TECHNICAL ISSUES UNRESOLVED FOR REALIZATION OF DUPIC FUEL CYCLE IN KOREA

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ABSTRACT

A research and development (R&D) project on DUPIC (Direct Use of Spent PWR Fuel in CANDU®) fuel is jointly underway, involving three countries: Korea, Canada and USA. There are strong incentives for developing DUPIC fuel from the standpoints of improved utilization of uranium resources, reduction of nuclear wastes, and proliferation resistance. But, in terms of manpower and resources, there are a number of technical issues to be resolved before full-fledged research efforts on the DUPIC fuel project can be initiated in Korea. It is desirable for the participating parties to demonstrate that the issues can be resolved with little or no change, or modification to the design or equipment, of the existing CANDU reactors in Korea, and that they will not pose any threat to the progress of the DUPIC fuel project. Hence, the cooperating parties in the DUPIC project need to focus effort on resolving these technical issues prior to committing major research work.

I. INTRODUCTION

A research and development (R&D) project on DUPIC [1,2] (Direct Use of Spent PWR Fuel in CANDU) fuel is jointly underway, involving three countries, Korea, Canada and the USA. The concept of DUPIC fuel is based on the direct reuse of spent PWR fuel in CANDU reactors utilizing the spent fuel processing method called OREOX (Oxidation and Reduction process). The main incentives for developing DUPIC fuel are:

1. DUPIC fuel can achieve a fuel discharge burnup of more than twice that of the current natural uranium fuel, due to the higher fissile content remaining in the spent PWR fuel.
2. Nuclear waste can be significantly reduced, not only because the spent PWR fuel is reused in CANDU reactors, instead of being disposed of as high level waste, but also because less spent CANDU fuel is produced due to the increased discharge burnup compared to that of the current CANDU fuel.
3. DUPIC fuel fabricated from spent PWR fuel using OREOX is highly proliferation-resistant.

Since DUPIC fuel is designed for existing CANDU reactors, it should satisfy the fuel design and other safety requirements of existing CANDU reactors. Considering the estimated large sum of research funds to develop DUPIC fuel, it is desirable that all technical issues are checked and critically reviewed before a major investment is made in the DUPIC project. The DUPIC project has been pursued for the past few years and may continue into the next century before the full commercial realization of DUPIC fuel. There are, however, technical issues yet to be resolved for this successful realization of DUPIC fuel in Korea. The purpose of this paper is to identify some of the key technical issues associated with the development of DUPIC fuel and to encourage cooperative and productive research efforts among the participating countries.

II. BASIC REQUIREMENTS FOR THE DEVELOPMENT OF NEW NUCLEAR FUEL

Because DUPIC fuel is a new type of fuel which has not yet been tested in existing CANDU reactors, it must go through a thorough review process conforming with the Safety Review Guidelines (SRG) to be licensed in Korea.. Since the SRG is intended for licensing of LWR fuel, DUPIC fuel to be used in CANDU reactors should also be developed with due regard to the requirements of the SRG.

The basis for new nuclear fuel development in Korea is that the newly developed fuel should be usable in nuclear power reactors currently in operation. Therefore, DUPIC fuel should satisfy this requirement . Any modification of current reactors should be minimized.

III. TECHNICAL ISSUES FOR DEVELOPMENT OF DUPIC FUEL

DUPIC fuel is based on the concept that spent PWR fuel is thermo-mechanically re-fabricated with its fission products intact to produce fuel bundles for CANDU reactors. Technical issues have been raised because of the variation of the fuel content, the inherent radioactivity, and the Pu and fission product content of the spent PWR fuel:

A. Compatibility With Existing CANDU Reactors

The current control systems for CANDU reactors are designed for natural uranium fuel. The fissile content of DUPIC fuel is different from that of natural UO_2. Therefore it should be confirmed that the control systems of existing CANDU reactors are adequate for DUPIC fuel. The fueling method may have to be altered due to higher reactivity as a result of the higher fissile content of DUPIC fuel. Flux and power distributions will also be changed. Since the reactivity worth of reactivity devices depends on the flux shape of the reactor core, reactivity worth and the function of control systems should be confirmed in terms of the design requirement of each control system.

The total delayed neutron fraction of DUPIC fuel is less than that of UO_2 fuel because of the higher Pu content. Since this may change the feedback effect from perturbation, response time of the control systems to overcome anticipated perturbations should be confirmed. When DUPIC fuel is refueled the functions of bulk and spatial controls should be verified to override perturbation due to refueling.

For the operation of CANDU reactors, on-line flux/power mapping system and regional over-power protection system are available for the purpose of regulation and safety. These systems are designed for natural UO_2 fuel. Therefore, the design principle and application of these systems should be verified for DUPIC fuel. During residence of the DUPIC fuel in CANDU reactors, the maximum channel and bundle power should fall within the current limits .

The spectrum of neutron flux will harden due to the higher fissile content, hence the fraction of fast neutrons in the core will increase. Therefore, the potential impact on the pressure tubes and calandria tubes due to the increased fast neutron flux, and change of flux distribution, should be examined. Also, the impact of radioactivity from fresh DUPIC fuel on the fueling machine should be checked. Because the power distribution is changed, the cooling capability of coolant system and thermal margin should also be confirmed.

The criticality and cooling capacity of spent fuel being stored from CANDU reactors is not a safety concern due to the fuel having a very low fissile content. However, the fissile content of DUPIC fuel is high, exceeding 1%, and the inherent fission products are retained. Decay heat from the spent fuel will increase due to the increased fission products, therefore it should be confirmed that the criticality response and cooling capacity of existing spent fuel storage systems is adequate to store spent DUPIC fuel.

B. Safety and Licensing

CANDU reactors have a low negative fuel temperature reactivity coefficient and a positive coolant temperature reactivity coefficient. Therefore, the power coefficient of current CANDU reactors with natural UO_2 fuel is of very low negative value. In the case of DUPIC fuel, the fuel temperature reactivity coefficient decreases in magnitude due to the Pu contained in DUPIC fuel, with little change in the positive coolant temperature reactivity coefficient. Therefore, the power coefficient might assume positive values. The SRG require that the net effect of the prompt inherent nuclear feedback characteristics compensates for a rapid increase in reactivity. This is interpreted as negative power coefficient. For licensing purposes, the SGR requirement for the negative power coefficient should be satisfied.

The delayed neutron fraction of DUPIC fuel decreases due to the Pu content. The void reactivity of CANDU reactors is positive. When a postulated LOCA (Loss of Coolant Accident) occurs, it affects power pulse and the consequences following the LOCA. The impact of DUPIC fuel on the accident should be reanalyzed and the safety criteria satisfied.?

DUPIC fuel possesses fission products generated from both PWR and CANDU reactors. Therefore, the exclusion area boundary (EAB) may be affected due to the increased source term. Since this EAB is a very important siting factor in Korea, because of lack of land, it should be carefully evaluated and reviewed.

C. Radiation Protection

Even fresh DUPIC fuel is radioactive due to fission products inherited from PWRs. Therefore, transportation of radioactive DUPIC fuel should be carefully controlled. By the time DUPIC fuel is commercialized, transportation of spent PWR fuel and DUPIC fuel between the PWR fuel sites and the DUPIC fabrication plant will be frequent.. A transportation plan should be provided prior to commercialization.

There is currently no requirement for special equipment to handle fresh fuel at CANDU sites because it is natural uranium fuel with no radiation. Since DUPIC fuel is radioactive, however, handling DUPIC fuel on site requires adequate radiation protection measures from initial receipt to the refueling machine. The impact on operators and structural materials due to the increased radiation source should also be evaluated. It should be confirmed that the regulation criteria for radiation protection are satisfied.

The on-power refueling method will be changed due to the higher fissile content of DUPIC fuel. In the case of DUPIC fuel, 2 or 4 fuel bundles may be refueled during one refueling. Therefore, the neutron flux can be shifted to the periphery of the core. Accordingly, this may increase the neutron leakage and radiation dose outside the core. Impact on operator and structural materials due to the increased radiation outside of the core should be evaluated.

Design Tools

Various computer codes are needed for design and safety analysis of DUPIC fuel. Since the current computer code system is designed for natural uranium fuel and low burnup, they should be validated for DUPIC fuel which has higher enrichment and higher burnup, compared with the current UO_2 fuel. The equivalent discharge burnup of DUPIC fuel may be much greater than that of natural UO_2. Therefore fuel performance data at extremely extended burnup are required for fuel design and validation of computer codes.

PWRs have a neutron spectrum different from that of CANDU reactors. DUPIC fuel has a variety of fission products. The composition of fresh DUPIC fuel may be determined through calculations for the PWR core. On the other hand, design of DUPIC fuel can be done from the computer codes for CANDU reactors. In this case, there is an interface problem between computer codes for PWRs and CANDU reactors because the lattice code has its own assumptions or approximations. Also, there is a large uncertainty in the composition of fuel materials calculated by the computer code at discharge burnup for PWRs.

Data for nuclear fission products and transuranium elements are not well known, compared with those for natural uranium elements. Since DUPIC fuel will contain fission products and transuranium elements, computational results on the DUPIC fuel using the CANDU physics computer codes should be verified and validated.

Fuel Design

As mentioned in the previous section, the equivalent discharge burnup of DUPIC fuel is larger than that of natural UO_2. Therefore, the fuel integrity should be assured at sufficiently extended burnup. This is being separately addressed by the CANFLEX advanced fuel bundle program, a cooperative activity between AECL and KAERI. CANFLEX is designed as the optimal fuel carrier for advanced fuel cycles in CANDU. The solid fission products remaining in the fuel matrix after the OREOX process may y affect fuel performance. DUPIC fuel fabrication employs different conversion and blending processes from the ADU process, the conventional process for the natural uranium fuel of CANDU reactors. These different characteristics may also alter the thermal and mechanical behavior of the fuel. To assure fuel integrity and good performance of DUPIC fuel, a fuel performance database, covering the extended burnup and different characteristics of the fuel, is required.

The use of fuel containing poison has been proposed as a possible means of reducing coolant void reactivity. In this case, homogeneity of the poison and its behavior will be important and the effect on fuel integrity should be examined.

Supply of Fuel Bundles

The initial composition of DUPIC fuel materials depends on the previous burnup history in the PWR. Hence, the composition will change depending on the spent PWR fuel batch. Since the refueling method in CANDU reactors is on-power, nuclear characteristics of the DUPIC fuels should be similar bundle-to-bundle . Nuclear characteristics depend on the ratio of fissile to fertile isotopes, the ratio of uranium to plutonium, the ratio of various isotopes in the same material, and so on. Therefore, the content of the fuel to be supplied for CANDU reactors should be carefully controlled, particularly the enrichment of the supplied fuel should be kept to an acceptable value.

Since DUPIC fuel is composed of numerous isotopes, its homogeneity is important. Meeting the acceptable fuel density is also pivotal. Therefore, DUPIC fuel should be supplied with an acceptable range of homogeneity and density.

IV. CONCLUSIONS

There are several advantages in developing DUPIC fuel. The R&D work has been in progress for only a few years. Some of the technical issues in developing DUPIC fuel, discussed can be resolved, and resolution of the remaining issues will then be sought. To convince policy makers and users as well, the above issues require closure before full-fledged research efforts (in terms of manpower and research funds) on the DUPIC fuel research project are initiated in Korea. It is important to demonstrate that the issues can be resolved with little or no changes to, or modifications of, either the design or equipment of existing CANDU reactors in Korea.. The cooperating parties in the DUPIC project need to resolve these technical issues prior to large-scale research work being committed.

REFERENCES

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