CURRENT STATUS OF GLOBAL ACTINIDE CYCLE INTERNATIONAL DEMONSTRATION PROJECT

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Abstract

The current status of the Global Actinide Cycle International Demonstration (GACID) Project, being conducted under the GIF/SFR System Arrangement signed on February 15, 2006, has been summarized. The Project Arrangement for GACID was signed on September 27, 2007 and the following activities are underway as a part of the five years' effective period of the Arrangement: MA-bearing fuel raw material preparation, fuel fabrication, material property measurement, precedent irradiation tests in Joyo, irradiation behavior modeling and licensing study for pin-scale irradiations in Monju and Joyo, and program planning for future bundle-scale demonstration in Monju.

I. INTRODUCTION

Recovering and recycling the Minor Actinides (MAs), such as Neptunium (Np), Americium (Am) and Curium (Cm), with conventional Uranium (U) and Plutonium (Pu) in the spent fuel is generally called 'Actinide Recycle' or 'TRU Recycle' and the research and development (R&D) activities for its future commercialization are underway in several nations.

Actinide recycle (TRU recycle) has a potential to reduce the geological repository burden of the high-level radioactive waste. Moreover, an idea is being proposed that actinide recycle can drastically reduce the potential radioactive hazard in a timeframe of over thousands of years, thus significantly contribute to enhance the public understanding and acceptance of the radioactive waste and fuel cycle. More than several millions of years will be necessary to reduce the potential radioactive hazard of the current vitrified high-level radioactive waste, which assumes only U and Pu recycling, to the same radioactive-hazard level of the original U ore. On the contrary, this time period can be shortened to several hundreds of years by the actinide recycling, as shown in Figure 1.

At the same time, nuclear fuel materials containing MAs have some difficulties of their accesses, because Am is a gamma-ray emitter, and Cm is a neutron emitter and also a heat source. Another viewpoint is being discussed that the need for an inaccessible separation work of the chemically similar elements for pure Pu separation can contribute to the nuclear non-proliferation policy.

Background R&D activities for actinide recycle research in France, the United States of America (US) and Japan, which are participating in the GACID Project, will be briefly reviewed, at first. Then the Project Plan and the current status of the Project will be reviewed and summarized.

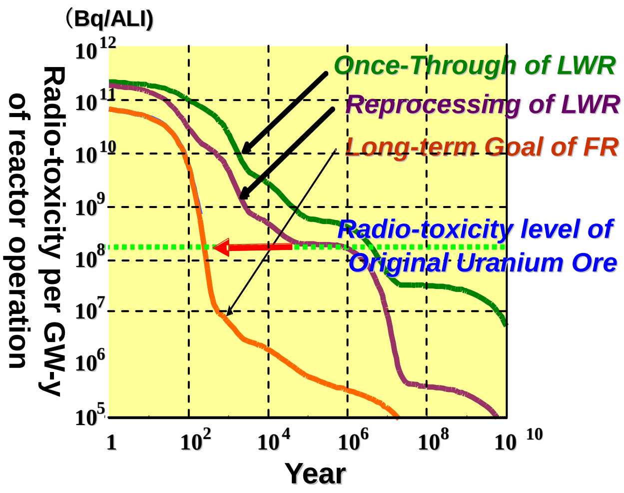

Figure 1: Potential Radioactive Hazard of High-level Radioactive Waste

II. BACKGROUND ACTIVITIES IN FRANCE[1]

The construction and operation experiences of a series of Fast Breeder Reactors (FBRs), such as Rapsodie (Thermal Power: 40 MWt, Initial Criticality: January 1967, Closed: January 1983), Phenix (Electric Power: 250MWe, Initial Criticality: August 1973, to be shutdown in 2009) and Super Phenix (Electric Power: 1 200 MWe, initial Criticality: September 1985, Closed: February 1998) have already been accumulated in France. These experiences will provide technical bases for the future sodium-cooled FBR development. Gas-cooled FBR is positioned in France as an alternative future option with the potential to combine the advantages of fast neutrons and possibly high temperature process heat generation.

As a result of French June 2006 Act on the sustainable management of waste, CEA is committed to evaluate by 2012 the industrial feasibility of MA actinide transmutation in GEN IV systems and in particular in SFR. For that, the various possible options for MAs recycling in a SFR will be evaluated. This includes the homogeneous recycling of MAs diluted in the standard fuel which is the objective of the GACID project, and the heterogeneous mode of recycling, in which MAs are concentrated in specific subassemblies (SA). For this option the preferred choice is to introduce them in a UO_2 matrix which means that MAs are recycled at core periphery in blanket SAs.

Basic pin-scale irradiation tests on MA-bearing Mixed Oxide (MOX) fuel have been carried out since the 1980's in France (SUPERFACT Program which still constitutes a reference experiment). Several experiments on MAs heterogeneous recycling were performed in Phenix this decade and have finished their irradiation now; their Post-Irradiation Examinations (PIEs) will bring interesting original results. Moreover, a radioactive-waste management scenario was proposed to the French Congress by the CEA in 2006, based on the Radioactive-Waste-Management Study Act.

The scenario fundamentally proposed is to separate the MAs form Fission Products (FPs) in the spent fuel, and to vitrify and to geologically reposit only the FPs. A concept is being proposed, as a first step, to construct a pilot-scale MA-fabrication plant in an existing commercial-based reprocessing plant for the engineering-scale demonstration of the MA fabrication technology from the high-level radioactive waste. Although this concept is a preliminary proposal, to produce a kg-order amount of MAs (Am in a first step) in this pilot-scale plant, to mix a part of it into a MOX fuel and to demonstrate the technical feasibility on an engineering scale by a bundle-scale MA-bearing fuel demonstration irradiation in an actual reactor, such as Monju, is being discussed, as shown in Figure 2.

In addition, the former President Chirac issued a communiqué in January 2006, saying that a Generation IV prototype reactor shall be commissioned in 2020 in France.

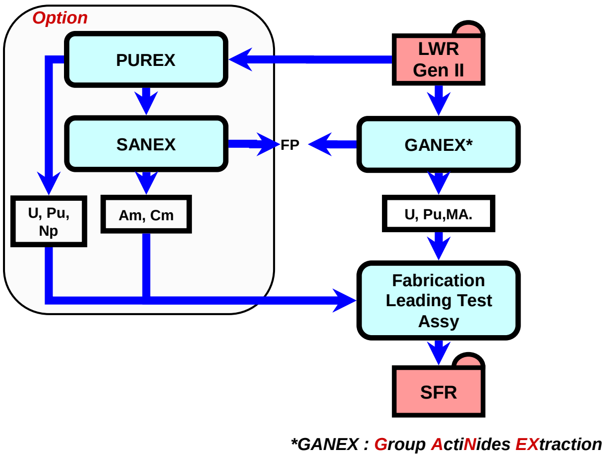

Figure 2: A Concept of MA-bearing Fuel Engineering-scale Demonstration in France

III. BACKGROUND ACTIVITIES IN THE U.S.A.[2]

The Generation IV International Forum (GIF) Project was established in July 2001, based on the activity of the US Department Of Energy (DOE) to promote the development of the next-generation reactor by international collaboration. This Project promotes the selection of the next-generation reactor concept in an international collaborative framework, based on the contributions of the participating nations.

At the same time, not only the reactor concept but also the corresponding next-generation reprocessing system is being developed by each participating nation. The Advanced Fuel Cycle Initiative (AFCI) Project is being conducted in the US to complement the GIF Project in parallel. The concept of the actinide recycle, based on the fast reactor system, is considered as one of the most promising candidates in the GIF Project due to its excellent advantages in natural-resource-utilization efficiency and environmental-burden reduction, that is sustainability, and proliferation resistance.

The AFCI program performs the research and development activities needed for a high proliferation resistant and advanced fuel recycling technology while minimizing the amount of the radioactive waste. A concept is being proposed, in parallel, to organize an international consortium by the fuel-supplier nations and to assure the fuel supply to the fuel-user nations, which commit the use of the nuclear power only for peace.

The actinide recycle scheme, which recovers and recycles the MAs together with U and Pu, is being assumed as a key candidate for advanced fuel recycling while maintaining a high proliferation resistance. Early demonstration of MA transmutation by MA-bearing fuel in actual reactors, such as Joyo or Monju, will help to promote the AFCI fuel cycle concept.

IV. BACKGROUND ACTIVITIES IN JAPAN[3]

The Fast Breeder Reactor Commer–cialization Strategic Study (FS) has been conducted in Japan since July 1997 and the final report was issued in July 2006 by Japan Atomic Energy Agency (JAEA) and Electric Power Utilities as a result of the Phase-II study. The TRU recycle (actinide recycle) scheme has been introduced from the viewpoints of environmental-burden reduction and proliferation-resistance enhancement, based on the FS's design requirements. Moreover, Low Decontamination (LD) fuel concept was being pursued, which allowed for residual FPs to simplify and to reduce the reprocessing procedures. This TRU and LD fuel concept is one of the reference concepts in the Fast Reactor Cycle Technology Development (FaCT) Project, which took over the FS Project.

The fabrication of such a TRU and LD fuel needs to be performed in a hot cell with sufficient radiation protection and heat removal, because of the MAs and FPs in the fresh fuel raw material.

For the commercialization of this MA-bearing fuel technology, engineering-scale pilot plants are to be constructed, and the technical feasibility of the reprocessing and fuel fabrication procedures should be demonstrated on an engineering scale. Six MA-bearing fuel pins have already been fabricated and irradiated in Joyo, and approximately 650 MOX fuel pellets, including MA-bearing fuel pellets, have already been sintered in a hot cell of JAEA by remote operation. However, these experiences are on an experimental scale and not sufficient for the commercialization of the technology. An engineering-scale demonstration of the reprocessing and fuel fabrication procedures is one of the issues to be resolved in the future.

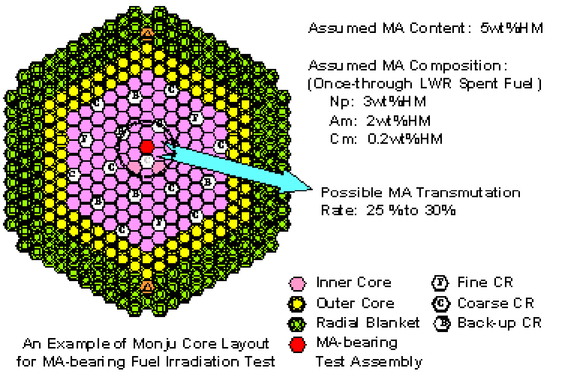

Figure 3: An Example of MA-bearing Fuel Irradiation Test Concept in Monju

At the same time, an engineering-scale irradiation demonstration of the MA-bearing fuel is also needed for the commercialization. Pin-scale experimental irradiations can be performed in Joyo, while the bundle-scale engineering demonstration irradiation is desired to be performed in a larger-scale reactor, such as Monju, as shown in Figure 3.

However the bundle-scale demonstration irradiation of MA-bearing fuel in Monju requires engineering-scale pilot plants for the reprocessing and fuel fabrication, which will need a certain period of time and budget for the preparation. International collaboration was considered to have the potential to reduce the necessary period of time for the bundle-scale demonstration.

On the other hand, Monju is the Japanese prototype FBR with an electric power of 280 MWe and its safety regulation is basically based on that of the current commercial-based electric-power-generation reactors. Precedent experimental data is needed by Joyo irradiation tests for the licensing in Monju.

Therefore a series of irradiation tests in Joyo and Monju was being planned to be discussed and succeeded to the GACID Project as shown below.

V. PROJECT ARRANGEMENT FOR GACID

The Project Arrangement (PA) for GACID was signed by the participating three Signatories, CEA France, USDOE and JAEA Japan on September 27, 2007, under the GIF Sodium-cooled Fast Reactors (SFR) System Arrangement signed on February 15, 2006. The discussions on the Project Plan were initiated in June 2004, in Tokyo among the specialists from CEA, USDOE and JAEA. Figure 4 shows the overview of the whole GACID Project conceptual scheme, as a result of the thorough discussions.

A series of irradiation tests in Joyo and Monju in three steps was proposed by JAEA and the Project Plan was determined to conduct the following irradiations.

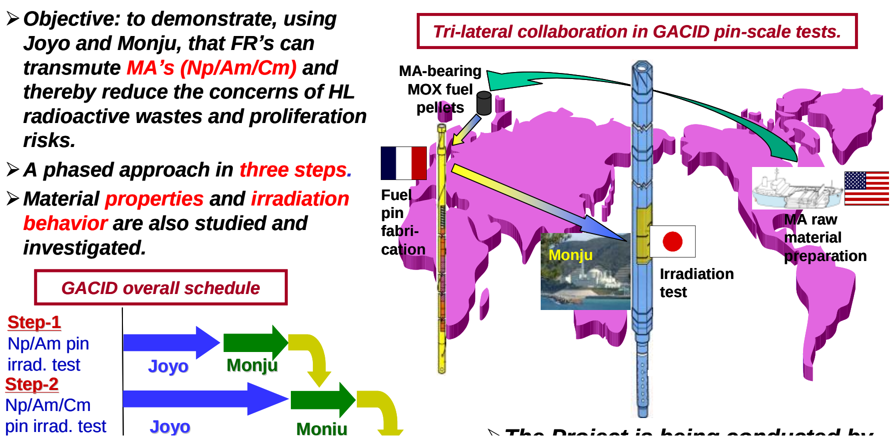

Figure 4: Overview of the GACID Project Conceptual Scheme

(1) Step-1: Precedent Limited MA-bearing Fuel Preparatory Irradiation Test

This test assumes Np-237 and Am-241 only as for the MAs. The radiation and heat source intensities of these isotopes are not so strong. Moreover only a single pin-scale irradiation test in Monju is planned, while the precedent Joyo irradiation tests are already underway. Therefore this test is expected to be implemented at an earliest stage of the Project, because the test fuel can be prepared by a minimum effort of only a small amount of the MA raw materials with minimal additional radiation protection for the bundle assembling. Although the MA isotopes are limited, the fundamental framework for the subsequent future MA-bearing fuel irradiation tests is expected to be established by this precedent test, as a model case of the irradiation tests in Monju.

All the necessary procedures for the MA-bearing fuel irradiation tests in Monju will be experienced as follows:

- MA raw material preparation and shipping.
- MA-bearing MOX fuel pellet sintering.
- Material property measurement and design correlation validation by measured data.
- Precedent Joyo irradiations and PIEs,
- Irradiation behavior modeling and design model validation by irradiation test data.
- Licensing in Monju.
- Test pellet and pin fabrication and shipping.
- Test bundle assembling and shipping, and
- Irradiation in Monju and PIE.

The basic geometries, dimensions and structures of the test assembly will be the same as the ordinary Monju driver fuel. Only the fuel composition of a single fuel pin in a bundle will be different. This concept will also contribute to the earliest implementation of the test.

(2) Step-2: Pin-scale Cm-bearing Fuel Irradiation Test

A full-range of MA composition is assumed for this test. Not only Np and Am but also Cm will be contained in the test fuel, although the test will be conducted on a pin scale. Gamma-ray and neutron radiation from Am-243 (From daughter nuclide: Np-239) and Cm-244 will no longer be ignored in this test. However only a single pin fabrication and irradiation will allow for the easier management of raw material preparation, radiation protection and heat removal issues. A precedent irradiation test in Joyo is being planned for the Monju irradiation licensing.

Fabrication and irradiation of Cm-bearing MOX fuel will be the world’s first trial.

(3) Step-3: Bundle-scale MA-bearing Fuel Irradiation Demonstration

After completing the above mentioned two steps of the precedent irradiation tests, the final goal, bundle-scale full-range-MA-bearing fuel irradiation demonstration, will be performed in Monju. Engineering-scale pilot plants for MA raw material preparation and MA-bearing fuel fabrication and assembling will be needed for this demonstration. Therefore the technical demonstration will be done in a reasonable time frame and the whole Project is to be conducted over a period of 20 years.

On the other hand, the effective period of time of the current PA is 5 years, with a first milestone two years after the PA signature to decide on the feasibility of pursuing the remaining tasks included in the original five years of the Project. Therefore the purpose of the current PA is to conduct collaborative R&D with a view to demonstrate the MA incineration capability of fast reactors on an engineering scale with a MA-bearing MOX fuel.

The schedule and allocations of activities during the initial 5 years of the Project are shown in Figures 5 and 6.

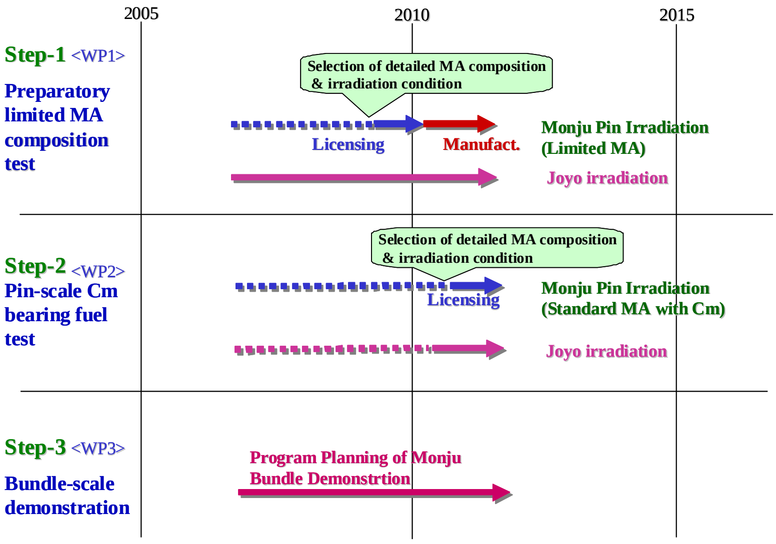

Figure 5: Schedule of GACID Project for Initial 5 Years

Organi-zation	*Individual Activities (5 years)*	*Common Activities*
JAEA (JP)	- *Precedent irradiation tests in Joyo (Am-1 test, etc.)* - *MA-bearing fuel material property measurement (low Am content fuel)* - *Licensing for Joyo and Monju irradiations* - *Preparation for Monju irradiation, PIE and transportation* - *Bundle assembling for Step-1 test fuel*	- *Project Management* - *MA bearing Fuel Material Property Dat Evaluation* - *MA bearing Fuel Irradiation Behavior Modeling* - *Analysis and Evaluation of Irradiated Fuel Data* - *Program planning for*
CEA (FR)	- *MA-bearing fuel material property measurement (high Am content fuel and Cm-bearing fuel)* - *Fabrication and transportation of Step-1 and -2 test fuel pins*	
	- *Raw material preparation for material property*	

Figure 6: Allocations of Activities for Initial 5 Years

VI. CURRENT STATUS OF THE PROJECT

The Project is in progress based on the planned schedule and allocated activities mentioned above. The current status of the Project can be summarized as follows.

(1) MA Raw Material Preparation and Shipping

AmO_2 and NpO_2 feedstocks have been provided from USDOE to CEA/ ATALANTE at mid 2008 for Step-1 fuel material property measurement. Additional AmO_2 and CmO_2 feedstocks for the Step–2 fuel material property measurement are under preparation in USDOE.

(2) MA-bearing MOX Fuel Pellet Sintering

Am and Am/Np-bearing MOX fuel pellets have already been sintered and irradiated in Joyo in JAEA. Preliminary Am/Np-bearing MOX fuel sintering for material property measurement is underway in CEA and USDOE.

(3) Material Property Measurement

Material property measurement for Step-1 Am/Np-bearing MOX fuel is underway based on the planned measurement matrices of each organization. A Np content of up to 3wt%HM, Am content of up to 4wt%HM and Cm content of up to 0.6wt%HM is being assumed as the envelope MA composition of Once-through LWR, Recycled LWR (MOX) and Recycled FBR spent fuel with MA doping. Preliminary measurements in JAEA showed a tendency of slight decrease in melting point and deterioration in thermal conductivity, at lower temperature region, by Am doping for low-Am-bearing MOX fuel with an Am content of up to 3wt%HM.

(4) Precedent Joyo Irradiations and PIEs

Short term irradiations of 10 minutes and 24 hours for Am and Am/Np-bearing MOX fuel have already been completed in Joyo and the PIEs are underway. The preliminary PIE results showed an early restructuring of the pellets and Am redistribution behavior similar to Pu.

These results will be used for the irradiation behavior modeling for MA-bearing MOX fuel.

(5) Licensing in Monju and Joyo

The fuel specifications and licensing strategy for the Step-1 Monju irradiation test are being discussed. Discussions on the material-property and irradiation-behavior data-base preparation, linear heat rate, correlations, models and design methods for licensing, fabrication tolerances, etc. are underway. Similar discussions for the Step-2 Joyo irradiation test are also ongoing.

(6) Preliminary Program Planning for Bundle-scale Irradiation Demonstration

A notional overall schedule, and procedures and steps to achieve the bundle-scale MA-bearing fuel irradiation demonstration in Monju are under preparation.

VII. FUTURE PROSPECTS

The GACID Project is to be performed based on the current status, mentioned above, during the initial five years. The following issues are being identified to be resolved in the nearest future: fuel fabrication and characterization procedures, and material property measurement protocols. The details of the fuel fabrication and characterization procedures seem slightly different among the three participating organizations, although the basic procedures are the same. The material property measurement protocols also seem slightly different depending on the facilities and researchers to be used or assigned. These possible differences are to be investigated and harmonized so that the results will be technically consistent with each other. Moreover the preliminary program planning for the future bundle-scale demonstration is to be promoted. The final goal of the whole GACID Project is to be pursued.

At the same time, Joyo and Monju restart schedules are under discussion in JAEA. The results will be taken into account in the review of the Step-1 and Step-2 irradiation test schedules, together with the review of the material property measurement and test fuel preparation schedules, at the occasion of the PA review after two years of the effective period of the current PA, at the earliest.

VIII. CONCLUSION

The current status of the GACID Project has been reviewed and summarized together with the related background activities of each participating nation. Although each nation has individual future fuel cycle strategy, the final goal of the Project, bundle-scale engineering demonstration of MA-bearing fuel technology, is being fully shared. The Project will be conducted, as originally planned, until the end of the initial two years' effective period of the current PA, September 2009, first milestone to decide on the feasibility of pursuing or to review and revise the future plan, if necessary. Thus the current PA will be renewed and the Project will be continued until the end of the final goal of the whole GACID Project.

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