United States
Nuclear Regulatory Commission
Washington, D.C. 20555-0001

U.S. NUCLEAR REGULATORY COMMISSION REPORT TO THE U.S. DEPARTMENT OF ENERGY, ON ACTIVITIES COVERED UNDER INTERAGENCY AGREEMENT DE-AI01-07NE24496/001

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1. BACKGROUND

On July 13, 2007, the U.S. Nuclear Regulatory Commission (NRC) and the U.S. Department of Energy (DOE) signed a Memorandum of Understanding that established the initial framework for NRC participation in technical exchange activities related to the recycling of spent nuclear fuel (SNF) under the Advanced Fuel Cycle Initiative (AFCI)/Global Nuclear Energy Partnership (GNEP) Program. NRC participation includes an exchange of information, between the NRC and DOE, and interaction between the NRC and DOE and its National Laboratories and international regulators and operators of SNF recycling facilities.

On September 12, 2007, the NRC and DOE signed an Interagency Agreement (IA) to foster the NRC/DOE technical exchange of information on AFCI/GNEP. The IA requires NRC to provide, to DOE by April 30, 2009, a status report on the activities NRC has performed, under the IA, during the latest performance period. The IA also requires the NRC to discuss, in the report, any potential safety, safeguards, and security issues of proposed advanced SNF recycling facilities, including design or operational insights that would facilitate or expedite NRC licensing of a recycling facility. This is the second report to DOE under the IA. The first report was issued on April 18, 2008 (Agencywide Documents Access and Management System [ADAMS] Accession No. ML080990542).

2. PURPOSE

The objective of this report is to provide DOE with the status of the activities that NRC has performed under the IA. This report includes regulatory insights that would inform DOE's AFCI research and development activities and insights regarding the domestic licensablility of SNF recycling facilities gained from the staff's technical assessment. The report also summarizes facility tours, conferences, and seminars that NRC staff has attended.

Enclosure

3. TECHNICAL ASSESSMENT

a. Gap Analysis

On June 28, 2007, in the Staff Requirements Memorandum (SRM) for SECY-07-0081, "Regulatory Options for Licensing Facilities Associated with GNEP" (ADAMS Accession No. ML071800084), the Commission directed the staff to conduct a regulatory gap analysis for recycling facilities proposed under DOE's GNEP initiative, to determine which regulations would need to be revised to allow for a stable, predictable, and timely licensing review of the proposed facilities. The purposes of this effort are to identify: (1) what NRC regulations clearly apply; (2) what regulations clearly do not apply; (3) what regulations partially apply, or apply in intent; and (4) gaps in the regulations, including their characterization, that would need to be addressed through rulemaking. The NRC staff completed its preliminary first-order gap analysis in December 2008 (ADAMS Accession No. ML082260223).

In accordance with SECY-08-0134, entitled, "Regulatory Structure for Spent fuel Reprocessing," dated September 12, 2008, the NRC staff completed its final gap analysis in March 2009. The NRC staff provided the Commission with a summary of the results, in a Commission paper, SECY-09-0082, dated May 28, 2009 (ADAMS Accession No. ML091520243). NRC efforts associated with the development of the regulatory framework for recycling facilities is being conducted outside the IA.

b. Regulatory Insights

Several regulatory insights were provided in the previous report to DOE (ADAMS Accession No. ML080990542). Additional regulatory insights obtained during the performance period of this report are provided below.

Sellafield Visit

In February 2009, NRC staff members specializing in nuclear criticality safety (NCS) visited the Sellafield site in the United Kingdom (UK), where SNF from nuclear reactors is reprocessed. The purpose of the visit was to: (1) observe, and discuss with Sellafield Ltd., the operator of Sellafield site including the Thermal Oxide Reprocessing Plant (THORP), the implementation of its criticality safety program; (2) participate in technical tours of THORP and other related facilities; (3) gain regulatory insights into the licensing, operation, and oversight of an operating reprocessing facility; and (4) identify technical issues, in the area of NCS, that would need to be addressed as NRC develops its regulatory infrastructure to regulate potential future reprocessing facilities in the U.S. Some key regulatory insights are listed below.

Understanding process chemistry

At THORP, there is a much greater reliance on controlling process chemistry for NCS purposes, than at current NRC-licensed fuel processing facilities. NRC NCS specialists would need to have a good understanding of this chemistry to license and inspect a similar reprocessing facility. Experimental data on the credible chemical process upsets (e.g., from pilot process studies) would be needed for an NCS specialist to have confidence that chemical controls provide a sufficient margin of safety and to confirm risk analysis. Technical demonstration on an acceptable means of chemical control would need to be developed.

Discussions with Sellafield Ltd., made it clear to the NRC staff, that it is essential for a safety or safeguards analyst, involved in either demonstrating or reviewing safety or safeguards for a reprocessing facility, to understand the chemistry of the processes under both normal and credible abnormal conditions.

Extensive use of neutron and alpha monitors

The use of neutron and alpha monitors for NCS at THORP, is much more extensive than at current NRC-licensed fuel facilities. The need to recalibrate these monitors for each batch is not something that occurs at NRC-licensed fuel facilities. Technical demonstration on the reliability of using these monitors in this manner would need to be developed.

Burnup credit

NRC already has guidance on the use of burnup credit in the NCS basis for transportation and storage casks (see Division of Spent Fuel Storage and Transportation – Interim Safety Guidance 8, Rev. 2), but additional guidance would be needed if it were to be applied to allow burnup credit for dissolved SNF.

Remote inspection capability

Much of the reprocessing operations takes place inside hot cells, where observation and inspection of the operation are limited. Technical demonstration of the necessity and acceptability of remote means of inspection (e.g., cameras) would need to be developed.

Fixed neutron absorbers

The American National Standards Institute/American Nuclear Society (ANSI/ANS) standards for Raschig rings and fixed neutron absorbers (ANSI/ANS-8.5 and -8.21, respectively) require periodic inspection to ensure that they are still adequate to perform their safety function. These inspections are not performed at THORP, because of the difficulty of conducting them inside very high radiation areas in the hot cells. Technical demonstration on the acceptability of deviating from standard inspection practices would need to be developed. Such guidance would likely influence the selection and suitability of NCS controls in an NRC-licensed reprocessing facility.

Safety-case basis

The safety case for THORP relies to a large extent on experimental data obtained from pilot plant operations. For THORP, process flow sheets were first developed and then tested at a pilot plant at the Sellafield site, where data were obtained by intentionally modifying controlled parameters, such as pH and temperature, to mimic credible abnormal conditions. The NRC considers this process to be an appropriate method for demonstrating safety of a new SNF reprocessing technology.

Programmable Logic Controllers

At THORP, all active structures, systems, and components (SSCs) important to safety are required to be hard-wired and, therefore, programmable logic controllers (PLCs) cannot be used for SSCs important to safety. At NRC-licensed fuel facilities, the needed reliabilities of PLCs for active items relied on for safety (IROFS) have been found to be acceptable for various applications. If an SNF reprocessing facility were to be licensed in the U.S., because of the relatively high hazards associated with such a facility, the needed reliability of any PLC used for an IROFS would first need to be appropriately demonstrated.

THORP licensing documents

The key licensing documents for THORP include the Design Safety Report, Preliminary Safety Report, Inactive Commissioning Safety Report, Active Commissioning Safety Report, and Operating Safety Report. The key licensing documents for fuel facilities licensed by the NRC are the License Application and the "Integrated Safety Analysis Summary." These differences illustrate some of the differences in licensing approaches used in the UK and the U.S.

Seismic requirements for structures

Key structures associated with THORP were built to withstand a seismic-induced ground acceleration of 0.25g that would result from a 10,000-year earthquake. This criterion is similar to what is required for new fuel facilities licensed by NRC, that can have significant onsite and/or offsite consequences as a result of earthquakes.

Risk evaluation

The risk to a worker from each significant accident sequence, process, and plant is pessimistically estimated, to demonstrate compliance with the risk targets. In addition, the risk to a member of the public from site-wide operations is also estimated. Although, 10 *Code of Federal Regulations* (CFR) Part 70 requires risks to workers and members of the public to be evaluated qualitatively or quantitatively for each significant accident sequence, it does not require such evaluations for an entire process, plant or site.

Incidents of Criticality Interest at Sellafield

In providing a historical perspective of criticality safety at the Sellafield site, Sellafield staff described three events that had criticality safety implications which could have led to a criticality accident, if they were not discovered. These are summarized below:

Event One – Accumulation of Fissile Bearing Powder in a Glovebox (March 2005)

This event involved the accumulation of powder in a glovebox. The powder could have been plutonium oxide, plutonium oxalate or a mixture of both, and had accumulated as a result of a minor leak developing from normal containment within a furnace glovebox. It then became deposited in another glovebox, due to the action of the ventilation system.

The accumulation was detected during a glovebox inspection. At the time of detection, the accumulation was spread around the glovebox floor with a thickness of less than 1 centimeter – this being much less than the safe slab thickness for any credible fissile compound which could be present. Nonetheless, the accumulation did represent a fissile mass outside of containment which was significantly larger than normal. The main concern from a criticality safety perspective was that if the accumulation had carried on undetected, an eventual unsafe condition could have potentially been reached. However, it is not expected that a criticality would have occurred in this manner due to the very long timescale which would have been required for this to happen.

The main learning from this event was the importance of properly considering the potential for accumulation of fissile material in unexpected places, and the importance for making adequate provision for the detection of such material. As a result of this event, a number of improvements were introduced to the plant which included: (1) a complete review of glovebox housekeeping arrangements; (2) formalization of the inspection regime; (3) installation of a trip system based on neutron monitoring; and (4) tighter surveillance of process losses by means of a batch accountancy system.

Event Two – Leakage of Fissile Liquor from a Failed Flexible Hose (January 2005)

This event involved the failure of a flexible hose coupling in the discharge line from a pump which feeds high concentration fissile liquor from storage tanks into the process. A temporary plant modification had been put in place and the plant had then been returned to what was thought to be its original condition. However, the end state was in fact different to the original, in that the attachment locations for the flexible hose connection had changed. This subjected the hose to more strain than normal, and a leak occurred. Such spills had been anticipated and assessed in the Safety Case, with the following lines of defense designated: (1) the glovebox had a sump, with a drain line to a safe geometry tank (designed to cope with the maximum credible pumping rate); (2) a sump probe alarm was installed to alert the operator in the plant control room should liquor be detected in the sump; and (3) a sump interlock was installed to stop the pump, and hence delivery of liquor to the leak site, should liquor be detected in the sump.

In the event of the leak, the sump became blocked and two out of the three designated lines of defense (the drain line and the sump interlock) failed to work properly. However the alarm function did work correctly and an operator responded and cleared out the drain blockage. In addition to this, liquor was able to flow down suction selectors in the base of the glovebox into safe geometry tanks. However, it is noted that these were not formally designated in the Safety Case at the time.

The main learning from this event was the importance of giving proper consideration to change control, and the importance of avoiding common cause failures between the initiating event (the leak) and the protection system (the leak itself caused the blockage of the drain line). This incident was of concern as two of the three designated lines of defence failed to perform correctly. Improvements following this incident included: (1) installing better drain line strainers; (2) formally designating the suction selectors (where these are present); (3) modifying the sump probes to improve their ability to detect liquor; and (4) improving housekeeping measures within the glovebox.

Event Three – Leak of Fissile Material from an Evaporator (September 1992)

In this event a failure occurred in a pipe connected to a plutonium evaporation system. This resulted in a leak of plutonium nitrate liquor into a cell. Due to the high temperature of the evaporator vessels, most of the liquor crystallised before it could reach the cell sump, which would have led to the leak being revealed promptly.

The leak was detected and operations stopped before an unsafe situation was reached. As a result of this incident several improvements to the leak prevention and detection aspects of the evaporator were carried out. These included: (1) replacement of the steel evaporator with a zirconium based one, which is less susceptible to corrosion and leakage; (2) use of a camera based inspection regime to check for leaks; and (3) installation of drip trays with leak detection mechanisms under potential leak sites.

The main learning to come from this event was the importance of properly considering the progression of a potential accident sequence (in this case a leak) and the adequacy of the detection mechanisms in place.

Recycling Reactors

NRC's Office of New Reactors staff continued its review of the documentation related to liquid-metal reactor (LMRs). Some of these are listed below:

- NUREG-0968, "Safety Evaluation Report Related to the Construction of he Clinch River Breeder Reactor Plant" and its associated application for a construction permit;
- NUREG-1369, "Pre-application Safety Evaluation Report for the Sodium Advanced Fast Reactor (SAFR) Liquid-Metal Reactor;"
- NUREG-1368, "Pre-application Safety Evaluation Report for the Power Reactor Innovative Small Module (PRISM) Liquid-Metal Reactor;"
- NUREG-1860, "Feasibility Study for a Risk-Informed and Performance-Based Regulatory Structure for Future Plant Licensing;" and

- other documents, letters, Advisory Committee on Reactor Safeguards presentations, etc.

In July 1993, SECY-93-0092, "Issues Pertaining to the Advanced Reactor [PRISM, Modular High Temperature Gas-cooled Reactor (MHTGR), and Process Inherent Ultimate Safety (PIUS)] and CANDU 3 Designs and their Relationship to Current Regulatory Requirements" (ML040210725), provided the Commission with results of its review of several advanced reactors, including the PRISM reactor. In its pre-application review of the PRISM design, the NRC staff found that the criteria for eight areas proposed by the PRISM designers deviate from the current light water reactor (LWR) guidance. These areas are: (1) Accident Evaluation; (2) Calculation of Source Term; (3) Containment Performance; (4) Emergency Planning; (5) Operator Staffing and Function; (6) Residual Heat Removal; (7) Positive Void Reactivity Coefficient; and (8) Design of Control Room and Remote Shutdown Area.

Based on the NRC staff's review of the available literature, confirmatory research in the reactor system arena would be needed to support the review and verification of the advance burner reactor (ABR) license application. In particular, the proposed use of any new fuel and its qualification program would represent a challenge. This confirmatory research should include, but not be limited to, detailed analysis in the following areas: (1) thermal-hydraulics; (2) fuel qualification that includes the mechanical, thermal, and neutronic behavior of the fuel, as well as the effect that the addition of transuranics has on these properties, the fuel behavior, and the safety margin; (3) nuclear phenomena, including reactivity and the positive void reactivity coefficient; (4) severe accident and source term; (5) residual-heat removal, including analysis of the passive systems; (6) materials; and (7) containment/confinement performance. Along with conducting the confirmatory research, there should be considerable effort to update the computer codes and other infrastructure that were developed in the 1970s as part of an extensive research and development program to support deployment of sodium-cooled fast reactors. Ideally, confirmatory research would be conducted early in the program, to bound uncertainties and to ensure that NRC could ultimately license the resulting design if it met NRC's licensing requirements. Collectively these additional research and development tools would help facilitate the review and verification of the ABR design and its impact on public health and safety, and the environment, and that, in turn, would help expedite the licensing review. However, NRC focus on future research activities continues, at this time, to represent a challenge, in terms of resources, because significant resources are currently devoted to the review of the current LWR applications that were recently submitted.

Material Control and Accounting

To better address the current threat environment, NRC staff recommended to the Commission, in a paper entitled "Rulemaking Plan: Part 74 – Material Control and Accounting of Special Nuclear Material," SECY-08-0059 dated April 25, 2008, that 10 CFR Part 74 be amended by revising the special nuclear material (SNM) categorization values, and summarizing this information in a new NRC SNM categorization table. This table would define threshold quantities and forms for fissile material requiring varying levels of protection, taking into consideration the relative attractiveness of the material for fabricating an improvised nuclear device. On February 5, 2009, the Commission approved the rulemaking but did not support expanding material control and accounting (MC&A) requirements to americium and neptunium. In addition, the Commission directed the NRC staff to consider integrating its MC&A recommendations, presented in SECY-08-0059, into its effort to develop the regulatory framework for reprocessing facilities.

c. Summary of Technology Related Seminars/Meetings/Site Visits for NRC Staff

This section identifies seminars, meetings and site visits that the NRC staff participated in during the current performance period of this report as well as seminars, meetings and site visits from the previous performance period which were not reported in the previous report.

Seminars and Training

In accordance with the IA, DOE provided the NRC with two seminars on advanced recycling technology waste forms, on April 23, 2008, and safeguards, on June 10, 2008. These seminars provided insights to NRC staff regarding waste management and safeguards associated with a reprocessing facility.

On December 16-18, 2008, five NRC staff members attended a nuclear chemistry course, on reprocessing, at Vanderbilt University in Nashville, Tennessee.

Meetings

On April 29, 2008, NRC staff met with General Electric-Hitachi (GEH), in a closed meeting, to discuss proprietary portions of a GEH conceptual design of an Advanced Recycling Center that would use the U.S. National Laboratory-developed electrometallurgical process to separate actinides, fission products, and uranium from LWR SNF, then use the separated actinides, in the PRISM reactor, for electrical production, while consuming actinides.

On May 6-7, 2008, NRC staff participated in a GNEP Transmutation Fuels Campaign meeting in Gaithersburg, Maryland.

On June 5, 2008, NRC staff met with the International Nuclear Recycling Alliance (INRA), in a closed meeting, to discuss INRA's proprietary proposal to DOE for the Consolidated Fuel Treatment Center (CFTC) and the Advanced Recycling Reactor.

On June 17-18, 2008, NRC staff participated in a GNEP Safeguards Campaign meeting in Gaithersburg, Maryland.

On July 8, 2008, NRC staff participated in a GNEP Separations Campaign meeting in Washington, DC.

On July 15, 2008, NRC staff met with EnergySolutions, in a closed meeting, to discuss the conceptual design of its proprietary proposal to DOE, for the CFTC.

On October 7-8, 2008, five NRC staff members attended the GNEP annual meeting in Idaho Falls, Idaho. At this meeting, the current status of activities related to DOE's AFCI/GNEP Program, and also the industry's perspective on recycling, were presented. While in Idaho Falls, on October 6, 2008, the NRC staff toured various SNF recycling-related processing and storage facilities.

On October 27-28, 2008, NRC staff participated in a GNEP Transmutation Fuels Campaign meeting in Salt Lake City, Utah.

On November 12, 2008, NRC staff met with the INRA, in a closed meeting, to discuss INRA's safety approach recommendations for the CFTC, in light of safety analysis approaches used at SNF recycling plants in France and Japan, and the mixed-oxide fuel fabrication facility under construction at the Savannah River Site near Aiken, South Carolina.

Site Visits

On February 26-28, 2008, four NRC staff members conducted technical tours of various SNF processing and storage facilities at the Savannah River National Laboratory, in Aiken, South Carolina. While in Aiken, the NRC staff also attended part of a separations campaign technical meeting, where various national laboratories presented the status of their ongoing research and development efforts in the area of SNF recycling.

On April 30, 2008, five NRC staff members visited the Oak Ridge National Laboratory, to tour DOE's laboratory-scale Coupled End-To-End (CETE) demonstration of various aqueous technologies used to separate SNF.

On May 12-23, 2008, four NRC staff travelled to the UK and France to participate in technical tours of the SNF reprocessing facilities in Sellafield, UK, La Hague, France, and the MELOX production site in Marcoule, France. The staff also attended a 4-day international conference (ATALANTE 2008) in Montpellier, France, in which ongoing work related to SNF reprocessing technologies was presented by various international organizations and research facilities.

On September 16, 2008, four NRC staff members visited the Oak Ridge National Laboratory, to tour DOE's laboratory-scale CETE demonstration.

On February 1-6, 2009, two NRC staff members accompanied NRC's Executive Director for Operations, on his visit to the UK to meet with Nuclear Installations Inspectorate Officials and tour the Sellafield site, to gain regulatory insights into the licensing, operation, and oversight of an operating reprocessing facility.

On February 23-27, 2009, three NRC staff members, including two specializing in NCS visited the Sellafield site in the UK, where SNF from nuclear reactors is reprocessed. The purpose of the visit was to observe and discuss, with Sellafield Ltd. (the Sellafield site operator), implementation of its NCS program; participate in technical tours of THORP and other related facilities; gain regulatory insights into the licensing, operation, and oversight of an operating reprocessing facility; and identify technical issues, in the area of NCS, that would need to be addressed as NRC develops its regulatory infrastructure, to regulate potential future reprocessing facilities in the U.S.

4. PROPOSED FUTURE ACTIVITIES

The NRC staff plans to become acquainted with and verify computer codes that have been used for modeling associated with the reprocessing facilities and the LMR, such as modeling of the various separation strategies and plant conditions at an aqueous reprocessing facility. A review of conditions and assumptions used for AMUSE and ASPEN (the current models that are being developed and used for aqueous reprocessing), would assist the NRC staff in providing DOE insights into conducting future research and development activities related to aqueous reprocessing.

In 2009, the NRC staff anticipates visiting the Rokkasho Mura reprocessing plant, in Japan, to conduct technical observations in the areas of MC&A and risk/safety analysis. The NRC staff anticipates obtaining valuable regulatory insights from this visit, as it had done in the area of NCS from its February 2009, Sellafield visit.

Now that the regulatory gap analysis is complete, the NRC staff will begin preparing a technical-bases document to support rulemaking. If sufficient resources are available, the NRC staff estimates that the technical-bases document could be completed in approximately one year, although this work is not covered by the IA. After the technical-bases document is completed, NRC will make a decision on whether to move forward with rulemaking. The necessary rulemaking effort will likely involve multiple, simultaneous rulemakings and parallel development of the associated regulatory guidance documents.