o Subtask 5.1.4. Develop a model for the effects of size of weldments and multiaxiality in weldments. (JAEA/DOE)

- Subtask 5.2. Evaluation of degradation mechanisms of weld at liquid metal reactor operating temperature for 60 years. (JAEA/DOE)

2. **Sites**

The tasks will be conducted at:

1. Oak Ridge National Laboratory, Oak Ridge, Tennessee, USA
2. Argonne National Laboratory, Argonne, Illinois, USA
3. Oarai Research and Development Center, Japan Atomic Energy Agency, Ibaraki, Japan

3. **Schedule**

		2013 CY*	2014CY				2015CY				2016CY			
Activity		Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Task 1	Data exchange, base metal	X	X	X	X	X								
	Data exchange, weld metal and weldment					X	X	X	X	X				
	Data exchange, additional data								X	X	X	X	X	X
Task 2	Design allowables	X	X	X	X	X	X	X	X	X	X	X	X	X
Task 3	Creep-fatigue (base metal)	X	X	X	X	X	X	X	X	X	X	X	X	X
Task 4	Type IV cracking					X	X	X	X	X	X	X	X	X
Task 5	Creep-fatigue (weldment)					X	X	X	X	X	X	X	X	X

* "CY" is Calendar Year, Q1: January-March, Q2: April-June, Q3: July-September, Q4: October-December

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[3] JAEA and DOE, co-lead

4. **Deliverables**

A joint progress report will be produced by DOE and JAEA on active tasks at the end of 2014CY and 2015CY. A joint final report for all tasks will be produced by DOE and JAEA.

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APPENDIX II-1
Key Personnel List

U.S. Department of Energy

1. DOE Headquarters

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APPENDIX I-2

Description of Tasks for Advanced Reactor Modeling and Simulation

1. Outline and Responsibility of Tasks

Numerical simulations have increasingly become powerful tools for phenomena elucidation, design optimization and safety margin rationalization against the background of the rapid progress of computer systems. The tasks deal with modeling and simulation on plant dynamics of sodium-cooled fast reactors (FRs) under various operating conditions from normal to severe accident conditions. The main objectives of the tasks are:

- review and mutual understanding of plant dynamic issues in the next generation sodium-cooled FRs and current levels of modeling and simulation for the issues, and
- active collaborations on specific items of common interests to promote development of FR plant simulation tools for rational design and safety assessment with high fidelity and reliability.

The tasks will be carried out for the efficient development of advanced simulation methods by utilizing both resources effectively and by sharing scientific knowledge and technical know-how concerning modeling and simulation. The ultimate aim of the tasks is to contribute to the development of comprehensive advanced numerical simulation systems for FR plant dynamic behavior analyses including in-vessel/ex-vessel event evaluations.

In the tasks, the following collaboration forms can be considered:

- information exchange on physical and numerical models in neutronics, thermal-hydraulics, structure mechanics as well as field coupling methods and platform techniques,
- mutually complementary exchange of simulation tools,
- joint research and development of simulation tools for specific items of common interests,
- construction of database for code Verification & Validation (V&V) by mutually complementary exchange of existing experimental data and, if necessary, by planning and performing new experiments, and
- benchmark exercises for accuracy evaluation of simulation tools.

Two tasks will be conducted with the following phases:

- Task 1: Collaboration toward the development of advanced comprehensive plant simulation systems that contribute to achieve the best possible balance between ultimate safety and economic competitiveness of FRs

Phase 1: Formulation of working plan

- Review and mutual understanding of plant dynamic issues that should be covered for the design, operation and safety assessments of next generation sodium-cooled FRs
- Information exchange on current status of physical and numerical models development (or computer codes) and available experimental data for the reviewed plant dynamic issues.
- Selection of subjects solvable by the bilateral collaboration
- Set-up collaboration working plans

Phase 2: Active collaboration based on the working plan

- Shift to active collaboration according to the working plan. (The term of this phase depends on the selected collaboration items and their plans.)

Examples of the collaboration items:

- Enhancement of the ex-vessel accident analysis program CONTAIN-LMR that was originally developed in Sandia National Laboratories and subsequently refined by JAEA
  - ➢ Although this program can be applied to most ex-vessel event analyses of FRs, uncertainties are still large. Simplified models (e.g., the sodium-debris-concrete interaction model) should be improved based on experimental data for higher prediction accuracy.
- Development of an advanced FR plant dynamic simulation system
  - ➢ As the first step, combination use of a plant system code and multi-dimensional core and upper plenum models (CFD code) is being investigated.

- Task 2: Collaboration on the development of multi-physics simulation methods that can be also utilized as parts of comprehensive FR plant simulation systems

Phase 1: Formulation of working plan

- Information exchange on current status of physical and numerical models development related to multi-physics phenomena, that are considered as key issues of sodium-cooled FR design and safety assessment, and on available experimental data for V&V
- Identification of issues and selection of subjects solvable by the bilateral collaboration
- Set-up collaboration working plans

Phase 2: Active collaboration based on the working plan

- Shift to active collaboration according to the working plan. (The term of this phase depends on the selected collaboration items and their plans.)

Examples of the collaboration items:

- Development and V&V of multi-physics mechanistic numerical simulation methods
  - ➢ Mechanistic simulation methods have been developed for the evaluation of sodium fire and sodium-water reaction phenomena. Construction of experimental database

for V&V and evaluation of the model performances. Improvement of the physical and numerical models.

2. **Sites**

The tasks will be conducted at:

1. Argonne National Laboratory (ANL)

2. Oarai Research & Development Center (ORDC)
   FBR Safety Technology Center (FSTC)

3. **Schedule**

		2013 CY	2014CY				2015CY			
Activity		**Q4**	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**
Task 1-1	Phase 1 (Review & WP Set-up)	X	X	X	X	X				
Task 1-2	Phase 2 (Active collaboration)					X	X	X	X	X
Task 2-1	Phase 1 (WP Set-up)	X	X	X						
Task 2-2	Phase 2 (Active collaboration)			X	X	X	X	X	X	X

(Phase 2 may be continued after 2015CY. The term depends on selected collaboration items and their plans.)

4. **Deliverables**

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

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APPENDIX II-2

Key Personnel List

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APPENDIX I-3
Description of Tasks for Metal Fuel Core

1. Outline and Responsibility of Tasks

Task 1: Metal fuel core design

The objective of task 1 is to verify methodologies and computer codes used for the calculation of reactivity coefficients in metal fuel sodium cooled fast reactor aiming at enhancing the utilization of plutonium and minor actinides, and to compare conceptual metal fuel core design of each party.

(a) Core design benchmark
- Conduct a benchmark analysis of a reference metal fuel core with latest library and method.

(b) Conceptual core design study
- Conduct a conceptual design study utilizing the characteristics of metal fueled core.

Task 2: Safety performance of metal fuel core

The objective of task 2 in the first phase (phase 1) is to assess the safety characteristics of metal fuel core, by confirming metal fuel core safety features as represented by fuel failure mode during transient and, radial expansion and its associated reactivity coefficient. In the second phase (phase 2), CDA prevention scenario for metal fuel SFR will be studied based on the safety properties of metal fuel core obtained by the past experiments and/or future experiments as necessary.

The phase 1 is estimated to take 3 years. Based on the results of phase 1, the determination as to whether or not to proceed to phase 2 should be done. The items in phase 2 will be reviewed reflecting the outcomes of phase 1

(a) Investigation on metallic fuel element failure mode

Phase 1
- Validation of metallic fuel element failure behavior models during Transient Over Power (TOP) and Loss of Flow (LOF) using experimental data (e.g., TREAT, WPF).
- Examine test plans for validation of post-failure metal fuel element dispersal behavior during LOF. Examine in-sodium ex-reactor heating test plan and/or in-core nuclear heating test plan of irradiated fuel pins.

Phase 2
- Joint experiment and evaluation

(b) Investigation on the effect of core radial expansion

Phase 1

- Validate radial expansion effect using related experimental data
- Examine in-core or ex-core experiment plans for validation of radial expansion effect.

Phase 2

- Joint experiment and evaluation

(c) Study on safety characteristics

Phase 1

- Share the perceptions on safety performance of the metal fuelled reactor system, considering the safety properties for metal fuel, which are different from that of oxide fuel.
- Conduct simplified examination of Core Disruptive Accident (CDA) prevention scenario

Phase 2

- Examine CDA prevention scenario for metal fuel SFR in case of Anticipated Transient Without Scram (ATWS).
- Confirmation of CDA prevention scenario
- Core design taking into account the inherent safety properties of metal fuel core.

Task 3: MA,RE bearing metal fuel irradiation tests in « Joyo »

The objective of task 3 is to demonstrate performance and reliability of Minor Actinides, Rare Earths (MA,RE)-bearing metal fuel in normal and off-normal condition and to accumulate necessary data for industrial applications of fuel cycle and for safety licensing of metal fuel reactor.

The phase 1 is estimated to take 3 years. Based on the results of phase 1, the determination as to whether or not to proceed to phase 2 should be done. The items in phase 2 will be reviewed reflecting the outcomes of phase 1.

(a) Examination of irradiation test plan

Phase 1

- Examine test specimens (e.g. fuel specimen fabrication and specification, target discharge burnup, post-irradiation examination (PIE) plan)
- Examine test design (e.g. capsule assembly, fuel rodlet assembly, pin sale assembly)

Phase 2

- Test preparation, irradiation test, PIE and evaluation

(b) Pre-test analysis

Phase 1

- Conduct pre-test analysis for irradiation tests

Phase 2

- Conduct pre-test analysis for open core irradiation tests

(c) Examination of open core irradiation test plan

Phase 2

- Examine test specimens (e.g., fuel specimen fabrication and specification, target discharge burnup, post-irradiation examination plan)
- Examine test design
- Examine open core (standard type) irradiation test possibility and the application for Joyo modified license approval.
- Prepare Joyo modified license approval
- Test preparation, irradiation test, PIE and evaluation

2. **Sites**

The tasks will be conducted at:

1. Argonne National Laboratory (ANL)
   Idaho National Laboratory (INL)

2. Oarai Research and Development Center (ORDC)

3. **Schedule**

		2013 CY	2014CY				2015CY				2016CY			
Activity		Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Task 1	Phase 1	X	X	X	X	X	X	X	X	X				
Task 2	Phase 1	X	X	X	X	X	X	X	X	X	X	X	X	X
Task 3	Phase 1	X	X	X	X	X	X	X	X	X	X	X	X	X

* Determination as to whether or not to proceed to Phase 2 may be done in 2016CY.

4. **Deliverables**

DOE and JAEA will produce reports related to the phase 1 works of tasks 1, 2 and 3, by the end of 2016CY.

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APPENDIX II-3

Key Personnel List

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