Transactions of the Korean Nuclear Society Autumn Meeting
Busan, Korea, October 27-28, 2005

Safeguardability Analysis of Advanced Spent Fuel Conditioning Process

Won-Il Ko [a], Ho-Dong Kim [a], Sang-Yoon Lee [a] and T.K. Li [b]
a Korea Atomic Energy Research Institute, 150 Deokjin-dong, Yuseong-gu, Daejeon, Korea, khd@kaeri.re.kr
b Los Alamos National Laboratory, Los Alamos, NM 87545 USA, tli@lanl.gov

1. Introduction

The Advanced Spent Fuel Conditioning Process (ACP) is an electro-metallurgical treatment technique to convert oxide-type spent nuclear fuel into a metallic form. The Korea Atomic Energy Research Institute (KAERI) has been developing this technology since 1997 for the purpose of spent fuel management. By using of this technology, a significant reduction of the volume and heat load of spent fuel is expected, which would lighten the burden of final disposal in terms of disposal size, safety and economics.

A joint study on the safeguardability of the ACP technology has been under way by the Los Alamos National Laboratory (LANL) and the KAERI since 2002 under a collaborative agreement to develop the safeguards system for the ACP. This paper summarizes the preliminary results of joint research. The sub-processes and material flow of the pilot scale ACP facility were designed for this study. Then, their MBA and KMP were defined based on diversion scenario analysis. The limit of error in MUF value was also estimated with international target values for the uncertainty of measurement methods.

2. Main Process Concept

The ACP technology is based on the pyro-chemical process that was designed in the 1960s and 1970s. The reference concept consists of six major sub-processes as Lithium Reduction Process. Recently, a modified concept of Li reduction was proposed by KAERI to simplify the reference technology and to increase the proliferation resistance of the process. In the electrolytic reduction (ER) process, the lithium recovery (electro-winning) step is conducted at the uranium oxide cathode simultaneously with the reduction of oxide fuel to metal. Consequently, the lithium recovery process is no longer needed in this concept, and the possibility of separating actinides is inherently ruled out. The ACP consists of several process steps as shown in Fig. 1. Various solid wastes will be generated in the process, and all wastes containing nuclear material will be managed for safeguarding.

3. Facility Design

A pilot scale ACP facility with a capacity of 30 MTHM/year was designed in this study to analyze the safeguardability of the ACP facility. The facility stands alone physically (operationally), and is administratively isolated from reactors and interim spent-fuel storage facilities. The main process of the facility is assumed to be the electrolytic reduction concept, shown in Fig. 1, which has no need of a Lithium recovery system. The facility availability is assumed 60%, which is equivalent to 219 full operating calendar days per year. The process consists mainly of three parts: spent fuel handling area (spent fuel disassembling and rod extraction), main hot cell (decladding, reduction, smelting, casting, etc.), and U-metal handling area (loading metal rods into storage cask and temporary storage).

The reference fuel used in the ACP facility is Korean Yong-Gwang Unit 1 & 2 PWR's 17×17 standard spent fuel assemblies with a minimum 10 years of cooling time after discharge from the reactor.

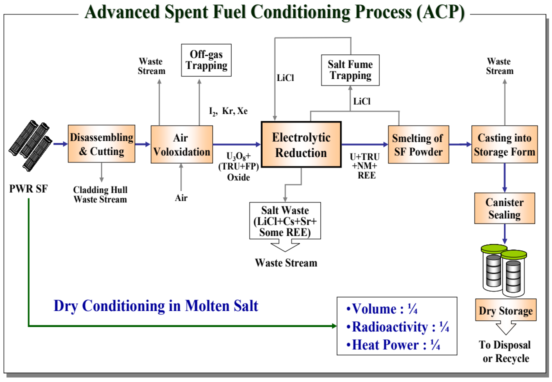

Fig. 1. Process Flow of ACP Facility

4. Diversion Scenario Analysis

There are several inherent attributes of the ACP process that make this fuel cycle unattractive for diversion when compared with conventional fuel reprocessing and plutonium recycling. The processes used for the ACP do not produce a pure or partially pure plutonium product. The reconstitution options require a highly remote operation in canyons of highly shielded cells. It is difficult to gain undetected access to these cells to modify hardware or install new processes.

Diversions of normal materials in the bulk processing areas are detectable using special analysis methods that are available to detect protracted diversions. Another possibility for diversion is through the misuse of the accountancy system. Such a diversion scenario could be detected using a well-designed verification regime that will adequately verify both the desirable and undesirable materials at the facility. Diversion of item counting materials will be readily detected with high probability during IAEA inspections that would include a well-designed sampling plan, item counting, seals verification, and an attribute measurement scheme to detect gross defects.

Materials diverted from ACP facility could be processed through a simplified PUREX cycle or its equivalent to remove the remaining fission products and uranium to recover plutonium. Because IAEA inspectors have access to many areas on-site, it is unlikely that such a process could be operated within the ACP facility could be operated without detection. By keeping track of all nuclear materials within the ACP facility using material accountancy, containment and surveillance, and routine inspections by the IAEA, one could detect significant diversion of feed materials to operate a clandestine facility operating to recover the plutonium.

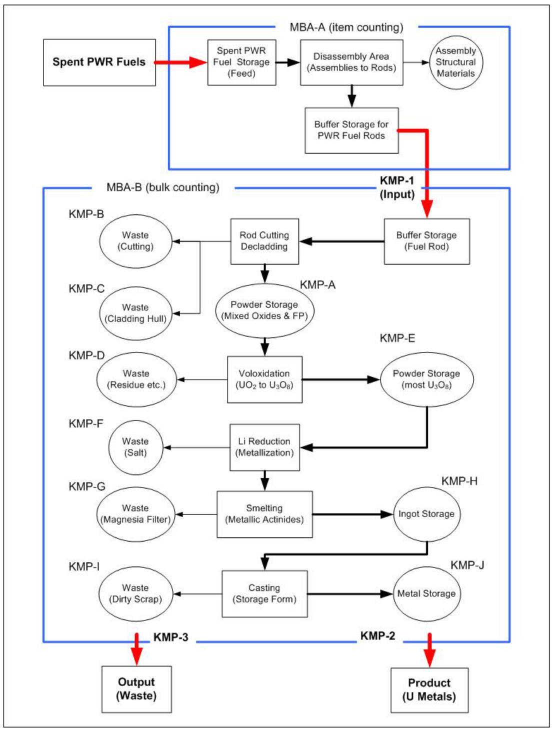

Fig. 2. Material Flow and KMPs at a Conceptual ACPF

5. Material Control & Accountability

Figure 2 is an abbreviated representation of the major processes of this conceptual ACP facility. The fuel conditioning facility is composed of two MBAs. The operations of MBA-A are based on individual item counts because the composition is not varied and items are only broken into other discrete items. Material accountancy in the MBA-A is similar to that in any storage area and is not described further in this report.

In MBA-B, the facility operator does material accounting based on some declared values for feed materials; destructive chemical analyses for mixed oxides and metal ingots; and NDA measurements for U-metals, recyclable scraps, and disposable waste streams.

The KMPs associated with both material flow and inventories at the conceptual ACP facility are illustrated in Fig. 2. The flow KMPs are represented by numbers and the inventory KMPs are designated by letters.

If the measurement methods in question are of the same design, it is assumed that the use of several scales is equivalent to the use of one scale with several shifts in the systematic error. Using these assumptions and uncertainty values, the result for the σMUF is 1.881 kg of elemental plutonium, assuming no data falsification. The corresponding limit of error value for MUF is 3.761 kg of plutonium.

This result suggests that it would be possible to meet typical IAEA detection goals for campaigns having 3 months or fewer.

6. Conclusion

Based on the assumptions we have made during this preliminary study, the conceptual ACP fuel conditioning facility credibly meets reasonable diversion resistances and safeguards goals. Therefore, it is reasonable to conclude that (1) using the options proposed for Phase-I study, ACP fuel conditioning facility can be designed, built, and operated to meet the goals of IAEA safeguards; and (2) additional technologies necessary to make this possible can be developed in a timely fashion so that an inventory of the ACP facility materials can be verified by both the state and international safeguards inspectors.

The results described in this paper should be considered only as a preliminary evaluation, subject to possible modifications as more reliable information on technical parameters becomes available. Those features that best promote safeguards on the ACP are: ability to make good measurement; continuous knowledge of the amounts and locations of materials; building designs that contain nuclear materials in easily controlled and monitored areas; and process operations that minimize pathways for diversion.

ACKNOWLEDGEMENTS

This study was sponsored by Ministry of Science and Technology(MOST) through the National Nuclear R&D Program.

REFERENCES

[1] K. Budlong-Sylvester, K. E. Thomas, and J. F. Pilat, “Proliferation Resistance for AFCI,” LA-UR-03-0501, LANL (2003).

[2] W. H. Hannum, et al., “Nonproliferation and Safeguards Aspects of the IFR,” Progress in Nuclear Energy, Vol. 31, No.1/2, 203-217 (1997).

[3] IAEA , “Safeguards Techniques and Equipment - 2003 Edition,” International Nuclear Verification Series No. 1 (Revised), IAEA, Vienna (2003).