ADVANCED FUEL RECYCLE SYSTEM CONCEPT TO REALIZE MINOR ACTINIDES RECYCLE

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ABSTRACT

MA recycle has several benefits such as ease of waste problems and enhancement of proliferation resistance, [illegible]ling MAs by means of aqueous process apparently needs more equipment, which requires more capital cost. [illegible] by process optimization and simplification and integration of reprocessing and fabrication, which is one candidate goal of the Advanced Fuel Recycle System, is necessary to realize MA recycle.

In the present paper, PNC proposes an drastically improved recycle concept which is integrated system of reprocessing and fabrication. This concept mainly consists of a simplified PUREX process with single cycle extraction process flowsheet which gives rather low decontamination factors around 10^3 and simplified fabrication process such as vibro-packing. Such simplified extraction process can radically reduce number and volume of contactors, vessels, waste treatment components, and all auxiliary equipment which can brings forth the economical innovation.

The concept shows enough economical performance for application of MA recovery process.

1. INTRODUCTION

In compliance with the "Long-Term Program for Research, Development and Utilization of Nuclear Energy" issued in 1994 by the Atomic Energy Commission of Japan, PNC is expanding its development program for Advanced Fuel Recycle System as a new concept of fast breeder reactor (FBR) fuel cycle.

The primary objective of this program is to strengthen the performance of fuel cycle at various criteria. In the currently developed mixed oxide (MOX) of uranium (U) and plutonium (Pu) -fueled cycle, PNC recognizes that there are still issues to be substantially improved, particularly with respect to economics, generation of radioactive wastes both in terms of volume and quality, and international concerns about proliferation of nuclear material.

Recognizing the above-mentioned necessity of improvement, PNC believes that the following basic steps must be taken.

(1) Improve the system's economics as a total fuel cycle system (system simplification)

(2) Achieve Pu recovery without perfect purification

(3) Make the most of the features of the fast neutron system. In addition to the breeding, pursue other function as MA (Minor Actinide such as Np, Am, and Cm) burning.

By following the above steps, the effective utilization of all actinides can be achieved, resulting in a reduction of the cumulative production of MAs, reduction of long-lasting toxicity in the high level liquid waste (HLW), and so on. This is the way to realize MA recycle.

Among several candidate system for Advanced Fuel Recycle System, PNC's main concern has been focused on the improvement of the system composed of the PUREX process and MOX fuel fabrication which have been well experienced by PNC through the past three decades.

2. FEATURE OF THE IMPROVEMENT

In the current commercial light water reactor (LWR) reprocessing, decontamination factor (DF) for fission products (FPs) in the order of 10^7 to 10^8 is required because of easy handling of the product U and Pu in the grove box for fuel fabrication.

On the other hand, we have to consider the trend of burn-up extension in the LWR system. The recovered Pu even with such high DF will have higher activity of gamma and neutron emission. This fact shows that the system of remote fuel fabrication should be essential in future.

If we allow the remote fabrication, the DF around 10^3 or even smaller are acceptable in the product materials for recycling it to the FBR, because FBR has the low neutronic sensitivity to its fuel material impurities. The FBR system dose not require the fuel materials to be so pure like as the product from conventional reprocessing and such low DF can be attained easily by improved PUREX process with only one (single) cycle extraction.

In the conventional LWR reprocessing plant based on the PUREX technology using tri-butyl phosphate (TBP) as an extractant, the chemical separation process is composed of several extraction cycles in order to achieve high purity in both U and Pu products. Such multiple extraction cycles, usually consists of co-decontamination, partition of U and Pu and purification steps, become the multiple sources of aqueous and organic waste generation and then require quite a large capacity for the component to treat these waste. Figure 1 shows the ratio of liquid volume to be treated in each process of conventional reprocessing plant. It is apparent that around 70% or more are coming from partitioning of U and Pu and purification process.

Considering the single extraction process, we can eliminate all of partition and purification steps, which will result in the drastic reduction of total volume, i.e. 70% or more, and number of process component. Such reduction will lead to the proportional reduction in the required capacity of the waste processing and the reduction of waste itself. Thus the overall process is down sized and a significant reduction will be achieved on both plant capital and operating cost.

At present, the MOX fuel is usually fabricated in the form of sintered pellet at the facilities in the PNC Tokai Works as well as European countries. This fabrication method is featured with the powder preparation and pressing, sintering in furnace, chemical and physical inspections arraying pellets in a stack and inserting them into a cladding tube. Since most of these process depend on very precise mechanical handlings with complicated devices, they are not well fitted to the remote operation and alternative method are to be explored. Considering these facts, the gelation and vibro-packing method has been proposed as one of the methods suitable for remote fuel fabrication in Advanced Fuel Recycle System.

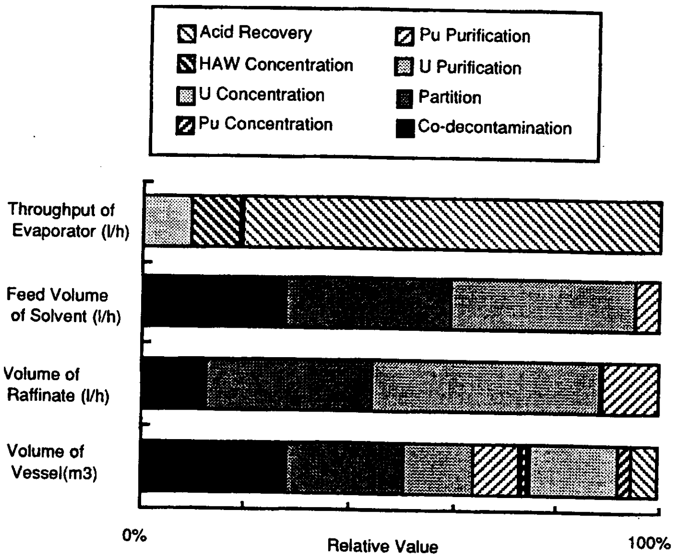

Fig.1 Volume comparison for each process in conventional reprocessing plant

3. DETAIL OF SINGLE CYCLE EXTRACTION PROCESS

One of the extremely simplified reprocessing flowsheet proposed as a part of Advanced Fuel Recycle System is shown in Figure 2, which is the improved PUREX process with single cycle extraction process as mentioned before.

In this case, both core and blanket fuel dissolved in nitric acid solution are treated by the process which consists of an extraction bank, a Pu and U co-stripping bank and a strip bank for residual U. The Pu and U co-stripping bank is made so that the Pu content is slightly higher than that required for core fuel fabrication. The process is also distinguished to extremely reduce amount of liquid waste by means of

(1) eliminate scrubbing process, and

(2) control process condition such as temperature, flow rate and so on in order to enable co-extraction of U and Pu without any reductant.

As for MA's behavior in this process, Np will be able to be recovered together with U and Pu if its valence in solution is adjusted in extractable form, but both Am and Cm will go to the raffinate from the extraction bank.

Further simplification will be made possibly by incorporating the supplemental technique to reduce heavy metal quantity to be fed to the extraction process in order to reduce aqueous and organic waste. One of the method under study is crystallization technique which is to collect, prior to solvent extraction, a large portion of uranium from the feed solution by crystallizing it as uranyl nitrate hexahydrate (UNH) at lower temperature. As the solubility of Pu is less than U and total amount of MAs and FPs are far below than the amount of U, only U cristallizes from the dissolved solution. After the cristallization, the residual solution with Pu/U ratio enriched to nearly 30% will be fed to the solvent extraction system which

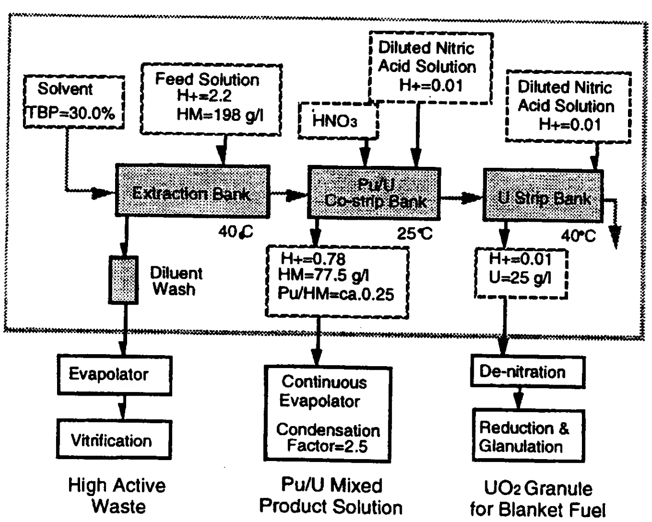

Fig. 2 Single-Cycle Extraction Flowsheet

consists of just an extraction and a stripping banks.

In either case, a major adjustment of Pu content in the product solution is to be made by the addition of recovered U before it is recycled for fuel fabrication.

It should be noted that the proposed process will completely eliminate the necessity for separation and handling pure Pu.

4. DETAIL OF REMOTE FUEL FABRICATION

Despite the automation of the process and inspection lines, radiation exposures to the workers tend to increase owing to occasional access for maintenance activities. In their aspect, a remote fuel fabrication process with an appropriate shielding is desirable or even necessary for the next generation MOX plants. And if we adopt the remote fabrication method for FBR fuel, we can drastically simplify the reprocessing process as discussed earlier.

Mixed solution of U and Pu with suitable concentration for MOX fabrication is fed to the gelation process to get particles with adequate diameter. Then particles are calcined and sintered to form granules. Finally granules are directly poured into cladding tube by applying vibration for dense filling.

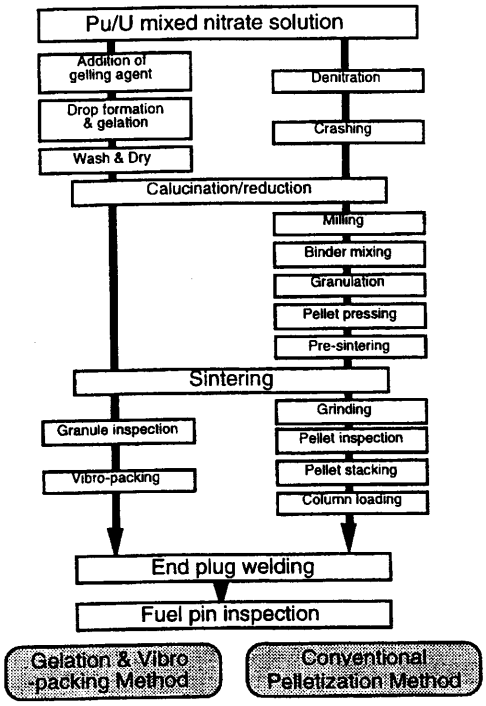

Fig. 3 Comparison of Fuel Pin Fabrication Process

In this case, most of the processes are fluidized, and therefore they are more suitable for remotization and easy to integrate into the reprocessing plant as its end process.

As shown in Figure 3, the system composed by gelation and vibro-packing can significantly shorten the fabrication process compared with the conventional process such as pelletization method. The inspection procedures will also be less complicated for the gelation process than in the pellet process.

5. EVALUATION ON ECONOMICSS

Since the major portion of electricity generation cost depends on the capital cost of the power reactor plant, significant effort is required for FBR plant to reduce its construction cost to become economically competitive. Also much effort to reduce the cost is needed for fuel cycle area which contributes about 20 to 30% of total electricity generation cost. About the fuel cycle cost comparison of LWR and FBR cycle, Figure 4 shows the relative effect of each constituents. As FBR fuel reprocessing has both functions of U purchase and conversion/enrichment in LWR cycle because of Pu recovery from spent fuel, it occypies larger portion in the fuel cycle cost than LWR fuel reprocessing. Inovation of reprocessing may brings forth larger cost effect. We believe the single cycle extraction process is one of the most effective method for this purpose.

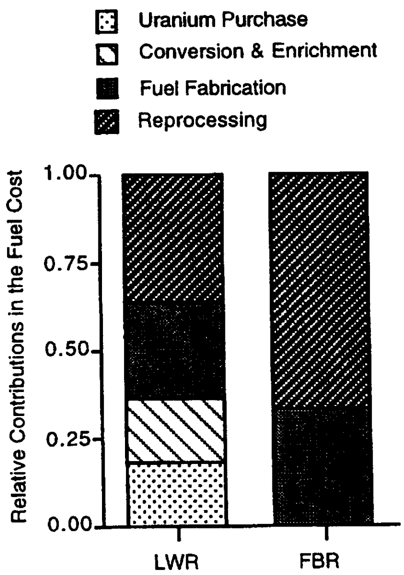

Fig. 4 Relative Comparison of Constituents in the Fuel Cost

In addition to the simplification and improvement of the process, the integration of reprocessing and fabrication processes into one fuel cycle plant will contribute to further reduction of the fuel cycle cost. It is often conceived that the remote handling might be more costly than the automated directly handling. However, the remote fuel fabrication based on gelation and vibro-packing has a very good chance to achieve far better economiy than the conventional pelletizing process, because the number of process steps in gelation is much smaller than in the pellet process preceded by the conversion process.

In Figure 5, a block flow diagram of an integrated fuel cycle plant based on Advance Fuel Recycle System is compared with that of conventionally separate reprocessing and fabrication plants. Based on a conceptual image of the Advanced Fuel Recycle Plant (AFRP), a preliminary cost evaluation has been carried out and compared with conventional reprocessing and fabrication plants with same throughput in Figure 6. As indicated in the Figure, the concept of AFRP will bring forth nearly 60% reduction in the plant capital cost for fuel recycling.

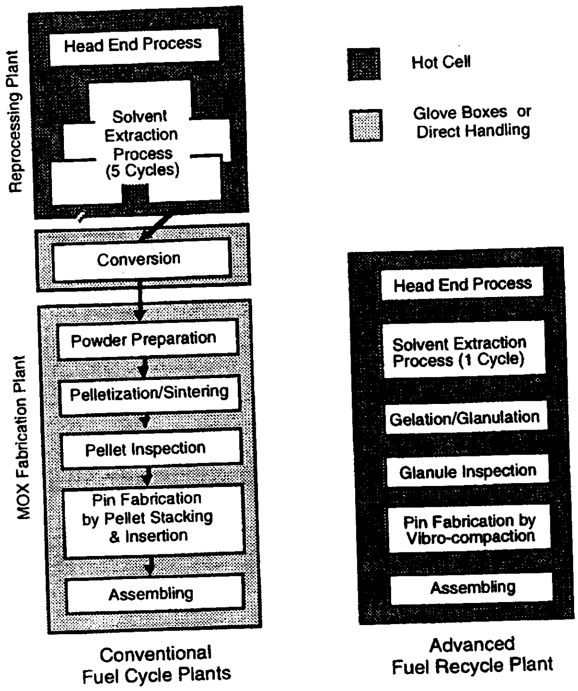

Fig. 5 Comparison of Fuel Cycle Plants

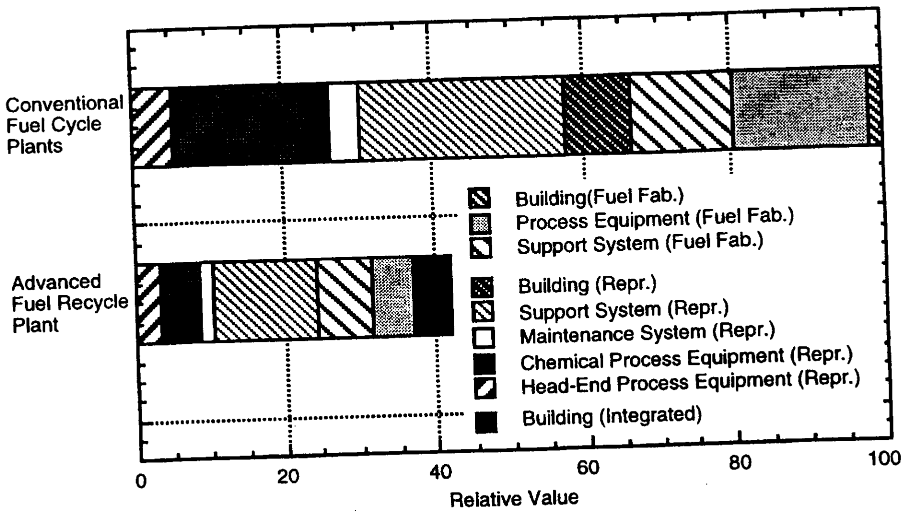

Fig.6 Capital Cost Comparison for Fuel Cycle Plants

6. CURRENT STATUS TOWARD MA RECYCLE

As the drastically improved recycle system signifies good performance on the economics, the addition of MA recovery system by means of aqueous process, that is TRUEX process in which CMPO is used as an extractant for MAs, may be acceptable, taking into account of merits of MA recycle such as easing the waste problem and strengtening the proliferation resistivity.

The cost gain due to addition of MA recycle function to the AFRP is estimated around only a few percent up.

Of course, the MA recovery process such as TRUEX process should be reasonably improved.

It has been examined by TRUEX process that MA nuclides can be recovered almost 100% from the PUREX process raffinate generated from FBR spent fuel reprocessing test in the Chemical Processing Facility (CPF) in Tokai Works, PNC. Besides this, process condition to co-extract Np with Pu in PUREX process has been confirmed. Now, CPF is under modification to carry out more effectively the examination of the proposed single cycle extraction process together with the basic study on the cristallization method focusing on the Pu solubility and the TRUEX process modification.

The possible recovered amount of MA from CPF is far below for conducting systematic irradiation test of MOX fuel containing MA nuclides, so that equipment to recover Am, which accumulates in the plutonium as a product from conventional LWR reprocessing plant, is going to be operation in near future at the Plutonium Fuel Development Facility (PFDF) in Tokai Works.

Enough amount of Am for irradiation test will be prepared into several pins at the cell of Alpha Gamma Facility (AGF), in Oarai Engineering Center, PNC, by remote technique to ensure workers exposure at low level. Irradiation test on MA contained fuel will be conducted at the Fast Experimental Reactor "Joyo" after getting the commission. It is expected that the test will be initiated around 2001.