BNL-100883-2013-CP

APPROACHES FOR ADDRESSING RISKS IN REPROCESSING FACILITIES: AN ASSESSMENT

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Presented at the ANS PSA 2013 International Topical Meeting on Probabilistic Safety Assessment and Analysis

Columbia, SC
September 22-26, 2013

Nuclear Science and Technology Department

Brookhaven National Laboratory

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ANS PSA 2013 International Topical Meeting on Probabilistic Safety Assessment and Analysis
Columbia, SC, September 22-26, 2013, on CD-ROM, American Nuclear Society, LaGrange Park, IL (2013)

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ABSTRACT

This paper addresses methods for assessing the risk posed by a reprocessing facility, which has not previously been quantified relative to other fuel-cycle facilities. Reprocessing facilities can have higher potential source terms than other fuel-cycle facilities, which heighten the risk of the former facilities. This paper focuses on considerations associated with the risk for such facilities, summarizing advances in the following related areas: 1) It describes approaches proposed by the U.S. nuclear industry (NEI) for regulating these facilities; 2) it explores the types of potential hazards that they pose to the public, their workers, and the environment; 3) it offers an overview of accidents and their consequences at these facilities worldwide; 4) it discusses the feasibility, advantages, and disadvantages of undertaking detailed quantitative risk assessments versus simplified qualitative ones for the range of accidents associated with large reprocessing facilities; 5) it briefly describes recent progress on risk-assessment methodologies and considerations for a reprocessing facility; and, 6) it gives some observations about these areas. The paper also lists references pertinent to these subjects.

Key Words: Nuclear Fuel Reprocessing, Risks

1 INTRODUCTION

1.1 Objectives

Brookhaven National Laboratory (BNL): (1) explored the potential hazards that reprocessing facilities pose to the public, workers, and the environment, (2) searched the literature for reports and other documents, particularly those related to regulating them, (3) reviewed the experience of current operating facilities in Japan, France, U.K., and elsewhere, and, (4) gleaned insights on fuel-cycle facilities from reports such as the recent NUREG-1909 [1], and a white paper from the Nuclear Energy Institute (NEI) [2]. This paper documents the observations of our study, assessing the feasibility, advantages, and disadvantages of conducting detailed quantitative risk assessments versus simplified qualitative ones for the range of accidents associated with large reprocessing facilities.

This paper summarizes our short-term, limited-scope study. The range of material for this subject area was not fully surveyed. Moreover, because some information was proprietary, some parts of the literature were unavailable. Nevertheless, we identified enough material from which to make sound observations and offer supportive insights.

1.2 Background

A suitably performed risk assessment of a fuel-reprocessing facility potentially can characterize adequately the associated risks of concern, as is the general sentiment of the NRC Advisory Committee on Nuclear Waste and Materials (ACNW&M) (NUREG-1909 [1]). SECY-09-0082 comments on the need to revise 10 CFR 70 to properly address the unique hazards and risks of these facilities.

Fuel-cycle facilities are distinguished from power reactors mainly by the diversity of their strongly interrelated inherent hazards, and by the large distribution and mobility of these hazards throughout the facilities. Hence, a comprehensive identification of initiating events and scenarios is a challenge in undertaking a fully integrated probabilistic risk assessment (PRA) for them. For a given design, a very consistent effort is deemed necessary to provide a realistic, accurate quantification of the risk; significant uncertainties generally are expected in the results.

1.3 International Contexts

Here, we give a brief synopsis of regulatory approaches to reprocessing facilities in other countries based, in part, on private communications with officials and researchers in those countries; it does not necessarily represent the stated positions of their governments.

The United Kingdom (UK) applies PRA to all facilities, using targets based on doses or risks to workers and the public, as they are for nuclear-power plants. In revising its Safety Assessment Principles (SAPs) for fuel facilities in 2006, the UK removed the two targets on the release of radioactivity and plant damage, as they were considered as reactor-orientated and unsuitable for fuel facilities. The UK's SAPs are expressed in terms of Basic Safety Objectives (BSO) and Basic Safety Limits (BSL). The former is considered a negligible level of risk (i.e., risks below the BSO do not require further regulatory attention), while the latter correspond to a risk level analogous to a regulatory limit, viz., risks above the BSL would be considered unacceptable. The region lying between the two is regarded as a "tolerable" risk region. In addition, the UK's Health and Safety Executive (HSE) recently published a Technical Assessment Guide (TAG) on Probabilistic Safety Analysis (PSA)[1] [4].

After the fire and explosion in Japan in 1997 ([5] and [6]) at the Tokai Reprocessing Plant (TRP), safety assessments were undertaken from 1998 to 1999; also various measures were completed to enhance plant safety. From 2002 to 2003, the relative importance of safety functions at the TRP was evaluated via a PRA. Thereafter, from 2004 to 2005, a PRA also was applied to four representative accident scenarios to quantitatively assess the effectiveness of the hardware modifications and the improvements made to operating procedures which were implemented based on PRA findings. Since then, the Japan Atomic Energy Agency (JAEA) has estimated the component failure rates for a reprocessing plant from maintenance records stored in the TRP.

In France, work was undertaken to develop the needed knowledge of existing risk-management tools, thereby allowing their use to assess the risk of nuclear facilities. Here, PRAs are of particular interest because of their significant role in the nuclear-safety culture. No

[1] Some publications use the term Probabilistic Risk Assessment (or Analysis) (PRA), while others use Probabilistic Safety Analysis (PSA). These terms have the same meaning and are used interchangeably in this paper.

distinctions are apparent in the approaches of the French nuclear authorities to various types of fuel-cycle facilities.

1.4 Organization of the Paper

This paper has six main sections. Section 2 briefly reviews previous work. Section 3 summarizes accidents at, and risk assessments for, reprocessing facilities. Section 4 discusses applying qualitative versus quantitative methods of assessing risk. The paper summarizes the report BNL-V6091-01-2011 [7], to which readers are referred for additional insights.

2 REVIEW OF RECENT WORK

2.1 ACNW&M Evaluation of Potential Regulatory Changes

The Advisory Committee on Nuclear Waste and Materials (ACNW&M) of the NRC published a report, "Background, Status and Issues Related to the Regulation of Advanced Spent Nuclear Fuel Recycle Facilities" (NUREG-1909 [1]). In the context of this present paper, the ACNW&M defines recycling as involving (a) reprocessing the spent nuclear fuel (SNF) to separate it into its constituent components, (b) refabricating fresh fuels containing plutonium and minor actinides, and, (c) managing and storing the gaseous-, liquid-, and solid-wastes generated along with the spent fuel. The report describes the historical approach to the SNF recycle, reviews recent advances in technology, and evaluates the technical -issues that must be addressed to assure the viability of commercially reprocessing spent fuel.

The ACNW&M report reaches two main conclusions: (1) It judges that no existing regulation in the United States is "entirely suitable" for licensing reprocessing facilities. Existing fuel-cycle plants, such as fuel-fabrication facilities, handle relatively small amounts of radioactive materials but future reprocessing facilities likely will process much larger quantities of radioactive materials as solids, liquids, and gases distributed in various locations throughout the facility. (2) It concludes that compared to other fuel-cycle facilities regulated under 10 CFR Part 70, the possibility of larger source terms, the presence of radioactive and chemical hazards, and the greater complexity of equipment and operations suggests employing correspondingly more sophisticated methodologies, such as PRAs, to analyze the risk of reprocessing facilities. Following the conclusions of this report, should PRA be adopted as the method for conducting risk assessments of reprocessing facilities, several improvements and enhancements to the traditional PRA methods for reactors are warranted for these facilities.

2.2 NEI Report

The NEI [2] proposed a licensing framework for a reprocessing facility that "…is modeled under the risk-informed and performance-based approach of Part 70 supplemented with provisions from Part 50." This framework is designed to implement a new part, labeled part 7x, under Title 10 of the CFR. The NEI suggests that the framework is technologically neutral, and suffices to encompass licensing of the different reprocessing technologies that industry is studying.

From a substantive, technical standpoint, the framework basically adopts the approach in Part 70. It proposes performance requirements mirroring those in Part 70, requires undertaking an ISA to identify facility accidents and items relied on for safety (IROFS), management measures to assure the availability and reliability of the IROFS, other associated administrative

requirements, quantitative assessments of risk to a member of the public located outside the controlled area from high-consequence accidents involving fission products to the extent practicable based on the availability of data to support quantitative analyses, and the establishment of Technical Specifications for the IROFS identified for such accidents.

3 ACCIDENTS AND RISKS ASSOCIATED WITH REPROCESSING FACILITIES

3.1 Accidents at Reprocessing Facilities Worldwide

The public is notified of the safety significance of events associated with sources of radiation via the International Nuclear and Radiological Event Scale (INES). International experts convened in 1990 by the IAEA and the Nuclear Energy Agency (NEA) of the Organization for Economic Co-operation and Development (OECD) developed it. According to the INES User's Manual [9], events are classified on the scale at seven levels: Levels 4–7 are termed "accidents," Levels 1–3 "incidents;" and events without safety significance are classified as "Below Scale/Level 0." Events with no safety relevance to radiation or nuclear safety are not classified on the scale.

We surveyed accidents at reprocessing facilities, obtaining the following insights:

1. Our most important conclusion is that accidents at reprocessing facilities can have very severe consequences, up to, and including early fatalities and injuries of personnel, and substantial environmental releases of radioactivity. The definition of high-consequence events in 10CFR70.61, "Performance requirements," includes, but is not limited to, those internally or externally initiated events that can, when unmitigated, deliver an acute worker dose of 1 Sv (100 rem) or greater total effective dose equivalent, or an acute dose of 0.25 Sv (25 rem) or greater total effective dose equivalent to any individual located outside the controlled area. The information about these accidents was insufficient to assess which ones, if any, met these criteria. Conversely, those involving early fatalities clearly exceeded them. In addition, those classified as 4, "Accident with local consequences," or higher in the INES scale also are significant ones. Table I lists accidents with documented early fatalities and accidents meeting this classification.

Table I. Significant Accidents in Reprocessing Facilities Worldwide

INES		Kind of Hazard[2]		
Level	Type of Event	Criticality	Radiation	Fire and/or explosion
6	Serious accident			Mayak PA, Russia, 9/29/1957
4	Accident with local consequences			Windscale, UK, 1973
Classification not available		Mayak PA, 4/21/1957 (1) Mayak PA, 1/2/1958 (3) Los Alamos Laboratory,	Mayak PA, 10/1/1951 (1)	Tomsk, Russia, 4/6/1993

[2] The number in parenthesis after an accident is the number of resulting early fatalities, if available.

	U.S., 12/30/1958 (1) Mayak PA, 12/10/1968 (1)		

2. Reprocessing facilities entail the risks associated with the traditional process industries, such as chemical toxicity and chemical reactions that lead to fire and explosion, as well as those from nuclear materials (such as radioactive contamination and criticality excursions). An accident may involve a combination of both hazards.
3. Many identified accidents occurred during the 1950s and 1960s, presumably because then there were minimal safety standards and/or regulatory oversight was relaxed or lacking. While accidents during the last two decades were fewer, serious events occurred, such as those at Siberian Chemical Enterprises (Russian Federation, 1993), THORP (UK, August 2004), and Tokai-mura (Japan, March 11, 1997). Hence, there is an apparent trend toward a decreasing number and severity of consequences of such accidents. This likely is due to a combination of implementing safer work practices, increasing operating experience, better safety standards, and/or stricter regulatory oversight; it also may reflect the fact that several countries have closed their main reprocessing facilities.
4. Accidents of differing severities (relatively mild to severe) have occurred in practically all countries with reprocessing facilities. However, there have been no known accidents at reprocessing facilities in Belgium and China.
5. Two of the identified events (not included in Table I) happened during shutdown of a reprocessing facility, indicating that risk also is associated with this activity.

3.2 Results of Risk Assessments

This section summarizes the findings of some Probabilistic Risks Assessments (PRAs) of reprocessing facilities worldwide. The inclusion of the approaches and results herein does not necessarily endorse them.

As an introduction to this subject, we first present a brief discussion by the IAEA in IAEA-TECDOC-1267 [10] on the level of detail to use when conducting a PRA of a non-reactor nuclear facility (NRNF): "…Facility hazard can influence the depth of analysis, since it may be appropriate to analyze lower hazard facilities to less depth than higher hazard facilities (i.e., the depth of analysis is commensurate to hazard). Similarly, facility complexity can influence the depth of analysis, since it may be appropriate to analyze simple facilities to less depth than more complex facilities…Thus, the concept of hazard-graded depth of analysis is appropriate for NRNF PSAs. This report seeks to provide a comprehensive guidance for assessing the risk of a high hazard NRNF for regulatory purposes…"

The following main observations were extracted from this IAEA report: 1) A large reprocessing facility has a large radioactive inventory, 2) a detailed quantitative PRA is applicable for such a facility, and, to some extent, to a medium-sized reprocessing facility, and, 3) this kind of PRA would include a Human Performance Analysis.

3.2.1 Rokkasho reprocessing plant

Evidently, safety analysts in Japan regarded PRA as an important aspect of risk evaluation of their reprocessing facilities, even before the Japanese Nuclear and Industrial Safety Agency promulgated risk-informed requirements. Takebe et al. [11] noted "…Performing PSA and utilizing the risk information for non-reactor nuclear facilities also has the same role in securing safe operation effectively and rationally as in the nuclear power plants. Taking into account the safety characteristics of reprocessing plants in which radioactive materials exist scattered in several chemical processes and storage facilities, we should evaluate risks of many events efficiently and systematically with various types, scenarios, frequencies and consequences in order to assess whole risk and its profile of the plant…" A simplified PRA method was developed for the Rokkasho Reprocessing Plant (RRP) [12], incorporating previously detailed PRA results of some representative events. Takebe et al.'s intent was to use the risk information in operating and managing the facility, for example, "…classifying the components and systems in classes of importance so as to determine the terms of periodical inspections…"

3.2.2 Tokai reprocessing plant

Ishida et al. [13] indicate that "…With the fire and explosion accident at the Tokai Bituminization Demonstration Facility in March 1997, JNC [Japan Nuclear Cycle Development Institute] had carried out the safety reassessment of the TRP [Tokai Reprocessing Plant] in 1999… The PSR [Periodic Safety Review] of the TRP has been carrying out to obtain an overall view of actual plant safety. As a part of the PSR, based on the results of the safety reassessments of the TRP, PSA methodology has been applied to evaluate the relative importance of safety functions that prevent the progress of events causing to postulated accidents…As evaluation methods, event tree and fault tree methodologies were selected by taking into account of the power plant PSA [14], PSA specialist opinions and document [10]…PSA methodologies have been applied on all postulated accidents…"

Concerning dependencies and common-cause failures (CCFs), Ishida et al. [13] state, "Dependent failures could be dominant contributors to the frequency of the postulated accidents and they should be taken into account in the analysis regardless of the selected modeling approach…" They also say that "…human reliability analysis was carried out based on the operation manual by using the Technique for Human Error Rate Prediction (THERP)…"

Ueda [15] indicated that the Japanese Nuclear Safety Commission (NSC) and the Nuclear and Industrial Safety Agency (NISA) were planning to use risk information for nuclear-safety regulation, and outlined studies in Japan on using such data for reprocessing facilities. He pointed out "…Studies on risk assessment methodology and related researches have been conducted by [Japanese organizations] based on methodologies such as the probabilistic safety assessment (PSA) used for nuclear reactors and the methods of hazard analysis and risk evaluation for chemical plants…" He presented the PSA results for some postulated events at the TRP, including risk importance factors and frequency versus consequence plots. He noted that a greater number and variety of events must be evaluated as possible major contributors to risk in a PSA for TRP than those for nuclear reactors because 1) radioactive- and nuclear-materials are processed throughout a facility in a variety of chemical- and physical-forms; 2) potential hazardous sources are distributed widely throughout the facility, e.g., radioactivity, heating sources, and flammable- and explosive-materials; and, 3) there is a wide spectrum of postulated events in many parts of a facility.

3.2.3 THORP

PRA was used during the design and the start of operation of the UK's THORP (Thermal Oxide Reprocessing Plant), and subsequently in its Periodic Safety Reviews, and for the Magnox reprocessing plant [16]. In particular, James and Sheppard [17] discuss the risk of thermal runaway in a nuclear-fuel-reprocessing plant due to red-oil reactions, using, for illustration, the uranyl-nitrate evaporator in the THORP plant.

No other PRA studies of THORP were found in the public literature, partly due to commercial confidentiality and partly to security concerns. One issue that the UK authorities recognized is that PRAs cannot be split easily into Levels1, 2, and 3 as the plant does not have a simple set of barriers. Two other issues are the changing nature of the hazard as the material moves through the plant,, and the need to account for much more human interaction as the process develops. In the UK analyses, this makes the form of the PRA somewhat different from that for reactors as the balance tends towards fault trees, rather than event trees.

The UK's Health and Safety Executive (HSE) issued its Safety Assessment Principles (SAPs) for Nuclear Facilities [18], and more recently published a Technical Assessment Guide (TAG) on Probabilistic Safety Analysis (PSA) [4]. The purpose of the TAG is to "…provide an interpretation of those Safety Assessment Principles … related to PSA and to provide specific guidance to inspectors engaged in the assessment of PSAs and PSA related submissions … from Licensees, Licence Applicants or Generic Design Assessment (GDA) Requesting Parties…" This guide does not apply different approaches or methods for evaluating reactor and non-reactor nuclear facilities. However, it recognizes that a comprehensive PRA, including quantitative evaluations, must be carried out for reprocessing facilities to demonstrate compliance with the UK's As Low As Reasonably Practicable (ALARP) risk requirement, as reflected by the following quote from its Section 3.2, "Fault analysis: PSA – Need for a PSA – FA.10": "…The depth of the PSA for a given facility may vary depending on the magnitude of the radiological hazard and risks and the complexity of the facility. For example, for some facilities simplified analyses, or even qualitative arguments, application of good practice and DBA [Design Basis Analysis] may be sufficient to demonstrate that the risk is ALARP. However, for complex facilities such as power reactors or reprocessing facilities, comprehensive PSAs that meet modern standards should be developed for all types of initiating faults and all operational modes…"

3.2.4 La Hague

Simonnet [19] reports that PRA was used in parts of the design of the La Hague reprocessing facility in France. No other PRA study of this facility was found in the public literature.

On the other hand, the French Atomic Energy Commission (Commissariat à l'Energie Atomique, or CEA) recently published a study (authored by Bassi) on applying PRA to non-reactor nuclear facilities (NRNFs) [20]. It deems that "The bibliography analysis shows that the PSA [Probabilistic Safety Assessment] approach for NRNF is close to that currently adopted for the NPPs, but it has to be adapted due to the specificities of these plants..." As part of doing so for assessing the risk of an NRNF, Bassi proposes quantifying the risk using the "ARAMIS" approach [21] that involves developing and quantifying a somewhat different version of fault trees and event trees. He considers that "…ARAMIS … provides a semi-quantitative approach of the risk, potentially interesting for fuel cycle facilities, oriented towards supplying of whole

risk management processes and regulatory demonstration, rather than towards an accurate quantification of the risk." This approach is a semi-quantitative one because it encompasses some qualitative aspects.

The French study recognizes that reprocessing plants are amongst the three most hazardous NRNFs, as Subsection 5.1.3, "Safety philosophy," stated, "…Because chemical processes form an integral part of the nuclear fuel cycle facilities, insurance of safety requires the control of both the chemical and nuclear hazards. It's important to notice that the hazards vary from one facility to another, depending on the processes employed, the age, the output, the physical and/or chemical properties of the substances, and possibly the specific conditions [22]...Therefore, reprocessing plants, high activity liquid waste tanks, and plutonium handling plants are the most dangerous facilities, even if the nature of the dangers is globally the same in the whole fuel cycle…"

The following conclusions were reached after evaluating the methods and results of risk assessments of reprocessing facilities:

1. A thorough approach, based on a comprehensive PRA that accounts for both radiological- and chemical-hazards, must be considered to assess the risk to receptors from reprocessing operations.
2. One Japanese study used a simplified PRA for a reprocessing facility. A detailed PRA first was undertaken for a limited set of accident scenarios associated with this facility, and then its models, data, and results were used to formulate the simplified PRA. The Japanese researchers who developed and applied this approach considered it an improvement over the "risk index method" typically used for the ISA.
3. A comprehensive risk assessment includes a quantitative evaluation of the risk to receptors. Though failure data may be scarce for such facilities, it can be supplemented with engineering judgment, as was common in the early days of applying the PRA method for nuclear-power reactors, and still is used for some technical issues.
4. Since nuclear- and chemical-hazards are distributed throughout reprocessing facilities, approaches that typically are not used for the PRA of nuclear-power reactors, such as methods of hazard analysis and risk evaluation for chemical plants, can be adapted to identify, model, and quantify the risk of individual processes or the entire facility.

4 QUALITATIVE VERSUS QUANTITATIVE RISK METHODS

4.1 Introduction

SECY-09-0082 [3] updated progress towards developing a regulatory framework for licensing reprocessing facilities, including a regulatory gap analysis. For risk considerations, Gap #5 indicated that (1) reprocessing facilities would have a higher source term, and thus, present a greater relative risk than fuel-cycle facilities licensed under 10 CFR Part 70, and, (2) the ISA methodology for risk assessment in Part 70 does not adequately address the risks posed by higher risk facilities. The gap analysis recognized the ACNW&M's recommendation for a quantitative approach to risk, such as a PRA, rather than ISA because of the latter's limitation in treating dependent failures, human reliability, uncertainties, and its aggregation of event sequences. However, the gap analysis also expressed reservations about using PRAs in reprocessing facilities, based on the dearth of relevant, reliable data.

Part 70 requires that an ISA, and the risk-index method used by most applicants and licensees involves an order-of-magnitude analysis. However, for a reprocessing facility, the following major benefits could be realized by risk-informing the facility's design and operation through a quantitative risk assessment, together with the quantitative risk guidelines proposed in SECY-04-0182 [23] and updated in [24]:

1. Significantly enhancing the ability of the NRC's staff to better understand and categorize risk-significant issues. Clearly, this would be useful in the license review process, in ensuring that the risks posed by a new facility or by additions to an existing one are well characterized and understood.
2. Playing an important role in the inspection process in assessing the risk significance of the inspection findings, in a way similar to the risk-oversight program for power reactors.
3. Identifying risk-important sequences and components to support the allocation of resources to lower risk.

The lack of quantitative risk criteria in Part 70 for likelihood can entail consistency problems, particularly for high-consequence events that might dominate a facility's risk. Here, PRA, with defined risk acceptance criteria, has distinct advantages. Over time, the issue of data should become less important for facilities, such as fuel-reprocessing plants, as demonstrated by experience with data needs for reactor PRAs over the last three decades. However, these PRA techniques, developed mainly for operating light-water reactors, must be enhanced in several ways to facilitate their application to the safety of nuclear- and chemical-processes characteristic of reprocessing plants.

4.2 PRA for Reprocessing Facilities

Probabilistic risk assessment is a fairly mature technology for understanding the vulnerabilities, and predicting the risks posed by commercial nuclear-power reactors. However, fuel-cycle facilities that also are chemical processing plants, present a different set of challenges including the nature and type of hazards posed, the kinds of accidents that can occur, and the recipients of the risk. This is recognized in the 10 CFR Part 70 regulations governing the licensing of these facilities; in particular, the performance criteria in Part 70.61 specify both the radiological- and chemical-hazards of fuel-cycle facilities and establish limits on their consequences for the public, workers, and the environment as a function of the likelihood of events.

The risk assessment methods that can respond to the needs of the reprocessing facilities should account for the facility's unique features that distinguish their risk profile from those of commercial power reactors; some major differences are noted below:

1. The hazards posed by the facility include toxic chemical- and explosion-hazards in addition to radiological ones,
2. There is no analog of the reactor core as the main source of hazard in the facility; the source term for both chemical- and nuclear-hazards might be distributed throughout the plant, with different amounts in each location depending on processing operations.
3. As noted in IAEA-TECDOC-1267, "Procedures for Conducting Probabilistic Safety Assessment for Non-Reactor Nuclear Facilities" [10], many current non-reactor

nuclear facilities rely heavily on manual control during normal operation, and on manual actuation to respond to faults and potential accidents. Future facilities, as reflected in the designs of proposed fuel-fabrication or reprocessing facilities, are transitioning to fully automated actuation, control, and monitoring.

4. There is major reliance on computer-driven systems for prevention and control, with less reliance on standby systems.

Due to these differences, the risk and reliability methods, data, and software tools developed for commercial nuclear power plants could be modified to become more suitable for using in risk assessments of non-reactor nuclear facilities. New tools or new databases may need to be developed.

5 SECY-11-0163

In SECY-11-0163, and its addendum "Draft Regulatory Basis for Licensing and Regulating Reprocessing Facilities" of November 2011 [8], NRC staff drafted resolution paths for 19 high- and moderate-priority gaps. It states "…Two high-priority gaps, "Safety and Risk Assessment Methodologies and Considerations for a Reprocessing Facility" (Gap 5) and "Regulatory Framework" (Gap 1), need additional work to reach resolution…"

As discussed in Subsection 1.2, this paper focusses on one of the unresolved gaps, Gap 5, on risk considerations for a production facility licensed under 10 CFR Part 70. The required risk assessment therein involves an ISA with characterization of the likelihood and consequences of credible accident sequences. SECY-09-0082 notes that existing requirements do not adequately address the increased risk posed by a reprocessing facility's higher potential source terms compared to that of other fuel-cycle facilities. SECY-11-0163 indicates that to "…determine an appropriate path of resolution to Gap 5, the [NRC] staff is investigating the use of a hybrid approach involving a PRA and an ISA as well as a standard PRA approach. The staff will continue to develop analytical methods that may allow the application of quantitative risk insights in the development of a reprocessing rule. It would apply these methods to appropriate reprocessing processes and event sequences to gain fundamental risk insights on likely reprocessing operations. The staff plans to gather data from international and domestic analogous facilities to support development of these quantitative methods. The staff will use these risk insights to develop appropriate risk criteria and risk guidelines for SNF reprocessing facilities, which have a range of potential hazards that differ significantly from the hazards at other U. S. production, utilization, and commercial fuel cycle facilities, caused in part by the presence of actinides and byproduct material in SNF…The staff expects that the preliminary risk assessments being conducted under Gap 5 would provide more clarity on these issues. The staff will also leverage international data and analogous designs to estimate the hazards from both internal and external events, such as fires, flooding, and earthquakes."

6 SUMMARY AND OBSERVATIONS

6.1 Summary

This paper discussed the current regulatory context for national and international reprocessing facilities. As noted in SECY-09-0082 [3], the existing requirements in 10CFR Part 70 do not adequately address the increased risk posed by such facility compared to that of other

fuel-cycle facilities. The former can have higher potential source-terms than the latter, and accordingly, this may increase their overall risk. The present paper concurs with this observation after examining accidents that have happened in the former, and other risk information on their hazards. In particular, as demonstrated in our review of accidents in reprocessing facilities, it is evident that the potential for health risk to the public is significantly greater than for other fuel-cycle facilities. Moreover, accidents there, if unmitigated, can entail very severe consequences, up to, and including early fatalities and injuries of personnel, and substantial releases of radioactivity to the environment. Accidents with documented early fatalities and accidents having a classification of 4, "Accident with local consequences" or higher in the INES scale are significant accidents; they are presented in Table 1.

6.2 Observations

NRC licensees and applicants currently implement varying degrees of ISAs, from qualitative to semi-quantitative ones. Most use the order-of-magnitude semi-quantitative approach described in NUREG-1520 [25]. The main virtues of such approaches are their ease of application and their limited resource requirements. For relatively simple nuclear fuel-cycle systems, the ISA can efficiently identify potential weaknesses in a facility's design or operation, enabling the identification of IROFS. However, since their approaches do not incorporate inter-system dependencies, nor offer an integrated assessment of risk, some higher-risk accidents in more complex facilities could be misrepresented.

The Commission's PRA policy statement issued in 1995 [26] states , "The use of PRA technology should be increased in all regulatory matters to the extent supported by the state of the art in PRA methods and data, and in a manner that complements NRC's deterministic approach and supports the NRC's traditional defense-in-depth philosophy." We observe that reprocessing facilities are distinct from other less complex fuel-cycle facilities, which do not represent a comparable level of risk.

Safety analyses of a reprocessing facility can benefit greatly from the systematic, disciplined procedures embodied in risk-assessment methodology. As discussed in Section 3.2, varying degrees of PRAs for reprocessing facilities have been carried out in several countries. Notwithstanding the limited data available for their PRAs compared to that for power reactors, the safety analyses of these facilities can benefit from the potential understanding gained by uncovering potential weaknesses in design, and identifying dominant contributors to the risk of a plant or facility, such as human errors and dependencies. Moreover, PRAs can indicate those areas of a facility that are not risk-significant. Consequently, in a reprocessing facility, regulatory attention and resources can be allocated according to the risk importance of operator's actions, and of its structures, systems, and components. In addition, the approaches to uncertainty analysis commonly employed in reactor PRA studies can be very useful in expressing risks for reprocessing facilities.

7 ACKNOWLEDGMENTS

The authors are indebted to colleagues in France, Japan, and the United Kingdom for providing valuable information for this study. They are F. Bertrand, G-L. Fiorini, R. Nakai, G. Vaughan, and D. Watson. Comments from the following USNRC staff who reviewed drafts of the report on which we based this paper were very helpful: D. Damon, Y. Faraz, F. Gonzalez, A. Murray, W. Reed, P. Reed, and T. Sippel.

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