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NRC INVOLVEMENT WITH THE TANK WASTE REMEDIATION SYSTEM-PRIVATIZATION (TWRS-P) AT HANFORD

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ABSTRACT

In 1995, the U.S. Department of Energy (DOE) embarked on an effort to privatize the processing through vitrification of 54 million gallons of radioactive waste that has been stored in 177 underground storage tanks at the Hanford Site. The U.S. Nuclear Regulatory Commission (NRC) provided assistance to DOE on the TWRS-P program, with a potential transition to NRC regulatory authority at a future time. In 2000, DOE terminated the privatization approach, and decided to use more traditional contracting methods. This paper summarizes NRC's participation in and observations on the TWRS-P program and identifies issues from the NRC's perspective.

During their reviews, NRC staff analyzed both unmitigated and mitigated consequences from potential accident scenarios at the proposed facility. Several generic scenarios were found to have potential accident consequences to the workers and the public of significant severity and risk (1E-2/yr to 1E-4/yr). Under such circumstances, accident prevention (reduced probability) and mitigation (reduced consequences) would become necessary, requiring the identification of items relied upon for safety. Suitable process accident prevention and mitigation methods exist that are compatible with the regulations and offer the potential for reducing process accident risk to more acceptable levels (circa 2E-6/yr). NRC staff's efforts identified several key areas of uncertainty, such as melter failure modes and frequencies, that would require further study before more refined analyses could be performed.

From an NRC staff perspective, the reviews identified several open issues, including the need for significantly more detailed design information and safety analyses, and greater defense-in-depth. In particular, the design, at the time of termination of the privatization, was found to be very preliminary and corresponded to perhaps a 15 percent level of design. DOE, as the current regulator, also identified similar issues. Throughout the length of the program, NRC and DOE reviews were held to tight schedules (typically a two week turnaround for a multivolume submittal) which limited the ability to identify action items and plans leading to closure on a significant number of the issues. Consequently, actual closure of some open items may not occur for some time. In addition, the likely impacts from further contractor changes are unclear but would imply more uncertainties, design changes, more new issues, and the need for additional time for review and resolution prior to proceeding into construction and operation.

The influence of cost and schedule (including capacity) upon the regulatory review activities, design/authorization basis (license) documentation, and the use of risk-based approach to the design without additional considerations, are also of some concern. The latter issue is of particular concern because risk-based analyses were used as the basis for the Integrated Safety Management (ISM) process, which includes hazards identification, consequence estimation, and control mitigation. For comparison, the NRC uses a risk-informed, performance-based approach with defense-in-depth,

appropriate levels of conservatism, and a minimum set of standards and requirements that are codified in the regulations.

INTRODUCTION

In 1995, the U.S. Department of Energy (DOE) embarked on an effort to privatize the processing through vitrification of 54 million gallons of radioactive waste that has been stored in 177 underground storage tanks at the Hanford Site. Under the initial phase of the Privatization plan, fixed-price waste treatment services for processing a portion of the waste were to be supplied, on leased land at the Hanford Site, by contractor-owned, contractor-operated facilities under a fixed-priced contract. The U.S. Nuclear Regulatory Commission (NRC) provided assistance to DOE on the TWRS-P program for three and a half years under a Memorandum of Understanding (MOU) signed in January 1997. The MOU provided for the NRC to acquire an understanding of the wastes and potential treatment processes, assist the DOE in performing reviews in a manner consistent with the NRC’s regulatory approach, and develop an effective regulatory program for the potential transition to NRC regulatory authority at a future time. In May 2000, DOE abandoned the privatization approach for cost reasons, and declared its intent to pursue a more conventional, maintenance and operations (M&O) style contract for the design, construction, and operation of the waste treatment facilities. The M&O contractor may or may not use the designs, technologies, and approaches already developed. With this contract change, DOE also signaled its intent to self-regulate the facilities for the foreseeable future. As a result of these changes, the NRC has decided to terminate its role in the program. This paper summarizes NRC’s participation in and observations on the TWRS-P program and identifies issues from NRC’s perspective. Technical information on the wastes, the conceptual approach, and the regulatory framework are also included.

HANFORD AND THE TANK WASTES

The U.S. Department of Energy (DOE) established the Tank Waste Remediation System (TWRS) program at the Hanford site to manage, retrieve, treat, encapsulate/immobilize, and disposition radioactive waste materials from the 177 underground waste storage tanks onsite in a safe, environmentally sound, and cost effective manner. These tanks primarily contain high-level wastes (HLW) and chemical species from processing spent nuclear fuels for more than forty years at the site (1,2). There are 149 single shell tanks (SSTs) and 28 double shell tanks (DSTs). There are several tank sizes but the average tank has about one million gallons of capacity. Both SSTs and DSTs are manufactured from carbon steels. However, the DSTs are newer, have more provisions for monitoring the wastes, and include an annulus for leak detection and confinement. To date, no DST has been confirmed to leak. In contrast, approximately 67 SSTs have been confirmed as leakers.

The tank contents consist of mixtures of materials from some eight major processes. Some of the wastes date back to 1944. Even though the radiation levels are high (typically exceeding 100 R/hr in the tank dome spaces and through riser connections), the great majority of the waste constituents are nonradioactive and contain some 240,000 tonnes of processed chemicals. The tanks hold approximately 54 million gallons of waste, and amount to over 200 million-plus curies of radioactivity, primarily from cesium and strontium but with smaller contributions from other fission products and transuranic (TRU) isotopes. Physically, the tank contents exist as liquids, sludges, salts, saltcakes, and mixtures thereof, and some tanks periodically release gas mixtures. The SSTs contain primarily sludges and saltcakes with relatively little liquids - most of the liquid phase has been removed due to concerns about potential leaks.

The DSTs contain most of the liquids but also have solid phases. The wastes stored in the tanks are defined as high-level waste (HLW; per 10 CFR Part 50, Appendix F) and hazardous waste (per RCRA - Resource Conservation and Recovery Act - with various codes).

DOE categorizes the wastes to simplify contractual and processing approaches (3). DOE uses the term LAW to denote "Low Activity Waste." Table I presents summary information on the composition of LAW. LAW is predominantly a liquid phase with soluble species such as nitrates and cesium; it may also contain up to 2 percent suspended solids or solids otherwise entrained by the waste transfers. Three envelopes of LAW have been defined; Envelope A is "standard," Envelope B contains higher levels of cesium, and Envelope C contains higher levels of strontium and TRU. The contract (3) identifies ranges for chemical and radioactive species in these LAW envelopes. LAW would come from the liquid phases of the DSTs and from solids washing operations. From a regulatory perspective, LAW is still HLW and has high radiation levels requiring handling within shielded structures. DOE identifies the solid phases as "HLW," defined as Envelope D. Table II provides summary compositional information on HLW. Envelope D contains cesium, strontium, and TRUs as the radionuclides. Metal oxides, hydroxides, nitrates, phosphates, and aluminates constitute the bulk of the chemical species. The contract (3) provides ranges for the chemical and radioactive species in Envelope D. Envelope D is assumed to be transferred as a slurry in concentrations up to 20 percent, from the removal of solid phases from the SSTs and DSTs. The solids in the LAW envelopes would have a composition similar to Envelope D.

Table I: Summary Information on LAW Radionuclide Composition

Radio-nuclide	Maximum Ratio, Bq/mole Sodium			Curies/Liter at 10 Molar Sodium		
	Envelope A	Envelope B	Envelope C	Envelope A	Envelope B	Envelope C
TRU	4.8E5	4.8E5	3.0E6	1.3E-04	1.3E-04	8.11E-04
Co-60	6.1E4	6.1E4	3.7E5	1.65E-05	1.65E-05	1.0E-04
Sr-90	4.4E7	4.4E7	8.0E8	1.19E-02	1.19E-02	2.16E-01
Tc-99	7.1E6	7.1E6	7.1E6	1.92E-03	1.92E-03	1.92E-03
Cs-137	4.3E9	2.0E10	4.3E9	1.16E+00	6.00E+00 (contract max.)	1.16E+00
Eu-154 + Eu-155	1.2E6	1.2E6	4.3E6	3.24E-04	3.24E-04	1.16E-03

No contribution from the suspended and entrained solids is included in this table. LAW envelopes may contain up to 2% solids, which are assumed to be HLW solids (see Table II). The solids contribution to radiotoxicity is significant and amounts to approximately 90% of the total unit liter dose from LAW.

Table II: Summary Information on HLW Radionuclide Composition

Isotope	Ci/liter	Isotope	Ci/liter	Isotope	Ci/liter
H-3	1.30E-04	Cd-115m	(NS)	Eu-152	9.60E-04
C-14	1.30E-05	Sn-119m	(NS)	Eu-154	1.04E-01
Fe-55	(NS)	Sn-121m	(NS)	Eu-155	5.80E-02
Ni-59	(NS)	Sn-126	3.00E-04	U-233	1.80E-06
Co-60	2.00E-02	Sb-124	(NS)	U-235	5.00E-07
Sr-90	2.00E+01	Sb-125	6.40E-02	Np-237	1.48E-04
Y-90	(NS)	Te-125m	(NS)	Pu-238	7.00E-04
Nb-93m	(NS)	I-129	5.80E-07	Pu-239	6.20E-03
Tc-99	3.00E-02	Cs-135	(NS)	Pu-241	4.40E-02
Ru-106	(NS)	Cs-137	2.00E+01	Pu-242	(NS)
Rh-106	(NS)	Ba-137m	(NS)	Am-241	1.80E-01
Sn-113	(NS)	Sm-151	(NS)	Cm-243/244	6.00E-03

(NS) = Not Specified in the new contract (3).
Feed concentration contains between 10 and 200 grams of unwashed solids per liter of solution. Values in the table are based upon the upper limit of 200 grams/liter, which is approximately a 20% slurry (the actual value is closer to 15%).

PROCESS AND PLANT OVERVIEW

Fig. 1 provides a conceptual overview of DOE's approach to tank waste treatment. LAW envelopes would be transferred to a treatment plant. The LAW would be pretreated to separate the radionuclides (primarily cesium, strontium, technetium, and TRU, and the suspended solids) from the remainder of the waste envelope. Two separate ion exchange systems would use organic resins; the first would remove cesium, while the second system would remove technetium. Crystalline silicotitanate (CST) might be used as an inorganic resin for cesium removal but is not in the current, planned approach. Strontium and TRU isotopes would be precipitated and removed by ultrafiltration methods. The separated radionuclides would be stored for an interim period of up to several years, pending vitrification operations and campaigns. Pretreatment reduces the level of radioactivity in the treated LAW to levels commensurate with near-surface disposal requirements (essentially equivalent to the Class A/B/C definitions of low-level waste in 10 CFR Part 61). Sulfur and sulfate may also require removal if their concentrations exceed glass formulation limits. The less radioactive, treated LAW would be vitrified and placed into stainless steel containers for long term storage or disposal at Hanford. Areas of the facility handling treated LAW might have reduced shielding and confinement requirements. The HLW (Envelope D) would be treated and washed, using a filter or other device to separate the liquid phase from the slurry. The liquid phase would be routed to pretreatment and combined with the feed LAW, primarily for cesium and technetium removal. The treated HLW would be combined with the separated radionuclides from LAW processing and vitrified in an HLW melter. The HLW glass would be stored at Hanford in stainless steel canisters until subsequent disposal in an HLW repository.

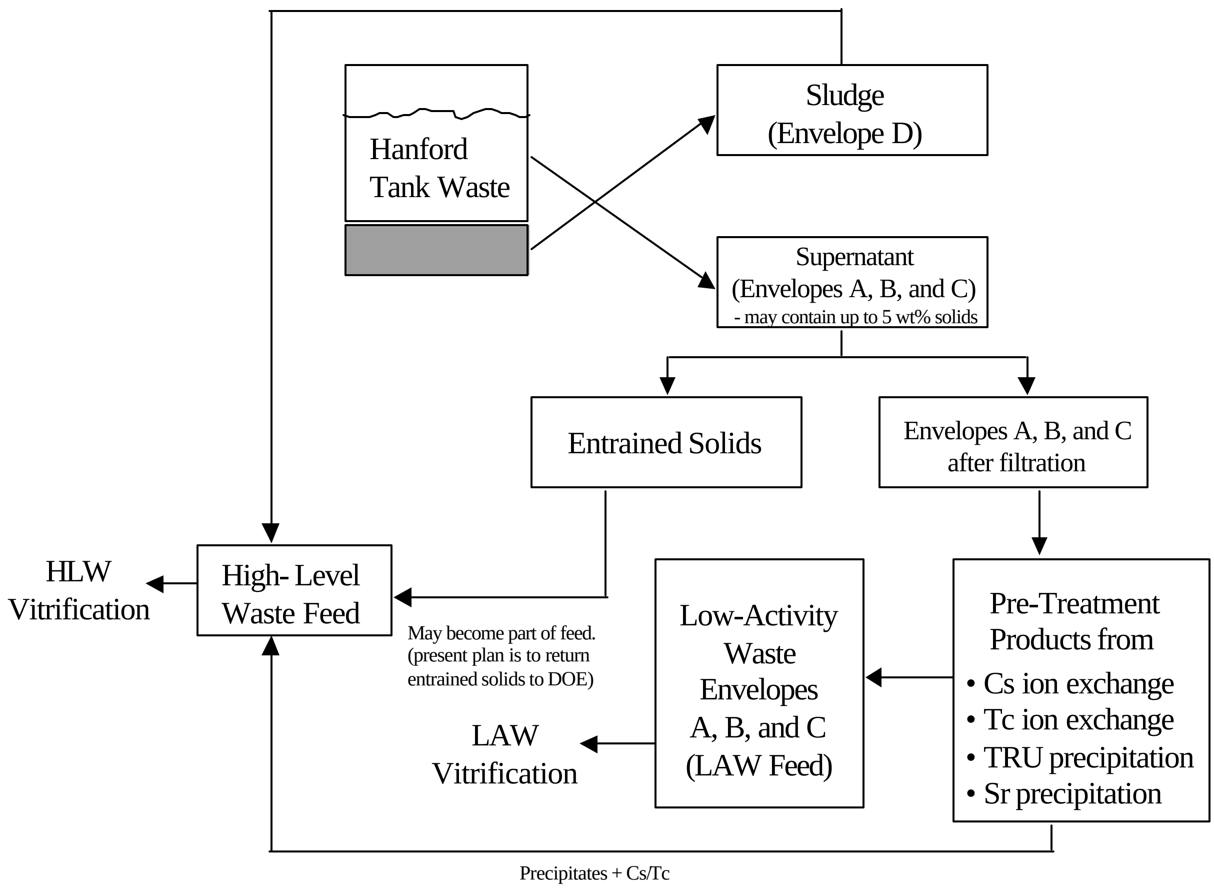

Fig 1: Overview of Hanford TWRS-P Processing Approach

The TWRS-P facility represents a radiochemical facility with a relatively large radionuclide inventory. Table III compares the potential radionuclide inventories at TWRS-P locations (calculated from Tables I and II) with selected radionuclide quantities at a nuclear power plant (4); the TWRS facility is likely to handle comparable quantities of radioactive cesium, strontium, and technetium, in significantly more mobile physical and chemical forms (e.g., as nitrates and aqueous solutions), as compared to ceramic oxide fuels in power reactors. In addition, while a reactor has more energy for potentially energetic scenarios during operations, including scenarios with delays of hours and days before the radionuclide release occurs, the TWRS-P facility has more stored chemical energy for prompt potential events directly involving the radionuclides in their mobile forms. Consequently, the TWRS/Waste Treatment Plant (WTP) facility may have some requirements that are more similar to reactor facilities than to commercial fuel fabrication facilities.

TWRS-P REGULATORY APPROACH

DOE established a dedicated Regulatory Unit (RU) led by a Regulatory Official (RO) at the DOE Richland Operations Office (DOE-RL) with regulatory authority exclusive to the regulation of TWRS-P contractors (5). The RO reported directly to the Manager of DOE/RL at a level equivalent to the DOE Program Manager for TWRS. The RU planned on following the five principles of good regulation as articulated by the NRC - independence, openness, efficiency, clarity, and reliability. The basic concept of DOE's regulatory approach at TWRS-P was that the contractor is responsible for achieving adequate safety, complying with applicable laws and regulations, and conforming with top-level safety standards and principles stipulated by DOE. Consistent with applicable laws and regulations, the contractor is required to tailor the exercise of this responsibility to the specific hazards associated with its activities, and is encouraged to do this in a cost-effective manner that applies best commercial practices. TWRS-P contractors have the responsibility to identify and recommend to DOE the set of standards, regulations, and requirements necessary to ensure adequate safety at the proposed facilities. This constitutes a risk-based, integrated safety management (ISM) process. DOE's responsibility is to execute the regulatory process, including authorization of contractor actions and confirmation that the contractor activities are performed safely and within approved limits. The authority of the RU to regulate a TWRS-P contractor is derived from the terms of the TWRS-P contract (i.e., "regulate by the contract").

Table III: Comparison of Curie Quantities between TWRS-P and a Commercial Reactor

Radio-nuclide	Bounding for TWRS-P Facility (curies)					1,000 MWe Nominal Reactor (PWR, in curies)			
						30,000 MWD/MTIHM		60,000 MWD/MTIHM	
	LAW Tanks, 100Kgal (Env. B)	HLW Tanks, 100Kgal	Cs Product, 1Kgal	Cs Resin Column, 100 liters	CST Column	Core, 1 year cooled	SNF Dry Cask, 5 year cooled	Core, 1 year cooled	SNF DRY Cask, 5 year cooled
Cs-137	2.3E6	7.57E06	1.32E6	72,000	3E5	9.2E6	1E6	1.8E7	1.9E6
Tc-99	727	11,400	(0)	(0)	0	1,200	140	2,200	260
Sr-90	4,500	7.57E06	(0)	(0)	0	6.6E6	7.2E5	1.2E7	1.3E6
TRU	8,700; 49 from solution	87,000	(0)	(0)	0	1.3E7	1.2E6	2E7	1.8E6

Note: Reactor core nominally contains 100 MTIHM and SNF cask nominally contains 12 MTIHM.
PWR values calculated using the Radiological Characteristics Database from Reference 4.
TWRS-P values calculated from Tables I and II for the new contract (3), using 2% and 20% as the suspended solids concentrations for LAW and HLW respectively. The HLW has not been washed. Non-TRU, LAW values do not include the solids contribution; for the new contract, inclusion of the solids contribution would respectively add 7.6E5, 1.1E3, and 7.6E5 curies to the cesium, technetium, and strontium values. Recent discussions have not included CST columns.

NRC INVOLVEMENT

The NRC provided assistance to DOE on the TWRS-P program for three and a half years under a Memorandum of Understanding (MOU) signed in January 1997(6). The MOU provided for NRC to acquire an understanding of the wastes and potential treatment processes, assist the DOE in performing reviews in a manner consistent with the NRC's regulatory approach for commercial nuclear facilities, and develop an effective regulatory program for the potential transition to NRC regulatory authority at a future time.

When NRC began its involvement, the TWRS-P program was initially designed to begin with a relatively small, pilot plant concept for early processing of the wastes. Such an approach would have allowed verification of design and technical approaches with minimal economic, programmatic, and safety risks, and would still have resulted in the processing of some of the waste materials. However, due to programmatic changes, including concerns regarding the feasibility of privately financing a short-term facility, DOE decided to pursue a much larger, full-scale facility instead of a pilot plant. This decision greatly increased the flow rates and radiochemical inventories for the proposed facility and contributed to some of the issues encountered during the program.

In carrying out its responsibilities under the MOU, NRC staff participated with DOE in technical reviews and meetings of various contractor submittals, including for example, Safety Requirements Documents (SRDs), Hazard Analysis Reports (HARs), Initial Safety Analysis Reports (ISARs), Design Safety Features (DSF) submittals, and the Firm Fixed Price (FFP) submittal. NRC staff also reviewed numerous other documents on specific features and concerns (e.g., seismic design, quality assurance/quality control, radiological plans, fire protection, chemical safety, etc.) as well as attended many safety and regulatory meetings with DOE and DOE's contractors (e.g., monthly Topical Meetings, design review meetings, etc.). Oral and written comments were provided by NRC staff to DOE as a result of these reviews and participation in these meetings. NRC staff also assisted DOE in the development of appropriate regulatory guidance and the NRC issued a final Standard Review Plan (SRP) for TWRS-P facilities for use in any future NRC regulatory oversight of the TWRS-P facilities. While participating in this program, NRC staff became fully cognizant of the waste issues, design requirements, safety, and regulation of the proposed facility, thus meeting the primary objectives of the MOU.

The NRC has determined that, if the TWRS-P facility were to be licensed by the NRC in the future, it would most likely be addressed by the regulations in 10 CFR Part 70 relating to fuel cycle facilities. The NRC has recently finalized revisions to Part 70 (7). In Section 70.61, the rule identifies performance requirements for two categories of consequences from events. Specifically, the risk for each high-consequence event must be limited; radiological limits of 100 rem for the worker and 25 rem for a member of the public are identified. Limits are also identified for uranium uptake and acute chemical exposures. The rule requires the application of engineering controls, administrative controls, or both to reduce the likelihood of occurrence so that it is either highly unlikely or the consequences are mitigated to below the limits. Similarly, risks from each intermediate consequence event must be limited; radiological limits of 25 rem and 5 rem are identified for the worker and the public, respectively. The rule requires the application of engineering controls, administrative controls, or both to reduce the likelihood of occurrence so that it is either unlikely or the consequences are mitigated to below the limits. Section 70.62 requires and integrated safety analysis (ISA) that identifies and analyzes potential hazards, scenarios, methods to estimate consequences and likelihoods, and controls.

The term "highly unlikely" is defined in the SRP to be an occurrence of 1E-5/yr or less (8). The term "unlikely" is defined in the SRP to be an occurrence in the 1E-2/yr to 1E-5/yr range.

In addition, the risk from potential events may be reduced due to new facility requirements and the concept of as low as reasonably achievable (ALARA). The revised Part 70 lists requirements for new facilities in 70.64, which include baseline design criteria (BDC) and defense-in-depth practices in Section 70.64. The BDC require an adequate level of protection from natural phenomena, fire, environmental/dynamic, and chemical hazards; quality standards and records; emergency capability; continued operation of essential utilities; inspection, testing, and maintenance; instrumentation and controls; and criticality control, including adherence to the double contingency principle. For defense-in-depth, the rule states:

Facility and system design and facility layout must be based upon defense-in-depth practices. The design must incorporate, to the extent practicable:
(1) Preference for the selection of engineered controls over administrative controls to increase overall system reliability; and
(2) Features that enhance safety by reducing challenges to items relied upon for safety.

Section 70.64 notes that licensees shall maintain the application of the BDC unless the ISA (Section 70.62(c)) demonstrates that a given item is not relied upon for safety or does not require adherence to the specified criteria. An similar ISA restriction does not exist for defense-in-depth practices. The SRP also refers to the ALARA provisions of Part 20. Section 20.1101(b) requires the licensee to use, to the extent practical, engineering controls to achieve radiation doses that are ALARA. BDC, defense-in-depth, and ALARA would reduce risk due to lower frequencies of events/scenarios, mitigation of consequences, or both. However, an estimate of such reductions in risk require a specific design for quantification.

NRC ANALYSES OF THE GENERIC PLANT

The NRC staff used generic and conceptual process approaches proposed by DOE contractors to analyze potential risks from process and materials aspects at potential TWRS-P facilities, using the SRP as guidance. These analyses identified the following, preliminary areas of concern from the process safety perspective:

- Radiochemical inventories
- Process efficacy
- Organic ion exchange resin/nitrate interactions
- CST drying
- Organic materials
- Radiolysis
- High temperature operations
- Nonradioactive chemical effects upon radiochemical processing

Several of these areas of concern involved events that could be analyzed at this early stage of design using a conservative, bounding approach suitable for an initial assessment of risk, determination of relative importance, and the preliminary categorization of structures, systems, and components (SSCs) and identification of controls. The NRC staff used parameters from the privatization contracts to estimate inventories and assess materials at risk. The NRC and DOE accident handbooks (9,10) outlined several scenarios (e.g., spray leak, tank rupture) with suggested values for release parameters (e.g., atmospheric release fractions, respirable fractions); the NRC staff primarily selected bounding values as these were recommended by the handbooks for preliminary accident analyses on conceptual designs. Dispersion calculations focused on the receptor at 100 meters as this is a typical distance to a member of the public in NRC licensee analyses, and it approximately corresponds to the likely distance from a surface release to the facility fenceline at the proposed, TWRS/WTP location on the Hanford Site. The calculations assumed a breathing rate corresponding to light activity. This allowed the determination of dose consequences from these various scenarios.

The NRC staff estimated risk using the LNT (linear no threshold) model for dose consequences, without any modification in the risk factor for acute doses above 10 rem. Frequencies were based upon published values in the literature (see, for example, References 11 and 12).

The potential consequences to the receptor at 100 meters from unmitigated events were very high, sometimes in the hundreds or thousands of rem. All of the potential accidents have potential consequences exceeding the thresholds and guidelines in regulations, including the revised 10 CFR Part 70. Many of the events have frequencies in the 1E-2 to 1E-4 range and would be considered to reside in the "unlikely" probability bin. Consequently, potential mitigating controls and their beneficial effects were investigated, and these are listed in Table IV.

Using the U.S. national average for workplace fatalities of 4.8E-5/yr (13,14) for comparison, ten process scenarios exceed that national average (at 100 meters). The total estimated, unmitigated potential risk from a generic, TWRS/WTP facility at 100 meters due to these incidents involving radionuclides is approximately 2.4E-2/yr, some 500 times larger than the U.S. workplace average risk. For contrast and comparison, Table V displays additional risk comparisons, and shows that the U.S. average background radiation dose dominates individual public radiological risk (at 1.8E-4/yr). Table V also lists the average risk due to cancer (2E-3/yr - see Reference 15). By comparison, the potential unmitigated risk from these process accidents at a TWRS/WTP facility exceeds the background dose risk by two orders of magnitude and the average cancer risk by a factor of ten. Four accident scenarios involving two forms of melter failure, and two forms of resin interactions dominate the risk by accounting for 90 percent of the total. A large portion of the risk from the two melter accident scenarios accrues from rapid thermal volatilization and dispersal of the aqueous cold cap from a catastrophic release of the high temperature, molten glass. Limited experimental data and experience are available for these melter failure scenarios. If these melter and resin accidents are effectively prevented and/or mitigated, the TWRS-P risk decreases to around 1.4E-3/yr, a level commensurate with the risk associated with occupational exposure limits, but still some 10 times greater than the risk due to average background exposure to radiation. Several accident scenarios involving tank failures or deflagrations also exhibit the potential for very high doses. In the case of chemical storage tank failure, the potential ammonia and nitric acid releases would result in irreversible, deterministic health effects around the TWRS-P facility and its environs, and could render the facility uninhabitable for operating and control purposes. If liquid anhydrous ammonia were used, the affected area could extend out beyond a mile. Thus, prevention and mitigation are required to minimize the impact of these chemical effects upon radioactive materials.

The NRC staff investigated the availability of controls for reducing the risks. Fortunately, relatively simple and effective, prevention and mitigation methods are available, and Table IV displays this situation. Prevention and mitigation methods reduce the total risk to the receptor at 100 meters from the TWRS-P facility to about 2.5E-6/yr. This result is about 5 percent of the average occupational risk and

Table IV: Summary of the Impact of Potential Controls at the Generic TWRS Facility

Event	Potential Controls/Items Relied Upon For Safety	Potential Mitigated Consequence to Receptor at 100 meters, rem	Mitigated Consequence Category	Mitigated Likelihood (Probability)	Likely Acceptable per New Part 70?	Mitigated Risk, year-1
LAW Tank Failure	1. Tank 2. cell/HEPA 3. Enclosure/sump 4. Spare tank	3-6	Intermediate	2E-6	Yes	3E-9 to 6E-9
HLW Tank Failure	1. Tank 2. cell/HEPA 3. Enclosure/sump 4. Spare tank	6-12	Intermediate	2E-6	Yes	6E-9 to 1.2E-8
Cs Tank LOCA, Boiling/1,000 gal	1. cell/vent./2 HEPA 2. emerg. cooling	25 (first HEPA fails due to moisture)	Intermediate to High	1E-6	Yes	1.3E-8
Cs Tank Failure, 1,000 gal	1. Tank 2. cell/vent. 3. Enclosure/sump 4. Spare tank 5. Cs as solid	0.1	Low	2E-6	Yes	1E-10
Cs Resin, Loaded	1. Enclosure 2. Cell/vent/HEPA	1.4	Low	1E-4	Yes	7E-8
Cs Resin, Elution	1. Enclosure 2. Cell/vent/HEPA	3.4	Low	1E-4	Yes	1.7E-7 (7% of total)
H2 Deflag/ LAW Tank Heel	1. Gas/vent./2 HEPA 2. Cell/vent 3. Sensor/N2 inject	20 (first HEPA rendered ineffective)	Intermediate	1E-6	Yes	1E-8

Table IV: Summary of the Impact of Potential Controls at the Generic TWRS Facility (continued)

Event	Potential Controls/Items Relied Upon For Safety	Potential Mitigated Consequence to Receptor at 100 meters, rem	Mitigated Consequence Category	Mitigated Likelihood (Probability)	Likely Acceptable per New Part 70?	Mitigated Risk, year-1
H2 Deflag/ HLW Tank Heel	1. Gas/vent./2 HEPA 2. Cell/vent 3. Sensor/N2 inject	38 (first HEPA rendered ineffective)	Intermediate	1E-6	Yes	2E-8
H2 Deflag/ Cs Tank Heel	1. Gas/vent./2 HEPA 2. Cell/vent 3. Sensor/N2 inject	2.5 (first HEPA rendered ineffective)	Low	1E-6	Yes	1.3E-9
H2 LAW Tank Deflag/ Low H2	1. Gas/vent./2 HEPA 2. Cell/vent 3. Sensor/N2 inject	2.3 (first HEPA rendered ineffective)	Low	1E-6	Yes	1.2E-9
H2/LAW Tank Deflag/ High H2	1. Gas/vent./2 HEPA 2. Cell/vent 3. Sensor/N2 inject	115 (first HEPA rendered ineffective)	High	1E-6	Yes	6E-8
H2/HLW Tank Deflag/ High H2	1. Gas/vent./2 HEPA 2. Cell/vent 3. Sensor/N2 inject	216 (first HEPA rendered ineffective)	High	1E-6	Yes	1.1E-7 (4.3% of total)

Table IV: Summary of the Impact of Potential Controls at the Generic TWRS Facility (continued)

Event	Potential Controls/Items Relied Upon For Safety	Potential Mitigated Consequence to Receptor at 100 meters, rem	Mitigated Consequence Category	Mitigated Likelihood (Probability)	Likely Acceptable per New Part 70?	Mitigated Risk, year-1
CST Drying/ H2 Deflag	1. Cell/vent/2 HEPA 2. Enclosure	48 (first HEPA rendered ineffective)	High	1E-6	Yes	2.4E-8
Melter/Canister/ Cap Dispersal	1. Cell/vent/2 HEPA 2. Instrumentation	15 (first HEPA rendered ineffective due to heat)	Intermediate	1E-4	Further Analysis Necessary	7.5E-7 (30% of Total)
Melter/Steam Explosion	1. cell/vent/2 HEPA 2. instrumentation	26 (first HEPA rendered ineffective due to blast and heat)	Intermediate to High	1E-4	Further Analysis Necessary	1.3E-6 (51% of Total)
Ammonia Tank Failure	1. Tank 2. Enclosure 3. Detect/Sprays	< ERPG-1	Low	1E-6	Yes	(0)
Nitric Acid Tank Failure	1. Tank 2. Enclosure 3. Detect/Sprays	< ERPG-1	Low	1E-6	Yes	(0)

Total mitigated risk = 2.5E-6/yr

Table V: Different Sources of Risk Limits

Risk Source/Basis	Dose Equivalent, Rem	Frequency, yr-1	Risk, yr-1
Worker Limits			
Part 20, Worker Limit	5	1	2E-3
Part 20, Typical ALARA Value	0.31	1	1.2E-4
U.S. Worker Average, All Causes	(-)	(-)	4.8E-5
Public Limits			
Part 20, Public Limit	0.1	1	5E-5
Part 20, D&D and Part 61, Public Limits	0.025	1	1.3E-5
Typical Public Values			
U.S. Average Background	0.350	1	1.8E-4
Background Difference between Denver and U.S. Average	0.500	1	2.5E-4
Average U.S. Public Cancer Fatality Rate	(NA)	(NA)	2E-3
Average Public Dose from Commercial Nuclear Plant	<0.001	1	< 5E-7

Note: Radiological comparisons assume Linear No Threshold (LNT) theory, with risk factors of 2,500 rem/fatality for workers and 2,000 rem/fatality for members of the public. These rates are kept constant, and not reduced for higher acute doses (e.g., 1,000 rem/fatality for individual, acute doses over 10 rem).

around 1.4 percent of the risk due to the average background dose. Incorporation of prevention and mitigation controls is likely to be acceptable to the revised Part 70, although further analysis may be necessary for the melter failure scenarios. Consequently, the preventative and mitigating design features are likely to become controls and items relied upon for safety.

The average worker and cancer risks presented in Table V include contributions from all sources, such as industrial accidents, environmental chemical exposures, and other nonradiological contributors. Therefore, acceptable limits for potential contributions from radiological risks associated with process hazards of TWRS-P are likely to be lower, perhaps a few percent of these averages. This preliminary analysis suggests this is indeed the case for a generic, TWRS-P facility design incorporating standard nuclear industry prevention and mitigation techniques; the estimated risk with prevention and mitigation features is 5% of the average occupational risk and 0.1 percent of the average, public cancer risk. This is consistent with discussions in the literature (15).

From this review of a generic facility, the NRC staff concluded that safety controls would be needed at the proposed, TWRS/WTP facility to meet likely risk goals, and that, with the possible exception of the melter areas, no unusual or special controls with unique characteristics would be necessary. More information is needed on the melter designs before specific control strategies can be postulated and evaluated.

As compared to the generic approach, the preliminary designs proposed by the contractors do not adequately consider prevention and controls, and usually only incorporate one mitigating approach to overcome failures. The designs do not include important auxiliary effects in the analyses, such as common mode failures, operability, recoverability, and plant habitability for operators, and means for controlling these effects. More defense-in-depth is desirable.

Obviously, DOE and its contractors will include experimental testing as part of the program leading to the design, construction, and operation of the TWRS-P facility. Few appropriate safety related parameters, such as failure rates, modes, and release fractions, are available for HLW processing and vitrification facilities. It would be beneficial if the measurement of such safety parameters could be included in the DOE and contractor programs.

POTENTIAL OPEN ISSUES

As a result of the NRC staff's technical review of documentation and participation in meetings with DOE and the contractors, several concerns and potential open issues were identified. These include the need for significantly more detailed design information and safety analyses, and greater defense-in-depth. In particular, the design, at the time of termination of the privatization contract, was found to be very preliminary and corresponded to perhaps a 15 percent level of design. The NRC staff has identified over two-dozen significant issues and over fifty specific topics in the current design and approach that would require further efforts and analysis to achieve adequate closure. These significant issues include both programmatic aspects of TWRS-P (e.g., maintenance of design/authorization basis, level of detail) and technical issues (e.g., large volumes of tankage and radionuclide inventories, combined chemical and radiological hazards, melter corrosion). DOE, as the current regulator, has also identified similar issues (16).

The melters present several issues, due to their size, capacities, and surface area fluxes, all of which would make the LAW melters become the largest for radwaste vitrification in the world. However, the experiential base, particularly from the perspective of potential environmental, safety, and health (ES&H) concerns, is limited. Towards the end of the program, the need for high alloys for corrosion resistance in areas of the melter that would usually be made of more conventional materials (e.g., carbon steel) in existing vitrification facilities was identified. Analyses were also presented that implied a relatively high level of risk to the worker (circa 1E-3/yr) from a melter offgas/NOx scenario. The melter designs also have several unique attributes that require safety evaluation, such as low flow areas and gaps that might be subject to localized corrosion phenomena. More information and analyses would be required to ascertain the safety ramifications if these melter designs are used by the new contractors.

DOE prescribed an expedited schedule at the beginning of the program, with limited flexibility. Consequently, throughout the length of the program, the NRC and DOE staff technical reviews were held to tight schedules (typically a two week turnaround for a multivolume submittal) which frequently resulted in the inability to identify action items and plans, and achieve full closure on a significant number of the issues. Consequently, resolution of several, significant design and safety issues may not occur for some time. In addition, the likely impacts from further contractor changes are unclear but would likely imply more uncertainties and more design changes, which, in turn, could raise more issues, and the corresponding need for additional time for review and resolution prior to proceeding into construction and operation.

POTENTIAL CONCERNS WITH CHANGES FROM THE NRC'S REGULATORY APPROACH

The working relationship between the NRC and the DOE evolved during the program, and DOE has acknowledged the value added by the NRC's involvement. In the opinion of the NRC staff, there are several significant concerns which could be ameliorated by revising the current regulatory approach. The most notable of these concerns are as follows:

- The influence of program issues, for example, schedule, upon the regulatory review activities
- Maintenance of design/authorization basis (license)
- The application of a risk-based approach to the development of the design without additional considerations, such as uncertainties and defense-in-depth
- Limited use of established NRC regulations and guidance

THE FUTURE TWRS/WTP PROGRAM

As previously noted, DOE has terminated the current privatization contract and approach and elected to follow an M&O contracting approach. DOE plans to self-regulate these TWRS facilities. The specific features of the regulatory approach and the balancing of programmatic and safety issues are not identified as of this writing, although the RU has been incorporated into the DOE WTP program office. The means to follow, address, and close the design, safety, and regulatory issues identified from the NRC reviews and summarized in this paper also have not been presented at this time. DOE's approach does include significant incentives for a contractor to reduce costs but, as of this writing, it is not clear how cost-savings incentives will be balanced with appropriate levels of safety.

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