PROSPECT AND CHALLENGES OF DUPIC DEVELOPMENT IN KOREA

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ABSTRACT

DUPIC fuel cycle technology is currently under development at KAERI in cooperation with Canada, the USA and the newly joined IAEA. The DUPIC concept is based on the idea that the bulk of spent PWR fuel can be directly refabricated into a reusable fuel for CANDU reactors, of which high efficiency in thermal neutron utilization would burn the fissile remnants in spent PWR fuel. As there is no seperation of sensitive materials involved in the direct refabrication, the DUPIC fuel cycle is dubbed proliferation-resistant. The anticipated benefits of the DUPIC fuel cycle are multiple: the removal of spent PWR fuel for reuse in CANDU reactors at doubling burnup, reduces spent CANDU fuel, savings of natural uranium for CANDU fuel, etc. In order for DUPIC fuel to be qualified ultimately as a licensable and proliferation-resistant fuel, the database of the fuel behavior and information on the fabricability, safeguardability, etc. should be established through the developmental phases. The characteristics of the DUPIC fuel cycle technology, together with its development program at KAERI, are described in this paper.

INTRODUCTION

The key issues affecting the future of nuclear-fission energy are the safe operation of nuclear plants, the disposal of spent fuel, concerns about nuclear weapons proliferation and the economy. It is hard to find a suitable repository site for disposing this spent fuel, especially for spent fuel disposal in countries which are heavily populated and small in geographical area. Korea is one such country, and has been seeking an option to reduce the growth of spent fuel by utilizing its mix of two reactor types, the PWR and CANDU.

In this regard, KAERI (Korea Atomic Energy Research Institute) is performing a joint research program for the development of DUPIC (Direct use of spent PWR fuel in CANDU reactors) fuel cycle technology in partnership with Canada (AECL), the USA and the IAEA. The DUPIC fuel cycle is based on the idea that the bulk of spent PWR fuel can be directly refabricated as a fuel for CANDU reactors without the conventional wet chemical reprocessing. In a CANDU reactor, the high efficiency of the thermal neutron utilization would burn the fissile remnants in the spent PWR fuel.

In this paper, the characteristics of the DUPIC fuel cycle and the direction of the DUPIC research program at KAERI are described.

CHARACTERISTICS OF THE DUPIC FUEL CYCLE

In order to manufacture DUPIC fuel, the spent PWR fuel assembly is disassembled and decladded to recover the spent fuel materials. The fuel fabrication processes are shown schematically in Figure 1. The recovered spent fuel materials are treated by repeated oxidation and reduction processes to produce the microcracks in the powder to increase the powder reactivity and are subject to additional powder milling to make the powder finer for the purpose of increasing powder sinterability. Once the resinterable powder feedstock is prepared, DUPIC fuel fabrication is almost similar to the conventional CANDU fuel fabrication process, except that all fabrication processes should be performed in hot cells due to their intrinsic radioactivity. Although volatile and some semi-volatile fission products will be removed during the fuel fabrication processes of oxidation, reduction and sintering, the bulk of the radioactive stable solid fission products will remain in the DUPIC fuel. This causes all the fabrication processes to be highly radioactive, thereby requiring heavy shielding through the fabrication processes. Although the maturity of fuel fabrication technology for conventional CANDU fuel has been well established, the remote fabrication and quality control technology required for DUPIC fuel fabrication needs further development (Yang et al., 1997).

The spent PWR fuel with a discharge burnup of about 35,000 MWd/T is composed of about 0.9 wt.% of fissile uranium, 0.6 wt.% of fissile plutonium and about 3 wt.% of fission products. Even though the retained fission products in DUPIC fuel act as absorber materials, the burnup of DUPIC fuel could be more than 15,000 MWd/T, about twice that of conventional CANDU fuel. However, the DUPIC fuel has distinct features from the conventional CANDU fuel, such as (1) high fissile content, (2) high plutonium content, (3) fuel composition variation due to initial enrichment and burnup history of spent PWR fuel, and (4) radioactivity due to residual fission products. Therefore, validity of the current reactivity control system, reactor safety systems such as the regional overpower protection and shutdown system, fuel handling system and fuel management shall be verified before utilizing DUPIC fuel in CANDU reactors (Choi et al., 1997).

One of the advantages of the DUPIC fuel cycle is the waste reduction of the whole fuel cycle. The fabrication process wastes are mainly metallic forms of the PWR assembly skeleton, the cladding hulls, and the trapped volatile and semi-volatile fission products, which are much smaller in volume compared to corresponding wet reprocessing process due to the characteristics of the dry process. The spent fuel of about three PWR reactors can be fabricated to supply DUPIC fuel for one CANDU reactor of equivalent reactor capacity, even though the optimum reactor ratio would depend on the discharge burnup of PWR fuel. Considering the doubling of the burnup of DUPIC fuel in CANDU reactors, the overall radioactive waste arising can be reduced by about 35 % in comparison with the once-through fuel cycle.

Recently, safeguardability has become an important factor to consider when selecting a fuel cycle option. The safeguardability of the DUPIC fuel cycle is regarded as excellent because there is no separation of fission products and plutonium during its processes. Also, it is difficult for the diversion due to its intrinsic radioactivity and heavy shielding on it. However, the improvement of the material accountability method using a non-destructive assay will be necessary for remote measurements.

DUPIC TECHNOLOGY DEVELOPMENT PROGRAM IN KAERI

Development Philosophy

Since DUPIC fuel is a relatively new concept fuel, KAERI is pursuing the coordinated development program encompassing a whole gamut of scopes such as: reactor physics and compatibility analysis, fuel fabrication, process waste management, fuel performance evaluation, safeguards and economic assessment.

The major goal of the development program is to fabricate and test the irradiation performance of DUPIC fuel in order to produce irradiation behavioral information for DUPIC fuel with the ultimate objective of qualifying the design and licensing proliferation-resistant fuel for CANDU reactors.

New fuel has usually been developed through a progression of developmental stages that include: (1) the design of a new fuel pellet and rod based on the anticipated behavior and reactor design consideration, (2) the accumulation of performance data on the new fuel rod design from test-reactor irradiation, (3) development of computational models for performance predictions based the test-reactor data, and (4) verification of the performance predictions by the sequential irradiation of lead rods and lead assemblies in a nuclear reactor.

Therefore, the starting point is to review and utilize the extensive technical data base for CANDU fuel for initial performance predictions of DUPIC fuel. Then, demonstration irradiation will be accomplished with behavioral testing to spot check the key behavioral phenomena and to permit correlation between the key behavioral characteristics of DUPIC fuel and the existing data base for current CANDU fuel.

Demonstration irradiation will be conducted to confirm and/or modify the performance prediction database. A minimum number of fuel variables and physical parameters can be evaluated for the verification of critical features in such demonstration irradiation. A reference CANDU fuel design will be also irradiated with DUPIC fuel designs to be used for benchmarking during all phases of testing and demonstration.

In order to provide the required information for licensing of the DUPIC fuel in nuclear reactors, a more comprehensive irradiation development program, including normal steady-state testing, safety-related testing and lead assembly irradiation, will be required later, based on the results of the developmental irradiation test.

Development Program

Following the feasibility study, which has been performed in cooperation with Canada and the USA to decide the OREOX (Oxidation and reduction of oxide fuel) process as an optimum DUPIC fuel process, the experimental verification program was started in 1993 and is currently underway in tripartite cooperation. The objective of the program is to verify the performance of prototypical DUPIC fuel experimentally. While AECL has successfully been fabricating the DUPIC fuel pellets at the Whiteshell Laboratories for irradiation tests, KAERI is preparing the required fabrication and test facilities for its main fabrication campaign starting in 1999. The existing research facilities including the hot cell facilities of the PIEF(Post-Irradiation Examination Facility) and IMEF(Irradiated Material Examination Facility), the Hanaro research reactor, and other fuel laboratories, will be utilized with minimum modification for the fabrication of prototypical fuel. The outlines of the experimental procedures at KAERI are shown in Figure 2. The equipment for the decladding, OREOX treatment, pelletizing and element fabrication are under development and are to be installed in IMEF in 1998. The modification of hot cells and off-gas trapping systems will also be completed by the end of 1998. From the middle of 1999, several DUPIC fuel pellets and elements will be fabricated, and a series of DUPIC fuel irradiation tests will be started at Hanaro research reactor to compare the behavior of DUPIC fuel pellets with conventional uranium oxide pellets. Following the pellet irradiation, element and bundle irradiation tests will be scheduled to gather information on the behavior of DUPIC fuel in reactor conditions.

INTERNATIONAL COOPERATION

In general, research using spent nuclear fuel receives focal attention from the safeguards and proliferation viewpoints, regardless of its objectives and research processes. For the DUPIC fuel development program, the safeguardability and transparency of the research were the primary considerations from the beginning. Therefore, the DUPIC program has been developed jointly by KAERI, AECL and the USA to strengthen both the technical capability and transparency of the research. While the fuel process technology, reactor physics and safety analysis are mainly being developed by AECL and KAERI, the safeguards technology is being jointly developed by KAERI and the USA. Moreover, the IAEA are became the fourth partner in the DUPIC program to bolster safeguards matters. Therefore, the DUPIC research program is a desired model of international cooperation program for promoting technological improvement while maintaining the transparency of the research.

When the DUPIC fuel cycle technology turns out to be safe and reliable in performance and economically competitive, it will become an alternative for the future fuel cycle and enhance a prospective cooperation scenario between adjacent LWR and CANDU countries.

CONCLUSIONS

DUPIC fuel cycle technology has the multiple advantages of reducing the accumulation of spent fuel, increasing the efficiency of uranium resource utilization, and proliferation-resistant characteristics. However, the performance and safety of the DUPIC fuel cycle should be examined before massive utilization of the fuel.

Therefore, KAERI is performing a coordinated research program to experimentally verify the performance of DUPIC fuel in cooperation with AECL and the USA. The DUPIC research program is a typical examples of international research programs for nuclear fuel cycles which efficiently harmonize the expertise of the participating parties while maintaining the transparency and safeguardability of the research.

REFERENCES

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KEY WORDS

DUPIC, Fuel cycle, Safeguardability, Fuel Fabrication Technology, OREOX process, KAERI.

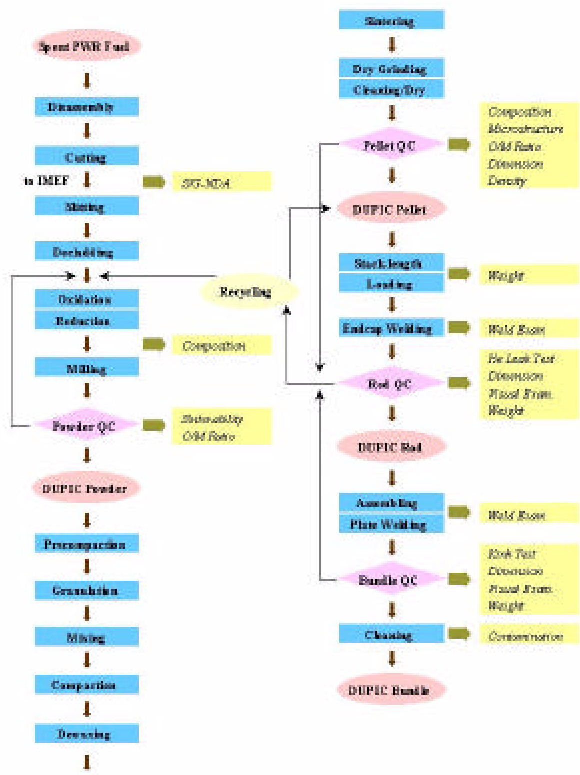

Figure 1. DUPIC Fuel Fabrication Processes

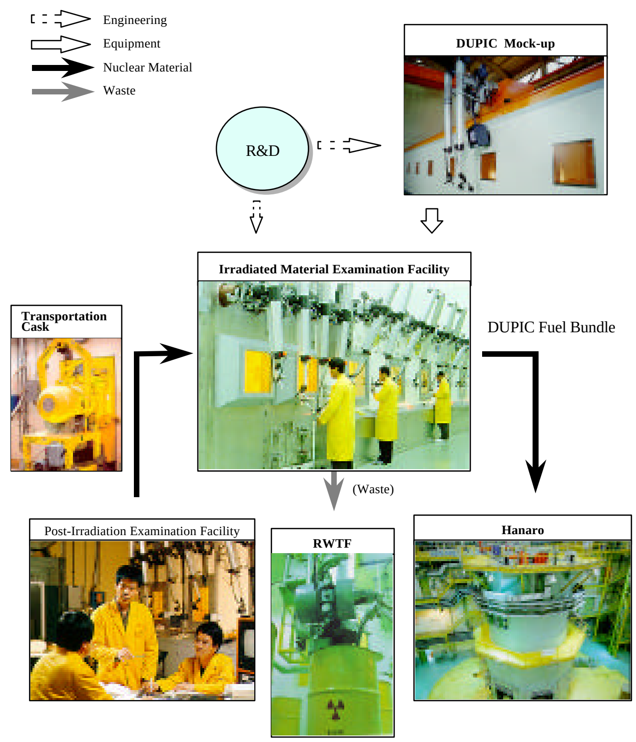

Figure 2. The Outlines of the Experimental Procedures I KAERI