ADVANCED SAFEGUARDS APPROACHES FOR NEW REPROCESSING FACILITIES

Philip Casey Durst
Pacific Northwest National Laboratory (PNNL)
Richland, Washington, USA

ABSTRACT
A project sponsored by the U.S. National Nuclear Security Administration "NNSA" to develop international safeguards approaches for the new nuclear fuel-cycle facilities was conducted by a joint team from several U.S. DOE National Laboratories. The team initially focused on the aqueous and pyro-reprocessing processes planned for the conceptual Advanced Fuel Cycle Facility "AFCF" and the very-large-scale reprocessing plant, "CFTC". The IAEA safeguards approach for the large-scale Rokkasho Reprocessing Plant in Japan and others were used to develop advanced safeguards approaches for the new processes and facilities. Looking towards future application of more complex aqueous and pyro-chemical and metallurgical processes and very-large-scale facilities, the team has identified "needs" and recommended areas that will require the development of additional advanced safeguards methods and technology to implement the new approaches.

INTRODUCTION
One result of U.S. efforts to promote the international expansion of nuclear energy through the Global Nuclear Energy Partnership (GNEP) will be a dramatic expansion of nuclear fuel cycle facilities in the United States. [1] New facilities employing advanced nuclear and chemical process technologies will be constructed. These demonstration facilities - the Advanced Fuel Cycle Facility (AFCF), the Advanced Burner Reactor (ABR), and the Consolidated Fuel Treatment Center (CFTC) - will be designed to be more proliferation resistant and more easily safeguarded.[2] The Project, "Advanced Safeguards Approaches for New Nuclear Fuel Cycle Facilities," commissioned by the NA-243 Office of NNSA, has been tasked with reviewing and developing advanced safeguards approaches for the demonstration facilities mentioned above. Because one goal of GNEP is developing and sharing proliferation-resistant nuclear technology and services with partner nations, the safeguards approaches considered will be consistent with international safeguards as currently implemented by the International Atomic Energy Agency (IAEA). AFCF in particular is envisioned to serve as a test bed demonstrating the advanced safeguards measures and equipment currently under consideration. The following paper summarizes the development "needs" of the advanced safeguards approaches for the reprocessing processes to be deployed at the AFCF and CFTC facilities.

This study considered the lessons learned in the course of the last 40 years from applying nuclear material safeguards to nuclear fuel reprocessing plants. In particular it referred to safeguards approaches applied to reprocessing plants at West Valley (New York/USA), Hanford (Washington/USA), AGNS-Barnwell (South Carolina/USA), Tokaimura and Rokkashomura (Japan). The safeguards and design experience with the pyro-metallurgical reprocessing process at EBR-II at Idaho Falls (Idaho/USA) and the pyro-electrochemical ACP facility at the Korean Atomic Energy Research Institute (KAERI) Site in Daejon (South Korea) were also considered.

The foundation for developing a nuclear material safeguards approach for aqueous reprocessing, based on the plutonium/uranium reduction extraction (PUREX) process, is well established. The international safeguards requirements are based primarily on the safeguards agreement between the state and the IAEA and the safeguards criteria used by the IAEA for reprocessing plants.[3] [4] The overarching safeguards objective is the timely detection of the diversion of one Significant Quantity "SQ" of plutonium (8 kg) within the "timeliness goal" of one month.[5] Additional safeguards measures have also been implemented because of the "93+2" program to strengthen IAEA safeguards and if the state has brought the Additional Protocol "AP" into force.[6] [7] Despite these well understood international safeguards requirements, new fuel reprocessing facilities may use more complex aqueous and pyro-chemical and metallurgical processes and are expected to be far larger than current facilities. For example, CFTC is envisioned to have a capacity of reprocessing 3,000 metric tonnes of spent fuel per year - nearly four times that of a typical large-scale commercial reprocessing plant. The technical challenges inherent in safeguarding these new processes and facilities were identified. With the current safeguards requirements in mind, advanced safeguards approaches were developed, which consequently identified "technical needs" for further development and demonstration of the new ideas and methods. The "needs" identified in the subject study are summarized at the end of this paper.

APPLYING LESSONS LEARNED FROM THE PAST AND LOOKING AT THE PRESENT

In considering how to address the application of international safeguards to the conceptual reprocessing processes at AFCF and CFTC, two points became evident: First, to regard the lessons learned from applying safeguards to the older reprocessing facilities - West Valley, New York, the Hanford PUREX Plant, the AGNS Reprocessing Plant at Barnwell, and the Tokai Reprocessing Plant in Japan. Second, to consider the safeguards approach applied at the recently commissioned large-scale Rokkashomura Reprocessing Plant (RRP) in Japan.[8] However, the relative uniqueness of the pyro-metallurgical and electro-chemical processes considered for testing at AFCF presented new challenges, since these processes have been developed only on a relatively small scale and have not been subject to international safeguards to any significant extent. To address this, the team considered the experience at the Integrated Fuel Cycle Facility in Idaho Falls and the Advanced Spent Fuel Conditioning Process (ACP) at the Korean Atomic Energy Research Institute.[9] [10] An additional challenge was posed to conceive a safeguards approach for the very-large-scale reprocessing facility, CFTC. At the outset of the project it became clear that if there are currently difficulties meeting the goals of international safeguards at large-scale reprocessing plants, based on traditional safeguards measures and nuclear material accountancy, then it would be necessary to explore additional and more advanced safeguards measures.

THE POINT OF REFERENCE

The team decided the most logical starting point would be to review the current international safeguards approach applied to the newly commissioned Rokkashomura Reprocessing Plant (RRP) in Japan. It is a large-scale, aqueous-based reprocessing plant, using the most modern safeguards measures as employed by the IAEA, the Japan Safeguards Office (JSGO), the Japanese Nuclear Material Control Center (NMCC), and the facility owner/operator – Japan Nuclear Fuel Ltd. (JNFL).[11] Referring to the safeguards approach at RRP was not intended to limit the scope of advanced or conceptual safeguards measures being considered, but the team believed it was essential to put one foot in the known world, before stretching into the future world of conceptual facilities. A photograph of RRP is shown in Figure-1.[12] A simplified process flow schematic of the aqueous separations process used at RRP, with the key measurement points for verifying nuclear material transfers is shown in Figure-2.[13] For comparison, the aqueous reprocessing process for AFCF and CFTC with prospective key measurement points is shown in Figure-3.[14] By comparing the safeguards approaches at RRP and other facilities the study revealed gaps in current technologies for implementing the advanced approaches. These are summarized in the Results Section of this paper.

Figure-1
Rokkashomura Reprocessing Plant "RRP" Complex

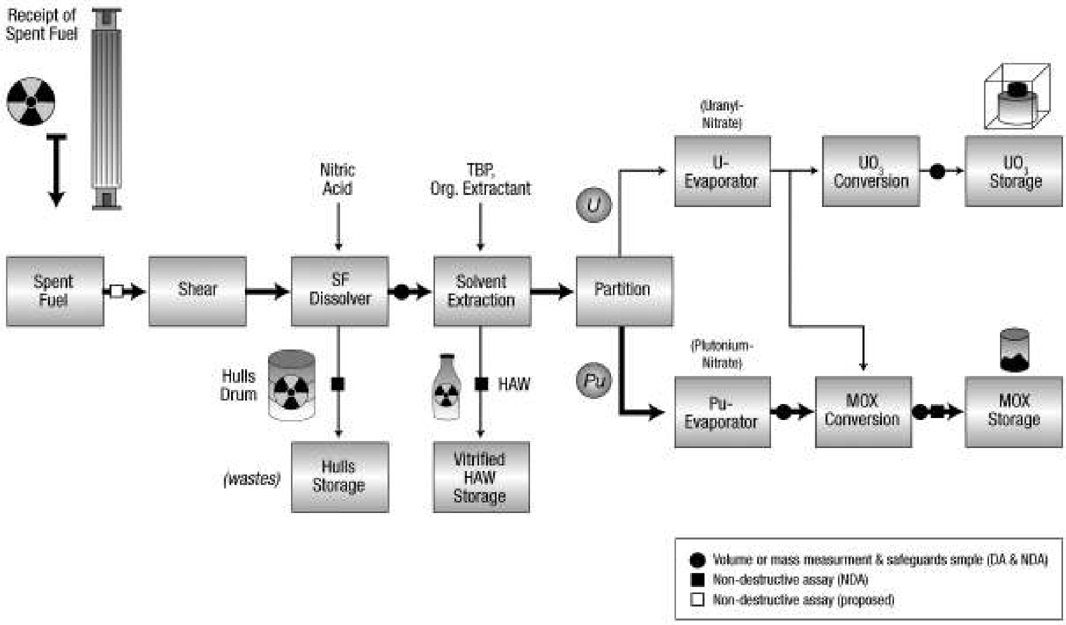

Figure-2
Simplified Process Flow Schematic for RRP with Key Measurement Points

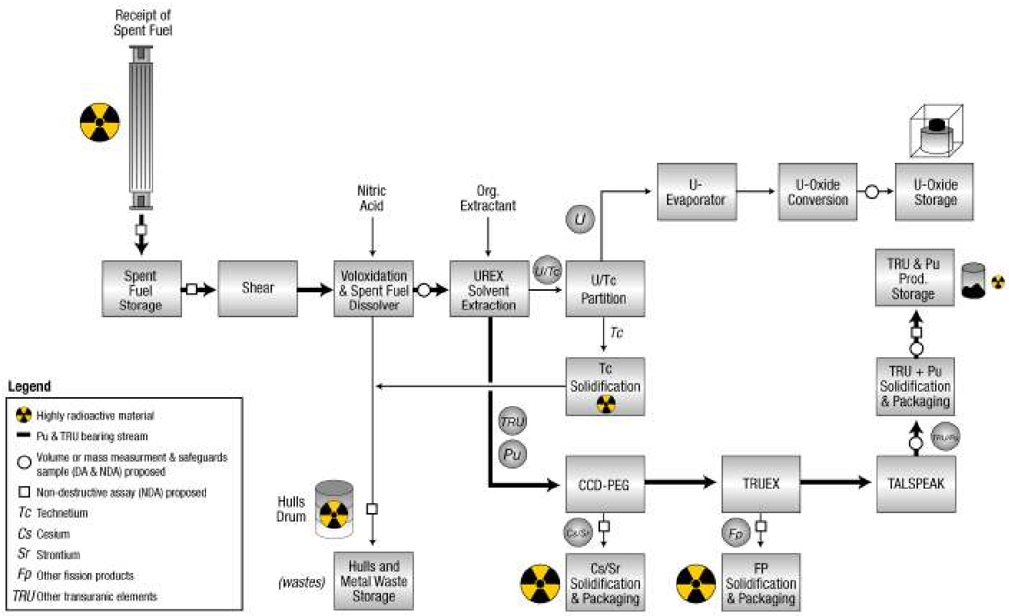

Figure-3
Simplified Process Schematic of the UREX+ Process with Key Measurement Points

RESULTS OF THE STUDY

As a consequence of studying advanced international safeguards approaches for new reprocessing plants, the project team concluded the following:[15]

1. An International Safeguards Project and Forum is needed to address the new challenges of safeguarding pyro-reprocessing and very-large-scale reprocessing plants along the lines of the LASCAR Project. The IAEA may need to consider new safeguards criteria specifically for the pyro-reprocessing processes, since the current criteria are based more on aqueous reprocessing processes – therefore the emphasis on solution volume (mass) measurement and sample taking for determining nuclear material content.

2. The use of "Remote Monitoring" and "Process Monitoring" will be required to more effectively and efficiently safeguard future reprocessing plants. However, to implement "remote monitoring" there will need to be provisions for protecting sensitive and proprietary data. To implement "Process Monitoring" there will need to be a more flexible interpretation of the IAEA SGTS Policy #20, regarding the joint use of equipment for safeguards purposes.

3. On-line assay techniques for determining the nuclear material content in process solutions will need to be developed to more effectively monitor reprocessing plants remotely. It should be possible to develop and optimize an on-line Hybrid K-Edge Densitometer, or equivalent. This is extremely important for safeguarding reprocessing plants more efficiently in the future, i.e. without a large "on-site" safeguards inspector presence.

4. Safeguards at both the aqueous and pyro-reprocessing processes would be improved by employing a non-destructive assay "NDA" technique to more accurately measure the nuclear material content of spent fuel (to the level of +/- 5% total Pu and actinide content). This is very important since the inventory of nuclear material in spent fuel is currently stored on "shipper declared values" and the spent fuel may remain resident longer than the "timeliness detection goal" before being reprocessed.

5. Safeguarding new reprocessing plants would require even more extensive and highly automated unattended safeguards and surveillance data collection and evaluation. Such systems would have to reach the same level of design and reliability as the centralized control systems used in modern petrochemical plants and nuclear power stations. These systems would have to be highly integrated and permit an automated evaluation of the safeguards and surveillance data.

6. If additional complementary safeguards measures such as process monitoring and highly integrated and automated data collection were employed, it may be possible to randomize safeguards verification activities, rather than sampling and verifying 100% of all plutonium-bearing solution transfers. This randomization and reduction in verification frequency would be analogous to applying the principles of "Statistical Process Control" to safeguards. However, it would require that the process be well-

characterized and monitored, and that the facility operator declare all activities involving nuclear material in advance.

7. An effective safeguards approach for the aqueous separations line of AFCF could be developed based on traditional safeguards measures, as have been applied to the Rokkashomura Reprocessing Plant (RRP). One of the greatest benefits of AFCF will be to test prospective safeguards measures for safeguarding the new aqueous and pyro-reprocessing processes. These tests will also benefit the prospective application of safeguards at the very-large-scale conceptual reprocessing plant, CFTC.

8. It would be very challenging to meet IAEA inspection goals at a reprocessing plant with a 3,000 tonne per year spent fuel throughput, based on current safeguards measurement uncertainties. However, it would be easier to meet these goals if the facility were constructed of four modular reprocessing lines with a capacity of 700 to 800 tonnes per year. Such a design would also be more flexible for periodic maintenance (i.e. shutting down lines in a rotating manner, rather than the entire facility).

9. It is very challenging to measure the nuclear material content of pyro-process metallic solutions by NDA, because of the self-shielding of the dense solutions and because the uranium and plutonium will be mixed with other actinides. Development is needed to reach a measurement accuracy of +/- 1% total plutonium and actinides for such plutonium-bearing metallic process materials.

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