UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON NUCLEAR WASTE
WASHINGTON, DC 20555 - 0001

ACNWMR-0270

October 11, 2007

The Honorable Dale E. Klein
Chairman
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Dear Chairman Klein:

SUBJECT: REGULATION OF ADVANCED SPENT NUCLEAR FUEL REPROCESSING AND REFABRICATION FACILITIES

SUMMARY

Facilities for reprocessing spent nuclear fuel (SNF) and fabricating new fuels (i.e., recycle) as envisioned by the U.S. Department of Energy (DOE) would produce a range of products, wastes, and effluents that are unfamiliar to the U.S. civilian sector. Examples of such unfamiliar materials are cladding waste, a mixture of cesium and strontium, krypton-85 (^{85}Kr), technetium-99 (^{99}Tc), recycled uranium, and a mixture of transuranic elements. The potential existence of these materials raises the need to develop regulations concerning their classification, form, packaging, storage, and disposal or release.

As envisioned by DOE, future recycle facilities would be much more complex than existing recycle facilities and would contain substantial inventories of (1) liquids that could be flammable, corrosive, and highly radioactive and (2) zircaloy-clad SNF in storage pools that can burn under certain conditions. Accidents involving these materials could lead to significant offsite releases of radioactive material. The U.S. Nuclear Regulatory Commission (NRC) needs to consider these unique hazards when developing or revising regulations to license recycle facilities.

Major Recommendations

The Advisory Committee on Nuclear Waste and Materials (the Committee) makes the following key recommendations concerning regulation of SNF recycle facilities:

- Regulations for licensing recycle facilities should require the use of an approach based on probabilistic risk analysis (PRA) for facilities processing large inventories of solid and liquid radioactive materials and hazardous chemicals.

- The NRC should consider using a two-step licensing process for SNF recycle facilities until the NRC staff becomes familiar with the processes, equipment, and materials in the recycle facilities.

- The gap analysis and the technical basis document being prepared by the NRC staff should include an analysis of the current civilian waste classification and disposal system for the range of wastes that may be produced by SNF recycle facilities.

The remainder of this letter provides supporting observations and additional recommendations.

BACKGROUND

DOE is pursuing programs to develop and deploy SNF recycle[1] technology. The current DOE recycle program contemplates building a nuclear fuel recycle facility, an advanced power (burner) reactor for irradiating transuranic elements, and a research facility to develop the required recycle technology. The NRC may license the first two of these facilities. Congress directed DOE to select a site for the nuclear fuel recycle facility by fiscal year (FY) 2007 [Congress, 2005] and to initiate construction of one or more such facilities by FY 2010. Licensing SNF recycle facilities will require changes to the NRC's existing regulatory framework, which is now structured to license light-water reactors and facilities associated with the once-through fuel cycle. The Commission directed [NRC, 2006 a,b] that the Committee become knowledgeable about developments in fuel recycle and help in defining the issues most important to the NRC concerning potential licensing of fuel recycle facilities.

In FY 2006, the Committee received initial briefings by Committee consultants, NRC staff, and DOE staff on SNF recycle. Based on these briefings, the Committee decided to prepare a white paper on this subject and chartered a group of experts[2] to do so. The goal of the paper is to summarize the technical, regulatory, and legal aspects of the history, status, and issues concerning SNF recycle for the following two purposes:

(1) to provide the primary basis for the Committee's initial observations on important regulatory issues that SNF recycle would raise and recommendations to address these issues

(2) to capture the knowledge of experts and the history of SNF recycle and implications for current SNF recycle programs in line with the Commission's knowledge management goals

The Committee and NRC staff offices reviewed successive drafts of the paper. A revised draft was posted on the Agencywide Documents Access and Management System (ADAMS) site, which is accessible to the public, and a list of expert reviewers (see Enclosure 1) was invited to submit comments. The draft final version of the white paper in Enclosure 2 incorporated

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[1] For the purposes of this document, "SNF recycle" involves SNF reprocessing (separating or potentially fractionating SNF into its constituent parts without producing a separated plutonium stream); refabrication (making the recovered uranium, transuranic elements, and possibly some fission products into fresh fuel or targets); storage of spent fuel; management of solid, liquid, and gaseous wastes; and incorporating radionuclides that cannot be readily destroyed by irradiation into tailored waste forms for disposal appropriate to their hazard and longevity.

[2] These experts included R.G. Wymer, Oak Ridge National Laboratory (retired); L.T. Tavlarides, Syracuse University; H.J. Larson, NRC (retired); J.H. Flack (Committee staff); and A.G. Croff (Committee).

comments on the public review draft, and final comments by the Committee and its staff. The Committee also obtained information on fuel recycle from numerous other public briefings and discussions, which are listed in Enclosure 3.

OBSERVATIONS AND RECOMMENDATIONS

Primary Licensing Regulation for Recycle Facilities

The NRC could use several regulatory options to license SNF recycle facilities. All have deficiencies that must be addressed to make them suitable for this purpose [Enclosure 2, Section VIII; NRC, 2007b]. To address these deficiencies, the Commission directed the staff [NRC, 2007a] to begin developing the regulatory framework to license SNF recycle facilities using an option based on Title 10, Part 70, "Domestic Licensing of Special Nuclear Material," of the *Code of Federal Regulations* (10 CFR Part 70) by preparing the following:

- a technical basis document to support rulemaking for 10 CFR Part 70 with revisions to 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," as appropriate to eliminate its applicability to licensing a SNF reprocessing plant

- a gap analysis for all NRC regulations (10 CFR Chapter I) to identify changes in regulatory requirements that would be necessary to license a reprocessing facility

The NRC has used 10 CFR Part 70 to license fuel fabrication facilities, and the regulation is currently the basis for reviewing the license application for the mixed-oxide fuel refabrication plant at the Savannah River Site. Experience and lessons learned from previous and ongoing use of 10 CFR Part 70 to license fuel refabrication facilities are likely to be useful when deciding how the regulation should be modified to license SNF recycle facilities. However, the Committee observes that important aspects of 10 CFR Part 70 will need to be addressed for it to be an efficient and effective regulation for licensing SNF recycle facilities. These aspects include the following:

- Use of an Integrated Safety Analysis (ISA): The regulations at 10 CFR Part 70 call for the use of an ISA to evaluate the hazards in a facility processing nuclear materials. Use of an ISA is an important step towards quantifying risk. However, the Committee believes that the effort required to prepare an ISA adequate for complex SNF recycle processes handling liquids containing substantial quantities of concentrated cesium, strontium, and transuranic elements is likely to approach the effort that would be required to evaluate risks using a PRA. The Committee and the Advisory Committee on Reactor Safeguards (ACRS) continue to recommend [Committee, 2002, 2006] that a regulation based on PRA is preferable to one based on ISA because the latter has significant limitations in its treatment of dependent failures, human reliability, uncertainties, and aggregation of event sequences.

  Recommendation 1: The revision of 10 CFR Part 70 for application in licensing recycle facilities should require use of PRA-based approaches for facilities processing large inventories of solid and liquid radioactive materials and hazardous chemicals.

- One-Step Construction and Operating License (Combined License): 10 CFR Part 70 allows for a one-step licensing process, which means that the design and process details necessary to review the adequacy of a recycle facility would not be available until relatively late in the licensing process. The Committee believes this approach is appropriate for facilities containing well-established processes and equipment and where there is prior licensing experience (e.g., reactors, fuel fabrication plants). SNF recycle facilities could involve equipment, processes, and materials that may require modification as a result of regulatory requirements that evolve as the license application is being reviewed.

  Recommendation 2: The NRC should consider using a two-step licensing process for SNF recycle facilities until the NRC staff becomes familiar with the processes, equipment, and materials.

- Risk-Informing Changes to 10 CFR Part 70: The NRC uses 10 CFR Part 70 to license many other nuclear material processing facilities that are much smaller, less costly, and less complex than an anticipated SNF recycle facility. Licensing requirements appropriate to SNF recycle facilities could be unduly burdensome and may need to be tempered to be cost-effective for applicants with simpler designs and well-established technology.

  Recommendation 3: The revision of 10 CFR Part 70 to license SNF recycle facilities could have unintended consequences for other types of facilities. The revision of 10 CFR Part 70 to accommodate SNF recycle facility licensing should be risk informed by embodying a graded approach to licensing requirements. Decisions in applying the graded approach should be based on the complexity of the facility and the size, form, and potential hazard of the projected nuclear material inventory. Guidance that supports the regulations could specify requirements for various facility types.

- Basing 10 CFR Part 70 Changes on Performance: It is important that 10 CFR Part 70 be performance based. Performance-based criteria for granting a license are expressed in terms of the requirements the applicant must meet but not the means by which the applicant meets the requirement. This allows the applicant to select the most efficient means to meet the requirements based on the specific circumstances of each facility.

  Recommendation 4: Revisions to 10 CFR Part 70 to accommodate SNF recycle facilities should be performance based.

- Specificity of Changes to 10 CFR Part 70: The NRC staff paper [NRC, 2007b] presenting options for licensing SNF recycle facilities focused on the DOE Global Nuclear Energy Partnership (GNEP) and the facilities currently being proposed by the GNEP. The Committee believes the scope, functional requirements, size, and timing of these facilities are still evolving and are likely to change in response to factors such as technology development, budget considerations, stakeholder input, and broader U.S. and international decisions on nuclear and energy policy.

Recommendation 5: Revisions to 10 CFR Part 70 should be sufficiently flexible so that they apply to a broad range of recycle technologies, equipment, and facility design concepts.

Impacts of SNF Recycle on Waste Management and Classification

Recycle of SNF could generate waste types that have not been produced in the U.S. civilian sector in decades (e.g., high-level liquid waste, cladding waste) and some that have never been produced anywhere (e.g., ^{85}Kr waste, combined cesium/strontium waste). The number and nature of these wastes are presently not known. They depend on future decisions such as the number of streams into which the SNF is fractionated and the extent to which internal streams are combined for purposes of waste management. To provide a basis for the discussion of the waste management and classification system, the white paper (Enclosure 2) includes an analysis of the types of wastes that might be generated if SNF recycle were to be implemented using the UREX+1a process under development by DOE.

The UREX+1a process could result in the following products and wastes:

- uranium containing traces of radionuclides such as ^{99}Tc and neptunium-237 (^{237}Np) that is expected to be reused

- a mixture of transuranic elements that could be stored for a few decades and eventually refabricated and fissioned in a reactor

- separate waste forms destined for disposal containing hydrogen-3 (^{3}H), carbon-14 (^{14}C), ^{85}Kr, iodine-129 (^{129}I), and, in the case of fuel that has been out of the reactor for less than about 5 years, ruthenium-106 (^{106}Ru) and antimony-125 (^{125}Sb)

- a waste form destined for disposal containing the cladding from which most of the SNF matrix has been removed, insoluble solids that remain after dissolving most of the SNF matrix, and possibly most of the ^{99}Tc

- a waste form containing essentially all of the strontium-90 (^{90}Sr) and cesium-135 and -137 (^{135,137}Cs) destined for long-term (about 300 years) storage in an engineered surface facility followed by closure in place

- a vitrified waste form destined for disposal containing essentially all of the fission products not mentioned above plus traces of actinides

- a wide variety of solid wastes (e.g., failed process and laboratory equipment, used protective clothing) or wastes converted to solids (e.g., analytical solutions, ion exchange material) destined for disposal and containing concentrations of transuranic radionuclides greater than 100 nanocuries per gram (nCi/g)

Based on traditional interpretations of the definition of high-level waste (HLW) and waste classification Tables 1 and 2 in 10 CFR Part 61.55, “Waste Classification,” the following classifications would apply:

- Captured ^{85}Kr would be Class A waste because it is not listed in the tables.

- ^{14}C, ^{129}I, and cladding waste with or without ^{99}Tc are all likely to be greater-than-Class C (GTCC).

- The vitrified fission product waste would be HLW.

- Cesium/strontium waste could be HLW, GTCC low-level waste (LLW), or Class C LLW depending on the interpretation of the definition of HLW, the extent to which credit is given for decay occurring during about 300 years of interim storage, and how risks posed by long-lived ^{135}Cs (not included in the tables) are taken into account.

The Committee believes these classifications raise questions such as the following:

- Are the classifications appropriate given the risks posed by the wastes?

- Do current efforts to define a disposal destination for GTCC wastes consider potential SNF recycle wastes?

- How should the unique features of a waste incidental to reprocessing determination for cesium/strontium waste be addressed if this waste is determined to be HLW?

As described above, reprocessing SNF yields a variety of wastes having differing radionuclide concentrations. Reprocessing plant operations [Vernaz, 2006] have improved to the point that the volume of wastes (excluding uranium and plutonium) from a reprocessing plant that are destined for disposal in a deep geologic repository is about the same as the volume of the SNF fed to the plant. The combined radioactivity of the wastes from reprocessing SNF is essentially the same as that of the original SNF.

Risk-informed, performance-based criteria will also need to be devised for (1) appropriate waste forms for an inert gas (^{85}Kr) and two very-long-lived and environmentally mobile radionuclides (^{14}C and ^{129}I) and (2) acceptable disposal destinations for each type of waste (e.g., near-surface disposal, deep geologic disposal, intermediate-depth disposal). Finally, requirements for engineered and institutional controls for long-term, near-surface storage of nuclear material may be needed for facilities storing very radioactive transuranic product for times extending to decades and cesium/strontium waste for a few hundred years followed by facility closure as a cesium/strontium disposal site.

Recommendation 5: The gap analysis and the technical basis document being prepared by the NRC staff should include an analysis of the current civilian waste classification and disposal system for the range of wastes that may be produced by SNF recycle facilities.

Recommendation 6: The NRC should consider initiating a comprehensive study on the durability of engineered and institutional controls for the purpose of establishing the basis for a consistent risk-informed NRC policy on the extent to which credit can be taken for such controls. Applications to be considered include radioactive material storage, near-surface waste disposal, and control of decommissioned sites and facilities.

Impacts of SNF Recycle on Regulation of Effluent Releases

Reprocessing SNF releases volatile radionuclides to gas streams inside the facility. A U.S. Environmental Protection Agency (EPA) standard (40 CFR Part 190) effectively requires capturing 99.5 percent of the ^{129}I and 85 percent of the ^{85}Kr originally present in the SNF. The regulation does not provide specific limits on the amount of other volatile radionuclides that can be released. Captured radionuclides would be converted to a suitable form,[3] packaged, and sent to a disposal facility. Reprocessing facilities in France capture about 99.5 percent of the ^{129}I and about 35 percent of the ^{14}C and release them to the sea. The ^{3}H, which is present in low concentrations in process water, is also released to the sea.

The Committee notes the following:

- EPA had planned to consider limits on the releases of ^{3}H and ^{14}C but never completed this activity. These radionuclides could be significant contributors to the dose from releases to the environment from recycle facilities.

- The approach used by EPA to establish the existing release limits in 40 CFR Part 190 involved dividing the estimated cost of various options for removing a volatile radionuclide by the collective dose (person-rem) to the affected population and comparing the result to criteria such as limiting expenditures on effluent treatment to $1000/person-rem. For the volatile radionuclides, calculation of the collective dose involved multiplying a small dose to individuals by a large population that is exposed to the dispersed radionuclides. Previous Committee letters [Committee, 2005] have stated that this approach to estimating the absolute impacts of radionuclides is not technically defensible, and the Committee reiterates that position here.

- Capture of ^{129}I in the French and United Kingdom reprocessing plants is accomplished by aqueous scrubbing of the off-gas. This approach is efficient in this situation because the resulting solutions are intended to be released to the sea. However, water scrubbing is not efficient if radionuclides need to be recovered for packaging and land disposal, as is likely in the United States, because additional recovery processes would be required. If ^{129}I is to be captured for land disposal, the currently preferred approach uses a solid sorbent containing silver in one of a number of forms. The Rokkasho reprocessing plant, which is just beginning operations, uses such sorbents, but there is little experience with silver-based sorbents in large, modern reprocessing plants or in combination with other off-gas treatment systems that may be required in the United States.

Recommendation 7: The NRC should hold interagency discussions with EPA on whether (1) existing release limits for ^{85}Kr and ^{129}I need to be reexamined to reflect current technology and (2) release limits need to be established for ^{3}H and ^{14}C. Additionally, methodologies based on concepts other than collective dose should be used as a basis for revised release limits.

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[3] Potential waste forms for ^{85}Kr include pressurized gas cylinders, a solid zeolite waste form, and a sputtered metal waste form.

Impacts of SNF Recycle on Other Regulations

Implementation of civilian SNF recycle would require modification of regulations other than the primary regulation for licensing SNF recycle facilities. The Committee believes that 10 CFR Part 61 and 10 CFR Part 63, "Disposal of High-Level Radioactive Wastes in a Geologic Repository at Yucca Mountain, Nevada," should receive particular attention.

Regarding 10 CFR Part 61, the Committee is aware that the NRC staff, pursuant to Commission direction [NRC, 2005], is undertaking an analysis of whether depleted uranium warrants inclusion in the waste classification tables in 10 CFR 61.55, "Waste Classification." Wastes resulting from SNF recycle that might be considered for near-surface disposal may contain other significant concentrations of radionuclides that are also not listed in the waste classification tables, including ^{85}Kr, ^{135}Cs, and recycled uranium containing minor uranium isotopes and trace amounts of some fission product and transuranic elements if the uranium were to be declared waste.

Recommendation 8: The NRC staff's ongoing evaluation of whether a specific concentration limit and classification should be developed for depleted uranium in the 10 CFR Part 61 waste classification tables should consider including ^{85}Kr, ^{135}Cs, and uranium recovered from a recycle facility.

Implementation of SNF recycle could have major impacts on a deep geologic repository. Depending on the outcome of decisions on disposal of GTCC waste, the repository might receive a variety of wastes that could affect its design and operation. The Committee believes that repository licensing regulations and associated guidance have not been devised with these situations in mind.

Recommendation 9: The NRC staff should assess the possible impacts of SNF recycle and associated wastes on a potential deep geologic repository. Accommodating SNF recycle may change the licensing requirements for a deep geologic repository.

Implications of SNF Recycle for NRC Infrastructure and Knowledge Needs

The NRC staff may need access to facilities and equipment for confirmatory research to validate key assumptions and data used by an applicant to support an SNF recycle facility license application. Of particular importance are hot cell facilities capable of handling significant quantities of highly radioactive solid and liquid materials. In the United States, such facilities exist almost exclusively at DOE sites. The number of appropriate hot cells is dwindling as is the NRC's access to them. This is evidenced by the delays that lack of access to a key hot cell at Argonne National Laboratory (ANL) has caused the NRC in obtaining information concerning the performance of high-burnup (greater than 45 GWd/MT) SNF.

Recommendation 10: The NRC should assess its future needs for hot cells and the potential availability of hot cells for the purpose of deciding on a strategy to maintain the required level of access for NRC confirmatory research. Options considered should include hot cells in the United States and in other countries.

The Committee believes it is necessary for the NRC staff (and the Committee) to remain abreast of DOE technical activities to provide the historical context (e.g., the alternatives that

were considered and rejected and the reasons for it) and technical insights to support development of regulations and then review a license application. The Committee believes the recent establishment of a memorandum of understanding between the NRC and DOE in this regard is a positive step.

Recommendation 11: The Committee recommends that the NRC staff continue to keep abreast of the DOE SNF recycle technology development program and that such involvement extends to NRC observation of key experimental activities such as the GNEP Coupled End-to-End Demonstration being conducted over the next few years.

Research Needs

To fulfill its role in developing regulations and reviewing a license application for SNF recycle facilities, the NRC staff needs to independently assess the safety of the facilities. Such an assessment requires sufficient understanding of key technical aspects of the processes and materials in the plant. The Committee noted a number of research needs likely to be important to the NRC's regulatory role. Enclosure 4 summarizes these needs.

Recommendation 12: The NRC should consider supporting research concerning radionuclide separation factors, integrated modeling of SNF recycle facilities, data and methods supporting cost-benefit analyses to assess effluent controls, chemical and radiolytic degradation of solvents and ion exchange media, the durability of institutional controls and cement for 300 years or more, the performance of novel waste forms (e.g., for krypton, iodine, carbon, and cesium/strontium), and the behavior of tritium in cladding under high-temperature oxidizing conditions.

Timing and Urgency[4]

The Committee notes a number of time-consuming activities that should be completed before receipt of a license application for SNF recycle facilities to provide the basis for preparation and efficient review of the application. These activities include developing the licensing requirements for recycle facilities, modifying supporting regulations (e.g., 10 CFR Parts 50, 51, 61, 63, 73, 74, and 75), preparing guidance documents underpinning the foregoing, establishing release limits for volatile radionuclides such as ^{3}H and ^{14}C, and reconsidering the waste classification and disposal technology system. Establishing release limits for volatile radionuclides could take a particularly long time because of the likely need to perform engineering design, cost, and risk studies as a basis for the limits.

The Committee notes that DOE also needs to complete a number of time-consuming activities before it can submit a license application for a recycle facility having the full capabilities presently envisioned by DOE (i.e., using the UREX+1a or other flowsheet). These activities include completing the development and testing of a complex four-step reprocessing flowsheet, testing equipment to implement the flowsheet, developing waste treatment processes and disposal facilities for a number of novel waste streams, completing a generic environmental impact statement for the recycle program, designing the facility, and preparing the license application and other regulatory documents.

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[4] See discussion in Section IX.F of Enclosure 3.

The Committee estimates that, in the foregoing scenario, the time required to accomplish both the regulatory and DOE activities is likely to be at least several years, but this estimate has substantial uncertainty. The Committee notes that DOE could decide to initially deploy SNF recycle facilities that do not have the full capabilities presently envisioned by the department and add additional modules over time to achieve the full capabilities. Such a facility is significantly less complex than a facility having all the envisioned capabilities at the outset and represents only a modest extension of existing technology. As a consequence, the time required to develop and submit a license application could be significantly less than the time needed to prepare an application for a fully capable facility, but the time required to undertake the required regulatory development would not be significantly reduced.

Recommendation 13: The Committee recommends that the highest priority should be given to modifying regulations concerning release limits for volatile radionuclides from SNF recycle facilities and addressing the interrelated issues related to waste classification and disposal destinations for novel wastes that could be produced by SNF recycle facilities.

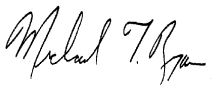
Recommendation 14: The Committee recommends that the NRC staff monitor DOE plans for implementing SNF recycle because DOE could develop a license application for a recycle facility based on a modest extension of existing technology in a timeframe that could challenge the ability of the NRC to establish a regulatory framework for recycle facilities.

Path Forward

The Committee appreciates the many informative briefings and discussions with staff members from the Office of Nuclear Material Safety and Safeguards, the Office of Federal and State Materials and Environmental Management Programs, and the Office of Nuclear Regulatory Research. The Committee looks forward to future interactions with NRC staff on activities that impinge on SNF recycle. Additionally, the Committee plans to continue modest efforts to keep abreast of SNF recycle technology and plans.

Enclosures: As stated

Sincerely,



Michael T. Ryan
Chairman

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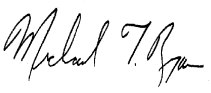

Michael T. Ryan
Chairman

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