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THE DUPIC ALTERNATIVE FOR BACKEND FUEL CYCLE

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Abstract

The DUPIC[1] fuel cycle was conceived as an alternative to the conventional fuel cycle backed options, with a view to multiple benefits expectable from burning spent PWR fuel again in CANDU reactors. It is based on the basic idea that the bulk of spent PWR fuel can be directly refabricated into a reusable fuel for CANDU of which high efficiency in neutron utilization would exhaustively burn the fissile remnants in the spent PWR fuel to a level below that of natural uranium. Such "burn again" strategy of the DUPIC fuel cycle implies that the spent PWR fuel will become CANDU fuel of higher burnup with relevant benefits such as spent PWR fuel disposition, saving of natural uranium fuel, etc. A salient feature of the DUPIC fuel cycle is neither the fissile content nor the bulk radioactivity is separated from the DUPIC mass flow which must be contained and shielded all along the cycle. This feature can be considered as a factor of proliferation resistance by deterrence against access to sensitive materials. It means also the requirement for remote systems technologies for DUPIC fuel operation. The conflicting aspects between better safeguardability and harder engineering problems of the radioactive fuel operation may be the important reason why the decades' old concept, since INFCE[2] , of "hot" fuel cycle has not been pursued with much progress. In this context, the DUPIC fuel cycle could be a live example for development of proliferation resistant fuel cycle. As the DUPIC fuel cycle looks for synergism of fuel linkage from PWR to CANDU (or in broader sense LWR to HWR), Korea occupies a best position for DUPIC exercise with her unique strategy of reactor mix of both reactor types. But the DUPIC benefits can be extended to global bonus, expectable from successful development of the technology.

1. INTRODUCTION

Spent fuel from PWR contains fissile remnants roughly two times higher than natural uranium. They can be separated by reprocessing or disposed of intact (i.e., the spent PWR fuel assemblies) in the geological repository. The DUPIC fuel cycle would be in fact a third alternative in-between the two conventional options in that spent PWR fuel is neither directly disposed of nor reprocessed to separate the fissile remnants in it, but that the bulk of spent PWR fuel is reformed into CANDU-compatible DUPIC fuel bundle with new cladding and appendages [1].

A precursor of the DUPIC concept would be the AIROX[3] technology developed in the early sixties by Atomics International in the USA It was destined to recycle spent LWR fuel back to LWR by addition of higher enrichment material to compensate the depleted portion in the spent fuel. Notwithstanding the difference with DUPIC in fuel form and content, a lot of its technical features are common to both fuel cycles which need remote fabrication of bulk oxides. Obviously, the AIROX concept attracted interest for its aspect of proliferation resistance in the late seventies [2], and for its possibility as an alternative to manage spent fuel in the USA [3]. There are more distant technical methods, in the family tree of fuel cycles, of remote fuel fabrication conceived for thorium oxides and metals [4].

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[1] DUPIC = Direct Use of Spent PWR Fuel in CANDU

[2] INFCE = International Nuclear Fuel Cycle Evaluation

[3] AIROX = Atomics International Reduction Oxidation

The DUPIC fuel cycle studies was initiated in the early nineties by joint efforts involving Korea, Canada and the USA The tripartite investigated technical feasibilities of the DUPIC fuel cycle including analysis of CANDU system with DUPIC fuel, comparison of various options and selection of reference process for DUPIC fuel fabrication, examination of safeguardabilities, etc. The confirmative conclusions of the feasibility study wrapped up in 1992 had lead to the next phase of the DUPIC program, experimental verification, with a target to the year 2000 in shared tasks between the tri-parties [5]. The IAEA has recently joined the program in safeguards affairs [6].

2. THE DUPIC TECHNOLOGY

A basic premise adopted for the DUPIC fuel cycle development is to minimize retrofittings that may arise in order to use DUPIC fuel in CANDU. This philosophy is based on the rationale that it would be much more cheaper and safer to fit fuel to reactor than to fit reactor to fuel. With this background, the technical question for the DUPIC fuel cycle converges to the feasibility of DUPIC fuel fabrication.

For the fabrication of DUPIC fuel, a process called OREOX[4] was selected as the most promising option, among other competing options, because it would allow maximum flexibility in fuel design satisfying the requirement of compatibility with existing CANDU system. The OREOX process is based on a thermal treatment of bulk powder of spent PWR fuel to prepare for manufacturing of pellet from which the DUPIC fuel bundle can be fabricated by remotized version of conventional technology for CANDU fuel production. Remote fabrication of DUPIC fuel will thus occupy the heart of DUPIC technology.

2.1. Compatibility with existing CANDU system

Compatibility of DUPIC fuel with existing CANDU system may be grouped in two major categories : nuclear and mechanical.

2.1.1. Nuclear compatibility

Spent PWR fuel from PWR contains fissile remnants around 1.5% depending on burnup attained in PWR. This is roughly two times higher than natural uranium which is used for fresh CANDU fuel. This is a theoretical indication that the DUPIC fuel could be burnt two times longer in a CANDU of equivalent output than natural uranium fuel. Frequency of fuel replacement will have to be adjusted accordingly.

Major technical considerations for DUPIC fuel use in CANDU have been in analyses since the feasibility study. The neutronic and thermohydraulic compatibilities are integrated into the homogeneity of DUPIC fuel composition. As there are a variety of PWR fuel burnups resulting in compositional differences, consideration is given to the preparatory selection for batch mixture in such way to fabricate DUPIC fuel of homogeneous composition.

A lot of efforts are also focused on the analysis of safety margins in CANDU and on the adjustment of control factors therefrom in the use of DUPIC fuel with reference to natural uranium fuel use. [7]

2.1.2. Mechanical compatibility

Concerning the feasibility of DUPIC fuel handling, both for charge and discharge, it was found that the existing refueling machine could be used for DUPIC fuel loading into the fuel channel in

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[4] OREOX = Oxidation and Reduction of Oxide Fuel

reverse sequence to the current handling of spent fuel discharged from the core. A minor addition of lifting mechanism seems to be needed, nevertheless, down in the spent fuel bay in order to move the DUPIC fuel up to refueling position because the current spent CANDU fuel handling system is designed only to slide down spent fuel.

2.2. Feasibility of DUPIC fuel fabrication

There are various methods to transform spent PWR fuel to CANDU type DUPIC fuel. They can be categorized into two technical groups : mechanical reconfiguration and powder conditioning, after decladding, for pellet formation or vibratory packing (vipac). The comparative assessment of these optional methods, during early feasibility study of the DUPIC program, concluded that the latter is preferred mainly for the reason of fuel compatibility as explained previously. Among the latter category, powder-pellet route was preferred mainly due to its wide commercial experience although the other option (vipac) may have advantages in remote fabrication due to its simpler process.

For the powder conditioning for pellet fabrication which has been adopted as reference process for development and test of DUPIC fuel, the OREOX process uses repeated oxidation and reduction to make the bulk powder more apt to pellet formation and sintering. Once pelletized, the rest of the processes to produce DUPIC bundle is not much different from conventional processes for CANDU fuel fabrication [8].

The radioactive wastes arising from DUPIC fuel fabrication are mainly non-fuel bearing structural materials removed from disassembly of spent PWR fuel and decladding and off-gases released from OREOX and sintering processes. These wastes can be treated and managed by existing technologies, except the semi-volatile gases for which special trapping methods are being developed in the DUPIC program.

As remarked above, all the processes involved in the DUPIC fuel fabrication must be performed remotely in biological shielding and containment to protect the workers from radiation hazards. The remote systems feature of the DUPIC fuel fabrication would require a new dimension in technological efforts and costs. This is just the penalty to the enhanced safeguardability of the radioactive process. This new direction, however, is convergent to the recent technical trend toward increasing automation in the manufacturing industry to reduce labor costs and risks.

2.3. Safeguards

The DUPIC fuel fabrication is resistant to proliferation not only because it involves no separation of fissile material but also because the heavy shielding enclosing the radioactive process act as a barrier to diversion possibility. Similar technical principles have attracted considerable attention especially during the seventies when measures to enhance safeguardability of conventional reprocessing were looked for by such methods as low-decontamination or denaturing special nuclear materials with radioactive spikants. An extension of such principles is resumed recently as "spent fuel standard" by the National Academy of Science of the U.S. as a key security criterion for judging options for weapon plutonium disposition [9].

In the DUPIC program, systems for containment and surveillance are being developed to augment the safeguardability of DUPIC fuel fabrication. A recent outcome of this developmental efforts is an instrument that can measure fissile content in the spent fuel material with enhanced accuracy [10].

3. BENEFITS OF THE DUPIC ALTERNATIVE

The DUPIC alternative as a proliferation resistant fuel cycle concept offers a multiple benefits that are expectable from PWR-CANDU synergism in comparison with once-through option. Such benefits are maximized at a reactor a ratio between 3 PWRs and 1 CANDU (depending on burnup). At this optimal ratio, up to 30% saving in natural uranium possible. Another advantage, more significant in today's perspective, is the multiple reduction in spent fuel arising by removal of spent PWR fuel and by the doubling burnup in CANDU. Corollary to this quantity reduction to about one-third in comparison once-through, it was also revealed that there would be a "quality effect" of radiotoxicity reduction at long-term by DUPIC in the final disposal of spent fuel [11].

Regarding the DUPIC economics, a study in the DUPIC program has indicated that the DUPIC alternative can be competitive with once-through, as well as other recycle options taking the synergetic effects into account [12].

4. INTERNATIONAL DUPIC LINK

The DUPIC fuel cycle concept is characterized by burning spent PWR fuel again in CANDU, without separating any fissile material, taking advantage of high neutron economy of heavy water reactors. It requires therefore a reactor mix PWR-CANDU, which Korea adopted coincidentally. The possibility of DUPIC fuel linkage from LWR to HWR is not, however, limited to mixed reactor counties like Korea : it can be extended to countries of LWR or HWR by international cooperation if such linkage is agreed between the interested countries.

5. CONCLUSION

The DUPIC fuel cycle is an emerging alternative in fuel cycle backend for synergism between PWR and CANDU (and between LWR and HWR, in general). A conspicuous feature of the DUPIC fuel cycle concept is, among others, the proliferation resistance which is unique in its kind. Other benefits include not only saving of natural uranium for CANDU fuel, but also removal of spent PWR fuel that would be transformed into DUPIC fuel to give two times higher burnup in CANDU, thus contributing to more power production without additional burden to the environment. The developmental efforts are now in full swing, under international cooperation frame, in anticipation of multiple benefits on national and international level.

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