Department of Energy
Washington, DC 20585
January 5, 2011

The Honorable Peter Winokur
Chairman
Defense Nuclear Facilities Safety Board
625 Indiana Avenue, NW, Suite 700
Washington, DC 20004-2901

Dear Mr. Chairman:

On October 7 and 8, 2010, the Defense Nuclear Facilities Safety Board (Board) conducted a public hearing on safety-related aspects of the design and construction of the Department of Energy's (DOE) Waste Treatment and Immobilization Plant (WTP) at the Hanford Site. Originally, the Board's Federal Register Notice announcing the public hearing stated that the record, associated with the public hearing, would remain open until November 7, 2010, for the receipt of additional materials. On November 1, 2010, via another Federal Register Notice, the Board extended the period of time for which the hearing record would remain open an additional 60 days until January 6, 2011.

The enclosure provides the additional materials from DOE and its relevant contractors that are responsible for tank waste remediation activities. The elements of this information are targeted to the following areas:

1. Panelist Commitment - Commitments made to provide additional information by a panelist during their testimony.
2. Panelist Clarification - Clarifications of testimony provided by a panelist. In this case, a commitment was not specifically made during the public hearing however, the panelist, upon further reflection determined it necessary to provide a clarification for the public record.
3. Additional Information - Additional information relevant to a specific topical area addressed during a session of the public hearing, including topics identified by the Chairman at the conclusion of the hearing.

DOE appreciates the opportunity to meet with the Board in an open and public forum, in order to provide a common base of understanding supporting our common objective of ensuring a plant that can safely meet our important mission objectives.

If you have any further questions, please contact me or Mr. Kenneth G. Picha, Jr., Acting Deputy Assistant Secretary for Safety and Security Program at (202) 586-7709.

Sincerely,

Inés R. Triay

Inés R. Triay
Assistant Secretary for
Environmental Management

Enclosure

Attachment 1
10-WTP-348

Panelist Additions to the Public Record Based on Commitments Made During Testimony Provided at DNFSB Public Hearing Held on October 7 and 8, 2010
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  - Provide response to Pacific Northwest National Laboratory (PNNL) statement(s) provided in response to DNFSB Question #18 and explain the disposition of the PNNL "vulnerabilities" list.
- **Panelist Commitment: Session 1-3; Page 14 of 48**
  - Provide a summary of the percentage of tank waste that can be processed; What waste is the Project confident about processing and what percentage remains due to uncertainties.
- **Panelist Commitment: Session 1-4; Page 14 of 48**
  - Provide a summary of how PNNL and other expert's issues are being incorporated into the Large Scale Testing program.
- **Panelist Commitment: Session 1-5; Page 16 of 48**
  - Identify the number of tanks that have been "cleaned".
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  - The following information is provided to clarify what measurements are being made on the vessel pre-qualification primarily related to hydrogen and other gases.
- **Additional Information: Session 1-7: Page 17 of 48**
  - The following information is provided to summarize developments in the approach for large scale pulse jet mixing tests and progress that has been made in planning for these tests.

SESSION 2: FEED PREPARATION AND SUPPLEMENTAL TREATMENT (OCTOBER 7, 2010 PM)

- **Panelist Clarification: Session 2-1; Page 20 of 48**
  - The following information is being provided to clarify the record with regard to an assessment of the impact on the risk of waste transfers due to "changes in waste acceptance criteria".
- **Panelist Clarification: Session 2-2; Page 21 of 48**
  - The following information is being provided to clarify the record with regard to a response concerning the circumstances under which grinding maybe required.

SESSION 3: PRETREATMENT FACILITY SAFETY AND OPERATION (OCTOBER 7, 2010 PM)

- **Panelist Commitment: Session 3-1; Page 21 of 48**
  - Provide DOE position/policy statement on use of Quantitative Risk Assessment (QRA) prior to QRA implementation.
- **Additional Information: Session 3-2; Page 22 of 48**
  - The following information is being provided to clarify the record with a concise statement on line plugging in the process piping of the WTP.

SESSION 4: HYDROGEN IN PIPING AND ANCILLARY VESSELS (OCTOBER 8, 2010 AM)

- **Panelist Commitment: Session 4-1; Page 24 of 48**
  - Provide response to questions posed regarding variability in hydrogen generation rates. Specifically, will the hydrogen generation rate vary from the start of tank transfer to the completion of tank transfer due to stratification of solids?
- **Panelist Commitment: Session 4-2; Page 25 of 48**
  - How much hydrogen will you generate per day? How much is retained? When is it released?
- **Panelist Commitment: Session 4-3; Page 25 of 48**
  - Describe the actions to be taken to perform a typical jumper replacement due to failed component. Include spill response, decontamination, work steps, design features (sump and liner), pre-op checks, time to repair, etc.
- **Panelist Commitment: Session 4-4; Page 33 of 48**
  - Provide a crosswalk of the PRT and IRT Findings/Recommendations.
- **Panelist Commitment: Session 4-5; Page 35 of 48**
  - Provide timeline for qualification testing of inline components from Hydrogen in Piping and Ancillary Vessels Implementation and Closure Plan (24590-WTP-RPT-ENG-10-021).
- **Statement of Dr. Steven Krahn, Deputy Assistant Secretary for Safety and Security Program regarding DOE-EM Oversight of the Development of the Quantitative Risk Assessment Methodology for WTP; Page 45 of 48**
  - Attachment of Waste Treatment Plant Quantitative Risk Assessment of Hydrogen Events in Piping and Vessels; **Page 2 of 70**
  - Memo to Dale E. Knutson on August 25, 2010; **Page 42 of 70**
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  - Memo for Distribution from Inés Triay on March 6, 2009; **Page 65 of 70**

Panelist Additions to the Public Record Based on Commitments Made During Testimony Provided at DNFSB Public Hearing Held on October 7 and 8, 2010

December 9, 2010

List of Terms

BC	black cell
BNI	Bechtel National, Inc.
BOD	basis of design
BVEST	Bethel Valley Evaporator Service Tanks
CCN	correspondence control number
CRESP	Consortium for Risk Evaluation and Stakeholder Participation
DBE	design basis event
DEI	Dominion Engineering, Inc.
DNFSB	Defense Nuclear Facilities Safety Board
DOE	U.S. Department of Energy
DSA	documented safety analysis
DST	double shell tank
E&NS	Environmental and Nuclear Safety
EFRT	External Flowsheet Review Team
EPC	Engineering, Procurement & Construction
FRP	waste feed receipt process system
HGR	hydrogen generation rate
HPAV IRT	Hydrogen in Pipes and Ancillary Vessels Independent Review Team
HLW	high-level waste
HLP	HLW lag storage and feed blending process system
HPAV	hydrogen in piping and ancillary vessels
hr	hour
HTF	Hanford Tank Farm
HTR	hard-to-reach
ICD	Interface Control Document
INL	Idaho National Laboratory
ITS	Important to Safety
LANL	Los Alamos National Laboratory
LAW	low-activity waste
M3	major issue 3
NAMF	North American Mixing Forum
ORNL	Oak Ridge National Laboratory
ORP	Office of River Protection
PDBE	post design basis event

PJM	pulse jet mixer
PNNL	Pacific Northwest National Laboratory
PRT	(QRA) peer review team
PSDD	particle size and density distribution
PTF	pretreatment facility
QRA	quantitative risk analysis
RPP	River Protection Project
sec	second
SRNL	Savannah River National Laboratory
TOC	Tank Operations Contractor
TSG	Technology Steering Group
UFP	ultrafiltration process
ULD	unit liter dose
WSU	Washington State University
WTP	Waste Treatment Plant
VVROM	very, very rough order of magnitude
ZOI	zone of influence

Panelist Additions to Public Record from DNFSB Hearing

1. Introduction

This document provides additions to the public record for the commitments made by panelists that participated in the Defense Nuclear Facilities Safety Board (DNFSB) Public Hearing that was held on October 7th and 8th, 2010 in Kennewick, WA. The document is organized by the order of the public hearing sessions and contains three types of items being submitted for addition to the public record. These are specifically:

1. **Panelist Commitment** - Commitments made to provide additional information by a panelist during their testimony.

2. **Panelist Clarification** - Clarifications of testimony provided by a panelist. In this case, a commitment was not specifically made during the public hearing however, the panelist, upon further reflection determined it necessary to provide a clarification for the public record.

3. **Additional Information** - Additional information relevant to a specific topical area addressed during a session of the public hearing.

For each item, the panelists or other persons providing commitments, clarifications, and additions are identified, along with their title and organizational affiliation.

2. Session 1 - Pretreatment Facility Mixing Session (October 7, 2010 am)

PANELIST COMMITMENT SESSION 1-1	**Provide a schedule for completion of operating procedures.**

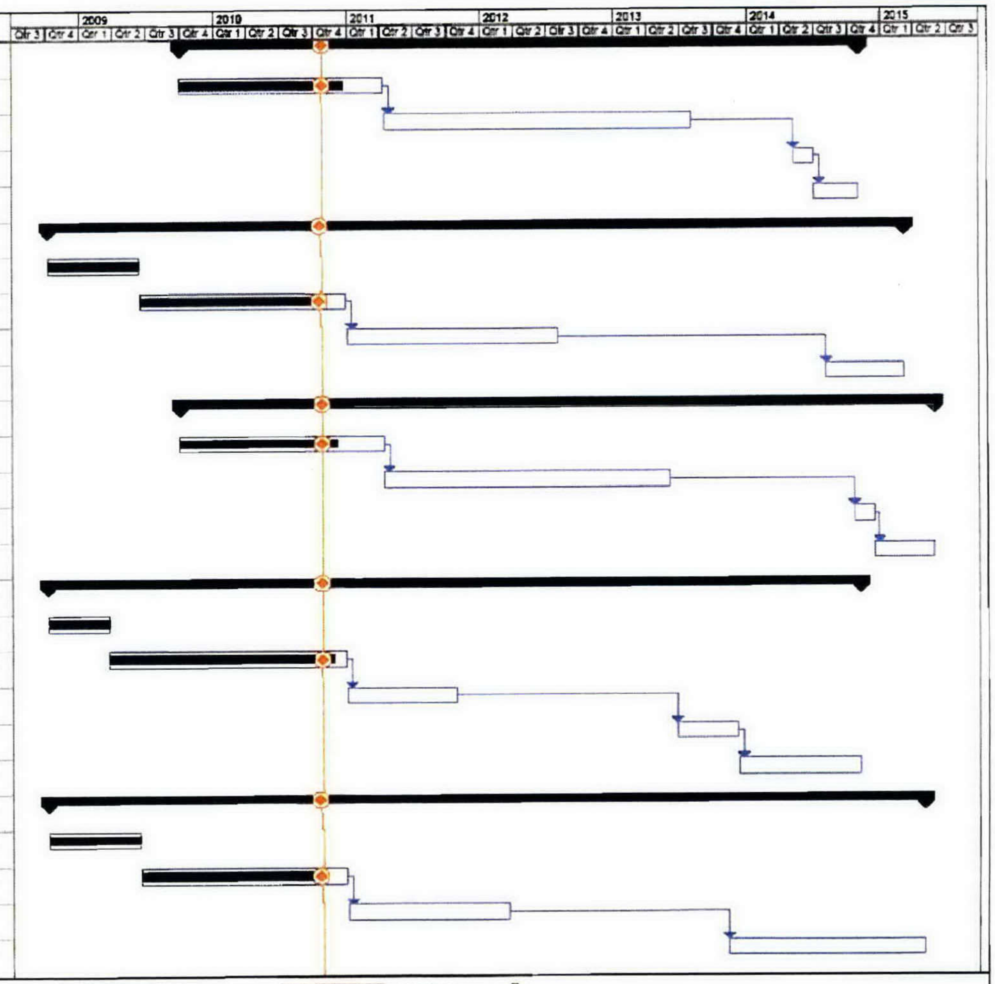
Panelist: **Hanford Tank Waste Treatment and Immobilization Plant Project**
Greg Ashley, Project Technical Director

Response Contributors: **Hanford Tank Waste Treatment and Immobilization Plant Project**
George Matis, Commissioning Operations Manager
Mike Coyle, Integration and Training Manager

Response: The schedule included below shows the expected completion dates for Waste Treatment Plant (WTP) procedures broken down by facility (Pretreatment, Low Activity Waste, High Level Waste, Laboratory, and Balance of Facilities).

Figure 1-1.1: WTP Operating Procedure Development Schedule.

ID	Task Name	OBS Activity ID	Start	Finish
1	**PreTreatment - Procedures**		**Thu 10/1/09**	**Fri 10/31/14**
2	PT Procedure Analysis	5HPC1TB063	Thu 10/1/09	Mon 4/11/11
3	PT Procedure Development	5HPC1TA073	Thu 4/14/11	Wed 7/31/13
4	PT Revise Procedure Analysis	5HPC1TB073	Thu 5/8/14	Wed 7/2/14
5	PT Revise & Approve Procedures	5HPC1TA083	Thu 7/3/14	Fri 10/31/14
6	**Low Activity Waste - Procedures**		**Mon 10/6/08**	**Fri 3/6/15**
7	LAW Procedure Analysis	5HLC1TB063	Mon 10/6/08	Thu 6/11/09
8	LAW Procedure Development - 1	5HLC1TA073	Mon 6/15/09	Thu 12/30/10
9	LAW Procedure Development - 2	5HLC1TA074	Mon 1/3/11	Fri 8/3/12
10	LAW Revise & Approve Procedures	5HLC1TA083	Mon 8/4/14	Fri 3/6/15
11	**High Level Waste - Procedures**		**Thu 10/1/09**	**Fri 5/29/15**
12	HLW Procedure Analysis	5HHC1TB063	Thu 10/1/09	Wed 4/13/11
13	HLW Procedure Development	5HHC1TA073	Thu 4/14/11	Wed 6/5/13
14	HLW Revise Procedure Analysis	5HHC1TB073	Mon 10/20/14	Fri 12/12/14
15	HLW Revise & Approve Procedures	5HHC1TA083	Mon 12/15/14	Fri 5/29/15
16	**Laboratory - Procedures**		**Mon 10/6/08**	**Wed 11/5/14**
17	Lab Procedure Analysis	5HTC1TB062	Mon 10/6/08	Thu 3/19/09
18	Lab Procedure Development - 1	5HTC1TA073	Mon 3/23/09	Thu 12/30/10
19	Lab Procedure Development - 2	5HTC1TA075	Mon 1/3/11	Fri 10/28/11
20	Lab Revise Procedure Analysis	5HTC1TB063	Mon 6/24/13	Fri 12/6/13
21	Lab Revise & Approve Procedures	5HTC1TA074	Mon 12/9/13	Wed 11/5/14
22	**Balance of Facilities - Procedures**		**Mon 10/6/08**	**Thu 4/30/15**
23	BOF Procedure Analysis	5HBC1TB063	Mon 10/6/08	Thu 6/11/09
24	BOF Procedure Development - 1	5HBC1TA073	Mon 6/15/09	Thu 12/30/10
25	BOF Procedure Development - 2	5HBC1TA074	Mon 1/3/11	Fri 3/16/12
26	BOF Revise & Approve Procedures	5HBC1TA072	Fri 11/8/13	Thu 4/30/15



Project: StaffingPlanEL3
Date: Mon 10/25/10

Task | Split | Progress | Milestone | Summary | Project Summary | External Tasks | External Milestone | Deadline

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PANELIST COMMITMENT	Provide response to Pacific Northwest National Laboratory (PNNL) statement(s) provided in response to DNFSB Question #18 and explain the disposition of the PNNL "vulnerabilities" list.
SESSION 1-2	

Panelist: **Hanford Tank Waste Treatment and Immobilization Plant Project**
Greg Ashley, Project Technical Director

Response Contributors: **Hanford Tank Waste Treatment and Immobilization Plant Project**
Phil Keuhlen, Commissioning/Facilities Operations Manager

Response: In its response to DNFSB question 18, the PNNL depended largely upon its report of *Pulse Jet Mixing Tests With Non-Cohesive Solids* (WTP-RPT-182, Revision 0) issued in May 2009 on testing completed in July 2008. PNNL's response expresses opinions on the capability of the current WTP pulse jet mixer (PJM) mixing design based on their testing before July 2008 and peripheral involvement in the three major testing campaigns conducted since that time. These responses do not reflect the evolution of the vessel designs, assessment techniques, mixing requirement metrics, and the margin in those designs. Key elements the PNNL responses have not considered include:

- PNNL's response was based on PJM mixed vessel designs from 2008. The current designs have more PJMs, higher jet velocities, and angled nozzles.
- While functional mixing requirements remain essentially unchanged, the metrics used to evaluate them have evolved. Off-bottom suspension is not a relevant metric to demonstrate the functional mixing requirement for no accumulation.
- PNNL's response was based upon an untested method of representing a solids size and density distribution by a single particulate size and density with a characteristic settling velocity. Later evaluation methods evaluate a conservative representation of the waste size and density distribution, reflecting further process analysis, with multiple constituent settling velocities.
- PNNL's response is predicated upon a single scale-ratio exponent is appropriate for testing/assessing all mixing metrics. The technical literature and testing conducted after PNNL's involvement, demonstrate that different exponents are appropriate for different requirements. An exponent of 0.33 is used for normal operation and assessment of accumulation, while a 0.18 exponent is appropriate for remobilization following a design basis event (DBE).

Given these differences, the PNNL responses provide an inaccurate picture of the current state of WTP PJM mixed vessel design.

Performance of PJM Mixed Vessels

PNNL's response relative to the performance of the PJM mixed vessels is based upon analysis of the design as it existed in 2008 as documented in their report *Pulse Jet Mixing Tests with Non-*

Cohesive Solids (WTP-RPT-182, Revision 0) issued in May 2009. The principal objective of the testing at that time was to develop correlations to understand the scaling of two observable phenomena related to mixing, off bottom suspension and solids cloud height. PNNL was requested to include examples of how their resulting correlations might be incorporated into an assessment methodology, but not to assess vessel performance. The distinction is important: WTP and the U.S. Department of Energy (DOE) understood in 2008 that several aspects of PJM mixed vessel design and mixing requirements were not finalized. That potential need for further changes in PJM mixed vessel design and evolution of mixing requirements/metrics is explicitly documented in the final revision of the Issue Response Plan for External Flowsheet Review Team (EFRT) issue M3, developed and issued in that time frame.

The example methodology PNNL developed for application of their correlations to evaluate full scale performance requires representing the entire distribution of slurry properties as a single particle size and density. PNNL had previously published four potential models for the particle size and density distribution (PSDD) of Hanford wastes in PNNL report *Estimate of Hanford Waste Insoluble Solid Particle Size and Density Distribution* (WTP-RPT-153, Revision 0). These distributions are very conservative in that they are probabilistic constructs and contain primary particle sizes that exceed the maximum observed primary particle sizes in Hanford wastes by at least an order of magnitude. Additionally, PNNL selected the most conservative PSDD as the basis for their vessel evaluations, even though their source report states that other cases "are expected to be more representative of actual Hanford waste conditions." To represent this already twice conservative distribution, PNNL selected the 95th percentile of the particle settling velocity distribution to represent the entire slurry for one evaluation case; the volume weighted average settling velocity for the fastest settling 10% of the Hanford tank waste for a second evaluation case; and WTP Engineering's then current assessment of the maximum credible particle size of any solid species to be found in each vessel for a third evaluation case. The latter case generally bound the former two. PNNL then assessed each vessel assuming it was filled at the maximum allowed solids loading of the vessel with only solids of that particle size. In contrast, the Handbook of Industrial Mixing cites studies that indicate the mass-mean diameter of a distribution of particles is the appropriate particle diameter to use in determining the settling velocity of a distribution. Data provided by PNNL indicates that the assessment results are very sensitive to this characterization assumption, with small changes in the percentile of settling velocity distributions changing the outcome of the assessment.

PNNL's report *Pulse Jet Mixing Tests with Non-Cohesive Solids* (WTP-RPT-182, Revision 0) is valuable for the correlations developed. Its assessment methodology examples provide an accurate depiction of the relative strength of the mixing performance of the PJM mixed vessels at that state of design development. However, as a result of compounding of evaluation conservatisms (probabilistic particle size distributions; most conservative distribution case; very conservative 'representative' settling velocity; maximum solids loading), the examples shown in the report do not accurately reflect expected vessel performance.

Since the publication of PNNL's report, the mixing power in the most critical designs have been increased significantly and the understanding of the process solids envelope to be used in design, and methods to represent it in vessel performance assessment, refined. The assessment methodology examples provided in *Pulse Jet Mixing Tests with Non-Cohesive Solids* (WTP-RPT-182, Revision 0) are not representative of the current design, even with respect to the relative mixing power of various vessels.

PJM Mixed Vessel Design Evolution

Since PNNL's testing involvement in 2008, significant modifications have been made to the designs of PJM mixed vessels, the understanding of vessel solids content during operational campaigns has been refined, and assessment inputs adjusted accordingly. In addition to this refinement of inputs, WTP has used an assessment methodology that does not rely upon representing the entire PSDD with the construct of a single particulate size/density.

Table 1-2.1, below, summarizes key changes between PNNL's 2008 assessment examples and the 2010 WTP Design Authority vessel assessment. The "Number of PJMs," "PJM Velocity," and "Solids Content" columns are considered self explanatory. In the "Largest Particle Size" column, the entry for 2008 PNNL represents the most challenging of the three evaluation cases presented in the PNNL report. It is the case that resulted in the largest settling velocity being selected to represent the entire Hanford waste distribution. For single numbers, the Engineering maximum particle was selected; where a range is given, one of the Case 3 representations in WTP-RPT-153, Revision 0, *Estimate of Hanford Waste Insoluble Solid Particle Size and Density Distribution*, was selected. In contrast, in the "Largest Particle Size" column the entry for 2010 WTP is the high and low bound of the particulate species used in the evaluation. For that evaluation a separate settling velocity was calculated for each particulate specie. Consequently, the "Maximum Ut" column presents the settling velocity of the entire waste distribution for the PNNL column and the settling rate of the waste distribution component with the largest settling velocity for the WTP column.

Ten PJM mixed vessels have undergone significant design changes to increase mixing power and improve the distribution of mixing power since 2008. These changes include increasing the number of pulse tubes in 3 vessels, increasing PJM discharge velocity in 10 vessels (PWD-44, FRP-2A/B/C/D, UFP-1A/B, HLP-22, FEP-17A/B), and angling PJM nozzles in 7 vessels.

In addition to design change impacts on vessel assessment, there are two key assessment input parameter changes that are also evident in Table 1-2.1. First, the solids content used in the WTP vessel assessment changed from that used by PNNL in their methodology examples. PNNL's statement implies that these inputs were manipulated to make mixing "easier." However, Table 1-2.1 demonstrates that the solids content actually increased for some vessels, and decreased for others. Changes in solids loading were generally made to better reflect the expected flowsheet conditions and have been evaluated to demonstrate they do not have an adverse impact on throughput. Second, changes were made in the maximum particle size and to the particle size distribution used in the analysis to better reflect actual vessel contents. In several cases, the maximum particle size used in analysis actually increased as did the maximum settling velocity associated with that particle. However, the analysis methods used by WTP do not represent the PSDD as a single particle as the PNNL evaluation methodology examples did. This results in an assessment that is conservative, but not overly conservative.

Table 1-2.1: Summarizes of Key Changes Between PNNL's 2008 Assessment Examples and The 2010 WTP Design Authority Vessel Assessment

Vessel Type	Vessel Number	Number of PJMs		PJM Velocity		Solids Content (Wt%)		Largest Particle Size (Microns)		Maximum Ut (cm/sec)		Ut Change
		2008 PNNL	2010 WTP	2008 PNNL	2010 WTP	2008 PNNL	2010 WTP	2008 PNNL	2010 WTP	2008 PNNL	2010 WTP	Factor
Group 1	CXP-26A-C	6	6	8	8	NA	0	NA	0	-	-	-
Group 2	CNP-03/04	4	4	8	8	NA	0	NA	0	-	-	-
	CXP-04	1	1	8	8	NA	0	NA	0	-	-	-
	UFP-62A-C	6	6	8	8	NA	0	NA	0	-	-	-
	RDP-02A-C	4	4	8	8	NA	17.8	NA	455	-	-	-
Group 3	HLP-27A/B	6	6	12	12	NA	20	NA	5-300	-	-	-
	HLP-28	8	8	12	12	NA	20	NA	5-300	-	-	-
	UFP-02A/B	6	6	12	12	NA	20	NA	5-300	-	-	-
Group 4	HOP-903/904	4	4	8	8	1.0	1.0	**210**	**3.9 - 26**	1.8	0.06	-30.0
	PWD-15/16	8	8	8	8	**3.0**	**0.2**	**210**	**11 - 700**	1.8	9.91	5.5
	RLD-08	4	4	8	8	**2.2**	**1.0**	**210**	**3.9 - 26**	1.8	0.06	-30.0
	TCP-01	8	8	8	8	**2.7**	**0.1**	**164**	**3.9 - 26**	1.33	0.02	-66.5

Table 1-2.1: Summarizes of Key Changes Between PNNL's 2008 Assessment Examples and The 2010 WTP Design Authority Vessel Assessment

Vessel Type	Vessel Number	Number of PJMs		PJM Velocity		Solids Content (Wt%)		Largest Particle Size (Microns)		Maximum Ut (cm/sec)		Ut Change
		2008 PNNL	2010 WTP	2008 PNNL	2010 WTP	2008 PNNL	2010 WTP	2008 PNNL	2010 WTP	2008 PNNL	2010 WTP	Factor
	TLP-09A/B	8	8	8	8	0.3	1.0	164	3.9 - 26	1.74	0.06	-29.0
Group 5	PWD-33	8	8	8	8	8.1	1.0	210	11 - 700	1.8	5.12	2.8
	PWD-43	8	8	8	8	0.2	0.5	210	3.9 - 26	1.8	0.036	-50.0
	PWD-44	8	8	8	12	8.1	0.5	210	11 - 700	1.8	9.91	5.5
Group 6	FRP-02A-D	12	12	8	12	4.9	3.8	50 - 1000	5.5 - 100	1.04	0.017	-61.2
Group 7	UFP-01A/B	8	12	8	12	3.8	10	210	10 - 700	1.25	11.1	8.9
Group 8	HLP-22	12	18	8 & 12	12	15.4	10	210	10 - 700	1.25	11.1	8.9
Group 9	FEP-17A/B	8	8	8	12	4.4	2	50 - 1000	10 - 700	1.04	11.1	10.7
Group 10	RLD-07	4	4	8	8	2.2	0.1	210	3.9 - 26	1.8	0.06	-30.0

Key:		
	(yellow)	Indicates a difference between PNNL Phase 1 test report analysis and current design analysis parameters.
	NA	Indicates that analysis was not performed by PNNL in the Phase 1 test report.

Panelist Additions to Public Record from DNFSB Hearing

PJM Mixed Vessel Mixing Requirements

In a discussion of mixing requirements, it is important to distinguish between a functional requirement, and the metric(s) used to evaluate whether a requirement is met. The majority of WTP functional mixing requirements have remained unchanged since PNNL's testing involvement in 2008. The sole exception is that the functional requirement for *de minimus* solids has been replaced by the more conservative limit solids accumulation functional requirement.

As an example, WTP has a functional mixing requirement to maintain fluid properties to meet the pump suction requirements for slurry viscosity and density. Early in the test program, solids concentration near the pump inlet (derived from cloud height) was used as a metric to indicate whether the functional requirement was being met. It was found to be a problematic approach for several reasons and alternate methods were developed to evaluate performance against the functional requirement. In the alternate method, the slurry density was measured directly, at the peak of the PJM drive cycle, in the earliest increment of pump out. This provided a more reliable and conservative direct measurement in testing than the cloud height method. Pump inlet solids concentration could also be calculated using the low order accumulation method. Hence, even though cloud height was not used in later testing, the functional mixing requirement to maintain fluid properties to meet the pump suction requirements remained unchanged and was evaluated in vessel mixing performance evaluations.

Similarly, WTP has a functional mixing requirement to mobilize settled solids to release gas and that requirement has remained unchanged since 2008. The mixing metrics for WTP PJM-mixed vessels were still in development at the time of PNNL's experiments. The early use of off-bottom suspension as a testing metric reflected the appraisal that it could be reliably evaluated and that it was one of the options to be considered in selecting final mixing evaluation criteria. PNNL has stated that off-bottom suspension is the mixing industry's standard requirement for mixing design. The Handbook of Industrial Mixing, sponsored by the North American Mixing Forum (NAMF), an affiliate of the AIChE, is the most succinct source for "standard requirements" in industrial mixing design. It identifies several states of solids suspension and distribution such as on-bottom motion, off-bottom suspension, and uniform suspension. It describes the types of process applications in which each may be the desired final state for solid-liquid mixing. Separately, it describes off bottom suspension as a valuable testing criterion for mixing studies because it is a state that can be observed reliably/repeatedly.

However, it does not describe off bottom suspension as a "standard requirement" in mixing system design. In fact, it points out that over designing relative to the necessary mixing criteria brings a potential adverse impact, with off bottom suspension requiring approximately 5 times the power and uniform suspension requiring approximately 25 times the power that is necessary for on-bottom motion with rapidly settling particulate. The statement of Dr. David Dickey (included in Appendix 1), past President of NAMF, provides amplification of this discussion.

In summary, the WTP functional mixing requirements associated with releasing gas and solids transfer have not changed.

Testing Simulants

PNNL expressed concerns about the simulants used by WTP in testing after PNNL's active involvement in PJM testing ended. They expressed the opinion that the simulants were not physically representative, nor bounding of actual waste.

The basis for the simulants used in the latter phases of M3 testing are described in 24590-WTP-RPT-PET-10-008, Revision 1, *Revised Simulant Design and Basis for FEP-17, FRP-02, HLP-22, and UFP-01 Vessels for EFRT M3 Mixing Studies.* This document describes the basis for the selection of simulant properties. Key waste properties were selected to conservatively bound the design basis waste properties, thereby making successful demonstrations in the scaled mixing facility exceed the expected performance required in full scale WTP vessels. Since the objective of M3 was to evaluate the effect of rapidly settling particles in Newtonian slurries, several conservatisms were introduced in simulant design. These included:

- Matching the design basis (RPP-9805, Revision 1, *Values of Particle Size, Particle Density, and Slurry Viscosity to Use in Waste Feed Delivery Transfer System Analysis*, 95% UL) particle size/density distribution
- Exceeding the design basis maximum particle size by over 200%
- Exceeding the spherical equivalent PuO2 particle size by over 200%
- Matching the upper bound shear strength for Hanford waste at 24 hours
- Testing in water, rather than a caustic medium, which eliminates the contributions of ionic strength and viscosity, conservatively overstating settling rates.

Further details on waste properties used for simulant development are contained in 24590-WTP-ES-ENG-09-001, Revision 2, *Determination of Mixing Requirements for Pulse-Jet-Mixed Vessels in the Waste Treatment Plant*, Sections 2 and 3, as well as 24590-WTP-RPT-PET-10-014, Revision 0, *Slurry Property Ranges in Non-Newtonian Pretreatment Vessels at WTP.*

PNNL suggests that failure to include a yield stress component in the simulant could have resulted in an overstatement of mixing performance. This statement ignores the fact that a yield stress component would retard settling, actually reducing the solids concentration near the bottom, hence improving mixing performance. It also ignores a published study of the effect of rheology on suspension velocity that found that in the transition between mixing in water to mixing in a fully non-settling, non-Newtonian fluid, the suspension velocity requirement was never larger than it was in water (Wu, et.al.).

PNNL took exception to the 200 Pa simulant used for post design basis event (PDBE) testing pointing out that some of its shear strength was achieved as a result of granular compaction. One should note that shear strength is a measurement of the resistance of sediments to shear, and that the same units of measurement apply, whether the resistance is developed by granular compaction or inter-particle attraction. That is, the same force is required to overcome 200 Pa of resistance, (i.e. to cause the sediment to yield) whether the sediment resistance is achieved by granular compaction or inter-particle attraction.

WTP has searched for literature to support the PNNL assertion that a cohesive shear strength of a given value is somehow different than a non-cohesive shear strength of the same value and can find no technical literature supporting this position, nor suggesting how to distinguish between them in measurement. In point of fact, since the granular simulant used had over twice the mass to be cleared (approximately 65 wt%) as a similar yield stress non-cohesive (kaolin) simulant, in WTP's judgment it actually provided a more conservative mixing challenge.

Finally, PNNL points to a recommendation they provided with respect to simulant properties for scaled non-Newtonian testing. This recommendation would apply to a proposed new test series, not to testing that was recently performed. However, it does reflect a divergence from PNNL's previous guidance on scaled non-Newtonian testing simulants provided in a series of reports (WTP-RPT-111, Revision 0, *Non-Newtonian Slurry Simulant Development and Selection for Pulse Jet Mixer Testing*, WTP-RPT-112, Revision 0, *Final Report: Technical Basis for HLW Vitrification Stream Physical and Rheological Property Bounding Conditions*, and WTP-RPT-113, Revision 0, *Technical Basis for Testing Scaled Pulse Jet Mixing Systems for Non-Newtonian Slurries*) associated with 2004-2005 non-Newtonian scaled testing. In that testing, PNNL recommended that full scale velocities and full scale rheology be used in the scaled tests. In their most recent recommendation PNNL departs from that recommendation and recommends scaling both the jet velocity and the rheology. However, their recommendation would scale velocity and rheology by different factors, with rheology being reduced more than velocity. WTP believes that reducing rheology (fluid resistance to mobilization) by a factor greater than the reduction in velocity, (force to overcome fluid resistance) is potentially non-conservative relative to the previous PNNL recommendations.

Test Scaling

In their response to DNFSB Question 18.A, PNNL stated:

> "Finally, the current design lacks an adequate scaling basis to relate small-scale test results to full-scale plant performance. Some WTP testing applied a scaling law with a velocity scale exponent of 0.18 rather than 0.33. The smaller scale-up exponent allowed the scaled PJMs to be operated at higher velocity in the test stand, thus improving the observed clearing behavior. We think the use of the 0.18 scale exponent (derived from wall shear measurement from steady air jets impinging on a flat plat) to unsteady mobilization of solids in the test stands is not supported by existing data."

PNNL further stated that they were not aware of any testing data with non-cohesive solids that supported such scaling, and in several places has expressed concern that a 0.18 scale-ratio exponent was used for pump out (accumulation) tests. However, on the latter point, all test reports clearly indicate that a scale-ratio exponent of 0.33 was used for the pump out (accumulation) tests. On the former point, such testing was conducted and is described in 24590-WTP-ES-PET-10-001, Revision 0, *WSU Radial Flume Test Data Study*. That study reported on zone of influence (ZOI) measurement data obtained at multiple scales; the independent development of correlations for ZOI from that data; and the comparison of those test-based correlations to those reported in the published technical literature by multiple sources. The conclusion of the report was that the WTP testing supported the selection of Porch and the 0.18 scale-ratio exponent for ZOI evaluations.

In the discussion of scale-up, a clear distinction needs to be made between an "exponent" of 0.33 and a "scaling factor," which is the scale ratio raised to the scale-ratio (scaling) exponent. For instance, a 10:1 scale ratio with a 0.33 scale-ratio exponent results in a scale factor of 2.13, or a small scale test velocity of 12m/s x 1/2.13 = 5.6 m/s. (For scale-down, a 1:10 scale factor with a 0.33 scale-ratio exponent results in a scale factor of 1/2.13) A 5:1 scale ratio with the same 0.33 scale-ratio exponent results in a scale factor of 1.7, or a small scale velocity of 12m/s x 1/1.7 = 7.1 m/s. The exponent is the same, the factor is different, and it results in a different (not constant) scale ratio. A greater velocity difference (lower test velocity) was used for testing conditions representative of larger WTP vessels.

In their statements, it appears that PNNL may have confused two different suspension characteristics and the need for different scale-ratio exponents. The exponents were applied to the scale ratio between the specific WTP vessels and the test vessel and multiplied times the jet velocity. The first scale-ratio exponent used in Phase 2 testing was used to adjust PJM jet velocity from full scale vessels to test stand scale vessels. A scale-ratio exponent of 0.33 was used based on the common industrial application of constant power per unit volume of liquid from one scale to another for geometrically similar vessels. Since the volume of a vessel is proportional to a geometric similarity dimension (size) cubed, jet velocity is scaled as vessel size to the one-third power. This scale-ratio exponent of 0.33 on PJM jet velocity was used to predict off-bottom particulate suspension in the plant scale vessel given the results of the test stand vessel performance. In the case of WTP, the units for velocity were meters/second. Phase 1 testing reported by PNNL suggests a lower scale-ratio exponent, in the range of 0.26 for an average of all test results. The test results for low concentrations of solids correlated with an exponent of 0.33. For WTP design purposes the larger exponent of 0.33, with its inherent conservatism, has been applied to the design.

The second scale-ratio exponent used in Phase 2 testing also uses PJM velocity as a parameter, but for a different purpose; the prediction of the bottom clearing radius associated with the PJM discharge on the bottom vessel head that moves particulate radially away from the point of impingement. The cleared area has a characteristic clearing radius that defines the PJM zone of influence. Research (Poreh et. al) shows that clearing radius scales with an exponent of 0.176 for jet impingement velocity. This scale-ratio exponent is normally rounded to 0.18 or 0.2 for convenience. It is normal to encounter different scale-ratio exponents for different mixing phenomena, both for Newtonian and non-Newtonian fluids. PNNL's suggestion that the WTP design team has confused different types of scale-ratio exponents, and have used inappropriate equations and data from test stand scales to full vessel size scales is not justified.

PNNL suggests that the application of equations to predict mobilization of solids on a vessel bottom using pulsed jets is not supported by existing data. In fact, the WTP conducted full scale pulsed jet impingement tests at the Washington State University (WSU) radial flume test facility and collected scaled impingement tests in the scaled PJM test stand in Richland (24590-WTP-ES-PET-10-001, *WSU Radial Flume Test Data Study*). A. Edmondson, June 18, 2010, Bechtel National, Inc., Richland, Washington. PNNL did not participate in these tests. At WSU, impingement tests were conducted for a wide range of jet impingement velocities and particulate bed depths using a dual nozzle arrangement that allowed observation of jet interactions. Data reduction confirmed that standard equations developed from steady jets applied to pulsed jets as well, using the same parametric variables and parametric exponents. These results provided confirmation that a scale-ratio exponent of 0.18 is applicable to vessel bottom clearing.

Further, a comparison between predicted bottom clearing and actual clearing radius measured during test platform Phase 2 testing has been conducted. The full scale WSU radial flume data and small scale vessel test stand data were correlated independently, from tests that used broad size spectrum sand simulant with variable sand depths in the radial flume to mimic particulate resettle during PJM refill. The flume and test stand bottom clearing data correlations developed by WTP show close correlation to Poreh and its inherent velocity scale-ratio exponent of 0.18. Predicted clearing and actual clearing data matched with an error in the range of 5 to 6% (24590-WTP-RPT-PET-10-015, Rev. 0, *Review of Analysis Methods for Investigating Solids Accumulation*) for the test stand vessel, while the WSU clearing radius matched predicted clearing with error in the range of 2 to 4%. Both independent research literature and WTP testing confirm the scale-ratio exponent applied for vessel bottom clearing.

PNNL suggests that fundamental equations from Poreh used to predict bottom clearing are based solely on air jet impingement studies. However, while Poreh's initial study was based on air jet impingement, he published a second paper in the same year on experiments with submerged fluid jets and particulate bed erosion that showed excellent agreement with the first work. Numerous later papers on aspects of submerged jets cite his work as the seminal work in the field. See 24590-WTP-RPT-PET-10-015, Revision 0, *Review of Analysis Methods for Investigating Solids Accumulation* for discussions of agreement of this approach with benchmark data, alternate approaches, and the applicability of Poreh.

A citation listing of research work that supports the scale-ratio exponents used by WTP in its recent testing has been compiled by Dr. David S. Dickey, MixTech, Inc. (CCN 210455, *Scaling of PJM Vessels Containing Settling Solids in Newtonian Slurries*) and includes more than 60 technical references that combine to demonstrate that WTP has applied appropriate, well founded scale-ratio exponents to the WTP in translation of test results to full scale vessel application. Based on the application of the combined research work on jet impingement over the past 40 years, and upon extensive industrial experience and detailed knowledge of the WTP PJM vessel mixing designs, Dr. Dickey's recommendation of scale-ratio exponent for mobilization is that boundary layer shear can be represented for scale-up by an exponent of one-fifth, $n = 1/5$, as derived from Poreh et al.

PNNL Feedback and Recommendations

WTP takes PNNL feedback seriously, and considers it in both present and future work. In July 2010, PNNL provided the WTP Project Director, at his invitation, with a list of PNNL perceived "vulnerabilities" for WTP. The transmittal noted that PNNL staff might not be aware of the complete suite of actions that Bechtel National, Inc. (BNI) is taking to address vulnerabilities, and that in some cases there are legitimate differences of technical and engineering opinions between the PNNL and BNI staff. WTP convened a panel to review the "PNNL Input to WTP Vulnerabilities" and document their status from the WTP perspective. The responses were developed by key personnel from Engineering, Environmental and Nuclear Safety (E&NS), Commissioning, Process Engineering and Technology, and Operations Technology. The panel determined that approximately half of the issues had been addressed by WTP, while approximately half of the issues remained open and were being actively addressed by WTP. There were no new issues raised by PNNL that WTP was previously unaware of. The panel's consensus with respect to each PNNL concern has been documented in a WTP internal memorandum (CCN 223293, *PNNL Issues List*) . Most of these have been addressed in the preceding sections of this document and are not repeated. However, the PNNL assertion that, "There has been a fundamental misperception about the maturity of PJM technology. This is new technology which is unproven for applications involving significant amounts of solid." bears critical examination.

PJMs have been used successfully for decades: This is not a new technology. The original designers of PJMs for nuclear waste clean-up (British Nuclear Fuels, PLC) have been using PJMs for over twenty years at the Sellafield site in the United Kingdom. Their experience includes mixing fast settling, high solids content slurries, as well as non-Newtonian slurries. A report prepared for WTP (CCN 185587, *Data Summary of WEP Sellafield PJM Data and Operating Experience*) provides information on their experiences at mixing slurries up to 46 wt% and rheologies up to 30 Pa. PJMs were deployed at Oak Ridge (1997-1999) to homogenize Bethel Valley Evaporator Service Tanks (BVEST) sludge wastes for retrieval. BVEST wastes had solids concentrations, PSDs and rheology similar to Hanford wastes. This deployment also demonstrated the ability to recover plugged PJM nozzles successfully. PNNL has also been directly involved in high solids loading PJM operation. They conducted previous full scale PJM mixing experiments (PNWD-3054/BNFL-RPT-048, Revision 0, *Pulsed Jet Mixing of Simulant Pretreated HLW Sludge*) with simulants closely matching Hanford waste rheology. The simulant used was characterized in the PNNL report as being "indicative of some of the worst-case scenario conditions encountered during the Hanford waste processing" and the testing showed highly successful results with complex simulants between 10 and 36 wt% solids. Additionally, NuVision has more recently demonstrated the ability to mobilize waste sludge simulants using PJMs for the UK buffer storage facility with yield strengths in the range from 10- 50kPa.

PNNL made two key recommendations in its statement to the DNFSB. The first was to add substantial power, and hence margin, to the PJM mixed vessels. One assumes that this recommendation is relative to the design state in 2008, the last time PNNL was actively involved in the WTP mixing program. The second was to conduct large scale tests, especially if power is not added. As discussed above, the design improvements made by WTP since PNNL's involvement have added substantial mixing power to 10 vessels. A margin analysis is included in each vessel assessment demonstrating the acceptability of the current vessel designs. Thus the first of PNNL's recommendations has been constructively accepted and is being implemented into the WTP design. Additionally, DOE and WTP have elected to perform large scale testing to further mitigate residual risk in the PJM-mixed vessel designs. While the test scope is still in planning, the key elements recommended by PNNL have been captured in the conceptual planning and are being tracked for implementation.

Current planning has identified the concept of an advisory panel to provide technical advice and external review for large scale mixing tests. It is envisioned that PNNL would be a part of that panel. This approach worked well in an independent review of the ability to mix using PJMs in non-Newtonian vessels. In that instance SRNL assembled of team of experts, including members from SRNL, LANL, INL, ORNL, and the BHRG Group (see *Independent Technical Review of the Assessment of Pulse Jet Mixing Performance in Vessels Containing Non-Newtonian Sludges at the Waste treatment and Immobilization Plan*, SRNL-RP-2010-00898, Rev. 1, dated June 30, 2010).

Panelist Additions to Public Record from DNFSB Hearing

PANELIST COMMITMENT SESSION 1-3	Provide a summary of the percentage of tank waste that can be processed; What waste is the Project confident about processing and what percentage remains due to uncertainties.

Panelist: **<u>Hanford Tank Waste Treatment and Immobilization Plant Project</u>**
Greg Ashley, Project Technical Director

Response Contributors: **<u>Hanford Tank Waste Treatment and Immobilization Plant Project</u>**
Garth Duncan, Manager of Process Engineering and Technology

Response: There are 31 waste acceptance criteria identified in 24590-WTP-ICD-MG-01-019, Revision 4, *ICD-19 - Interface Control Document for Waste Feed.* In early 2008, WTP, with input and review from the Hanford Tank Farm (HTF) contractor at that time issued an evaluation of the risk associated with meeting those criteria (see 24590-WTP-ES-PET-08-001, Revision 4, *Technical and Risk Evaluation of Proposed ICD-19.* That report in the Executive Summary recommended, among other things:

"*Agree that approximately 5% of feed that may not meet some given waste acceptance limits, can likely be adjusted to meet the limits by dilution, blending, chemical adjustment, or other means with baseline tank farms and WTP equipment capabilities.*"

DOE agreed with this recommendation in a letter from John R. Eschenberg, DOE to L. J. Simmons, Bechtel National, Inc., dated April 18, 2008 (CCN 177718).

PANELIST COMMITMENT SESSION 1-4	Provide a summary of how PNNL and other expert's issues are being incorporated into the Large Scale Testing program.

Panelist: **<u>Hanford Tank Waste Treatment and Immobilization Plant Project</u>**
Greg Ashley, Project Technical Director

Response Contributors: **<u>Hanford Tank Waste Treatment and Immobilization Plant Project</u>**
Garth Duncan, Manager of Process Engineering and Technology
Phillip Keuhlen, Large Scale Testing Manager

Response: Source documents for issues potentially affecting large scale test planning were assembled into a crosswalk matrix (CCN 223281). The baseline worksheet in the cross-walk was a compilation of the recommendations of the Technical Steering Group (TSG) contained in the EFRT M3 Closure package. This was screened to identify actions/issues related to large scale testing. Such items could bear upon large scale test planning in a variety of ways. For example, some related to test objectives, while some tracked to plant design changes that needed sufficient implementation to be modeled in large scale testing. Those related to large scale testing were copied into a consolidated output matrix.

Each subsequent source document was similarly screened to identify those issues/actions associated with large scale testing. Additionally, it was compared to the TSG action list to determine if it had already been captured. The duplicate TSG action was documented, or new items were added to the consolidated output matrix. Hence the individual worksheets document the full screening of each document, while the consolidated output matrix contains only non-duplicate recommendations, commitments, and actions from the source documents. The following source documents were considered:

- Technology Steering Group (TSG) closure packages for EFRT Issue M3 (CCN 204767, CCN 208996, CCN 211816, CCN 214951, CCN 220452, CCN 220453, CCN 220454, CCN 220455, CCN 220456, CCN 221575),
- CRESP Review Team Letter Report 7 recommendations (CCN 218915),
- SRNL report SRNL-RP-2010-00898, Revision 1 (CCN 218916) recommendations,
- Open DNFSB actions tracked by WTP,
- 24590-WTP-RPT-ENG-10-001, Revision 0, *Integrated Pulse Jet Mixed Vessel Design and Control Strategy*
- DOE, Assistant Secretary for Environment Management letter to DNFSB Chair, dated May 17, 2010
- PNNL letter, WTP/RPP-MOA-PNNL-00507, *Test Considerations for the Potential Engineering-Scale HLP-27 Test*,, dated June 25, 2010
- PNNL letter, WTP/RPP-MOA-PNNL-00508, *Guidance on the Scaling and Operation of Air Spargers for the Proposed Engineering-Scale HLP-27 Test Vessel*, dated July 2, 2010
- E-mail, *Vulnerabilities - Technical Concerns related to the WTP Plant*," from T. Walton (PNNL) to F. Russo (BNI), July 6, 2010
- E-mail, *WTP Potential Open Issues Task List* forwarded by W. Tamosaitis, June 30, 2010

The consolidated output matrix was issued as a project document (CCN 223281). The section of the crosswalk identifying issues related to a large scale integrated test was used by a WTP Task Team to prepare a Large Scale Integrated Testing Strategy white paper (CCN 223286). The white paper documents preliminary conceptual planning for a Hanford mixing test facility to jointly serve the needs of the Tank Farm Operating Contractor (TOC) and the WTP Project. It is written to identify WTP conceptual functional requirements and test objectives for a large scale integrated Hanford mixing test facility. It precedes and supports follow on discussion and coordinated planning with the TOC and DOE-Office of River Protection (ORP).

Panelist Additions to Public Record from DNFSB Hearing

PANELIST COMMITMENT SESSION 1-5	**Identify the number of tanks that have been "cleaned."**

Panelist: **U.S. Department of Energy, Office of River Protection**
Stacy Charboneau, Assistant Manager, Tank Farms Project

Response Contributors: N/A

Response: DOE is "retrieving" Single Shell Tanks (SST) under the requirements of the Hanford Federal Facility Agreement and Consent Order (HFFACO or Tri-Party Agreement or TPA). DOE has performed retrieval activities on thirteen tanks. Retrieval is complete on seven of these tanks.

ADDITIONAL INFORMATION SESSION 1-6	**The following information is provided to clarify what measurements are being made on the vessel pre-qualification primarily related to hydrogen and other gases.**

Person Making Clarification or Addition:

Hanford Tank Waste Treatment and Immobilization Plant Project
Garth Duncan, Manager of Process Engineering and Technology

Washington River Protection Solutions
Paul Rutland, Mission Analysis & Strategic Planning Manager

Response Contributors: N/A

Response: The document 24590-WTP-ICD-MG-01-019, Revision 4, *ICD-19 - Interface Control Document for Waste Feed,* in Table 8 shows that hydrogen and ammonia are to be measured as part of feed pre-qualification.

Panelist Additions to Public Record from DNFSB Hearing

ADDITIONAL INFORMATION	The following information is provided to summarize developments in the approach for large scale pulse jet mixing tests and progress that has been made in planning for these tests.
SESSION 1-7	

Panelist: **Hanford Tank Waste Treatment and Immobilization Plant Project**
Greg Ashley, Project Technical Director

Response Contributors: **Hanford Tank Waste Treatment and Immobilization Plant Project**
Phil Keuhlen, Commissioning/Facilities Operations Manager

Response: The approach to large scale testing has been further developed in the period since October 2010 and significant progress has been made in planning for these tests. The following information is provided as an update to summarize developments in this regard.

The conceptual strategy for large scale testing was initially documented in *Large Scale Integrated Testing White Paper* (CCN 223286). It was predicated upon an approach that would field an integrated mixing testing facility that would support both the Waste Treatment Plant and the Tank Farms throughout the balance of the Hanford tank waste retrieval and treatment mission. This approach had the merit of supporting mission integration and promoting efficiency through a common infrastructure. However, it became apparent that it would be a larger and more complex facility than immediately needed by the Waste Treatment Plant alone. Additionally, it would require significant joint planning and coordination that would probably extend the window of availability beyond certain near term need dates.

With this understanding, the WTP Federal Project Director and BNI Project Director directed investigation of alternatives in September 2010 (CCN 220520, *Issues Resolution Team [IRT])*. WTP immediately began development of an alternative approach to large scale testing that could proceed independent of participation with the TOC and be more closely coupled with interim Engineering, Procurement & Construction (EPC) risk reduction objectives. The approach does not preclude future integration of the large scale test stand into an integrated mixing test facility at a later date, as originally envisioned. This approach was communicated to the WTP Federal Project Director and BNI Project Director on November 19, 2010. It was accepted as the planning basis and the WTP Federal Project Director has initiated contract direction in that regard to BNI.

Approach Overview

Two key enabling insights underpin the current approach. The first is that large scale PJM testing commitments do not all have to be completed at the same time. The second is that accomplishing test objectives in increments could allow some types of large scale testing to be accomplished earlier than originally forecast, achieving a better alignment between the availability of test information and related EPC activities. To take advantage of these opportunities, the large scale testing was divided into increments as described below.

Increment I:

The earliest increment of large scale testing supports EPC risk reduction associated with confirmation of PJM mixed vessel scaling. The residual risk for these vessels are associated with unverified assumptions in the vessel assessment process. With the exception of scaling, these risks are being addressed by smaller scale tests or analysis. Tests at full scale are required to resolve the scaling risk. These tests would replicate tests performed at smaller scale in important aspects such as configuration, drive system, and simulants so that the only variable, to the extent feasible, would be the change in scale. WTP has two classes of PJM arrays, the distributed arrays used in the Newtonian vessels, in which there is space between each PJM, and the 'chandelier' arrays used in the five non-Newtonian vessels that have the PJMs in the center of the vessel with the area between them enclosed in a monolithic, grout-filled shroud. The chandelier PJM arrangement would be very difficult to modify after vessel installation in the plant, so confirmation of scaling for the non-Newtonian vessels becomes the pre-eminent objective for the first increment of testing. Other objectives for the first increment of testing include confirmation of scaling for the distributed array type and evaluation of prototypic response of level and density instruments in the presence of pulsed jets in prototypic vessel locations. These test objectives do not require fully prototypic control systems, nor integrated operation of mixing, transfer, sampling, and heel management systems. The tests would be conducted in a relatively simple test stand. The capabilities required to support more complex, integrated tests would be added to the test stand after completion of the first increment of tests.

Increment II:

The second increment of testing are tests that support other aspects of design confirmation, reduce WTP commissioning risk through early demonstrations of integrated operation, and support optimization of early facility operations. These tests will be sequenced based upon the timing of risk reduction drivers, and in the case of demonstrating new design features, the availability of the design to support testing. At the end of Increment I tests, the test stand will be modified to add hardware to support the Increment II tests. This will include the addition of prototypic density compensated, bubbler level measurement and JPP controls, prototypic transfer and sampling systems, and the heel management capabilities that are currently being designed. Increment II tests will be designed to demonstrate integrated mixing/transfer/sampling in planned operating modes, over the range of operating temperatures. The core objectives for these tests will be to support design confirmation and demonstrate the efficacy of the new heel management capabilities. Beyond those core objectives, subject to project needs and funding, Increment II may also be used to demonstrate aspects of rheology control, to accelerate tests that would otherwise be performed during commissioning, to optimize normal operating bands, and to explore the effects of extended operation and off-normal conditions.

Increment III:

The third increment of large scale tests provides post commissioning support for continuing WTP operation. Such tests are not a WTP PJM testing commitment. Conceptually, such testing overlaps with testing that could be conducted during the previously discussed second increment of testing such as optimization of normal operating bands, effects of extended operation, and off-normal conditions. In addition, such testing could support other operational needs including operational investigations, procedure development, maintenance mockups, equipment or plant modification development, and operator familiarization. Increment III testing would be planned and conducted by the Waste Treatment Plant operating contractor.

Increment IV:

The fourth increment of large scale testing is conditional testing related to the original basis documented in the *Large Scale Integrated Testing White Paper* (CCN 223286) concept for an integrated mixing test facility supporting both the Waste Treatment Plant and the Tank Farms. In this approach, the opportunity to add mixing test capability for Tank Farm retrieval and delivery testing would be preserved. It could be added to the existing WTP large scale test facility, or alternatively the Increment I/II test stand could be moved into it, based upon timing, DOE needs, and funding. Depending on the timing, Increment IV testing could be conducted in parallel with Increments I through III. As with Increment III testing, such tests are not a WTP PJM testing commitment.

Increment I testing supports risk reduction for the installation of the non-Newtonian vessels while Increment II supports demonstration of new design features, design confirmation and commissioning risk reduction. Preliminary schedule milestones for the first and second testing increments are shown in Table 1-7.1 below.

Table 1-7.1: Preliminary Schedule For First & Second Large Scale Test Increments

Project Activity	Preliminary Schedule Milestone
Options study	Jan 2011
Construction complete	Jan 2012
Increment I Primary testing	Mar 2012
Release NNV installation	Apr 2012
Complete Increment I	Aug 2012
Reconfigure & Complete Increment II (VVROM)	Dec 2013

3. Session 2 - Feed Preparation and Supplemental Treatment (October 7, 2010 pm)

PANELIST CLARIFICATION SESSION 2-1	The following information is being provided to clarify the record with regard to an assessment of the impact on the risk of waste transfers due to "changes in waste acceptance criteria"

Panelist: **Washington River Protection Solutions**
Paul Rutland, Mission Analysis & Strategic Planning Manager

Response Contributors: N/A

Response: There are four WTP Waste Acceptance Criteria (WAC) changes that have been recently discussed and are expected to be included in the next revision of ICD-19. The impact of each is addressed below:

Material at Risk – It has been agreed (CCN 209161, *ICD 19 Team Meeting - Finalize Issues to be Included in Revision 5*) that the ICD-19 Waste Acceptance Criteria for Unit Liter Dose (ULD) will be changed from <1.07E8 Rem/liter to <1500Sv/liter for low-activity waste (LAW) feed and from 7.97E7 Rem/liter to <2.9E5 Sv/L for high-level waste (HLW) feed. This change has no impact on the planned tank farms operations primarily because it simply aligns the WTP limits with the limits that are already imbedded in the tank farms Documented Safety Analysis (DSA).

Feed Receipt Temperature – It has been agreed (CCN 209161, *ICD 19 Team Meeting - Finalize Issues to be Included in Revision 5*) that the ICD-19 Waste Acceptance Criteria for maximum HLW feed receipt temperature be changed from 190°F to 150°F. This change has minimal to no impact on planned tank farms operations. The sequence of operating mixer pumps prior to WTP feed delivery is not precisely defined yet; however, a thermal evaluation of potential operating scenarios has been completed (c) to provide insight on thermal conditions. The evaluation identified some mixer pump operating scenarios with the potential to exceed the 150°F limit under current double shell tank ventilation operating conditions. This information will be used as design input to the planned double shell tank (DST) ventilation upgrade projects to ensure all potential feed deliver scenarios can be accommodated.

Feed Receipt Volume – In order to accommodate proposed design changes in the WTP HLW feed receipt vessel (HLP-22), it has been proposed to change the ICD-19 Waste Acceptance Criteria for maximum HLW receipt volume from 160,000 gallons to approximately 150,000 gallons. This proposed change will have no impact on tank farm daily operations and will have a minimal impact over the course of the mission primarily related to the potential for an additional 7% in the number of HLW transfer operations needed to deliver the same volume. These additional transfer activities are not considered to have noticeable impact to tank farms life cycle planning budgets or schedule.

LAW Settling Rate – In order to insure the WTP LAW feed receipt vessels can mobilize entrained solids that may settle, it has been proposed to change the ICD-19 Waste Acceptance Criteria to limit entrained solids to those that settle no faster than 0.03 feet/minute. This proposed change will have no impact on planned tank farm operations. Current feed deliver planning includes a 6 month period of no tank activity prior to feed delivery. This 6 month period ensures that all faster settling solids have more than sufficient time to settle below the transfer pump suction location. The elevation of the transfer pump suction can be administratively controlled to provide confidence that any fast settling solids are not re-mobilized.

PANELIST CLARIFICATION	**The following information is being provided to clarify the record with regard to a response concerning the circumstances under which grinding may be required.**
SESSION 2-2	

Panelist: **Washington River Protection Solutions**
Paul Rutland, Mission Analysis & Strategic Planning Manager

Response Contributors: N/A

Response: The TOC has no plans to grind feed to the WTP. The tank farm relies on the new tank cleanout capability to deal with any small amount of solids that may be outside of the WTP waste acceptance criteria. Grinding would only be employed should the tank cleanout design be found to be inadequate in the large scale mixing tests. In addition, although not currently planned, grinding could be employed during hard heel removal during SST retrievals, if required.

4. Session 3 - Pretreatment Facility Safety and Operation (October 7, 2010 pm)

PANELIST COMMITMENT	**Provide DOE position/policy statement on use of Quantitative Risk Assessment (QRA) prior to QRA implementation.**
SESSION 3-1	

Panelist: **U.S. Department of Energy - Headquarters**
The Honorable Dr. Ines Triay, Assistant Secretary of Energy for Environmental Management

Response Contributors: **U.S. Department of Energy - Headquarters**
Dr. Steven Krahn, Deputy Assistant Secretary For Safety And Security

Response: Written testimony addressing the commitment made during the public hearing is included in Appendix 2 to this document, along with copies of the references cited therein.

ADDITIONAL INFORMATION	The following information is being provided to clarify the record with a concise statement on line plugging in the process piping of the WTP.
SESSION 3-2	

Person Making Clarification or Addition:
Hanford Tank Waste Treatment and Immobilization Plant Project
Dan Mildon, Deputy, PTF Engineering Group Supervisor

Response Contributors: N/A

Response:

In PTF, there is a non-Important to Safety (ITS) flush system and two ITS flush systems for post-DBE flushes. The purpose of these systems is to remove sufficient waste slurry from the transfer lines and the ultrafilter loop following a normal operation or post-DBE, that plugging of the line due to solids accumulation and/or gelation of the waste does not occur. The non-ITS system has five flush vessels which are connected via racks to all process systems in PTF for line flushing, with line velocities at 6 ft/s or greater, following a normal waste transfer.

In addition to the normal, non-ITS, flushes there are two ITS flush systems for post-DBE flushing of lines. One system has two ITS flush vessels dedicated to the flushing of transfer lines with high solids content transfers (UFP and HLP systems). The vessels are pressurized with an ITS air supply such that the flush velocity is at 6 ft/s or higher in the transfer line. The second system also has two ITS flush vessels that are dedicated to the flushing of the two ultrafilter loops. The ultrafilter loop piping is 10" diameter and flush velocities are lower than 6 ft/s, however, testing has shown that solids-bearing slurries in the ultrafilter loop can be effectively removed with the flush pressure and volumes used in the current design.

The P&ID references for the flush systems are as follows:

Non-ITS Flush System

- 24590-PTF-M6-PWD-00064
- 24590-PTF-M6-PWD-00065
- 24590-PTF-M6-PWD-00066
- 24590-PTF-M6-PWD-00067

ITS Flush Systems

- 24590-PTF-M6-DIW-00003001
- 24590-PTF-M6-DIW-00003002

- 24590-PTF-M6-DIW-00003003
- 24590-PTF-M6-DIW-00004001
- 24590-PTF-M6-DIW-00004002
- 24590-PTF-M6-SHR-00002001
- 24590-PTF-M6-SHR-00002002
- 24590-PTF-M6-UFP-00032002

Design Guides used for the design of WTP piping systems are:

1. 24590-WTP-GPG-M-027, Revision 5, *Recommended Slopes for Piping Systems* - Recommended slopes for slurry process lines (main defense against line plugging)
2. 24590-WTP-GPG-M-0059, Revision 0, *Avoiding Chemical Line Plugging - Plant Design Considerations* - Design methods to avoid and recover from chemical line plugging (Chemistry control)
3. 24590-WTP-GPG-M-0058, Revision 0A, *Minimum Flow Velocity for Slurry Lines* - Design methods to establish safe slurry line transfer and flush rates
4. 24590-WTP-GPG-M-016, Revision 2, *Pipe Sizing for Lines with Liquids Containing Solids - Bingham Plastic Model* - Non-Newtonian line transfers - Power Law
5. 24590-WTP-GPG-M-039, Revision 2, *Determination of Pressure Drop for Lines with Liquids Containing Solids - Power LAW Fluids* - Non-Newtonian line transfers - Bingham Plastic

5. Session 4 - Hydrogen in Piping and Ancillary Vessels (October 8, 2010 am)

PANELIST COMMITMENT	**Provide response to questions posed regarding variability in hydrogen generation rates. Specifically, will the hydrogen generation rate vary from the start of tank transfer to the completion of tank transfer due to stratification of solids?**
SESSION 4-1	

Panelist: **Hanford Tank Waste Treatment and Immobilization Plant Project**
Greg Ashley, Project Technical Director

Response Contributors: **Hanford Tank Waste Treatment and Immobilization Plant Project**
Garth Duncan, Manager of Process Engineering and Technology

Response: For a limited set of areas and conditions in the WTP the HGR in a pipe would vary with some significance from the start of tank transfer to the completion of tank transfer due to the stratification of solids. This phenomenon should only be significant in the three Newtonian high solids (up to 10 wt%) vessels, the HLW feed receipt tank (HLP-22), and the ultrafiltration feed preparation vessels (UFP-1 A/B). Vessels beyond these in the process either do not significantly stratify or do not have significant solids. For these three Newtonian vessels the predominant contributing mechanism for hydrogen generation is decomposition of organics from thermolysis. Since the organics are in the liquid phase of the waste, there is no stratification effect for thermolyisis. As seen in Table B-1 in memorandum *Partial Response to Condition of Acceptance 2.3 on Evaluation of Uncertainty in the WTP Hydrogen Generation Rate Correlation* (CCN 142843), the HGRs in these two vessels are largely due to thermolysis of organics. The values shown in the table are based on worst-case temperatures in those vessels, however, and not the lower temperatures for expected pipe transfers, so the effect is not as pronounced (thermolysis is a strong function of temperature).

The other hydrogen generation mechanisms are radiolysis of water and of organics. In the solids carrying vessels of interest, the largest contributor to radiolysis is Sr^{90} which is associated with the solids particles in the waste and thus subject to variability due to stratification. It is seen, that a large fraction of the waste particles do not stratify appreciably. As seen in Figure 15 of Appendix A to 24590-WTP-RPT-ENG-08-021, *EFRT Issue M3 PJM Vessel Mixing Assessment, Volume 8 - HLP-22*, Revision 1, there should be little stratification below a particle size of 58 microns after the first quarter batch. As seen in Table 3-2 of RPP-9805, *Values of Particle Size, Particle Density, and Slurry Viscosity to Use in Waste Feed Delivery Transfer System Analysis*, Revision 1, the d75 particle size is 58 microns. Testing data shows that for HLP-22, there was an appreciable variation in wt% solids in the first quarter-batch pump-out, but for UFP-1 there is not.

Overall there is basis for a variation in HGRs in piping from certain vessels that will need to be taken into account in HPAV analyses and there is a basis for the quantification of that variation.

PANELIST COMMITMENT	How much hydrogen will you generate per day? How much is retained? When is it released?
SESSION 4-2	

Panelist: **Hanford Tank Waste Treatment and Immobilization Plant Project**
Greg Ashley, Project Technical Director

Response Contributors: **Hanford Tank Waste Treatment and Immobilization Plant Project**
Garth Duncan, Manager of Process Engineering and Technology
Kimberly Clossey, WTP Process Engineer

Response: A rough estimate is on the order of 50 standard cubic feet per day of hydrogen would be generated in the Pretreatment facility assuming average hydrogen generation rates within the feed and with all the vessels in Pretreatment at their normal high operating volumes. Although hydrogen is certainly soluble to some extent in the waste, the solubility is not well known as a function of waste parameters. The hydrogen generation rate, and time to the lower flammability limit analyses for vessels for normal operation (with continuous mixing) conservatively assume there is no retention of hydrogen and any hydrogen generated is immediately released to the vessel headspace. Similarly, for HPAV analyses, hydrogen is assumed to immediately develop into a bubble in a pipeline containing waste during a loss of flow event. For post accident conditions (without mixing) in non-Newtonian vessels and in the settled solids layer in Newtonian vessels, it is conservatively assumed that all the hydrogen is retained until mixing is restored or the vessels otherwise recovered.

PANELIST COMMITMENT	Describe the actions to be taken to perform a typical jumper replacement due to failed component. Include spill response, decontamination, work steps, design features (sump and liner), pre-op checks, time to repair, etc.
SESSION 4-3	

Panelist: **Hanford Tank Waste Treatment and Immobilization Plant Project**
Greg Ashley, Project Technical Director

Response Contributors: **Hanford Tank Waste Treatment and Immobilization Plant Project**
George Matis, Commissioning Operations Manager

Response: The current design of the PTF and HLW facility hot cells/melter caves (canyons) will separate the worker from both the chemical and radiological hazards of the tank farm waste. For over 60 years the DOE has embraced the use of canyons as part of nuclear facility design to separate workers from a high hazard environment yet still allow for servicing of remote waste handling equipment. Remote waste handling equipment is equipment (pumps, piping, valves, instruments components, etc) that require routine maintenance and/or replacement during the facility life. Maintenance of this remotely located equipment is accomplished using remotely operated cranes with cameras which separate the worker from both the chemical and radiological hazards, yet allow maintenance activities to be completed.

Attributes of the PT Hot Cell:

- No personnel entry is required to maintain or service hot cell equipment.
- Remote hot cell equipment is serviced with a remote crane operated from the crane control room
- The remote hot cell crane has three hoists and a PAR power manipulator
- The remote hot cell crane has lights, and cameras as well as crane hook deployed cameras which allow for side viewing
- The remote hot cell crane has a variety of crane hook deployed tools (e.g. impact wrenches, nut runners, torque tool, etc.)
- The remote hot cell floor is:
  - Lined with stainless steel
  - Sloped toward sumps, which have level indication and are monitored in the control room
- The hot cell has remotely operated spray lances to facilitate washdown of equipment, the floor, walls and direct waste to sumps for removal.
- The east end of the PT Hot Cell (Room P-0123A) is designated as the remote equipment maintenance and decontamination area
- Equipment will be remotely decontaminated, repaired, regasketed, etc. or size reduced for disposal
- Waste will be remotely packaged for disposal
- Remote operations in this area are supported by a second bridge crane
- The equipment and decontamination area has a series of shielded windows that:
  - Allow for direct viewing while separating the worker from the chemical and radiological hazards
  - Have electro-mechanical manipulators to allow remote operation of tools and to perform decontamination activities.
- Both cranes may be operated remotely from the crane control room or by direct viewing through shielded viewing windows. The design allows operation of the cranes from the crane control room or by direct viewing through shielded windows which separate the worker from chemical and radiological hazards.

- Both hot cell cranes can be removed from the hot cell into a shielded crane maintenance area to perform maintenance on the cranes. The cranes have recovery features which allow them to return to the shielded crane maintenance area should a crane equipment failure occur while a crane is in the hot cell. The crane maintenance area isolates the workers from the hot cell hazards and allows maintenance activities to be performed on the cranes.

The WTP safety design strategy is to assure that piping and ancillary vessels are not adversely affected by postulated hydrogen events (deflagrations and detonations). These hydrogen in piping and ancillary vessels events are referred to as "HPAV" events. The WTP safety design strategy for HPAV events has been, and continues to be, the provision of engineered features based on two options: 1) conservative design of the primary process fluid boundary to withstand HPAV events without compromise (passive accommodation); or 2) the addition of active systems designed to limit the accumulation of hydrogen to levels where the piping is not challenged by HPAV events. In either case, the goal is to provide high confidence of low probability of failure of the primary process fluid boundary due to an HPAV event.

The "revised HPAV safety design strategy", that is being implemented to make passive accommodation practical in pipes ranging from 2 to 4 inches in diameter (approximately 80% of pretreatment piping affected by HPAV events), is the result of insights gained through extensive testing and analysis performed by the Project to first understand and then to conservatively quantify the effects of an HPAV event on the WTP piping systems. The revised criteria and methodology is significantly more rigorous than previous requirements, including the requirement to consider: 1) potential for multiple events over the plant life, 2) multiple classes of events, and 3) previously unrecognized load components such as high frequency pressure oscillation. The revised criteria and methodology also introduce higher load limits (limited localized strain) for piping (remotable) in the PTF hot cell that preclude failure with reduced margin recognizing that piping (remotable) could be repaired, if necessary. The revised HPAV criteria and methodology provide required assurance that the primary process fluid boundary is protected without requiring installation of additional active engineered controls that are judged to impair operational reliability and introduce additional worker safety risk. There is limited installed capability to maintain hard-to-reach (HTR) piping in the hot cell. For this reason piping in the hot cell that is defined as HTR, will meet the same design criteria as black cell (BC) piping as defined per 24590-WTP-DB-ENG-01-001 Revision 1P, *Basis of Design,* Section 16.2.

Remotable hot cell equipment (piping and inline components) may also be required to perform an active function, such as a valve closing. Designing the piping and components in accordance with HPAV criteria will preclude a breach of primary confinement and component inoperability (if that is a required function). The worst case consequences to facility operations for an HPAV event in the hot cell involving remotable equipment (piping and components) are judged to be similar to those that would be encountered for normal equipment failures.

Remotable equipment (piping and components) will be repaired or replaced when they no longer meet their functional requirements. Conditions caused by HPAV event, should they occur, that would warrant maintenance/repair are judged to be similar in end result (leaks) to those that would be encountered for normal equipment failures.

During HPAV testing, piping was subjected to repeated hydrogen events and the resulting deformation of the piping was on the order of 0.001 to 0.050 inch which is typical of values encountered for diametrical thermal expansion during normal operations of a typical steam pipe. The deformations that resulted were not detectable through visual inspection. A remote PUREX connector was subjected to multiple deflagration-to-detonation transitions at a closed end, following this testing, the mechanical joint (PUREX connector with graphite impregnated Teflon gasket) passed hydrostatic testing.

The hot cell is designed such that remotable equipment (piping and components) are removed from their installed location and taken to the decontamination maintenance cave (Room P-0123A) at the far end of the hot cell for repair or replacement. The vast majority of the remotable equipment is comprised of piping with remote connectors and this piping may or may not contain components. Remotable piping section with and without components are commonly referred to as jumpers. Jumpers connect remotable equipment in the hot cell to other remotable equipment in the hot cell or vessels in the BC or equipment in bulges. Failure of a jumper that would preclude its removal is not anticipated, since testing shows deformations are very small. Damage from a HPAV event to an in line component (seal or seat leakage) may require replacement of the component, however, the frequency of replacing components due to HPAV events is expected to be less than the replacement due to normal service life. Therefore, a jumper that experienced a HPAV event which resulted in a leak would be removed and replaced or repaired. Replacing/repairing jumpers and components will be a normal maintenance activity. The most common failure of a jumper (without an inline component) is a leaking gasket at a remote connector.

The following example will describe the attributes and sequence for operations in the PT Hot Cell, operations in the HLW melter caves is similar using similar remote handling equipment, cameras and remotely operated tools to separate the worker from the high hazard environment (chemical and radiological).

The example selected is from the Waste Feed Receipt Process System (FRP) and is associated with the remote jumpers which connect the remote FRP-Pump-00002A into the process. FRP-Pump-2A provides motive force to move supernate received from the tank farm and stored in the four FRP vessels to the ultrafiltration trains for processing. FRP-Pump-2A (see Figures 4-3.1 and 4-3.2) is connected in the remote hot cell by four rigid jumpers (pump suction, suction vent/flush if installed, power supply and pump discharge) and three flexible jumpers (pump seal water, suction valve position indication, suction valve actuator air supply; these flexible jumpers are not shown in Figures 4-3.1 and 4-3.2).

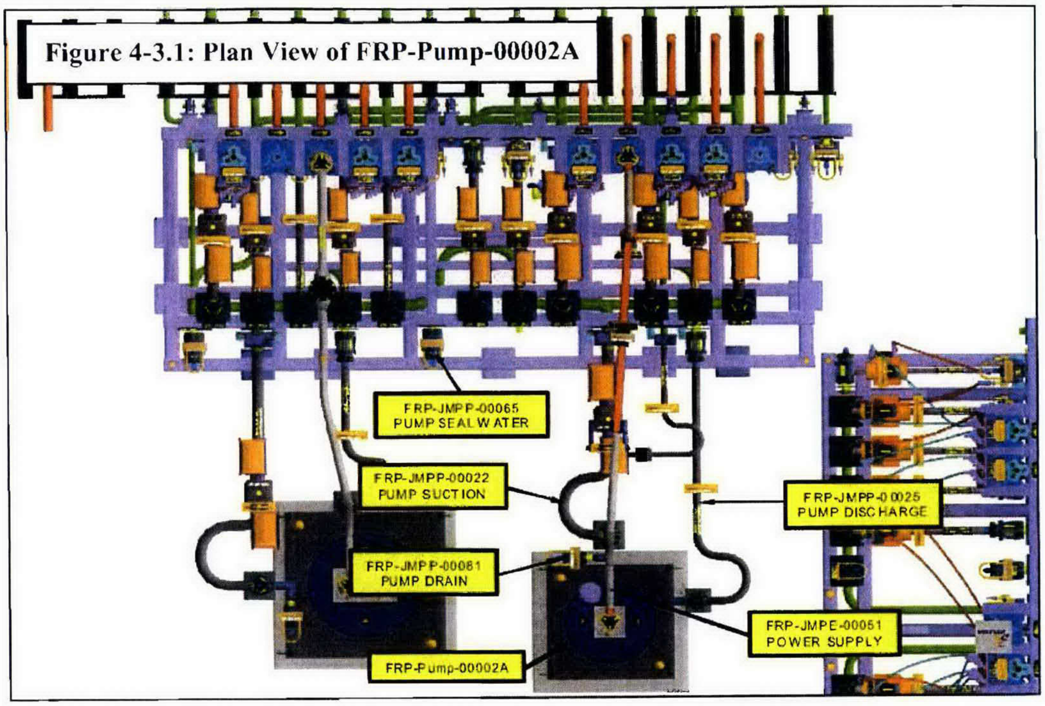

Figure 4-3.1: Plan View of FRP-Pump-00002A

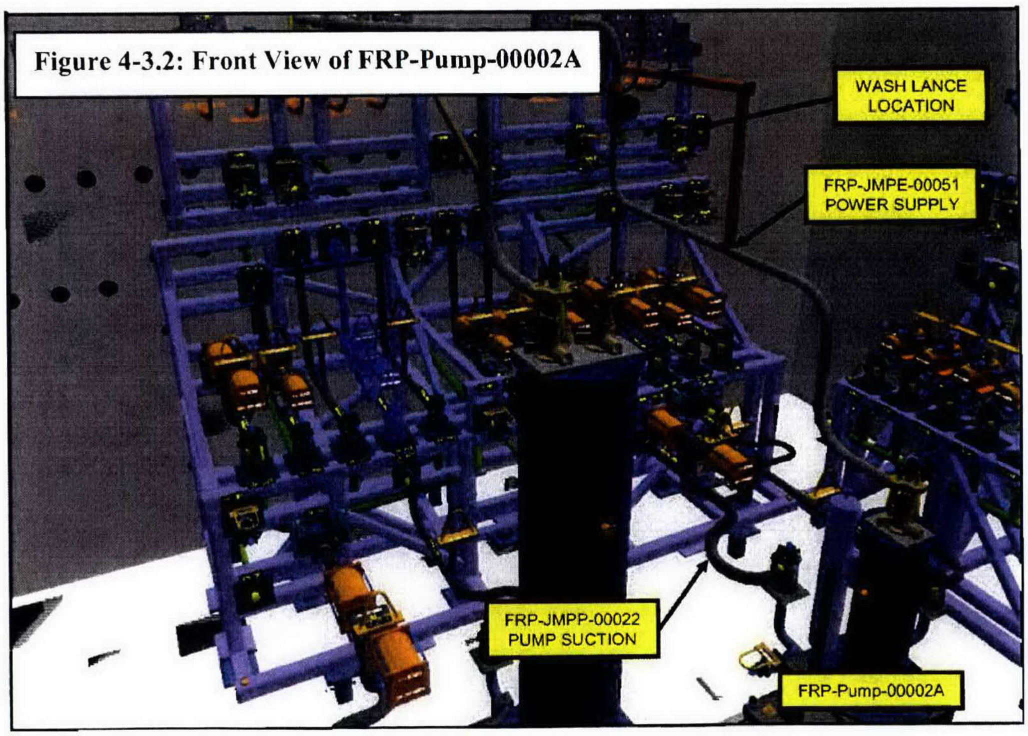

Figure 4-3.2: Front View of FRP-Pump-00002A

We will examine the time to perform remote repair or replacement activities for three scenarios associated with FRP-Pump-00002A. The first scenario (Table 4-3.1) shows the number of hours by activity required to remotely remove FRP-Pump-00002A and install a replacement pump.

Table 4-3.1: PT Hot Cell FRP-Pump-00002A Replacement Time.

Replace Process	Replace Hours	Parallel Work	Parallel Work Hours	Parallel Work	Parallel Work Hours	Parallel Work	Parallel Work Hours	PIH Usage Hours	Assumptions
Problem Diagnoses (Leakage)	12	Write Canyon Tagout	12	Flush system and rinse floor	12	Check New Pump	12	6	**Flush system**
Work Package	24					Move New Pump to CMA	8		
		Install Canyon Tagout	4						
		Pull Jumpers	14					14	**2 hrs per jumper**
Pull Pump Assembly	4							4	
Install New Pump Assembly	6					If required re-gasket jumpers during pump change out		6	**6 nuts per pump/impact wrench/yoke**
Install Jumpers	14							14	**2 hrs per jumper**
Remove Canyon Tagout	4								
Refill Seal Water	1								
Post Maintenance Test (PMT)	4							4	**Check Pump Rotation, leak check**
Total Hours Crane Usage								**48**	
Total hours MTTR	**69**								

The second scenario (Table 4-3.2) shows the number of hours by activity required to remotely remove FRP-Pump-00002A discharge jumper (without valve), re-gasket the jumper and reinstall the jumper.

Table 4-3.2: PT Hot Cell FRP-Pump-00002A Discharge Jumper (remove, re-gasket and reinstall) Time.

Replace Process	Replace Hours	Parallel Work	Parallel Work Hours	Parallel Work	Parallel Work Hours	Parallel Work	Parallel Work Hours	PIH Usage Hours	Assumptions
Problem Diagnoses (Leakage)	12	Write Canyon Tagout	12	Flush system and rinse floor	12	Move new gaskets to CMA	12	6	**Flush system**
Work Package (to re-gasket)	12	Install Canyon Tagout	4						
		Pull Jumpers	4**					4	** **2 rigid jumpers at 2 hrs per jumper**
Re-gasket	4							4*	* **if required**
Install Jumpers	4							4	**2 hrs per jumper**
Remove Canyon Tagout	4								
Post Maintenance Test (PMT)	4							4	**Leak check**
Total Hours Crane Usage								**22**	
Total hours MTTR	**40**								

The third scenario (Table 4-3.3) shows the number of hours by activity required to remotely remove FRP-Pump-00002A suction jumper (with valve), and reinstall a replacement jumper if a valve bonnet or valve stem leak has occurred. If the suction jumper has a gasket leak the suction jumper could be removed and re-gasketed within the times shown in Table 4-3.3.

Table 4-3.3: PT Hot Cell FRP-Pump-00002A Suction Jumper (remove old, and reinstall new) Time

Replace Process	Replace Hours	Parallel Work	Parallel Work Hours	Parallel Work	Parallel Work Hours	Parallel Work	Parallel Work Hours	PIH Usage Hours	Assumptions
Problem Diagnoses (Leakage)	12	Write Canyon Tagout	12	Flush system and rinse floor	12	Move New Suction Jumper to CMA	12	6	Flush system
Work Package (to re-gasket)	12	Install Canyon Tagout	4						
		Pull Jumpers	8**					8	** 2 rigid, 2 flex jumpers at 2 hrs per jumper
Re-gasket	4							4*	* if required
Install Jumpers	8							8	2 hrs per jumper
Remove Canyon Tagout	4								
Post Maintenance Test (PMT)	4							4	Leak check
Total Hours Crane Usage								**30**	
Total hours MTTR	**44**								

A leak in the hot cell will be required to be cleaned up. As discussed earlier the hot cell floor is lined and sloped to sumps to facilitate removal of material on the floor, these sumps pump their contents to the plant wash and disposal system. In addition wash lance connections to facilitate washdown are located along the hot cell walls (see Figure 4-3.2). Initial cleanup of material on adjacent equipment and the hot cell floor will be accomplished in the first 24 hours. A second washdown may be required following completion of the job. Cleanup and maintenance activities associated with FRP area (unit operation) will not preclude the continuation of processing in other areas (unit operations) in the PTF.

Panelist Additions to Public Record from DNFSB Hearing

PANELIST COMMITMENT SESSION 4-4	**Provide a crosswalk of the PRT and IRT Findings/Recommendations.**

Panelist: **<u>Hanford Tank Waste Treatment and Immobilization Plant Project</u>**
Greg Ashley, Project Technical Director

Response Contributors: **<u>Hanford Tank Waste Treatment and Immobilization Plant Project</u>**
Mike Wentink, Technical Issues Manager, HPAV and 1066

Response: Two independent teams reviewed the WTP HPAV QRA in 2010; a DOE-HS sponsored QRA Peer Review Team (PRT) and the HPAV Independent Review Team (IRT). DOE chartered the PRT, as a subject matter expert panel, to conduct a review in the absence of an official DOE policy on development and use of risk assessments. The need for a policy regarding risk assessments is the subject of DNFSB Recommendation 2009-1, *Risk Assessment Methodologies at Defense Nuclear Facilities*. The team was composed of Brookhaven National Lab probabilistic risk analysis experts. The PRT conducted their review from February through May 2010 and issued a final report, *Peer Review of Waste Treatment Plant Quantitative Risk Assessment of Hydrogen Events in Piping and Vessels*, on May 28, 2010. It has been issued into the WTP document system as CCN 217138. The review concluded the QRA model was reasonable and well thought out, but provided four Recommendations to be incorporated into the final model.

The second review, a panel of industry experts composed the HPAV IRT, conducted a review from April through July of 2010. The HPAV IRT report, *Hydrogen in Piping and Ancillary Vessels in the Pretreatment Facility of the Hanford Waste Treatment Plant* has been issued into the WTP document system as 24590-CM-HC4-W000-00182-01-00001. This review was completely independent of the first review and also concluded the QRA approach is acceptable for defining loads to be used in design. There also were several Findings and Recommendations identified by the HPAV IRT with similar intent as the PRT Recommendations, but with more detail.

All PRT Primary Recommendations and HPAV IRT Findings and Recommendation are addressed in the *Hydrogen in Piping and Ancillary Vessels Implementation and Closure Plan*, 24590-WTP-RPT-ENG-10-021. A review of both team reports has demonstrated that there are overlapping findings and actions. The HPAV IRT was able, with a larger team, to identify the specific issues encompassed within the overarching issues identified by the PRT. Table 4-4.1, below, provides a cross walk showing how the PRT Recommendations are covered by the HPAV IRT Findings and Recommendations where appropriate. Table 4-4.1 identifies the primary HPAV IRT Findings or Recommendations that resolve the PRT Recommendations. The table also identifies secondary Findings or Recommendations that provide additional justification in support of resolving the PRT items but not in the direct sense that the primary Findings or Recommendations provide. Based on mapping between PRT and HPAV IRT Findings and Recommendations, WTP is confident that resolution of the HPAV IRT Findings will resolve the PRT Recommendations.

Table 4-4.1: HPAV IRT to PRT Crosswalk.

PRT Recommendations Note 1	Corresponding Primary HPAV IRT Findings Note 2	Corresponding Secondary HPAV IRT Finding Notes 2 and 3
A. Benchmarking the QRA	F4-1 Comparison of Test and Finite Element Pipe Dynamic Response F4-3 Behavior of Pipes with Gas and Liquid R4-2 Recommended Modifications or Edits to Chapter 7 of 07-011 R4-4 Material Testing	F3-6 Settling and Yield stress of waste F3-7 Yield stress range over plant life F4-2 Effect of the Initial Detonation Location on Piping System Dynamic Response
B. Sensitivity Analysis	F2-4 Need to Consider Plant Level Events in QRA Models F2-6 Need to Enhance Treatment of Model and Parameter Uncertainties F2-7 Enhanced Treatment of Phenomenological Uncertainties F3-9 DDT Run-up Correlation	F2-5 Need to Enhance Treatment of Event Durations and Uncertainties F2-6 Need to Enhance Treatment of Model and Parameter Uncertainties F3-2 Hydrogen Nitrous Oxide ratios F3-5 HGR conservative and enveloping
C. Uncertainty Analysis	F2-4 Need to Consider Plant Level Events in QRA Models F2-5 Need to Enhance Treatment of Event Durations and Uncertainties F2-6 Need to Enhance Treatment of Model and Parameter Uncertainties F2-7 Enhanced Treatment of Phenomenological Uncertainties	F3-7 Yield stress range over plant life F3-2 Hydrogen Nitrous Oxide ratios F3-5 HGR conservative and enveloping
D. Discussion of Remaining Conservatisms	F2-6 Need to Enhance Treatment of Model and Parameter Uncertainties F2-7 Enhanced Treatment of Phenomenological Uncertainties	F3-8 "De minimis Gas Bubble" R4-4 examine tested pipe R4-12 Dual Certification

Notes:

1. The categorical Recommendations listed below are from the DOE-HSS Peer Review Team report. Detailed discussion of these Recommendations can be found in the Peer Review Team report; *Peer Review of Waste Treatment Plant Quantitative Risk Assessment of Hydrogen Events in Piping and Vessels*, May 28, 2010.
2. The Findings and Recommendation listed below are from the HPAV Independent Review Team report. More discussion regarding each of the referenced Findings and Recommendations can be found in the Peer Review Team report, *Hydrogen in Piping and Ancillary Vessels in the Pretreatment Facility of the Hanford Waste Treatment Plant Rev 1 of 1 August 10, 2010.*
3. The Secondary Findings and Recommendations listed below support the Primary Findings in closing the Peer Review Team Recommendations.

PANELIST COMMITMENT	**Provide timeline for qualification testing of inline components from Hydrogen in Piping and Ancillary Vessels Implementation and Closure Plan (24590-WTP- RPT-ENG-10-021).**
SESSION 4-5	

Panelist: **Hanford Tank Waste Treatment and Immobilization Plant Project**
Greg Ashley, Project Technical Director

Response Contributors: **Hanford Tank Waste Treatment and Immobilization Plant Project**
Mike Wentink, Technical Issues Manager, HPAV and 1066

Response: WTP components (including valves, instruments, and equipment) that are subject to HPAV loads will require testing or analysis to demonstrate they are qualified to perform their safety function. This includes active safety functions such as worker safety isolation and passive functions such as confinement. Testing will be performed to IEEE 323-83, *IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Station* by an NQA-1-2000 qualified subcontractor. Table 4-5.1 shows the timeline for issuing the HPAV Testing Specification and awarding the subcontract.

While the previous HPAV testing was not to directly qualify components, testing was performed on a valve and PUREX connector. The testing demonstrated no failure of the primary pressure boundary; however, it did provide insights into the design that will be incorporated into the HPAV component test program. For more information on HPAV component testing see question 8.0 of the DNFSB question responses submitted previously.

Table 4-5.1: Component Test Timeline.

Issue the HPAV Component Test Specification	November 2010
Issue preliminary list of HPAV components requiring testing	February 2011
Issue the Statement of Work for bid	June 2011
Award the HPAV component testing subcontract	August 2011
Finalize list of HPAV components requiring testing	December 2011
Complete testing	August 2013

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Panelist Additions to Public Record from DNFSB Hearing

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- APPENDIX 1 -

DEGREE OF SUSPENSION FOR SOLIDS WITH PJMS IN THE WTP

DR. DAVID S. DICKEY

(OCTOBER 17, 2010)

DEGREE OF SUSPENSION FOR SOLIDS WITH PJMS IN THE WTP
DR. DAVID S. DICKEY
(OCTOBER 17, 2010)

Conclusion: The change from the requirement for critical-suspension velocity to bottom motion velocity is not only an acceptable criterion for solids suspension by PJMs in the WTP, but it may have advantages for operation with no accumulation.

The degree of suspension of solids for typical mixer applications falls in three generally accepted categories, on-bottom motion, off-bottom suspension, and uniform suspension. These definitions apply to stirred tank solids suspension, but can be adapted to pulse jet mixers (PJMs). On-bottom motion refers to the agitation intensity required to keep all of the solids that remain on the bottom in motion, while most of the solids typically are suspended off the bottom. Off-bottom suspension refers to the agitation intensity required to get all of the solids off the bottom of a vessel, or as defined: so that no particles remain on the bottom for more than one second. Uniform suspension describes the condition where solids are suspended as uniformly as possible throughout the tank volume. Complete uniformity can never be achieved because of random fluid motion and a less dense concentration that remains near the free surface of the suspension or slurry. With rapidly settling particles the difference in agitation intensity between these different levels of suspension can be considerable. With slowly settling particles, all three levels of suspension can be observed at nearly the same agitation intensity.

Off-bottom suspension has become a standard definition for visually observable agitation intensity applied to solids suspension. With little more than good description of what should be observed in a transparent vessel, most engineers or scientists can observe a transition from on-bottom motion to off-bottom suspension. Because this transition can be observed by many different people and for them to arrive at similar results, off-bottom suspension has become a "standard" for conventional rotating mixers. The condition is even referenced with a rotational speed associated with that "just suspended" transition. That speed is commonly designated by a capital letter "N" and the subscript "js" for "just suspended." The Njs is the rotational speed a particular mixer design needed to "just suspend" particles off the bottom. As mixer speed is increased, a transition occurs when some solids only move around on the bottom and when solids rest only briefly on the bottom and then become suspended. This transition defines the "just suspended" speed, Njs.

Besides mixer and vessel geometry, particle characteristics, such as size and density, and solids concentration also influence the just suspended speed for a mixer. Large size or high density particles may settle more rapidly and be more difficult to suspend than small size and low density particles. Because particle sizes may vary over several orders of magnitude in the Hanford waste and particle density varies by no more than about one order of magnitude, particle size effects usually define slowly or rapidly settling particles. Higher concentrations of solids are more difficult to suspend than low concentrations. With Newtonian concentrations of solids, an increased concentration of easily suspended solids makes suspension of even small quantities of rapidly settling particles more difficult. Hindered settling seems to have less of an effect than hindered suspension, at least with PJMs.

For the suspension of settling solids with PJMs, both on-bottom motion and off-bottom suspension describe conditions that exist only at the end of the power or drive portion of the cycle. For PJMs, the jet velocity describes their performance like rotational speed for rotating mixers. Consequently, solids suspension conditions for PJMs are referenced to a "critical suspension velocity," which corresponds to just suspended speed, Njs, for off-bottom suspension with rotating mixers. The jet velocity for on-bottom motion is called "bottom motion velocity." Bottom motion describes the jet velocity at which all of the settled particles are in motion on the bottom of the vessel at the end of the PJM power stroke. In the immediate region of jet impingement, all of the particles are suspended and the other particles will move in and out of those regions of off-bottom suspension. Critical suspension velocity describes a condition where the rapidly settling particles at all locations on the bottom are suspended momentarily at the end of the power pulse. For both bottom motion and critical suspension the rapidly settling particles return to the bottom during the refill portion of the pulse cycle. Because nearly all of the high velocities from PJMs are near the bottom of the vessels, uniform suspension occurs only for very slowly settling particles. Then only when the liquid level is not much greater than equal to the vessel diameter. Only a small fraction, usually less than 1% of the solids in Hanford waste would be considered rapidly settling, and most of those are large silicon dioxide (sand or quartz) particles.

The just suspended mixer speed, representing off-bottom suspension, is often used to correlate experimental results or compare the performance of different types of impellers in different situations. The use of off-bottom suspension for measurement and comparison is because the transition from on-bottom motion to off-bottom suspension can be more consistently observed than other conditions. Not because it is a necessary condition for all process requirements. From a process perspective, off-bottom suspension is a practical degree of suspension for dissolving solid particles. Each particle is fully surrounded by moving liquid and none are resting on the bottom. Since the rate of dissolution is usually dictated by particle solubility and liquid saturation, increased mixing intensity typically has only a minor effect in improving the rate of dissolution. However, in the WTP, complete liquid contact is needed in only some reactive vessels. In other vessels, the sufficient need is for no accumulation, which can be accomplished with less than off-bottom suspension.

From an industrially practical perspective, on-bottom motion is sufficient for many applications, such as mineral or waste processing, where off-bottom suspension would require significant increases in energy requirements. One major mixing equipment manufacture uses a one (1) to ten (10) scale to describe agitation intensity for different categories of phases present. An agitation intensity of one (1) describes a minimum level acceptable for process applications. An intensity of ten (10) describes a maximum practical level of agitation. For solids suspension, an agitation intensity of one (1) represents on-bottom motion, an intensity of three (3) represents off-bottom suspension, and an intensity of ten (10) represents uniform suspension. Each level between those points corresponds to increasing energy levels. On bottom motion is not a failure, it is an industrially accepted level of solids suspension and an energy efficient condition for many applications.

For solids suspension with PJMs in the WTP, the primary processing requirement is "no accumulation" of solids in any vessel. To prevent accumulation no particles can remain permanently in a vessel and a sufficient quantity must be suspended to allow removal of a higher concentration than that entering with each new batch. Both the on/off operation of the PJMs and the batch operation in the WTP present some unusual conditions for solids suspension. In PJM suspension, rapidly settling particles are only suspended during the power stroke of the PJMs and then only near the end of the power pulse with a higher concentration near the bottom. At the beginning of a power stroke, only some solids are in motion. At the end of a power stroke, all of the solids must be at least in motion, while at that same condition all of the slowly settling particles and most of the rapidly settling particles are suspended. Fortunately, sufficient intensity for bottom motion also means that most of the other particles are suspended off the bottom of the vessel and often well suspended vertically in liquid.

No accumulation in a PJM vessel is effectively accomplished because a much higher concentration of rapidly settling particles exists near the bottom of the vessel during the power stroke. The concentration near the bottom is high enough during the power stroke that more of the rapidly settling particles are removed during that power stroke than not removed during the refill period. The concentration is high enough during the power stroke to offset the low concentration during the refill. This condition also means that rapidly settling particles will be withdrawn preferentially to the slower setting, more uniformly suspended particles. It appears that a lower PJM intensity will improve the preferential removal of rapidly settling particles with those expected for WTP waste and vessel design.

The condition of bottom motion velocity is sufficient for PJM applications in the WTP for several reasons. Particles are lifted high enough in the batch during the power stroke to be withdrawn through the transfer pipe. The particles not lifted off the bottom during one power stroke are moved sufficiently on the bottom to avoid permanent accumulation. By random flow, the particles not lifted on one pulse cycle may be moved and lifted on the next cycle. The random nature of turbulent mixing means that all particles of a practical size are lifted periodically. The random flow patterns will result in particles initially near the wall of the vessel eventually being moved near the center, so opportunities exist for removal of any portion of the solids.

The final influence on PJM solids suspension in the WTP is the batchwise nature of processing. The intermediate storage applications in the WTP are filled with the equivalent of from one to four batches of waste and then removed down to a heel volume. While at a full level, the PJMs may only achieve bottom motion, as the liquid level decreases with batch transfer, suspension improves. So at the lower liquid levels, typically less than half a tank diameter, the solids reach critical suspension before the next batch is added. Preferential removal of some solids with previous transfers reduces the concentration remaining at the lower liquid levels. PJM velocities also increase with lower liquid level. Because of preferential removal of rapidly settling particles during the first part of a batch transfer, on average that initial transfer out of the vessel will contain a higher concentration of solids than the concentration remaining in the vessel. This successively reduced concentration in the WTP vessel assures that no accumulation will occur. Since that portion of the solids removed is greater than the quantity added at the beginning of the batch, along with complete bottom motion, no accumulation will occur.

Bottom motion velocity is a sufficient and potentially preferred solids suspension level for PJM operation in the WTP. Whatever reduction in suspension intensity from critical suspension velocity at a full tank, is offset by preferential removal of rapidly settling solids. Suspension requirements are less at lower liquid levels because of lower concentrations, smaller volumes, and higher jet velocities all of which improve suspension. At the heel conditions, critical suspension velocity will be achieved.

- APPENDIX 2 -

STATEMENT OF DR. STEVEN L. KRAHN

DEPUTY ASSISTANT SECRETARY FOR SAFETY AND SECURITY, DOE-EM

REGARDING DOE-EM OVERSIGHT OF THE DEVELOPMENT OF THE QUANTITATIVE RISK ASSESSMENT METHODOLOGY FOR WTP

&

COPIES OF REFERENCES CITED THEREIN

STATEMENT OF DR. STEVEN L. KRAHN

DEPUTY ASSISTANT SECRETARY FOR SAFETY AND SECURITY, DOE-EM

REGARDING DOE-EM OVERSIGHT OF THE DEVELOPMENT OF THE QUANTITATIVE RISK ASSESSMENT METHODOLOGY FOR WTP

Good morning Mr. Chairman, members of the Board and its staff, along with members of the public. I am here to discuss the oversight that DOE-EM (EM) has provided for several safety-related issues associated with the WTP.

First though, it is important to discuss a vital cog in the EM safety oversight process: the Technical Authority Board, or TAB. The EM TAB was first chartered by the Assistant Secretary for Environmental Management on March 6, 2009. The EM TAB serves as a consensus building and advisory body to integrate certain functional responsibilities with the coordination and cooperation of other program offices, across the DOE-EM project portfolio. The EM TAB develops policies, planning, standards, and guidance to provide an effective and efficient integration of technical responsibilities (includes, design, engineering, technology, and safety) for capital and major modification projects. The EM TAB has authority across the entire DOE-EM portfolio, providing particular focus on projects identified to have significant technical issues or risks. The EM TAB also provides review and guidance regarding projected related actions that require EM corporate approval within the Critical Decision (CD) process. Where appropriate, the TAB will recommend to senior DOE-EM management possible engineering solutions to technical issues that have broad application across the project portfolio and provide the synergistic benefit of a unified DOE-EM approach. The EM TAB Charter was revised April 5, 2010. (Both the original and revised TAB Charters are attached.)

During discussions with DOE-ORP and the WTP Project in 2009, EM was informed of the planned use of probabilistic insights to inform the design of Hydrogen Piping and Auxiliary Vessels (HPAV) in the WTP; since we understood that this was the subject of Board Recommendation 2009-1, which had been assigned to DOE-HS to lead, we informed DOE-HS of this planned use of quantitative methods in the QRA. Since I was a member of the DOE Risk Working Group (RWG) established by the 2009-1 Implementation Plan, the RWG was given a summary brief on the QRA methodology. I also worked with the RWG to have an independent peer review performed of the then Draft QRA Methodology, under the auspices of DOE's implementation of DNFSB Recommendation 2009-1.

Since the Secretary of Energy had stated in the Implementation Plan for Board Recommendation 2009-1 that, when the Department used quantitative methods to inform its deterministic safety analysis, it did so in a manner that was consistent with accepted industry standards, the RWG-sponsored QRA Peer Review Team (PRT) was tasked to review the methods of the QRA against applicable NRC and chemical industry standards. The PRT reviewed the Draft QRA methodology, found it to be generally consistent with industry practices, and provided several comments for improvement. The report of the PRT (*Peer Review of Waste Treatment Plant Quantitative Risk Assessment of Hydrogen Events in Piping and Vessels*, May 28, 2010) was provided to the Board in a letter dated June 18, 2010 (attached).

The RWG-sponsored PRT was finishing its review just as plans for the HPAV Independent Review Team (HPAV IRT) were being developed. For this reason, it was decided to defer any EM action on the PRT comments until the more comprehensive HPAV IRT review was completed; however, the HPAV IRT

Team Member evaluating the QRA was tasked to review the PRT report and provide comments on it as part of his review. The HPAV IRT report notes:

> "The overall approach followed in the QRA is technically sound and contains the essential elements of a quantitative risk analysis, referred to in the nuclear power industry as 'Probabilistic Risk Assessment (PRA)'."

Further the HPAV IRT found that there was "very good consistency between the findings and recommendations of this review [HPAV IRT] and those of the BNL review [i.e, the QRA PRT]."

Because of the subject matter addressed by the calculations performed in the QRA, pipe loadings due to hydrogen combustion events, I have recently (in a memorandum dated 8/25/10, attached) asked the WTP Project, in a letter to the Federal Project Director, to conduct an assessment of the QRA methodology and its use against the DOE-STD-3009 requirements relative to quantitative calculations. The requested assessment will be part of the information used by the EM Technical Authority Board (TAB) in its on-going review of the QRA methodology for Assistant Secretary for Environmental Management.

A related issue that EM exercised its safety management responsibilities on was the manner in which the detailed piping analysis was carried out on HPAV piping. The focus of this oversight was on whether the methods used by the WTP Project were consistent with the code of record--ASME B31.3. A concern along these lines had been voiced by the Board in its quarterly report to Congress on design issues associated with new defense nuclear facilities, dated June 22, 2009 (the same report that voiced the Board's preliminary concerns with the use of PRA in the QRA). EM and DOE-ORP each obtained the services of an independent ASME code expert to review the HPAV analysis methodology being used by the WTP Project. Both experts performed detailed reviews of the WTP Project approach in the period November 2009 – March 2010. Their opinions, independently arrived at, were that the methodology used by the WTP Project was consistent with the expectations of the ASME code. In April 2010, the EM Technical Authority Board reviewed the question of whether an ASME code case was required in order to use the planned HPAV design methodology. Based on the information provided by the ASME code experts, which indicated that a code case was not required and that the methods employed by the WTP Project met the intent and requirements of ASME 31.3, the TAB concluded that a code case was not necessary. This same conclusion was also reached by the team of ASME code experts that served on the HPAV IRT (discussed above).

In addition, as part of our oversight and interaction with the Board staff, concerns with deposition velocity (as used in unmitigated analysis) and the spray leak methodology at WTP were identified. Actions in response to these concerns include a memorandum from EM to the Office of Health, Safety and Security (dated 02/01/2010, attached) outlining the issues regarding Airborne Release Fraction for a Pressurized Spray Leak and Deposition Velocity, and requesting that the appropriate value(s) for these two parameters be established and revised guidance be issued. Also, an External Technical Review of the WTP Spray Leak Methodology was initiated, in accordance with the EM process for external technical reviews, which will be reported to the EM TAB when completed.

Thank you.

<<COPIES OF REFERENCES CITED AS "ATTACHED"

IN THIS TESTIMONY FOLLOW THIS SHEET>>

Attachment 2
10-WTP-348

Peer Review of Waste Treatment Plant Quantitative Risk Assessment of Hydrogen Events in Piping and Vessels
Pages 70

Peer Review of Waste Treatment Plant Quantitative Risk Assessment of Hydrogen Events in Piping and Vessels

Final

May 28, 2010

Executive Summary

This report provides the results of a Peer Review of the Hanford Waste Treatment Plant (WTP) December 2009 Draft Quantitative Risk Assessment (QRA) of the impact of potential hydrogen combustion events on WTP pipes and vessels. The WTP project intends to utilize the results of the QRA to support the design of the piping in the WTP.

The purpose of this review was to provide the WTP Project and the Department of Energy's (DOE's) Office of River Protection feedback on:

- QRA and available standards
- Appropriateness of the QRA model including the modeling assumptions
- Adequacy of data utilized in the QRA and treatment of uncertainties
- Adequacy of QRA development process to ensure quality

QRA and Available Standards

The WTP QRA report correctly notes that, presently, no DOE standards or guidance exist that could be followed for this specific application. Rather, the WTP project used best practices and lessons learned from the U.S. Nuclear Regulatory Commission (NRC), the Center for Chemical Process Safety (CCPS), and the National Fire Protection Association (NFPA) as guidance. This, of course is not the same as following an established consensus Standard for performing a risk assessment (the only true consensus standard for probabilistic risk assessment is the ASME/ANS Standard (RA-Sa-2009) which was recently developed explicitly for commercially operating light water power reactors). However, to the extent applicable the WTP QRA logic model appropriately adapted techniques and methods from the light water reactor industry and the chemical process industry including standard practices for utilizing fault trees and event trees to logically model failure likelihoods and event progression. The QRA model used for WTP appears reasonable and well thought out.

QRA Model and Modeling Assumptions

As in all probabilistic risk assessments, the QRA methodology combines probabilistic and deterministic features. Key elements of the QRA model included models to determine (1) Gas Pocket Formation Frequency, (2) Hydrogen Generation, (3) Hydrogen Distribution and Pocket Formation, (4) Hydrogen Ignition, and (5) Hydrogen Combustion. In all of the above models, some parameters are treated probabilistically. For hydrogen ignition, the current QRA model sets this probability to unity.

In general the Peer Review Team concluded that the QRA logic used to estimate the frequency of gas pocket formation was reasonable and in accordance with conventional risk assessment practices. Furthermore, many aspects of the models and assumptions were appropriately based upon physical laws for the phenomena being modeled and on the experimental data. For example the hydrogen combustion model was based upon state of the art mechanistic deflagration and detonation formulations with support from experiments supported by WTP.

However, the Peer Review Team identified several assumptions relative to gas distribution and pocket formation that were made with insufficient justification, leading to concerns that substantial differences between the actual and modeled hydrogen combustion consequences could potentially exist.

QRA Data and Uncertainties

The QRA method includes data inputs for parameters such as initiating events (e.g., human failure, hardware failure, and loss of offsite power); hydrogen distribution and pocketing (e.g., holdup conversion factor and critical angle of pipe inclination); hydrogen generation (e.g., composition and amount of waste); hydrogen combustion (e.g., cell width and run up length).

The Peer Review Team found that the selection of QRA model parameters treated as point estimates versus those treated as uncertainty distributions was not performed systematically in accordance with conventional risk assessment practices. Furthermore, for those parameters selected for uncertainty distribution treatment, the Peer Review Team found that the sources of parameter uncertainty and the construction of the probability distributions were not adequately described. The Peer Review Team understands that a Phenomena Identification and Ranking Table (PIRT) analysis has been performed and is currently being documented. The Peer Review Team further understands that the PIRT analysis will be used to justify the basis for the representation of inputs as distributions or point values in the QRA model going forward, and also guide follow-up sensitivity and uncertainty analyses.

The Peer Review Team also found the QRA document's discussion of the treatment of uncertainties to be brief and the area to be narrowly focused. These factors limit the ability of the reader of the QRA report to understand the uncertainties associated with the QRA results.

QRA Development Process

The QRA report had a very limited discussion of the approach to quality assurance of the product, which consisted of a summary of the NRC approach. The Peer Review Team was unable to conclude whether the QRA was developed in accordance with standard industry quality assurance processes for developing a PRA/QRA. However, the Peer Review Team did conclude that the WTP project members were highly skilled and competent to develop the QRA for the potential hydrogen combustion events on WTP pipes and vessels.

The QRA method has been exercised for some example cases, but apparently there has not yet been a more formal benchmarking of the method against a test facility or other small facility to determine if the predictions of the methodology are consistent with the observable outcomes, or at least conservative.

Summary

In summary, the Peer Review Team concluded that the QRA logic model for estimating gas pocket formation frequency was reasonable and in accordance with conventional risk assessment practices. For the most part, the various models and their assumptions were appropriately based upon physical laws for the phenomena being modeled and on the experimental data. However, some modeling assumptions (most importantly hydrogen distribution and pocketing) lacked sufficient justification. Finally, uncertainty was not systematically treated in accordance with conventional QRA practices and the QRA could document in greater detail how it utilized industry practices for ensuring QRA quality.

These issues limit the usefulness of the QRA as a tool for providing the technical basis for the adequacy of the design of the WTP piping to meet code requirements. The Peer Review Team recognizes that the QRA was developed to prevent unnecessarily complex designs for mitigating hydrogen combustion events. However, without further refinement of the modeling and treatment of uncertainty the WTP runs the risk of making inappropriate design decisions.

The Peer Review Team identified several recommendations for improving the QRA that are included in the body of this report. The Peer Review Team is aware the final QRA was issued in March 24, 2010, and that it addresses some of these issues and recommendations. Draft comments by WTP on the draft final version of this peer review report are included as an appendix to this final report.

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1. PURPOSE AND BACKGROUND

1.1 Purpose of Peer Review

The report provides the results of a Peer Review of the Hanford Waste Treatment Plant (WTP) December 2009 Draft Quantitative Risk Assessment (QRA) of the impact of potential hydrogen combustion events on WTP pipes and vessels.

The purpose of this review was to provide the WTP Project and the Department of Energy's (DOE's) Office of River Protection feedback on:

- QRA and available standards
- Appropriateness of the QRA model including the modeling assumptions
- Adequacy of data input to the QRA and treatment of uncertainties
- Adequacy of QRA development process to ensure quality

1.2 Background and Standards

Background

In late 2008, the Office of River Protection (ORP) chartered a team to investigate how WTP operational complexities and design constraints that result in over-conservatisms in hydrogen event analysis methodology may be reduced. The team recommended implementation of alternative analysis methods and design criteria that could result in a WTP design that is operationally simplified, more reliable, and of reduced construction and operational costs. Use of a QRA was one of the key alternative analysis approaches recommended by the team.

The QRA report states that its purpose is to provide a technical basis for quantifying the demand from a postulated hydrogen event and the associated hydrogen event frequency in order to assess available margin in piping systems at the WTP. The conservative assumptions and acceptance criteria previously used in the design analysis of the WTP led to the need for hydrogen controls for the majority of the WTP piping systems. This resulted in added construction and operational complexity and cost, and significant risk to plant availability.

The WTP project developed a QRA method that (1) determines the likelihood of hydrogen events and the relative importance of event hazards; (2) models gas pocket formation using physically based engineering judgment; (3) takes credit for improved phenomenological understanding and test-informed analytical models for deflagrations and detonations; and (4) guides implementation of the appropriate code-based structural response and acceptance criteria tied to the frequency of postulated hydrogen events. The WTP QRA method is documented in the Dominion Engineering, Inc. report "Quantitative Risk Analysis of Hydrogen Events at WTP: Development of Event Frequency-Severity Analysis Model," R-6916-05-01 Rev 1, December 2009 [DE 2009].

Standards

WTP appropriately takes guidance from process industry developed guidance (i.e., *Guidelines for Chemical Process Quantitative Risk Analysis* from the American Institute of Chemical Engineers) as well as commercial nuclear industry guidance (e.g. Regulatory Guide 1.200, *An Approach for Determining the Technical Adequacy of Probabilistic Risk Assessment Results for Risk-Informed Activities*). However, the WTP QRA report notes that currently no DOE standard or guidance exist that directly applies to this specific application, i.e., the use of RA for design margin quantification. Rather, they used good practices and lessons learned from the U.S. Nuclear Regulatory Commission (NRC), the Center for Chemical Process Safety (CCPS), and the National Fire Protection Association (NFPA) as guidance for model development. Therefore the WTP project followed conventional risk assessment practices in the development of their tool for assessing piping design margins. This, of course is not the same as following an established consensus Standard for performing a risk assessment. The only true consensus Standard for probabilistic risk assessment is the ASME/ANS Standard (RA-Sa-2009) which has recently been developed explicitly for commercially operating light water power reactors.

It is reasonable for WTP to take guidance from this standard and the above cited sources, as well as NASA guidance for risk assessment. However, their model QRA development cannot be said to meet any specific Standard because there is no specific standard for their situation. See Appendix A for additional discussion.

2. REVIEW METHODOLOGY

The review was conducted in accordance with the Peer Review Project Plan. The Peer Review Team consisted of four engineers/scientists with extensive knowledge in risk assessments and/or multiphase fluid transport and hydrogen combustion phenomena. As discussed in more detail in the Plan, the Peer Review Team, at Brookhaven National Laboratory (J. Lehner, T. Ginsberg and R. Bari) and DOE (R. Nelson), evaluated the QRA against state-of-the-art risk assessment practices.

The scope of the review was focused on whether the QRA was conducted in accordance with the industry conventions for performing risk assessments and whether the resulting model and data inputs were appropriate to serve the intended purpose of the QRA (i.e., support evaluation of the adequacy of the piping design to meet code requirements). A limited check on selected elements of the calculational model was performed; however, the peer review team did not re-calculate the model. Particular attention was given to the treatment of uncertainty in the modeling and data.

The peer review team did not evaluate the engineering analysis and calculation of pressure increases from the hydrogen events, i.e. the structural analysis. However, the review did include a high level evaluation of the reasonableness of mathematical models of physical processes utilized to calculate the consequences of hydrogen combustion.

In performing the review, the peer review team reviewed the WTP QRA report (December draft) and some of the references mentioned in the report as well as numerous other pertinent WTP Project references, as listed in Section 5 of this report. The peer review was performed over a four week period of time during February and March 2010. Several meetings/conference calls were held with the WTP Project to obtain clarification on the QRA and to request additional information, including supporting reports for the QRA.

3. RESULTS

This section provides a summary of the results from the Peer Review Team review in the areas of modeling, input data and treatment of uncertainty, and quality assurance. Each subsection below includes a brief discussion of the industry approaches and practices, the approach utilized in the QRA, the Peer Review Team evaluation of the QRA relative to industry approaches and practices, and the recommendations. Further details of the Peer Review Team review are included in Appendix A. Draft comments by WTP on the draft final version of this peer review report are included as Appendix B to this final report.

3.1 QRA Model and Modeling Assumptions

3.1.1 Introduction and Discussion of Industry Practice

The WTP QRA is being developed as a design tool to reduce conservatisms while still providing an acceptable structural design of the WTP, given that hydrogen events will occur. The QRA method is an innovative approach to a difficult design problem.

It should be noted that the use of quantitative risk analysis as a design tool is relatively novel. In the nuclear industry probabilistic risk assessment (PRA) has been used mostly to assess vulnerabilities or integrated risk of existing plants or completed designs. Only with the next generation of reactors is PRA expected to be used during the design stage to help in the development of the design. The chemical industry has used HAZOP and other reliability analyses in plant design, but this has generally not extended to a complete quantitative analysis used to demonstrate satisfaction of structural criteria. Therefore, the QRA method is innovative in both the type of facility it is being applied to, as well as its application as a design tool.

As noted (and enumerated) in the QRA report, significant benefits can be obtained from the use of an analysis which is conservatively realistic rather than very conservative. However, a key feature of using a more realistic approach, instead of a conservative one, is a thorough quantification of the uncertainties of the more realistic analysis and the inclusion of the total uncertainty when the comparison of the analysis results with acceptance criteria is made. A well-documented example of such an approach is the best estimate calculation approved by the NRC for demonstrating emergency core cooling system capability during a loss-of-cooling-accident [INL 1989]. That calculation, when uncertainties are properly accounted for, can be used instead of the conservative Appendix K calculation of 10 CFR Part 50

3.1.2 Overview of WTP QRA Model and Assumptions

The QRA method has a logical structure which is used to develop estimates of the frequency of hydrogen combustion events, as well as estimates of the severity of the events. The method uses a conventional fault tree approach for determining the potential frequency of gas pocket formation from a set of initiating events and subsequent failures. Based on an elaborate gas pocket logic model, the type of event and its severity are then determined from a series of event-tree-like questions. The severity of the events is represented by a series of pressures resulting from the various hydrogen combustion events, and these pressures are then used to estimate loadings on the WTP piping system.

3.1.3 Peer Review Team Evaluation

To the extent applicable the WTP QRA logic model appropriately adapted techniques and methods from the light water reactor industry and the chemical process industry including standard practices for utilizing fault trees and event trees to logically model failure likelihoods and event progression. The QRA model used for WTP appears reasonable and well thought out.

The model has multiple strengths. It incorporates a very detailed representation of the piping system in the WTP facility, breaking piping routes down into sectors, portions and segments, whose geometry is faithfully modeled. The method uses Monte Carlo sampling of selected distributed parameters to allow a characterization and propagation of the uncertainty associated with those parameters. Much testing was carried out on simple piping configurations to obtain and justify many of the parameters used in the gas pocket logic model. The model can be easily used to carry out sensitivity and "what-if" type of analyses, including the effect of mitigating devices placed in the routes.

The Peer Review Team identified the following opportunities for improvement in the WTP QRA model:

Modeling of hydrogen pocket formation

In the QRA model the WTP piping routes are broken down into sectors, portions and segments, whose geometry is faithfully modeled. The distribution of hydrogen pockets and their size is highly dependent upon this geometry in the QRA modeling method. The method is not based upon solution of conservation of mass, momentum and energy balance equations applied on a local basis within the pipe network. Instead the method is based upon gas transport rules developed from extensive testing in simple piping configurations and with what the WTP team believes are conservative assumptions. One such assumption is that the mass of gas generated in a route remains in the route piping, despite outflows of gas through pipe segments open to the process building volume.
Although this is a reasonable approach, the Peer Review Team concluded that the method lacks sufficient justification to assure its conservatism relative to how the hydrogen may actually be distributed in the WTP pipes during accumulation conditions. This issue could result in substantial differences between the actual and modeled hydrogen combustion consequences.

The QRA report does not discuss why this modeling approach is justified relative to other modeling approaches, such as those using first principles, i.e., the report does not discuss modeling uncertainty (see Section 3.2 below).

Benchmarking of the Model

The basis for the physical aspects of the QRA model has relied in part on extensive testing in simplified piping configurations, but there has not been a more formal evaluation of the model, as would be expected before application as a design tool. There has been no benchmarking of the physical aspects of the model against a test facility or other small facility with a reasonably complex piping network to determine if the predictions of the model are consistent with the observable outcomes, or at least conservative. This facility would be designed to simulate the transient multiphase processes within the complex WTP piping networks that result in pocket formation. The complexity of a network that would be needed and the choice of fluids that would be used for additional benchmarking could be a subject for a subsequent review.

3.2 QRA Data and Treatment of Uncertainties

This section focuses on the data inputs that the WTP project uses with the QRA logic model structure and then propagates through the model (utilizing tools such as Monte Carlo sampling) to provide calculations of the frequency and magnitude of hydrogen combustion events, along with a measure of the associated uncertainty.

3.2.1 Introduction and Discussion of Industry Practice

Input data into the WTP QRA model includes:

Data Related to Calculation of the Frequency of Hydrogen Pocketing Events (e.g., human failure frequency, equipment failure frequency, seismic events frequency)

Data Related to Hydrogen Generation (e.g., mass and composition of waste material)

Data Related to Combustion Phenomena (e.g., detonation limits, run-up length)

Good practice for these type of input parameters is to include a central value (e.g., mean) with an uncertainty distribution. The central value and distribution is typically determined from physical data, expert judgment, and operating experience.

Regarding the treatment of uncertainty, it is considered good practice (NUREG-1855 [NRC 2009]), to categorize the epistemic uncertainties into those that are associated with the parameter values used and those that involve aspects of models used, because the methods for the characterization and analysis of uncertainty are different for the two types. In addition, a third type of uncertainty exists, namely uncertainty about the completeness of the model. While this type of uncertainty cannot be handled analytically, it needs to be considered when making decisions using the results of an analysis.

Parameter uncertainty is the uncertainty in the values of the parameters of a model given that the mathematical form of that model is satisfactorily established. Conventional practice is to characterize parameter uncertainty using probability distributions on the parameter values.

A model uncertainty can arise because the phenomenon being modeled is not completely understood, and/or while some data or other information about the phenomena may exist, it needs to be interpreted to infer behavior under conditions different from those in which the data were collected. Model uncertainty may occur in the choice of the model itself or as uncertainty about the logic structure of the model. While it is possible to embed a characterization of model uncertainty into a risk assessment by including several alternate models, this approach is not commonly followed. Instead the usual approach is to demonstrate that the key uncertainties, reasonable alternative hypotheses, or modeling methods would not significantly change the assessment.

3.2.2 Overview of WTP QRA Data Input and Uncertainty Analysis

The QRA model is constructed as a probabilistic model to reflect the random nature of some of the constituent basic events such as the initiating events and equipment or human failures. In the QRA report some parameter uncertainty is addressed with the Monte Carlo sampling that is part of the methodology. Considerations of model uncertainty, or compensation for completeness uncertainty, are not explicitly mentioned.

Single values were provided for route and segment specific parameters that reflect geometric or other deterministic features. Furthermore single valued parameters were provided for initiating event frequencies and error rates. Some parameters did include distributions, such as the event duration parameters. Failure rate parameters for equipment failure and human errors were obtained from what appear to be acceptable industry sources. The QRA report identified that the value of some of these parameters had not been finalized.

3.2.3 Peer Review Team Evaluation

The QRA report appropriately references the source of some of the point estimates used (e.g., human failure rates). The Peer Review Team concludes that these were taken from conventional industry sources. However the basis for other input parameters was not clear.

Although the QRA report provides a brief discussion on how it treated input parameter uncertainty it does not provide a comprehensive discussion that demonstrates that uncertainty has been addressed in accordance with best industry practices. While the developers of the QRA methodology obviously attempted to incorporate uncertainty considerations, there is very little discussion in the report as to what process was used to decide which parameters would be treated as distributed, and how the distributions were chosen. There is also little discussion as to what parameters drive the model results. In other words, the treatment of the uncertainties appears to be ad hoc rather than following a systematic process. With respect to parameter uncertainties the Monte Carlo sampling incorporated in the approach is certainly a very useful tool. However, only some parameters are treated as distributed and many others (such as initiating event frequencies, error rates, and gas pocket model parameters) are input as single values when they would be more correctly also treated as distributed. The report notes that some of these single valued parameters may be treated as distributed, but this adds to the impression that the methodology is not quite ready for application at the time of the peer review. In addition, the range and distributions chosen for some of the key distributed parameters should be justified to make the modeling more credible.

Model uncertainty is not discussed in the report. In this respect it would be reassuring, especially for the gas pocket modeling, to have a discussion in the report of what other modeling methods were considered and why the one chosen was preferred. Further discussion could address whether alternative models were likely or not to lead to similar results.

With regard to completeness there is some discussion of perceived conservatisms retained in the modeling, but there is no discussion as to the margins that can be appealed to or the defense-in-depth provisions that could mitigate unforeseen load aggravating phenomena or events.

Adding to the overall uncertainty is the fact that one had the impression from the report, as well as from discussion with the modelers, that the model and the parameter choices are still in somewhat of a state of flux at the time of the peer review.

3.3 Adequacy of QRA Development Process to Ensure Quality

3.3.1 Introduction and Discussion of Industry Practice

Standard industry quality assurance processes for development of QRAs/PRAs involve development of an internal protocol that is implemented to assure the quality of the product before it undergoes peer review. Typical topics would be qualification of personnel, review of technical correctness of the model, review of computer model development and implementation, sanity check of the results, and documentation.

3.3.2 Overview of WTP QRA Development Process to Ensure Quality

The WTP QRA report notes that there is not an existing standard or model that could be followed for this specific application. To ensure the quality of the QRA processes in the absence of approved DOE policy, the report states that: "...the WTP project has used the guidance and best practices of other agencies that have formalized the use of QRA through relevant standards. In particular, the WTP project is using lessons learned from the U.S. Nuclear Regulatory Commission (NRC), the Center for Chemical Process Safety (CCPS), and the National Fire Protection Association (NFPA) as guidance. In addition, personnel with experience in use of probabilistic analysis are supporting the development of the HPAV QRA tool to ensure its quality and completeness."

3.3.3 Peer Review Team Evaluation

The discussion of the development process appropriately indicated that conventional quality practices from other industries were used, to the extent applicable, to guide the WTP project. The QRA report did not discuss what internal protocols were used to assure quality in the development of the model and its results.

However, the Peer Review Team did conclude that the WTP QRA was developed by risk assessment experts with support of experts in hydrogen combustion phenomenology and the design of the WTP.

4. SUMMARY

In summary, the Peer Review Team concluded that the QRA logic model was reasonable and used conventional risk assessment practices to estimate hydrogen event frequencies. Some of the modeling assumptions were appropriately based upon physical laws for the phenomena being modeled and on the experimental data. However, a number of concerns were identified:

- Some modeling assumptions (most importantly aspects of hydrogen distribution and pocketing) lacked sufficient justification;
- Uncertainty was not systematically treated in accordance with good QRA practices.
- The QRA report did not document in sufficient detail what protocol the project team developed for ensuring QRA quality.

These concerns should be addressed before using the QRA as a tool for providing the technical basis for the adequacy of the design of the WTP piping to meet code requirements. The PRT recognizes that the QRA was developed to prevent unnecessarily complex designs for mitigating hydrogen combustion events. However, without further refinement of the modeling and treatment of uncertainty the WTP runs the risk of making inappropriate design decisions.

The Peer Review Team is aware the final QRA was issued in March 24, 2010, and that it addresses some of these issues and some of the following recommendations. The Peer Review Team understands from WTP that, subsequent to the March 24 report, there will be follow-up PIRT and sensitivity studies.

5. RECOMMENDATIONS

The Peer Review Team recommends the following actions be taking to improve the QRA to where it could serve as a design tool:

<u>Benchmarking the QRA</u>
Benchmark the QRA results (i.e., frequency and magnitude of hydrogen combustion events) against a test facility or other small facility to determine if the predictions agree with observable outcomes, or are at least conservative. More complex simulant experiments than have been performed would be especially useful.

The development of the WTP QRA is being supported by an extensive experimental program in a number of areas. It is recommended that the Project demonstrate that the models that are developed to describe phenomena in the prototypic WTP system are based on an interpretation of the experimental data that accounts for any potential scaling distortions. The processes and time scales of the phenomena that are expected to occur in prototype systems should be described and compared with those observed in the experimental systems.

Sensitivity Analysis

It is recommended that the integrated QRA be used for sensitivity calculations to test the effect of specific variables on calculated results. In particular, the ratio of run-up length to cell width is assigned a very large range that reflects the considerable uncertainty in understanding of flame acceleration phenomena. A uniform probability distribution between the selected end points is used in the QRA for the shape of the distribution. The PRT is unclear as to whether this is a conservative assumption or not. It is recommended that the sensitivity of the shape of the distribution and its end points on the computed results of the QRA be computed to determine if the results are particularly sensitive to these uncertainties.

As noted above, the Peer Review Team understands that a sensitivity analysis of the QRA model is planned to be performed in the near term.

Uncertainty Analysis

A systematic, robust estimate of the uncertainties inherent in the QRA methodology should be conducted. This should include:

- A phenomena identification and ranking tables (PIRT) type process that systematically lists the phenomena involved and their ranking relative to their importance on the results by a group of subject experts. Such a ranking scheme would then allow defensible judgments to be made as to which phenomena and associated uncertainties need to be included and addressed in the model, and how well the uncertainties in each case need to be addressed. The Peer Review Team understands that a PIRT analysis has been performed and is currently being documented and that this is intended to guide subsequent uncertainty analysis.

- The parameters treated as distributed should be expanded based on the PIRT.

- For those parameters that are represented by distributions, such as the event duration parameters, the choice of distribution type and range should be justified.

- Model uncertainty, especially for the gas pocket modeling, should be addressed with discussion of what other modeling methods were considered and why the one chosen was preferred.

- With regard to completeness a more complete discussion as to the margins that can be appealed to or the defense-in-depth provisions that could mitigate unforeseen load-aggravating phenomena or events would be helpful.

Discussion of Remaining Conservatisms

The report would also benefit from a thorough discussion of the conservatisms remaining in the WTP QRA method, and why they outweigh any non-conservatisms or incompleteness in the analysis. A discussion as to what parameters and model features drive the model results would be informative. This discussion would include information on which conservatisms were reduced by the QRA methodology, and by how much.

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APPENDIX A
DETAILS OF PEER REVIEW

A.1 INTRODUCTION

The peer review team reviewed the WTP QRA and some of the references mentioned in the report as well as numerous other pertinent WTP Project references, as listed in Section 6 of this report. The peer review team level of detail of review was limited due to the short-term schedule for the review and due to the level of resources applied. The basic idea of the review was to form some high-level judgments about the overall method proposed in the QRA model and to give feedback to the WTP for improvement of its modeling for the intended application.

One meeting and three conference calls were held with the WTP Project to obtain clarification on the QRA. Several email exchanges occurred between the WTP Project and the peer review team for purposes of obtaining additional information, including supporting reports for the QRA.

This appendix provides material that expands on Sections 3.1 and 3.2 of the Main Report. There is no further discussion of Section 3.3 of the Main Report because that section is brief and self-explanatory.

A.1.1 <u>QRA and Available Standards</u>

WTP takes guidance from process industry developed guidance (i.e., *Guidelines for Chemical Process Quantitative Risk Analysis* from the American Institute of Chemical Engineers) as well as commercial nuclear industry guidance (e.g. Regulatory Guide 1.200, *An Approach for Determining the Technical Adequacy of Probabilistic Risk Assessment Results for Risk-Informed Activities*). However, the WTP QRA report notes that currently no DOE standards or guidance exist that could be followed for this specific application of using QRA for design margin quantification. Rather, they used good practices and lessons learned from the U.S. Nuclear Regulatory Commission (NRC), the Center for Chemical Process Safety (CCPS), and the National Fire Protection Association (NFPA) as guidance. Therefore the WTP project followed conventional risk assessment practices in the development of their novel tool for assessing piping design margins. This, of course is not the same as following an established consensus Standard for performing a risk assessment. The only true consensus Standard for probabilistic risk assessment is the ASME/ANS Standard (RA-Sa-2009) which was developed explicitly for commercially operating light water power reactors.

The light water reactor standard applies to operating power reactors. It notes that for plants under design or construction, for advanced LWRs, or for other reactor designs, revised or additional requirements may be needed. A new risk standard is being developed for that application. It does not apply to the next generation gas-cooled reactor or to sodium-cooled reactors. Risk standards will be developed for those applications. Consensus standards for the portions of risk assessments that deal with physical phenomena and offsite consequences for operating light water reactors are still in development. The development of nuclear risk standards by consensus standards organizations is coordinated by a Nuclear Risk Management Coordinating Committee (NRMCC or "Committee") has been established by the American

Nuclear Society (ANS) and the ASME (American Society of Mechanical Engineers). Attachment 1 to this Appendix is an excerpt from the current strategic plan of the NRMCC. It clearly shows that the Level 1 (events leading to core damage in operating light water reactors) plus Large Early Release Frequency (LERF) is the only currently approved consensus standard. It also provides the planning for future standards that go beyond this first standard. (Note that in the long range, NRMCC plans to address risk assessment for other nuclear facilities, transportation and storage of nuclear materials, and related activities, including design of such facilities)

The AIChE CCPS "*Guidelines for Chemical Process Quantitative Risk Analysis" (Second Edition, 2000)* is a guide and not a consensus standard; while it focuses on chemical hazards and their offsite consequences, it does not provided guidance on the details of combustion modeling and potential loading on piping. According to the WTP, however, the AIChE document did guide their thinking on setting up a fault tree and event tree framework, on finding appropriate data, and on approaches to quality assurance.

While it is reasonable for the WTP project to take guidance from the ASME/ANS consensus Standard and the above cited sources, as well as NASA guidance for risk assessment, their model QRA development cannot be said to meet a Standard because there is no specific standard for their situation. The WTP is creating a methodology for risk assessment of a new facility and addressing physical phenomena (hydrogen distribution and combustion) that are not addressed in current risk assessment standards.

In subsequent work, the WTP could provide, if possible, specific discussions of what they drew from each standard or guide and how it was used in their model development.

Appendix B contains the draft responses to this report by WTP and discusses their plans for future work in that regard.

A.2 REVIEW OF PHYSICAL MODELING AND MODELING ASSUMPTIONS

The WTP developed models in the following areas: 1) Gas Pocket Formation Frequency, 2) piping route modeling, 3) hydrogen generation, 4) pocketing of hydrogen in piping, 5) ignition and 6) combustion. Each subsection below provides the observations of the PRT in the specific area.

A.2.1 Gas Pocket Formation Frequency

The modeling to estimate the annual frequency of hydrogen pocketing, termed Operational Frequency Analysis (OFA) in the report, is carried out using a conventional fault tree approach. In the OFA various initiating events are propagated through the Boolean logic of the fault tree structure which includes the equipment and human failures that can influence the development of the initiator. The commonly used program CAFTA is used to generate minimum cut sets, whose frequency is added to obtain the frequency of the top event.

The types of initiating events analyzed seem reasonable, and the logic structure of the fault trees seems sound. The OFA model appears reasonable.

A.2.2 Piping Route Modeling

The modeling of the piping routes within the WTP is based on the plant drawings. The modeling seems to be carried out in detail and with great fidelity. The use of the piping modeling for estimating gas pocket formation is discussed in Section 2.4 in this appendix to the review report.

A.2.3 Hydrogen Generation

The objective of this element of the WTP model is to predict the rates of combustible gas generation that lead to a combustible gas pocket within a pipe segment. WTP assumes that hydrogen is generated volumetrically by thermolysis and radiolysis in the waste and that nitrous oxide is present as an oxidizing agent that would support combustion. The WTP currently assumes that there are no other gases present.

The gas generation rate from the Hanford wastes has been extensively studied and rate equations have been developed to characterize various waste types. The rate equations are based upon what appears to be a very extensive survey of the Hanford tanks in which gas generation was measured from waste samples, tank surveillance data and waste characterization data. Separate rate equations are presented for thermolysis and for radiolysis. At least two formulations are discussed, and reflect different levels of conservatism in terms of correlating the data. The experimental errors have been quantified. DE 2007b defines the specific WTP model being used, and presents the uncertainty distribution.

In addition to H_2 and N_2O other gases are present in the waste stream. These include inert gases that could potentially reduce the severity of combustion events. These other gases are not currently accounted for in the QRA analysis. This is clearly a conservative assumption, since the presence of inert gas would decrease the mixture reactivity and would decrease resulting combustion pressures. Since the effect of inert gas is a real physical phenomenon whose influence is readily calculated, the rationale for not taking credit for the inert gas is not apparent to the PRT. It is recommended that inert gases be included in the QRA analysis.

The hydrogen generation modeling is based on empirical fit of a rate equation to experimental data and the PRT concludes that approach is reasonable. DE 2009 presents a triangular uncertainty distribution for the hydrogen generation rate. The PRT has not reviewed the arguments used to justify this distribution.

A.2.4 Piping Segmentation and Pocketing of Hydrogen

The objective of this element of the WTP model is to identify the location, geometry and mass of combustible gases in the gas pockets that develop in the waste contained in a WTP pipe segment. The previous hydrogen combustion analysis conservatively assumed that combustible gases would accumulate at one location in a piping network. In the revised WTP model it is recognized that gas generation would take place within all of the waste found in the piping system, and that gas pockets could develop at many locations. A combustion event at one such location could conceivably involve less combustible mixture than previously assumed. The development of the revised WTP model is supported by an extensive simulant experimental program [DE 2010].

The phenomenon of hydrogen pocketing in the WTP complex involves gas generation and transport within the piping network of the WTP. The physical scenario constitutes a typical problem in the area of transient multiphase flow and transport. Such problems are typically analyzed using computer models involving solution of transient, one-dimensional conservation equations. In the case of the WTP facility, two phases would be considered. Conservation of mass, momentum and energy equations would be solved in conjunction with boundary and initial conditions. A set of constitutive relations would be developed for material properties and flow regime transition phenomena. Solution of such equations would provide the transient distribution of gas (and liquid) within the piping system which could be tracked as a function of time. The solution of the equations could be used by the QRA analysts to identify the locations and dimensions of gas pockets as a function of time since the start of the gas generation within the liquid. The WTP system is complicated by the fact that the liquid being considered is non-Newtonian and the constitutive relationships may not be readily available. Typically, analysis of complex problems such as this will be accompanied by simulation experiments, sometimes using real materials, in order to verify the prediction results in suitably complex and prototypic test facilities. This process was not totally followed in the WTP program.

Elements of the WTP gas pocket logic model are based upon observations of the transport phenomena made in the simulant experimental program. However, considerable uncertainties exist in the phenomena of pocket generation and transport. The basic assumption that the gas generated will attempt to be transported to higher elevations under buoyant force is physically reasonable. And, while the rule-based approach to tracking the gas through the maze of junctions has some physical sense, it is not clear that the assumed motion of the fluids satisfies conservation of mass, momentum and energy principles generally used to approach such problems. The gas pocket model is non-mechanistic in the sense that it is not based upon solution of conservation of mass, momentum and energy balance equations applied on a local basis within the pipe network. The WTP model does, however, conservatively assume that the mass of gas generated in a route remains in the route piping, despite outflows of gas through pipe segments open to the building volume.

The Project assumes that "vertical segments which are not part of a local high point are assumed to retain no gas in the form of pockets." This assumption seemingly would limit the lengthwise extent of gas pockets between neighboring segments. As a result the PRT believes that it may be possible for pocket lengths to be larger than the model would predict. Furthermore, considering that the experimental program was carried out using simplified idealized piping configurations and simulant fluids, the PRT cannot conclude that the gas pocket dimensions that would be predicted by the model are not non-conservative. This aspect of the WTP model requires more in-depth review. Largely because the WTP pocketing model is not based upon first principles; therefore, on the basis of its limited review effort, the PRT cannot conclude at this time that the pocket model predictions would be either realistic or conservative.

As discussed above, the PRT believes that there is significant modeling uncertainty associated with prediction of the pocket dimensions and mass of combustible gas in a pocket beyond the uncertainties associated with the current model parameters. It is recommended that WTP consider inclusion of model uncertainty in the pocket length formulation. One possibility is to use a pocket length multiplier with a probability distribution that is developed based upon physically-based engineering judgment.

A.2.5 Ignition

The objective of this element of the WTP analysis is to predict the likelihood of ignition and the likely location of ignition within a gas pocket.

The likelihood of ignition of combustible gas in a gas pocket is treated by WTP using an ignition source logic model [DE 2009, Appendix B, and Table B-1]. Three types of ignition sources are identified: mechanical, thermal and discharge, each characterized with its own probability. Finally, each source type is assigned a probability of packing sufficient energy to ignite the gas mixture. Combining these probabilities the probability of ignition by any of the sources is 0.32. The Project staff, however, has related that they are currently assuming a probability of ignition somewhere within a pocket of unity. Within its limited scope of review, the PRT has not reviewed the literature dealing with ignition and its applicability to the WTP. The PRT accepts this assumption as suitably conservative.

The current Project assumption is that the probability of ignition of a gas bubble is one. Given that the project assumes that ignition sources may be present, it is reasonable to assume that any bubble may ignite and the consequences must be determined. It is also reasonable to assume that ignition could occur anywhere along the length of a gas pocket with no bias since a plausible physical argument that would bias the ignition location has not been identified by the PRT.

A.2.6 Combustion Phenomenology

The objective of this portion of the WTP model is to identify conditions within a gas pocket likely to support combustion, to predict the mode of combustion, whether deflagration or DDT or PRC-DDT, and to predict the dynamic pressures developed within the combustible gas and transmitted to the remainder of the pipe network.

The Project treats the combustion phenomenology of H_2-N_2O mixtures with mechanistic methods that have been developed over the past 25 years, and has pursued a vigorous research program to acquire the combustion data and develop advanced models required for combustion analysis of the specific mixtures and specific geometries of interest to the WTP facility. These experiments have been performed in prototypic pipe sizes using gaseous mixtures covering a wide range of compositions. A substantial database has been developed. In the work reported here, only combustion in the facility piping network was considered. The potential for hydrogen combustion in any of the facility vessels was not reviewed.

The Project assumes that any ignition source that might be present at the facility would be of insufficient strength to directly initiate a detonation. Based upon previous experience, this is a reasonable assumption for initiating a gaseous detonation with low energy density sources of the type likely to be found at a chemical plant. As a result, the assumed ignition source would, if mixture stoichiometry were within the flammability limits of the mixture, ignite the mixture to initiate a deflagration which might, or might not, accelerate and develop into a transition to a detonation.

The Project combustion model begins with identification of the hydrogen event type and then proceeds to compute the characteristics of the pressure-time history of the event. The event types are (1) no event if the mixture composition renders it not flammable, (2) a deflagration, or (3) a deflagration-to-detonation transition (DDT) and (4) the pressure-reflection event PRC-DDT. The Project logic model for the combustion analysis is presented in Figure 2- 7 and Section 2.4.2.1 of [DE 2009]. This logic model is based upon several basic ideas concerning gaseous combustion developed over the last few decades: Flammability limit data are used to determine if a mixture will ignite, mixture cell size compared with pocket diameter is used as a measure of detonability, and run-up length compared with pocket length is used as a measure of the ability of a deflagration to rapidly accelerate to a detonation within the length of a gas pocket. The general concepts described here were reviewed and some of the data that have been developed to support the evaluations were also reviewed.

If an event is a deflagration with no transition to detonation, the pressure event is computed using standard methods as an adiabatic, constant-volume deflagration characterized by a quasi-static load on the piping network. This is a reasonable and conservative approach for slow deflagrations. For fast deflagrations, where the flame front is moving at a speed approaching the speed of sound, it is not clear if dynamic events are considered. The Project should consider if such events can generate dynamic pressures that can contribute significantly to the load analysis of the pipe network.

The cell width is used in the WTP combustion modeling as a measure of mixture detonability when compared with the lateral dimension of a confining pipe, and is also used as the scaling parameter for the run-up distance. For this reason, as well as others, it is an important parameter. The cell width, a function of mixture composition, is an empirical quantity, and has been measured as part of the WTP experimental program. These experiments have not been reviewed as part of the current review effort. However, it is known, and the data for H_2 and N_2O mixtures confirm, that measured cell widths for a given mixture composition can vary by a factor of two or more from experiment to experiment. There is a significant experimental uncertainty associated with the cell width variable associated with any specific mixture composition. WTP should consider converting the cell width into a variable with an uncertainty distribution for the analysis, where the distribution represents the experimental uncertainty.

The WTP combustion analysis makes use of the run-up distance concept to quantitatively capture the likelihood of the physical processes of flame acceleration, DDT and PRC-DDT within the piping network. This is being accomplished by comparison of the run-up distance with the axial extent of the combustible gas mixture within a WTP pipe segment. While the run-up concept has been a part of the combustion literature for decades, its current use by the Project to predict the combustion regime within a gas bubble and, hence, to determine the severity of the associated dynamic pressure event, is an advance in the state-of-the art. While the concept is a useful one, methods of predicting the actual quantitative value of the parameter is still in its early stages [Ciccarelli 2008]. Using available experimental data, the Project has chosen to use a probability distribution function to represent the range of the variable defined by the ratio of the run-up distance to cell size. They have used a very large range of the parameter to capture the uncertainties. The ratio of run-up distance to cell size was assumed to be in the range of 50 to 500, with a uniform probability distribution. It is the PRT's judgment that the direction taken to quantify the run-up concept is reasonable. The shape of the probability distribution is based, in part, on engineering judgment. It is recommended, therefore, that sensitivity analyses be performed using alternative characteristics of the probability distribution to determine the sensitivity of the QRA results to the particular assumptions regarding the shape of the distribution function.

If there is a DDT event, then the possibility of pre-compression effects and reflected pressure, PRC-DDT, is considered. These pressure events are among the largest that are encountered when considering detonations. The logic for the further analysis of the potential for these events is presented on p. 2-16 of [DE 2009]. Additional DDT severities are defined here, including the PRC-DDT. While the motivation to more finely subdivide the detonation severity is reasonable, it is not clear that available experimental data support this division. The Project should present the analysis of the available experimental data that supports this portion of the combustion logic model. It is recommended that the sensitivity of the QRA results to these assumptions should be determined.

The DDT and PRC-DDT events are dynamic and time-dependent. For the DDT events the peak pressure is taken as three times the Chapman-Jouget pressure and is combined with a function of space and time to reflect the fact that the detonation wave travels down the pipe and decays as it travels. The PRC-DDT events are treated similarly, except that the peak pressures may be larger than for a DDT event, and were shown by a limited number of experiments to vary with run-up distance. These pressure-time functions are provided as input to the structural loading calculations. The data reports supporting these developments were only briefly reviewed. The analytical approach, however, is judged reasonable.

The peak pressures associated with DDT and PRC-DDT are considerably larger than the theoretical Chapman-Jouget (CJ) pressures. For DDT the peak pressures are taken as three times the CJ values, while for the PRC-DDT events the peak pressures are represented as functions of the run-up distance. The pressures can be up to nearly 10 times the CJ values according to the correlation for pressure vs. run-up distance that was developed. It is unclear to the PRT how large the uncertainties are in the CJ pressure multipliers that are presented in the reports. The Project should consider these uncertainties and consider if the multipliers should be represented as uncertainty parameters.

A detailed review of the bulk of experimental and analytical work performed in support of the combustion analyses was not possible in the available time frame for review. The basic combustion modeling approach is judged to make use of accepted concepts, and the research program that has provided a sound basis for development of the combustion modeling adopted by the project. The basic approach to the modeling of the combustion phenomenology is judged reasonable.

A.3 Treatment of Uncertainties

When a more realistic method is used in place of a conservative approach it is important to have a good estimate of the total uncertainty involved in the more realistic method and to include the uncertainty in any comparison with acceptance criteria. Under the best of circumstances rigorous estimation of risk using a quantitative risk assessment is subject to many uncertainties for a one of a kind facility. For analysis of the WTP facility, where several unique, complex, and not fully understood processes occur, a robust uncertainty estimate is essential.

The QRA model is constructed as a probabilistic model to reflect the random nature of some of the constituent basic events such as the initiating events and equipment or human failures. The QRA report provides a brief discussion on input parameter uncertainty versus variability, where it is pointed out that the Monte Carlo simulation used in the approach does not distinguish between aleatory and epistemic uncertainty, and this seems acceptable for the purposes of the report. However, since uncertainty is such an important topic for the application of the QRA methodology, it is worthwhile to discuss the various sources of epistemic uncertainty that should be considered.

As discussed in the literature, for example NUREG-1855 [NRC 2009], it is helpful to categorize the epistemic uncertainties into those that are associated with the parameter values used and those that involve aspects of models used, because the methods for the characterization and analysis of uncertainty are different for the two types. In addition, a third type of uncertainty exists, namely uncertainty about the completeness of the model. While this type of uncertainty cannot be handled analytically, it needs to be considered when making decisions using the results of an analysis.

Parameter uncertainty is the uncertainty in the values of the parameters of a model given that the mathematical form of that model is satisfactorily established. Conventional practice is to characterize parameter uncertainty using probability distributions on the parameter values, and that is the case for some of the parameters used in the QRA model. A model uncertainty can arise because the phenomenon being modeled is not completely understood, and/or while some data or other information about the phenomena may exist, it needs to be interpreted to infer behavior under conditions different from those in which the data were collected. Model uncertainty may occur in the choice of the model itself or as uncertainty about the logic structure of the model. While it is possible to embed a characterization of model uncertainty into a risk assessment by including several alternate models, this approach is not commonly followed. Instead the usual approach is to demonstrate that the key uncertainties, reasonable alternative hypotheses, or modeling methods would not significantly change the assessment.

While lack of completeness is not in itself an uncertainty, but rather recognition of the limitations in the scope of the model, the result is an uncertainty about where the true risk lies. Incompleteness in the modeling can arise in two different ways: (1) some contributors/effects may be knowingly left out of the model for a number of reasons (lack of methods of analysis, can be screened as unimportant, cost, etc.), and (2) some phenomena or failure mechanisms may be omitted because their potential existence has not been recognized. These latter true unknowns cannot be addressed analytically. However, often such unknowns are addressed through the use of safety margins and defense in depth.

In the QRA report some parameter uncertainty is addressed with the Monte Carlo sampling that is part of the methodology. Considerations of model uncertainty, or compensation for completeness uncertainty, are not explicitly mentioned. To come to a good estimate of the total uncertainty involved in the modeling, the methodology would greatly benefit from a process like that used to establish phenomena identification and ranking tables (PIRT), illustrated for example in [ORNL 2008]. Such a process would consist of the systematic listing of the phenomena involved and their ranking relative to their importance on the results by a group of subject experts. Such a ranking scheme would then allow defensible judgments to be made as to which phenomena and associated uncertainties need to be included and addressed in the model, and how well the uncertainties in each case need to be addressed. The Peer Review Team understands from the WTP that a PIRT has been done recently and is currently being documented.

While the developers of the QRA methodology obviously attempted to incorporate uncertainty considerations, there is very little discussion in the report as to what process was used to decide which parameters would be treated as distributed, and how the distributions were chosen. There is also little discussion as to what parameters drive the model results. In other words, the treatment of the uncertainties appears to be ad hoc rather than following a systematic process. It is recommended that a more systematic and robust estimate of the uncertainties inherent in the QRA methodology be conducted, starting with a PIRT type of ranking of the significance of the phenomena involved. With respect to parameter uncertainties the Monte Carlo sampling incorporated in the approach is certainly a very useful tool. However, only some parameters are treated as distributed and many others (such as initiating event frequencies, error rates, and gas pocket model parameters) are input as single values when they would be more correctly also treated as distributed. The report notes that some of these single valued parameters may be treated as distributed, but this gives the impression that the choice of parameter values has not been finalized for applications. In addition, the range and distributions chosen for some of the key distributed parameters should be justified to make the modeling more credible. It should be noted that the PIRT type process, recommended above, could be used here to justify using only single (but conservative) values for some parameters that rank low in importance for the analysis results.

Model uncertainty is not discussed in the report. In this respect it would be reassuring, especially for the gas pocket modeling, to have a discussion in the report of what other modeling methods were considered and why the one chosen was preferred. Further discussion could address whether alternative models were likely or not to lead to similar results.

With regard to completeness there is some discussion of perceived conservatisms retained in the modeling, but there is no discussion as to the margins that can be appealed to or the defense-in-depth provisions that could mitigate unforeseen load aggravating phenomena or events. The formulators of the QRA method are convinced that the method is still a conservative one for use in the design of the WTP facility. A more detailed and thorough discussion of the conservatisms that remain in the QRA WTP method would be helpful to justify that this is the case and that uncertainties, including the completeness issue, have been adequately addressed.

Adding to the overall uncertainty is the fact that one had the impression from the report, as well as from discussion with the modelers, that the model and the parameter choices are still in somewhat of a state of flux at the time of the review.

ATTACHMENT 1: Status of ANS/ASME Risk Standards

(excerpted from the Strategic Plan of Nuclear Risk Management Coordinating Committee, Rev. 0, November 2009)

Current Status of Operating LWR Projects

The ASME Committee on Nuclear Risk Management (CNRM) and the ANS Risk-Informed Standards Committee (RISC) have the responsibility for development of consensus standards. Guidance can also be provided. However, such actions should be discussed with the NRMCC prior to ASME or ANS doing this work. ASME CNRM has accepted the overall responsibility to develop and maintain a new ASME/ANS Standard that incorporates the requirements to determine the technical adequacy to support risk-informed applications using a Level 1/LERF PRA (estimating core damage frequency CDF)) supplemented by an estimation of large early release frequency (LERF) for three plant operating conditions (power, low power, and shutdown), and for accidents initiated by internal hazards (including internal events, internal floods and internal fires), and external hazards (including external flood, seismic events, and wind). ANS RISC has accepted the overall responsibility to develop and maintain new ASME/ANS Standards to ascertain Level 2 PRA and Level 3 PRA technical adequacy to support risk-informed applications.

• An ASME/ANS PRA Standard has been issued as ASME/ANS RA-Sa-2009, "Standard for Level 1/Large Early Release Frequency Probabilistic Risk Assessment for Nuclear Power Plant Applications" (this is Addendum A to Revision 1). Revision 1, Addendum A of the PRA Standard has been endorsed by the NRC via Regulatory Guide (RG) 1.200, Revision 2, issued in March 2009.

• Low Power/Shutdown (LP/SD) – ANS RISC is preparing a LP/SD PRA Standard for incorporation into the above mentioned ASME/ANS PRA Standard.

• Extend PRA to full Level 2 PRA and Level 3 PRA – ANS RISC has established two writing groups to prepare these new standards.

Risk-Informed Developments for New LWRs

Identify needs, priorities and timing for development of new or modification of existing Standard(s) to address unique PRA requirements for new LWRs.

Action Plan:

- The NRMCC will assign a New Reactor Task Group to develop recommendations in this area.
- The committee works with industry, NSSS vendors and NRC on risk initiatives needed to support 10CFR52 licensing for new LWRs.
- ASME CNRM has established a project team to address changes in the existing LWR standards to treat new plant licensing, design and construction phases as well as unique requirements for advanced LWRs.
- ANS RISC will support the standard, providing expertise in Low Power/Shutdown and Level 2 and Level 3 PRA.
- Pending formation of a joint ANS/ASME committee and new agreements that may result, both societies will ballot this standard.

Risk-Informed Developments for Advanced Non-LWRs

Determine the need for a Standard to assess the technical adequacy of a PRA to support risk-informed applications and risk-informed safety classification scheme, to assist the advanced non-LWR designs.

Action Plan:

- ANS is addressing safety classification requirements for high temperature gas-cooled reactors (HTGRs). ASME is developing complementary risk-informed safety classification requirements for pressure boundary systems and components.
- ASME CNRM has established a project team to address the PRA standards needs for the advanced non-LWRs, such as HTGRs. This standard includes development of PRAs to be used in the design and construction stage. In addition, the ASME/ANS PRA Standard is being reviewed in detail for applicability for future reactors and identification of missing needed guidance.
- ANS RISC will support the standard, providing expertise in Low Power/Shutdown and Source Term and Consequence Analysis, as appropriate.
- Pending formation of a joint ANS/ASME committee and new agreements that may result, both societies will ballot this standard.

PROPOSED LONG TERM PROJECTS

- Assign a Task Group to investigate approaches for the development of a Life Cycle, Risk-Informed Nuclear Code.
- Determine need for, and, if appropriate, develop standards for Qualification of RISC-3 items (Safety-Related, Low Safety Significant SSCs).
- Address PRA for other nuclear facilities, transportation and storage of nuclear materials, and related activities.
- Develop risk methodology to address terrorism threats at nuclear power plants.
- Promote use of risk-informed approaches in the design, safety review, licensing and operation of nuclear facilities.

The Member Organizations of the Nuclear Risk Management Coordinating Committee are:

American Nuclear Society
American Society of Mechanical Engineers
Institute of Electrical and Electronic Engineers
U. S. Nuclear Regulatory Commission
U. S. Department of Energy
Nuclear Energy Institute
Electric Power Research Institute
Nuclear Steam Supply Systems Owners Groups

#	Page	Section	Action Item / Comment	Responsible	Proposed QRA Team Response (DRAFT)
1	iv	QRA Data and Uncertainties	"The Peer Review Team also found the QRA document's discussion of the treatment of uncertainties to be brief and the area to be narrowly focused. These factors limit the ability of the reader of the QRA report to understand the uncertainties associated with the QRA results.		A more thorough discussion on the treatment of uncertainty in the QRA model will be provided as part of a follow-up report / calculation documenting the details of the QRA model including the latest modifications to the model based on feedback from the HPAV Independent Review Team (HIRT) as well as results of sensitivity studies.
2	iv	QRA Development Process	"The QRA report had a very limited discussion of the approach to quality assurance of the product, which consisted of a summary of the NRC approach. The Peer Review Team was unable to conclude whether the QRA was developed in accordance with standard industry quality assurance processes for developing a PRA/QRA."		The "For Information Only" report [DE 2009] was intended to document the methodology employed in the WTP hydrogen event QRA model. Because the model is being developed in a rapid application development (RAD) environment, the documentation supporting the development of the model is being advanced in parallel with the model itself. This documentation will be made available as part of final documentation of the QRA model. An explanation of how the QRA development process is compliant will be provided in the next report revision.
3	iv	QRA Development Process	"The QRA method has been exercised for some example cases, but apparently there has not yet been a more formal benchmarking of the method against a test facility or other small facility to determine if the predictions of the methodology are consistent with the observable outcomes, or at least conservative."		Two sets of benchmarking cases are currently being performed. The first set is intended to test the model against results generated during hydrogen event testing at SwRI. Specifically, the model will be used to probabilistically determine the resulting hydrogen events for various initial (pre-ignition) test conditions within a piping system of a geometry consistent with that tested at SwRI. These benchmark cases will be used to determine if the QRA model's Event Progression Logic (EPL) module produces results consistent with the SwRI test results. The EPL module is responsible for the calculation of the frequency of the various event types (deflagrations, DDTs, PRC-DDTs) given a pocket as well as their severity. The second set of benchmark cases is intended to test the QRA model's Gas Pocket Logic (GPL) module against results generated during gas pocket retention and formation testing performed at DEI. The testing was performed by injecting nitrogen gas in a static test fluid in a representative piping system. Experiments were conducted for multiple values of fluid yield stress as well as at various system configurations. The QRA model will be tested against these experiments by calculating the location and dimensions of gas pockets for the same fluid rheology and piping system configuration as simulated during several of the gas pocket formation tests. Results of this benchmarking are expected to support the modeling approach used in the GPL module by showing that the model predictions are consistent with the experimental results.
4	v	Summary	"The Peer Review Team recognizes that the QRA was developed to prevent unnecessarily complex designs for mitigating hydrogen combustion events. However, without further refinement of the modeling and treatment of uncertainty the WTP runs the risk of making inappropriate design decisions."		A detailed sensitivity analysis is being performed which entails approximately 100 cases in which the uncertainty associated with the selection of specific distributions for key parameters as well as key assumptions will be quantified. When not readily quantifiable through the use of a sensitivity case, the effect of other parameters, distributions, or assumptions will be discussed and arguments made as to their appropriateness and / or conservative treatment with regards to the QRA model results.

5	1	1.2 Background	"The WTP project developed a QRA method that (1) determines the likelihood of hydrogen events and the relative importance of event hazards: (2) models gas pocket formation using physically based engineering judgment; (3) takes credit for improved phenomenological understanding and test-informed analytical models for deflagrations and detonations; and (4) guides implementation of the appropriate code-based structural response and acceptance criteria tied to the frequency of postulated hydrogen events. The WTP QRA method is documented in the Dominion Engineering, Inc. report "Quantitative Risk Analysis of Hydrogen Events at WTP: Development of Event Frequency-Severity Analysis Model," R-6916-05-01 Rev 1, December 2009 [DE 2009]."		It should be noted that [DE 2009] is a "For Information Only" report intended to document the approach used in the QRA model and is therefore not inclusive of a complete description of the various data flows in the model nor of the latest improvements / adjustments made to the model since the report's issuance. Specifically, the information contained in this report is not considered sufficient to "re-calculate" the model in its entirety. The complete QRA model will be documented in detail in a separate report following incorporation of the latest recommendations made by the HPAV Independent Review Team.
6	4	3.1.3 Peer Review Team Evaluation	"Much testing was carried out on simple piping configurations to obtain and justify many of the parameters used in the gas pocket logic model."		The test program used to support the development of relevant input parameters and correlations used in the gas pocket logic model was performed in a transparent piping system of representative diameter which included piping features commonly found in WTP piping systems. These included two test rigs of 2 and 4 inch diameter piping sizes with inverted U-bends (used to model gas accumulation at system high points), multiple dead legs in close proximity (representative of jumper headers in the hot cell), inclined horizontal piping (commonly used throughout WTP), and stair step piping. Although the length of typical WTP waste transfer routes exceeds that of the piping system used in testing, the results generated during the test program are scalable to longer piping systems. Gas pocket behavior in the vicinity and / or within piping features such as dead legs and local high points is dependent only on the presence of these features and therefore can be readily applied to these same features in WTP waste transfer piping systems.
7	4	3.1.3 Peer Review Team Evaluation	"In the QRA model the WTP piping routes are broken down into sectors, portions and segments, whose geometry is faithfully modeled. The distribution of hydrogen pockets and their size is highly dependent upon this geometry in the QRA modeling method. The method is not based upon solution of conservation of mass, momentum and energy balance equations applied on a local basis within the pipe network. Instead the method is based upon gas transport rules developed from extensive testing in simple piping configurations and with what the WTP team believes are conservative assumptions. One such assumption is that the mass of gas generated in a route remains in the route piping, despite outflows of gas through pipe segments open to the process building volume. Although this is a reasonable approach, the Peer Review Team concluded that the method lacks sufficient justification to assure its conservatism relative to how the hydrogen may actually be distributed in the WTP pipes during accumulation conditions. This issue could result in substantial differences between the actual and modeled hydrogen combustion consequences. The QRA report does not discuss why this modeling approach is justified relative to other modeling approaches, such as those using first principles, i.e., the report does not discuss modeling uncertainty (see Section 3.2 below)."		The gas pocket logic model is based on the principle of conservation of mass of gas evolved from the waste located in the waste transfer piping system at the initiation of the hydrogen accumulation event. Once the event duration is determined (as part of OFA calculations), the amount (mass) of gas evolved from the waste is fully defined. From this point, the gas pocket logic model performs conservation of mass on the gas evolved from the waste and distributes it throughout the system based on observations made during Gas Pocket Formation testing. The gas pocket logic model does not perform conservation of mass on the waste itself meaning that the reduction in evolved gas which would result from waste being displaced out of the open piping system by expanding gas bubbles is conservatively neglected. The amount of waste displaced from the system by expanding gas bubbles is not tracked as it was concluded to not impact the determination of hydrogen event types. Conservation of momentum is not considered as the systems are considered quasi-static and stationary (i.e., the actual velocity of bubbles moving in the system are not considered critical to the determination of event types). The form of the gas pocket logic (GPL) model discussed above lent itself to its implementation in an Excel workbook space for integration with the remainder of the QRA model. It is acknowledged that a differential model incorporating the gas transfer rules currently implemented in the existing gas pocket logic model may have provided the user with additional flexibility but given the Rapid Application Development (RAD) environment in which the QRA model was developed, the currently employed approach was deemed most likely to yield the necessary data in the

					allowable time frame. It is possible that limited studies be conducted as part of sensitivity analyses to quantify the impact of certain assumptions made in the gas pocket logic model and that this be performed using a different formulation for the accumulation and transfer of gas within a piping system.
8	5	3.1.3 Peer Review Team Evaluation	"The basis for the physical aspects of the QRA model has relied in part on extensive testing in simplified piping configurations, but there has not been a more formal evaluation of the model, as would be expected before application as a design tool. There has been no benchmarking of the physical aspects of the model against a test facility or other small facility with a reasonably complex piping network to determine if the predictions of the model are consistent with the observable outcomes, or at least conservative. This facility would be designed to simulate the transient multiphase processes within the complex WTP piping networks that result in pocket formation. The complexity of a network that would be needed and the choice of fluids that would be used for additional benchmarking could be a subject for a subsequent review."		See Response 6 regarding Gas Pocket Formation test program. See Response 3 regarding model benchmarking.
9	6	3.2.2 Overview of WTP QRA Data Input and Uncertainty Analysis	"The QRA model is constructed as a probabilistic model to reflect the random nature of some of the constituent basic events such as the initiating events and equipment or human failures. In the QRA report some parameter uncertainty is addressed with the Monte Carlo sampling that is part of the methodology. Considerations of model uncertainty, or compensation for completeness uncertainty, are not explicitly mentioned."		See Response 1.
10	6	3.2.2 Overview of WTP QRA Data Input and Uncertainty Analysis	"Single values were provided for route and segment specific parameters that reflect geometric or other deterministic features. Furthermore single valued parameters were provided for initiating event frequencies and error rates. Some parameters did include distributions, such as the event duration parameters. Failure rate parameters for equipment failure and human errors were obtained from what appear to be acceptable industry sources. The QRA report identified that the value of some of these parameters had not been finalized."		Indeed, at the time of the PRT review, some of the QRA model inputs had not been finalized and are currently being refined. Given the level of knowledge associated with route geometry and the presence (or absence) of certain components in a waste transfer route (i.e., pumps, valves, heat exchangers, etc.) the QRA team maintains that it is appropriate to represent these inputs as point values. Although some of the initiating event frequencies and error rates were represented with point values, it is expected that the results of the PIRT analysis being documented in parallel with the model development will help inform whether some of these point value inputs would be better represented as distributed inputs. Additionally, a sensitivity analysis will be performed in which the effect of uncertainty in input parameters otherwise modeled as point values is quantified.
11	6	3.2.3 Peer Review Team Evaluation	"The QRA report appropriately references the source of some of the point estimates used (e.g., human failure rates). The Peer Review Team concludes that these were taken from conventional industry sources. However the basis for other input parameters was not clear."		The basis for all input parameters, their value, and their distribution (if applicable) will be provided as part of a comprehensive report following the incorporation of the latest modifications to the QRA model based on feedback from the HPAV Independent Review Team.
12	6	3.2.3 Peer Review Team Evaluation	"Although the QRA report provides a brief discussion on how it treated input parameter uncertainty it does not provide a comprehensive discussion that demonstrates that uncertainty has been addressed in accordance with best industry practices. While the developers of the QRA methodology obviously attempted to incorporate uncertainty considerations, there is very little discussion in the report as to what process was used to decide which parameters would be treated as distributed, and how the distributions were chosen. There is also little discussion as to what parameters drive the model results. In other words, the treatment of the uncertainties appears to be ad hoc rather than following a systematic process. With respect to parameter uncertainties the Monte Carlo sampling incorporated in the approach is certainly a very useful tool. However, only some parameters are treated as distributed and many others (such as initiating event frequencies, error rates, and gas pocket model parameters) are input as single values when they would be more correctly also treated as distributed. The report notes that some of these single valued		See Response 10 regarding status of input definitions at the time of the PRT review. See Response 4 regarding sensitivity analysis. See Response 1 regarding uncertainty.

			parameters may be treated as distributed, but this adds to the impression that the methodology is not quite ready for application at the time of the peer review. In addition, the range and distributions chosen for some of the key distributed parameters should be justified to make the modeling more credible."		
13	7	3.2.3 Peer Review Team Evaluation	"Model uncertainty is not discussed in the report. In this respect it would be reassuring, especially for the gas pocket modeling, to have a discussion in the report of what other modeling methods were considered and why the one chosen was preferred. Further discussion could address whether alternative models were likely or not to lead to similar results."		See Response 1 regarding uncertainty.
14	7	3.2.3 Peer Review Team Evaluation	"With regard to completeness there is some discussion of perceived conservatisms retained in the modeling, but there is no discussion as to the margins that can be appealed to or the defense-in-depth provisions that could mitigate unforeseen load aggravating phenomena or events."		The conservatisms reduced by the QRA model and how the remaining conservatisms still outweigh any non-conservatisms introduced by selected models and / or modeling approaches will be discussed as part of comprehensive report following finalization of latest model modifications based on HIRT recommendations.
15	7	3.2.3 Peer Review Team Evaluation	"Adding to the overall uncertainty is the fact that one had the impression from the report, as well as from discussion with the modelers, that the model and the parameter choices are still in somewhat of a state of flux at the time of the peer review."		At the time of the peer review, some of the QRA model inputs as well as some of the constituent models remained in a state of development. Updates to both have been made since the "For Information Only" report [DE 2009] was issued. These updates and a more detailed description of the QRA model, including all data flows within the model, will be covered as a part of a comprehensive report to be issued following the latest updates to the model resulting from HPAV Independent Review Team recommendations later this summer.
16	7	3.3.3 Peer Review Team Evaluation	"The discussion of the development process appropriately indicated that conventional quality practices from other industries were used, to the extent applicable, to guide the WTP project. The QRA report did not discuss what internal protocols were used to assure quality in the development of the model and its results."		See Response 2 regarding the parallel development of the documentation supporting model development and development of the model itself.
17	8	5 Recommend ations	"Benchmark the QRA results (i.e., frequency and magnitude of hydrogen combustion events) against a test facility or other small facility to determine if the predictions agree with observable outcomes, or are at least conservative. More complex simulant experiments than have been performed would be especially useful."		See Response 6 regarding Gas Pocket Formation test program. See Response 3 regarding model benchmarking.
18	8	5 Recommend ations	"The development of the WTP QRA is being supported by an extensive experimental program in a number of areas. It is recommended that the Project demonstrate that the models that are developed to describe phenomena in the prototypic WTP system are based on an interpretation of the experimental data that accounts for any potential scaling distortions. The processes and time scales of the phenomena that are expected to occur in prototype systems should be described and compared with those observed in the experimental systems."		See Response 5 regarding issuance of a comprehensive report documenting all of the model inputs and their justification.
19	9	5 Recommend ations	"It is recommended that the integrated QRA be used for sensitivity calculations to test the effect of specific variables on calculated results. In particular, the ratio of run-up length to cell width is assigned a very large range that reflects the considerable uncertainty in understanding of flame acceleration phenomena. A uniform probability distribution between the selected end points is used in the QRA for the shape of the distribution. The PRT is unclear as to whether this is a conservative assumption or not. It is recommended that the sensitivity of the shape of the distribution and its end points on the computed results of the QRA be computed to determine of the results are particularly sensitive to these uncertainties."		See Response 4 regarding performance of detailed sensitivity study.

20	9	5 Recommendations	"• The parameters treated as distributed should be expanded based on the PIRT. • For those parameters that are represented by distributions, such as the event duration parameters, the choice of distribution type and range should be justified. • Model uncertainty, especially for the gas pocket modeling, should be addressed with discussion of what other modeling methods were considered and why the one chosen was preferred. • With regard to completeness a more complete discussion as to the margins that can be appealed to or the defense-in-depth provisions that could mitigate unforeseen load-aggravating phenomena or events would be helpful."		See Response 1 regarding uncertainty. See Response 5 regarding issuance of a comprehensive report documenting all of the model inputs and their justification.
21	9	5 Recommendations	"The report would also benefit from a thorough discussion of the conservatisms remaining in the WTP QRA method, and why they outweigh any non-conservatisms or incompleteness in the analysis. A discussion as to what parameters and model features drive the model results would be informative. This discussion would include information on which conservatisms were reduced by the QRA methodology, and by how much."		See Response 14 regarding remaining conservatisms.
22	A-2	A.1.1 QRA and Available Standards	"In subsequent work, the WTP could provide, if possible, specific discussions of what they drew from each standard or guide and how it was used in their model development."	URS / DEI	No additional discussion will be provided except for the planned revisions in response 2.
23	A-3	A.2.3 Hydrogen Generation	"In addition to H2 and N2O other gases are present in the waste stream. These include inert gases that could potentially reduce the severity of combustion events. These other gases are not currently accounted for in the QRA analysis. This is clearly a conservative assumption, since the presence of inert gas would decrease the mixture reactivity and would decrease resulting combustion pressures. Since the effect of inert gas is a real physical phenomenon whose influence is readily calculated. the rationale for not taking credit for the inert gas is not apparent to the PRT. It is recommended that inert gases be included in the QRA analysis. "		The effect of other gases was investigated and it was concluded that these other gases act as diluents. Neglecting other gases is a known conservative assumption. Due to the uncertainty associated with the concentration of these other gases in the WTP waste streams, it has been imposed on the QRA modeling that negligible credit will be taken for the presence of diluents. The correlation currently used to determine the pressure associated with a deflagration and a CJ detonation requires a non-zero input for the concentration of diluents. These correlations conservatively predict a maximum peak pressure greater than the theoretical maximum when the triangular distribution used for percent diluents is specified with an upper bound of 3%. In reality, it is expected that diluent concentrations will often significantly exceed these negligible values.
24	A-4	A.2.4 Piping Segmentation and Pocketing of Hydrogen	"Elements of the WTP gas pocket logic model are based upon observations of the transport phenomena made in the simulant experimental program. However, considerable uncertainties exist in the phenomena of pocket generation and transport. The basic assumption that the gas generated will attempt to be transported to higher elevations under buoyant force is physically reasonable. And, while the rule-based approach to tracking the gas through the maze of junctions has some physical sense, it is not clear that the assumed motion of the fluids satisfies conservation of mass, momentum and energy principles generally used to approach such problems. The gas pocket model is non-mechanistic in the sense that it is not based upon solution of conservation of mass, momentum and energy balance equations applied on a local basis within the pipe network. The WTP model does, however, conservatively assume that the mass of gas generated in a route remains in the route piping, despite outflows of gas through pipe segments open to the building volume."		See Response 7 on the Gas Pocket Logic model.

25	A-4	A.2.4 Piping Segmentation and Pocketing of Hydrogen	"The Project assumes that "vertical segments which are not part of a local high point are assumed to retain no gas in the form of pockets." This assumption seemingly would limit the lengthwise extent of gas pockets between neighboring segments. As a result the PRT believes that it may be possible for pocket lengths to be larger than the model would predict. Furthermore, considering that the experimental program was carried out using simplified idealized piping configurations and simulant fluids, the PRT cannot conclude that the gas pocket dimensions that would be predicted by the model are not non-conservative. This aspect of the WTP model requires more in-depth review."		The test fluid used in the Gas Pocket Formation test program was fabricated so as to have representative yield strength and viscosity. The piping systems in which the testing was performed included representative piping features and configurations (i.e., not simplified). Despite the fact that actual waste transferring piping systems at WTP are typically longer than the piping used in the test program, the testing and test program was designed such that the results could be applied to systems of greater length. In the Gas Pocket Logic model, pockets are actually not necessarily restricted to be at most as long as the segment they are in. In fact, if a pocket forms at a local high point, it can extend all the way back to the beginning of the sector in which its initiating segment is located.
26	A-5	A.2.4 Piping Segmentation and Pocketing of Hydrogen	"As discussed above, the PRT believes that there is significant modeling uncertainty associated with prediction of the pocket dimensions and mass of combustible gas in a pocket beyond the uncertainties associated with the current model parameters. It is recommended that WTP consider inclusion of model uncertainty in the pocket length formulation. One possibility is to use a pocket length multiplier with a probability distribution that is developed based upon physically-based engineering judgment."		Pockets are not restricted to be of a certain length. Rather, they are assumed to grow in length assuming a fixed cross-sectional area (as a function of simulant yield stress). Depending on the location of the pocket in the piping system, the pocket can either grow to the full length of the sector in which its initiating segment is located (if pocket is predicted to occur at a local high point) or the full length of the segment in which it is located (e.g., if the segment is located somewhere in the middle of a multi-segment sector). It should be noted that, during the Gas Pocket Formation test program, very few gas pockets in non-Newtonian waste were observed to extend beyond more than a few pipe diameters in length, irrespective of the length of the straight pipe segment in which they formed. It is acknowledged that if these observations were taken into account in the Gas Pocket Logic model, a greater number of shorter pockets would be predicted to exist. However, given the typical event durations and the fact that the worst hydrogen events require a certain minimum length of gas pocket to occur, it was concluded to be more conservative to not limit the length of gas pockets based on observations made during Gas Pocket Formation testing but rather, let them grow potentially to the required lengths to support the more severe hydrogen events in each piping segment.
27	A-5	A.2.5 Ignition	The likelihood of ignition of combustible gas in a gas pocket is treated by WTP using an ignition source logic model [DE 2009, Appendix B, and Table B-1]. Three types of ignition sources are identified: mechanical, thermal and discharge, each characterized with its own probability. Finally, each source type is assigned a probability of packing sufficient energy to ignite the gas mixture. Combining these probabilities the probability of ignition by any of the sources is 0.32. The Project staff, however, has related that they are currently assuming a probability of ignition somewhere within a pocket of unity. Within its limited scope of review, the PRT has not reviewed the literature dealing with ignition and its applicability to the WTP. The PRT accepts this assumption as suitably conservative.		The QRA model currently assumes a probability of ignition of one in all modeled gas pockets. A segment-specific parameter has been added to the inputs so as to specify whether a different probability of ignition should be computed based on a combination of physical (geometric) arguments, available test data, and location of a given pipe segment. This relatively new optional input to the QRA model will be documented in detail in the comprehensive report documenting the model.
28	A-6	A.2.6 Combustion Phenomenology	"If an event is a deflagration with no transition to detonation, the pressure event is computed using standard methods as an adiabatic, constant-volume deflagration characterized by a quasi-static load on the piping network. This is a reasonable and conservative approach for slow deflagrations. For fast deflagrations, where the flame front is moving at a speed approaching the speed of sound, it is not clear if dynamic events are considered. The Project should consider if such events can generate dynamic pressures that can contribute significantly to the load analysis of the pipe network. "	TCL	The potential for prolonged fast speed deflarations is low and this is documented in calulation 6916-00-13. The dynamic affects of fast speed deflagrations affects have been provided in the HPAV Analysis and Design Criteria Report, 07-011.

29	A-6	A.2.6 Combustion Phenomenology	"The cell width is used in the WTP combustion modeling as a measure of mixture detonability when compared with the lateral dimension of a confining pipe, and is also used as the scaling parameter for the run-up distance. For this reason, as well as others, it is an important parameter. The cell width, a function of mixture composition, is an empirical quantity, and has been measured as part of the WTP experimental program. These experiments have not been reviewed as part of the current review effort. However, it is known, and the data for H_2 and N_2O mixtures confirm, that measured cell widths for a given mixture composition can vary by a factor of two or more from experiment to experiment. There is a significant experimental uncertainty associated with the cell width variable associated with any specific mixture composition. WTP should consider converting the cell width into a variable with an uncertainty distribution for the analysis, where the distribution represents the experimental uncertainty. "	TCL	
30	A-6	A.2.6 Combustion Phenomenology	"The WTP combustion analysis makes use of the run-up distance concept to quantitatively capture the likelihood of the physical processes of flame acceleration, DDT and PRC-DDT within the piping network. This is being accomplished by comparison of the run-up distance with the axial extent of the combustible gas mixture within a WTP pipe segment. While the run-up concept has been a part of the combustion literature for decades, its current use by the Project to predict the combustion regime within a gas bubble and, hence, to determine the severity of the associated dynamic pressure event, is an advance in the state-of-the art. While the concept is a useful one, methods of predicting the actual quantitative value of the parameter is still in its early stages [Ciccarelli 2008]. Using available experimental data, the Project has chosen to use a probability distribution function to represent the range of the variable defined by the ratio of the run-up distance to cell size. They have used a very large range of the parameter to capture the uncertainties. The ratio of run-up distance to cell size was assumed to be in the range of 50 to 500, with a uniform probability distribution. It is the PRT's judgment that the direction taken to quantify the run-up concept is reasonable. The shape of the probability distribution is based, in part, on engineering judgment. It is recommended, therefore, that sensitivity analyses be performed using alternative characteristics of the probability distribution to determine the sensitivity of the QRA results to the particular assumptions regarding the shape of the distribution function."	TCL	The proposed recommendation has merit and will be analyzed as part of the sensitivity analysis and changes made accordingly.
31	A-7	A.2.6 Combustion Phenomenology	"If there is a DDT event, then the possibility of pre-compression effects and reflected pressure, PRC-DDT, is considered. These pressure events are among the largest that are encountered when considering detonations. The logic for the further analysis of the potential for these events is presented on p. 2-16 of [DE 2009]. Additional DDT severities are defined here, including the PRC-DDT. While the motivation to more finely subdivide the detonation severity is reasonable, it is not clear that available experimental data support this division. The Project should present the analysis of the available experimental data that supports this portion of the combustion logic model. It is recommended that the sensitivity of the QRA results to these assumptions should be determined. "	TCL / REJ / JEC	The proposed recommendation has merit and will be analyzed as part of the sensitivity analysis and changes made accordingly. The severity of events is discussed in more detail in the HPAV Analysis and Design Criteria Report, 07-011.
32	A-7	A.2.6 Combustion Phenomenology	"The peak pressures associated with DDT and PRC-DDT are considerably larger than the theoretical Chapman-Jouget (CJ) pressures. For DDT the peak pressures are taken as three times the CJ values, while for the PRC-DDT events the peak pressures are represented as functions of the run-up distance. The pressures can be up to nearly 10 times the CJ values according to the correlation for pressure vs. run-up distance that was developed. It is unclear to the PRT how large the uncertainties are in the CJ pressure multipliers that are presented in the reports. The Project should consider these uncertainties and consider if the multipliers should be represented as uncertainty parameters. "	TCL / REJ / JEC	The appropriate multipliers are addressed in the time history calculations that are discusseed in more detail in the HPAV Analysis and Design Criteria Report, 07-011.

33	A-9	A.3 Treatment of Uncertainties	"However, only some parameters are treated as distributed and many others (such as initiating event frequencies, error rates, and gas pocket model parameters) are input as single values when they would be more correctly also treated as distributed. The report notes that some of these single valued parameters may be treated as distributed, but this gives the impression that the choice of parameter values has not been finalized for applications. In addition, the range and distributions chosen for some of the key distributed parameters should be justified to make the modeling more credible. It should be noted that the PIRT type process, recommended above, could be used here to justify using only single (but conservative) values for some parameters that rank low in importance for the analysis results. "		See Response 10 regarding status of input definitions at the time of the PRT review and use of PIRT analysis to confirm or update inputs and their distributions.
34	A-9	A.3 Treatment of Uncertainties	"Model uncertainty is not discussed in the report. In this respect it would be reassuring, especially for the gas pocket modeling, to have a discussion in the report of what other modeling methods were considered and why the one chosen was preferred. Further discussion could address whether alternative models were likely or not to lead to similar results."		See Reponse 1 on uncertainty.
35	A-9	A.3 Treatment of Uncertainties	Page A-10 (Section A.3). "The formulators of the QRA method are convinced that the method is still a conservative one for use in the design of the WTP facility. A more detailed and thorough discussion of the conservatisms that remain in the QRA WTP method would be helpful to justify that this is the case and that uncertainties, including the completeness issue, have been adequately addressed."		See Response 14 regarding remaining conservatisms.

Department of Energy

Washington, DC 20585

AUG 2 5 2010

MEMORANDUM FOR DALE E. KNUTSON
FEDERAL PROJECT DIRECTOR
WASTE TREATMENT PLANT

FROM: DR. STEVEN L. KRAHN
DEPUTY ASSISTANT SECRETARY FOR
SAFETY AND SECURITY PROGRAM
ENVIRONMENTAL MANAGEMENT

SUBJECT: Review of Hydrogen on Piping and Ancillary Vessels Implementation and Closure Plan

In your memorandum dated August 20, 2010, you requested Environmental Management (EM) review of the subject plan, which presently addresses the findings of the Hydrogen on Piping and Ancillary Vessels (HPAV) Independent Review Team (IRT). It is noted that the IRT differentiated between its findings and recommendations; their report stated, "The IRT has differentiated between its Findings and Recommendations.. Findings are things that must be done... if the new design approach is to meet its objectives and satisfy the safety and mission requirements of the piping and components... Recommendations are discretionary opportunities for improvement..." Thus, the subject plan logically focused on addressing findings first. The initial monthly revision of the plan will expand its coverage to address the recommendations of the HPAV IRT.

I have reviewed the structure, process and content of the subject plan and concur with it, subject to the following comment:

> It is my understanding, developed in several conversations with your staff and your contractor, Bechtel National Incorporated, that the Waste Treatment Plant (WTP) Quantitative Risk Analysis (QRA) is not used in the DOE-STD-3009 safety analysis process for either the unmitigated event consequence (which assumes piping system failure) nor in the mitigated analyses that rely upon secondary confinement (C5 cells and HVAC with HEPA filtration). Instead, the WTP QRA supports implementation of the design code, (ASME B31.3) for unconventional loads that may be imposed by combustion events within piping systems. Its use for that purpose is governed by the project's Safety Requirements Document (SRD).
>
> Subject to the SRD requirements, the QRA was approved as suitable for that purpose and accepted by Department of Energy (DOE)-Office of River Protection (ORP) in February 15, 2010. Use of the HPAV QRA as a code implementation tool was reviewed and determined to be acceptable by the HPAV IRT in their July 12, 2010, report, subject to several findings.

However, questions have been raised occasionally regarding the relationship of the QRA to STD-DOE-3009, and this has not been clearly discussed and documented in DOE–ORP and project technical documents. DOE-ORP should clearly define and document the role of the QRA relative to STD-3009 and provide this information to EM for review.

I look forward to continuing to work with you and your project team on issues of safety significance. If you have any further questions, please contact me at (202) 586-5151.

cc: I. Triay, EM-1
D. Chung, EM-2
M. Gilbertson, EM-3 (Acting)
G. Riner, EM-10 (Acting)

Department of Energy
Washington, DC 20585

FEB 0 1 2010

MEMORANDUM FOR ANDREW LAWRENCE
DIRECTOR
OFFICE OF NUCLEAR SAFETY, QUALITY ASSURANCE AND ENVIRONMENT
OFFICE OF HEALTH, SAFETY AND SECURITY

FROM: DR. STEVEN L. KRAHN
DEPUTY ASSISTANT SECRETARY FOR SAFETY AND SECURITY PROGRAM
ENVIRONMENTAL MANAGEMENT

SUBJECT: Department of Energy Guidance for Performing Dose Consequence Analyses

DOE-STD-3009, *Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Safety Analysis* provides guidance for estimating the radiological consequences of material released from nuclear facilities under accident conditions. Additional guidance for performing dose consequence analyses is provided in other Department of Energy (DOE) documents, such as DOE-HDBK-3010, *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities.* Some of these guidance documents are directly referenced in the DOE-STD-3009 (such as DOE-HDBK-3010) and some are not. This DOE guidance, if properly utilized, is intended to ensure an estimated dose consequence that is conservative. However, recent issues raised during the technical review of unmitigated dose consequence results for the Waste Treatment Plant (WTP) at the Hanford Site have identified that this may not currently be the case. As a result of these reviews, two parameters recommended for use by the DOE guidance are being questioned. These two parameters are described briefly below.

Airborne Release Fraction for a Pressurized Spray Leak:

DOE-HDBK-3010-1994 provides an airborne release fraction (ARF) and respirable fractions (RF) to be used for a spray leak. Handbook Section 3.2.2.3.1, "Venting Below the Liquid Level," provides the following bounding ARFxRF recommendation, along with limited additional guidance related to the geometry of the leak and evaporation:

"... a conservative assumption would be the pressurized release of the liquid via a very fine hole as occurs in a commercial spray nozzle... It is not anticipated that drops formed from breaches, cracks, leaks would generate finer drop size distribution. Therefore, the respirable fraction of the coarsest distribution generated by commercial spray nozzles shown in Figure 3-4 is selected as the bounding ARF, 1E-4, with a RF of 1.0. For other size fractions, the values can be inferred from the 0.128-inch (3.25-mm) diameter spray nozzle values at 200 psig (1.38 MPA_g) upstream pressure.

Other recent investigations ... suggest that, under some conditions, the fraction of drops in the finer size fractions (i.e., 10-µm and less) are greater for fine orifices (and possibly slot-type breaches) at high pressures, and that the evaporation of the liquid prior to deposition may reduce the size of the larger diameter drops to some extent. There is considerable uncertainty as to the value to assign the critical factor (Q, a drop size fitting parameter) and the analytical model, though useful in understanding the phenomenon, cannot presently be used to predict the size distribution of sprays."

Given this guidance, and the normally assumed maximum respirable size of 10µm, the spray leak has been modeled as a 0.128-inch orifice with an ARFxRF of 1E-4. Consideration of evaporation and a smaller or slit-type leak are not presently encouraged by the DOE-HDBK-3010 guidance. During the review of the WTP, the Defense Nuclear Facility Safety Board (DNFSB) staff provided comments on the unmitigated spray leak analysis that have called into question the ARF value in DOE-HDBK-3010. Specifically, the staff commented that the DOE-HDBK-3010 ARF may not conservatively represent the droplet size distribution produced by a slit or crack shaped spray leak; also, evaporation from the droplets, as they settle, could change the size distribution of the spray, increasing the amount of respirable material available for release.

Jofu Mishima, one of the principal authors of DOE-HDBK-3010-1994, has also observed that the Handbook may not be conservative in establishing an ARFxRF for a spray leak (see attached white paper). Limited experimental data relevant to liquid waste fluids (e.g., slurries, high-salt content solutions, mixtures, etc.) has been identified upon which a technical basis can be formulated. There is experimental data from industry with respect to spray nozzle droplet distributions and there are textbook correlations for some parameters but this information may not be directly applicable for the range of fluids of interest in high-level waste applications (for example). Parameters to be explored include leak size and shape, dissolved and suspended solids, plugging, surface tension, viscosity, density, and pressure.

Deposition Velocity:

In June 2004, the Department issued MACCS2 Code Guidance in response to DNFSB Recommendation 2002-1, "Software Quality Assurance." This guidance recommended using a deposition velocity of 1 cm/s to estimate exposures for unmitigated releases from DOE facilities. Deposition velocity is a simplified factor for representing plume depletion and is affected by the size distribution of particles released, wind speed, and the roughness of the surface upon which the plume is travelling.

At Hanford, the WTP incorporated a deposition velocity of 1 cm/s into MACCS2 dispersion calculations, consistent with this DOE MACCS2 code use guidance. The DNFSB staff raised a concern that this value was not conservative for unmitigated releases at the Hanford site, since the value did not bound measured values associated with a known and documented 1985 Hanford Tank Farm radiological release incident. The staff also referenced modeling assumptions cited in NUREG/CR 3332/ORNL-5968, and suggested that a value of 0.1 cm/s would be more appropriate.

Concluding Thoughts:

1) The uncertainty regarding these two parameters has potential impact across the complex. Pending resolution, guidance is needed regarding these parameters and what actions, if any, should be taken in the interim.
2) DOE needs to establish the appropriate value(s) for these two parameters and issue revised guidance. This will require the development of a suitable technical basis, and will likely require some research and development.
3) More broadly, it is essential that the proper implementation of DOE guidance produce results that are predictable and reasonably conservative. As such, it would appear that an ongoing effort to update and/or confirm the technical basis of its guidance related to nuclear safety is needed.
4) In addition, there is need to establish a mechanism for assessing and dispositioning future challenges to this guidance using a controlled, complex-wide approach as opposed to facility-by-facility adjustments or corrections.

If you have any questions, please contact me at (202) 586-5151.

Attachment

cc: Ines Triay, EM-1
Dae Chung, EM-2
Frank Marcinowski, EM-3
Don Nichols, CDNFS
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Review of the DOE-HDBK-3010-1994 Airborne Release Fractions and Respirable Fractions for Spray Releases from Hanford Waste Solutions

Jofu Mishima and Terry L. Foppe
Navarro Research and Engineering Consultants
(subcontractor to Longnecker and Associates, Inc.,
supporting the DOE Office of River Protection)

January 20, 2010

1.0 INTRODUCTION

The U.S. Department of Energy (DOE) Handbook, DOE-HDBK-3010-1994, *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities* (DOE 1994), provides guidance for modeling spray leak scenarios involving pressurized liquid releases and recommends bounding airborne release fractions (ARF) and respirable fractions (RF) to be used in accident consequence analysis. In response to review comments on the application of Handbook methodology for the Hanford Waste Treatment and Immobilization Plant (WTP) Preliminary Safety Analysis Report, the DOE Office of River Protection (ORP), sponsored a review of the technical basis of the Handbook guidance by Mr. Jofu Mishima, one of the principal authors of DOE-HDBK-3010, and Mr. Terry Foppe, support service subcontractor to ORP. The review was to support WTP project modeling of potential spray releases to consider whether a change to the previous approach was needed when accounting for leakage from pipes carrying pumped viscous waste slurries at pressures up to several hundred psig.

In December 2009, preliminary conclusions were provided to ORP that the Handbook spray release model may not be conservative in establishing the [ARF][RF] value for the WTP application. The purpose of this paper is to document the review findings, to provide recommendations regarding path forward for the WTP project, and to consider implications of potential revision to the DOE-HDBK-3010.

2.0 DOE-HDBK-3010 BOUNDING ARF/RF RECOMMENDATION

The Handbook Section 3.2.2.3.1, "Venting Below the Liquid Level", provides the following bounding ARF and RF recommendation and additional guidance related to the geometry of the leak and evaporation *{note: includes minor editorial changes made for clarity}*:

> "If the container or pipe holding an ambient-temperature liquid under pressure is breached, the liquid can escape in a variety of ways. Breaches venting pressurized liquids can range from pinhole leaks in pipes (generating a mist) to drips from very slow leaks to large jets of liquids that may gush from large holes. The amount and aerodynamic size distribution of the spray generated are a function of the size and characteristics of the breach, the upstream pressure, and the liquid characteristics (e.g., viscosity, density, volatility).
>
> For the purposes of airborne suspension, a conservative assumption would be the pressurized release of the liquid via a very fine hole as occurs in a commercial spray nozzle. The size

distribution of *{water drops from}* some commercial spray nozzles as a function of orifice diameter and upstream pressure were shown *{in a document}* by Mishima, Schwendiman and Ayer (October 1978). The size distribution of the liquid drops *{becomes finer (the fraction of small droplets increases)* ~~decreases~~ with *decreasing}* orifice diameter and increasing upstream pressure. It is not anticipated that drops formed from breaches, cracks, leaks would generate finer drop size distributions than equipment specifically designed for that purpose. Therefore, the respirable fraction of the coarsest distribution generated by commercial spray nozzles shown in Figure 3-4 is selected as the bounding ARF, 1E-4, with a RF of 1.0. For other size fractions, the values can be inferred from the 0.128-inch (3.25-mm) diameter spray nozzle values at 200 psig (1.38 MPa_g) upstream pressure.

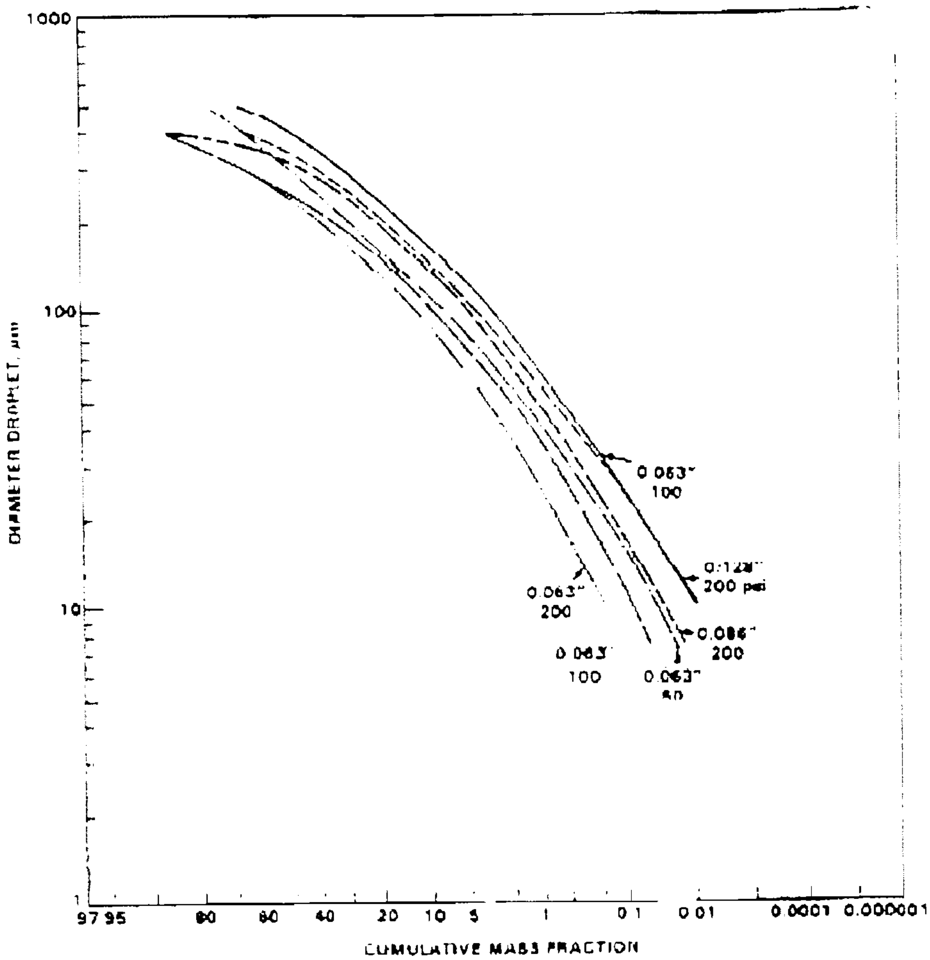

Figure 3-4 Mass Fraction vs. Droplet Diameters for Sprays as a Function of Orifice Diameter and Upstream Pressure (Mishima, Schwendiman, and Ayer October 1978)

{Note 1: The x-axis is labeled "Cumulative Mass Fraction". As shown on the scale, the value increases to the left to a maximum of 97.95. These values are in units of percent, i.e., the maximum value is 97.95% of the mass. For example, the 200 psig and 0.128" curve shows that the cumulative mass fraction for particles less than 10 um is 0.01 on the x-axis, which is 0.01% or 1E-4 of the mass.

Note 2: The liquid drop size distribution, of those plotted here, is considered the coarsest distribution since it has the smallest fraction of droplets d_{AED}≤10-um.}

> Other recent investigations (Leach, 1993; Gieseke, Kogan and Shaw, September 1993) using an analytical model suggest that, under some conditions, the fraction of drops in the finer size fractions (i.e., 10-μm Aerodynamic Equivalent Diameters [AED] and less) are greater for fine orifices (and possibly slot-type breaches) at high pressures, and that the evaporation of the liquid prior to deposition may reduce the size of the larger diameter drops to some extent. There is considerable uncertainty as to the value to assign the critical factor (Q, a drop size fitting parameter) and the analytical model, though useful in understanding the phenomenon, cannot presently be used to predict the size distribution of sprays."

To summarize the above, the Handbook [ARF][RF] recommendation is based on limited data from commercial hollow cone spray nozzles with orifice diameters of 0.063 inch, 0.086 inch, and 0.128 at three pressures (i.e., 50, 100, and 200 psig). The Handbook selects the respirable release fraction from the coarsest distribution generated by these commercial spray nozzles (i.e., 0.128 inch and 200 psi) as the bounding [ARF][RF].

3.0 REVIEW AND DISCUSSIONS

The situations and events considered for this type of phenomenon has expanded greatly over the 15 years since the DOE-HDBK-3010 was issued. Leaks from metal piping and vessels holding liquids of significantly different properties (e.g., slurries, high-salt content solution, mixtures, etc.) are now analyzed. Several questions regarding the validity of the DOE-HDBK-3010 spray release methodology for such waste solutions have resulted in a critical examination of the basis for the recommended bounding value.

It is apparent from examination of Figure 3-4 on page 3-20 of the handbook that the bounding value of 1E-4 [ARF][RF] does not bound all potential sprays from nozzles and therefore may not be bounding for metal vessels and piping. As illustrated in the figure and stated in the Handbook discussion, the size distribution of a spray formed by forcing liquid through a pressure nozzle/orifice becomes finer with decreasing size of the orifice and increasing pressure. The Handbook data and discussions were adopted from previous accident consequence studies for nonreactor nuclear facilities as discussed below.

The following information from the *Chemical Engineers' Handbook* (Perry 1941) was considered for the original evaluations:

- Pg 1982 – "Other Methods of Comminution"
- Pg 1983 – "Spray Nozzles"
- Pg 1985 – "Pressure Nozzles" - "Hollow cone Nozzles" This is the most common type of pressure nozzle in use. Fluid is passed into a whirl chamber through tangential passages or through fixed spiral so that it acquires a rapid rotation. The orifice is placed on the axis of the whirl chamber, and the fluid exits in the form of a hollow, conical sheet which then breaks up into drops.
- Pg 1988 Table 1, "Discharge Rates and Included Angle of Spray of Typical Pressure Nozzles" (reproduced at the end of this report)

The data listed demonstrate that the discharge rate and included angle (the area covered by the spray which increases with distance from the nozzle to some maximum) increase with upstream pressure and orifice diameter. Also note that the discharge rate and included angle of the various types of pressure nozzle vary with the hollow cone nozzle having the largest discharge rate of the three nozzles listed.

A graph of the data first appeared as Figure 6 (same as the Handbook Figure 3-4) in the evaluation of a mixed oxide fuel fabrication facility, *Increment of Analysis – An Estimate of Airborne Release of Plutonium from Babcock and Wilcox Plant as a Result of Severe Wind Hazard and Earthquake* (Mishima, Schwendiman & Ayer 1978). The evaluation was performed by the Pacific Northwest (National) Laboratory (PNL) for the U.S. Nuclear Regulatory Commission (NRC). It was used to confirm a bounding release estimate from seismic shaking of a glove-box with liquids in fragile containers and vessels such as glass based on the "fog limit" and a small enclosure. Relevant excerpts include *{note: includes minor editorial changes made for clarity}*:

"The volume of the average enclosure is assumed to be (3-ft X 3-ft X 8-ft = 72-ft^3) 2-m^3." *{pg 30}*

"For liquids held in a fragile container (those that could be ruptured by the impact of debris), it is assumed the entire volume of the enclosure is filled with a mass of respirable particles equivalent to the maximum mass formed in nature – fog, 10-mg/m^3 – and **size distribution of a coarse spray** *{bold emphasis added}*. Figure 6 *{pg 3-21}* is a plot of the cumulative mass fraction versus droplet diameters for hollow cone nozzles of orifice diameter ranging from 0.063- to 0.178-inches [1.6- to 3.25-mm, (1,600- to 3,250-μm)] at various liquid upstream pressures. The orifice diameter appears small and the pressures high for the conditions envisioned for most situations resulting in the break-up of fragile containers. The distribution of the coarsest spray (0.128-inches diameter at 200 psig) indicates the mass of droplets 100-μm or less is 50 times the mass of droplets 10-μm and less. Particles 100-μm could be carried beyond the remnants of the structure from wind hazards scenario and it was assumed that the airborne mass concentration of the particle d_{AED} and less in the enclosure was 500-mg/m^3." *{pg 33}*

The mass fractions for the various drop-size bins in Perry's *Chemical Engineers' Handbook* are not cited and the mass of the various numbers of drops in each size fraction must be converted using the volume of the drops and the density of water (1-g/cm^3). The mass fractions upon which the graph is based are cited in another PNL study, *Source Term and Radiation DOE Estimates for Postulated Damage to the 102 Building at the General Electric Vallecitos Nuclear Center* (Mishima, Schwendiman & Ayer 1979). The data are presented in Table A.1 of the Appendix A, "Discussion of Factors Used to Estimate Potential Airborne Release from Seismic Activity at the Vallecitos Nuclear Center" on page A.4 (reproduced at the end of this report). This data came from Table 4.1 "Drop Size of a Hollow Cone Nozzle at Various Pressures" from the 1943 printing of Perry's *Chemical Engineers' Handbook* in the section "Spray Nozzles authored by H.G. Houghton (Houghton 1943).

In the discussion in the Appendix A, under "AIRBORNE MASS CONCENTRATIONS WITHIN ENCLOSED SPACES, Liquids" *{note: includes minor editorial changes made for clarity}*:

{Pg A.1} – "Oak Ridge National Laboratory has been able to demonstrate ... that the meta-stable aerosol concentration of 10-mg/m^3 (approximately equivalent to fog) and has size distribution

shown in Figure A.2 *{pg A.3, 'Particle Size Distribution of a Stable Aerosol that has Encountered Several Changes in Direction in a Pipeline'.}* ... *{Pg A.3}* Table A.1 shows the cumulative masses associated with droplets less than various size ranges for three orifice diameters ranging from 0.063-in. (1.6-mm) to 0.129-in. (3.3-mm) at various pressures. These size distributions become coarser with increasing orifice diameters and decreasing pressure. ... These conditions appear to greatly exceed the pressures and are much finer than openings found for the breakage of glass equipment. Thus, an assumption of 10^{-4} of the inventory is conservative."

The above excerpts from the previous PNL evaluations of mixed oxide fabrication facilities in the late 1970s justified the bounding [ARF][RF] of 1E-4 for releases from liquids in glass equipment using two approaches, a "fog limit" and perspectives from hollow cone nozzles. The value is an estimate of the stable (post interaction and deposition) liquid aerosol in a glove-box. The value has been incorrectly labeled as a "spray release" and has been used in similar evaluations of NRC and DOE nonreactor nuclear weapons facilities since that time until the present day. Additional experimental studies have been performed at Pacific Northwest (National) Laboratory and are reported in Sutter (1983) and Ballinger, Sutter, and Hodgson. (1986). The information and data were compiled in NUREG-1320 and its update NUREG/CR-6410 (1998). This value was carried over to the guidance for investigators for the DOE Safety Survey in 1992 for engineering analysis of the potential releases from DOE Weapons Complex facilities. The Safety Survey guidance was shortly thereafter formalized into DOE-HDBK-3010 which included the commercial spray data for water (Figure 3-4) and recommended the 1E-4 as a bounding value for spray releases. The reliance on the bounding values cited for these 1970's studies without careful examination of the basis led to the selection of the bounding value for the Handbook and its long-time use.

3.0 CONCLUSIONS AND RECOMMENDATIONS

Although the value cited, 1E-4 [ARF][RF], was appropriate for the conditions postulated at the time (i.e., airborne release of material inside an enclosure due to seismic shaking or toppling of glass equipment containing water-like solutions), the value cited, fraction $\leq d_{AED}$ 10-μm AED, is not a bounding value for airborne releases from a spray of liquids with properties significantly different than water (e.g., neutralized and processed High-Level Waste). The reliance on the bounding values cited without careful examination of the basis led to the selection of the bounding value for the Handbook and its long-time use.

Summary of key review findings.

- The Handbook recommended bounding [ARF][RF] of 1E-4 of respirable droplets (≤10 μm AED) is based on "the coarsest distribution generated by commercial spray nozzles shown in Figure 3-4." While the 1E-4 value corresponds to discharge from a nozzle of 0.128" diameter and 200 psig, no specific recommendations regarding leak size and pressure was intended in the Handbook.
- The [ARF][RF] of 1E-4 of respirable droplets was originally selected for the PNL/NRC evaluation of a seismic scenario in a specific facility, Babcock and Wilcox mixed oxide fuel fabrication, and was incorrectly labeled as a "spray release". The value is an estimate of the stable (post interaction and deposition) liquid aerosol in a glove-box based

on 10 mg/m^3 "fog" limit due to breakage of glass/fragile equipment. Droplet evaporation is limited in such an environment.

- It was considered conservative by comparing to the commercial spray nozzle data for largest diameter coarse sprays which showed that a 1E-4 respirable value would be bounding.

- The 1E-4 value was carried over to the guidance for investigators for the DOE Safety Survey in 1992 for engineering analysis of the potential releases from DOE Weapons Complex nonreactor nuclear facilities.
- The Safety Survey guidance was shortly thereafter formalized into DOE-HDBK-3010 that included the commercial spray data for water (Figure 3-4) and recommended the 1E-4 as a bounding value for spray releases.
- Figure 3-4 shows that the size distribution of a spray formed by forcing liquid through a pressure nozzle/orifice becomes finer with decreasing size of the orifice and increasing pressure.
- The recommended 1E-4 value in DOE-HDBK-3010 remains valid for the studied glove-box, but is ***not*** a bounding value for liquid droplets of respirable size generated by sprays from metal piping and vessels as a function of opening size, configuration, and upstream pressure, with liquid properties that may be significantly different than water.

Resolution of the problem is made difficult by the fact that there are at least four types of liquids that must be addressed;

- Supernatant liquids that over-lie un-dissolved solids – these liquids may range from water-like fluids to high-dissolved solid solutions;
- High-dissolved solids solutions – the dissolved materials may cover a wide range of compounds but are primarily caustic/neutral sodium salts that may also contain organic compounds used to treat the waste at various times;
- Low solids (≤7-wt%) slurries; and,
- High solids (up to 20-wt%) slurries.

There is a lack of data available for the relevant physical properties (densities, viscosities, surface tension, etc.) of the liquids that are necessary to use in analytical models.

Some potential remedial measures for the WTP Project and for consideration of potential revision to the DOE-HDBK-3010 are:

<u>Establish a Data Base of Relevant Physical Properties of the Various Fluids Anticipated for the Tank Farms and WTP</u>. Some data may currently exist for properties of the fluids anticipated and should be compiled, technically supported, and documented.

<u>Analytical Models</u> - Rather than relying on commercial spray nozzle data using water, consider application of empirical correlations from the literature, using appropriately conservative assumptions for input parameters specific to the waste solution physical properties and applicable ranges of the correlations, to calculate the bounding $d_{AED} \leq 10$-

μm for spray releases. Although each method is not fully supported and simplifications need to be made to make the engineering calculations tractable, better experimental data for these types of event and materials is not currently available.

- An example of an empirical correlation is one similar to the SPRAY code developed for the Hanford Tank Farms in *A Model for Predicting Respirable Releases from Pressurized Leaks* (Hey and Leach. 1994), and its current modifications using a Microsoft Excel® spreadsheet. Other correlations may also be suitable. Prior to use, this methodology should be critically reviewed to assure that the selection of input parameters results in an overall bounding value, e.g., one approach is to consider using the 90th percentile-type value for up to 3 parameters and technically based average values for the remainder.

- It is acknowledged that the recent concern of evaporation of larger droplet sizes to respirable sizes can be addressed using these empirical models, however, as stated in the Handbook discussion, there is considerable uncertainty as to the value to assign the critical factor (Q, a drop size fitting parameter), which is also true for many other input parameters. Caution is urged to select appropriate input values such that the overall result is not unrealistically high or even physically not plausible, which would significantly over-estimate the release potential. Grossly conservative assumptions (e.g., 5% RH at 30° C) may skew the results and yield results that are misleading. It should be borne in mind that in ventilated areas, the air is conditioned to a comfort level for the personnel (70° F, 50% RH) and liquids sprayed into this environment would rapidly saturate. Liquids sprayed into a confined volume (even with a low ventilation rate) rapidly saturate the air from the liquid evaporated from the drops, liquids impacted on surfaces, and the pool formed by rainout. Only for liquids sprayed into the ambient atmosphere would evaporation be a significant concern for the entire release duration.

<u>Potential Plugging of Breaks by</u> Solids - Consider the plugging potential of the waste slurry, e.g., base the bounding $d_{AED} \leq 10$-μm for spray [ARF][RF] on the ratio of the largest particles and the minimum dimension (i.e., orifice diameter or crack width) with the expectation that if the ratio is >1, the leak will plug. Use the [ARF][RF] value for the orifice diameter that exceeds the size of the largest particles.

<u>Experimental Studies</u> - Perform experimental studies to determine the discharge rates droplet size distributions of the various fluids or their surrogates for the range and types of breaks anticipated. . Such experimental studies would face some severe difficulties such as:

- Providing fluids to use as surrogates without knowledge of the range of chemical composition and their effect on the physical properties to be defined; and,
- Determining the drop sizes of sprays generated – liquid drops splatter when impacting hard surfaces and potentially large number of drops in any location during any time.

Recommendations:

- Prepared a documented estimate/methodology for the maximum mass fraction of droplets in the respirable size range ($d_{AED} \leq 10$-μm) to appropriately bound Hanford waste solution spray releases.

- Consider publishing a "Change Notice" to DOE-STD-3010 to provide additional clarifications on the applicability of the current recommendations and alternative approaches to establish a bounding estimate.
    - Consider increasing from the current value of 1E-4 to 2E-3 (an increase by a factor of 20) based on the depressurization of containment via a failure above the liquid level or overall containment failure with the highest [ARF][RF] for a release from aqueous solutions (< 1.2 g/cm^3) from up to 500 psig (DOE-HDBK-3010, page 3-3). This is believed to be bounding, if not overconservative for many situations in the DOE Complex, but may not be appropriate as bounding for some unique situations since the ≤10-μm fraction for spray increases with decreasing orifice diameter and increasing upstream pressure.
    - As an alternative to a single fixed value, consider establishing a more general model through a complex-wide consensus process.

3.0 REFERENCES

Ballenger, Sutter & Hodgson 1986	Ballinger, M.Y., S.L. Sutter, and W.H. Hodgson. 1986. *New Data for Aerosols Generated by Releases of Pressurized Powders and Solutions in Static Air*, NUREG/CR- 4779 (PNL-6065), Pacific Northwest (National) Laboratory, Richland, WA.
DOE 1994	DOE Handbook *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities*, 1994, DOE-HDBK-3010-94, Change Notice 1, March 2000, U.S. Department of Energy, Office of Environment, Safety and Health, Washington, DC.
Hey and Leach 1994	B.E. Hey and D.S. Leach. 1994. *A Model for Predicting Respirable Releases from Pressurized Leaks*, WHC-SD-GN-SWD-20007, Westinghouse Hanford Company, Richland, WA.
Houghton 1943	Houghton, H.G. 1943. "*Spray Nozzles*" in Chemical Engineers' Handbook, 2nd Edition, (later printing than the 3rd Impression by J.H. Perry, Editor, cited below), McGraw-Hill, New York, NY.
Mishima, Schwendiman & Ayer 1978	Mishima, J., L.C. Schwendiman, and J.E. Ayer. October 1978. Increment of Analysis – *An Estimate of Airborne Release of Plutonium from Babcock and Wilcox Plant as a Result of Severe Wind Hazard and Earthquake*, PNL-2812, Pacific Northwest (National) Laboratory, Richland, WA.
Mishima, Schwendiman & Ayer 1979	Mishima, J., L.C. Schwendiman, and J.E. Ayer. February 1979. *Source Term and Radiation DOE Estimates for Postulated Damage to the 102 Building at the General Electric Vallecitos Nuclear Center*, PNL-2844, Pacific Northwest (National) Laboratory, Richland, WA.

Perry 1941	Perry, J.H. 1941. Chemical Engineers' Handbook, 2nd Edition, 3rd Impression, McGraw-Hill Book Co., Inc., New York, NY.
Sutter 1983	Sutter, S.L. August 1983. *Aerosols Generated by Release of Pressurized Powders and Solutions in Static Air*, NUREG/CR-3093 (PNL-4566), Pacific Northwest (National) Laboratory, Richland, WA.

Table 1 Discharge Rates and Included Angle of Spray of Typical Pressure Nozzles (Perry's pg 1988)

Type	Orifice Diameter, in.	Discharge, gal/min, and included angle of spray							
		10 psig		25 psig		50 psig		100 psig	
		Discharge	Angle	Discharge	Angle	Discharge	Angle	Discharge	Angle
Hollow cone	0.046	—	—	0.10	65	0.135	68	0.183	25
	0.140	0.535	82	0.81	88	1.1	90	1.50	93
	0.218	1.25	83	1.88	86	2.55	89	3.45	92
	0.375	7.2	62	11.8	70	16.5	70	---	----
Solid cone	0.047	---	---	0.167	65	0.235	70	---	---
	0.188	1.60	55	2.46	58	3.43	60	4.78	60
	0.250	3.35	65	5.40	70	7.50	70	10.4	75
	0.500	17.5	86	27.5	84	38.7	87	---	---
Fan	0.031	0.085	40	0.132	90	0.182	110	0.252	110
	0.093	0.70	70	1.12	76	1.57	80	2.25	80
	0.187	2.25	50	3.70	59	5.35	65	2.70	65
	0.375	9.50	66	15.40	74	22.10	75	30.75	75

Table A.1 Drop Size Distribution of 3 Hollow Cone Nozzles at Various Pressures
(Pg A.4 Mishima, Schwendiman, and Ayers 1979)

Drop Size, µm)[a]	Percent Drops in Size Fraction											
	0.063-in. (1.6-mm)						0.086-in. (-mm)				0.128-in. (3.3-mm)	
	50-psig		100-psig		200-psig		100-psig		200-psig		200-psig	
	Vol%	Wt%[b]	Vol%	Wt%[b]	Vol%	Wt%[b]	Vol%]	Wt%[b]	Vol%	Wt%[b]	Vol%	Wt%[b]
10	0.038	0.038	0.079	0.08	0.17	0.2	0.01	0.01	0.03	0.03	0.01	0.01
25	0.31	0.35	0.44	0.5	0.9	1.1	0.09	0.1	0.24	0.3	0.12	0.1
50	2.0	2.4	2.2	2.7	3.2	4.3	0.5	0.6	1.3	1.6	0.73	0.8
100	5.0	7.4	6.0	8.7	7.0	11.3	2.6	3.2	3.4	5.0	3.5	4.3
150	9.1	16.5	10.4	19.2	11.8	23.1	4.6	7.8	6.1	11.1	6.5	10.8
200	15.2	31.7	18.3	37.5	21.5	44.6	7,19	14.9	9.6	20.7	11.3	22.1
300	21.7	53.4	24.5	82.0	29.9	74.5	13.5	28.4	21.4	42.6	21.1	43.2
400	12.8	66.2	25.5	87.5	25.5	100	25.3	53.9	44.9	87.5	24.6	67.7
500	12.5	78.7	12.5	100	---	---	24.8	78.6	12.6	100	32.2	100
600	21.5	100	---	---	---	---	21.4	100	---	---	---	---

[a] The Test fluid is water with a density of 1-g/cm^3 ∴ $d_G = d_{AED}$.
[b] Cumulative fraction associated with drops ≤ than the stated size.

Department of Energy
Washington, DC 20585

April 5, 2010

MEMORANDUM FOR DISTRIBUTION

FROM: INÉS R. TRIAY
ASSISTANT SECRETARY FOR
ENVIRONMENTAL MANAGEMENT

SUBJECT: Federal Technical Authority Board Charter

The Office of Environmental Management (EM) formally established a Federal Technical Authority Board (TAB) on March 6, 2009. The TAB serves as a consensus building and advisory body to integrate certain functional responsibilities within EM and the Office of Safety and Security Program, with coordination and cooperation from other program offices. This technical responsibility includes design, engineering, technology, safety and has authority across the entire Department of Energy EM portfolio, providing particular focus on projects identified to have significant technical issues or risks.

Due to changes made during the EM reorganization, it is necessary to update and reissue the TAB Charter (attached). Dr. Steven L. Krahn, Deputy Assistant Secretary for Safety and Security Program is assigned as the TAB Chairman.

If you have any questions, please contact me or Dr. Krahn at (202) 586-5151.

Attachment

cc: C. O'Dell, EM-1
D. Chung, EM-2
F. Marcinowski, EM-3

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DEPARTMENT OF ENERGY
OFFICE OF ENVIRONMENTAL MANAGEMENT
TECHNICAL AUTHORITY BOARD
CHARTER

Purpose

This Charter describes the Technical Authority (TA) Board, (hereinafter referred to as the 'Board') within the Department of Energy (DOE) Office of Environmental Management (EM). The Board will serve as a consensus building and advisory body to integrate certain functional responsibilities with the coordination and cooperation of other program offices, across the DOE-EM project portfolio. The Board will develop policies, planning, standards, and guidance to provide an effective and efficient integration of technical responsibilities (includes design, engineering, technology, and safety) for capital and major modification projects. The Board has authority across the entire DOE-EM portfolio, providing particular focus on projects identified to have significant technical issues or risks. The Board will also provide review and guidance regarding project related actions that require DOE-EM corporate approval within the Critical Decision (CD) process, including:

- Actions involving technical issues that require a critical response to senior DOE management and stakeholders outside of DOE;
- Actions which will establish the technical requirements for future, major EM procurement activities; and
- Recommendations regarding the adequacy of resources available within EM to establish a level of technical excellence.

Where appropriate, the Board will recommend to senior DOE-EM management possible engineering solutions to technical issues that have broad application across the project portfolio and provide the synergistic benefit of a unified DOE-EM approach. The Board will exercise stewardship in creating a structure of DOE-EM technical experts, under the administration of this Board; along with establishing a process for the effective utilization of these resources within DOE-EM, to assist Federal Project Directors (FPDs) in conducting their responsibilities and assisting the Board in achieving its functional responsibilities. Further, the actions of this Board will be closely coordinated with the schedules of major EM projects to support CDs and other important milestones.

The Board will establish and maintain the necessary structure and methodology for DOE-EM involvement at the corporate level in safety and technical issues, when such project involvement is required.

The types of EM activities that the Board will consider include, but are not limited to:

- Proactive review of the status of required technical information associated with EM projects to support CD schedules;
- Response to specific technical issues of concern raised by the Defense Nuclear Facilities Safety Board (DNFSB), Nuclear Regulatory Commission (NRC), Environmental Protection Agency (EPA), or other important stakeholder groups;
- Response to Price Anderson related enforcement actions, technical inquiries raised by Congress, General Accountability Office, Office of Management and Budget, and other similar federal oversight authorities;
- Identify common technical issues across EM sites and develop lessons learned and foster standard practices to address them;
- Review draft sections and appendices of major EM procurements that establish contractor technical and safety requirements;
- Evaluate and resolve technical issues to support CDs; and
- Determine actions/decisions based on the External Technical Reviews (ETRs) and the Technology Readiness Assessments (TRAs).

In conducting these, and other related activities, the Board advises and provides actionable recommendations to senior DOE-EM management; specifically EM-1, EM-2, and EM-3.

Membership

The Board Chair shall be designated by EM-1.

The following are standing Members of the Board:

- Deputy Assistant Secretary (DAS) for the Office of Program and Site Support, EM-50
- Deputy Assistant Secretary (DAS) for the Office of Safety and Security Program, EM-20 (DOE-EM Chief Safety Officer)
- Senior Representative from the Office of Safety and Security Program, EM-20 (designated in writing by EM-20)
- Senior Representative from the Office of Technology Innovation and Development, EM-30 (designated in writing by EM-30)
- Chief of Nuclear Safety (US-1)

Additional advisory personnel will be added by the Chair on an ad hoc basis to address specific issues. The Deputy Assistant Secretary for Technical and Regulatory Support (EM-40), and the Deputy Assistant Secretary for Project Management, (EM-10), and the Deputy Assistant Secretary for Acquisition and Contract Management (EM-80) will be called upon by the Chair, as required, to provide advice in their areas of responsibility and all Board decision-making documents will be provided to them.

Though the Chief of Nuclear Safety (CNS) is considered a regular member of the Board, the CNS may be excused as a voting member to support independent auditing or oversight of Board functions. This should be coordinated in advance by the CNS to ensure a minimum Board quorum will exist.

Roles & Responsibilities

1. Chair

   a. Establishes, implements, and maintains the Board vision, mission, goals, and objectives with the Board;
   b. Approves all Board agendas and meeting minutes;
   c. Assigns Technical Issue Leads for topics of interest to the Board;
   d. Directs the work of the Technical Issue Leads to ensure that deliberations of the Board are consistent with the needs of EM senior management and this charter; and
   e. Assigns issue specific advisors to each Board meeting.

2. Board Member Roles and Responsibilities

   a. Provide solutions, ideas, and suggestions to issues that affect the vision, mission, and goals of the Board;
   b. Actively participates in Board activities and attends all Board meetings, unless excused;
   c. Assists the Chair to prioritize issues and initiatives and make decisions; and
   d. Brings knowledge of and is prepared to discuss perspectives and plans for issues relating to engineering excellence and integration of technical and safety issues within EM project management.

3. Technical Issue Leads

   a. Are assigned by the Chair to analyze and document issues, coordinate deliberations and present recommendations;
   b. Attend meeting(s) pertaining to the issues that they have been assigned;
   c. Coordinate the distribution of technical information to the Board members;
   d. Develop a plan for resolution of the issue that they have been assigned;
   e. Coordinate factual presentations to the Board; and
   f. Document the results of Board deliberations for their assigned issues.

Quorum

Normally the attendance or participation of all five regular (voting) Members shall constitute a quorum of the Board. If Members fail to attend a meeting for which proper notice has been given, and the absence is excused by the Chair (due to emergency or other critical situations) then three Board Members shall constitute a quorum.

Meetings

- Attendance at Board meetings will be by invitation. While advisors may attend meetings, if requested by one of the Board Members, their participation should be limited to addressing questions expressed by Board Members.
- Special meetings of the Board may be called by the Chair to address specific topics which require a timely EM corporate response. The Chair will determine the appropriate participation in these cases.
- Meeting Frequency: The Board meets approximately monthly in person, or as necessary, to provide guidance for the DOE-EM mission. Additional (e.g., special) meetings may be called by the Chair and may be conducted via electronic media.
- Notice of Meeting: Written notice of regular meetings stating the place, day, and hour of the meeting and the purpose or purposes for which the meeting is called shall be delivered by the Chairman no less than five days prior to the meeting, along with all briefing materials and background information.
- Format: Meeting agenda will be designed to encourage interactive discussion and minimize time spent for presentations.

Issue Resolution and Change Process

- An issue may be brought before the Board by a variety of sources, including for example: Board Members, Field Office Managers, EM Corporate Managers, and Federal Project Directors.
- A request for the Board to consider an issue is submitted to the Chairman who develops the agenda for the meetings.
- The Board will review an issue and may:
    - Assign a Technical Issue Lead;
    - Direct further study;
    - Request more information;
    - Select technical advisors and/or form a subcommittee to prepare advice for the Board; and
    - Make a consensus recommendation (a formal request is prepared by the Technical Issue Lead documenting the Board's recommendation for submittal to the Chair).

- Board Members will develop action plans to ensure implementation of the Board direction in the associated Projects.

Board Decision Making and Dispute Resolution Process

The Board will come to a consensus recommendation. Consensus is defined as general agreement or accord. Simply, this means that each Board Member is comfortable with the recommendation, even if it may not be his or her first choice. For Board purposes, consensus will mean at least three-fourths of the voting Members agree. Any dissenting Board member will provide a written recommendation to the Chair to be attached to the Board's recommendation. However, from time to time, the Board may not be able to reach consensus. On those rare occasions, the Board will provide the disparate recommendations to EM Senior Management for consideration.

Department of Energy
Washington, DC 20585

March 6, 2009

MEMORANDUM FOR DISTRIBUTION

FROM: INÉS R. TRIAY
ACTING ASSISTANT SECRETARY FOR ENVIRONMENTAL MANAGEMENT

SUBJECT: Federal Technical Authority Board Charter

The Office of Environmental Management (EM) continues to make progress in establishing a Federal Technical Authority (TA) framework that places special emphasis on establishing a disciplined technical decision-making process for EM capital and major modification projects. I am pleased to formally establish the EM Technical Authority Board (TAB).

I have established the EM TAB to serve as a consensus building and advisory body to integrate certain functional responsibilities of the Office of Engineering and Technology and the Office of Safety Management and Operations, with coordination and cooperation of other program offices. These technical responsibilities include design, engineering, technology, and safety. The TAB has authority across the entire DOE-EM portfolio, providing particular focus on projects identified to have significant technical issues or risks.

The TAB has already proven its worth through its timely and effective action to address Radioactive Liquid Waste tank integrity issues raised by the Defense Nuclear Facilities Safety Board. Further, the TAB is soliciting technical issues from the field that warrant its consideration. Finally, several field offices have already designated Site Technical Authority personnel. Regardless of the title, designating principal site points of contact for the TAB is required. Most importantly, technically qualified personnel in these positions are critical to establishing the Technical Authority network. Each of the large sites (Richland, Office of River Protection, Oak Ridge, Savannah River, Carlsbad, Portsmouth/Paducah, and Idaho) is to confirm their Technical Authorities in writing (email) with the TAB Chair by April 5, 2009.

Attached is the charter for the TAB. Mr. Dae Chung, Deputy Assistant Secretary, Office of Safety Management and Operations will be the first chair. If you have any further questions, please contact Mr. Chung, at (202) 586-5151 or Mr. Mark Gilbertson, Deputy Assistant Secretary of Engineering and Technology, at (202) 586-0755.

Attachment

Distribution:

David A. Brockman, Manager, Richland Operations Office (RL)
Shirley Olinger, Manager, Office of River Protection (ORP)
Jeffrey M. Allison, Manager, Savannah River Operations Office (SR)
David C. Moody, Manager, Carlsbad Field Office (CBFO)
William E. Murphie, Manager, Portsmouth/Paducah Project Office (PPPO)
Steve McCracken, Assistant Manager, Oak Ridge Office (OR)
Rick Provencher, Deputy Manager, Idaho Operations Office (ID)
Mike Moore, Acting Director, Office of Small Sites Projects

cc:
C. O'Dell, EM-1
J. Owendoff, EM-3
C. Anderson, EM-3
J. Fiore, EM-6
F. Marcinowski, EM-10
M. Gilbertson, EM-20
M. Sykes, EM-30
D. Cochran, EM-40
J. Surash, EM-50
D. Chung, EM-60
C. Lagdon, EM-60
P. Bosco, MA-50
D. Miotla, ID
G. Boyd, OR
T. Spears, SR

DEPARTMENT OF ENERGY
OFFICE OF ENVIRONMENTAL MANAGEMENT
TECHNICAL AUTHORITY BOARD

CHARTER

Purpose

This Charter describes the Technical Authority (TA) Board, (hereinafter referred to as the 'Board') within the Department of Energy (DOE) Office of Environmental Management (EM). The Board will serve as a consensus building and advisory body to integrate certain functional responsibilities of the DOE-EM Chief Engineer (CE) and the Chief Safety Officer (CSO), with the coordination and cooperation of other program offices, across the DOE-EM project portfolio. The Board will develop policies, planning, standards, and guidance to provide an effective and efficient integration of technical responsibilities (includes design, engineering, technology, and safety) for capital and major modification projects. The Board has authority across the entire DOE-EM portfolio, providing particular focus on projects identified to have significant technical issues or risks. The Board will also provide review and guidance regarding project related actions that require DOE-EM corporate approval within the Critical Decision (CD) process, including:

- Actions involving technical issues that require a critical response to senior DOE management and stakeholders outside of DOE;
- Actions which will establish the technical requirements for future, major EM procurement activities; and
- Recommendations regarding the adequacy of resources available within EM to establish a level of technical excellence.

Where appropriate, the Board will recommend to senior DOE-EM management possible engineering solutions to technical issues that have broad application across the project portfolio and provide the synergistic benefit of a unified DOE-EM approach. The Board will exercise stewardship in creating a structure of DOE-EM technical experts, under the administration of this Board; along with establishing a process for the effective utilization of these resources within DOE-EM, to assist Federal Project Directors (FPDs) in conducting their responsibilities and assisting the Board in achieving its functional responsibilities. Further, the actions of this Board will be closely coordinated with the schedules of major EM projects to support CDs and other important milestones.

The Board will establish and maintain the necessary structure and methodology for DOE-EM involvement at the corporate level in safety and technical issues, when such project involvement is required.

The types of EM activities that the Board will consider include, but are not limited to:

- Proactive review of the status of required technical information associated with EM projects to support CD schedules;

- Response to specific technical issues of concern raised by the Defense Nuclear Facilities Safety Board (DNFSB), Nuclear Regulatory Commission (NRC), Environmental Protection Agency (EPA), or other important stakeholder groups;
- Response to Price Anderson related enforcement actions, technical inquiries raised by Congress, General Accountability Office, Office of Management and Budget, and other similar federal oversight authorities;
- Identify common technical issues across EM sites and develop lessons learned and foster standard practices to address them;
- Review draft sections and appendices of major EM procurements that establish contractor technical and safety requirements;
- Evaluate and resolve technical issues to support CDs; and
- Determine actions/decisions based on the External Technical Reviews (ETRs) and the Technology Readiness Assessments (TRAs).

In conducting these, and other related activities, the Board advises and provides actionable recommendations to senior DOE-EM management.

Membership

The Board Chair shall be designated by EM-1 on a rotational basis.

The following are standing Members of the Board:

- Deputy Assistant Secretary (DAS) for Engineering and Technology, EM-20 (DOE-EM Chief Engineer)
- Deputy Assistant Secretary (DAS) for the Office of Safety Management and Operations, EM-60 (DOE-EM Chief Safety Officer)
- Senior Representative from the Office of Engineering and Technology, EM-20 (designated by EM-20 in writing)
- Senior Representative from the Office of Safety Management and Operations, EM-60 (designated in writing by EM-60)

Additional advisory personnel will be added by the Chair on an ad hoc basis to address specific issues. The Deputy Assistant Secretary for Regulatory Compliance (EM-10) and the Deputy Assistant Secretary for Acquisition and Project Management (EM-50) will be called upon by the Chair, as required, to provide advice in their areas of responsibility and all Board decision-making documents will be provided to them.

Roles & Responsibilities

1. Chair
    a. Establishes, implements, and maintains the Board vision, mission, goals, and objectives with the Board;
    b. Approves all Board agendas and meeting minutes;
    c. Assigns Technical Issue Leads for topics of interest to the Board;
    d. Directs the work of the Technical Issue Leads to ensure that deliberations of the Board are consistent with the needs of EM senior management and this charter; and
    e. Assigns issue specific advisors to each Board meeting.

2. Board Member Roles and Responsibilities
    a. Provide solutions, ideas, and suggestions to issues that affect the vision, mission, and goals of the Board;
    b. Actively participates in Board activities and attends all Board meetings, unless excused;
    c. Assists the Chair to prioritize issues and initiatives and make decisions; and
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    e. Coordinate factual presentations to the Board; and
    f. Document the results of Board deliberations for their assigned issues.

Quorum

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