Hanford Tank Waste Remediation System Regulatory Oversight Program Briefing Book

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Topics

- Hanford overview
- TWRS timeline
- NRC mission in the program
- Accomplishments
- Lessons learned
- Summary
- Future

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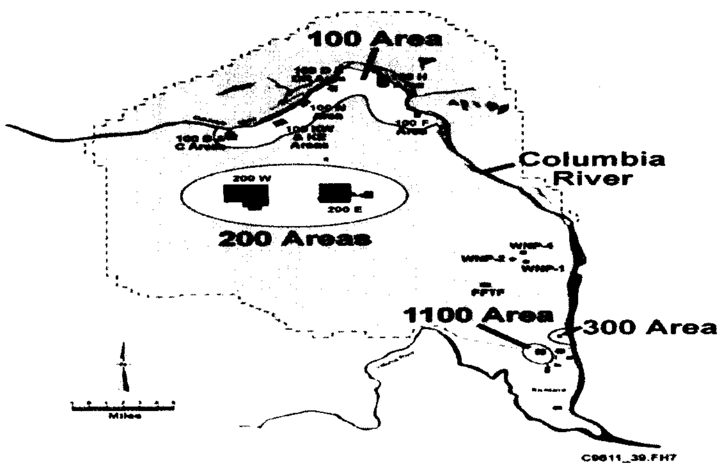
TWRS = Tank Waste Remediation System

NRC = Nuclear Regulatory Commission

Hanford Site



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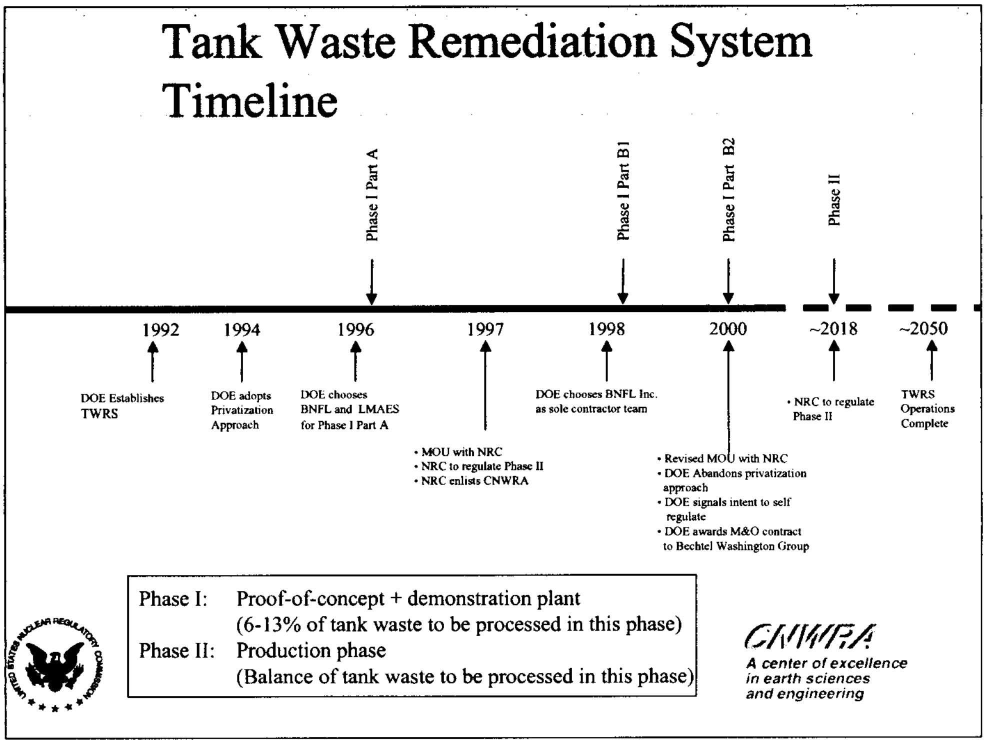
- The Hanford site in Washington State holds one of the largest concentrations of radioactive waste in the world
- ~54 million gallons of radioactive waste stored in 177 underground tanks
- Radioactive waste tanks and vitrification facilities located in the "200 Areas"
- 28 Double Shell Tanks (DST), 149 Single Shell Tanks (SST)
- Tank material of construction carbon steel, average capacity 1 million gallons
- ~67 SSTs have confirmed leaks
- DSTs contain most of the liquid and some solid phase waste
- SSTs contain mostly sludges and saltcakes (liquid phase removed due to concerns about leaks)

<u>Low Activity Waste (LAW)</u>

- Comes from DST liquids and from solids washing operations
- Classified as envelopes A, B, C wastes depending on contained levels of Cs-137, Sr-90, and transuranic (TRU) isotopes
- Predominant radionuclides are Cs-137, Tc-99, Sr-90, Co-60, Eu-154, and Eu-155
- Contains up to 2% solids

<u>High Level Waste (HLW)</u>

- Comes from solid phases of SSTs and DSTs
- Is classified as envelope D waste
- Is transferred as up to 20% solids slurry
- Predominant radionuclides are Cs-137, Tc-99, Sr-90, Co-60, and TRU



Phase I Part A

- 20-month conceptual design effort (started 1996)
- Two DOE contracts for $27 million each with BNFL Inc. & Lockheed Martin Advanced Environmental Systems (LMAES)

Phase I Part B1

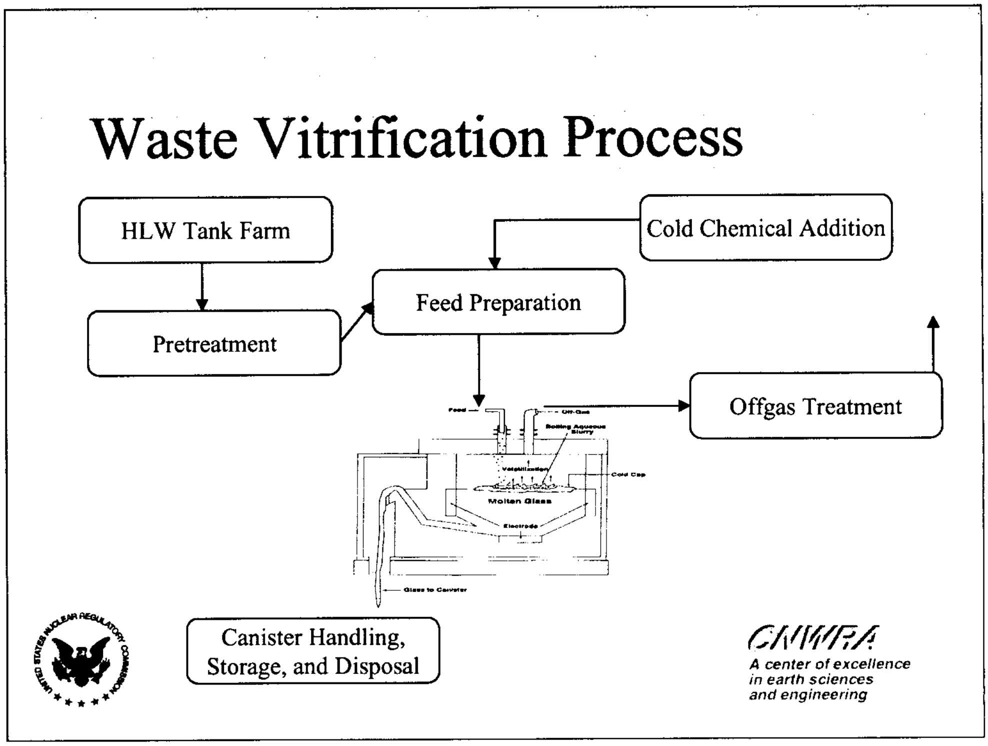
- 24-month facility design phase to advance design to ~30% level (started 1998)
- DOE chooses BNFL Inc. based on their use of viable, proven technology in Phase I Part A conceptual design
- Fixed Fee Type contract with estimated cost of $350 million

Phase I Part B2

- ~18-year effort to vitrify 6–13% of tank waste (scheduled start August 2000)
- BNFL Inc. to be paid per canister of glass produced (privatized approach)
- BNFL Inc. revised the estimated cost from $6.9 Billion to $15 Billion (mainly due to excessive financing costs under privatized approach)
- DOE cancelled BNFL Inc. contract in May 2000
- DOE awarded M&O style contract to Bechtel/Washington Group in November 2000

Phase II

- Complete in 10–30 years (potentially to ~2050)
- Would enlarge and utilize Phase I facilities



<u>BNFL Inc. Proposed Pretreatment Process</u>

(Feed consists of LAW and liquid phase of HLW)

- Sr & TRU precipitation, removal by Ultrafiltration
- HLW solids washing/removal of solubles (Al, P, Cr salts)
- Cs & Tc removal (ion exchange-organic resins)

<u>BNFL Inc. Proposed LAW Vitrification Process</u>

- 3 LAW Melters of 10 Mt/day glass making capacity each
- No cells, limited shielding
- Produces wastes that have radionuclide concentrations the equivalent of Class A/B/C low-level waste (per 10 CFR Part 61)
- Glass canister dose rate ~ 0.2 rem/hr contact

<u>BNFL Inc. Proposed HLW Vitrification Process</u>

Vitrifies radioactive elements and solids separated in Pretreatment

- 1 HLW Melter of 1.5 Mt/day glass making capacity
- Remote operation in hot cell
- Final storage of HLW in federal repository
- Glass canister dose rate ~ 10,000 rem/hr contact

NRC Mission Objectives

- Become familiar with Hanford/TWRS
- Participate in meetings and review DOE contractor submittals
- Prepare regulatory framework for potential licensing of waste solidification facility
- Prepare procedures and tools for potential inspection

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Familiarization

Objectives

- Develop reports and manuals
  - Hanford site and hazardous materials
  - State of the current technology
  - Potential safety issues
  - Technical challenges
- Basis for developing regulatory framework and associated guidance
- Support regulation of Phase II facility, if directed

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Familiarization

Key Accomplishments

- Developed overview reports and manuals
  - Hanford TWRS Familiarization Report (CNWRA 97–001)
  - Survey of Solidification Process Technologies (NUREG/CR–6666)
  - Hanford TWRS HLW Chemistry manual (NUREG/CR–5751)
  - Process Hazards and Safety Issues for TWRS-P, Vols. I, II, and III (Vols. I&II, IM 01403-102-940; Vol. III, IM 01403.102.004)
  - Hanford TWRS Pretreatment Chemistry and Technology (NUREG/CR –xxxx)

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• Hanford TWRS Familiarization Report (CNWRA 97–001)

Report presents detailed information on the Hanford site and the 200 Area tank farms including a pictorial database of the tanks using a Geographic Information System (GIS). The GIS tool contains detailed information on the chemical and radionuclide inventories of the 177 large underground storage tanks and allows rapid retrieval of this data for evaluation of the hazards posed by the wastes.

• Survey of waste solidification Process Technologies (NUREG/CR–6666)

Report provides current status of high-temperature solidification technologies used around the world.

• Hanford TWRS HLW Chemistry Manual (NUREG/CR–5751)

Report reviews the chemical processes adopted at Hanford and potential hazardous situations in storage, retrieval, and processing of Hanford HLWs.

• Process hazards and safety issues for TWRS, Volumes I, II, and III

(Vols. I&II, IM 01403-102-940; Vol. III, IM 01403.102.004)

Reports identify the hazards, safety, and technical issues involved in LAW and HLW processes, and evaluate vulnerabilities in the BNFL Inc. design.

• Hanford TWRS Pretreatment Chemistry and Technology (NUREG/CR–xxxx)

Report provides a review of pretreatment processes and technologies with emphasis on technologies proposed by BNFL Inc. and LMAES

Familiarization
Key Accomplishments

- Developed point papers/technical reports
  - Hydrogen Control in HLW Storage Tanks
  - Ultrafiltration in LAW & HLW Processes: A Critical Review
  - Corrosion Induced Heat Exchanger Failures

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• Hydrogen Control in HLW Storage Tanks

Report independently evaluates hydrogen generation by radiolysis in the aqueous radioactive tank wastes and concludes that the rates used by BNFL Inc. in their calculations are nonconservative. The use of best-basis chemical and radionuclide tank inventories by BNFL Inc. without consideration of uncertainty estimates could significantly underestimate the consequences of accidents involving hydrogen explosion in tanks. The report recommends use of the 90^{th} percentile chemical and radionuclide inventories.

• Ultrafiltration in LAW and HLW Processes: A Critical Review

Report evaluates the proposed use of ultrafiltration (UF) to separate entrained solids and precipitated Sr-90 and TRU elements in the TWRS Pretreatment process. The report discusses uncertainties about UF performance as well as corrosion, erosion, and criticality concerns and concludes that the use of UF in the BNFL Inc. design is based on limited BNFL Inc. experience and will require further monitoring.

• Technical Review Report on Corrosion-Induced Heat Exchanger Failures

Report examines the possible environmental degradation mechanisms that could lead to a breach of the heat exchangers widely used in the BNFL Inc. design. The various corrosion processes, monitoring and inspection methods, and schemes for materials selection are presented. The report concludes that given the range of anticipated environments, all modes of corrosion are possible, and the major effect of corrosion is potential contamination in the steam and cooling water loops.

Familiarization
Key Accomplishments

- Developed point papers/technical reports
  - Materials Considerations of Proposed TWRS
  - Process Safety of Proposed TWRS

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• Materials Considerations of Proposed TWRS

Paper provides an overview of materials selection concerns for the TWRS project. Proper materials selection and monitoring are necessary to ensure adequate confinement of the large volumes of radioactive waste encountered in TWRS processes. The paper identifies a relative lack of published corrosion and erosion information under expected operating conditions, particularly in the melter and offgas areas. Also, failure and release data for accident analysis are not well established.

• Process Safety of Proposed TWRS

Paper presents chemical and process safety analyses for the TWRS facilities based on the generic and conceptual process approaches proposed by BNFL Inc. The analyses estimate the combined, unmitigated risk to the receptor at 100 m as ~2.4E–2/yr, about an order of magnitude above the equivalent risk of the 10 CFR Part 20 radiation worker annual dose limit of 5 rem. Melter and organic resin scenarios dominate the potential unmitigated risk at 100 m, accounting for about 94% of the risk total. Prevention and mitigation offer the potential to reduce the risk from TWRS operations to a more acceptable level of ~2E–6/yr. The paper suggests the measurement of safety parameters such as failure rates, modes, and release fractions for the HLW processing and vitrification facilities should be included in the DOE program. In addition, since a rupture of ammonia and nitric acid storage tanks would have onsite and offsite effects exceeding ERPG–3 levels and require evacuation of the facility, the facility design should include provisions such as dedicated breathing air to control and operator areas, a remote control facility, automated operation shutdown, etc.

ERPG = Emergency Response Planning Guide

Review of Contractor Submittals
Objectives

- Identify regulatory deficiencies
  - Based on 10 CFR Part 70 and Standard Review Plan
- Identify technical uncertainties
  - Based on accepted practices
  - Lessons learned
- Develop tool to aid the review process
  - Database to track open item issues and their resolutions

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Review of Contractor Submittals
Key Accomplishments

- Reviewed several multi-volume submittals
  - Safety Requirements Documents (SRDs)
  - Hazard Analysis Reports (HARs)
  - Initial Safety Analysis Reports (ISARs)
  - Design Safety Features (DSF) Submittals
  - Firm Fixed Price (FFP) Submittal
- Attended safety and regulatory meetings
  - Topical Meetings
  - Design Review Meetings

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- DOE's expedited schedule demanded quick turn-around time for reviews (Typically 2–3 weeks for multivolume submittals)
  - Insufficient time to fully identify and achieve closure on issues
  - Potential impact on depth and quality of reviews

- Key findings from these submittals and meetings are highlighted in the Review of Contractor Submittals slides that follow

Review of Contractor Submittals
Key Accomplishments

- Developed database to track open item issues and their resolution
  - Database created in MS Access to provide easy retrieval and sorting capabilities

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• Database was developed to record, track, and status open items and issues, and to keep the list current with changes in the design. Database allows rapid retrieval and sorting of items.

Review of Contractor Submittals
Key Accomplishments

- Key Open Issues
  - Need for significantly more detailed design information and safety analyses
    - Current information based on ~15% level of design
  - Need for greater defense-in-depth and margin of safety in design
    - Lack of conservatism, particularly at this early stage of design

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<u>Concerns with lack of conservatism in design</u>

- Inadequate margin, non-conservatism, and lack of defense-in-depth resulting in potential under-estimation of consequences and inadequate controls on Items Relied On For Safety
- Use of optimistic design assumptions and reliabilities
- Inconsistent approach to use of standby equipment in design
  - Process ventilation system has three 100% capacity fans
  - Three emergency diesel generators are served by a single fuel oil tank (i.e., tank leak will disable all 3 emergency generators)

Review of Contractor Submittals

Key Accomplishments

- Regulatory Differences and Deficiencies
  - Standards for radiation protection
    - NRC uses 10 CFR Part 20, Standards for Protection against Radiation
    - DOE uses 10 CFR Part 835, Occupational Radiation Protection
  - DOE uses a co-located worker category in TWRS-P
  - Hazard and Safety Analyses
    - NRC use of 100 meters distance to a public receptor (the facility fence line) results in higher estimated consequences
    - DOE use of Hanford site security parameter (11,000-15,000 m) results in lower estimated consequences and fewer Items Relied On For Safety

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- NRC concept has a fence line at ~100 m, beyond which the smaller public dose limits apply.
- DOE concept has co-located worker (i.e., worker beyond the contractor controlled area of ~100m), which allows the higher occupational dose limits to apply to a much greater distance of approximately 9 miles (~15,000 m)

Review of Contractor Submittals
Key Accomplishments

- Regulatory Differences and Deficiencies
  - There may be a much higher risk from certain chemical events than from a radiological event
    - Contractor's use of standard chemical industry approach to design and safety results in a corresponding worker risk level of ~1E–3/yr, per their analyses
    - Acceptable worker risk for high consequence radiological event 1E–5/yr per SRP
  - RU use of ERPG values is nonconservative for longer duration scenarios such as control room habitability

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- Because RU regulates by approved SRD, which uses chemical industry standards; they accept the higher risk level for chemical events
  - The risk from chemical event pertains to the certain fatality of the exposed worker
- Per SRP
  - High Consequence Hazard is to be rendered Highly Unlikely (<E–5/yr)
  - Medium Consequence Hazard is to be rendered Unlikely (E–2/yr to E–5/yr)
  - Per 10 CFR Part 70, High Consequence = >100rem/event to worker
- ERPG values are for 1 hour exposure time

  TLV (8 hr exposure) values better suited for control room occupancy scenario

RU = Regulatory Unit (of the DOE)

TLV = Threshold Limit Value

Review of Contractor Submittals
Key Accomplishments

Major design concerns and open safety issues identified by CNWRA/NRC team:

- Explosion from radiolytically produced hydrogen in vessels
  - An independent evaluation of magnitude of hydrogen generation in a passive system was provided
  - BNFL Inc. subsequently shifted their strategy from passive control to active control

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- Also see notes on Hydrogen Control in HLW Storage Tanks (slide 10)

Review of Contractor Submittals
Key Accomplishments

- Steam explosions in melter
  - Contact of water on molten glass pool was addressed by BNFL
  - Refractory failure allowing molten glass to heat water in cooling jacket remains an open safety issue

- Sugar dust explosion
  (during dry chemical storage and transfer)
  - BNFL Inc to mix sugar with other feed chemicals to prevent sugar dust explosion in the radiologically controlled areas
  - Impact on radiologically controlled areas due to explosion in adjacent chemical mix area remains an open safety issue

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Review of Contractor Submittals
Key Accomplishments

- Melter offgas release
  - Potential for severe NO_x exposure to worker during manual operations performed on top of LAW melters remains an open safety issue
- Energetic reactions due to misfeeding of incompatible chemicals
  - Potential for misfeed of concentrated nitric acid to caustic tank and vice versa remains an open safety issue
- Break in ammonia supply line to NO_x abatement unit
  - This significant toxicological hazard to facility worker remains an open safety issue

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- NO_x Exposure

  Contractor presented analysis that implied a relatively high level of risk to worker (~1E–3/yr)

  – The risk pertains to the certain fatality of the exposed worker

- Ammonia

  Break in ammonia supply line to NO_x abatement unit will result in discharge of ~17 cfm of gas indoors, requiring ~55,000 cfm of air to dilute to IDLH concentration of 300 ppm

IDLH = Immediately Dangerous to Life and Health

Regulatory Framework for Licensing
Objectives

- Revise 10 CFR Part 70
- Develop Standard Review Plan

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Regulatory Framework for Licensing
Key Accomplishments

- 10 CFR Part 70 revised and issued
- Standard Review Plan developed and issued
- Two reports produced on Risk Informed Classification of Process Systems

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Regulatory Framework for Licensing
Key Accomplishments

- Standard Review Plan for the Review of a License Application for TWRS (NUREG–1702)
  - Provides NRC guidance for review and evaluation of health, safety, and environmental protection issues in license application for TWRS
  - Based on 10 CFR Part 70, Domestic Licensing of Special Nuclear Material, as revised

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Regulatory Framework for Licensing
Key Accomplishments

- Two reports were produced on the Risk Informed Classification of Process Systems
  - Classification of Process Systems Used in the BNFL Inc. Design
    - The BNFL Inc. design was divided into 25 process systems, which were then classified based on hazard, estimated frequency, and potential consequence
  - Consequence Criteria and Recommendations for Acceptable Accident Frequencies for TWRS
    - Accident frequencies and consequences from various safety analysis reports and incident reports were compiled
    - Acceptable accident frequencies based on constant risk philosophy were examined

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Risk Informed Classification of Process Systems

Classification of Process Systems Used in the BNFL Inc. Design

System ID	System Description	Accident Type	Accident Description	Accident Cause	Typical Control Strategies	Estimated Frequency	Estimated Facility Worker Consequence	Estimated Public Consequence
01A	LAW Feed Evaporator System	Spill of radioactive liquid/slurry in-cell	Rupture of LAW feed evaporator feed tank (V2101, V2102)	Corrosion	Materials selection for corrosion resistance; pressure, temperature, and pH monitoring and control	High (1.7 E–02) (American Institute of Chemical Engineers, 1989)	Low (Mitigated by shield walls)	Low
		Circumvention of shielding	LAW leak into LAW feed evaporator condenser (E2102) cooling water	Corrosion of condenser tubes	Radiation monitoring on cooling water lines; materials selection for corrosion resistance	High (2.3 E–01) (American Institute of Chemical Engineers, 1989)	Low (Mitigated by alarm and evacuation)	Low
		Circumvention of shielding	LAW leak into LAW feed evaporator reboiler (E2101) steam condensate stream	Corrosion of reboiler tubes	Radiation monitoring on condensate lines; materials selection for corrosion resistance; pH, temperature, and halide monitoring and control	High (2.3 E–01) (American Institute of Chemical Engineers, 1989)	Low (Mitigated by alarm and evacuation)	Low

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• Frequencies are classified per DOE* as

Low	$10^{-6} < p < 10^{-4}$ events per year
Intermediate	$10^{-4} < p < 10^{-2}$ events per year
High	$p > 10^{-2}$ events per year

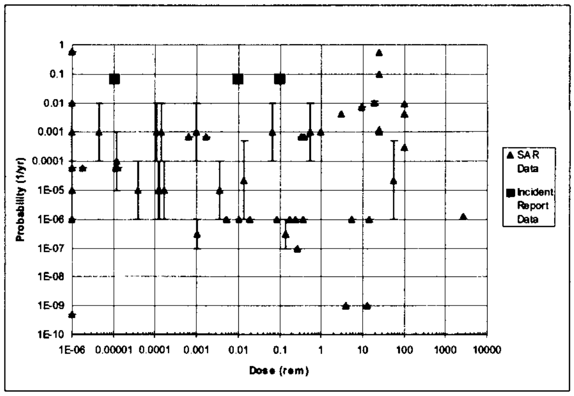
* U.S. Department of Energy. *Top-Level Radiological Nuclear and Process Safety Standards and Principles for TWRS Privatization Contractors.* DOE/RL–96–0006. Revision 0. Washington, DC: U.S. Department of Energy, Richland Operations Office. 1996.

• Consequences are classified per 10 CFR Part 70 as

Consequence	Worker	Public
Low	< 25 rem/event	< 5 rem/event
Intermediate	25-100 rem/event	5-25 rem/event
High	> 100 rem/event	> 25 rem/event

Risk Informed Classification of Process Systems

Consequence Criteria and Recommendations for Acceptable Accident Frequencies for TWRS



- Actual events have a higher probability than the accidents calculated in SARs
- No historical events occurred that led to a significant dose to public

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- Most of the input data was obtained from vitrification SARs for WVDP and DWPF (WVNS SAR 1992, 1997; WSRC SAR 1997).
- Various accident scenarios were postulated in the SARs, each with its estimated dose and frequency of occurrence.
- If the data were given in frequency ranges, they are represented by a vertical line in the figure.
- Incident Reports of the vitrification facilities at DWPF, WVDP, and the VPP at Fernald indicated that 3 radiological contamination events have occurred in the combined ~12 years of operations for these facilities (Both DWPF and WVDP started vitrification in 1995. VPP suspended operation shortly after starting in 1996).
- Accident frequency for each of these events was calculated as 1 event/12 yr of combined operation. The doses were estimated from the accident records.

SAR = Safety Analysis Report

WVDP = West Valley Demonstration Project

DWPF = Defense Waste Processing Facility

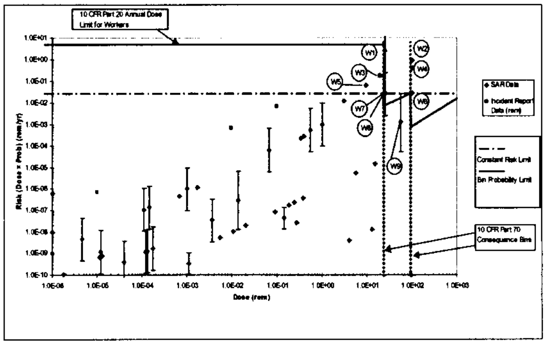
WVNS = West Valley Nuclear Services

WSRC = Westinghouse Savannah River Company

VPP = Vitrification Pilot Plant

Risk Informed Classification of Process Systems

Consequence Criteria and Recommendations for Acceptable Accident Frequencies for TWRS



- Major differences in DOE and NRC regulations
  - Frequency limits already defined in DOE standards
  - NRC does not have co-located worker category
- Comparison of SAR data with 10 CFR Part 70 show that only few accidents described in SARs would be out of compliance

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Notes on figure

- Dashed line = CNWRA proposed Acceptable Constant Risk Level of 31 mrem/yr

  (This is 1/10th of average annual occupational dose for radiation workers from NRC- licensed activities 1989–1998, and is equivalent to 1.25×10^{-5} fatalities/yr)
- Two sloping solid lines are lines of constant probability for Consequence Categories II & III per 10 CFR Part 70
- Left of the saw tooth solid line = compliant with 10 CFR Part 70 and CNWRA proposed Acceptable Constant Risk Level of 31 mrem/yr
- The few postulated accidents that fall right of the saw tooth solid line may need to be examined further.

Co-located Worker—See slide 16

Frequency Limits are classified per DOE*

Low	$10^{-6} < p < 10^{-4}$ events per year
Intermediate	$10^{-4} < p < 10^{-2}$ events per year
High	$p > 10^{-2}$ events per year

*U.S. Department of Energy. *Top-Level Radiological Nuclear and Process Safety Standards and Principles for TWRS Privatization Contractors.* DOE/RL-96–0006. Revision 0. Washington, DC: U.S. Department of Energy, Richland Operations Office. 1996.

Inspection & QA
Objectives

- Develop inspection procedures
- Develop tools to support reviews and inspection

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Inspection & QA
Key Accomplishments

- Inspection procedures
  - Radioactive Waste Treatment/Nuclear Material Production Facility Integrated Design Inspection Program
  - NRC Procedure for Inspection of TWRS-P Quality Assurance Program Implementation
- Tools to support reviews and inspection
  - Spreadsheet model for estimating radionuclide concentration in the plant

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- Radioactive Waste Treatment/Nuclear Material Production Facility Integrated Design Inspection (IDI) Program

  Report describes methodology for performing multidisciplinary IDIs to gain assurance that the facility design process effectively implements NRC regulations and license commitments. Inspection plans should verify:

  i) regulatory requirements and design basis are correctly implemented in specifications, drawings, calculations, and procedures

  ii) design engineers have sufficient guidance and experience to perform their functions

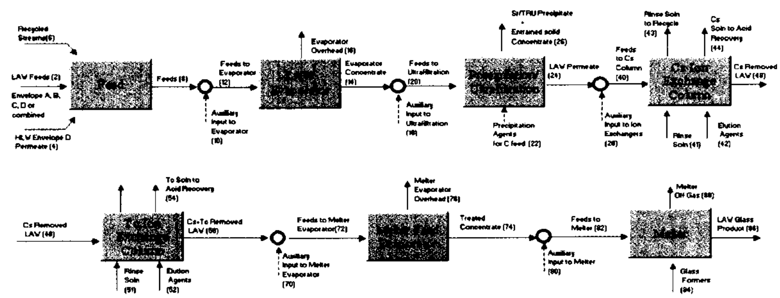
  iii) design controls are consistently applied to the original design, design changes, and field changes.

  As a minimum, inspection plans should include design of the following systems: mechanical, civil, structural, electric power, instrumentation & control, nuclear safety, and fire safety.

- NRC Procedure for Inspection of TWRS-P QA Program Implementation

  Report details the inspection procedure to be applied to assess implementation of the QA program (i.e., is the QA program being implemented effectively?). Inspection Planning and Checklist for Evaluating Acceptance of QA Program Elements are discussed in detail. 10 CFR Part 70, the TWRS-P SRP, and NQA–1–1994 are cited as sources to be used for QA guidance.

Modeling of TWRS Process Flowsheet



- PRETREAT: A Spreadsheet-based Mass-balance Model For Hanford TWRS Pretreatment Processes
  - Spreadsheet model (Microsoft Excel)
  - Allows quick estimates of composition and radionuclide concentration of LAW streams at each stage in pretreatment process
  - Ease of use assured with a graphical user interface

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Model created to track effects of changes in feed on downstream process steps

Major Concerns are

- Hydrogen accumulation in vessels
- Accumulation of radionuclide precipitates in vessels (criticality)

Mass Balance calculation method

- At each process step, program uses literature supplied decontamination factors (DFs) for each species

Programmatic Issues
Things that worked well

- Good NRC/CNWRA interactions
  - Team effort
  - Open and frequent dialogue
  - CNWRA oral presentations to NRC on each major project

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Programmatic Issues
Things that did not work well

- DOE's expedited schedule provided insufficient time to
  - Identify safety issues
  - Achieve full closure on issues
- Design/Authorization Basis Documents (D/ABD) were not kept up to date by BNFL Inc.
  - Inadequate safety input into the design due to time lag between D/ABD and design

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Programmatic Issues
Things that did not work well

- Limited use of NRC regulations and guidance
  - DOE did not adopt use of 10 CFR Part 70 and TWRS SRP
- RU approved the use of contractor selected standards, codes, and regulations
  - Resulted in regulatory differences and deficiencies as discussed

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Summary

- Completed full set of reports outlining current status of technology
- Provided to DOE Regulatory Unit timely input on regulatory and technical concerns
- Issued revised 10 CFR Part 70 and new Standard Review Plan for TWRS facility
- Developed initial inspection procedures and tools for inspection
- Issued summary report outlining accomplishments of TWRS program.

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Present NRC position on participation in RPP-WTP

- At present the DOE has
  - terminated the privatization contract
  - indicated its intent to self regulate the project
  - has also acknowledged the value added by NRC/CNWRA participation
- NRC has terminated its participation in the program
- Should NRC resume participation in future, it is felt that
  - Enabling legislation from Congress would be desirable for NRC regulatory oversight of the Hanford RPP–WTP

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Reference Documents

- US NRC Terminated MOU with DOE RU
  (ADAMS No. ML010120329)
- Letter to DOE
  (ADAMS No. ML010110525)

RPP–WTP = River Protection Project–Waste Treatment Plant

MOU = Memorandum of Understanding

It's not all waste

- Experience gained from the TWRS program will be valuable to the NRC in reviewing the license application for other DOE facilities such as MOX facility licensed under 10 CFR Part 70

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MOX = Mixed Oxide (fuel)