Department of Energy
Washington, DC 20585

February 11, 2015

The Honorable Jessie H. Roberson
Vice Chairman
Defense Nuclear Facilities Safety Board
625 Indiana Avenue NW, Suite 700
Washington, DC 20004

Dear Ms. Vice Chairman:

Enclosed is the Department of Energy's (DOE) Office of River Protection (ORP) response to the Defense Nuclear Facilities Safety Board's (Board) letter, dated October 23, 2014. The letter requested a written response outlining DOE's intent and plan to incorporate the updated Hanford volcanic ashfall hazard assessment into the Waste Treatment and Immobilization Plant (WTP) design and nuclear facility safety basis.

In addition to members from ORP and other DOE offices, subject matter experts within DOE Headquarters Office of Environmental Management (EM) participated in the Ashfall Planning Team (APT) to identify viable options and recommend a preferred strategy that EM supports. The APT also consulted with a number of external experts in developing this report and its recommendation. In an effort to maintain continuous open communications, EM ORP invited Board staff members to observe the deliberations of the APT. On December 2, 2014, ORP briefed Board staff members on the results of the APT's evaluation, their recommendations, and the proposed path forward. We are moving forward with the APT recommendations as described in the attached APT report, *Evaluation of Alternatives to Address Volcanic Natural Phenomena Hazards at the WTP.*

If you have any questions, please contact me or Mr. James A. Hutton, Acting Deputy Assistant Secretary for Safety, Security, and Quality Programs, at (202) 586-0975.

Sincerely,

Mark Whitney
Acting Assistant Secretary
for Environmental Management

Enclosure

Attachment
to
14-NSD-0048

Evaluation of Alternatives to Address Volcanic Natural Phenomena Hazards at the Waste Treatment and Immobilization Plant

(total number of pages, 216)

DOE/ORP-2014-07
Revision 0

Evaluation of Alternatives to Address Volcanic Natural Phenomena Hazards at the Waste Treatment and Immobilization Plant

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Office of River Protection
P.O. Box 450
Richland, Washington 99352

DOE/ORP-2014-07
Revision 0

Evaluation of Alternatives to Address Volcanic Natural Phenomena Hazards at the Waste Treatment and Immobilization Plant

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Assistant Secretary for Environmental Management

Office of River Protection

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EXECUTIVE SUMMARY

The Waste Treatment and Immobilization Plant (WTP) has two issues related to the design criteria for volcanic hazards. First, there is a gap between the current requirements and the current WTP design/safety basis. The U.S. Department of Energy (DOE), Office of River Protection (ORP) and the WTP contractor, Bechtel National, Inc., (BNI) had partially addressed this issue via safety analysis and cost baseline changes when the second issue arose: A new analysis by the U.S. Geological Survey (USGS)[1] resulted in a significant change to the volcanic hazard design criteria.

The new criteria included an increase in the postulated structural load from accumulated ash, which is not anticipated to impact the WTP structural design beyond some reduction of margin in the Analytical Laboratory and Low-Activity Waste Facilities. However, the criteria also include new requirements that represent greater than an order of magnitude increase in the ash airborne concentration. This increase represents additional design challenges because of the high outside air demand to support equipment required for safety-related mixing of high-level waste. In addition, the assumed duration of the suspended ash event in the new criteria changed from 20 hours to 60 days (due to wind resuspension), bringing into question the long-term sustainability of the many active components supporting safety-related mixing.

The WTP prime contractor provided an impact estimate associated with adopting the updated volcanic design criteria, but it was cost prohibitive for the project, and likely unsustainable for the required duration of an ashfall event. The WTP Federal Project Director subsequently directed the establishment of the Ashfall Planning Team (APT) to study the problem, identify viable options, and recommend a path to safe and sustainable resolution of volcanic ash design issues.[2] The APT was composed of nuclear safety experts; mechanical, electrical, and structural engineers; a geologist/volcanologist; operations specialists; a particulate resuspension subject matter expert; a contracting officer; and project risk experts.

The team studied the problems associated with implementing the new volcanic hazard design criteria at WTP, including associated schedule risks. The team found that design of nearly all impacted equipment is currently on hold for reasons other than volcanic hazards.

The team recognized immediately that a multi-faceted approach provided the best solution to current design challenges. With that goal, the team studied 16 alternatives and provided recommendations related to (1) existing assumptions/methodologies supporting the volcanic hazard design criteria; (2) potential operational strategies to mitigate impacts from an ashfall event, (3) potential hazards analysis alternatives to address the current ashfall controls, (4) facility design solutions for dealing with impacts from excessive ash concentrations and event duration; and (5) advanced notifications available before a Mount St. Helens eruption.

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[1] USGS, 2011, *Open-File Report 2011-1064: Estimate of Tephra Accumulation Probabilities for the U.S. Department of Energy's Hanford Site, Washington*, U.S. Geological Survey, Reston, Virginia.

[2] 14-WTP-0184, 2014, "The U.S. Department of Energy, Office of River Protection Waste Treatment and Immobilization Plant Ashfall Planning Team Charter," memorandum to W.F. Hamel from P.R. Hirschman, U.S. Department of Energy, Office of River Protection, Richland, Washington, September 22.

Table ES-1 summarizes the team's recommendation, which comprises a phased, comprehensive suite of options. The table includes associated rough order of magnitude cost estimates, and organizations assigned to lead follow-on actions. This approach has been presented to, and endorsed by, ORP management.

Table ES-1. Options to Address Waste Treatment and Immobilization Plant Ashfall Natural Phenomena Hazard.

Top Alternatives/Actions	ROM	Responsible Organization	Start Date
1. Commission USGS and NOAA to revise the estimate of ashfall consequences for the Hanford Site, with peer review by NARAC.	$200 thousand	ORP WED	Now
2. Pursue waste acceptance criteria or implement operational controls to address high hydrogen-generating or criticality-related feed.	-$500 million (cost savings)	ORP One System	Now
3. Conduct qualitative event tree evaluation (in accordance with DOE-STD-3009-94)	-$500 million (cost savings)	ORP NSD	Now
4. Perform filtration technology value engineering study: Grout vaults as settling chambers, sand filters, and other options to sustain confinement ventilation	$400,000 to $400 million	BNI update risk, MSOW, and hold ETG seismic qualification; ORP communication to initiate remainder of action	MSOW now; study after providing Action 1-3 results
5. Pursue 7-day warning notifications from USGS.	$20 million and interagency agreement	ORP to determine need	Revisit after Actions 1-3 are complete
6. Conduct ashfall focus group meetings every 6 months to review status of each action.	—	—	—

DOE-STD-3009-94, 2006, *Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Documented Safety Analyses*, Change Notice No. 3, U.S. Department of Energy, Washington, D.C.

BNI = Bechtel National, Inc.
ETG = emergency turbine generator.
NARAC = National Atmospheric Release Advisory Center.
NOAA = National Oceanic and Atmospheric Administration.
NSD = Nuclear Safety Division.
MSOW = management suspension of work.
ORP = U.S. Department of Energy, Office of River Protection.
ROM = rough order of magnitude.
USGS = U.S. Geological Survey.
WED = Waste Treatment and Immobilization Plant Engineering Division.

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TERMS

APT	Ashfall Planning Team
BNI	Bechtel National, Inc.
DOE	U.S. Department of Energy
DX	direct expansion
ETG	emergency turbine generator
HEPA	high-efficiency particulate air
HLW	High-Level Waste (Facility)
HYSPLIT	Hybrid Single Particle Lagrangian Integrated Trajectory (model)
Lab	Analytical Laboratory
LAW	Low-Activity Waste (Facility)
MSOW	management suspension of work
NARAC	National Atmospheric Release Advisory Center
NOAA	National Oceanic and Atmospheric Administration
NPH	natural phenomena hazard
ORP	U.S. Department of Energy, Office of River Protection
PC	performance category
PT	Pretreatment (Facility)
ROM	rough order of magnitude (estimate)
TTLFL	time to lower flammability limit
USGS	U.S. Geological Survey
VEI	Volcanic Explosivity Index
WNP-2	Washington Nuclear Plant 2
WTP	Waste Treatment and Immobilization Plant

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1.0 INTRODUCTION

The Hanford Waste Treatment and Immobilization Plant (WTP) Project is a complex of radioactive waste treatment processing facilities being designed and constructed by Bechtel National, Inc. (BNI) for the U.S. Department of Energy (DOE), Office of River Protection (ORP). The mission of the WTP is to process and immobilize Hanford tank farm waste into a stable glass form suitable for permanent disposal. Hanford tank waste comprises approximately 56 million gallons of highly radioactive and mixed hazardous materials, containing about 170 million curies of radioactivity, stored in 177 underground storage tanks at the Central Plateau of the Hanford Site.

The WTP Project is required to be designed to withstand natural phenomena hazards (NPH) in accordance with DOE-STD-1020-94, *Natural Phenomena Hazards and Design Criteria for DOE Facilities*, and DOE O 420.1B, *Facility Safety*. The current design criteria includes volcanic ash impacts expected from Mount St. Helens—the nearest active volcano and the only volcano in the region forecasted by the U.S. Geological Survey (USGS) as likely to produce significant quantities of volcanic ash at the Hanford Site within the operating life of WTP. Figure 1 shows the approximate frequencies and timeframes of Cascade Mountain volcanic eruptions over the last 4,000 years.

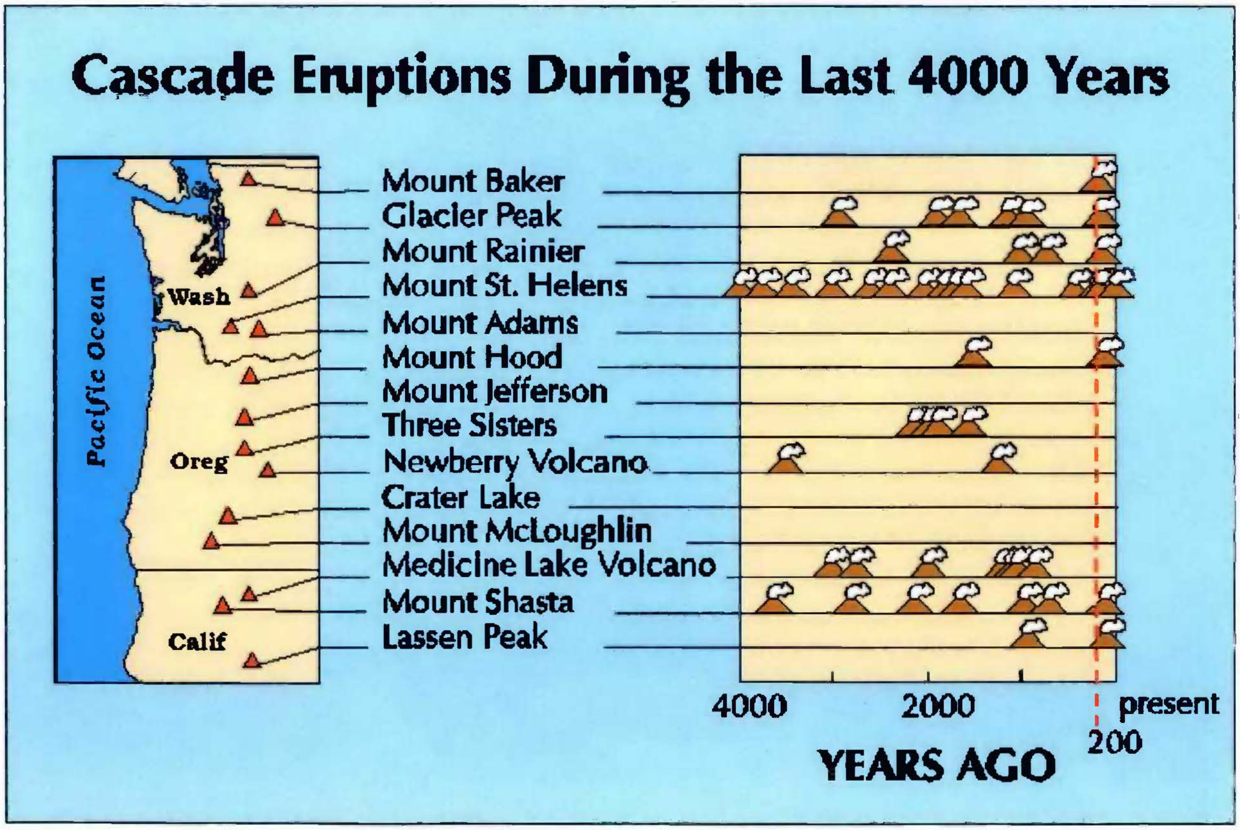

Figure 1. Cascade Volcanic Eruption Frequency.[3]

[3] Source: http://www.geology.ewu.edu/dept/eruption.gif.

Volcanic ash, like the ash from the 1980 eruption of Mount St. Helens shown in Figure 2, is composed of tiny jagged particles of rock and glass, as shown in Figure 3. Even a light dusting of volcanic ash can pose a health hazard to people and animals and damage crops, electronics, and machinery. Heavy ashfall, such as that from a large caldera-forming eruption, would devastate the surrounding area and affected areas downwind.

Figure 2. Volcanic Ash from Mount Saint Helens, 1980.

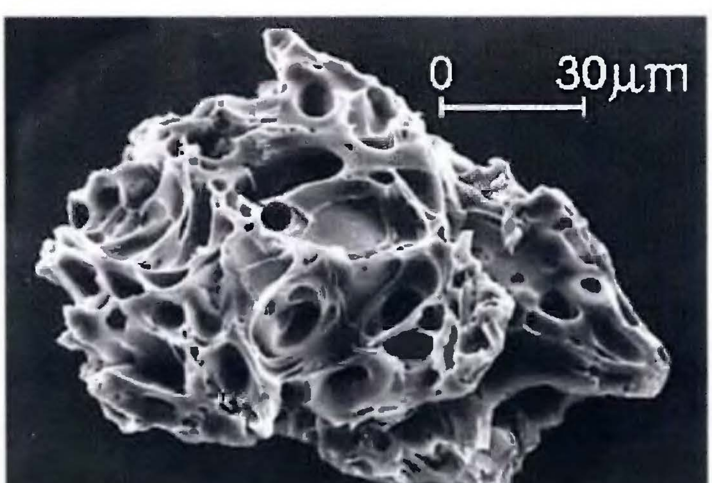

Figure 3. Ash Particle Magnified about 200 Times.

In the event of a large ash-producing eruption of Mount St. Helens, impacts to Hanford Site facilities potentially could include the following:

- Structural impacts from ash roof load
- Loss of site power due to ash-related arcing of electrical components
- Failure of air-cooled mechanical equipment or equipment that provides intake air (e.g., chillers, compressors, ventilation systems, generators) as a result of the airborne concentration of ash as it falls or from wind resuspension of ash.

1.1 BACKGROUND

The baseline BNI design strategy for mitigating ashfall impacts depended only on manual changeout of supply air filters serving the safety mixing, emergency power, and ventilation systems. In 2008, the DOE Office of Health, Safety and Security conducted an assessment of the WTP NPH safety strategy for volcanic ash and found this safety strategy to be unsustainable, given the air demand for safety mixing (HSS 2009, *Independent Oversight Inspection of Environment, Safety, and Health Programs at the Hanford Site Waste Treatment and Immobilization Plant*).

In 2010 and 2011, BNI completed Integrated Safety Management meetings and drafted an authorization basis amendment request to address the Office of Health, Safety and Security finding. The concept was based on isolating chemical hazards and idling melters to begin burning off the cold cap in the High-Level Waste (HLW) and Low-Activity Waste (LAW) Facilities upon receiving notice that a significant eruption was in progress, then allowing the Analytical Laboratory (Lab) and LAW Facility to shut down if ashfall were to reach the plant and interrupt site power. The HLW and Pretreatment (PT) Facilities would not operate or transfer waste during the ashfall event, but would maintain active safety functions of mixing, cooling, and confinement, relying on active supply filtration via bag-house filters to address the ash airborne concentration for systems that required outside air (24590-WTP-RPT-ENG-10-016, *An Evaluation of WTP Ashfall Design Requirements and Recommended Mitigation Strategy*). This approach was included in the project baseline via baseline change proposal 24590-06-05085, "Implementation of Technical Issues Resolution, Incorporation of the Multiple Operational Readiness Review Strategy, and Commissioning & Training Integrated Facility Testing," which incorporated Trend 24590-06-04855, "Ashfall Hazards Design Evolution," adding $15.6 million for self-cleaning bag-house filters, cleaned via compressed air back-pulse.

However, this strategy was not included in the WTP safety basis because of potential changes to the volcanic ash requirements. The volcanic ash requirements at that time (derived in WHC-SD-GN-ER-30038, *Volcano Ashfall Loads for the Hanford Site*, Rev. 0, and incorporated into HNF-SD-GN-ER-501, *Natural Phenomena Hazards, Hanford Site, Washington*, Rev. 1) were based on early USGS estimates, which came into question when ORP identified errors in the document. As a result, ORP requested that USGS update the Hanford Site estimate of ash accumulation using a probabilistic approach. The USGS completed the updated analysis in 2011 (USGS 2011, *Open-File Report 2011-1064: Estimate of Tephra Accumulation Probabilities for the U.S. Department of Energy's Hanford Site, Washington*).

After the USGS open file report was issued in April 2011, ORP contracted Pacific Northwest National Laboratory (via Washington River Protection Solutions LLC) to complete the data set.

The USGS report did not include airborne ash concentration or rain-on-ash structural load. Pacific Northwest National Laboratory used empirical methods to derive these values from the USGS data, and updated the Hanford Site criteria (WHC-SD-GN-ER-30038, Rev. 2, and HNF-SD-GN-ER-501, Rev. 2) in 2012. In 2012 and 2013, ORP directed BNI to quantify the impact of adopting the new criteria (12-WTP-0268, "Notice of Intent to Modify the Contract – U.S. Department of Energy [DOE] Document HNF-SD-GN-ER-501, Natural Phenomena Hazards, Hanford Site, Washington, Revision 2;" and 13-WTP-0032, "Request for Cost Estimate for Impact to the Waste Treatment and Immobilization Plant (WTP) for the Updated HNF-SD-GN-ER-501, Natural Phenomena Hazards (NPH), Hanford Site, Washington"). Revision 2 of HNF-SD-GN-ER-501 calculated a revised ash load that was nearly double the previous estimate. The report also included new criteria for tephra (ash) airborne concentration and resuspension of ash deposits. BNI had previously based airborne concentration on Columbia Generating Station/ Washington Nuclear Plant 2 (WNP-2) airborne ash criteria, while wind resuspension of ash had not been factored into the previous criteria. The new concentration and resuspension criteria led BNI to develop a basis of estimate that expanded on their previous bag-house filtration concept.

BNI predicted impacts to structural design to be limited to rework of calculations (3 man-years), with Lab and LAW bounded by snow load (with potential for reduced design margin due to ash drifts) and HLW and PT Facilities bounded by seismic loads. This conclusion was endorsed by the Structural Peer Review Team (13-WTP-0252, "Transmittal of Surveillance Report S-13-WED-RPPWTP-012 – Review of the May 2013, Structural Peer Review Team [SPRT] Report").

However, mechanical impacts were estimated by BNI to be significant because of the large amount of air needed for cooling and intake air for the equipment necessary to sustain safety mixing (e.g., compressors, emergency turbine generators [ETG], chillers). The concept added six new buildings, several of which were seismically rated. The overall outside air demand to sustain all of this equipment was 975,000 cfm (93 percent of this total was used to support equipment needed to produce 4,400 scfm of compressed air required for safety mixing). Power demand was 5.6 MW, which exceeded the capacity of the ETG (4.8 MW, but derated to 4.1 MW due to the 60-day duration). This added two new ETGs, and doubled the size of the ETG building. Parasitic load for facilities to support all the active filtration equipment, switchgear for added equipment, and cooling for added equipment was significant. The cost for this option was prohibitive, and the baseline cost to meet the current ash requirements, which had never been fully implemented in design, was not well understood and lacked supporting analysis.

It quickly became apparent to DOE that the uncertainties from other technical issues, (e.g., air demand required to accomplish safety mixing, equipment cooling, confinement ventilation) were driving BNI to adopt unsustainable design solutions for the new ashfall criteria. It was also clear that the baseline cost to meet the requirements was not quantified or well understood. To address these challenges, ORP directed BNI to focus on solving the other project technical issues (e.g., safety mixing), and subsequently determine the cost of the baseline ash mitigation design (14-WTP-0026, "Request for Design and Cost Estimate for the Baseline Natural Phenomena Hazards of Ash Fall, Hanford Site, Washington").

To provide a clear project path forward on this issue, the WTP Federal Project Director directed the formation of the Ashfall Planning Team (APT), which was chartered to review the available options and recommend a path to safe and sustainable resolution of volcanic ash design issues that is in the best interest of the government.

1.2 ASHFALL PLANNING TEAM SCOPE

In accordance with its charter (14-WTP-0184, "The U.S. Department of Energy, Office of River Protection Waste Treatment and Immobilization Plant Ashfall Planning Team Charter") the primary function and responsibility of the APT was to formally recommend to the WTP Senior Technical Authority and the WTP Federal Project Director a path to resolve the issues surrounding the new ashfall NPH criteria and the proposed safety strategy for ashfall mitigation at WTP. Innovative solutions were evaluated and considered relative to facility design and operations alternatives, keeping in mind nuclear safety requirements and the desired hierarchy of controls (i.e., prevention over mitigation, engineered controls over administrative).

The APT worked within the guidance of MGT-PM-IP-14, *Waste Treatment and Immobilization Plant Project Risk Management Procedure*. The team's goal was to recommend a path forward that could ultimately be integrated with the authorization-to-proceed processes for the HLW and PT Facilities to align with the resolution of other project technical issues and support the project schedule.

1.3 TEAM COMPOSITION

The APT had a core team with expertise in structural, electrical, and mechanical engineering, as well as nuclear safety. Members of the APT were selected based on technical qualifications, experience, familiarity with the subject matter, understanding of DOE nuclear safety requirements, and the individual's availability relative to the project activities they would support. Team members included senior and technical staff from the following organizations:

- ORP
- DOE Office of Nuclear Safety
- DOE Office of Safety, Security, and Quality Programs
- DOE Office of Tank Waste and Nuclear Material
- Support contractors.

1.4 TECHNICAL APPROACH

The APT conducted an initial review of WTP design criteria, supporting data, and the impacts of current design criteria. The evolution of WTP volcanic hazards design criteria, the technical basis used in the derivation of airborne concentration from wind resuspension of ash, and the technical basis for airborne concentration of this magnitude (based on data from other volcanic events) were evaluated. Section 2.0 presents the results of this review.

With a general understanding of the design criteria and associated impacts, the APT brainstormed a number of potential solutions that ranged from alternate design criteria to changes in design or operational strategies. The team then narrowed the solutions to a select number of alternatives that were investigated by APT members, either individually or in small groups. Section 3.0 summarizes the results of the investigations, which are documented in Appendices A through L.

As alternatives investigations were completed, they were presented to the team. The team brainstormed criteria that would form the basis of the decision of which alternatives to recommend, and deciding which should be considered prerequisites (i.e., mandatory requirements) and which should be weighted criteria. The team then used a secret ballot to determine weighting of each criterion. When all alternatives had been presented, the team used another secret ballot to ensure each member had an equal voice in determining the team's recommendation. Finally, to determine the team's recommendation, the team met after ballots were counted to review the results and ensure consensus. Table 1 shows the prerequisites and weighted criteria selected and weighted by the team.

Table 1. Criteria for Selection of Ashfall Planning Team Recommendations.

Prerequisite	**Justification for Requirement**
Mitigates ashfall NPH DBA	Required safety function
Prevents secondary common-cause accidents	Required safety function
Supports confinement ventilation (reduced flow)	Required safety function
Self-sustainable	Safety function cannot rely on outside support from entities also impacted by ash
Operable/reliable/maintainable/robust	Must be able to make it work and prove it works
Response time < 1 week	Per USGS warning guidance

Weighted Criteria	**Weight**	**Weight**
Technically defensible/solid technical basis	Very High	9
Proven technology	High	5
Hierarchy of controls/defense in depth	High	5
Minimal design impact	High	5
Low capitol cost impact	High	5
Low life-cycle cost impact	High	5
Dual purpose (solves other tech issues)	Medium	3
Low environmental impact	Medium	3
Minimal impact to available infrastructure (power, water, roads)	Medium	3
Low WTP schedule impact/could be dovetailed with T1-T8	Medium	3
Independence from other Hanford entities	Low	1
Recoverability	Low	1
Response time < 2 hours	Low	1
Benefit to other facilities (HLW, BOF, LAW)	Low	1

BOF = Balance of Facilities.
DBA = design basis accident.
HLW = High-Level Waste (Facility).
LAW = Low-Activity Waste (Facility).
NPH = natural phenomena hazard.
USGS = U.S. Geological Survey.
WTP = Waste Treatment and Immobilization Plant.

2.0 WASTE TREATMENT AND IMMOBILIZATION PLANT VOLCANO DESIGN CRITERIA

2.1 U.S. DEPARTMENT OF ENERGY REQUIREMENTS

The requirements in the WTP code of record for mitigating NPH in DOE facilities are defined in a hierarchy of directives under DOE O 420.1B that includes DOE G 420.1-2, *Guide for the Mitigation of Natural Phenomena Hazards for DOE Nuclear Facilities and Nonnuclear Facilities*, and DOE-STD-1020-94, *Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities*. DOE O 420.1B (Chapter IV) requires that the design and construction of new facilities address the "impact of all NPH events (e.g., earthquake, wind, flood, and lightning)." While not specified, this includes the impacts from volcanos.

DOE-STD-1020-94 ties target performance goals to structure, system, and component performance categories (e.g., PC-2 is associated with a performance goal annual probability of 5×10^{-4} and PC-3 is associated with 1×10^{-4}) and defines the probabilistic framework for assessment and application of NPH loads. As discussed in this standard, design and evaluation criteria aimed at target probabilistic performance goals require probabilistic NPH assessments. NPH loads are developed from such assessments by specifying natural phenomena hazard mean annual probabilities of exceedance. Performance goals may then be achieved by using the resulting loads combined with deterministic design and evaluation procedures that provide a consistent and appropriate level of conservatism.

The probabilistic framework specified in DOE-STD-1020-94 for seismic, wind, and flood hazards is extended to address volcanic hazards, utilizing the performance goals identified in DOE-STD-1020-94, Appendix B, Table B-1 for PC-1, 2, and 3.

2.2 DERIVED WASTE TREATMENT AND IMMOBILIZATION PLANT DESIGN CRITERIA

The current volcanic hazards design criteria proposed for the WTP are described in WHC-SD-GN-ER-30038, Rev. 2, and HNF-SD-GN-ER-501, Rev. 2. Criteria applicable to facilities requiring PC-3 level design include a structural loading of 23.5 lb/ft^2 and a peak airborne ash concentration level of 2,600 mg/m^3 (sum of peak concentration and peak resuspension at 12 hours following the initiation of an ashfall event). At 48 hours after the event, the total concentration is assumed to be reduced to approximately 980 mg/m^3, and the concentration is assumed to continue to diminish over roughly 60 days.

2.3 COMPARATIVE ANALYSIS OF WASTE TREATMENT AND IMMOBILIZATION PLANT VOLCANIC DESIGN CRITERIA

The current WTP volcanic hazards design criteria in HNF-SD-GN-ER-501, Rev. 2, represent a significant increase over previous WTP criteria, as shown in Table 2. For PC-3 design, structural loads (based on assumed compacted ash) were increased nearly twofold from 12.5 lb/ft^2 to 23.5 lb/ft^2. Airborne concentration values were added to the most recent WTP criteria and are considerably higher than the volcanic design criteria imposed by the Nuclear Regulatory Commission at the nearby Energy Northwest WNP-2 reactor (see Appendix A). Concentrations are also high when compared to measured data from Mount St. Helens and other known volcanic eruptions. A comparison of WTP design criteria against other known data is provided in Table 3. Additional information is provided in Appendix B.

Table 2. Increase in Ash Natural Phenomena Hazards Requirements.

Year	1996	2011	2012
Source	WHC-SD-GN-ER-30038, Rev. 0	USGS 2011	WHC-SD-GN-ER-30038, Rev. 2 HNF-SD-GN-ER-501, Rev. 2
Ash structural load	12.5 lb/ft^2	23 lb/ft^2	23.5 lb/ft^2 (including rain)
Ash concentration	220 mg/m^3 for 20-hour event (based on WNP-2 criteria as described in 24590-WTP-PSAR-ESH-01-002-01)	not included	2,600 mg/m^3 (1,500 from initial event, 1,100 from wind resuspension, decaying slowly over 60 days)

24590-WTP-PSAR-ESH-01-002-01, *Preliminary Documented Safety Analysis to Support Construction Authorization*, Rev. 5c, Bechtel National, Inc., Richland, Washington.

HNF-SD-GN-ER-501, 1998, *Natural Phenomena Hazards, Hanford Site, Washington*, Rev. 1, Numatec Hanford Company, Richland, Washington.

HNF-SD-GN-ER-501, 2012, *Natural Phenomena Hazards*, Hanford Site, Washington, Rev. 2, Washington River Protection Solutions LLC, Richland, Washington.

USGS, 2011, *Open-File Report 2011-1064*: *Estimate of Tephra Accumulation Probabilities for the U.S. Department of Energy's Hanford Site, Washington*, U.S. Geological Survey, Reston, Virginia.

WHC-SD-GN-ER-30038, 1996, *Volcano Ashfall Loads for the Hanford Site*, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-GN-ER-30038, 2012, *Volcano Ashfall Loads for the Hanford Site*, Rev. 2, Washington River Protection Solutions LLC, Richland, Washington.

Measurements of initial airborne concentrations of ash collected from worldwide eruptions demonstrate conservatism in the WTP airborne ash concentration design criteria of 2,600 mg/m^3 (1,500 mg/m^3 initial concentration + 1,100 mg/m^3 wind resuspension during initial settling). The data collected from literature reflects airborne concentrations of ash that are orders of magnitude below that predicted in the new Hanford criteria. A measured airborne ash concentration value of 33.4 mg/m^3 was recorded at Yakima (about 100 km from Mount St. Helens) on May 18, 1980 (date of eruption). The depth of deposited ash recorded at Yakima was about 1 cm. If the airborne concentration value is scaled to an ash depth of 10 cm (in the WTP design criteria), the scaled air concentration of 334 mg/m^3 is still substantially less than 1,500 or 2,600 mg/m^3. Concentrations of this magnitude have been found only at closer ranges to volcanic vents (i.e., much closer than the 200 km distance between Hanford and Mount St. Helens) in areas so close to the volcano that the largest particles have not settled out.

Table 3. Measured Values of Airborne Concentration.

Concentration (mg/m^3)	Basis of Measurement	Source
33.4	Actual peak measurement from Yakima, Washington, on May 18, 1980.	Bernstein et al. (1986)
5.8–13	Range of 24-hour average measurements collected in Yakima during the span of May 19-25, 1980, thus representing some degree of resuspension.	Bernstein et al. (1986)
5	Maximum post-Mount St. Helens value measured in the Hanford area, representing resuspension, on May 25, 1980.	Sehmel (1982)
10	Maximum measured value in Argentina in October 2011 during a major resuspension of ash first deposited in June 2011.	Folch et al. (2014)
0.25	Maximum measured value from an aircraft, several hundred meters above ground level near Yakima on May 23, 1980.	Hobbs et al. (1983)
< 10–1,000	Ground-based C-band radar measurements of volcanic clouds from Mt. Spurr, Alaska, less than 30 minutes after eruptions in 1992, while clouds still contained particles 2-20 mm diameter.	Rose et al. (2001)
> 2	Measurement of PM_{10} concentration (only particles less than 0.01 mm diameter) in Iceland during a June 4, 2010, resuspension of ash first deposited in April and May 2010.	Leadbetter et al. (2012)
< 2	Measurements of PM_{10} concentration near Soufriere Hills Volcano, Montserrat, shortly after an eruption on October 10, 1997	Baxter et al. (1999)
1.4–11.8	Range of eruption cloud total mass concentrations, collected from aircraft, from Mount St. Helens eruptions between March 28 and June 13, 1980.	Hobbs et al. (1982)
2,600	Initial plus resuspended concentration based upon Pacific Northwest National Laboratory estimate.	WHC-SD-GN-ER-30038, Rev. 2

Baxter, P.J., Bonadonna, C., Dupree, R., Hards, V.L., Kohn, S.C., Murphy, M.D., Nichols, A., Nicholson, R.A., Norton, G., Searl, A., Sparks, R.S.J., and Vickers, B.P., 1999, "Cristobalite in Volcanic Ash of the Soufriere Hills Volcano, Montserrat, British West Indies," *Science*, v. 283, pp. 1142-1145.

Bernstein, R.S., Baxter, P.J., Falk, H., Ing, R., Foster, L., and Frost, F., 1986, "Immediate Public Health Concerns and Actions in Volcanic Eruptions: Lessons from the Mount St. Helens Eruptions," May 18-October 18, 1980, *American Journal of Public Health*, v. 76, Supplement, pp. 25-38.

Folch, A., Mingari, L., Osores, M.S., and Collini, E., 2014, "Modeling volcanic ash resuspension – application to the 14-18 October 2011 outbreak episode in central Patagonia, Argentina," *Natural Hazards and Earth System Sciences*, v. 14, pp. 119-133.

Hobbs, P.V., Hegg, D.A., and Radke, L.F., 1983, "Resuspension of Volcanic Ash From Mount St. Helens," *Journal of Geophysical Research*, vol. 88, No. C6, pp. 3919-3921.

Leadbetter, S.J., Hort, M.C., von Löwis, S., Weber, K., and Witham, C.S., 2012, "Modeling the resuspension of ash deposited during the eruption of Eyjafjallajökull in spring 2010," *Journal of Geophysical Research*, v. 117, D00U10.

Rose, W.I., Bluth, G.J.S., Schneider, D.J., Ernst, G.G.J., Riley, C.M., Henderson, L.J., and McGimsey, R.G., 2001, "Observations of Volcanic Clouds in Their First Few Days of Atmospheric Residence: The 1992 Eruptions of Crater Peak, Mount Spurr Volcano, Alaska," *Journal of Geology*, v. 109, pp. 677-694.

Sehmel, G.A., 1982, "Ambient Airborne Solids Concentrations Including Volcanic Ash at Hanford, Washington Sampling Sites Subsequent to the Mount St. Helens Eruption," *Journal of Geophysical Research*, v. 87, No. C12, pp. 11087-11094.

WHC-SD-GN-ER-30038, 2012, *Volcano Ashfall Loads for the Hanford Site*, Rev. 2, Washington River Protection Solutions LLC, Richland, Washington.

The WTP design criterion of 1,100 mg/m^3 for wind resuspension of deposited ash was derived in WHC-SD-GN-ER-30038, Rev. 2, based on a model developed by Maxwell and Anspaugh (2011). As part of the APT's efforts, Dr. Lynn Anspaugh reviewed the resuspension modeling and its results. His review is provided in an attachment to Appendix C. In his review, Dr. Anspaugh states that the initial and resuspended concentration and duration is likely greatly overestimated in the new criteria. He concluded that, for an ashfall thickness of 10 cm corresponding to the WTP criteria, "it would not be appropriate to apply the resuspension equation from Maxwell and Anspaugh (2011)" (p. C.1-3).

Dr. Anspaugh explained that the resuspension equation from Maxwell and Anspaugh (2011) is not intended for situations analogous to a thick layer of deposited ash. In addition, ash resuspension would not encompass a continuous high concentration for a period of 60 days. In addition, Dr. Anspaugh concluded that resuspension events would be limited to short durations (i.e., hours) as opposed to the current WTP criteria, which assumes a substantial concentration that diminishes over a longer period of time (~60 days). The more plausible condition would be episodic events of resuspended material caused by windstorms of magnitude greater than the friction velocity required for ash resuspension (derived by Dr. Robert Nelson as approximately 12 miles per hour [Appendix C]). Dr. Anspaugh's conclusions include predicted values similar to those measured in Table 3.

Dr. Anspaugh concludes that resuspension via episodic dust storms will likely still occur for some time (1 year) following an ashfall event because of the potential for episodic strong winds that might occur at the site. Based on measurements at Yakima and elsewhere, Dr. Anspaugh concluded that a year-long average value of 1 mg/m^3 would be reasonable, with peak values expected in the range of 20 mg/m^3. While still quite dusty (average values are about 10 times the normal average), these values are in the range of WTP design criteria required for dust storms and far below the diminishing concentrations represented in Figure 5 of WHC-SD-GN-ER-30038, Rev. 2, which includes concentrations still above 200 mg/m^3 20 days after the volcanic eruption event.

Per Dr. Anspaugh's guidance, Dr. Robert Nelson studied Hanford meteorological data from the past 5 years and found winds above friction velocity occur only 11.7 percent of the time, with an average persistence of 4.24 hours. This analysis supports the conclusion by Dr. Anspaugh that 60 days of resuspension is implausible.

Maxwell and Anspaugh (2011) present measurements of resuspended material following Project Schooner, which was the explosion of a 30-kt nuclear device buried at a depth designed to create a crater—probably as close as man can get to simulating a volcano. The observation was that resuspended air concentrations were much lower and decreased much more quickly than would be predicted by the equation derived from trace deposition data. Measurements at Yakima, other locations in Washington State, and other locations worldwide also indicate that air concentrations returned to much lower levels (< 1 mg/m^3) within a week following a volcanic eruption (Bernstein et al. 1986; Rautenstrauch 2003).

During this study, the APT discussed the findings described above with experts at the USGS Cascades Volcano Observatory. One question posed was the current methodology to estimate airborne concentration consequences. The USGS recommends use of their Ash3d computer code to calculate ash deposition and airborne concentration at the Hanford Site. Ash3d is a three-dimensional Eulerian atmospheric model developed by the USGS and used to forecast volcanic ash transport, dispersal, and deposition. The model is supported by a substantial and growing body of peer-reviewed literature and has been validated by USGS against airborne ash concentrations derived from satellite imagery following volcanic events. USGS believes there is a high probability that the Ash3d model would produce defensible ashfall projections. USGS also believes Ash3d results would be more consistent with actual measured data.

The Ash3d model does not have the capability to produce a resuspension estimate. Based on a review of the WTP design criteria, Dr. Anspaugh was consulted regarding developing alternate values that would be appropriate at the Hanford Site. Dr. Anspaugh recommended examining Hanford meteorological data to determine the frequency and duration of occurrence of wind speeds greater than the expected friction velocity for resuspension of volcanic ash. These times would correspond to the frequency and duration of expected dust storms. Hanford meteorological data was reviewed from the past 5 years and initially indicated wind events with friction velocity > 45 cm/s typically occur 11.7 percent of the time. Data conservatively evaluated from 2009 Hanford Meteorological Station data resulted in an average persistence of 4.24 hours and single episodes of 24, 29, and 30 hours. Based on literature from Dr. Draxler, NOAA Air Resources Laboratory (Draxler et al., 2010), these are the times when resuspended ash could occur. Details of this analysis can be found in Appendix C.

USGS and APT members also talked with the NOAA Air Resources Laboratory about their HYSPLIT (Hybrid Single Particle Lagrangian Integrated Trajectory) model, which has the capability to model wind resuspension of particulate matter based on Hanford meteorological data. HYSPLIT is commonly used for dust storm simulations and NOAA concluded it would be appropriate and feasible to apply it to this problem. The project could use this model to refine the resuspension portion of the airborne ash criteria.

The APT also talked with the National Atmospheric Release Advisory Center (NARAC), a DOE/National Nuclear Security Administration entity specializing in atmospheric particulate transport models used for radioactive material dispersion calculations. Although they do not have the capability within their models to address a volcanic eruption, modeling experts from NARAC could be called on to peer review the USGS and NOAA modeling efforts.

The matter of quality assurance of the various software tools described above is an open question. These models have been validated against airborne concentration measurements, and there is an extensive body of peer-reviewed literature regarding their use. A version of NOAA's HYSPLIT has been used by DOE for radioactive material dispersion calculations in the recent past. Results for both agencies are published via fundamental science practices that are codified and built into peer review processes. Discussion with quality assurance personnel would be necessary to determine the details of accepting this data for use as quality affecting data. It would be advisable to involve NARAC as a peer review entity to lend additional rigor to the existing processes.

Given the information gathered by the APT, there is cause to question the airborne concentration and resuspension data in WHC-SD-GN-ER-30038, Rev. 2, and there is new methodology for estimating airborne concentration of ash that could be used to develop a more accurate and defensible estimate. Consulting the USGS and NOAA experts on atmospheric transport models would be advisable.

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3.0 EVALUATION OF VOLCANIC HAZARD CRITERIA

The APT was charged with evaluating BNI's proposed strategy for mitigating ashfall hazards, as well as investigating other innovative solutions. The team considered a number of alternatives that can be categorized into one of five categories:

1. Advanced notifications of pending eruptions
2. Refinement of volcanic hazard design criteria
3. Facility design options
4. Operational strategies
5. Other DOE-STD-3009-compliant hazards analysis methodologies.

The ATP investigated the alternatives using the following set of assumptions:

- The revised ash structural criteria for the LAW Facility and Lab are bounded by snow load. The Structural Peer Review Team was consulted by BNI and DOE structural engineers regarding how best to model ash drifts. The proposed correlation, which considers ash density from USGS 2011, results in no design impact to LAW and Lab according to the preliminary analysis, though some reduction in design margin for these facilities is anticipated. According to the preliminary analysis, the revised ash structural criteria for the HLW and PT Facilities are bounded by existing structural criteria for these facilities. No impact is expected. Associated documentation is provided as attachments to Appendix F.
- The LAW and HLW Facilities isolate chemical hazards (primarily ammonia) and burn off cold cap[4] during an assumed 2-hour warning period (i.e., time before the volcanic ash reaches Hanford after a volcanic event has occurred). Following these actions, the HLW and LAW Facilities can withstand the event without mechanical equipment associated with the melters and offgas systems running.
- The Lab hot cell confinement safety function is not challenged by the ashfall event. Therefore, the Lab can withstand the event without mechanical equipment running.
- The HLW and PT Facilities must maintain the active safety functions of safety mixing of high-level liquid radioactive waste, cooling of safety-related equipment, and confinement ventilation for the duration of the event. The major impact from airborne ash concentration is to the equipment that supports safety mixing, which requires 93 percent of the approximately 1,000,000 cfm of outside air necessary to sustain BNI's proposed approach. The impacted safety mixing equipment includes:
  - The ETGs
  - The ETG building
  - The safety air compressors

[4] The "cold cap" refers to the glass formers and waste recently added to the melter that releases oxides of nitrogen into the offgas systems as it is heated on the surface of the melt pool.

  - The room in PT Facility Annex designed to hold the safety air compressors (note there is an existing issue in that the equipment as sized for baseline operations does not fit in this location)
  - The switchgear to support the safety air compressors and chillers
  - The safety air-conditioning units located throughout HLW and PT Facilities (approximately 30 each)
  - The proposed bag-house filters that support this equipment
  - The C5V high-efficiency particulate air (HEPA) filters
  - The C3/C5 inbleed assemblies.
- For alternatives that involved an assumed ashfall event duration, a 60-day duration of airborne ash was conservatively assumed (based on the resuspension analysis in WHC-SD-GN-ER-30038, Rev. 2). A reduction of event duration may make other options sustainable that previously were ruled out.
- For alternatives that involved mixing or vessel volume, the new standard high-solids vessel design was used to determine volume and time to lower flammability limit (TTLFL).

3.1 ADVANCED NOTIFICATION OF PENDING ERUPTIONS

The team inquired regarding the ability of the USGS Cascades Volcano Observatory to provide advanced warning of an eruption on the scale predicted in USGS 2011, and whether USGS could document its capabilities and commit to an agreement to monitor Mount St. Helens conditions and provide advanced notifications. Such notifications would allow sufficient time for the plant to transition to a safe and secure state that would require fewer air and power demands (e.g., returning waste to tank farms or processing forward to de-inventory vessels that require safety mixing). This option could lead to a much simpler and more sustainable solution that would not require substantial design modifications to WTP.

The APT held meetings with the USGS, who affirmed that it was possible to detect conditions at least 1 week before an eruption on the scale of a Volcanic Explosivity Index (VEI) 6 or larger. The VEI was developed in 1982 to provide a relative measure of the explosiveness of volcanic eruptions (Newhall and Self 1982). The scale is open-ended with the largest volcanoes in history given a magnitude VEI of 8. The Mount St. Helens eruption of 1980 was rated a VEI 5 (i.e., greater than 1 km^3 of ejected volume).

The ability of the USGS to provide advanced notifications is based on advanced seismic monitoring instrumentation and methods implemented following the 1980 Mount St. Helens eruption. While there is confidence in the instruments and the USGS capabilities, data is only available from the 1991 Pinatubo eruption demonstrating the performance of new seismic instruments. Hence, only one confirmatory data point exists to date.

There is also some risk to DOE related to the cost of sustaining the monitoring capability, if USGS is impacted by Federal budget decisions outside of DOE's control. The USGS stated that the current Level 4 Mount St. Helens seismic monitoring instruments are owned and operated by another entity funded through the National Science Foundation, and that the program sunsets in

2018. After that time, some instruments may be removed from service and the monitoring network would degrade to Level 3. Maintaining the current Level 4 monitoring capability past 2018 is estimated to cost $500,000/year, $20 million over the 40-year life of the plant. The Level 3 monitoring may still provide 24–48 hours of warning time, but USGS could not provide any assurance of this.

The approach of ceasing or curtailing WTP operations upon USGS notification of a pending eruption would require protection as an important safety basis control. This brings some risk of operational impacts as operations would be shut down until a potential volcanic threat is downgraded. USGS mentioned one similar event from the last period of Mount St. Helens volcanic activity in 2004-2008, in which they had 8 days advance seismic warning, then a 10-day period in which they conducted further analysis to determine if it was leading to a major eruption or not (in that case, it did not). The APT's discussions with the USGS are documented in Appendix D.

3.2 REFINEMENT OF VOLCANIC HAZARD DESIGN CRITERIA

The APT investigated whether alternate design criteria to that proposed in HNF-SD-GN-ER-501, Rev. 2, were appropriate and defensible. As noted in Section 2, these criteria are very conservative compared to design criteria approved by the Nuclear Regulatory Commission at regional nuclear power plants, and are orders of magnitude higher than measured airborne concentration data from volcanic events. Dr. McDuffie, Dr. Anspaugh and Dr. Nelson, in review of the design criteria proposed in HNF-SD-GN-ER-501, Rev. 2, found the new criteria to be inconsistent with literature documenting actual airborne concentration measurements associated with volcanic eruptions, unsupported by correlations governing wind resuspension of particulate matter, and infeasible when compared to Hanford meteorological data.

Based on the APT's review of the body of evidence presented in Section 2, there is significant technical justification to support delaying implementation of the ashfall criteria in HNF-SD-GN-ER-501, Rev. 2, and pursuing additional efforts to refine these criteria.

The team evaluated other methods for deriving volcanic hazard design criteria with the objective of selecting viable methods that produce defensible results. The APT consulted with USGS, NOAA, and NARAC, and discussed the potential to establish interagency agreements with these organizations to accomplish modeling to achieve a more accurate and defensible estimate of airborne concentration of ash and duration of wind resuspension.

The rough order of magnitude (ROM) cost of obtaining a refined estimate from USGS and NOAA, including peer review by NARAC, is $200,000. Work could be completed under an interagency agreement, a tool that has been used in the past to fund USGS work. Preliminary estimates of the time required to complete these efforts indicate roughly 6–12* months (potentially more because the USGS output would be the NOAA input; i.e., the activities are sequential).

3.3 FACILITY DESIGN OPTIONS

The APT studied several design alternatives to address the latest ashfall criteria described in HNF-SD-GN-ER-501, Rev. 2. When considered independently, most of the alternatives address only a portion of the problem (e.g., safety mixing or ventilation), and several alternatives were found to be unsustainable during an ashfall event. The design alternative studies are summarized in the following sections.

3.3.1 Acceptance of Bechtel National, Inc., Proposed Approach

The APT reviewed and discussed the proposed BNI ashfall design strategy (documented in CCN 258256, "Responses to DOE Comments/Questions Concerning Ashfall Conceptual Design"). The BNI proposal includes six new buildings, all seismically rated. The compressors and chillers that do not fit in the current designed PT Facility Annex would be moved to a new facility east of the PT Facility. The additional equipment, and the parasitic load caused by ventilation and other services to the additional buildings/equipment, would drive up ETG load, requiring four total ETGs (two running with two in standby), and require a significant expansion of the ETG building. BNI predicted no impact to structural design of existing buildings, but did estimate 3 man-years of work to revise all structural calculations for Lab, LAW, HLW, and PT to include the new criteria.

The baseline and new criteria demand is shown in Table 4. The site plan showing all proposed additional buildings and equipment is shown in Figure 4. All buildings highlighted in yellow in Figure 4 are new construction except the ETG building, which is much larger than the baseline. Figure 5 shows a drawing of the safety chiller/air compressor plant portion of the proposed design. The proposed new chiller building and bag-house building are three and two stories, respectively, with a combined floor area of at least 40,000 ft^2. Figure 6 shows a plan view of the baseline safety air compressor design in the PT Facility Annex, approximately 4,000 ft^2.

Table 4. Baseline vs. Basis of Estimate for Impact of New Requirement – Air and Power.

	Baseline	New Ash Proposal	Existing Capacity
Mixing and purging air	2,500 scfm	4,400 scfm (+750 scfm for backpulse cleaning of bag-houses) (+1,150 scfm for increased mixing duration)	3,600 scfm but there is an existing issue: safety air compressors do not fit in the safety air compressor room, nor would chillers
Bag-house filter load: ETG air Safety chillers/compressors Safety DX condensers Confinement ventilation	 53,000 scfm (ETG) 200,000 scfm Est. 30,000 scfm 45,000 scfm	 460,000 scfm (2 ETGs) 440,000 scfm (safety chillers) Included in chillers 75,000 scfm	No bag-houses in current design, but cost baseline includes \$15.6 million for some
ETG load	3.3 MW	5.6 MW	4.1 MW (derated for continuous operation for 60 days), 4.8 MW otherwise
ETG fuel supply	Storage tank + 1 diesel truck/day	Storage tank + 2 diesel trucks/day	Difficult to guarantee resupply for WTP post-NPH events

DX = direct expansion.
ETG = emergency turbine generator.
NPH = natural phenomena hazard.
WTP = Waste Treatment and Immobilization Plant.

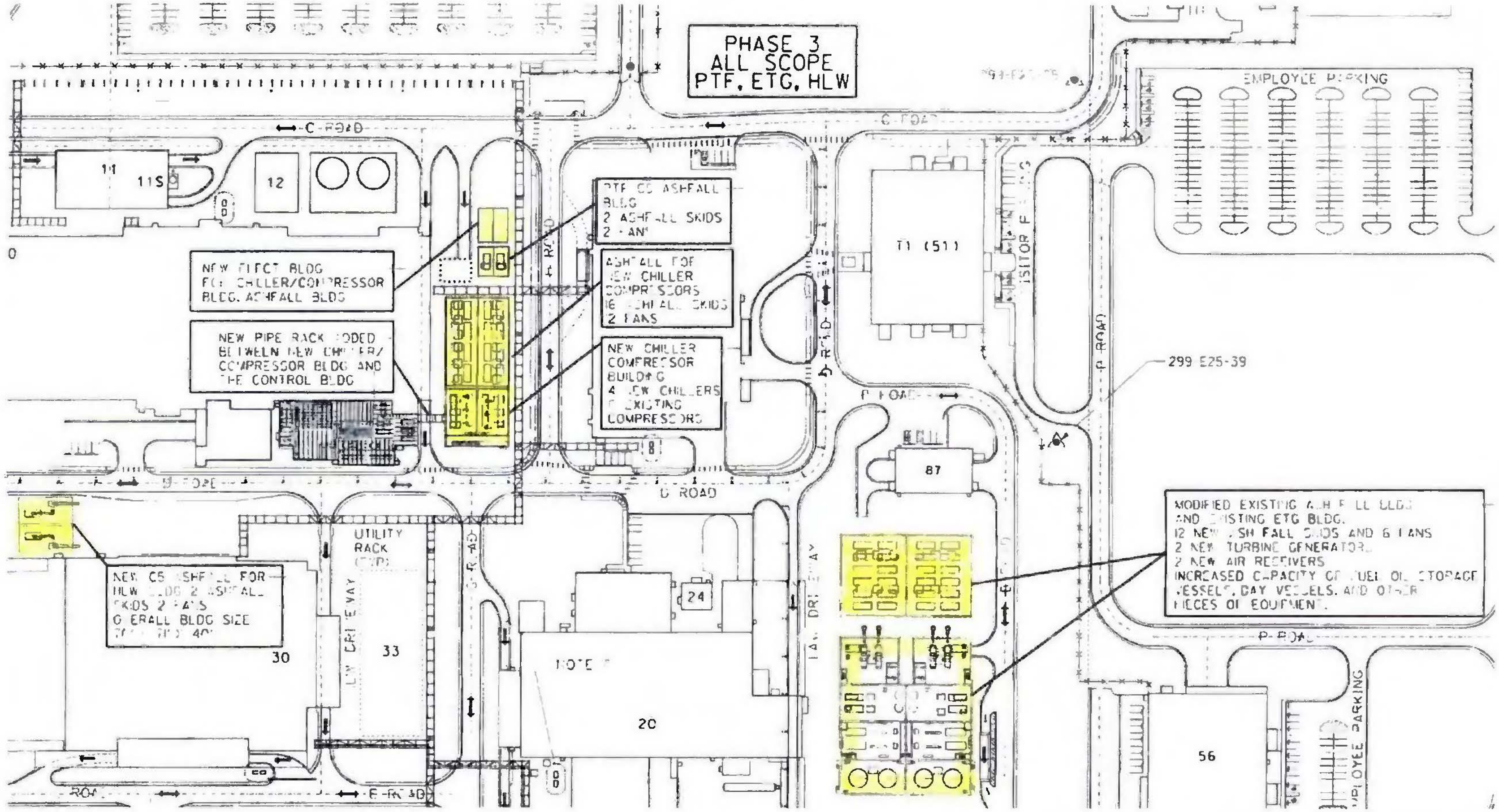

Figure 4. Waste Treatment and Immobilization Plant Site Plan View Showing All Bechtel National, Inc., Proposed Modifications.

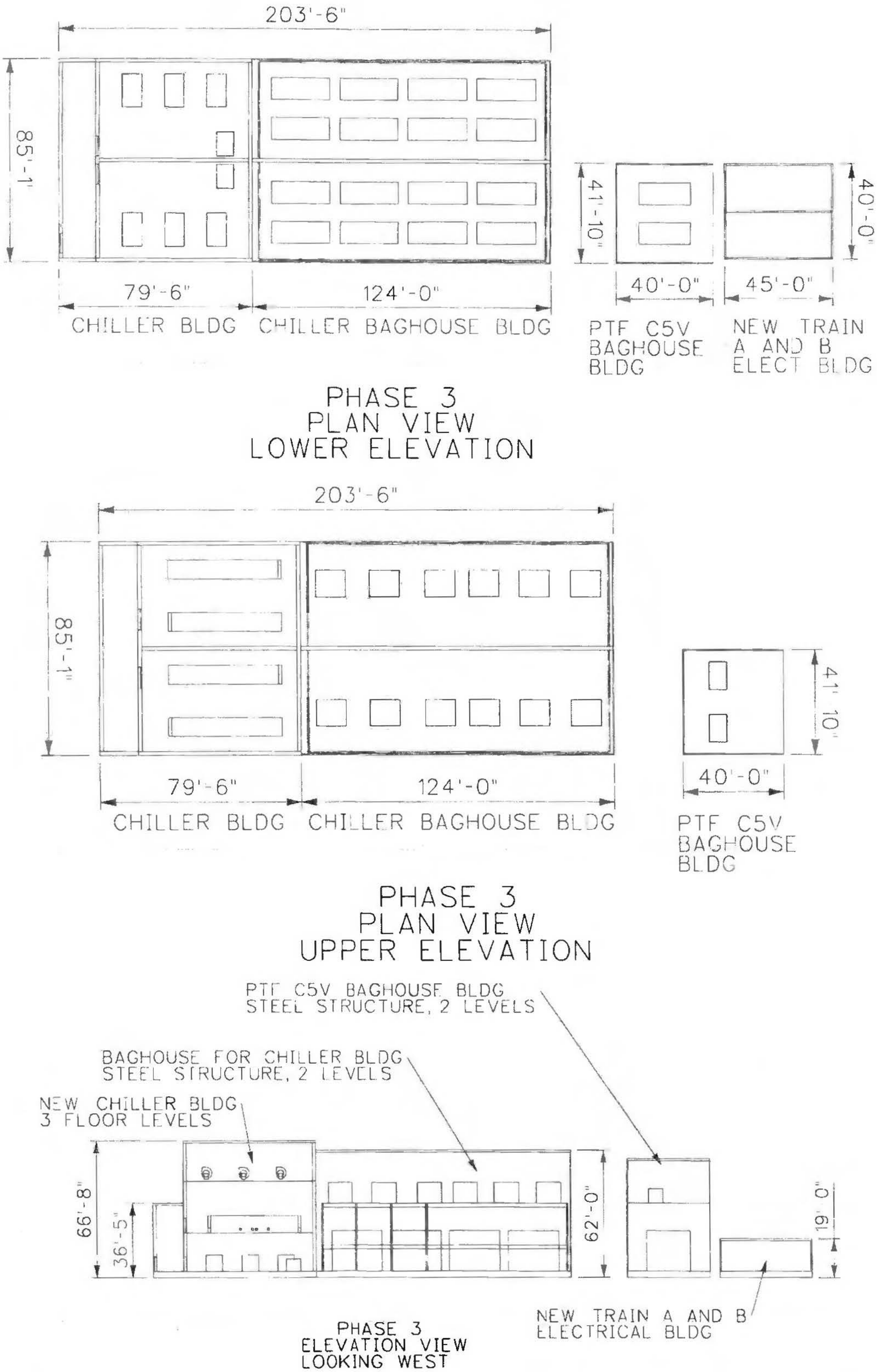

Figure 5. Proposed Safety Chiller/Compressor Building Conceptual Design.

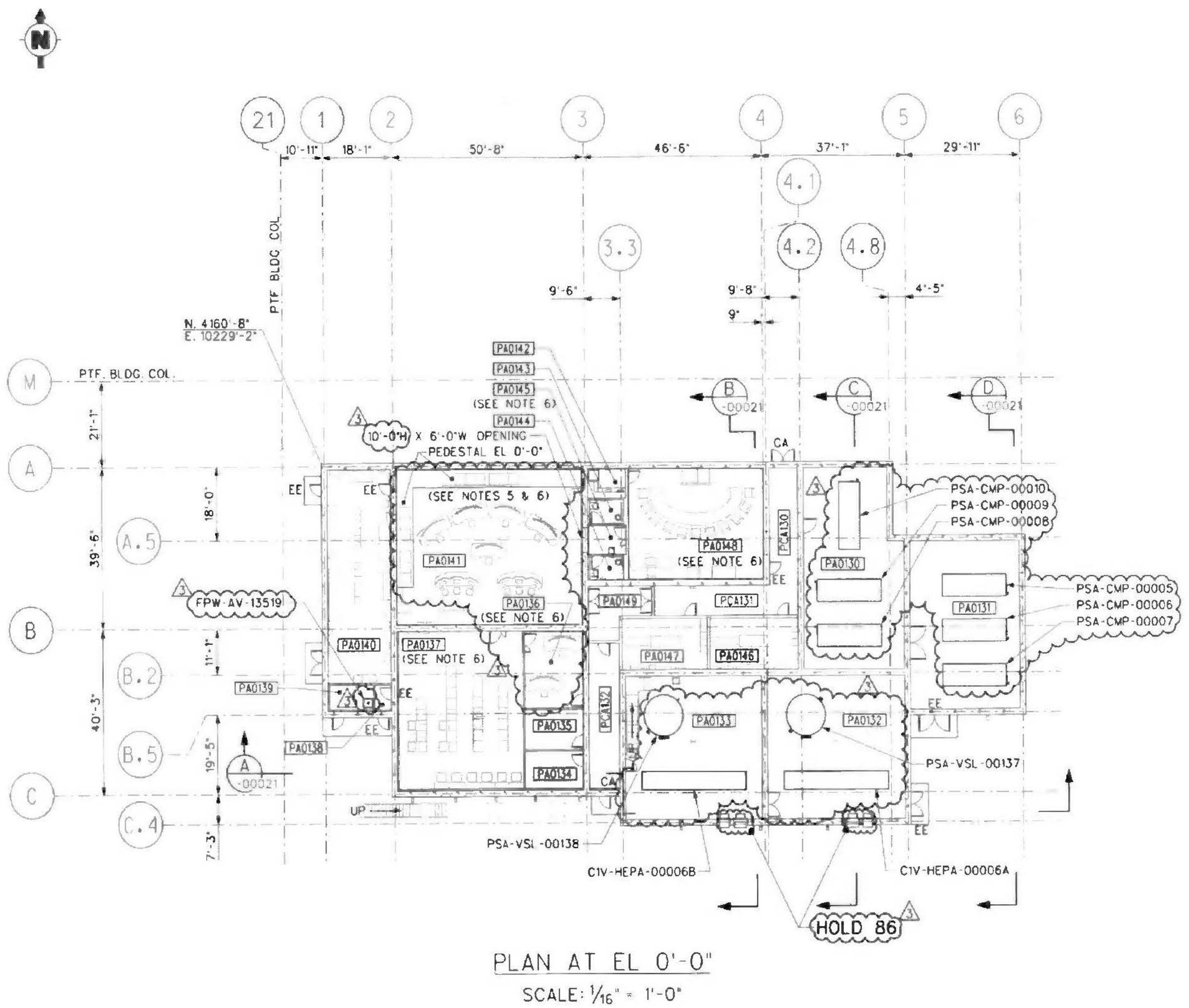

Figure 6. Pretreatment Facility Annex Plan View Showing Location of Safety Air Compressors and Receivers (Column Lines 3-6).

The cost of design changes is cost prohibitive to the project and likely unsustainable in terms of diesel fuel demand required to support a 60-day resuspension event (i.e., two trucks per day of diesel fuel on days 2-60). This requires mechanical equipment to continue to run for 60 days to supply clean air to the safety equipment. A passive safety approach would be far simpler and more sustainable.

The team also noted that there are unaddressed design evolution problems within the current design. Notably, the safety air compressors cannot fit within the PT Facility Annex.
The building envelope is not designed to provide the airflow required for intake and cooling of this equipment.

Details of the review of BNI's current approach are contained in Appendix E.

3.3.2 Competitively Bid Bechtel National, Inc., Path Forward

The alternative to competitively bid the proposed solution does not make it more sustainable, so this option was not explored in great detail. It could perhaps make the option slightly less than prohibitively expensive, but if the option is unsustainable, it is not worth further review. Depending on selected outcomes, competitively bidding these solutions may be considered.

3.3.3 Trimmed Down Bechtel National, Inc., Approach

This alternative examined several aspects of the BNI proposed ashfall mitigation strategy to determine if the approach becomes more viable when considering it in combination with reductions of utility loadings and other design simplifications (e.g., reusing filtered air, optimizing ETG performance, reducing compressed air demand, combining/simplifying external service buildings [compressors, switchgear, filtration, etc.]).

The ETG output power could be increased by approximately 0.4–0.8 MW via water injection. This technique is used for stationary, heavy industrial gas turbines for peaking power. The added benefit of water injection is a significant reduction in NO_x output from the turbine, which could be as much as 150 ppm (where 20 is immediately dangerous to life and health). However, a water source of 450 gal/hr would be needed. This correlates to 650,000 gallons over the 60-day event. This alternative could be studied further if a source of safety water is established (see water cooling options in Section 3.3.6) and/or if the duration of the event is reduced via review of resuspension estimate.

An additional opportunity for improvement that came from the ETG analysis was conversion of ETG fuel source to natural gas. The minimum life-cycle cost savings of switching from diesel fuel to natural gas is estimated to be about $933 million, assuming an initial 6-year low-activity waste treatment operation followed by a 25-year operation for treating both high-level and low-activity waste in the WTP. Natural gas also solves a challenging diesel supply issue regarding trucking diesel to WTP to supply the steam plant, but may create a new design basis accident related to natural gas explosion and damage to associated safety-related equipment. Assuming a consumption rate of 7 gpm of ETG operation, more than a tanker truckload of diesel fuel per day would be required for the duration of the ashfall event of 60 days. This presents an insurmountable transportation obstacle to overcome.

Alternatives for reuse of air to minimize filtration load for outside air are examined further in the sand filter alternatives section, Section 3.3.7.

The team also examined an option suggested by the Structural Peer Review Team to modify structural load combinations for the event in order to preserve margin for LAW and Lab associated with incorporating the new requirements. This option was ruled out because it had no basis in code and there was essentially no benefit.

Details of trimming BNI's current approach are found in Appendices F and G.

3.3.4 Liquid Nitrogen Cryogenic Plant or Pre-Supply to Sustain Safety Mixing

This alternative involves the addition of a new cryogenic plant and storage tank to make liquid nitrogen when warned of an imminent volcanic event, or simply pre-supplying liquid nitrogen in trucks during a warning period. An evaporator would consume diesel or natural gas to slowly evaporate pressurized nitrogen to be used in lieu of compressed air for supply air mixing.

Advantages of this approach include sustaining safety mixing without any dependence on outside air, assuming 60-day liquid nitrogen storage capacity, and significant warning time to create a supply of liquid nitrogen. This reduces the overall quantity of filtered supply air that must be provided to meet the plant's operational and safety needs.

Disadvantages are a significant spike in power consumption while the cryogenic plant is making liquid nitrogen. Additional plant equipment and redesign of tie-ins with supply air would also be required. Optional nitrogen supply via tankers staged onsite during the week warning period may be unsustainable (nominally 1–3 trucks per day).

An opportunity for improvement noted during this investigation is that having the option to supply mixing air with liquid nitrogen trucks may provide operational flexibility for outages.

The ROM estimate for this approach is $80 million, and the time to implement this approach is 3 years. Details of this alternative are found in Appendix H.

3.3.5 Repurpose Unused Grout Vaults as Settling Chambers for Ash Filtration

To the west of the HLW and PT Facilities are four abandoned grout vaults—large empty concrete underground rooms 50 ft wide, 34 ft deep, and 125 ft long. This alternative involves installing ductwork and fans to pull air slowly through these grout vaults, end to end, as it is drawn into the facilities. Depending on the airflow rate through the vaults, a large amount of the ash would settle out in the grout vaults. The settling rate (efficiency) could be improved with water spray.

This approach offers several advantages. It is simplistic and uses existing facilities. It requires very little power (i.e., fans). Depending on operational flow, the process is very efficient (96-98-percent efficient for the expected particle size distribution of ash).

The disadvantage is that it is not a full solution to meeting air supply demands. The filtration approach can supply HLW and PT Facility C5V ventilation alone for 2 days at the current peak ash concentrations (likely longer because concentration drops after 12 hours) or 27 days at lower concentrations, with no additional filtration, before plugging downstream C5V HEPA filters. At higher flows, this approach becomes less efficient, with a maximum capacity of approximately 400,000 cfm. Table 5 shows flows, efficiencies, and time to plug C5V with this approach.

The ROM estimate for this approach is $400,000, with an estimated time to implement design of 3 years.

Details of this alternative are found in Appendix I.

Table 5. Filtration Efficiency of Grout Vault Settling Chamber and Time to Plug Filters.

Airflow per Vault and Total Capacity (scfm)	Particles Removed (microns)	Percent by Mass Removed	Time to Plug C5V Filters at 2.7 g/m³	Time to Plug C5V Filters at 0.22 mg/m³
100,000 per vault 400,000 total	≥ 45	75	8.6 hours	4 days [a]
40,000 per vault 160,000 total	≥ 20	96	2.2 days [a]	27 days [a]
10,000 per vault 40,000 total	≥ 3.5	98	4.5 days [a]	55 days [a]

[a] Time to plug is overconservative because the calculation assumes a constant airborne concentration equal to the peak concentration during the initial settling of ash. In the new criteria, concentration decreases after 12 hours.

3.3.6 Cooling of Plant Equipment Using Site Water Sources

Roughly 75 percent of the outside air demand is used for cooling of mechanical equipment, amounting to a 950 refrigeration ton demand. This cooling requirement could be met with water at an estimated rate of 2,200 gpm.

Options for water cooling include pumping groundwater or storing water in a large underground tank or cooling pond. The tank option may be preferable because the groundwater would require a reservoir or holding pond before release back to ground, and the pond would also be susceptible to ash causing filter plugging. The underground tank option provides some cooling of the returned water due to contact with the ground. Assuming a 1 million-gallon underground tank, the tank would start heating up within 7–14 hours, causing heat transfer to be less efficient. This is likely not a 60-day solution, but it could provide sufficient cooling capacity for periods less than a day (~14 hours). If air demand is reduced, cooling load will likewise be reduced.

Meeting this cooling load with water would reduce outside air demand to 246,000 cfm: 75,000 for C5V confinement ventilation in HLW and PT Facilities; 91,000 cfm for ETG combustion, enclosure, and ventilation; 38,000 cfm for control room cooling; and 42,000 cfm for compressor ventilation and electrical. There is the potential to reuse air once cleaned of ash to meet all of these purposes, but ETG NO_x output may prevent significant reuse.

The ROM cost estimate for installation of a 1 million-gallon water tank and water cooling system to support mixing equipment is $40 million. Time to implement this approach would be roughly 3 years.

Details of this alternative are found in Appendix J.

3.3.7 Install a Sand Filter

Sand filters are robust filtration devices, and the up-flow configuration allows large amounts of dust loading to settle on the floor of the upstream plenum without clogging the media. A sand filter could be installed in WTP, and valved in such a way that it could function as a supply filter during ashfall, and an exhaust filter in emergencies when HEPA filters are plugged. This would simultaneously address several other technical issues.

The disadvantage of sand filters is their size. A sand filter could not practically be sized to supply the entire 1,000,000 cfm needed to sustain the current approach. However, if water cooling was used to reduce the outside air needs, the sand filter size would be 50,000 ft^2. If flow could be further reduced by reusing some air as described in Section 3.3.6, the sand filter sizing could be further reduced to 18,000 ft^2.

Another challenge with sand filters is permitability. Sand filters are typically abandoned in place and cannot be effectively remediated. Because of this it is recommended that the sand filter would not be used for normal operations to reduce the amount of radionuclides accumulated during the WTP mission duration.

Because this option would have to be combined with water cooling to be practically applied, the ROM cost includes the cost for water cooling. A ROM cost of $400 million, with a duration to implement of 3–4 years, is anticipated.

Details of the sand filter and water cooling options are found in Appendix J.

3.3.8 Bag-Houses or Other Filtration Technologies for a Portion of the Air Needs

Additional filtration options could be considered, from multiple banks of manually changed filters, to mechanical filters (e.g., cyclone separators), to other types of bag-house filters (e.g., shaker bag-houses). In light of potential reductions in airborne concentration requirements and duration of resuspension, as well as air demand for mixing, it is recommended that once these requirements are established, several options be considered for filtration of remaining air demand, in a cost/benefit analysis (value engineering study) format.

3.4 OPERATIONAL STRATEGIES

The APT reviewed several options that BNI had previously explored, as well as some new alternatives. Several of the alternatives addressed by the team involved operational strategies in combination with engineered controls. The following sections briefly describe each explored operational strategy.

3.4.1 Pump Back to Tank Farms or a Reserve Tank

Assuming DOE received a 1-week warning from USGS for an eruption as described in Section 3.1, there may be an option to de-inventory the HLW and PT Facilities to ensure the TTLFL was greater than 60 days, therefore eliminating the need for safety mixing.

Upon calculating headspace per vessel needed to achieve TTLFL > 60 days, it became immediately apparent that certain batches were driving the demand for safety mixing. Of the 518 PT Facility feed batches, only 5 percent (28 batches, numbers 2, 5, 8-19, 103-114, 365, 376) present high hydrogen generation rates. These 28 batches represent the worst waste in terms of cesium, strontium, and organics content—the three key drivers of higher hydrogen generation rates. Figure 7 illustrates the difference in cesium content between batches. For the remaining 490 batches, the TTLFL is an order of magnitude or more higher, and to achieve TTLFL > 60 days throughout PT Facility, only 50,000 gallons must be transferred or balanced between tanks. To achieve TTLFL > 60 with the bounding waste for hydrogen generation, upon which the safety mixing design is currently based, 540,000 gallons of waste would need to be transferred.

The capacity of PT Facility to pump waste (i.e., transfer) out is nominally 450,000–700,000 gal/week, assuming current transfer rates and a safety factor of 2 for jumper alignment. Table 6 compares pump-back capacity to volume to be transferred by waste category.

One issue with the pump-back option is that the tank farms may be ill-equipped to receive the waste. It is estimated that the tank farms would need several weeks to configure valves to receive waste.

Therefore, to transfer waste, a dedicated tank may have to be reserved to receive waste. This could be accomplished by installing a new emergency storage tank. It would be advisable to size the pump-back vessel(s) such that headspace was large enough to achieve TTLFL > 60 days without mixing.

Table 6. Pump-Back Capacity vs. Volume to be Transferred to Achieve Time to Lower Flammability Limit > 60 Days.

Pump-Back Capacity of PT Facility	**Volume to be Transferred to Achieve TTLFL > 60 days**	
90-140 gpm	5 percent of waste batches	90 percent of waste batches
450,000-700,000 gal/week	540,000 gal	50,000 gal

PT = Pretreatment (Facility).
TTLFL = time to lower flammability limit.

The ROM cost estimate for the dedicated tank pump-back option was not fully developed. Based upon experience from similar changes, one could assume perhaps $100 million for a new dedicated tank and supporting piping and changes to WTP, much less to reconfigure piping to use Waste Feed Receipt Process System vessels. ROM time to implement is 3 years for permitting, contracting, engineering, procurement, and construction.

Details of the pump-back option are found in Appendix K.

3.4.2 Operating Controls on Waste Feed

Considering there are only 28 batches driving the large demand for pump back, there is a separate option to use tank farm sampling results or blending in the Tank Waste Characterization and Staging Facility to tailor operations to limit the waste being processed. This option would entail processing low-hydrogen-generating waste normally, and then either processing the high-hydrogen-generating waste in small batches to increase vessel head space and TTLFL, blending in the Tank Waste Characterization and Staging Facility, or directly feeding the worst of the 28 batches to the HLW Facility. Fourteen of the 28 batches are planned to be included in the first 20 batches processed through WTP. This is part of the strategy to reduce the amount of tank waste curies early in the mission. During the initial radioactive operations of WTP, it may not be advisable to process the most challenging waste.

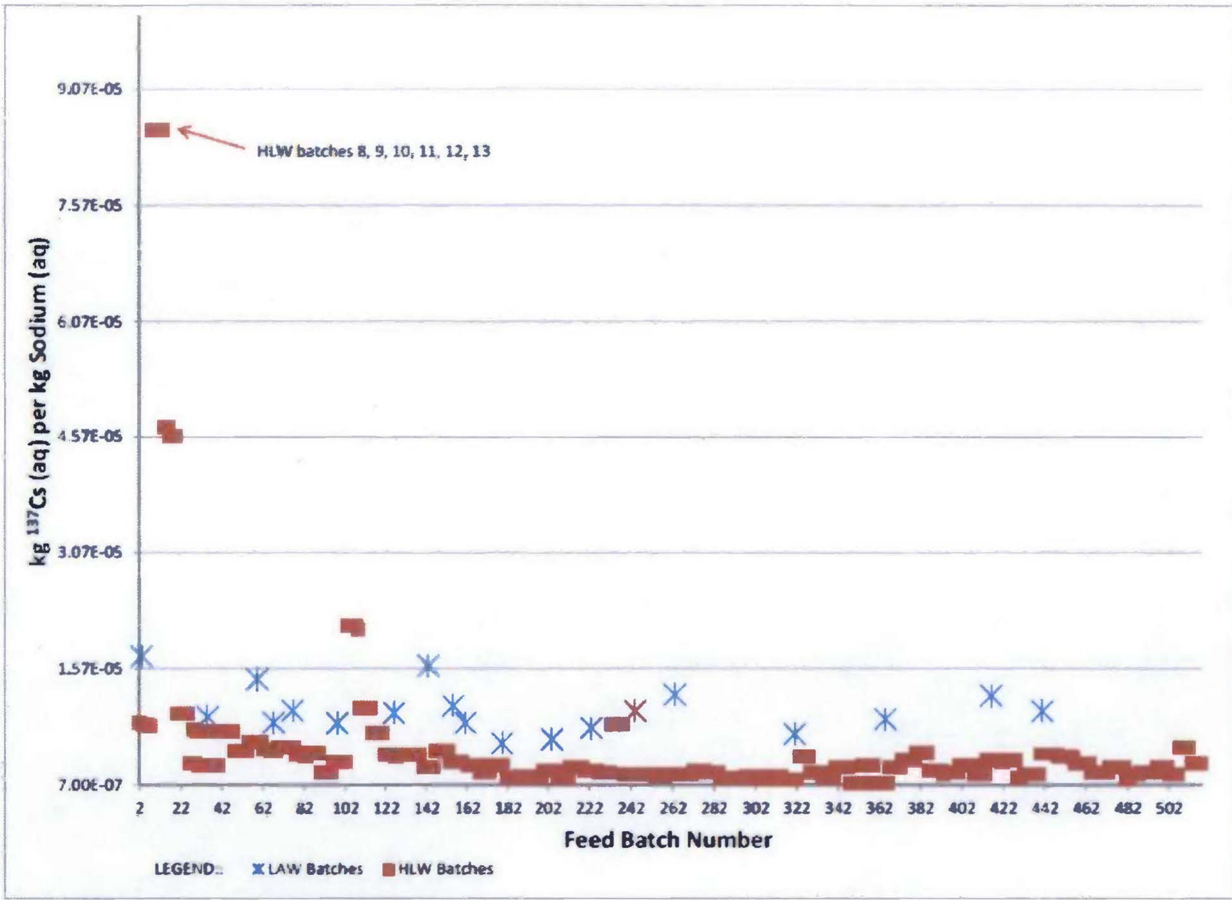

Figure 7. Hydrogen Generation Potential of Feed Batches due to Cesium-137.[5]

The advantages of this unique solution include that it requires no design changes at WTP. In fact, it could eliminate or simplify expensive and complex safety mixing equipment, it does not require significant advanced warning, and it does not require extensive transferring of waste during a week when a large NPH event is imminent, or in other ways provide any motive force that could lead to a release. It also has the potential to provide a safety mixing solution for the seismic event to significantly simplify normal mixing and to solve aerosol issues associated with safety sparging and overblow.

There could be tank farm infrastructure modifications required to deliver waste from multiple double-shell tanks for blending of batches to meet more restrictive waste acceptance criteria, but likely these capabilities will be provided by the Tank Waste Characterization and Staging Facility.

This operational control could result in a project cost savings/avoidance of greater than $0.5 billion as a result of resolved technical issues and elimination of safety mixing equipment. The ROM time to implement is likely 2 years to provide new contract direction, prove the concept with flowsheet models, and implement into the safety basis and design.

[5] BNI Calculation 24590-HLW-M4C-V11T-00002, Sheet no. 89, Sheet rev A, Fig 7-10.

The ROM impact to extending WTP mission duration from adopting operational controls is anywhere from 3 months to 2 years. This estimate is based on running half batches for 5 percent of the processing time.

Details of the operating controls option are found in Appendix K.

3.4.3 Process Waste Forward

The de-inventory options for HLW include processing waste forward, or pumping back to a new emergency storage vessel. With extreme worst-case hydrogen generation rate waste, and 7 days of warning, a total of approximately 20,000 gallons would need to be removed from vessels HFP-VSL-00001, -00002, -00005, and -00006 to achieve TTLFL > 60 days. The nominal feed-forward capacity of HLW is 20,000 gal/week minimum, and 40,000 gal/week maximum (one versus two melters). By establishing controls to limit the vessel level in the feed vessels serving a melter before taking it out of service (e.g., melter replacement, major offgas system component replacement), the volume required to feed forward is reduced to 10,000 gallons—well within the one-melter capacity of HLW. However, these numbers reflect the worst 5 percent of waste. Limits upstream or vessel level limits could also be imposed to avoid any need to process waste.

Appendix K includes the details of the process-forward option. It should also be noted that reduction in resuspension duration supported by Dr. Anspaugh would increase feasibility of the pump-back, process-forward, and operating controls options. All were evaluated assuming worst-case, 60-day event duration.

3.4.4 Qualitative Event Tree Evaluation

The qualitative event tree is a qualitative evaluation of aggregate risk: The risk of hydrogen explosions in vessels, combined with the likelihood of bounding hydrogen-generating waste in the vessel, high vessel level, high vessel temperature, the likelihood of a NPH-level volcanic eruption, and other event probabilities. The combined likelihood of this event is evaluated as part of the hazards analysis.

The next step is a very detailed unmitigated and mitigated dose consequence analysis of the postulated event, followed by controls selection.

ROM estimate for this alternative is zero because hazards analysis is already baseline work; however, the process of justifying this approach technically to stakeholders would likely require significant time and resources (ROM 2 years).

Appendix L includes the details of this approach.

3.4.5 Drain Pretreatment Facility Waste to the Hot Cell Floor and Sump

This alternative looked at the option, which exists in the current design, to drain the hot cell waste to the floor of the hot cell. By doing so, the headspace becomes nearly the entire hot cell volume, such that safety mixing is not required.

ROM estimate for this alternative is zero; however, the process of justifying this approach technically to stakeholders would likely require significant time and resources (ROM 5 years).

Note: This option was briefly reviewed, but not considered further because it was deemed to be unrecoverable and technically indefensible.

3.4.6 DOE O 420.1B Exemption

This alternative involves writing a letter to DOE Headquarters to request exemption from the 10-year update requirement in DOE O 420.1B. The team agreed the likelihood of success of this option was very small, and there is no technical justification to support pursuing this approach further.

ROM estimate for this alternative is zero; however, the process of justifying this approach technically to stakeholders would likely require significant time and resources (ROM 5 years).

3.4.7 Manually Change Filters

This alternative studied filter capacity and calculated the maximum airflow that could be sustained by a single team of operators working constantly to change intake filters in the hours following an ashfall event.

The ROM estimate for this alternative is limited to the cost to store and procure a 60-day supply of filters, perhaps $50,000. However, the analysis showed this alternative is not sustainable at the current or new proposed airborne concentration value. This alternative could be revisited if significantly lower airborne ash concentration is predicted, if significantly less outside air demand is needed, or both.

Appendix E includes the details of the manual filter change alternative.

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4.0 ASSESSMENT OF PROJECT RISK IN TERMS OF CONTINUED ENGINEERING, PROCUREMENT, AND CONSTRUCTION AHEAD OF ASHFALL DECISION

The APT investigated the schedule need associated with implementation of the revised ashfall NPH criteria, and made the following determinations.

4.1 STRUCTURAL IMPACT

- The revised ash structural criteria, for LAW and Lab, are bounded by snow load. However, drifts of ash could build up, creating regions where ash load is higher than snow load. The Structural Peer Review Team was consulted by BNI and DOE structural engineers regarding how best to model ash drifts. The proposed correlation, which considers ash density from USGS 2011, results in no design impact to LAW and Lab (according to preliminary analysis). There may be some reduction in design margin for these facilities.
- According to preliminary analyses, the revised ash structural criteria for HLW and PT Facilities are bounded by existing seismic structural criteria for these facilities. No impact is expected.
- Although no design impact is expected, approximately 6,000 hours are required to revise structural calculations to incorporate the new criteria.
- Based on the above, there is low risk to continuing structural buildout on all four main facilities.

Attachments to Appendix F document this analysis.

4.2 MECHANICAL IMPACT

- The LAW and HLW Facilities isolate chemical hazards (primarily ammonia) and idle melters to burn off cold cap during the 2-hour warning period before volcanic ash reaches Hanford after a volcanic event has occurred. From this point forward, the LAW and HLW Facilities can withstand the event without mechanical equipment associated with the melters and offgas systems running. The ability to isolate ammonia and idle melters is already included in the design. No impact is expected for these functions.
- The Lab hot cell confinement safety function is not challenged by the ashfall event. Therefore, the Lab can withstand the event without mechanical equipment running.
- The HLW and PT Facilities must maintain the active safety functions of safety mixing, cooling, and confinement for the duration of the event.
- The major impact from airborne ash concentration is to the equipment that supports safety mixing, which requires 93 percent of the approximately 1,000,000 cfm of outside air necessary to sustain BNI's proposed approach.
- The impacted safety mixing equipment includes the ETGs, the ETG building, the safety air compressors, the space in the PT Facility Annex designed to hold the safety air compressors, the switchgear to support the safety air compressors and chillers, the safety

air-conditioning units located throughout HLW and PT Facilities (approximately 30 each), and the proposed bag-house filters that support this equipment. Of the listed equipment, only the ETGs are not currently on hold.

- The remainder of the air (7 percent) supports confinement ventilation and PT Facility control room ventilation. The PT Facility control room air-handling units, filters, and fans; the HLW and PT Facility C3/C5 inbleed assemblies; C5V HEPA filters and fans; and the proposed bag-house supply filters for these systems are impacted by the ashfall issue. All of the ventilation equipment is currently on hold.
- With the exception of the ETGs, all of the equipment described above is currently on hold in accordance with management suspensions of work (MSOW) 24590-WTP-MSOW-ENG-13-0006, 24590-WTP-MSOW-ENG-13-0007, 24590-WTP-MSOW-ENG-13-0010, 2013, 24590-WTP-MSOW-MGT-11-0009, 24590-WTP-MSOW-MGT-11-0010, and 24590-WTP-MSOW-MGT-11-0012. However, these MSOWs were based on multiple technical issues over several years. As a minimum, the ashfall MSOW (24590-WTP-MSOW-ENG-13-0006) should be updated to address the current situation and all of the equipment listed above should be included.
- The ETG building design has been rescheduled to parallel HLW and PT Facility continued design, in recognition of the fact that it supports the HLW and PT Facilities only.
- The ETGs have been procured and are in the process of being commercially dedicated. The remaining scope includes seismic and environmental qualification, which is scheduled as a separate subcontract to be issued soon.
- If WTP Project management opts to pursue alternatives that eliminate the need for safety mixing, the emergency power needs will drop significantly (from 5.6 MW to something approaching 50 kW due to the reduced flow of the C5V fans [half flow = ⅛ power]). Confinement ventilation, control room, and some limited control system function would be the only remaining power needs. A small portable diesel generator inside each facility would be more appropriate for this power demand than attempting to run a large turbine requiring 230,000 cfm outside air each.
- Given that three of the most compelling alternatives eliminate safety mixing, it would be prudent to place a hold on the issuance of the qualification subcontract for the ETGs. The ETG commercial grade dedication effort should continue, because it would be difficult to regenerate after the procurement has closed. However, further work that is separate in scope on this equipment (e.g., qualification subcontracts and design of the building and ancillary equipment) should be held until the future of safety mixing is clear.
- Because the HLW and PT Facility startup schedules are likely several years out, and because the current design approach is to filter intake air with equipment placed external to the existing building footprints, the solution does not impact other equipment within the facilities. The ETG facility would grow, and the safety air compressors could be relocated, resized, and equipped with safety chillers. However, (with the exception of the ETGs discussed above), all of this equipment and these facilities are currently on hold. Nominally, a minimum of 3 years would be needed to design, procure, and construct

these facilities. The schedule baseline for the HLW and PT Facilities is in need of review, and the startup date for these facilities is not currently clear. Assuming the implementation of the ashfall solution into the design and safety basis is 4 years, there is likely adequate time to determine a path forward and implement a definitive ashfall safety strategy for WTP. Therefore, there is low risk of continuing design development on other equipment (not mentioned above) in the HLW and PT Facilities.

- Because safety mixing is 93 percent of the air demand, the safety-mixing-related technical issue resolution processes (T1, T4, T6) are key to reducing the impact of this major change in criteria. These efforts should continue on schedule, but with added emphasis on reduction of safety mixing air needs, which reduces the overall impact of any change in ash airborne concentration, and has significant benefit to other NPH events as well.
- As key decisions are made regarding technical issue resolution for HLW and PT Facility, the ashfall issue should be considered in key decisions for potential benefit by adding flexibility to key decisions for risk reduction. For instance, there may be opportunity to include flexibility to add small safety compressors, generators, or filters within the proposed HLW melter airlock, to give HLW the ability to be self-sustaining during an ashfall event.

4.3 OTHER ONGOING WORK

- Technical teams are working now to resolve many of the issues plaguing the HLW and PT Facilities. Many of the alternatives considered would be most effectively addressed as a combined effort with these activities.

  The APT recommends the following updates to the project risk register on ashfall to reflect the information gathered during the APT's studies:

  a. A new BNI risk to capture the gap between the current criteria and the current design and safety basis.

     Bounding cost half of $715 million, less $65 million for item b = $292 million.

     Mitigated cost zero to $35 million, best to worst, based on BNI estimate details.

     Mitigating actions are the actions recommended in this report.

  b. A new BNI risk to capture the safety air compressors sizing issue regarding placement in the PT Facility Annex.

     Bounding cost $65 million per BNI estimate for the safety chiller-compressor building.

     Mitigated cost $500,000–$20 million, best to worst, depending on level of modification to the existing building.

     Mitigating actions are T1, T2, T4 technical issues teams (hydrogen gas release from vessel solids, potential criticality in WTP vessels, and pulse-jet mixing vessel performance).

c. Update the DOE risk to capture the fact that the new criteria are not implemented.

   Bounding cost $357 million, the balance of the $715 million.

   Mitigated cost $900,000 best (options 1 and 4), $100 million worst (USGS warning plus a reserved tank to pump back).

   Mitigating actions are the actions recommended in this report.

5.0 RECOMMENDATIONS

The team recommends a phased, comprehensive approach that includes the following actions:

1. **Commission USGS and NOAA to revise the estimate of ashfall consequences for the Hanford Site, with peer review by NARAC.**

   Literature reviewed by the team and peer reviews of methodology used to derive the current ashfall criteria developed for the Hanford Site indicate that the airborne concentration values are unusually high and the severity and duration of the resuspension event is exceedingly conservative.

   The USGS Ash3d model can predict ash airborne concentration and deposition using inputs based on empirical data from past eruptions. The NOAA Air Resources Laboratory HYSPLIT model could be utilized to derive ash concentration estimates due to wind resuspension of particulate matter based on Hanford meteorological data.

   These models have been validated against airborne concentration data, and there is an extensive body of peer-reviewed literature regarding their use. NARAC, a DOE agency also studying atmospheric transport of particles, could be called upon to peer review both efforts.

   Because the new criteria have been called into question, the APT recommends immediately commissioning USGS, NOAA, and NARAC to assist with developing a new estimate of airborne ash concentration consequences at Hanford during and following an NPH volcanic event. ORP would function as the responsible organization to perform technical oversight and interface for this work.

2. **Pursue waste acceptance criteria or implement operational controls to address high hydrogen-generating or criticality-related feed.**

   Twenty-eight of WTP's 518 batches of waste feed have at least an order of magnitude higher hydrogen generation than 90 percent of WTP's waste. This results in safety mixing design requirements (i.e., agitation of wastes to preclude buildup of hydrogen gas bubbles) for vessels with very low TTLFL. If high-hydrogen-generating waste can be controlled such that actual TTLFL is significantly longer, more time is permitted to respond to the effects of an ashfall event. It is likely that waste feed controls could be established to ensure TTLFL was beyond the duration of the ashfall event, eliminating or significantly reducing the need for safety mixing.

   The APT recommends that ORP refine requirements for safety mixing and determine associated impacts on throughput by blending, processing in small batches, or direct feeding to HLW the 28 problem batches for hydrogen, in order to achieve TTLFL beyond the duration of the ashfall event at all times. If this can be achieved, safety mixing may not be required as an ashfall control, and the ashfall mitigation strategy is greatly simplified.

   The One System team, ORP, and the T1 technical issue team are already investigating similar alternatives and would pursue this recommendation in parallel with ongoing technical issue resolution for HLW and PT Facilities, and safety design strategy development, with One System as the responsible organization.

3. **Conduct qualitative event tree evaluation (in accordance with DOE-STD-3009).**

   During the hazards analysis process for the HLW and PT Facilities, the probabilities of an NPH volcanic event will be evaluated and the mitigated risk will be weighed to determine if safety mixing is required. This effort would be included in the safety design strategy development for PT Facility and the hazards analysis process for the HLW Facility.

   The APT recommends qualitative event tree evaluation to address the safety mixing challenge on the WTP, which is driving numerous other technical issues, including ashfall. ORP would be the responsible organization to coordinate and provide oversight of this work.

4. **Perform filtration technology value engineering study: Grout vaults as settling chambers, sand filters, and other options to sustain confinement ventilation.**

   Assuming Actions 1, 2, or 3 successfully eliminate safety mixing, there are still safety functions that require support, such as confinement ventilation. There will still be emergency power needs associated with this equipment.

   After the outcome of Actions 1, 2, and 3 are known and shared with the contractor, the merits of several of the alternatives studied by the team to address confinement ventilation and emergency power should be reviewed in a value engineering study, in order to choose the best approach to meeting these requirements.

   The study should take into account actual power usage of the C5V fans at minimum flow (approximately ⅛ of the power usage currently estimated for this equipment in the BNI basis of estimate), as well as other remaining power needs after Actions 1, 2, and 3 have been evaluated. Determine if different emergency power alternatives that are more sustainable during the event would be more appropriate to supply the remaining power needs for the ashfall NPH. The study should examine options for natural gas supply piping to WTP instead of diesel fuel supply via truck. The study also should examine the opportunity for air reuse/recirculation, and the opportunity to use filtration alternatives such as grout vaults as settling chambers or sand filters.

   The APT recommends a value engineering study, as described above, after the outcome of Actions 1, 2, and 3 are known and shared with the contractor to determine the most effective means of meeting the remaining power and air needs.

   In the meantime, the holds on engineering, procurement, and construction are in place, but should be clarified. The APT recommends BNI immediately update their ashfall MSOW to ensure all impacted equipment remains on hold. This includes placing a hold on the seismic qualification portion of the ETG procurement, although the commercial grade dedication should continue to completion. The APT further recommends updating project risks as described herein to accurately capture potential project cost increases.

   ORP would notify BNI when Action 1 is complete, and Actions 2 and 3 would be conducted in collaboration with BNI. At that point, this value engineering study could be included with technical issue T8, with ORP as the responsible organization to initiate action.

5. **Pursue 7-day warning from USGS.**

   USGS affirmed that it is possible to detect conditions at least 1 week before an eruption of the scale that would lead to NPH ash quantities at the Hanford Site. The ability of the USGS to provide advanced notifications is based on advanced seismic monitoring instrumentation and methods implemented following the 1980 Mount St. Helens eruption.

   Via an interagency agreement, the USGS could provide DOE with at least a 7-day warning of an event of this magnitude. However, funding would be required to maintain the current network of seismic instruments, scientists, etc.

   If the results of Actions 1, 2, and 3 do not eliminate the need for safety mixing or significantly reduce the ash burden, funding this effort could provide warning time needed to de-inventory the HLW and PT Facility tanks (via balancing tanks, pumping to a reserved tank, and/or processing forward) sufficiently to achieve TTLFL beyond the duration of the ash event.

   This effort would not need to be pursued immediately, but ORP should revisit this option after the results of Actions 1, 2, and 3 are clear, and could elect to pursue this alternative at any time if the other options failed to provide a comprehensive safety strategy.

6. **Other recommendations**:

   Due to the number and complexity of the actions being undertaken, and the myriad of different groups who will be responsible for the work, the APT recommends ORP management conduct ashfall focus group meetings every 6 months to review status of each action and determine if further action by ORP is necessary to keep actions on track.

   The outcome of the actions may significantly change underlying assumptions of this analysis such as duration of the event due to wind resuspension of ash. If so, ORP management may wish to reconvene the APT to review the outcome of certain actions and consider if the recommendations are still appropriate.

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6.0 CONCLUSION

In accordance with its charter, the APT:

- Studied the problems associated with implementing the new ash criteria on WTP, including the associated schedule risk
- Peer reviewed the analysis forming the basis of the new criteria (WHC-SD-GN-ER-30038, Rev. 2, and HNF-SD-GN-ER-501, Rev. 2)
- Performed a literature search to compile airborne ash concentrations measured after other volcanic eruptions
- Brainstormed potential solutions and researched 16 alternatives
- Down-selected a recommended path forward for the project that is viable, technically defensible, safe, robust, and sustainable
- Updated the project risks to reflect the team's recommendations.

A summary of the APT's findings and recommendations follows.

- The APT peer reviewed the analysis forming the basis of the new criteria,[6,7] and found that the wind resuspension methodology overestimated airborne concentration of ash. As a comparison, the team reviewed airborne ash concentrations measured after other volcanic eruptions and found that concentrations of ash are typically orders of magnitude lower than the new criteria for sites that are not near the volcano's vent. Therefore, the APT recommends delaying implementation of the revised ashfall criteria in HNF-SD-GN-ER-501, Rev. 2, and pursuing additional efforts with support from USGS and NOAA to refine ash airborne concentration estimates associated with a significant Mount St. Helens eruption (i.e., VEI 6 event). This action (Action 1) should begin immediately.
- Because sustaining safety mixing (i.e., agitation of high-level waste to mitigate hydrogen hazards) requires significant (approximately 1 million cfm) outside air for intake, cooling, and power generation, a large portion of the team's work involved examining alternatives to safety mixing. The data gathered by the team indicates there are several options that could effectively reduce or eliminate safety mixing. The most promising of these options includes demonstrating that the TTLFL may be beyond the revised duration of the ash event resulting from Action 1. This could be achieved by revising waste acceptance criteria to address the 5 percent of WTP batches that contain the waste with bounding hydrogen generation rate. Further, additional analysis of the likelihood associated with hydrogen explosion hazards following an ashfall event may support this position. These two options (Actions 2 and 3, respectively) should begin immediately.

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[6] WHC-SD-GN-ER-30038, 2012, *Volcano Ashfall Loads for the Hanford Site*, Rev. 2, Washington River Protection Solutions LLC, Richland, Washington.

[7] HNF-SD-GN-ER-501, 2012, *Natural Phenomena Hazards, Hanford Site, Washington*, Rev. 2, Washington River Protection Solutions LLC, Richland, Washington.

- Less than 10 percent of the power and outside air demand supports other safety functions, such as confinement ventilation. However, these safety functions would still be required regardless of the ability to eliminate safety mixing for the duration of the ashfall event. Therefore, several alternatives were studied to provide filtration for the remaining air demand. Because the ETGs represented half of the outside air demand, they were deemed unsustainable during this event. Action 4 recommends a value engineering study to explore filtration options (some of which were explicitly reviewed by the team and found promising), and power generation options that are sustainable throughout the event. Action 4 should be completed based on the outcome of Actions 1, 2, and 3. Action 4 calls for immediate completion of a revised MSOW by BNI to ensure the impacted equipment is on hold for this reason, a hold to be placed on ETG qualification, and updating of project risks to be consistent with the team's findings and recommendations..
- Based on discussions with USGS, capabilities exist to forecast a volcanic event of this magnitude at least a week in advance. If Actions 2 and 3 to eliminate safety mixing are not successful, another option would be to obtain warning from USGS and use the warning time to de-inventory WTP by pumping to a reserve tank, balancing tanks within the plant, or processing waste forward to the HLW Facility. However, the sophisticated seismic instrumentation at Mount St. Helens is funded via a program for which no funding source has been identified after 2018. Thus, an interagency agreement and associated funding would be required. Action 5 will not be pursued immediately, but may be revisited if the outcome of Actions 1, 2, and 3 are unsuccessful in mitigating the issue.

In summary, the APT recommends a phased, comprehensive approach to the ashfall challenge that addresses refinement of ashfall criteria, hazards analysis alternatives, consideration of additional operational controls, and further evaluation of remaining design changes,. This approach has been presented to, and endorsed by, ORP management. The project path forward is captured in Table 7.

Table 7. Options to Address Waste Treatment and Immobilization Plant Ashfall Natural Phenomena Hazard.

Top Alternatives/Actions	ROM	Responsible Organization	Start Date
1. Commission USGS and NOAA to revise the estimate of ashfall consequences for the Hanford Site, with peer review by NARAC.	$200 thousand	ORP WED	Now
2. Pursue waste acceptance criteria or implement operational controls to address high hydrogen-generating or criticality-related feed.	-$500 million (cost savings)	ORP One System	Now
3. Conduct qualitative event tree evaluation (in accordance with DOE-STD-3009)	-$500 million (cost savings)	ORP NSD	Now
4. Perform filtration technology value engineering study: Grout vaults as settling chambers, sand filters, and other options to sustain confinement ventilation	$400,000 to $400 million	BNI update risk, MSOW, and hold ETG seismic qualification; ORP communication to initiate remainder of action	MSOW now; study after providing Action 1-3 results
5. Pursue 7-day warning notifications from USGS.	$20 million and interagency agreement	ORP to determine need	Revisit after Actions 1-3 are complete
6. Conduct ashfall focus group meetings every 6 months to review status of each action.	—	—	—

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BNI = Bechtel National, Inc.
ETG = emergency turbine generator.
NARAC = National Atmospheric Release Advisory Center.
NOAA = National Oceanic and Atmospheric Administration.
NSD = Nuclear Safety Division.
MSOW = management suspension of work.
ORP = U.S. Department of Energy, Office of River Protection.
ROM = rough order of magnitude.
USGS = U.S. Geological Survey.
WED = Waste Treatment and Immobilization Plant Engineering Division.

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APPENDIX A

ASHFALL PLANNING TEAM REVIEW: INVESTIGATION OF TECHNICAL BASIS BEHIND THE ENERGY NORTHWEST DESIGN BASIS ASHFALL PARAMETERS

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APPENDIX A

ASHFALL PLANNING TEAM REVIEW: INVESTIGATION OF TECHNICAL BASIS BEHIND THE ENERGY NORTHWEST DESIGN BASIS ASHFALL PARAMETERS

INVESTIGATOR(S)

Steve McDuffie

ISSUE DESCRIPTION

I traced the history of the design basis ashfall parameters used at the Energy Northwest (formerly Washington Public Power Supply System, or WPPSS) Columbia Generating Station (CGS). The oldest available document is a memorandum from Burns and Roe, Inc., dated December 22, 1981, also identified as TM-1250. Table 1.1 in this document contains several parameters:

- 4.2 inches of uncompacted ash, compacted 40 percent to 3.0 inches
- A maximum fall rate of 0.5–1.0 in./hr with an average of 0.21 in./hr uncompacted
- An event duration of 20 hours
- An airborne concentration maximum of 700 mg/m^3 and average of 200 mg/m^3.

The airborne concentration values cite a document prepared by United Engineers & Constructors that we could not locate, and a study performed by Woodward-Clyde is cited for the maximum thickness and average fall rate values. TM-1250 also cites an interoffice memorandum dated September 9, 1980, as the source of the 0.2 in./hr fall rate. Combining this rate with a maximum accumulation of "approximately 4 inches" may be the basis for the 20-hour event duration. The 20-hour event duration can also be traced to an unpublished white paper in the Nuclear Regulatory Commission (NRC) archives. This paper, without citing a source, notes that a 20-hour event duration is based on eruption records from the 1912 Mt. Katmai eruption in Alaska.

A WPPSS letter to NRC dated October 4, 1982, summarized the outcome of task force that studied ashfall impacts on the CGS site. It provided a comparison of ashfall parameters provided in the initial Final Safety Analysis Report (FSAR) and the NRC's Safety Evaluation Report (SER). Some of the NRC's values (7.4 inches of uncompacted ash, 0.35 in./hr average fall rate, and compaction up to 60 percent), derived through discussions with the U.S. Geological Survey, are more conservative. However, both the utility's (125 mg/m^3) and NRC's (175 mg/m^3) proposed airborne concentration values are lower than the 200 mg/m^3 average value proposed in TM-1250. The origin of this discrepancy is unclear. The October 4, 1982, letter states that the utility evaluated plant performance using the NRC's preferred values, and the letter proposed changes to procedures and equipment to ensure the plant can withstand those ashfall parameters. In subsequent NRC Supplement 3 to the SER, the utility's analysis using the NRC's preferred values was found acceptable and the issue closed.

The next step in this chronology is Amendment 54 to the FSAR dated April 2000. This amendment apparently changed some of the ashfall parameters. The revised values assume a compacted thickness of 3 inches, but a compaction of only 20–40 percent (implying a maximum uncompacted thickness of 5 inches, versus 7.4 inches in 1982), and an average fall rate of

0.15 in./hr. The basis for the reduced compaction and fall rate is unclear. Moreover, the ashfall parameters in this amendment contain no mention of airborne concentration. This is the most recent documentation available regarding the Energy Northwest design basis ashfall parameters. A September 2010 NRC inspection report contained a finding related to ashfall mitigation, but it was related solely to the Energy Northwest implementation of ashfall mitigation measures.

During and after an ashfall event, the CGS does not have a need for abundant compressed air to maintain tank mixing as does the Waste Treatment and Immobilization Plant. The Energy Northwest ashfall mitigation strategy is fairly straightforward, simply maintaining an ash-free environment in certain buildings and rooms. As a result of the ashfall hazard extra filtration equipment was installed in two diesel generator rooms, six critical equipment rooms in the reactor building, and two standby service water pump houses. Energy Northwest has an emergency procedure to implement special preparations once an ashfall event is expected. TM-1250 states that offsite power could be lost for up to 8 hours in an ashfall event, but the analysis in the October 8, 1982, letter accepted by NRC assumes offsite power is lost for no more than 2 hours.

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DISCUSSION

The technical basis for the CGS design basis volcanic ash airborne concentration values remains elusive. Nonetheless, the fact that the values appearing in licensing documents range from about 100 mg/m^3 to a maximum of 700 mg/m^3, with an accepted average around 200 mg/m^3, merits attention. The Performance Category-3 design value of 1,500 mg/m^3 for the Hanford Site provided in WHC-SD-GN-ER-30038 is significantly higher than the values considered throughout the CGS licensing history. The 1,500 mg/m^3 value is suspect, especially considering the highest value measured during the 1980 Mt. St. Helens ashfall was 33.4 mg/m^3. A separate appendix examines historical measurements of airborne concentration during ashfall events and the validity of assumptions behind the 1,500 mg/m^3 value.

CONCLUSIONS

The technical basis of the CGS design value of 175 mg/m^3 average airborne ashfall concentration is insufficient for DOE to adopt such a value for WTP. Additional analysis of airborne concentrations measured in ashfall events worldwide, as well as ashfall settling rates that bring into question the 1,500 mg/m^3 value, may provide adequate basis for adopting a value much lower than 1,500 mg/m^3 for WTP.

RECOMMENDATION

Viable Alternative by Itself?

No. However, an analysis of worldwide measurements of airborne concentrations measured during major ashfall events may help justify a design basis airborne concentration similar to the NRC's design value of 175 mg/m3 employed in the 1982 event analysis.

Viable Alternative in Combination with other Alternatives?

Yes. As noted above, further analysis may support a much lower design basis airborne concentration value, and that value in combination with other alternatives may be a viable solution to the ashfall conundrum.

Estimated Impacts and Other Considerations:

None.

SIGNATURE

Investigation Lead: [signature] **Date:** 12/16/14

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APPENDIX B

ASHFALL PLANNING TEAM REVIEW: INVESTIGATION OF ACTUAL MEASUREMENTS OF AIRBORNE CONCENTRATIONS IN HISTORIC ASHFALL EVENTS

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APPENDIX B

ASHFALL PLANNING TEAM REVIEW: INVESTIGATION OF ACTUAL MEASUREMENTS OF AIRBORNE CONCENTRATIONS IN HISTORIC ASHFALL EVENTS

INVESTIGATOR(S)

Steve McDuffie

ISSUE DESCRIPTION

WHC-SD-GN-ER-30038, *Volcano Ashfall Loads for the Hanford Site*, Rev. 2, contains design basis airborne particulate concentrations for an ashfall event. The value for a Performance Category (PC)-3 facility during an initial ashfall is 1,500 mg/m^3, and an additional 1,100 mg/m^3 from peak resuspension that decreases over time. The initial ashfall value was calculated with some basic assumptions of eruption duration (12 hours) and particle settling velocity (1.7 m/s), which could result in the value being overly conservative. With the intent of comparing the design basis value with measured values, volcanic ashfall literature was reviewed for measurements of airborne ash concentrations during ashfall events and during resuspension events shortly after completion of volcanic eruptions and direct ash transport.

Following are several key points from the literature:

- Small ash particles, particularly below 0.1 mm diameter, normally aggregate and fall from the atmosphere at a rate much faster than predicted by Stokes settling of individual particles. This has been noted by Carey and Sigurdsson (1982); Soren (1982) as cited in Baxter et al. (1999); Rose et al. (2001); Rose and Durant (2009); Durant et al. (2009); Van Eaton et al. (2012) as cited in Mastin et al. (2014); and Mastin et al. (2013). Larger particles above 1 mm diameter usually fall at their individual terminal velocity and are removed from ash clouds in less than 30 minutes (Mastin et al., 2009).
- Evidence of high settling velocities during ashfalls might suggest the Hanford 1,500 mg/m^3 concentration is too high: higher velocities imply lower residence time in the atmosphere and lower airborne concentrations. However, the velocities noted in the literature do not discredit the 1.7 m/s velocity used in the Hanford calculation. Carey and Sigurdsson (1982) best modeled the May 18, 1980, Mount St. Helens ashfall as a result of aggregations only a few hundred microns in diameter with a settling velocity of 0.35 m/s. Moreover, Durant et al. (2009) calculated a Mount St. Helens 1980 average fall velocity of 1.5 m/s.
- Eruption duration does not appear to vary systematically with eruption rate or total volume (Mastin et al., 2009). The 1912 Novarupta eruption produced 15 km^3 over approximately 52 hours, and the 1815 Tambora eruption produced about 50 km^3 in 24 hours (Hildreth, 1983 and Self et al., 1984 as cited within Mastin et al., 2014). Therefore correlating eruption and ashfall duration with a given ashfall volume is highly uncertain. Challenging the 1,500 mg/m^3 value based on the average fall velocity or the eruption duration used in the calculation does not appear feasible based on research performed. Table B-1 shows relevant airborne concentration values recorded from various volcanic eruptions.

Table B-1. Measured Airborne Ash Concentration from Various Eruptions

Concentration	Comments	Source
33.4 mg/m^3	Actual peak measurement from Yakima, Washington, on May 18, 1980.	Bernstein et al. (1986)
5.8–13 mg/m^3	Range of 24-hour average measurements collected in Yakima during the span of May 19-25, 1980, thus representing some degree of resuspension.	Bernstein et al. (1986)
5 mg/m^3	Maximum post- Mount St. Helens value measured in the Hanford area, representing resuspension, on May 25, 1980.	Sehmel (1982)
10 mg/m^3	Maximum measured value in Argentina in October 2011 during a major resuspension of ash first deposited in June 2011.	Folch et al. (2014)
0.25 mg/m^3	Maximum measured value from an aircraft, several hundred meters above ground level, near Yakima on May 23, 1980.	Hobbs et al. (1983)
<10–1,000 mg/m^3	Ground-based C-band radar measurements of volcanic clouds from Mt. Spurr, Alaska, less than 30 minutes after eruptions in 1992, while clouds still contained particles 2-20 mm diameter.	Rose et al. (2001)
>2 mg/m^3	Measurement of PM_{10} concentration (only particles less than 0.01 mm diameter) in Iceland during a June 4, 2010, resuspension of ash first deposited in April and May 2010.	Leadbetter et al. (2012)
<2 mg/m^3	Measurements of PM_{10} concentration near Soufriere Hills Volcano, Montserrat, shortly after an eruption on October 10, 1997.	Baxter et al. (1999)
1.4–11.8 mg/m^3	Range of eruption cloud total mass concentrations, collected from aircraft, from Mount St. Helens eruptions between March 28 and June 13, 1980.	Hobbs et al. (1982). This reference was incorrectly cited by Durant et al. (2009) as documenting a measurement of 7,000 mg/m^3 collected 389 km downwind of Mount St. Helens on May 18, 1980. The measurement was actually 7 mg/m^3.

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Table B-1. Measured Airborne Ash Concentration from Various Eruptions

Concentration	Comments	Source

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DISCUSSION

The few measurements of airborne concentrations collected from recent worldwide eruptions lend skepticism to the Hanford value of 1,500 mg/m^3, especially given the 200 km distance between Hanford and Mount St. Helens. Concentrations of this magnitude are found only close to a volcanic vent before the largest particles have settled. This information alone does not provide adequate technical basis to select an alternative, specific design value for airborne particulate concentration, but it certainly supports the contention that 1,500 mg/m^3 is conservative. The Ash3d model developed by the U.S. Geological Survey (USGS) continues to be refined, and that ash deposition model can provide an estimate of airborne concentrations at Hanford during a major ashfall event. Given that USGS experts are well recognized at modeling volcanic ashfall, the Ash3d estimates could provide a valuable data point and may be a more defensible value for design purposes than would the 1,500 mg/m^3 figure.

CONCLUSIONS

The calculations in WHC-SD-GN-ER-30038, Rev. 2, leading to the 1,500 mg/m^3 PC-3 ashfall concentration design value were not reviewed by experts in the volcanic ashfall community. The report was peer reviewed, but not by the most knowledgeable experts. Therefore, it is recommended those airborne concentration values not be used as Waste Treatment and Immobilization Plant design values. The U.S. Department of Energy, Office of River Protection, should consult with the USGS to derive appropriate design values for airborne ash concentration. Methods for analyzing this particular natural hazard are not mature, and multiple experts should be involved in deriving future design values.

RECOMMENDATION

Viable Alternative by Itself?

No. However, with further consultation with the USGS, a more technically defensible airborne concentration value may be achieved.

Viable Alternative in Combination with other Alternatives?

Yes. Further consultation with the USGS may arrive at a much lower design basis airborne concentration value, and that value in combination with other alternatives may be a viable solution to the ashfall conundrum.

Estimated Impacts and Other Considerations:

None.

SIGNATURE

Investigation Lead: Stephen McDonald **Date:** 12/16/14

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APPENDIX C

ASHFALL PLANNING TEAM REVIEW: INVESTIGATION OF AIRBORNE RESUSPENSION OF VOLCANIC ASH

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APPENDIX C

ASHFALL PLANNING TEAM REVIEW INVESTIGATION OF AIRBORNE RESUSPENSION OF VOLCANIC ASH

INVESTIGATOR(S)

Robert C. Nelson

ISSUE DESCRIPTION

WHC-SD-GN-ER-30038, Rev. 2, *Volcano Ashfall Loads for the Hanford Site*, contains design basis airborne particulate concentrations for an ashfall event. The value for a Performance Category (PC)-3 facility during an initial ashfall is 1,500 mg/m^3, and an additional 1,100 mg/m^3 from peak resuspension that decreases over 60 days. The initial ashfall value was calculated with some basic assumptions of eruption duration (12 hours) and particle settling velocity (1.7 m/s).

Appendix B addresses the initial concentration from the settling of ash following historic volcanic events. This appendix summarizes a study of the resuspension values predicted by Pacific Northwest National Laboratory that form the basis of WHC-SD-GN-ER-30038, Rev. 2, in regard to resuspension of ash.

The study included the following elements:

1. A review by particle science expert Dr. Lynn Anspaugh, author of the correlation used by Snow to determine airborne ash resuspension.
2. A simplified analysis of five years of wind data from the Hanford Meteorological Station and calculation of duration and frequency of friction velocity estimated high enough to resuspend ash.
3. Investigation into tools used to predict initial airborne concentration and wind resuspension of particulate matter (discussions with the U.S. Geological Survey [USGS], National Oceanic and Atmospheric Administration [NOAA], National Atmospheric Release Advisory Center [NARAC], and Dr. Anspaugh).

REQUIREMENTS REVIEWED

- WHC-SD-GN-ER-30038, 2012, *Volcano Ashfall Loads for the Hanford Site*, Rev. 2, Washington River Protection Solutions LLC, Richland, Washington.

DOCUMENTS REVIEWED

- Attachment C.1, Dr. Lynn Anspaugh, 2014.
- Maxwell, R.M., and Anspaugh, L.R., 2011, "An improved model for the prediction of resuspension," *Health Physics*, Vol. 101(6), pp. 722-730.
- WHC-SD-GN-ER-30038, 2012, *Volcano Ashfall Loads for the Hanford Site*, Rev. 2, Washington River Protection Solutions LLC, Richland, Washington.

DISCUSSION

Following are several key points from the study:

- Literature on resuspension from Mount St. Helens and other volcanoes indicates significantly less airborne concentration of ash than empirical data from worldwide volcanic eruptions support (see Appendix B). Resuspension would be smaller and decrease more rapidly than would be predicted with the Maxwell and Anspaugh (2011) equation, which was developed from empirical data for trace deposits on soil surfaces. Resuspension of ash will occur, but it likely will be episodic and driven by strong winds and/or efforts at cleanup. Based on measurements at Yakima and elsewhere, a year-long average value of 1 mg/m^3 is reasonable. (This is still quite dusty, about 10 times the normal average.) Peak values of 20 mg/m^3 can be expected.
- Hanford meteorological data scanned during the review from the past 5 years initially indicate wind events with friction velocity > 45 cm/s typically occur 11.7 percent of the time. Data conservatively evaluated from 2009 resulted in an average persistence of 4.24 hours and single episodes of 24, 29, and 30 hours. Based on literature from Dr. Draxler, NOAA Air Resources Laboratory (Draxler et al., 2010), these are the times when peak resuspended ash could occur. Further peer reviewed evaluation of 10 years of meteorological data is recommended to provide further empirical validation of historical data.
- The postulated concentration of 1,500 mg/m^3 during ashfall is likely overestimated by at least a factor of 4, based on scaling up the Yakima 1980 data to a 10 cm deposit, which seems reasonable for the event based on empirical data. The associated fall velocity predicted in WHC-SD-GN-ER-30038 (>1 m/s) would likely be too fast for filter face velocity to capture.
- USGS has the capability of modeling wind velocity and wind speed using weather data and determining consequences of volcanic events using the Ash3d software. The software tool offers much more refined probability estimates regarding wind speed and direction, using real weather data history, and can run numerous cases to determine bounding events. The model has been validated against NOAA airborne concentration data from satellite imagery. However, Ash3d must be backfit with empirical data regarding particle size distribution likely to be deposited at the site of interest. This can be addressed with data from previous Mount St. Helens eruptions.
- The NOAA HYSPLIT (Hybrid Single Particle Lagrangian Integrated Trajectory) model has the ability to model airborne resuspension of ash and should be further evaluated as a tool for determining a defensible resuspension design criteria value.
- The NARAC suite of models generally used to support emergency response activities for numerous potential scenarios do not have the ability to model volcanic ash, but NARAC could be involved in a modeling effort as a peer reviewer.
- Caution must be exercised when using models that the inputs are based on empirical data and the model has been validated against empirical data.

- Recommend modelers and resuspension experts from NOAA, NARAC, and USGS team to study the problem and provide more accurate models of the PC-1, PC-2, and PC-3 probability eruption consequences for Hanford.

CONCLUSIONS

Both resuspended airborne concentration and initial concentration of ash predicted by WHC-SD-GN-ER-30038, Rev. 2, appear to be significantly overconservative and further evaluation is warranted. Resuspension will occur, but it likely will be episodic and driven by strong winds and/or efforts at cleanup. Based on measurements at Yakima and elsewhere, a year-long average value of 1 mg/m^3 is reasonable. Peak values of 20 mg/m^3 can be expected.

Recommend Hanford reject the WHC-SD-GN-ER-30038, Rev. 2, airborne ash concentration values (for both initial concentration and resuspended ash) and commission modelers and resuspension experts from NOAA, NARAC, and USGS to study the problem and provide more accurate models of the PC-1, PC-2, and PC-3 probability eruption consequences for Hanford.

RECOMMENDATION

Viable Alternative by Itself?

Potentially. Depending on the results of the team modeling approach, a much smaller airborne ash concentration (initial and resuspension) may determine the current design is viable without modification.

Viable Alternative in Combination with other Alternatives?

Yes. Many of the design alternatives studied by the team are non-starters in 2,700 mg/m^3 airborne ash concentration, but become viable with ash concentration resembling previous measurements and model results.

Estimated Impacts and Other Considerations:

Least expensive alternative in that it does not require early warning. (USGS stated that the current seismic instrumentation can provide a 1-week warning period before any major eruption of Mount St. Helens. However, the Pacific Northwest Seismic Network funding (by National Science Fund) sunsets in 2018. After that, funding of the Mount St. Helens network of instruments and scientists is indeterminate. The current estimate of that cost is $200,000/year.

ATTACHMENTS

C.1 ASHFALL PLANNING TEAM REVIEW INVESTIGATION OF ASHFALL AMOUNT, AIR CONCENTRATION, RESUSPENSION

SIGNATURE

Investigation Lead: Robert C. Nelson **Date:** 12/16/14

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ATTACHMENT C.1

TITLE: Ashfall Planning Team Review
Investigation of Ashfall Amount, Air Concentration, Resuspension

INVESTIGATOR(S): Lynn R. Anspaugh

ISSUE DESCRIPTION

- Members of the USGS (Hoblitt and Scott 2011) have estimated that there is an annual probability of 1 in 10,000 that ashfall from a volcanic eruption could be 10 cm thick or more at the USDOE Site at Hanford.
- Staff at PNNL (Snow 2012), based on some measurements and several assumptions, calculate that the mass loading associated with a 10 cm ashfall might be 1500 mg/m^3 for 12 hours.
- Staff at PNNL (Snow 2012) have assumed that the resuspension equation of Maxwell and Anspaugh (2011) would apply to the postulated 10-cm thick ashfall at Hanford. Making this assumption results in high concentrations of resuspended mass slowly declining over time.
- The purpose of this investigation was to examine the validity of the data referred to in the above three points.

REQUIREMENTS REVIEWED (IF RELEVANT)

None.

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DISCUSSION

Introduction

The estimated 1 in 10,000 year, 10-cm thick ashfall at Hanford seems reasonable, as it is based on empirical data (although of limited extent). It has been suggested that a USGS model named Ash3d be run with the apparent hope that a more accurate prediction could be achieved. However, Ash3d cannot be run without several input assumptions, which would have to be based on empirical data.

An important issue is the postulated air concentration of 1500 mg/m^3 for 12 hours during the postulated ashfall (Snow 2012). This airborne material is calculated to have a fall velocity of 1.7 m/s; such a value is consistent with the fall velocities that must be assumed to calibrate various ashfall models, as discussed by Mastin (2013). At such a high fall velocity, the ashfall would have to be coming down not as individual particles, but as a conglomerate of mass held together by gravitational forces (in the same way that the Earth and its moon orbit the sun together due to gravitational attraction). In such a case most of this airborne material would not be sampled by vertical-face filter systems.

For an ashfall thickness of 10 cm it would not be appropriate to apply the resuspension equation from Maxwell and Anspaugh (2011). No one can say for certain from what thickness of soil or ash resuspension might occur, but it cannot be 10 cm except possibly during a severe windstorm. Maxwell and Anspaugh discuss some measurements of resuspended material following Project Schooner, which was the explosion of a 30-kt nuclear device buried at a depth designed to create a crater—probably as close as man can get to simulating a volcano. The observation was that resuspended air concentrations were much lower and decreased much more quickly than would be predicted by the equation derived from data from trace depositions.

Data from the 1980 eruptions of Mount St. Helens

There are numerous data associated with the 1980 eruptions of Mount St. Helens. The May 18 eruption was the largest, with the ash cloud moving to the ENE, but there were also significant eruptions on May 25, June 12, July 22, August 7, and October 16–18 (Sarna-Wojcicki et al. 1981). The total mass from the May 18 eruption was estimated as 4.9×10^{14} g; estimated normalized masses for the six eruptions are given in Table 1.

The May 25 ashfall pattern was to the NW. The pattern from the June 12 eruption was complicated with an initial path to the south, then turning to the west, and then south again. The deposition pattern from the July 22 eruption was to the NE. For the August 7 eruption the pattern was to the NNE. The October 16–18 eruption produced a complicated pattern with one lobe to the SE and another to the SW.

There are few data on air concentrations during ashfall as measured with a typical EPA-type air sampler. There is one data point from Yakima during the eruption on May 18; this value for total suspended particles (TSP) was reported as 33.4 mg/m^3 (Bernstein et al. 1986). During May 19–25 the reported values for TSP were stated to vary from 5.8 to 13 mg/m^3; on May 26 the TSP was 0.25 mg/m^3; and during May 27–June 11 the TSP varied from 0.05 to 0.25 mg/m^3. The ashfall at Yakima was about 1 cm; if the air-concentration value is scaled to the postulated

Table 1. Dates and masses of the six eruptions of Mount St. Helens in 1980. Data are from Sarna-Wojcicki et al. (1981)

Date, 1980	Estimated normalized mass
May 18	1 [a]
May 25	0.1
June 12	0.1
July 22	0.01
August 7	0.001
October 16–18	0.001

[a] Estimated total mass is 4.9×10^{14} g.

ashfall depth of 10 cm, the scaled air concentration of 334 mg/m^3 is substantially less than the 1500 mg/m^3 postulated by Snow (2012).

As for resuspension following the eruptions of Mount St. Helens, Rautenstrauch (2003) has assembled TSP data for six locations in Washington State for the period of 1979–1982. These locations were selected among others in Washington State, because they had at least one 24-hour concentration above 0.4 mg/m^3. The ashfall amounts and locations are given in Table 2. Clarkston is in the SE corner of the state, Longview is about 55 km almost directly W of Mount St. Helens, and Vancouver is near Portland, Oregon. These TSP data were reportedly extracted from the EPA AirData database; such ancient data are no longer kept in the online EPA database. The ashfall amounts were extracted by Rautenstrauch from figures contained in Sarna-Wojcicki et al. (1981). For analysis in this current report the TSP data from Rautenstrauch (2003) were

Table 2. Location and ashfall amounts for locations in Washington State for which TSP data are provided in Rautenstrauch (2003), who estimated the ashfall amounts from figures in Sarna-Wojcicki et al. (1981).

Location	Ashfall, cm	From Mount St. Helens	
		Distance, km	Direction
Clarkston	0.05	~400	E
Richland	0.05–0.1	~240	E
Longview	0.1–0.3	~55	W
Spokane	0.25 0.5	~400	ENE
Vancouver	0.4–0.5	~75	SSW
Yakima	0.5–1.0	~140	ENE

copied into an Excel file for the period of April 1–November 29, 1980. The data are shown in Table 3. As is typical, the TSP samplers were not run every day. Some of the daily values for Yakima during and immediately after the May 18 eruption are missing from Rautenstrauch (2003), apparently because he was more interested in resuspension rather than activity during ash passage. And data from Bernstein et al. are not detailed for the entire week, although Bernstein et al. do indicate that TSP values were significantly elevated for the entire week.

A plot of these data is shown in Fig. 1. The May 18 data point for Yakima is very notable. (Remember that some values for Yakima for the week beginning May 18 are not included in the database from Rautenstrauch.) The two next higher values are from Longview, which was impacted by the May 25 eruption. An overall impression is that the TSP values at Yakima had returned to normal values within a few weeks of the May 18 eruption, even though smaller eruptions of Mount St. Helens continued to occur. Another impression is that the TSP values in Spokane appear to be unusually high compared to the other five locations. This is shown more clearly in Fig. 2, which is a log-probability plot of the data from Table 3. The data for Spokane are definitely higher than those for the other five locations. A Kruskal-Wallis test of all six distributions shows that they are statistically different with $p = <0.0001$. Data for the four locations of Clarkston, Richland, Longview, and Vancouver are not significantly different from each other. When data from Yakima are added to the other four locations, the five data sets differ from each other with $p = 0.016$. The data for Yakima were obviously influenced by the May 18 eruption. The data for Spokane are consistently higher than for the other locations, even before the May 18 eruption. This increased level is likely because Spokane is a larger and more industrialized city. (Fig. 2 was created and the statistical tests performed within KaleidaGraph 4.5 software.[1]) The geometric means and geometric standard deviations for the data from the six locations are given in Table 4. Again, Spokane is shown to have higher concentrations than the other locations; Yakima has a higher geometric standard deviation that reflects the influence of ashfall.

The data discussed so far have been for stationary, ambient air samplers. Occupational workers, especially those involved in cleanup activities can experience substantially higher exposures. Table 5 shows concentrations of respirable and total dust for a variety of workers during June 1980, as measured by industrial hygienists from the National Institute for Occupational Safety and Health (NIOSH). Only one value of respirable dust exceeded 1 mg/m^3, but several of the workers were exposed to very high levels of TSP; given that their occupations are known to create dusty environments, this is not surprising.

According to Buist et al. (1986) another study was carried out by NIOSH on four groups of loggers working in ashfall areas to the west of Mount St. Helens and two control groups in Oregon. The airborne concentrations of respirable dust in June 1980 for the Washington logging areas with the most ash were 0.9 and 0.28 mg/m^3 for the cutting and rigging crews, respectively. In September 1980 the levels were 0.27 and 0.32 mg/m^3. Given the type of disturbances that logging creates, it is not surprising that high levels of resuspended ash are going to be experienced by occupational workers for long times following the initial deposition.

[1] Synergy Software, Reading, PA.

Table 3. TSP data for six locations in Washington State for April 1–November 29, 1980. Data are from Rautenstrauch (2003), except for the May 18 datum for Yakima taken from Bernstein et al. (1986). All values in mg/m³.

Date	Clarkston	Richland	Longview	Spokane	Vancouver	Yakima
4/1/1980	0.073					
4/3/1980	0.056	0.057	0.107	0.261	0.058	0.055
4/6/1980	0.047					
4/8/1980	0.068					
4/9/1980		0.202	0.026	0.063	0.014	0.01
4/12/1980	0.094					
4/15/1980	0.071		0.035	0.197	0.063	0.092
4/17/1980	0.144					
4/21/1980	0.054	0.017	0.037	0.118	0.036	0.033
4/24/1980	0.129					
4/27/1980	0.113	0.065	0.066	0.093	0.102	0.057
4/30/1980	0.037					
5/3/1980	0.081	0.067	0.05		0.137	0.075
5/6/1980	0.043					
5/9/1980	0.029	0.023	0.026		0.024	0.114
5/10/1980				0.072		
5/13/1980	0.061					
5/15/1980	0.032	0.05	0.036		0.041	0.062
5/18/1980	0.678					33.4
5/21/1980	0.601		0.017		0.196	
5/23/1980		0.611				
5/24/1980	0.423					
5/27/1980			1.42	0.461	0.093	
5/28/1980						0.172
5/29/1980		0.099				
6/2/1980	0.089	0.083	0.526	0.699		0.426
6/3/1980					0.044	
6/8/1980			0.986	0.521	0.046	0.289
6/10/1980		0.109				
6/14/1980		0.049	0.071	0.299		0.105
6/15/1980					0.474	
6/20/1980	0.149	0.093		0.52		0.422
6/21/1980					0.233	
6/24/1980	0.062					
6/26/1980	0.044	0.074	0.168	0.228	0.239	0.18
6/29/1980	0.094					
7/1/1980					0.206	
7/2/1980	0.076	0.091	0.143	0.449		0.315
7/8/1980		0.133	0.097	0.743	0.134	0.176

Table 3. (Continued)

Date	Clarkston	Richland	Longview	Spokane	Vancouver	Yakima
7/14/1980	0.05	0.15	0.053	0.253		0.13
7/15/1980					0.095	
7/20/1980		0.065	0.106	0.22	0.216	0.093
7/23/1980	0.526					
7/26/1980		0.181	0.067			0.295
7/27/1980				0.335		
7/29/1980					0.118	
8/1/1980	0.147	0.171	0.044	0.402	0.087	0.205
8/4/1980	0.089					
8/7/1980	0.128	0.077	0.181	0.266	0.193	0.075
8/13/1980	0.167	0.128	0.046	0.185	0.105	0.119
8/16/1980	0.133					
8/19/1980	0.054	0.103	0.054	0.114	0.117	0.107
8/21/1980	0.085					
8/25/1980	0.102	0.081	0.048	0.247	0.088	0.104
8/27/1980	0.104					
8/31/1980	0.039		0.025	0.232	0.026	0.036
9/6/1980	0.119	0.091	0.056	0.299	0.069	0.171
9/10/1980	0.109					
9/12/1980	0.106	0.071	0.036		0.053	0.227
9/16/1980	0.077					
9/18/1980	0.087	0.085	0.044	0.354	0.031	0.058
9/22/1980	0.076					
9/24/1980	0.091	0.086	0.093	0.285	0.06	0.091
9/28/1980	0.094					
9/30/1980	0.144	0.076	0.053	0.224	0.033	0.245
10/6/1980			0.062	0.431	0.084	0.196
10/7/1980	0.18	0.146				
10/9/1980	0.182					
10/12/1980	0.105	0.049	0.077	0.111	0.039	0.055
10/15/1980	0.055					
10/18/1980	0.114	0.094	0.119	0.192	0.123	0.066
10/21/1980	0.114					
10/24/1980	0.13	0.075	0.118	0.213	0.053	0.12
10/28/1980	0.123					
10/30/1980	0.148	0.052	0.103	0.371	0.058	0.16
11/2/1980	0.063					
11/5/1980	0.139	0.033	0.059	0.139	0.035	0.041
11/7/1980	0.049					
11/11/1980	0.04	0.025	0.078	0.098	0.057	0.035
11/13/1980	0.082					
11/17/1980	0.143	0.037	0.037	0.159	0.03	0.085

Table 3. (Concluded).

Date	Clarkston	Richland	Longview	Spokane	Vancouver	Yakima
11/20/1980	0.075					
11/23/1980	0.052	0.023	0.078	0.087	0.034	0.052
11/25/1980	0.086					
11/29/1980	0.048	0.048	0.026	0.069	0.014	0.037

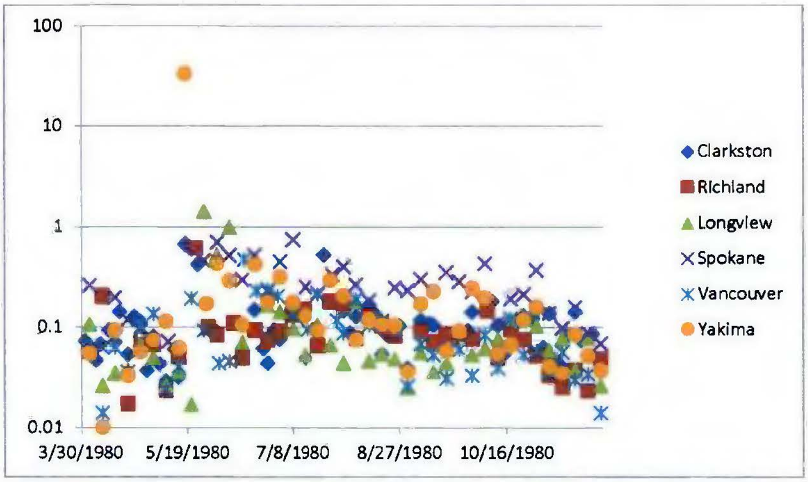


Fig. 1. A plot of the data from Table 3 as a function of time for the six locations in Washington State. The TSP values (ordinate) have units of mg/m^3.

Data from sites around other volcanic eruptions

There have been a variety of efforts to measure and model resuspension from sites in the vicinity of previous eruptions of volcanoes. One of the more interesting is related to the June 2011 eruption of Puyehue-Cordón Caulle Volcanic Complex in Chile (Folch et al. 2014). Deposits in central Patagonia were mobilized during October 14–18, 2011; ash clouds were dispersed across Argentina, including Buenos Aires, which is 1380 km distant from the volcano complex. During this period a southwestern frontal system crossed northern Patagonia with surface wind speeds of 65–85 km/h and with gusts of up to 95 km/h. In Buenos Aires the daily averaged value of PM_{10} was 0.252 mg/m^3. (PM_{10} is the airborne concentration of particles with diameters less than 10 μm.) Maximum concentrations of TSP at other locations in Argentina were as high as 10 mg/m^3 for a few hours. Thus, there is clear evidence that severe windstorms can cause episodic events of resuspended material even at long distances and several months after ashfall occurred.

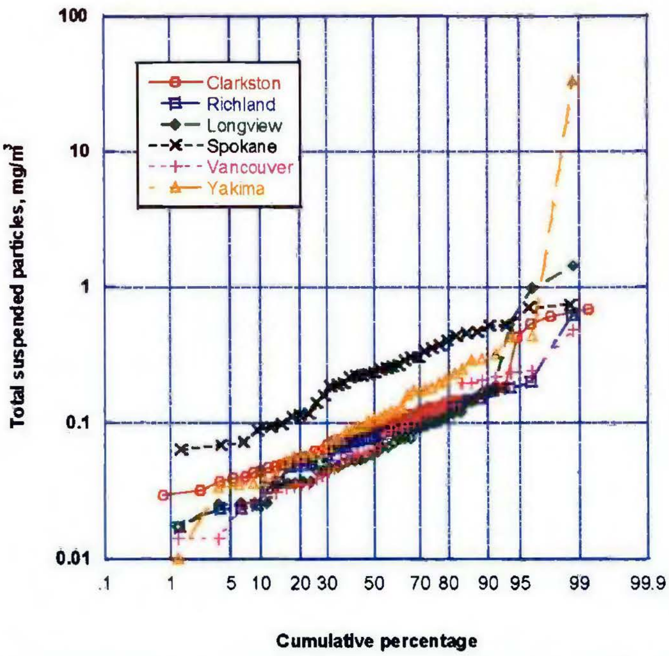


Fig. 2. Log-probability plot of the TSP data from Table 3 for the six locations in Washington State for the time period of April 1–November 29, 1980.

Table 4. Statistics for the data as shown in Table 1 from six locations in Washington State. Data were extracted from Rautenstrauch (2003) for the period from April 1 through November 29, 1980.

Location	Number	Geometric mean, mg/m^3	Geometric standard deviation, unitless
Clarkston	65	0.093	1.85
Richland	39	0.075	1.94
Longview	40	0.072	2.36
Spokane	37	0.223	1.91
Vancouver	41	0.071	2.22
Yakima	41	0.117	2.87

Table 5. Dust levels for different occupational workers as measured by industrial hygients from NIOSH. This table was reproduced from Buist et al. (1986)'s Table 2, as noted. They state that the source of the data is Baxter et al. (1981), but no such data appear in Baxter et al.

TABLE 2—Total and Respirable Dust Levels for Different Occupations, June 1980*

Occupations	Total Dust mg/cu m mean (range)	Respirable Dust† mg/cu m mean (range)
Cleanup Crews		
Hand-shoveling and sweeping	2.65(0.64-6.46)	0.46(0.02-2.08)
Sweeper-truck or broom-truck drivers	5.50(0.60-23.1)	0.64(0.03-2.83)
Front-end-loader operators	...(5.17-33.6)	0.50(0.21-0.98)
Grader operators	5.96(0.01-31.9)	0.59(0.01-2.39)
Water-truck drivers	1.48(0.23-6.14)	0.21(0.04-0.64)
Truck drivers	...	0.19(0.10-0.37)
Manual hosing	...	0.05(0.03-0.06)
Rubbish Worker	9.01(0.73-25.5)	0.67(0.11-5.51)
Idaho Forest Worker	...	0.48(0.01-2.46)
Agricultural Worker	1.42(0.79-3.20)	0.44(0.01-1.39)
Law Enforcement Personnel	0.97(0.04-4.17)	0.10(0.01-0.23)
Area Samples		
Homes	0.09(0.03-0.20)	0.03(0.01-0.08)
Schools	0.30(0.20-0.50)	0.06(0.01-0.11)
Commercial establishments	0.30(0.11-0.44)	0.09(0.03-0.20)
Autos	...	0.10
Combines		
With air-conditioned cabs	5.82(4.24-8.20)	0.40(0.17-0.74)
Without air-conditioned cabs	...	2.24(2.20-2.38)
Trucks	2.10(1.70-2.75)	0.35(0.21-0.50)

*Data obtained by National Institute of Occupational Safety and Health industrial hygienists as reported in the Centers for Disease Control's Mount St. Helens Volcano Reports Nos. 12 and 17.

†Respirable dust particles collected on a 37 μm polyvinyl chloride filter after passing through a 10 μm cyclone.

SOURCE: Baxter, et al,[3] with permission of author and publisher.

Another recent investigation considered resuspension from the ash deposited from the April and May 2010 eruption of the Eyjafjallajökull volcano in Iceland (Leadbetter et al. 2012). Ash was deposited over an area of more than 3000 km^2 to the east and southeast of the volcano. Leadbetter et al. state that dust storms are not unknown in Iceland, as there are about 22,000 km^2 of sandy desert. On June 4, 2010, the PM_{10} concentration in Reykjavik exceeded 2 mg/m^3. Reykjavik is about 130 km to the NW of Mt. Eyjafjallajökull. Two stations in southern Iceland to the W of the volcano had maximum PM_{10} concentrations of 4.161 mg/m^3 (Heimaland, about 25 km to the W) on May 26 and 1.9 mg/m^3 (Hvolsvöllur, about 30 km to the W) on May 26.

Baxter et al. (1999) and Searl et al. (2002) describe studies related to the Soufriere Hills Volcano, Montserrat, British West Indies. This volcano began erupting on July 18, 1995, and continued for years with major explosions on June 25, 1997, August 3–12, 1997, and September 21–October 24, 1997. Minor activity and ash emissions continued into 1999 and started to tail off in November 1999. Cumulative ashfall was very thick, up to 30 cm. The more impacted locations in the southern part of the island were evacuated at various times during the series of eruptions; concentrations of PM_{10} were regularly monitored at a few sites, including those that had been evacuated. Because the volcano erupted over such a long time, it is difficult to distinguish between activity coming from continuing eruptions and that from resuspension—either passive or caused by human activity.

Some results from Searl et al. are shown in Table 6 for respirable dust (the meaning of respirable is apparently equivalent to PM_4).

Montserrat is a small island about 10 km wide by 18 km long. Plymouth was evacuated in April 1996, but monitoring continued. The ashfall at Plymouth was >30 cm; it is about 4 km to the W of the volcano. Cork Hill was evacuated in June 1997; the ashfall was about 15 cm deep; Cork Hill is about 4.5 km NW of the volcano. Salem was evacuated sometime in Autumn 1997; the ashfall at Salem was 5–10 cm. Salem is about 6 km NW of the volcano. The North area was not evacuated; it had ashfall of <1 cm. In general, these levels of respirable dust are rather low. The ash from this volcano had significant content of cristobalite (a form of free silica), which was the major health concern.

Few data are shown in Baxter et al., but the statement is made that PM_{10} values regularly exceeded the UK air quality standard of 0.05 mg/m^3 for a 24-hour rolling average. Graphs of data are shown for 14 hours on October 10, 1997, at three sites, including inside and outside a primary school. The most interesting point is that human activity on old ashfall material, such as

Table 6. Concentration of respirable dust measured at four locations on Montserrat, British West Indies. The Soufriere Hills Volcano erupted from July 1995 through November 1999. Data are from Searl et al. (2002).

	Plymouth	Cork Hill	Salem	North
Sep 1996				
Concentration (mg/m^3)	0.153	0.183	0.076	
Number of samples	12	12	7	0
Oct 1996 May 1997				
Concentration (mg/m^3)	0.116	0.075	0.023	0.021
Number of samples	53	29	6	4
June 1997				
Concentration (mg/m^3)	0.183	0.236	0.078	0.045
Number of samples	3	8	26	12

playing and housework activities, produced higher PM_{10} concentrations (up to 2.5 mg/m^3) than did the passing ashfall cloud (~1.5 mg/m^3) from an eruption that day.

Predicting the frequency of major resuspension events

Because the resuspended clouds of ash in Patagonia and Iceland have caused major concerns for people and aircraft, there have been recent attempts to try to form predictive models. Examples are Leadbetter et al. (2012) for Iceland and Folch et al. (2014) for Patagonia. Where there is a large amount of resuspendible material deposited, it is generally assumed that resuspension will occur when some threshold wind speed is exceeded. A fairly recent paper by Draxler et al. (2010) has considered this with particular reference to the western United States. Draxler et al. do not specifically consider ashfall, but rather are concerned with the resuspension of erodible soil.

Rather than using wind speed at some height as a predictive tool it is common to consider the friction velocity, typically denoted as $u*$. In ordinary terms a defining equation for $u*$ is

$$u(z) = \frac{u*}{\mathrm{k}} \ln\left[\frac{z}{z_0}\right] ; \quad (1)$$

where $u(z)$ is the wind speed at height z, k is von Kármán's constant, z_0 is the height at which u is equal to 0. This parameter z_0 is also frequently called the roughness length. The roughness length is typically about 10% of the height of obstacles in the vicinity, which I estimate would be mainly bushes of height less than one meter. The coefficient of $u*/u_{10}$ is typically equal to 0.05 to 0.1. von Kármán's constant is equal to 0.4.

According to Draxler's work, episodic events of resuspension can be predicted according to

$$u* - u*_t . \quad (2)$$

where the subscript t denotes a threshold value of the friction velocity at which resuspension begins. Draxler et al. consider that a reasonable value for the threshold friction velocity is about 45 cm/s.

The atmospheric sciences persons at Hanford are well acquainted with the above concepts.

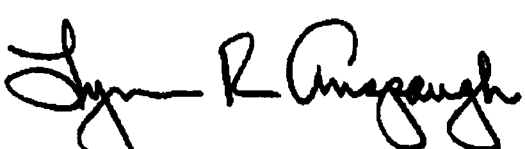
CONCLUSIONS:

1. The 10-cm or more ashfall has a reasonable basis as being a 1 in 10,000 year event: it is based on empirical data.
2. The postulated concentration of 1500 mg/m3 during ashfall is likely overestimated by at least a factor of four.
3. Resuspension is going to be smaller and decrease more rapidly than would be predicted with the Maxwell and Anspaugh (2011) equation. Resuspension will occur, but it likely will be episodic and driven by strong winds and/or efforts at clean up. Based on measurements at Yakima and elsewhere, a year-long average value of 1 mg/m^3 is reasonable. [This is still quite dusty, about 10 times the normal average.] Peak values of 20 mg/m^3 can be expected.

RECOMMENDATIONS

1. Do not run atmospheric transport models, as empirical data would have to be used for input; it is better to just start with empirical data. It is doubtful that the results of a theoretical model that depends on empirical data for input would be more believable than the empirical data on ashfall.
2. If you must run a model, run three of them: Ash3d, HYSPLIT, and NARAC.
3. Don't accept at face value the air concentration of 1500 mg/m^3 postulated by Snow (2012). With a fall velocity of 1.7 m/s, this material is going to be coming down so fast only the smaller particles would reach a filter. Do calculate the face velocity of airflow at the filter and compare to 1.7 m/s. Consider building a wooden barrier (like a building with slats) to any important filter, so that rapidly falling ash could not directly reach the filter.
4. Keep traffic in the area to a minimum at least until a major rain occurs.
5. Have the atmospheric sciences people at Hanford calculate distributions of friction velocities at Hanford and plot them on a probability scale, so that we can estimate how often there might be episodic events. Hourly values over a 10-year period should be sufficient.
6. Consult with Dr. Draxler (NOAA Air Resources Laboratory) to see if he finds this analysis credible for a post-volcanic environment.

SIGNATURE



November 10, 2014

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APPENDIX D

ASHFALL PLANNING TEAM REVIEW: DISCUSSIONS WITH U.S. GEOLOGICAL SURVEY

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APPENDIX D

ASHFALL PLANNING TEAM REVIEW: DISCUSSIONS WITH U.S. GEOLOGICAL SURVEY

INVESTIGATOR(S)

Elaine Diaz

Kelly Ebert

Steve McDuffie

ISSUE DESCRIPTION

Three discussions with U.S. Geological Survey (USGS) were held (October 1, 2, and 14, 2014) to determine if:

1. Warning time could be provided before an eruption of Mt St Helens of the scale predicted for the Hanford natural phenomena hazard requirement (based on the 2011 open file report).
2. Ash3d is appropriate for use to determine the thickness and airborne concentration of ash at Hanford.

DOCUMENTS REVIEWED

- Schwaiger, H.F., Denlinger, R.P., and Mastin, L.G., 2012, "Ash3d: A finite-volume, conservative numerical model for ash transport and tephra deposition," *Journal of Geophysical Research*, Vol. 117, B04204.
- Mastin, L.G., Schwaiger, Hans, Schneider, D.J., Wallace, K.L., Schaefer, Janet, and Denlinger, R.P., 2013, "Injection, transport, and deposition of tephra during event 5 at Redoubt Volcano, 23 March, 2009," *Journal of Volcanology and Geothermal Research*, Vol 259, p. 201-213.
- Mastin, L.G., Van Eaton, A.R., and Lowenstern, J.B., 2014, "Modeling ash fall distribution from a Yellowstone supereruption," *Geochemistry, Geophysics, Geosystems*, Vol 15, 3459–3475.
- Durant, A.J.; Rose, W.I.; Sarna-Wojcicki, A.M.; Carey, S.; Volentik, A.C.M, 2009, "Hydrometeor-enhanced tephra sedimentation: Constraints from the 1980 eruption of Mount St. Helens," *Journal of Geophysical Research*, Vol. 114, B03204.
- Bonadonna, C., Folch, A., Loughlin, S., Puempel, H., 2011, "Ash Dispersal Forecast and Civil Aviation Workshop - Model Benchmark Document," https://vhub.org/resources/505.
- "2nd IUGG-WMO Workshop on Ash Dispersal Forecast and Civil Aviation, Geneva, Switzerland, Model Definition Document," 18-20 November 2013.

PERSONNEL CONTACTED

- John Ewert, Scientist in Charge, USGS Cascades Volcano Observatory (CVO)
- Larry Mastin, Expert in Ash3d modeling, USGS CVO
- Will Scott, Volcanologist, Mt St Helens expert, USGS CVO.

DISCUSSION

Discussions were held October 1 and 2 with John Ewert, Scientist in Charge at the USGS CVO, and a followup discussion was held on October 14.

Questions were posed on the feasibility of the USGS CVO providing advanced warning of an eruption on the scale predicted in *Open-File Report 2011-1064: Estimate of Tephra Accumulation Probabilities for the U.S. Department of Energy's Hanford Site, Washington*, and whether USGS could send a letter or report documenting its capabilities and timing of advanced notifications. The USGS affirmed that it was possible to detect conditions at least 1 week before a Volcanic Explosivity Index (VEI) 6 eruption with a Y-N scale deposit at Hanford. A letter from USGS can be prepared with their conclusions, but the following caveats are noted:

1. Data is only available from the 1991 Pinatubo eruption demonstrating the performance of new seismic instruments deployed in monitoring Mount St. Helens. While there is confidence in the instruments and the USGS capabilities, there is only one confirmatory data point to date.
2. When Mount St. Helens was last active in 2004-2008, there were 8 days of advance seismic warning, followed by a 7–10 days of uncertainty regarding predictions of a major eruption. (Note: Current monitoring capabilities did not exist at that time). The dome building in 2004 was fairly significant, and the mountain has produced back-to-back major explosions in the past (1479 and 1481, both VEI 5), so a major eruption cannot be ruled out just because there was a previous major eruption in the recent past. Given the present instrumentation and capabilities, the USGS feels confident on providing a week's notice of an eruption. However, the magnitude of an expected eruption cannot be reliably predicted; therefore, USGS could not advise the Waste Treatment and Immobilization Plant (WTP) on the length of time operations would need to be suspended until a determination could be reached that a predicted eruption is not likely to be major.
3. USGS is one of only a handful of Federal agencies that Congress has ever threatened to defund and shut down. The Level 4 seismic monitoring instrumentation network at Mount St. Helens and the associated maintenance, monitoring, and interpretation are funded by a National Science Foundation program through 2018. Adopting a safety strategy requiring warning from USGS makes the assumption there will be an ability to monitor Mount St. Helens activity and provide warnings of anticipated volcanic events within the Federal government. Mr. Ewert suggested an interagency agreement between the U.S. Department of Energy (DOE) and USGS to provide funding beyond the National Science Foundation program for the Mount St. Helens monitoring system throughout the life of the WTP, and estimated the cost at $500,000 per year ($20 million over the 40-year design life of WTP).

The use of Ash3d to model impacts at the Hanford Site was also discussed with USGS. Mr Ewert was confident, with some financial support from WTP, that Hanford Site impacts could be modeled with defensible results. The model is supported by a substantial and growing body of peer-reviewed literature. USGS also felt that results using the Ash3d model (i.e., ash accumulation and air concentrations) would be much closer to measured airborne concentration values associated with volcanic events (see Appendix B) than that produced using empirical methods, based on comparisons elsewhere. The model would also allow consideration of varying wind directions and speeds based on weather data and derived probabilities.

The October 2 meeting focused on questions raised by Dr. Lynn Anspaugh regarding Ash3d. Dr. Anspaugh's concern is that bulk ash ejected from a volcano may not behave like individual particles in air. Mr. Ewert sent three papers to Dr. Anspaugh to address his concerns.

The meeting on October 14 was held to discuss whether other airborne dispersion models (e.g., HYSPLIT [Hybrid Single Particle Lagrangian Integrated Trajectory], NAME, FALL3D) are more suitable for modeling Mount St. Helens impacts. The team reviewed Ash3d capabilities against the other air dispersion models and determined that is the most appropriate for modeling air particulate transport from volcanic eruptions. However, Dr. Mastin is in contact with several other modelers, including one from the National Oceanic and Atmospheric Administration (NOAA), who could be called on to peer review Ash3d results.

In follow-on discussions with NOAA, the APT determined that NOAA's HYSPLIT model could be used to address the question of wind resuspension of ash—a capability that Ash3d lacks. The two models together could be used to produce a new ash estimate for the Hanford Site.

On October 19, another discussion with USGS and Dr. Anspaugh took place, this time with Dr. Mastin, the USGS Ash3d expert. Dr. Anspaugh explained his concern that large concentrations would exhibit different settling characteristics (ballistic settling vs. settling as individual particles). Dr. Mastin explained that the (Ash3d) model uses ash collected at the site from previous eruptions to backfit the particle size distribution of settled ash into the model, thus forcing the model to settle the particles as agglomerated particles.

Dr. Anspaugh prefers empirical data to model results, and recommends a 3D model approach if the modeling option is pursued further.

The options to include NOAA and the National Atmospheric Release Advisory Council (NARAC) should be explored. Each has independent modeling capability in atmospheric transport of particulate.

The DOE Office of River Protection has sent a request letter to USGS for warning time and for an estimate for USGS CVO to develop an Ash3d model for the Hanford Site.

The USGS CVO provided a draft response letter to support the Ashfall Planning Team report (attached). The draft response letter contains the details of the Ash3d approach.

USGS included an independent peer review from NOAA and NARAC in the Ash3d estimate, which is nominally $100,000 and 6-12 months.

There is also the question of quality assurance of the models. Although USGS and NOAA are the world's preeminent experts in volcanic ash behavior and atmospheric transport of suspended particulate, their software quality assurance procedures may differ from those imposed by DOE. Discussions with NOAA indicate versions of HYSPLIT have been qualified for DOE use. Discussions on this topic with USGS are scheduled, but have not occurred as of the date of this report.

CONCLUSIONS

The ability to provide advanced warning time before a Mount St. Helens eruption opens up many possibilities for controls at WTP, such as returning waste to tank farms or processing forward to de-inventory vessels that require safety mixing. This could lead to a much more cost-effective and sustainable solution that would not require extensive substantial design modifications to WTP.

However, there is a risk to DOE related to the cost of sustaining monitoring capability, should USGS be impacted by Federal budget decisions outside of the DOE's control. In addition, the approach of ceasing or curtailing WTP operations upon USGS notification of a pending eruption would require protection as an important safety basis control. This brings some risk of operational impacts as operations would be shut down until a potential volcanic threat has been downgraded.

The Ash3d and HYSPLIT programs will provide more reliable estimates of airborne concentration and deposition at the Hanford Site that are likely to be less extreme than currently estimated. However, it is possible that current volcano hazard design requirements could also increase. When posed with this question, USGS experts stated this was highly unlikely based on results they have seen; it is much more likely to decrease. The final outcome will not be known for sure until the modeling is performed.

The model has unique capabilities based on real data from previous volcanic eruptions and considers actual meteorological data from the Hanford Site. Such modeling is consistent with the intent of consequence analysis methods used in safety analysis (i.e., 95th percentile meteorological conditions as prescribed in DOE-STD-3009-94, *Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Documented Safety Analyses*). However, Ash3d is not currently listed in the DOE Central Registry of approved safety software (i.e., DOE Toolbox code), and therefore may need to be subjected to DOE software quality assurance requirements (see previous quality assurance discussion). In addition, technical questions raised regarding the model and inputs (i.e., in light of other capabilities available at NOAA or NARAC) would need to be resolved before adopting any results in WTP design requirements. Dr. Lynn Anspaugh recommended a peer review of the Ash3d results by NOAA and NARAC modeling personnel.

RECOMMENDATION

Viable Alternative by Itself?

Warning Time: No.

Warning time would also require a demonstration (by analysis) of ability to pump back, process forward, or otherwise prepare for airborne ash within the warning time.

Ash3d: Yes, partially.

There is a possibility that Ash3d results would remain within the bounds of the current ashfall requirement. This would eliminate the need for a contract change, but would still leave the remaining technical issue open. The current ash approach is still very likely unsustainable. Other methods studied in this report may assist.

Viable Alternative in Combination with other Alternatives?

Yes.

Warning time, combined with pump-back, process-forward, and perhaps settling chambers for confinement ventilation, eliminates compressed air needs for the volcanic ash natural phenomena hazard and reduces power needs by nearly 2 orders of magnitude, significantly increasing the sustainability of the solution throughout the ashfall event and resuspension events to follow.

Ash3d, is very likely to result in a significant reduction in ash airborne concentration. HYSPLIT or other NOAA resuspension analysis could result in a significant reduction in duration of the resuspension event, which makes many of the other alternatives more feasible and unsustainable. This, combined with use of other technologies such as using the grout vaults as settling chambers for ash, could present a solution to the problem.

Estimated Impacts and Other Considerations:

See attached letter and draft USGS response.

ATTACHMENTS

D.1 DRAFT USGS LETTER, J.W. EWERT, USGS CFO, TO W.F. HAMEL, ORP

SIGNATURE

Investigation Lead: Eleazar Diaz **Date:** 12-17-14

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ATTACHMENT D.1

United States Department of the Interior
U. S. GEOLOGICAL SURVEY
Cascades Volcano Observatory
1300 SE Cardinal Court Suite 100
Vancouver, WA 98683

Mr. William F. Hamel
U.S. Department of Energy
Office of River Protection
P.O. Box 450, MSIN H6-60
Richland, WA 99352

7 November 2014

Mr. Hamel,

This letter is in response to your request for additional information about potential volcanic ash falls at the Waste Treatment Plant on the Hanford Reservation (WTP). As requested, I address warning times, airborne concentration, deposit thickness, particle size distribution, and duration of ash fall. I also include background for and information about our warning capabilities, and some details about funding requirements that would need to be met for the USGS to provide timely warning of large eruptions that may affect operation of the WTP over the next 50 years.

To summarize my analysis: The USGS has the capability to do numerical modeling of ash fall from volcanic ash clouds that will provide useful information for the design of mitigation measures at the WTP. The USGS also has the capability to provide advance notice of a week or more of volcanic activity that may impact the Hanford Reservation area, provided that the current high-quality monitoring network at Mount St. Helensis maintained for your 50-year timeframe. A caveat is that both our modeling and warning capabilities are subject to unavoidable uncertainties owing to the infrequent occurrence of very large explosive eruptions (Volcano Explosivity Index ≥5) in the Cascade Range, and globally, that would provide more empirical constraints on these capabilities.

Funding requirements for the modeling study are straightforward and are estimated as $100 K. Funding requirements related to maintaining the monitoring network and eruption forecasting capabilities for Mount St. Helens over a 50 year period are more complex and will require some additional investigation of operational costs within the USGS and with our partner institutions. Before embarking on such an exercise we would like to have an agreement in principle with the DOE-WTP that outlines your interest and potential support for maintaining the Mount St. Helens monitoring network. Ultimately, a cooperative agreement could be established to provide for the incremental costs to the USGS of maintaining the network at its current high quality (Level 4, explained below).

MODEL SIMULATIONS TO IMPROVE ESTIMATES OF AIRBORNE ASH CONCENTRATION AT HANFORD DURING A LARGE ERUPTION OF MOUNT ST. HELENS

Background

A previous USGS analysis (Hoblitt and Scott, 2011) has indicated that a large volcanic eruption at Mount St. Helens could result in substantial ash fall at the site of the Hanford Waste Treatment Plant (approximately 200 km distant from the volcano), thus disrupting nuclear waste processing operations. According to DOE Office of River Protection (ORP), facilities must be constructed to filter tephra from the air during such eruptions. Consequently, an important design consideration is the maximum airborne concentration that might occur at the site; in particular, what is the maximum airborne ash concentration that might exist at Hanford with a recurrence interval of 2500 or 10,000 years.

Ash deposit thickness and airborne concentration

Hoblitt and Scott (2011) used a small observational dataset to estimate that the maximum deposit thickness (or mass load M) at Hanford from a large eruption could be as high as 10 cm (M=~100 kg m^{-2}) with an annual probability of 1×10^{-4}. Their result was the product of three probabilities: the annual probability (P1=0.008) of a VEI>=5 event (4 events in the past 500 years), the probability (P2=0.18) that the wind directs ash toward Hanford during an eruption (from historical wind data), and a probability (P3=0.067) that the deposit thickness exceeds 10 cm at 200 km distance (1 deposit of 14 studied). Assuming that the ash settles at a rate of u=~1 m s^{-1} over a time of D=12 hrs, this translates to an airborne concentration at ground level of C=M/(Du)= ~2,300 mg m^{-3}.

Alternatively, we propose a more sophisticated approach that uses about 10,000 computer simulations of ash transport to derive a probability histogram of airborne tephra concentration at Hanford given an eruption at Mount St. Helens. This result will replace P2, P3, and the calculation converting M to C. Combined with P1 from Hoblitt and Scott (2011), it can be used to determine threshold concentrations with a 2,500 or 10,000 year recurrence interval. The simulations will be run using the model Ash3d, developed by the USGS (Schwaiger et al., 2012), which calculates tephra transport during volcanic eruptions in a 3-D, time-varying wind field to produce maps of the deposit (Fig. 1a), plots showing the deposit accumulation with time at a given location (Fig. 1b), and airborne concentration with time at specified locations (Fig. 2). Model inputs include the vent location (Mount St. Helens in our case), erupted volume, plume height, eruption duration, a 3-D numerical wind field, and a size distribution of the tephra, which may be modified from that of the erupted material to consider the aggregation or clumping of particles in the atmosphere.

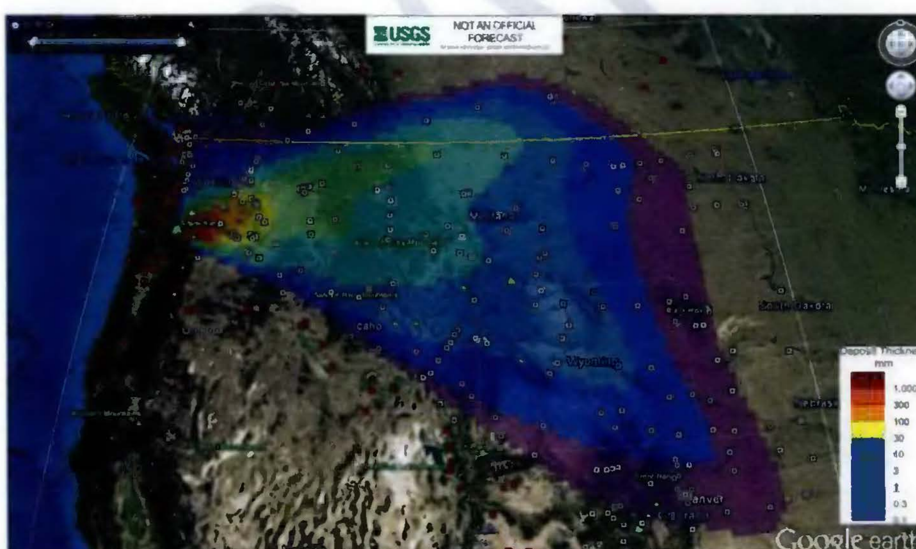

Figure 1a. Map of Tephra deposit thickness from a simulated eruption of 4km³ magma (dense rock equivalent) displayed in Google Earth. Input conditions for the model are given in Table 1. Airports where ash deposits have fallen are depicted as white squares that, when clicked in Google Earth, expand to show a plot of deposit-thickness accumulation with time during the ash fall. An example for the PSC Tri Cities airport is shown in Figure 1b. This simulation used a historical wind field from December 30, 2005.

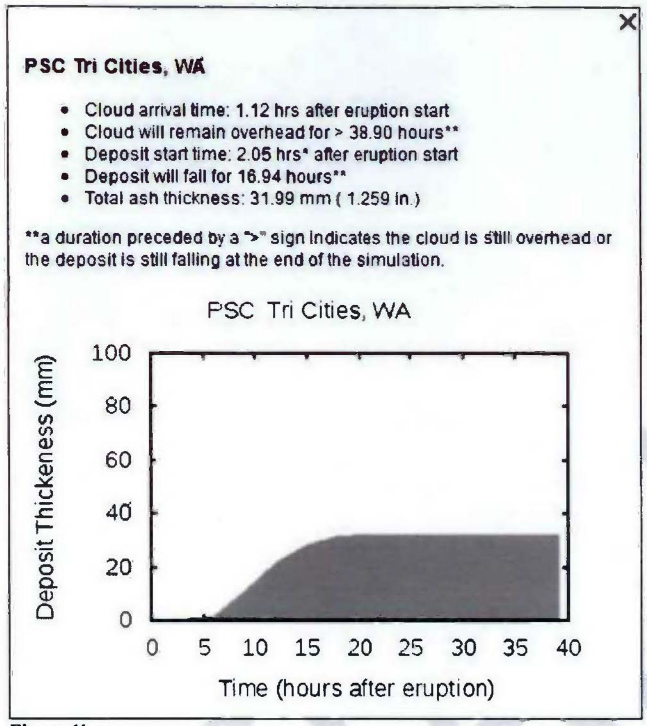

Figure 1b.

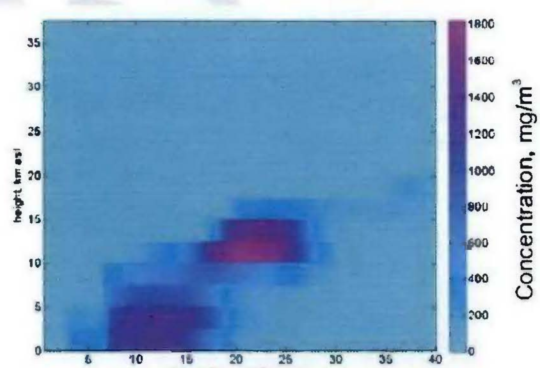

Figure 2: Example vertical profile of airborne ash concentration over Hanford (119.388°W, 46.584°N), versus time, using the simulation whose results are illustrated in Figure 1.

The simulations will be run using a Markov Chain Monte Carlo approach, meaning that for each model run, inputs such as plume height, duration, erupted volume, and grain-size distribution will be randomly sampled from reasonable ranges of values. For the wind field, we will use NOAA's global NCEP/NCAR Reanalysis 1 dataset (Kalnay et al., 1996), which covers the period from January 1, 1948 to the present, and pick a random start time within this period. From each run, the maximum airborne concentration at ground level will be noted from data like that in Figure 2. And from all the results, we will determine the fraction of simulations that result in more than e.g., 50, 100, 500, 1,000 mg m^{-3} concentration at ground level at Hanford. These data will be used in the above-mentioned probability histogram. Similar histograms can be derived for tephra thickness, mass load, dosage (concentration times time), or other parameters.

Table 1: Input conditions for model simulation illustrated in Figures 1 and 2.

Parameter	Value(s)
Plume height	30 km
Duration	26 hrs
erupted volume (mass)	4 km^3 DRE (10 Tg)
Model domain	-125° to -100° longitude 37.5° to 52.5° latitude
model resolution	0.2° horizontally, 2.5 km vertically
grain sizes	25% 2mm, 800 kg/m3 density 15% 1mm, 800 kg/m3 density 20% 0.5mm, 1000 kg/m3 density 15% 0.25mm, 1000 kg/m3 density 20% 0.125mm, 1800 kg/m3 density 5% 0.062mm, 2000 kg/m3 density
Diffusion constant	0 m^2 s^{-1}

Funding agreement

Undertaking the modeling study described here will necessitate reprioritizing the work plan of the USGS Ash3d development team. We estimate costs of salary time, USGS report editing and review time, and access to the USGS cluster computing facility to be about $100 K.

PROVIDING WARNING TO HANFORD WTP OF IMPENDING LARGE ERUPTIONS AT MOUNT ST.HELENS

Mount St. Helens volcanic threat

In 2005, the USGS published a national assessment of volcanic threat and monitoring capabilities in the United States, as part of an initiative to develop a National Volcano Early Warning System (NVEWS) (Ewert et al., 2005). The threat assessment evaluated both hazard and risk factors (Ewert, 2007) for the approximately 170 U.S. volcanoes, and Mount St. Helens ranked among the highest threat of all. The assessment of monitoring capabilities involved evaluation of existing and needed monitoring capabilities at U.S. volcanoes based on their threat level, and in 2008, the USGS published a study by government and university scientists which made instrumentation recommendations for volcano monitoring at U.S. volcanoes under NVEWS (Moran et al., 2008). In that report, the panel recommended that very high threat volcanoes such as Mount St. Helens should be monitored in the most complete manner possible, designated Level 4 monitoring (on a 1-4 scale).

As a result of the NVEWS assessment and the focus that Mount St. Helens received from the scientific community during the 2004-2008 eruption, it is now monitored at Level 4, one of only four US volcanoes to be so well monitored. At the present time, Mount St. Helens is monitored through a combined effort of the USGS-Cascades Volcano Observatory (CVO), the University of Washington Pacific Northwest

Seismic Network (PNSN), and the Plate Boundary Observatory (PBO) project under the NSF Earthscope Program. The USGS Volcano Hazards Program has the mission responsibility to analyze all available monitoring data, assign alert levels, and issue forecasts and warnings about volcanic activity at the volcano.

Pending status of monitoring of Mount St. Helens

At the present time, Mount St. Helens is one of the best monitored stratovolcanoes in the world. With the current monitoring network we have been able to detect the subtle earliest signs that the shallow magma reservoir 4-8 km beneath the volcano is being recharged and repressurized by new magma entering the system from depth (CVO Information Statement, 30 April 2014; http://volcanoes.usgs.gov/activity/archiveupdate.php?noticeid=10035). We are confident that with the Level 4 instrumentation network now in place we would be able to detect unrest at the volcano a week or more in advance of the onset of magmatic eruptive activity.

However, an important portion of the monitoring systems that CVO uses to track activity at the volcano is owned and operated by the UNAVCO consortium under contract to the PBO project. The NSF Earthscope program under which PBO is funded ends in 2018, and if no funding is identified to continue the operation of the PBO instrument networks, it is very likely that all PBO-operated instruments will be removed from service. If these geodetic and seismic instruments were to be removed, Mount St. Helens would no longer have a Level 4 monitoring network and our ability to forecast eruptions would be degraded. In addition, apart from the status of the PBO stations, continued high-quality seismic monitoring of Mount St. Helens will require converting approximately one half of existing short period analog stations to broadband digital operation.

Furthermore, it must be emphasized that despite the considerable recent advances in our ability to forecast eruptive activity, making precise forecasts (predictions) of the magnitude and exact timing of eruptive activity that will ensue is still a challenge. Large eruptions (i.e., those greater than VEI 5) are infrequent globally, and because precursory data for the largest eruptions are sparse, we must rely on monitoring data collected and analyzed during smaller magnitude eruptions to guide our forecasting of larger eruptions. If the operators of the Waste Treatment Plant can accept some uncertainty in eruption forecasting both in timing and in magnitude, and can suspend operation of the WTP for up to several weeks during an escalation of precursory activity at the volcano, then continued Level 4 monitoring of Mount St. Helens is warranted and necessary.

Eruption forecasting at Mount St. Helens beyond 2018 and funding issues

To confidently provide a week's warning of large magnitude eruptions at Mount St. Helens to the operators of the WTP over the next approximately 50 years, the Level 4 network at Mount St. Helens will need to be maintained and upgraded as new monitoring technologies become available. At the present time, CVO does not have the funding and staff to maintain a Level 4 monitoring network at Mount St. Helens beyond 2018 (when PBO instruments likely will be decommissioned) and simultaneously address our commitment to remedy inadequate monitoring at other very high threat volcanoes in the region that are also identified in the 2005 NVEWS assessment.

Given foreseeable constraints on USGS resources, it is likely that the Mount St. Helens network will be maintained by the USGS as a Level 3 network beyond 2018 with diminished ability to detect and quantify early signs of unrest. However, augmenting the monitoring infrastructure, operations, and maintenance activities to address the WTP volcano hazards mitigation needs could be accomplished through a long-term funding agreement to maintain Mount St. Helens at Level 4 status. In essence this would be a cooperative agreement established to keep Mount St. Helens monitored with a Level 4 network. Funding associated with the agreement would ideally begin in in 2018, in time to maintain the current NSF-funded, PBO-operated network. Details of a long-term agreement between the USGS and the DOE is beyond the scope of this letter, but would include the incremental costs of instrument and telemetry renewal, yearly operations and maintenance, and engineering staffing to maintain the Level 4 monitoring network over a 50 year period. Our initial estimate is that several hundred thousand dollars per year, but not more than $500 K/yr, would be necessary to keep Mount St. Helens at Level 4.

The USGS is committed to providing the best and most timely possible volcano hazards information to the public and operators of critical infrastructure. We look forward to further dialog with the Office of River Protection about how we can address the issue of eruption forecasts and warnings for Mount St. Helens.

Sincerely,

John W. Ewert
Scientist-in-Charge, USGS/CVO

REFERENCES

Cascades Volcano Observatory Information Statement, April 30, 2014:
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Ewert, J.W., 2007, System for ranking relative threats of U.S. Volcanoes: Natural Hazards Review, v.8, no. 4, p. 112-124.

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Hoblitt, R. P., and W. E. Scott (2011), Estimate of Tephra Accumulation Probabilities for the U.S. Department of Energy's Hanford Site, Washington, in U.S. Geological Survey Open-File Report 2011-1064, edited, p. 15.

Kalnay, E., et al. (1996), The NCEP/NCAR 40-Year Reanalysis Project, Bulletin of the American Meteorological Society, 77(3), 437-471, doi:10.1175/1520-0477(1996)077<0437:TNYRP>2.0.CO;2.

Moran, S.C., Freymueller, J.T., LaHusen, R.G., McGee, K.A., Poland, M.P., Power, J.A., Schmidt, D.A., Schneider, D.J., Stephens, G., Werner, C.A., and White, R.A., 2008, Instrumentation recommendations for volcano monitoring at U.S. Volcanoes under the National Volcano Early Warning System: USGS Scientific Investigations Report 2008-5114, 47 p.

Schwaiger, H., R. Denlinger, and L. G. Mastin (2012), Ash3d: a finite-volume, conservative numerical model for ash transport and tephra deposition, J. Geophys. Res., 117(B04204), doi:10.1029/2011JB008968, doi:doi:10.1029/2011JB008968.

APPENDIX E

ASHFALL PLANNING TEAM REVIEW: INVESTIGATION OF PREVIOUS ALTERNATIVES – MANUAL FILTER CHANGES

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APPENDIX E

ASHFALL PLANNING TEAM REVIEW: INVESTIGATION OF PREVIOUS ALTERNATIVES – MANUAL FILTER CHANGES

INVESTIGATOR(S)

Cecil Swarens

SCOPE

The review included:

- Reviewing previous alternatives involving manual filter changes.
- Pursuing additional information or mechanisms to define use of manual filter changes.

DOCUMENTS REVIEWED

- 24590-WTP-RPT-ENG-10-016, 2010, *Whitepaper: An Analysis of WTP Ashfall Design Requirements and Recommended Mitigation Strategy*, Rev. 1, Bechtel National, Inc., Richland, Washington.
- ANSI/ANS-58.8-1994, *Time Response Design Criteria for Safety-Related Operator Actions*, R2008, American Nuclear Society, La Grange Park, Illinois.
- ASHRAE 52.1-1992, 1992, *Gravimetric and Dust-Spot Procedures for Testing Air-Cleaning Devices Used in General Ventilation for Removing Particle Matter*, American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., Atlanta, Georgia.
- CCN 216061, 2010, "Preliminary Analysis of Time Response Criteria for Safety-Related Operator Actions for Changing Filters During an Ashfall Event at WTP," memorandum to M. Medsker from L. Goff, Bechtel National, Inc., Richland, Washington, July 12.
- Flanders/CSC Corporation specification sheet for 24x24x12" bag type filters

PERSONNEL CONTACTED

- Ken Wells, Waste Treatment and Immobilization Plant (WTP) Plant Operations Manager
- Tim Dallas, WTP Low-Activity Waste (LAW) Operations Manager

DISCUSSION

This investigation reviewed previous alternatives associated with manual changeout of filters supporting an ashfall event as a result of a volcanic eruption. These previous alternatives are contained in BNI documents 24590-WTP-RPT-ENG-10-016 and Memorandum CCN 216061. The whitepaper initially indicated manual changeout of filters was a viable alternative. However, after additional analysis provided in the memorandum, BNI concluded that manual changeout was not feasible for most facilities under the baseline or the alternative (hybrid) solution, if undertaken by a single team of two persons requiring 7 minutes per filter change (ANSI 51.2).

Due to the uncertainties of actual air demand and an incomplete design, this investigation focused on the air demand capacity that could be maintained by a single crew of two persons, requiring 7 minutes per filter change, based on filter loading, and ash concentration.
This mechanism and the subsequent values can be used to analyze future identified air demands in each facility as needed, based on filter loading criteria and documented ash concentration values to be utilized in the design.

To determine the filter loading criteria, data from Flanders/CSC Corporation concerning a 24-in. by 24-in. by 12-in. bag type filters (the only filters of this size for which Flanders had dust-loading capacities) was gathered and showed the specified filter attained full loading (1.5 in. WG) at 187 grams of dust during ASHRAE 52.1 filter testing. This information was used to assume the maximum amount of ash the filter will hold prior to a required change-out during an eruption event. However, the actual loading of a similar filter during an eruption event will likely differ due to the different characteristics and size distributions of particles encountered in the ash during the event. To ensure accurate calculation of filter loading weights and times, testing will be required similar to those of ASHRAE 52.1 using a simulant that best approximates the ash expected at Hanford during an eruption event. This will determine the actual loading experienced and time to full loading for the chosen filter arrangement. Once this data is attained, more accurate predictions of filter changeout abilities by WTP workforces can be calculated.

With the loading assumed to be 187 grams for a single filter, the time to full loading of the filter was calculated based on the assumed flow rate (1,500 cfm) and the assumed ash concentrations. Ash concentrations used for this purpose was the current WTP design of 219 mg/m^3; the revised Hanford natural phenomena hazard of 2,650 mg/m^3; and the peak measured at Yakima during the 1980 Mount St. Helen's event of 33.4 mg/m^3. The resultant time to filter change for each of the above ash concentrations were 20 minutes to load each filter flowing 1,500 cfm for an ash concentration of 219 mg/m^3; 2 minutes for an ash concentration of 2,650 mg/m^3, and 132 minutes for an ash concentration of 33.4 mg/m^3.

Table E-1. Time until Filter Fully Loaded/Filter Changes per Crew.

Flowrate (cfm)	Ash Concentration (mg/m^3)	Maximum Loading Filter (grams)	Time until Filter Fully Loaded (min)	Filter Changes Capable of 1 Crew
1,500	219	187	20	3
1,500	2,650	187	2	0
1,500	33.4	187	132	19

These times to full loading of each filter subjected to 1,500 cfm were then compared to the minimum time required to affect a filter changeout by WTP workers during an ashfall event. Utilizing data from 24590-WTP-RPT-ENG-10-016, it was determined a crew of two persons would be utilized to make filter changes requiring seven discrete actions.
From ANSI/ANS-58.8, a minimum time of 1 minute per discrete action is required for design purposes (unless time study data exists that allows changes to this requirement). This indicates 7 minutes is required for each filter change by a single team as a design criteria.

This information was used to calculate the number of filter changes that could be accomplished by a single team before the last changed filters become fully loaded (Table E-1). The information was also used to determine the maximum cubic feet per minute a team of two persons could support for a given ash concentration, if they were involved in continuously changing filters during an ashfall event. It was found the maximum cubic feet per minute was not dependent on the number of filters or flow through the filters, but instead on the maximum loading of the filter and the ash concentration.

Table E-2. Maximum Cubic Feet per Minute supported by a Single Team.

Ash Concentration (mg/m^3)	**Maximum Loading Filter (grams)**	**Maximum Cubic Feet per Minute Supported by a Single Team**
219	187	4,288
2,650	187	349
33.4	187	28,246

This maximum cubic feet per minute supported by a team can be used to determine the minimum number of teams required to support various scenarios based on filter loading to fully loaded, ash concentration, and cubic feet per minute requirements of the various scenarios. An example of such scenarios is included in Table E-3.

Table E-3. Number of Teams Needed to Support Air Demand.

Ash Concentration (mg/m^3)	**Maximum Loading Filter (grams)**	**Maximum Cubic Feet per Minute Supported by a Single Team**	**Air Design Demand (cfm)**	**Number of Teams Needed to Support Demand**
219	187	4,288	1,004,400	235
2,650	187	349	1,004,400	2,878
33.4	187	28,246	1,004,400	36
219	187	4,288	155,500	37
2,650	187	349	155,500	446
33.4	187	28,246	155,500	6
219	187	4,288	100,000	24
2,650	187	349	100,000	287
33.4	187	28,246	100,000	4

1,004,400 cfm = New ash criteria estimated air demand.
155,500 cfm = Old ash criteria estimated air demand.
100,000 cfm = Confinement ventilation air demand only.

In addition, an alternative including an automated paper roll pre-filter was analyzed, having an efficiency of approximately 50 percent for the dust size distribution anticipated (from historical dust size distribution data). The pre-filter effectively reduced the ash concentration seen by the final filter by one half, and increased changeout times and cubic feet per minute supported by a single team by a factor of 2 (Table E-4).

Table E-4. Number of Teams Needed to Support Air Demand with Automated Pre-Filter.

Effective Ash Concentration After Pre-Filter (mg/m³)	Maximum Loading Filter (grams)	Maximum Cubic Feet per Minute Supported by a Single Team	Air Design Demand (cfm)	Number of Teams Needed to Support Demand
112.6	187	8,375	1,004,400	120
1,382.4	187	682	1,004,400	1,473
17.1	187	55,167	1,004,400	19
112.6	187	8,375	155,500	19
1,382.4	187	682	155,500	228
17.1	187	55,167	155,500	3
112.6	187	8,375	100,000	12
1,382.4	187	682	100,000	157
17.1	187	55,167	100,000	2

CONCLUSIONS

Based on the restriction of manual changeout of filters requiring a certain time to perform, each team performing these changeouts can support a calculated air demand based on the ability of the chosen filter to hold a specified weight of volcanic ash and the anticipated concentration of that ash. This ability to support a specific air demand, coupled with the total air demand of a particular facility or function, determines the number of teams required to support that facility or function during an ashfall event. Automated or passive pre-filtering (roll filters or sand filters) or pre-conditioning (settling chambers) of ash prior to encountering the final filter can have substantial effect on the air demand per team that can be supported during an ashfall event. However, even with a pre-filter reducing the effective ash concentration seen by the final filter, given current ashfall criteria and projected air demands, manual changeout of filters would require far too many teams (1,473 or 2,946 persons) to keep pace with clogged filters. At current ashfall criteria, even maintaining confinement ventilation air demand for the facilities would require and excessive number of workers (157 teams, or 314 persons). However, if ashfall criteria can be shown to be much less than currently considered (on order with the baseline criteria), and effective pre-filtering, preconditioning, or longer filter loading times can be demonstrated, manual changeout of filters could be an effective strategy for specific functions, if not the entire facility, during an ashfall event.

RECOMMENDATION

The manual changeout of filters is not considered a viable solution under the current criteria for ash concentration, projected air demand, and assumed filter loading characteristics. If further analysis of ashfall criteria results in significant reductions in anticipated ash concentrations, it is recommended a selection of preconditioning strategies, automated pre-filters, and filters be made and the pre-filters and filters be tested under the conditions set forth in ANSI 52.1, but using a simulated ash that meets the ash concentrations and weight distributions of the then analyzed ashfall criteria. These tests should be used to determine a more accurate anticipated filter loading and time until loaded to be used to determine the number of two-person teams required to maintain the projected air demands of the facility or specific functions.

SIGNATURE

Investigation Lead: [signature] **Date:** 12/18/14

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APPENDIX F

ASHFALL PLANNING TEAM REVIEW: INVESTIGATION OF STRUCTURAL LOAD COMBINATIONS

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APPENDIX F

ASHFALL PLANNING TEAM REVIEW: INVESTIGATION OF STRUCTURAL LOAD COMBINATIONS

INVESTIGATOR(S)

Raman Venkata, P.E.

Kelly Ebert

ISSUE DESCRIPTION

Investigate Waste Treatment and Immobilization Plant (WTP) Structural Peer Review Team (SPRT) recommendation that designing for a 10,000-year ashfall event plus live load may be too bounding.

REQUIREMENTS REVIEWED

- 24590-WTP-DC-ST-01-001, 2011, *Structural Design Criteria*, Rev. 13, Bechtel National, Inc., Richland, Washington.

DOCUMENTS REVIEWED

- 13-WTP-0252, 2013, "Transmittal of Surveillance Report S-13-WED-RPPWTP-012 – Review of the May 2013, Structural Peer Review Team [SPRT] Report," letter to J.M. St. Julian, Bechtel National, Inc., from W.F. Hamel, U.S. Department of Energy, Office of River Protection, Richland, Washington, December 10.

PERSONNEL CONTACTED

Mark Axup, BNI Structural Engineer

Jim Booth, BNI Structural Engineer

DISCUSSION

Current Forecasted Impacts of Adopting the New Ash Structural Criteria

The structural impacts associated with a change to natural phenomena hazard (NPH) criteria for ashfall structural loading, by adopting the criteria from HNF-SD-GN-ER-501, *Natural Phenomena Hazards, Hanford Site*, Washington, Rev. 2, are dependent on the performance classification of the facility and, in general, are directly related to the steel and concrete load combinations used for design of each facility.

For Performance Category (PC)-3 facilities (e.g., the High-Level Waste and Pretreatment Facilities), the controlling load combinations include seismic loads, where the vertically induced seismic load component bounds the increased ashfall load, based on the magnitude of the change presented in HNF-SD-GN-ER-501, Rev. 2. Therefore, structural impacts (i.e., physical modifications to the structure) for PC-3-designed structures are not anticipated as a result of the proposed change to the ashfall criteria.

For PC-2 facilities (e.g., the Low-Activity Waste Facility and Analytical Laboratory), the seismic load combinations are bounded by the ashfall load combinations, as the seismic loading for PC-2 facilities does not include a vertical seismic component. Therefore, changes to the ashfall criteria for PC-2 facilities have a direct impact on current design margins for those facilities. Based on the magnitude of proposed change in ashfall criteria for PC-2 facilities (5 psf to 12.3 psf), it is anticipated that a closer re-evaluation of the existing roof structures would not result in required physical changes to the facilities, based on available margin in the roof steel. However, should there be significant additional increases in the ashfall criteria (e.g., wet/ dry density, intensity of fall, accumulation) that could demand possible change to existing criteria, the WTP Engineering Division, the SPRT, and Bechtel National, Inc., will reevaluate during the quarterly SPRT review.

Impact Estimate of Additional Analytical Workload

It is important to recognize that any change to existing criteria will result in a change to project design documents. Whether the change does or does not result in a physical impact to a facility, engineering documentation (e.g., criteria, specifications, drawings) affected by the change must be updated to address the change in accordance with the requirements of configuration management. Based on the previous Bechtel National, Inc., impact estimate, this effort will require 3,660 hours of civil, structural, and architectural only effort (according to civil, structural, and architectural quantity development plans). Additional hours for other disciplines' review will be necessary, but were not estimated in detail. A bounding assumption would be 6,000 hours total.

Feasibility of Reducing Live Load

Load combinations used for design of steel and concrete components are based on code requirements provided in structural design documents for each facility, and are consolidated in 24590-WTP-DC-ST-01-001.

Personnel contacted agreed that the code requirements do not allow room for tailoring of load combinations...they are prescriptive. They therefore believe that reducing live load for the volcanic ash NPH is not a viable option.

CONCLUSIONS

The team concluded that reducing live load for the ashfall NPH is not a viable option due to code constraints.

RECOMMENDATION

Viable Alternative by Itself?

No. Code is prescriptive regarding load combinations.

Viable Alternative in Combination with other Alternatives?

It may behoove the project to study feasibility of other alternatives that may reduce the structural impact (e.g., Ash3d, other models).

Estimated Impacts and Other Considerations:

Other alternatives with potential for refinement of ash structural load requirement (e.g., Ash3d, other models) should be pursued with consideration of the hours estimate to modify design documents, 6,000 hours total, as shown herein.

ATTACHMENTS

F.1 STRUCTURAL PEER REVIEW TEAM MINUTES (CCN 264941)

F.2 PRELIMINARY BNI ANALYSIS ON LOAD COMBINATIONS

SIGNATURE

Investigation Lead: E Dray for R. Venkata **Date:** 12-18-14

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ATTACHMENT F.1

Incoming Distribution List

TITLE/DISCIPLINE	NAME	eNotification	Hard Copy w Att.	Hard Copy w/o Att.	ACTION
Project Director	M. G. McCullough			X	
Project Manager	J. M. St. Julian	X			
Production Engineering Manager	M. L. Johnson	X			
Construction Manager	S. G. Overton	X			
Area Project Manager (PT/HLW)	R. L. Patterson	X			
Area Project Manager (LAW/BOF/LAB)	J. E. Rugg				
Procurement & Subcontracts Manager	L. W. Baker				
Acquisition Services Manager	F. R. Salaman				
Area Project Manager (Shared Services)	B. D. Zieroth				
Startup Manager	D. L. Collins				
Project Controls Manager	M. O. Blake				
Management Reserve Recovery & Risk Management Manager	R. S. Hajner	X			
Design, Operations & Integration Manager	E. F. Sproat III	X			
Nuclear Safety Commissioning & Operations Manager	M. A. Lindholm	X			
Plant Operations Manager	K. R. Wells				
Nuclear Safety & Plant Engineering Manager	F. Beranek	X			
Environmental & Nuclear Safety Manager	D. M. Busche	X			
Commissioning Manager	S. B. Booth				
Project Technical Director & Design Authority	R. B. Daniel	X			
One System Integrated Project Team, Deputy Manager	G. M. Duncan				
Nuclear Safety & Technical Design Integration Manager	R. T. Brock				
Business Services Manager	L. W. Baker	X			
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Prime Contracts Manager	S. S. Crawford	X			
Manager of Organizational Effectiveness	W. S. Oxenford				
Manager of Quality	L. M. Weir	X			
Safety Assurance Manager	R. C. Nugent				
BNI Legal	J. H. Dunkirk	X			
Chief of Staff	J. D. Norwood				
PAAA/Regulatory Interface Mgr.	D. E. Kammenzind	X			
Quality Assurance Engineer	K. J. Thomas	X			
Quality Assurance Engineer	J. B. King	X			
Administrative Specialist	D. A. Marmo	X			
	M. Axup	X			
	J. Booth	X			
	J. B. Monahan	X			
	I. Milgate	X			
	H. L. Moorman	X			
	J. S. Harmon	X			
	M. G. Wentink	X			
	B. K. Davis	X			
	W. M. Stone	X			
	A. R. Veirup	X			
	K. D. Irwin	X			
Project Archives and Document Control		ORIGINAL			

Doc. No. 264941
Date of Document Dec. 10, 2013
From William F. Hamel
To J. M. St. Julian

Written response required ☐ Yes ☒ No
Due date
Actionee

ATS action ☐ Yes ☒ No
Owed to
Due date
Actionee

SENSITIVE ☐ Yes ☒ No

Remarks Transmittal of Surveillance Report S-13-RPPWTP-012 – Review of the May 2013 Structural Peer Review Team (SPRT) Report

NOTE: Supersedes CCN

R11626800

OFFICE OF RIVER PROTECTION
P.O. Box 450, MSIN H6-60
Richland, Washington 99352

DEC 10 2013

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13-WTP-0252
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RPP-WTP
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DEC 16 2013
BY PDC

Mr. J.M. St. Julian
Project Manager
Bechtel National, Inc.
2435 Stevens Center Place
Richland, Washington 99354

Mr. St. Julian:

CONTRACT NO. DE-AC27-01RV14136 – TRANSMITTAL OF SURVEILLANCE REPORT S-13-WED-RPPWTP-012 - REVIEW OF THE MAY 2013, STRUCTURAL PEER REVIEW TEAM (SPRT) REPORT

This letter provides the results of the U.S. Department of Energy (DOE), Office of River Protection, Waste Treatment and Immobilization Plant (WTP) Engineering Division (WED) review of the May 2013 SPRT report of the independent confirmation of WTP structural design. Attached are copies of the subject surveillance report and the May 2013 SPRT report.

The May 2013 SPRT review resulted in 27 comments. WTP characterized the comments as 27 opportunities for improvement (OFI). A formal response to these OFIs is not required. However, Bechtel National, Inc. (BNI) is requested to review, and as appropriate, address these items to support a future SPRT follow-up review.

The action taken herein is considered to be within the scope of work of the existing contract and does not authorize the Contractor to incur any additional costs (either direct or indirect) or delay delivery to the Government. If the Contractor considers that carrying out this action will increase contract/project costs or delay of delivery, the Contractor shall promptly notify the Contracting Officer orally, confirming and explaining the notification in writing within ten (10) calendar days, and otherwise comply with the requirements of the Contract clause entitled *52.243-7*, – "Notification of Changes." Following submission of the written notice of impacts, the Contractor shall await further direction from the Contracting Officer.

264941

Mr. J.M. St. Julian
13-WTP-0252
REISSUE 12/10/13

-2-

DEC 10 2013

If you have any questions, please contact me, or your staff may contact Paul Hirschman, Director, WTP Engineering Division, (509) 376-2477.

William F. Hamel
Assistant Manager, Federal Project Director
Waste Treatment and Immobilization Plant

WTP:RMV

Attachments

cc w/attach:
M. Axup, BNI
J. Booth, BNI
D. Kammenzind, BNI
BNI Correspondence

REISSUE was to correct the surveillance number from S-13-WED-RPPWTP-011 to S-13-WED-RPPWTP-012.

Attachment 1
REISSUE 12/10/13 13-WTP-0252
S-13-WED-RPPWTP-012

Attachment 1

13-WTP-0252

REVIEW OF MAY 2013 STRUCTURAL PEER REVIEW TEAM REPORT

WED Assessment Report

October 2013

16 pages (including coversheet)

Attachment 1
REISSUE 12/10/13 13-WTP-0252
S-13-WED-RPPWTP-012

WED Assessment Report

Assessment Report Number:	S-13-WED-RPPWTP-012
Division Performing Assessment:	Waste Treatment and Immobilization Plant Engineering Division
Integrated Assessment Schedule Number:	451
Title:	Review of May 2013 Structural Peer Review Team Report
Date(s):	October 2013
Lead:	Raman Venkata, WED Safety Systems Oversight Structural Engineer
Attachment:	May 2013 Structural Peer Review Team Report

SCOPE

This assessment report documents the Waste Treatment and Immobilization Plant (WTP) Engineering Division (WED) review of the May 28 to May 31, 2013, independent Structural Peer Review Team (SPRT) report issued October 3, 2013. This report contains WED characterization of the comments contained in the SPRT report in accordance with Desk Instruction MGT-PM-DI-03, *Conduct of Engineering Oversight*, and Implementing Procedure TRS-OA-IP-01, *Integrated Assessment Process.*

REQUIREMENTS REVIEWED

- 24590-WTP-SRD-ESH-01-001-02, *Safety Requirements Document*, Rev. 7
- 24590-WTP-DB-ENG-01-001, *Basis of Design*, Rev. 1Q
- DOE-STD-1020-1994, *Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities.*

RECORDS/DESIGN/INSTALLATION DOCUMENTS REVIEWED

- Drawings: 24590-LAW-S0-S15T-00002, Rev. 25; 24590-LAW-S0-S15T-00011, Rev. 5; 24590-LAW-S0-S15T-00012, Rev. 3; 24590-LAW-S0-S15T-00014, Rev. 6; 24590-LAW-S0-S15T-00015, Rev. 2; 24590-LAW-S1-S15T-00005, Rev. 1; 24590-LAW-S1-S15T-00035, Rev. 1; 24590-LAW-S1-S15T-00043, Rev. 4; 24590-LAW-S1-S15T-00045, Rev. 3; 24590-LAW-S1-S15T-00046, Rev. 1; 24590-LAW-S1-S15T-00047, Rev. 2; 24590-LAW-S1-S15T-00048, Rev. 1; 24590-LAW-S1-S15T-00049, Rev. 2; 24590-PTF-DD-S13T-00065, Rev. 6; 24590-PTF-DD-S13T-00066, Rev. 13; 24590-PTF-DD-S13T-00067, Rev. 10; 24590-PTF-DD-S13T-00068, Rev. 9; 24590-PTF-DD-S13T-00069, Rev. 2; 24590-PTF-P1-P23T-00037, Rev. 1; 24590-PTF-P1-P23T-00038, Rev. 2; 24590-PTF-P1-P23T-00039, Rev. 1; 24590-PTF-P1-P23T-00040, Rev. 1; 24590-PTF-P1-P23T-00041, Rev. 0; 24590-PTF-S1-S15T-00501, Rev. 1; 24590-PTF-S1-S15T-00502, Rev. 1; 24590-PTF-S1-S15T-00503, Rev. 1; 24590-PTF-S1-S15T-00504, Rev. 1; 24590-PTF-S1-S15T-00510, Rev. 1; 24590-PTF-P1-P23T-00037, Rev. 1; 24590-PTF-P1-P23T-00038, Rev. 2; 24590-PTF-P1-P23T-00039, Rev. 1; 24590-PTF-P1-P23T-00040, Rev. 1; 24590-PTF-P1-P23T-00041, Rev. 0; 24590-PTF-S1-S15T-00501, Rev. 1; 24590-PTF-S1-S15T-00502, Rev. 1; 24590-PTF-S1-S15T-00503, Rev. 1; 24590-PTF-S1-S15T-00504, Rev. 1; and 24590-PTF-S1-S15T-00510, Rev. 1.

- Calculations 24590-LAW-SSC-S15T-00057,Rev. 0; 24590-PTF-SSC-S15T-00075,Rev. 0; 24590-PTF-SSC-S15T-00360,Rev. A; 24590-PTF-SSC-S15T-00365,Rev. A; and 24590-WTP-DC-ST-01-001, Rev. 13
- May 2013 SPRT Report, dated October 3, 2013.

DISCUSSION OF AREAS OR ACTIVITIES REVIEWED

U.S. Department of Energy (DOE) policy requires DOE facilities, such as the WTP, to be designed, constructed, and operated so workers, the general public, and the environment are protected from the impacts of natural phenomenal hazards on DOE facilities. Key considerations include earthquake design and evaluation criteria prescribed in DOE-STD-1020-94. The application of natural phenomena hazard (NPH) design requirements to structures, systems, and components (SSC) are based on the life safety or the safety classifications of the SSC as established by safety analysis focused on:

- Providing a safe work environment
- Protecting against property loss and damage
- Maintaining operation of essential facilities
- Protecting against exposure to hazardous materials during and after occurrences of natural phenomena events.

The purpose of the SPRT is to confirm the Bechtel National, Inc. (BNI) structural design process effectively implements authorization basis and other applicable technical requirements for the design activity under review, to ensure long-term safety, integrity, functionality/operability, and optimal life-cycle cost of WTP structural related SSCs.

The May 2013 SPRT included a review of facility structural steel drawings, calculations, design criteria, and design guides associated with structural design specific to the following:

1. Defense Nuclear Facilities Safety Board (DNFSB) issues and comments and responses to issues that have been transmitted to the DNFSB by BNI for the DOE Office of River Protection (ORP) since January 2011.
2. SPRT site visit to review general progress, emergency turbine generator (ETG) location, Analytical Laboratory (Lab) heating, ventilation, and air conditioning (HVAC) C5V duct, High-Level Waste (HLW) Facility platform
3. Review the Low-Activity Waste (LAW) Facility multi-commodity racks

4. Pretreatment (PT) Facility black cell liner
5. PT hot cell equipment frames
6. Review the transfer function comparison developed by the project for the Subtraction vs. Direct Method
7. Update the SPRT on the status of Lab HVAC C5V duct design/story drift issue, including HVAC seismic anchor motion
8. Discuss the resolution of PT/HLW crane rail girder design comments from October 2012 review
   - Review the crane bracket weld to embed, including distribution of vertical shear to flange welds
   - Discuss PT hot cell embed lamellar tearing issues
   - Discuss design issues with embed plates having Nelson D2L deformed bars
9. Review responses to past SPRT open comments
   - Discuss SPRT thinking on Project Issue Evaluation report (PIER) 12-0011, Action 6, related to DOE-STD-1020-94 peer-review requirements
   - Discuss resolution of PIER 12-1189 related to use of In-Structure Response Spectra (ISRS) curves
10. Discuss ETG building design
    - Update for on-power seismic design
11. Discuss HLW platform connection details
12. Review ashfall criteria revision
13. Review Design Criteria Revision 13 update.

As a result of the review, the SPRT made 27 new observations, which are provided in Attachment A of the SPRT report. A number of responses were presented to resolve previous SPRT comments and responses for seven comments were closed. In addition, the SPRT's review of draft calculation 24590-HLW-S0C-S15T-00236, Rev. 1, resolved the subtraction method issue for HLW Facility to the satisfaction of the SPRT.

A summary of the results of the review follows.

1. **SPRT site visit to review general progress, ETG location, Lab HVAC C5V duct, HLW platform**

   The SPRT participated in a site visit to review overall progress and status of construction. Specific attention was paid to the location of the ETG Building. In additional, the SPRT reviewed the Lab HVAC C5V duct and associated installed expansion joints and the designed location of the HLW platform. Details of the SPRT's observations from the site visit are incorporated into the specific items discussed below.

2. **Review the LAW multi-commodity racks**

   The SPRT held discussions with the project regarding the LAW multi-commodity racks, after which the SPRT reviewed calculations and drawings for typical designs provided by the project. Based on this review, the SPRT developed 15 comments and questions, which are included in Attachment A of the SPRT report.

3. **PT black cell liner**

   The SPRT held discussions with project personnel regarding the PT black cell liner, after which the SPRT reviewed calculations and drawings for typical designs provided by the project. Based on this review, the SPRT developed three comments and/or questions, which are included in Attachment A of the SPRT report.

4. **PT hot cell equipment frames**

   The SPRT held discussions with the project regarding the PT hot cell equipment, after which the SPRT reviewed calculations and drawings for typical designs that were provided by the project. Based on this review, the SPRT developed seven comments and questions, which are included in Attachment A of the SPRT report.

5. **Review the transfer function comparison developed by the project for the subtraction vs. direct method**

   The project provided comparisons of transfer functions in draft calculation 24590-HLW-S0C-S15T-00236, Rev. 1, as requested by the SPRT during the April 30 to May 1, 2012, SPRT meeting. The SPRT has reviewed the associated calculations and concurs that the use of the subtraction method does not have a significant effect on the computed results for the HLW Facility. This revision of the calculation addresses the path forward described in Topic 3 of the *Structural Peer Review Team Report of WTP Structures, Systems and Components*, dated August 20, 2012.

6. **Update the SPRT on the status of Lab HVAC C5V duct design/story drift issue, including HVAC seismic anchor motion**

   The SPRT held previous discussions with the project team regarding PIER 24590-WTP-PIER-12-0814-B related to incorporating story drift displacements into the design of the Lab HVAC C5V duct design. BNI has retrofitted the C5V duct system with expansion joints accommodate building drifts that were not considered as part of the original duct design. BNI engineers indicated that the controlling code provisions indicated that the ducts may be subject to local buckling due to the imposed (≈ 3 in.) seismic drift.

   The SPRT previously indicated that, given the magnitude of lateral drifts and displacement controlled duct loading, local buckling would likely result in a wrinkle or crinkle in the stainless steel duct shell. Neither response would lead to loss of duct operability even though the code stress limits would be exceeded. The SPRT further indicated that the expansion joints added to the system typically are less reliable than the duct itself and have larger life-cycle costs than the duct. It appeared to the SPRT that this may be an instance where reliability is reduced and costs increased to meet a "conservative" code criterion when the original configuration may have met the performance goal. The SPRT recommended implementing a waiver system to allow code exceedances in limited cases where fully justified.

Further discussion on this topic in the May 2013 SPRT meeting indicated that the Lab HVAC expansion joints now are installed. For future uses WED discussed using seismic experience database information and the SPRT recommended that the project have the Equipment Qualification PRT group (George Rawls) review the Seismic Qualification Utility Group (SQUG) qualification guidelines to assess whether the construction of the ductwork in question was consistent with the experience database. In addition, SBRT and the project discussed analysis methods to qualify the ducts. The analyses would have to consider nonlinear material behavior and nonlinear geometry (P-Delta) effects with the goal to demonstrate that the duct stays open (functional) during the displacement event. The discussion also addressed the need to implement some kind of waiver system to allow flexibility when strict adherence to design rules causes decisions that increase total risk. (The SPRT has made this comment before).

The project provided the SPRT with a list of Seismic Category III C5 duct and associated seismic parameters that will require evaluation for multi-level support displacement due to drift. The SPRT requested an opinion from George Rawls as to whether this would fall under the experience data gathered by the Electric Power Research Institute (EPRI) in Report 1016125, *Experience Based Seismic Equipment Qualification*, and Report 1007896, *Seismic Evaluation Guidelines for HVAC Duct and Damper Systems*. The peak ground acceleration for WTP Performance Category 2 structures is 0.6 g. The building in question is primarily a braced frame steel building with some concrete shear wall in the basement and a few shear walls at the first floor (ground level).

Table 1. Duct Tech Data.

Duct Size	Length	Pressure Class	Thickness
6 in. Ø	16 ft	B-3-*/M-1-C (± 56-in. WG)	304L 16 gauge
12 in. Ø	183 ft	B-3-*/M-1-C (± 56-in. WG)	304L 12 gauge
16 in. Ø	24 ft	A-1-F/L-1-A (± 15.25-in. to 20-in. WG)	304L 12 gauge
18 in. Ø	8 ft	B-3-E/J-1-C (± 10.25-in. to 15-in. WG)	304L 12 gauge
60 in. Ø	299 ft	B-3-A/J-1-C (± 10.25-in. to 15-in. WG)	304L 12 gauge
16 in. × 24 in.	12 ft	A-1-F/L-1-A (± 15.25-in. to 20-in. WG)	304L 12 gauge
14 in. × 20 in.	55 ft	B-3-E/J-1-C (± 10.25-in. to 15-in. WG)	304L 12 gauge

In addition, the project requested an opinion as to whether cable tray (raceway) would also fall into the category of distribution systems that are fundamentally unaffected by multi-level support displacement due to drift.

The SPRT forwarded the provided information to George Rawls with a request for his assessment. His assessment is included in Attachment E of the SPRT report. In summary, duct failures have been observed in past seismic events. As a result, evaluation of ductwork for differential displacements is required. More detailed discussion is provided in Attachment E.

7. **Discuss the resolution of PT/HLW crane rail girder design comments from October 2012 review**

   - Crane bracket weld to embed including distribution of vertical shear to flange welds
   - PT hot cell embed lamellar tearing issues
   - Embed plates having Nelson D2L deformed bars

   The SPRT held discussions with the project team regarding the October 2012 review comments that were based on the SPRT's review of the PT/HLW crane rail girder design. The project indicated that the calculation is being revised to address comments from the October 2012 SPRT summary report. Specific discussions regarding the previous comments resulted in the following:

   a. *Welds to embedment plates*. BNI agrees that welds for shear forces should be limited to welds in the direction of the shear forces. BNI will recalculate weld forces based on this basic assumption. This issue appears to be of generic concern.

   b. *Welds to embedment plate are controlling factor for capacity*. Comment from October 2012 meeting recommended that the project reconsider whether the capacity for an assemblage that will be inaccessible should be controlled by the size of the fillet weld. No additional discussion was held regarding this topic.

   c. *Use of back plate and embedment plate adequacy for HLW melter case overhead mast power manipulator*. BNI agreed to review and reissue calculations as necessary. The review will include evaluating the embedment plate.

   d. *Potential for laminar tearing of embedment plates*. BNI agreed to have a metallurgist provide a written opinion on the potential for laminar tearing, especially in the region of the top weld of the crane rail support brackets.

   e. *Nelson D2L deformed bar anchors*. The use of Nelson D2L deformed bars for the embed plate anchor is an issue. BNI agreed to develop a case study demonstrating that the embedded bars are fully developed with 60 percent of the ACI 318 development expression.

   f. *Vertical seismic loads*. The cranes have high vertical accelerations and restraints on one side of the rail. The vertical restraints for the crane are not addressed. This component of design should be included in the evaluation.

   g. *Additional topics*

      - Fy will not be used in the crane bracket design
      - Based on the discussions held with the project, it appears that there is a generic issue with computing shear capacity (0.4 Fy tw) for the design of welds to A36 plates.

   The items noted in 7a through 7g represent clarifications to the review comments from the October 2012 review and are not included in Appendix A of the SPRT report.

8. **Review responses to past SPRT open comments**

   - Discuss SPRT thinking on PIER 12-0011, Action 6 related to DOE-STD-1020-1994 peer-review requirements
   - Discuss resolution of PIER 12-1189 related to use of ISRS curves.

   PIER 12-0011, Action 6

   Discussions were held with the SPRT regarding Action 6 of PIER 12-0011. The SPRT concurs that DOE-STD-1020-1994 contains requirements for peer review. It is the SPRT's experience that peer reviews of calculations are performed by groups external to the performing group and most often come from external organizations.

   The decision on procedures and processes required to meet the requirements of DOE-STD-1020 should be a management responsibility, coordinated with the appropriate Quality Assurance personnel, and should flow to appropriate project (and Quality Assurance) procedures and processes. Due to the makeup and experience of the SPRT, the effectiveness of the WTP peer review process is not an appropriate topic for the SPRT to review and should be referred to the appropriate Quality Assurance group for evaluation.

   PIER 12-1189

   Comments on the existing control building are moot because the design for the control building will be changed. Thus the comments related to CCN 252553 (PIER 12-1189, PIER 12-1261) that are currently included in Attachment D of this report should be closed.[1]

9. **Discuss ETG Building design**

   - On-power seismic design

   BNI (Thomas Ma) provided a progress report on the status of the generator design. The SPRT has two issues:

   a. The vibration loads to the building need to be fully considered in the building design. Note that the turbine does not have an isolated foundation. The SPRT recommends getting formal building input from vendor and use that input in the design.

   b. The vendor wants to use transfer functions and evaluate the generator design using a frequency domain approach. DOE and the SPRT agree that approach can yield correct results if properly implemented. However, most of the analysis details have not been developed and there is nothing substantial to review at this time.

[1] Observations S-12-WED-RPPWTP-015-O01, S-12-WED-RPPWTP-015-O02, S-12-WED-RPPWTP-015-O03, and S-12-WED-RPPWTP-027-O04.

10. **Discuss HLW Vitrification Facility structural HEPA filter support details**

The SPRT held additional discussions with the project related to comments made during the October 2012 SPRT meeting. BNI is currently updating the analysis and revising the connection calculations. Two items that BNI needs to address in their revised calculations are:

a. *Fillet welds to A36 plate.* Fillet welds to A36 plate will be governed by 0.4 Fy tw (0.4 × 36,000 × weld size). The revised calculations will reflect this controlling condition. This is a generic issue with calculation of weld capacity.

b. *Welds resisting shear load.* BNI agreed to revise calculations to reflect using fillet welds parallel to the direction of applied load (shear is resisted only by welds to portions of members resisting shear) to resist shear.

The SPRT notes that there are roughly eight or nine complete load transfers (critical welds) required to develop this connection design. It is the SPRT's opinion that this is a poor design, even if BNI is successful in demonstrating that this design meets the minimum code requirements. Furthermore, it is the SPRT's opinion that this connection will be less reliable than the more direct girder-to-column connection that should have been used.

11. **Review ashfall criteria revision**

Discussions related to the revision of the ashfall criteria continued in the meeting from previous meetings. The discussions resulted in the following path forward. The SPRT noted that the proposed ashfall loads have a 10,000-year return period and the structural design criteria(SDC) specifies the same criteria as live load. At a minimum, it is the SPRT's opinion that ashfall loading should be considered as an upset loading and be evaluated using the same stress criteria as other upset loads, such as seismic. Note that this will require a change to the SDC. The SPRT suggested/concurred with the following:

a. Use mass scaling to get ash drift heights

b. Use reduced wind velocity for ash drift heights because ashfall is not a storm event like snow

c. Reduce the commodity load allowance if necessary

d. The WTP civil structural architectural discipline position should be documented in an engineering study or report.

In addition, ORP should convolve the ashfall hazard with typical gravity load building fragilities and determine the appropriate ashfall return period to achieve the DOE-STD-1020-1994 performance goal. The SPRT believes that using a 10,000-year return period and treating the ashfall load as a live load has a performance goal that is significantly smaller than the remaining NPH loads.

Pursuant to the meeting the SPRT has reviewed Calculation 24590-WTP-S0C-S15T-00033, Rev. 0, and understands how BNI is treating the ash drift loading. The SPRT deems the approach developed appropriate given the current state of the art. The SPRT also agrees with BNI conclusions that the snow drift loading is limiting compared to the ash drift load. However, it is the SPRT's opinion that the calculation is overly conservative in combining 23 psf (APE = E-4) of ash load with the full roof live load for Performance Category 3 structures, and this is a comment for the criteria document. The SPRT suggest that the 23 psf ash loading be accepted for the WTP Project unless the current criteria indicates modifications are required to the existing structures.

The current approach is sufficient to close the two comments from the SPRT October 2012 meeting related to HNF-SD-GN-ER-501, *Natural Phenomena Hazards*, Rev. 2.

12. **Review Design Criteria Revision 13 update**

    The SPRT has reviewed Rev. 13 of the Design Criteria and has one comment. The proposed ashfall loads have a 10,000-year return period and the SDC specifies the same criteria as live load. At a minimum, the ashfall loading should be considered as an upset loading and be evaluated using the same stress criteria as other upset loads, such as seismic. This comment is included in Attachment A of the SPRT report.

SUMMARY OF FINDINGS, OPPORTUNITIES FOR IMPROVEMENT, OR ASSESSMENT FOLLOWUP ITEMS

Reference Information for Opportunities for Improvement S-13-WED-RPPWTP-012-O01 through S-13-WED-RPPWTP-012-O15:

Document No. /Title: LAW Multi-commodity supports between Elevations +48 to +68

Calculation 24590-LAW-SSC-S15T-00057, Rev. 0; Drawings 24590-LAW-S0-S15T-00002, Rev. 25; 24590-LAW-S0-S15T-00011, Rev. 5; 24590-LAW-S0-S15T-00012, Rev. 3; 24590-LAW-S0-S15T-00014, Rev. 6; 24590-LAW-S0-S15T-00015, Rev. 2; 24590-LAW-S1-S15T-00005, Rev. 1; 24590-LAW-S1-S15T-00035, Rev. 1; 24590-LAW-S1-S15T-00043, Rev. 4; 24590-LAW-S1-S15T-00045, Rev. 3; 24590-LAW-S1-S15T-00046, Rev. 1; 24590-LAW-S1-S15T-00047, Rev. 2; 24590-LAW-S1-S15T-00048, Rev. 1; and 24590-LAW-S1-S15T-00049, Rev. 2.

- **OFI S-13-WED-RPPWTP-012-O01:**

  Refer to Calculation 24590-LAW-SSC-S15T-00057, page 22, and Drawing 24590-LAW-S1-S15T-00045. The unbraced length for a W18 × 46 is 8.33 ft. Beam G3-G4 at elevation +48 ft in drawing 24590-LAW-S1-S15T-00045 appears to have an unbraced length of roughly 16.2 ft. Please identify where the unbraced lengths shown on the drawings are considered.

- **OFI S-13-WED-RPPWTP-012-O02:**

  In drawing 24590-LAW-S1-S15T-00045 there is bracing between GL E.6-3 and E-4 that resists NS lateral loads. Please identify where the vertical bracing is called out that transfers NS lateral loads to the floor on the west side of this bracing.

Attachment 1
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S-13-WED-RPPWTP-012

- **OFI S-13-WED-RPPWTP-012-O03:**

  In the lateral load analysis on Page 30 of Calculation 24590-LAW-SSC-S15T-00057, where is the dead load of the platform considered?

- **OFI S-13-WED-RPPWTP-012-O04:**

  Drawings 24590-S1-S15T-00047 through -00049 show additional racks at elevations 56 ft 6 in. and 61 ft. Where is the weight of these racks and their contents considered in the lateral load analysis?

- **OFI S-13-WED-RPPWTP-012-O05:**

  Where is the lateral support for the racks between column lines 2 and 3 in Drawing 24590-LAW-S1-S15T-00045?

- **OFI S-13-WED-RPPWTP-012-O06:**

  Where are the brace loads from Drawings 24590-LAW-S1-S15T-00045 into the minor axis of columns J7, J8, and J9 considered?

- **OFI S-13-WED-RPPWTP-012-O07:**

  Similarly, where are the brace loads from Drawing 24590-LAW-S1-S15T-00045 into the minor axis of columns A8, A10, B8, and B10 considered?

- **OFI S-13-WED-RPPWTP-012-O08:**

  Where is Figure 6 that is referenced on Page 31 of Calculation 24590-LAW-SSC-S15T-00057?

- **OFI S-13-WED-RPPWTP-012-O09:**

  Where is the lateral and longitudinal load path for the hung platform shown on Page 6 of Calculation 24590-LAW-SSC-S15T-00057?

- **OFI S-13-WED-RPPWTP-012-O10:**

  Ref. Drawing 24590-LAW-S1-S15T-00049 shows racks that are supported above the elevation 59 ft 6 in. racks on posts. See also Section J on Drawing 24590-LAW-S1-S15T-00043. Where are the lateral and longitudinal loads for these members considered?

- **OFI S-13-WED-RPPWTP-012-O11:**

  Page 27 of the referenced calculation mentions a Veirendeel truss member. Where is the analysis for a Veirendeel truss?

  Is the intent of Section A on Drawing 24590-LAW-S1-S15T-00043 to act like a Veirendeel truss as mentioned on Page 27 of the calculation?

- **OFI S-13-WED-RPPWTP-012-O12:**

  Where the major and minor axis bending moments are from Section A on Drawing 24590-LAW-S1-S15T-00043 considered on the W18 support beam?

- **OFI S-13-WED-RPPWTP-012-O13:**

  A K factor of 2 is used for a W8 post that appears to be cantilevered off a W18 support beam. Please identify why a K factor of 2 is more appropriate than the American Institute of Steel Construction (AISC)-recommend value of 2.1 for cantilever columns.

- **OFI S-13-WED-RPPWTP-012-O14 & 15:**

  ECCN 24590-LAW-SSE-S15T-00106 evaluates the W18 × 46 girders for weak axis bending moments of 1-in. kip, major axis bending moments of 3-in. kip, and a torsional moment of 1-in. kip. What is the purpose of this calculation and is it appropriate to modify the calculation to account for such a small incremental load?

Reference Information for Opportunities for Improvement S-13-WED-RPPWTP-012-O16 through S-13-WED-RPPWTP-012-O17:

Document No. /Title: Qualification of Stainless Steel Liner for PT Black Cells, Non-Black Cells, and Filter Cave:

Calculation 24590-PTF-SSC-S15T-00075; Drawings 24590-PTF-DD-S13T-00065, Rev. 6; 24590-PTF-DD-S13T-00066, Rev. 13; 24590-PTF-DD-S13T-00067, Rev. 10; 24590-PTF-DD-S13T-00068, Rev. 9; 24590-PTF-DD-S13T-00069, Rev. 2

- **OFI S-13-WED-RPPWTP-012-O16:**

  This calculation uses AISC M016-89 for the design of Type 304L stainless steel. Type 304L stainless steel is not approved for use by AISC M016-89. Please obtain an appropriate code for the design of stainless steel.

- **OFI S-13-WED-RPPWTP-012-O17:**

  The calculation uses a minimum yield strength based on mill cert reports instead of the minimum specified yield strength required by AISC.

  The basis document for DOE-STD-1020, UCRL-CR-111478, takes credit for the difference between a design based on the minimum specified yield strength and the actual yield strength. Basing a design on the actual yield strength, reduces the code specified margin, and may not meet the DOE-STD-1020 performance goals.

  Note: This issue is also addressed by NRC Information Notice 2012-17 dated 9/6/2012 titled "*Inappropriate Use of Certified Material Test Report Yield Stress and Age-Hardened Concrete Compressive Strength in Design Calculations.*"

  Please use material strengths that are consistent with the code of record for the stainless steel components.

  Note that some material codes, such as ASCE 8-02 for stainless steel, allow the use of 90-percent exceedance test data for design strength. The use of code -llowed test data is consistent with DOE-STD-1020.

  The basis document for the 0.024-inch corrosion allowance SPRT report Reference 9.10, (Calcs 24590-WTP-M0C-50-00004 and Rev. E and ECCN 24590-WTP-M0E-50-00012) appears to address wear in systems with moving fluids/slurries. The section on corrosion allowance specifies a range on chemistries that can yield corrosion rates significantly larger than the 0.024-inch corrosion allowance used in the calculation. The link between the liner corrosion environment and the referenced corrosion allowance is not clear.

- **OFI S-13-WED-RPPWTP-012-O18:**

  Please provide an unambiguous liner specific corrosion allowance that considers the full range of postulated leaked material chemistries, environments, and flow rates, including stagnant flow. Please base the liner design on this corrosion allowance.

Reference Information for Opportunities for Improvement S-13-WED-RPPWTP-012-O19 and S-13-WED-RPPWTP-012-O25:

Document No. /Title: PT Hot Cell Equipment Platforms for Vertical Pumps:

Calculation 24590-PTF-SSC-S15T-00360, Rev. A; Drawings 24590-PTF-P1-P23T-00037, Rev. 1; 24590-PTF-P1-P23T-00038, Rev. 2; 24590-PTF-P1-P23T-00039, Rev. 1; 24590-PTF-P1-P23T-00040, Rev. 1; 24590-PTF-P1-P23T-00041, Rev. 0; 24590-PTF-S1-S15T-00501, Rev. 1; 24590-PTF-S1-S15T-00502, Rev. 1; 24590-PTF-S1-S15T-00503, Rev. 1; 24590-PTF-S1-S15T-00504, Rev. 1; and 24590-PTF-S1-S15T-00510, Rev. 1.

- **OFI S-13-WED-RPPWTP-012-O19:**

  The frequency calculation in Appendix A assumes that the pump mass is uniformly distributed to each of the five support beams. Please provide a technical basis for this assumed mass distribution or demonstrate that the actual mass distribution yields the same results.

- **OFI S-13-WED-RPPWTP-012-O20:**

  The frequency calculation does not consider rocking of the pump on the equipment platform. Rocking modes often dominate the response of tall-narrow equipment similar to these pumps. Please provide a technical basis for omitting the rocking mode or provide an analysis that considers the rocking mode.

- **OFI S-13-WED-RPPWTP-012-O21:**

  On page B6 the weld strength per unit length is based on 0.3 × Ftw × 0.707 tw and 0.4 Fy tplate; where Ftw is the nominal tensile strength of the weld, tw is the fillet weld leg size, Fy is the nominal tensile strength of the plate, and tplate is the plate thickness. The 0.4 Fy tplate check is incorrect and should be 0.4 Fy tw, not the plate thickness. While this criteria may not control the A572 plate in this specific calculation, the SPRT has observed this same error in other calculations with A36 plates where the 0.4 Fy tw does limit the weld strength. Please identify full extent of this error (i.e., buildings, calculations) and develop a plan to ensure that the welding is adequate.

- **OFI S-13-WED-RPPWTP-012-O22:**

  The load development in Appendix C is confusing. Please clarify if the 60 percent seismic response reduction on page C3 is an implementation of the ASCE 4 100-40-40 rule. If this is so then please explain why an absolute summation of reactions (page C4) is used.

- **OFI S-13-WED-RPPWTP-012-O23:**

  The weld design beginning on page C6 has a D/C=0.92. This calculation appears to overstate the overturning load acting on individual welds by using a two-step method to obtain the weld loads. Distributing the loads directly to welds on each of the four corners in one step will provide a more accurate load distribution. What is the actual demand to capacity ratio for this component?

- **OFI S-13-WED-RPPWTP-012-O24:**

  The beam flange is welded to the base plate with 16 inches of ½-in. fillet weld. Rough SPRT hand calculations suggest that bending of the beam flange may limit the force that can be transmitted to the ½-in. fillet weld. Please provide a technical basis for the load transfer between the beam web and the ½-in. fillet weld.

- **OFI S-13-WED-RPPWTP-012-O25:**

  This calculation contains an analysis of the equipment loads transmitted to individual base plates. Where is the analysis that verifies that these loads are less than the anchor capacity?

  This calculation contains an analysis of the equipment loads transmitted to individual base plates. Where is the analysis that verifies that these loads are less than the anchor capacity?

Reference Information for Opportunities for Improvement S-13-WED-RPPWTP-012-O26:

Document No. /Title: Design of Surface Mounted Plates for Support of PT Hot Cell Equipment Platforms:

Calculation 24590-PTF-SSC-S15T-00365, Rev. A; Drawings 24590-PTF-P1-P23T-00037, Rev. 1; 24590-PTF-P1-P23T-00038, Rev. 2; 24590-PTF-P1-P23T-00039, Rev. 1; 24590-PTF-P1-P23T-00040, Rev. 1; 24590-PTF-P1-P23T-00041, Rev. 0; 24590-PTF-S1-S15T-00501, Rev. 1; 24590-PTF-S1-S15T-00502, Rev. 1; 24590-PTF-S1-S15T-00503, Rev. 1; 24590-PTF-S1-S15T-00504, Rev. 1; and 24590-PTF-S1-S15T-00510, Rev. 1.

- **OFI S-13-WED-RPPWTP-012-O26:**

  Note: Attachment A of the SPRT report deals with plates for PT hot cell equipment platforms covered by Calculation 24590-PTF-SSC-S15T-0365, so only the part of Calculation 24590-PTF-SSC-S15T-0360 related to Calculation -0365 was reviewed.

  The model analyzed is shown on Sheet A-2 and consists of the 2-in. plate with four anchors to concrete near the four corners. Spacing of bolts is 23 in. in one direction, 16 in. in the other direction. The sketch on A-2 suggests the load is applied by a 10-in.-long weld attachment near one corner. The analysis that follows seems to utilize the four anchor bolts to share the load. However, at the bottom of sheet A-4 the term Ψ1 is taken as 1.0 with e'n equal to zero. This suggests the load is applied at the centroid of the bolt group, not near on corner as illustrated on Sheet A-2. It appears from the calculation that the four anchors are sharing to resist tension uplift with no eccentricity in the applied load. The calculation concludes with a tension and shear D/C of 0.99. This does not appear to be correct and it appears some anchors are overstressed.

The SPRT understands that these anchors are on construction drawings at the end of the 00360 calculation, specifically Drawings 24590-PTF-P1-P23T-00037 through -00041 plus 24590-PTF-S1-S15T-00501 through -00505 and -00510. In those drawings we see no plates of the dimensions analyzed in Attachment A of Calculation -00365. We see plates with four anchors on 9-ft-long plates. We see plates with 8 to 10 anchors up to 11 ft long. BNI should explain how the design of these plates corresponds with the drawings provided. It may be the four bolts at one end of these long plates matches Calculation -00365 Attachment A, but the sharing of the uplift by four anchors is still in question.

- **OFI S-13-WED-RPPWTP-012-O27:**

  Document No. /Title: Structural Design Criteria:

  24590-WTP-DC-ST-01-001, Rev. 13

  The proposed ashfall loads have a 10,000-year return period and the SDC specifies the same criteria as live load. At a minimum the ashfall loading should be considered as an upset loading and be evaluated using the same stress criteria as other upset loads, such as seismic.

CONCLUSION

WTP project staff gave presentations to the SPRT related to the analysis and design of the LAW multi-commodity racks, PT black cell liner, PT hot cell equipment frames, HLW Structural Analysis for Soil Structure Interaction (SASSI) analyses, Lab HVAC C5V duct design, PT/HLW crane rail girder, HLW platform connection details, the ETG Building, adoption of updated ashfall criteria, and the updated structural design criteria. The SPRT also visited the construction site. The meetings also included discussions aimed at addressing existing open SPRT observations. Draft responses to a number of SPRT open items were presented and an acceptable resolution was developed for seven of the open items. In addition, resolution of the subtraction method issue for HLW has been achieved with the issue of Calculation 24590-HLW-S0C-S15T-00236, Rev. 1. Comments and questions were developed by the SPRT based on review of the documents provided at the meeting and discussions held with the project team. These comments and questions are included in Attachment A of the SPRT report.

A potentially significant generic issue has been identified with the approach that the project has used those results in incorrect design of fillet welds. This approach has been implemented dating back to the beginning of the project. The two basic errors in design are: (1) all fillet welds within a connection are used to resist shear whereas shear should only be resisted by welds connecting portions of the sections that resist shear; and (2) for E70 fillet welds to grade A36 plate, the strength of the weld to the plate will govern capacity. BNI has been using the plate thickness rather than the fillet weld size in their calculations. The fillet weld designs implemented for the entire project should be reviewed to identify these calculation errors and determine if retrofits are required.

SIGNATURES

Assessor or Lead Assessor:	[signature]	**Date:**	12/10/2013
Assessor's Manager, Division Director, or Supervisor:	[signature]	**Date:**	12/10/2013

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ATTACHMENT F.2

Ashfall Criteria Comparison			
Current Design Basis		Proposed Design Basis	
HNF-SD-GN-ER-501, Rev. 1		HNF-SD-GN-ER-501, Rev. 2	
Section 4.3		Section 7.0	
Assumptions a) 50 % compaction ratio b) density = 48 lbs/cf (uncompacted)		**Assumptions** a) loads are on a dry ash basis b) intended for evaluation in combination with concurrent moisture loads, i.e., extraordinary event (A_k) load combination of ASCE 7-10, Section 2.5, $(0.9 \text{ or } 1.2)D+A_k+0.5L+0.2S$ c) when ash loads are considered without concurrent moisture loads, additional 0.5 psf should be applied	
Design Loads		Design Loads	
Performance Category (Seismic Category)	Design Ashfall Load (psf)	Performance Category (Seismic Category)	Design Ashfall Load (psf) value includes additional 0.5 psf to be used in load combinations without moisture load cases
1 (SC-IV)	3.0	1 (SC-IV)	3.7
2 (SC-III)	5.0	2 (SC-III)	12.3
3 (SC-I / II)	12.5	3 (SC-I / II)	23.5
4	30.0		
		Discussion: The extraordinary event load combination of ASCE 7-10, Section 2.5, only includes 50% live load, and 20% snow load. Current load combinations include ashfall combined with full roof live load. Full roof live load is 20 psf. Design snow load is approximately (conserv) 25 psf. Additional loading using the extraordinary load case combination would add 10 psf roof live load and 5 psf wet ashfall, or a total of 15 psf which is less than the full roof live load. **Conclusion:** The current load combinations should bound the extraordinary load combination of ASCE 7-10. The assessment provided below uses a comparison to current load combinations and ash loading considered without moisture loads, i.e., new design values provided increased by 0.5 psf.	

Facility Design Impact **Ashfall Load Increase**	
Load Combinations - Structural Design Criteria	
General 1. Ashfall loads shall be concurrent with roof live load, L_r 2. Unbalanced ashfall load (i.e., drifting) is enveloped in load combinations including roof live load, where $L_r \geq 20$ psf	Potential Impacts
SC-I & SC-II Facilities	
Concrete Design - Load Combinations Based on Section 9.2 of ACI 349-01	
Ashfall Load Combinations Normal Loads $U=1.4D+1.7L+1.7L_r+1.7A+1.4F+1.7H+1.7R_o$ Normal Load + Thermal $U=1.05D+1.3L+1.3L_r+1.3A+1.05F+1.3H+1.05T_o+1.3R_o$ Non-Ashfall, Non-Seismic. Load Combinations Normal Loads $U=1.4D+1.7L+1.7S_N+1.4F+1.7H+1.7R_o$ $U=1.4D+1.7L+1.7L_r+1.4F+1.7H+1.7R_o+1.7W$ $U=1.4D+1.7L+1.7S_N+1.4F+1.7H+1.7R_o+1.7W$ Normal Loads + Thermal $U=1.05D+1.3L+1.3S_N+1.05F+1.3H+1.05T_o+1.3R_o$ $U=1.05D+1.3L+1.3L_r+1.05F+1.3H+1.3W+1.05T_o+1.3R_o$ $U=1.05D+1.3L+1.3S_N+1.05F+1.3H+1.3W+1.05T_o+1.3R_o$ Seismic Load Combinations $U=D+L+L_r+F+H+T_o+R_o+E$ $U=D+L+S_N+F+H+T_o+R_o+E$	**Observations:** (for design references, see 24590-PTF-S0C-S15T-00062, Rev. C - PTF Roof Steel Structure Response Spectrum Analysis) 1. Ashfall combined with roof live load (12.5+20=32.5 psf) is always greater than roof snow load ~23 psf (neglecting drift). Ashfall load combinations control over other non-seismic load combinations. However, considering snow drift ~ 79 to 112 psf, will always be greater than ashfall + roof live load. 2. Ashfall is not combined with seismic loading - E 3. Seismic load E = accel x (seismic mass). Seismic mass = roof dead + 0.25 roof live. Roof dead load comprised of following: steel ~ 25 psf (est) roof commodities = 20 psf - (ref. Table 2.1) roofing material = 15 psf - (ref. Table 2.1) E=accel[25+20+15+(0.25)(20)]=accel x 65 psf Vertical seismic acceleration ~ 1.0 g (ref. Fig. 5.8) - conservatively estimated based on maximum vertical mass participation achieved at (approx) 25 hz (ref. Table 7.1) E = 65 psf 4. Ashfall load component increased to 23.5 psf 5. 65/1.7 = 38 psf > 23.5 **Conclusion:** Existing seismic load combinations should always control over increased ashfall loading.
Steel Design - Load Combinations Based on Table Q1.5.7.1 of N690, modified by Appendix F of Section 3.8.4 of NUREG-0800	
Ashfall Load Combinations $S=D+L+L_r+A$ $S=D+L+L_r+A+R_o+T_o$ Non-Ashfall, Non-Seismic, Load Combinations $S=D+L+S_N$ $S=D+L+S_N+R_o+T_o$ $S=D+L+L_r+W$ $S=D+L+S_N+W$ $S=D+L+L_r+W+R_o+T_o$ $S=D+L+S_N+W+R_o+T_o$ Seismic Load Combinations	**Observation:** Load combinations are similar to concrete load combinations in that ashfall is combined with roof live but not included in seismic. By comparison to concrete load combinations, seismic load cases control over ashfall.

$1.4S=D+L+L_r+R_o+T_o+E$ $1.4S=D+L+S_N+R_o+T_o+E$	
SC-III & SC-IV Facilities	
Concrete Design - Load Combinations Based on Section 9.2 of ACI 318-99	
Ashfall Load Combinations $U=1.4D+1.7L+1.7L_r+1.7A$ $U=1.4D+1.7L+1.7L_r+1.7A+1.7H$ $U=1.4D+1.7L+1.7L_r+1.7A+1.4F$ Non-Ashfall, Non-Seismic. Load Combinations $U=1.4D+1.7L+1.7S_N$ $U=0.75(1.4D+1.7L+1.7L_r+1.7W)$ $U=0.75(1.4D+1.7L+1.7S_N+1.7W)$ $U=0.9D\pm1.3W$ $U=1.4D+1.7L+1.7S_N+1.7H$ $U=0.9D+1.7H$ $U=1.4D+1.7L+1.7S_N+1.4F$ $U=0.9D+1.4F$ $U=0.75(1.4D+1.7L+1.7L_r+1.4T_o+1.4R_o)$ $U=0.75(1.4D+1.7L+1.7S_N+1.4T_o+1.4R_o)$ $U=1.4(D+T_o)$ Seismic Load Combinations $U=1.1(1.2D+L+0.2S_N+1.F+1.6H+1.2T_o+1.2R_o+E)$ $U=1.1(0.9D\pm E)$	**Observations:** 1. Ashfall combined with roof live load (5+20=25 psf) is always greater than roof snow load ~20 psf (neglecting drift). Ashfall load combinations control over other non-seismic load combinations. **Conclusion:** Ashfall load combinations control over all load combinations. Any increase in ashfall will reduce current design margins.
Steel Design - Load Combinations Based on UBC Section 1612.3.2	
Ashfall Load Combination $S=D+L+L_r+A$ Non-Ashfall, Non-Seismic, Load Combinations $S=D+L+S_N$ $S=0.75(D+L+W)$ $S=0.75(D+L+0.5S_N+W)$ $S=0.75(D+L+S_N+0.5W)$ Seismic Load Combinations $S=0.75(D+L+E/1.4)$ $S=0.75(0.9D\pm E/1.4)$	**Observation:** Steel load combinations similar to concrete load combinations in that ashfall is combined with roof live (seismic load combinations have no vertical component and therefore, do not control). Ashfall load cases control design.

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APPENDIX G

ASHFALL PLANNING TEAM REVIEW: INVESTIGATION OF OPTIMIZING EMERGENCY TURBINE GENERATOR CAPACITY

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APPENDIX G

ASHFALL PLANNING TEAM REVIEW: INVESTIGATION OF OPTIMIZING EMERGENCY TURBINE GENERATOR CAPACITY

INVESTIGATOR(S)

Mazen Al-Wazani

ISSUE DESCRIPTION

Optimizing emergency turbine generator (ETG) capacity.

DOCUMENTS REVIEWED

- 24590-WTP-PSAR-ESH-01-002-01, Rev 5c, *Preliminary Documented Safety Analysis to Support Construction Authorization; General Information,* Section 1.5.1.2, Volcanic Hazard Assessment, River Protection Project Waste Treatment Plant, Richland, Washington.
- Rolls-Royce vendor publication
- DOE/EIS-0467D, Description of the Proposed Action and Comparison of Impacts of Alternatives
- 24590-CD-POA-MUTC-00001-03-00001, *OnPower, Utility Requirements Non-Electrical*, OnPower, Inc., Lebanon, Ohio, for Bechtel National, Inc., Richland, Washington.
- 24590-CD-POA-MUTC-00001-07-00012, *Rolls-Royce Corporation Data Reduction Report EDR18944G*, Rolls-Royce Corporation for Bechtel National, Inc., Richland, Washington.

DISCUSSION

See Attachment G.1.

CONCLUSIONS

1. ETG capacity can be increased using water injection, though current ETG design would require modification.
2. ETG capacity can be increased using ETG performance curve; however, there is a cost of decreased available run times, decreased time between maintenance cycles, and increased chance of failure.
3. Maintenance of ETGs during and following an ashfall event will be a challenge unless in-house staff are trained to perform maintenance and repair activity on the ETG and have adequate spare parts for item replacement.
4. Natural gas is a viable alternative to diesel fuel and would resolve costly logistical challenges associated with storage and supply of diesel fuel needed to support continued

ETG operation in the wake of an ashfall event. Obtaining natural gas on the Hanford Site should be explored.

RECOMMENDATION

Viable Alternative by Itself?

No. Water injection and natural gas by themselves will not resolve ashfall-related issues. Water injection will reduce air demand and natural gas will resolve the fuel supply of the ETG.

Viable Alternative in Combination with other Alternatives?

Yes. The water injection and natural gas supply in combination with other alternatives should be pursued. By using the water injection and ETG performance curves, the capacity of the ETG can be increased and, depending on the final load calculations and other options related to decreasing electrical demands, a second ETG may not be required to accommodate the ashfall loadings. The water injection and natural gas options are currently offered by the manufacturer and can be incorporated through equipment modifications in the field or prior to purchase.

Estimated Impacts and Other Considerations:

None.

ATTACHMENTS

G.1 GENERAL DISCUSSION OF THE EMERGENCY TURBINE GENERATOR

SIGNATURE

Investigation Lead: Mazen E. [signature] **Date:** Dec 17, 2014

ATTACHMENT G.1
GENERAL DISCUSSION OF THE EMERGENCY TURBINE GENERATOR

The emergency diesel generator is classified as a safety class unit that provides fully redundant and independent electrical power to the safety load centers in the Pretreatment and High-Level Waste Facilities (24590-WTP-PSAR-ESH-01-002-05, *Preliminary Documented Safety Analysis to Support Construction Authorization; Balance of Facility Specific Information*, Section 3.3.3.5). The emergency turbine generators (ETG) must be able to withstand normal, abnormal, and design basis event environmental conditions and natural phenomenon hazards as noted on 24590-BOF-MUD-89-00001, *Emergency Turbine Generator Data Sheet*, and identified herein.

Emergency Turbine Generator for the Waste Treatment and Immobilization Plant Model 501-KB7S

501 Options for Power Generation Applications

The 501-K gas turbine provides electrical power output between 3.9 and 6.4 MW for applications such as cogeneration, offshore platforms, and emergency power. The single-shaft, designated as 501-KB5S/KB7S, is designed for electrical power generation and fixed speed mechanical drive applications. The steam injected single-shaft 501-KH provides 6.4 MW of power at efficiency levels unprecedented for gas turbines of this size. In addition, the amount of steam can be adjusted to meet varying process steam or electrical requirements, depending on the application.

The 501-K engine is designed to operate on a wide variety of fuels. Fuels include, but are not limited to, natural gas, liquid fuel (typically DF-2 or equivalent), and mid to low British thermal unit (BTU) gas fuels. Fuel system options also include dual fuel, steam, and water injection.

Fuel System

- On-skid fuel system includes all components needed to control fuel during startup and operation
- Operates on natural gas, liquid, dual fuel, and low BTU gas with steam and water injection.

Engine Performance

WTP will be using 501-KB7S.

Power Generation				
501-K Variant		501-KB5S	**501-KB7S**	501-KH5
Gross Electrical Power	kWe	3,897	**5,245**	6,447
Gross Heat Rate	kJ/kWe-hr	12,393	**11,445**	8,971
Gross Efficiency	%	29.0	**31.5**	40.1
Shaft Speed	rpm	14,200	**14,600**	14,600
Exhaust Flow	kg/sec	15.4	**21.1**	18.4
Exhaust Temperature	°C	560	**498**	530

Power Generation				
Mechanical Drive				
501-K Variant		501-KC5	501-KC7	
Shaft Power	shp	5,500	7,200	
Shaft Heat Rate	Btu/shp-hr	8,495	7,934	
Shaft Efficiency	%	30.0	32.2	
Shaft Speed	rpm	13,600	13,600	
Exhaust Flow	kg/sec	15.5	20.8	
Exhaust Temperature	°C	571	514	

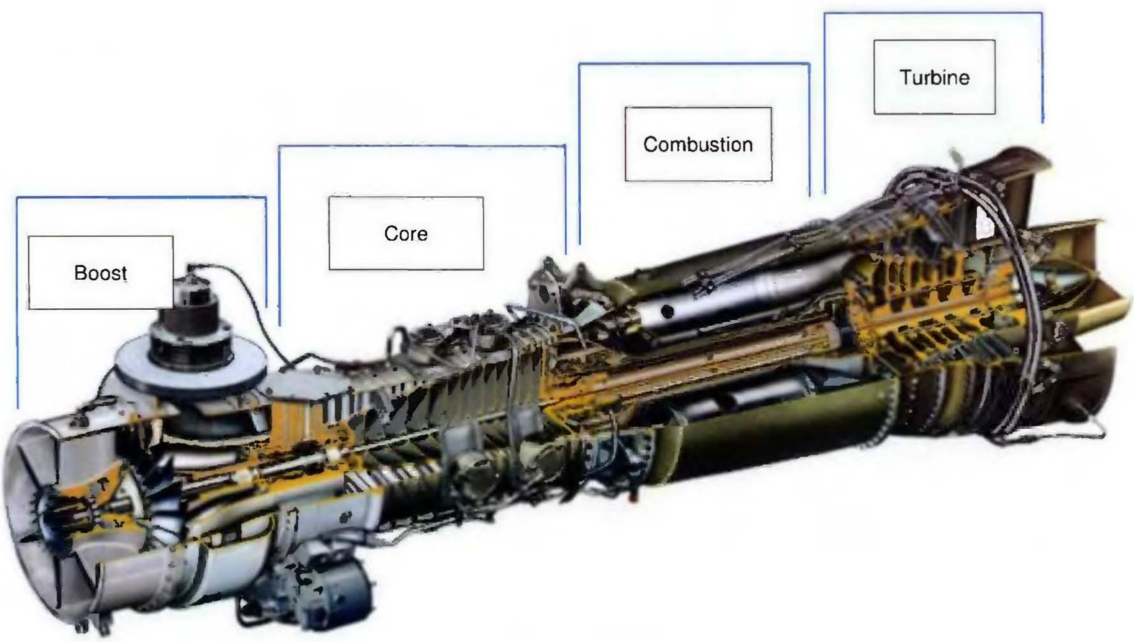

Figure G.1-1. 501-KB7S Gas Turbine.

1. Perform ETG maintenance during 60 days versus rerate capacity

   Bechtel National, Inc., has not documented or prepared a maintenance plan of the ETGs. They will be relying on the seller and manufacturer recommendation for maintenance activities. In accordance with a discussion with Bechtel National, Inc., they will be performing the regular inspections and maintenance, but when it comes to repair and replacement of major components, they will rely on manufacturer support. However, during an ashfall event, the manufacturer will likely be affected due to transportation impacts. It is recommended that there are enough spare parts on hand, especially for major components. It is also recommended that training be provided in order to conduct in-house repairs by personnel and to not rely of manufacturer support. This would necessitate that critical items (e.g., spare parts) be on hand to maintain the ETG during continued operation following an ashfall event, as well as emergency operations plans that account for surveillance and maintenance of ETGs during extended operations periods.

2. Use performance curves versus nameplate for ETG load rating:

   Performance curves were not evaluated for the specific turbine chosen as part of the Waste Treatment and Immobilization Plant (WTP) design package, but the nameplate is known to be about 5.2 MW. While power output of a turbine can be improved, it comes with a cost of decreased available run times, decreased time between maintenance cycles, and increased chance of failure. Available literature[1] support the viability of changing out fuel injectors to add steam with a resulting 20 percent gain in power. However, such measures could affect commercial grade dedication and equipment qualification.

   Peak load is an increase in firing temperature, typical of about 100 °F, which may result in approximately an 8–10 percent increase in unit output, from the base load. Hot gas path parts life is used at a faster rate, a typical "rule of thumb," 1 hour operating on peak is the equivalent of 6 hours of base load.

   As for calculating base or peak loads, the performance correction curves provided by the original equipment manufacturer should be used, with the realization that those curves are provided for a unit that is in new and clean condition, with specified internal clearances, with new and clean inlet air filters, with rated exhaust duct back pressure, and with fuel that meets the expected fuel characteristics supplied by the turbine purchaser at the time the turbine control system was configured. The performance correction curves can only correct for differences in ambient conditions (e.g., temperature, humidity, ambient pressure) between nameplate rated conditions and the day/time the performance data was collected.

3. Water injection

   Water is injected into the compressor, diffuser, or combustor to increase power output. This technique is used for the stationary, heavy industrial gas turbines for peaking power. Based on Rolls-Royce and OnPower, the change in ETG shaft output power due to water injection ranges between 9 and 10 percent depending on ambient temperature between 0 °F and 100 °F. Today, in order to control the formation of organic NO, demineralized/ deionized water is injected directly into the combustion zones of the gas turbine, thereby influencing the chemical reaction of the combustion process. In addition to lowering the flame and gas temperatures, vaporized water also increases the mass flow through the engine. As a result, at a constant power output, combustion and turbine temperatures are reduced. The combination of the reduced combustion temperatures and changes in the chemical reaction can reduce NOx formation up to 80 percent. The amount of water necessary to accomplish this reduction in NOx is a function of the diffuser, combustor,

[1] http://gasturbineworld.com/assets/july_aug_2012.pdf; http://intpower.com/wp-content/uploads/2012/10/GTW-CLN-Article-Apr-2008.pdf.

and fuel nozzle design. Water injection rates are generally quoted as a water-to-fuel ratio or as a percentage of compressor inlet airflow.

The water used for NOx control is demineralized and deionized to prevent deposits from forming on the hot metal surfaces of the combustor, turbine nozzles, and turbine blades. When handling demineralized/deionized water, care must be taken to select materials that are resistant to its highly reactive attack. Therefore, piping should be AISI 304L and valves and pumps should be 316L stainless steel.

According to the published literature of Rolls-Royce ETGs,[2] water injection is an option. However, at approximately 2 percent water-to-air, an unplanned demand of 450 gal/hr (21 kg/sec core flow requires 1 gallon of water every 8 seconds) is placed on DIW. While the flow is not a significant demand, if it must be reliable in accordance with quality assurance requirements for safety class systems, resulting in a new "Q" categorized DIW system. The existing system also may not meet the actual purity requirements (currently ASTM D1193, *Standard Specification for Reagent Water*, Type 4), and could decrease the inspection interval and firing time.

In addition, converting the Rolls-Royce 501-KB7S gas turbine from dry low emission (DLE) to Cheng Low-NOx (CLN®) combustion would increase unit output to 6 MW from 5.2 MW and cut emission to 18 ppm NOx and zero carbon monoxide. The estimated cost of conversion is approximately $600,000 per engine. The following shows the advantages of the conversion to CLN (Reference: Article by Victor de Biasi):

- More power. Base load rating of CLN units was increased to 6 MW from 5.2 MW at the 1,935°F firing temperature of the original DLE gas turbine.
- Emissions. At a 5 MW test point, CLN reduced emissions to less than 12 ppm NOx and 2 ppm carbon monoxide versus 25 ppm NOx and 50 ppm carbon monoxide for DLE.
- Efficiency. At base load output, CLN lowered heat rate to 10,245 BTU/kWh (33.3 percent efficiency) from 10,850 BTU/kWh (31.5 percent) for DLE.
- Part-load. At 3 MW part-load power output, CLN lowers NOx to 12 ppm while DLE is in excess of the allowable 25 ppm site limit.
- CLN combustion: The CLN system was developed by Dr. Dah Yu Cheng, a former rocket scientist with the National Aeronautics and Space Administration and professor at the University of Santa Clara, now president of Cheng Power Systems.

Natural Gas

The U.S. Department of Energy (DOE) has identified a number of potential advantages, including substantial cost savings and reduction in greenhouse gas emissions, of replacing the use of diesel fuel with natural gas, supplementing with diesel fuel as necessary. Because natural

[2] http://www.rolls-royce.com/Images/501_k_tcm92-55973.pdf.

gas is not currently available on the Hanford Site's Central Plateau, DOE would need to acquire a supply of natural gas to the WTP and the 242-A Evaporator package boilers.

Natural gas burns cleaner than diesel fuel and would reduce emissions of greenhouse gases. In ddition, the cost of natural gas is substantially lower than diesel fuel ($11 and $28 per million BTUs, respectively) (EIA 2014). Natural gas has the added advantage of being lighter than air and thus disperses more readily if there is a leak in an unconfined space. Natural gas could be delivered to the 200 East Area and WTP via pipeline, which would eliminate the need for daily tanker truck delivery of diesel fuel, resulting in further reduced greenhouse gas emissions. The minimum life-cycle cost savings of switching from diesel fuel to natural gas is estimated to be about $933 million, assuming an initial 6-year low-activity waste treatment operation followed by a 25-year operation for treating both high- and low-activity waste in the WTP. The potential life-cycle cost savings would vary based on the selected waste treatment option that DOE implements. Waste treatment options that operate for longer periods, up to 75 years, would substantially increase life-cycle cost savings, which could approach $3 billion. In light of the large quantity of diesel fuel required over the life cycle of the WTP for the generation of steam, and the favorable price difference and environmental benefits between diesel fuel and natural gas, using natural gas to generate steam for the 200 East Area offers the advantages identified above. Therefore, DOE is proposing to replace diesel fuel with natural gas as the energy source for the 242-A Evaporator and WTP. Considering the ashfall criteria for WTP require a 60-day fuel supply of diesel fuel, cost savings could be significant. The natural gas option also resolves other issues such transporting diesel fuel to WTP during and following an ashfall event.

DOE prepared DOE/EIS-0467D to evaluate the potential environmental impacts of the proposed action of constructing, operating, and maintaining a natural gas pipeline, and the reasonable alternatives to such action. The impact statement was provided to DOE Headquarters for review on June 2014. The DOE Richland Operations Office is working on comment resolution.

Following the public comment period for the draft DOE/EIS-0467D, DOE will prepare a final environmental impact statement. The final environmental impact statement will contain responses to comments received on the draft from Tribal Nations; Federal, state, and local agencies; and the public. The environmental analyses will be updated or revised, as needed. The U.S. Environmental Protection Agency will publish a Notice of Availability in the *Federal Register* when the final environmental impact statement is issued.

Once the final environmental impact statement is distributed, DOE will wait 30 days before publishing its record of decision in the *Federal Register.* A record of decision notifies the public of the decision(s) made regarding the proposed action and the reasons for the decision(s).

Diesel Fuel Supply for the Emergency Turbine Generator

24590-CD-POA-MUTC-00001-03-00001 shows a fuel consumption rate of 7 gpm for the ETG to produce 4,300 KW. 24590 CD POA MUTC-00001-07-00012 shows a range of fuel rates from approximately 6–8 gpm. The fuel oil storage vessels for the ETG, though not yet sized, will be sized to supply a 7-day storage based on the ETG fuel oil consumption rate. A rate of 7 gpm results in a daily usage of 10,080 gal. This quantity equates to 1.3 tanker trucks per day for each ETG (2.6 tankers truck per day for the operation of both ETGs) for the duration of the ashfall event of 60 days. That presents an insurmountable transportation obstacle to overcome.

REFERENCES

ASTM D1193, *Standard Specification for Reagent Water*, American Society for Testing and Materials, West Conshohocken, Pennsylvania.

Reference: Article by Victor de Biasi

EIA 2014

DOE/EIS-0467D, Hanford Natural Gas Pipeline Environmental Impact Statement

24590-WTP-PSAR-ESH-01-002-05, 2014, *Preliminary Documented Safety Analysis to Support Construction Authorization; Balance of Facility Specific Information*, Rev. 05E, Bechtel National, Inc. Richland, Washington.

24590-BOF-MUD-89-00001, 2012, *Emergency Turbine Generator Data Sheet*, Rev. 0, Bechtel National, Inc., Richland, Washington.

APPENDIX H

ASHFALL PLANNING TEAM REVIEW: INVESTIGATION OF STORED AIR OPTION

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APPENDIX H

ASHFALL PLANNING TEAM REVIEW: INVESTIGATION OF STORED AIR OPTION

INVESTIGATOR(S)

Elaine Diaz

Mark Hall

ISSUE DESCRIPTION

Key vessel mixing functions in the High-Level Waste (HLW) and Pretreatment (PT) Facilities are pneumatically driven. The motive air needed to operate these systems may be interrupted during an ashfall event. This appendix addresses the possibility of using stored air. The basic approach involves creatingcryogenic liquid nitrogen and storing it in a large tank to be subsequently vaporized to gaseous nitrogen at 125 psi at ambient temperature and tied into the building supply plant service air systems (PSA) to supply the vessel mixing systems during the facility safe shutdown.

This option includes making liquid nitrogen onsite from atmospheric air using Balance of Facilities (BOF) compressors or an impulse compressor, storage of the liquid nitrogen in a large cryogenic vessel, pumping and vaporizing the liquid nitrogen into compressed nitrogen gas using a jet fuel burner. The liquid nitrogen would be created after the ashfall hazard warning was received (onsite or by regional suppliers), and consumed by the Waste Treatment and Immobilization Plant (WTP) during the ashfall event. As the properties of nitrogen gas are similar to air, no design changes to the HLW and PT equipment are needed. The tie-in to the BOF compressed air supply piping is the major WTP system interface.

This option is to deploy commercial cryogenic equipment to supply a temporary air supply needed during WTP facility stabilization. Proper sizing of equipment could accommodate limited continued vitrification operations.

Liquid nitrogen is produced by compressing air, cooling it under compression, and then expanding it through a J-T valve. This process is repeated until the temperature of the air is cooled to below its phase-change temperature and it liquefies. Nitrogen and oxygen are separated due to specific gravity differences and stored separately. The liquid nitrogen is then pumped up to operating pressure using a cryogenic pump to 115 psi, and reheated to flash and warm the nitrogen gas, making usable compressed gas for use in driving pneumatically driven equipment (e.g., pulse-jet mixers).

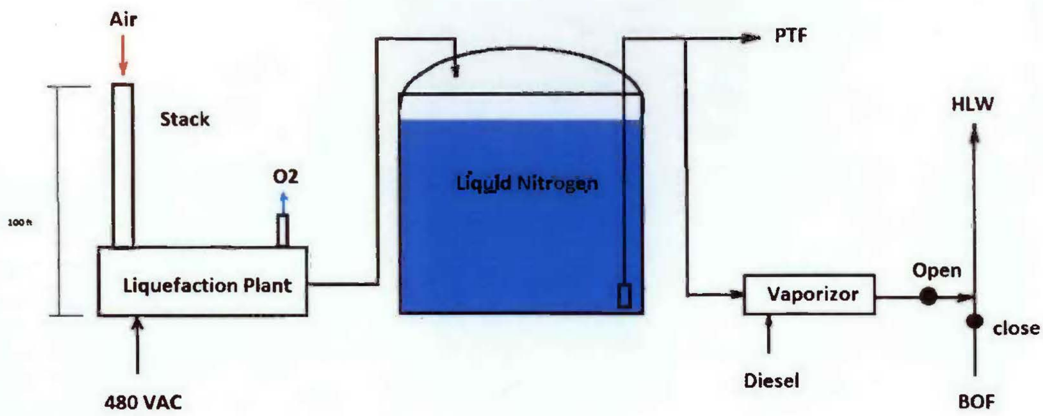

Figure H-1. Major Components of the Waste Treatment and Immobilization Plant Balance of Facilities Augmentation Air Supply System.

DISCUSSION

The calculation results below summarize the liquid nitrogen needed for various air demands and various duration ashfall events. The various air demand quantities are based on early predictions of air required for the new standard high-solids vessel design.

Case 1 – 650 scfm (pulse-jet mixers only)

Volume LN for 1 day	=	11,208 gal	Reflash fuel	=	101 gal
Volume LN for 30 days	=	336,248 gal	Reflash fuel	=	3,042 gal
Volume LN for 60 days	=	672,496 gal	Reflash fuel	=	6,084 gal

Case 2 – 1,400 scfm

Volume LN for 1 day	=	24,141 gal	Reflash fuel	=	218 gal
Volume LN for 30 days	=	724,226 gal	Reflash fuel	=	6,552 gal
Volume LN for 60 days	=	1,448,452 gal	Reflash fuel	=	13,105 gal

Case 3 – 1,900 scfm

Volume LN for 1 day	=	32,763 gal	Reflash fuel	=	296 gal
Volume LN for 30 days	=	982,878 gal	Reflash fuel	=	8,892 gal
Volume LN for 60 days	=	1,965,756 gal	Reflash fuel	=	17,785 gal

CONCLUSIONS

If created onsite, two 1 million-gallon cryogenic storage tanks could provide the needed operational air for 60 days. 20,000-30,000 gallons of fuel is needed to reflash the liquid nitrogen to 115 psi usable nitrogen gas. If regional sources are used, depending on air demand, the liquid nitrogen needed varies from one to three trucks per day. Compared to emergency turbine generators, which need one to two trucks of diesel fuel per day to support the safety mixing, this seems like a wash. However, this option requires significantly less outside air (zero) to sustain safety mixing, which makes it a potentially more sustainable solution in an ashfall environment.

Getting trucks to the plant in 10 cm of ash is not considered feasible, so a key question to investigate further would be: Can we order several trucks of liquid nitrogen when we receive warning of the ashfall event? Boil-offgas compressors can maintain the liquid nitrogen indefinitely in standby mode (vessel or truck). Creation of liquid nitrogen onsite could be less costly and a more reliable source. Creating liquid nitrogen onsite by 480VAC electrically driven compressors, either independent or in combination with BOF compressors, are options. Liquid nitrogen production skids are commercially available and generally use the Linde-double-column air separation process (Figure H-2). Note the liquid nitrogen purity produced is not critical. Liquid oxygen is a byproduct that may have commercial use.

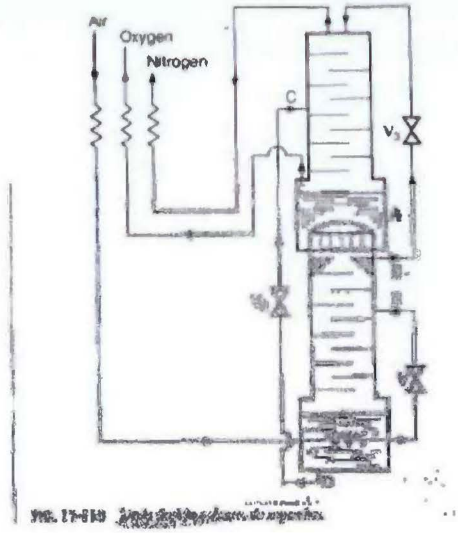

Figure H-2. Linde-Double Column Air Separation.[10]

RECOMMENDATION

Viable Alternative by Itself?

No. This option has the potential to support safety mixing at a reduced flow rate for an ashfall event of a reduced duration, without reliance on ash-laden outside air. Safety mixing represents 93 percent of the outside air demand during an ashfall event. This option does not address confinement ventilation (the other 7 percent).

Viable Alternative in Combination with other Alternatives?

Yes. Combined with a reduction in ash resuspension duration and a reduction in safety mixing air demand, this option could provide an alternative means of sustaining safety mixing throughout the ash event. Onsite production and storage is recommended in combination with BOF compressors and facility tie-ins. Alternately or in combination with regional supplied trucks of liquid nitrogen pre-ordered upon warning of the event and staged at the site. This alternative could also provide spare mixing capacity if BOF

[10] Perry's Chemical Engineering Handbooks.

piping or compressor capability were ever compromised for other reasons, in this case the tie-in would have to be at the facility entrance point. Use of regional supplies requires advanced warning to stage liquid nitrogen; it does not address the seismic issue alone. Liquid nitrogen could be produced and maintained onsite for both purposes (ashfall and seismic). There are also questions regarding the sustainability of this approach that require further study.

Estimated Impacts and Other Considerations:

Cryogenic systems are available commercially at large scale, developed for the liquefied natural gas and agriculture industries. However, purchasing one to the nuclear quality assurance requirements of ASME NQA-1 could be a challenge. Two independent liquid nitrogen trains (production, storage, vaporization) are recommended for reliability. The estimated commercial equipment cost per train is $32 million.

SIGNATURE

Investigation Lead: E Diaz **Date:** 12-15-14

APPENDIX I

ASHFALL PLANNING TEAM REVIEW: INVESTIGATION OF NEAR-SURFACE DISPOSAL FACILITY USE AS ASH SETTLING CHAMBERS

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APPENDIX I

ASHFALL PLANNING TEAM REVIEW: INVESTIGATION OF NEAR-SURFACE DISPOSAL FACILITY USE AS ASH SETTLING CHAMBERS

INVESTIGATOR(S)

Elaine Diaz

ISSUE DESCRIPTION

A study was conducted to determine if the four unused grout vaults directly west of the High-Level Waste (HLW) and Pretreatment (PT) Facilities could be used as settling chambers to reduce the airborne concentration of ash sufficiently to supply air to the Waste Treatment and Immobilization Plant (WTP) during a volcanic ashfall event. Objectives included:

- Determine particle sizes filtered effectively by settling chamber
- Determine flow limitations of chamber
- Determine time to load C5V high-efficiency particulate air (HEPA) filters in HLW and PT Facilities to determine if additional filtration is needed to supply that system

DOCUMENTS REVIEWED

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- WHC-SD-GN-ER-30038, 2012, *Volcano Ashfall Loads for the Hanford Site*, Rev. 2, Washington River Protection Solutions LLC, Richland, Washington.

PERSONNEL CONTACTED

- Gerard Garcia, Bechtel National, Inc.

DISCUSSION

The attached excerpt from the safety analysis of the Hanford grout facility shows a sketch of one of the four installed grout vaults, which are just to the west of the WTP HLW and PT Facilities. These grout vaults are 50 ft wide, 125 ft long, and 34 ft high, and offer significant opportunity for use as ash settling chambers.

The attached calculations demonstrate the ability of the settling chambers to effectively remove all particulate 20 micron and above, which accounts for 96 percent of the ash particles (by mass fraction) deposited at Hanford during the 1980 event. It should also be noted that the recommended flow capacity to achieve this removal efficiency is not more than 40,000 cfm per vault, 160,000 cfm total.

Each grout vault could support up to 100,000 cfm flow, but with less efficiency and higher particle sizes conveyed (particles 45 micron and larger would be removed, representing 75 percent by mass of the suspended ash).

The settling chamber velocity could also be reduced to just 10,000 cfm per vault, to increase the efficiency to capture particles 3.5 micron and larger, 98 percent by mass of the ash particle size distribution.

These results are reflected in Table I-1.

Table I-1. Filtration Efficiency of Grout Vault Settling Chamber and Time to Plug Filters.

Airflow per Vault and Total Capacity (scfm)	Particles Removed (microns)	Percent by Mass Removed	Time to Plug C5V Filters at 2.7 g/m^3	Time to Plug C5V Filters at 0.22 mg/m^3
100,000 per vault 400,000 total	≥ 45	75	8.6 hours	4 days [a]
40,000 per vault 160,000 total	≥ 20	96	2.2 days [a]	27 days [a]
10,000 per vault 40,000 total	≥ 3.5	98	4.5 days [a]	55 day [a]

[a] Time to plug is overconservative because the calculation assumes a constant airborne concentration equal to the peak concentration during the initial settling of ash. In the new criteria, concentration decreases after 12 hours.

Because the settling chamber's effectiveness is a function of airflow velocity and particle size, the concentration of airborne ash makes little difference to the analysis. Whether there is 2.7 g/m^3 (i.e., criteria from WHC-SD-GN-ER-30038, Rev. 2) or 0.22 g/m^3 suspended ash, the chamber will remove approximately 96 percent by mass—all particulate 20 micron and above at 40,000 cfm per chamber.

The analysis also includes filter loading time for the C5V HEPA filters in the HLW and PT Facilities, assuming a 25,000 cfm flow rate for each of these systems, and assuming the remaining small particulate is all deposited on the HEPA filters.

Because the HLW and PT Facility existing designs both include a primary HEPA filter bypass function, safety confinement for an event such as ash, where the filter loading is mostly by nonradioactive particulate matter, could feasibly be maintained following an event that caused significant filter plugging by bypassing the primary filters and relying on secondary HEPAs until the primary filters could be changed. This provides additional flexibility.

For other functions for which outside air is needed to support the ashfall design (e.g., air compressors to support safety mixing and emergency turbine generators), the analysis concludes that the grout vaults could be used to provide pre-filtration and remove 96 percent of the ash. However, additional filtration would be needed to achieve the air cleanliness required for cooling and intake air for this equipment.

The analysis also reviewed ash accumulation within the chamber, to ensure ash accumulation did not cause plugging of the settling chamber. In 60 days at the worst concentration, the ash accumulation was only 1.4 ft, assuming evenly distributed settling.

Pros and cons of this alternative include the following.

Pros:

- Large particles drop out.
- Passive, almost zero energy system (just need a fan).
- No question it will work. Cannot clog or fail. No moving parts but the fan.
- Could duct air directly to HLW and PT as heating, ventilation, and air-conditioning supply.
- Repurposing government facilities that are not in use.
- Could install duct during warning period.
- Depending on concentration, could potentially solve the confinement ventilation challenge by itself, without additional filtration.

Cons:

- Capacity is limited (does not have capacity for current 1,000,000 cfm flow).
- As flow increases, efficiency drops off.
- May still need some filtration for fine particles (except for heating, ventilation, and air-conditioning supplies).

CONCLUSIONS

Reuse of the unused grout vaults as settling chambers for ash to address WTP's volcanic ashfall natural phenomena hazard is a promising alternative. However, flow is limited to a maximum of about 40 percent of what is currently required to sustain the site through an ashfall event.

Option to use settling chambers for confinement ventilation supply:

This technology could be used to significantly decrease power demand associated with the Bag-House filtration serving the confinement ventilation, HLW and PTF C5V. Estimated power savings is 180 kW based on the BNI basis of estimate. This option would also reduce compressed air demand by 145 scfm. It could be demonstrated that the C5V filters could withstand the event without plugging, with no additional filtration, given a somewhat reduced concentration of ash.

Option to use settling chambers for confinement ventilation and safety air compressors:

This option (when used in combination with manual filters and a reduction in resuspended ash) could serve as the supply for the confinement ventilation air for HLW and PT C5V and also the supply for the safety air compressors.

The savings in compressed air demand associated with this option is 750 scfm, which brings the total air needs down to the current system capacity of 3,600 cfm. Thus, there is no longer need for a new safety chiller/compressor building.

Estimated power savings due to use of more efficient filtration methods than bag-house filters for compressed air and confinement ventilation, as well as reduction in associated compressed air load, is 1.6 MW. This reduction eliminates the need for a second emergency turbine generator running throughout the event, as it brings the power demand for the event to within the derated emergency turbine generator capacity of 4.1 MW.

The advantage of this technology is that it is a passive feature: There are no filters to fail or plug, the ductwork could be temporary and installed during a warning period prior to a volcanic event, and a fan is the only moving part.

Addition of a water spray or baffles to the chamber could increase the efficiency of this technology, but also requires more power or other utilities (water) to operate.

RECOMMENDATION

Viable Alternative by Itself?

Yes, but only solves part of one problem: Reduces power load and complexity of controls to sustain confinement ventilation.

Viable Alternative in Combination with other Alternatives?

Yes, in combination with a reduction in airborne concentration requirement and manual filtration, this technology could significantly reduce power and compressed air demand, enough that ETG and compressor sizing are within current design capacity.

Estimated Impacts and Other Considerations:

Minimal impacts to current design.

Would require furnishing government equipment to the project for use on WTP (grout vaults).

Would require minimal modifications to the roofs of grout vaults. Vaults have 43 roof penetrations for inert fill. Sizing and location may be adequate for duct tie-ins, or new penetrations may have to be drilled.

Two fans and a penetration to support the supply tie-in could be included in the design of the HLW airlock modification if it is selected as part of the key risk decisions.

ATTACHMENTS

I.1 VAULT SKETCH AND INFORMATION

I.2 AIR DEMANDS

I.3 POWER DEMANDS

I.4 CALCULATIONS

SIGNATURE

Investigation Lead: E Diaz **Date:** 12-15-14

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ATTACHMENT I.1

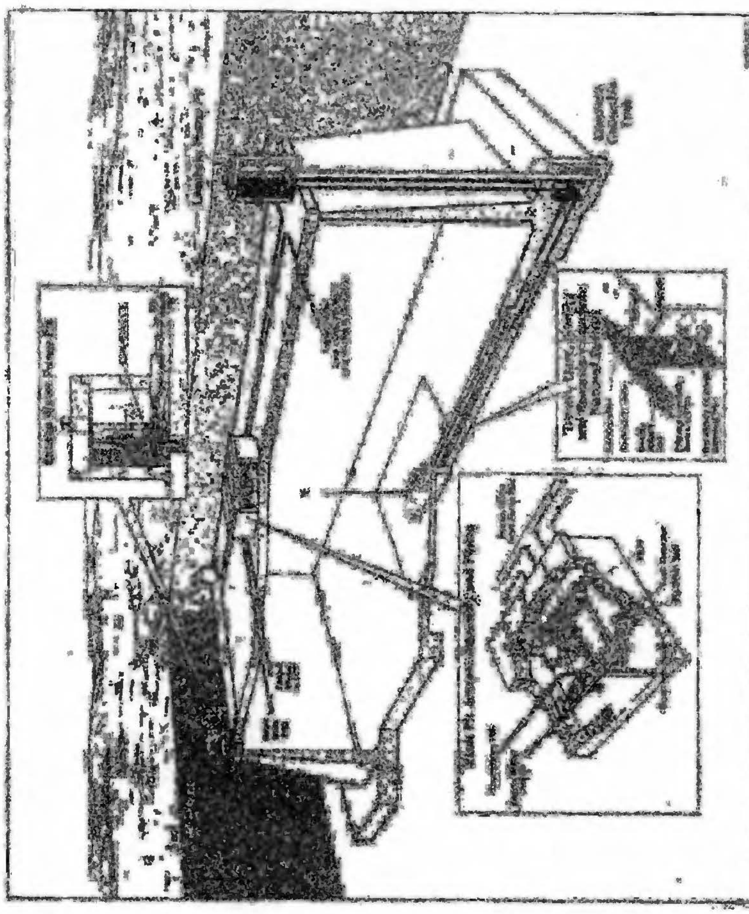

Figure 3-14. Vault Liner Configuration.

- 43 penetrations per vault
- dimensions: 50' x 125' x 34' deep

There are four excess water pump pits located at the corners of the vault roof. Piping extends from each of the excess water pump pits to the vault pit at the center of the vault. The excess water lines are constructed from 2-in.-dia. steel pipe with a 4-in.-dia. steel pipe encasement. The encasement provides secondary confinement and drains into the respective excess water pump pit.

Each excess water pump pit provides access to a 12-in. riser. When it is necessary to pump excess water from the vault, a submersible pump assembly will be installed through the 12-in. riser and be connected to the pit excess water piping nozzle. The riser will be capped when a pump is not in place. The pit is constructed of a precast, 48-in.-inner diameter (ID) concrete pipe that is 4 ft 2.5 in. high, and has a 5-in. wall thickness. An 8-in.-thick-concrete gasketed cover will provide shielding and containment for radioactive materials. The pump pits are provided with liquid detection elements and drain to the vault. Because excess water pipe encasement routes leakage back to the excess water pump pit, the liquid detection instrument serves as an excess water pipe leak detector. Each drain is designed with a plug for remote removal and installation. Excess water lines will be covered with soil to provide shielding.

The leachate pump pit is a 7-in.-thick, 72-in.-ID, 4-ft-deep concrete casting. There are two 18-in. and one 4-in. risers extending from the leachate collection tank to the pit floor. The pit houses access to the risers and pump assemblies used to pump collected leachate. Soil-covered piping will be used to transfer leachate back into the vault or the TGE LCT. The pit cover is 8-in.-thick concrete. Cover block penetrations are fitted with extension handles used to actuate valves located in the pump discharge piping and the upper leachate collection pipe. The pit is designed with a barrier dam and check valve drain that will be used to drain liquid accumulations to the leachate collection tank. The pit is provided with a liquid detection element and is designed to provide shielding and containment of radioactive liquids.

3.1.4.2 Grout Disposal Vault. The grout disposal vault is basically a 50-ft-wide (inside), 125-ft-long (inside), 34-ft-deep rectangular reinforced-concrete structure covered with a prestressed concrete roof (Fig. 3-14). Intérior vertical corners of the vault are square, while the floor-to-wall corners have a large 45° haunch or camfer. The vault floor is sloped at 2% toward a central 2-ft-wide leachate collection trench. The trench has square corners and varies in depth from 2 ft at the high point to 3 ft 6 in. at the low point located at the east end of the trench. The trench is 77 ft long.

The structural design of the vault walls is based on a vertical-cantilever model retaining wall with backfill soil pressure being the governing load. Massive (4 ft deep, 19 ft wide) footings are provided to resist the soil pressure overturning moments. Vertical walls are reinforced heavily on the tension face (outside).

pneumatically operated control valves. The decontamination solution can be recirculated within contaminated piping and process equipment until decontamination has been achieved.

The flow of fresh decontamination solution from the storage tank to the headers is initiated by opening a pneumatically actuated control valve and starting pump. Valve position indication is monitored in the control room. Alarms and interlocks are provided to ensure correct valve alignment. A pressure indicator is provided at the decontamination supply pump discharge to measure supply pressure.

3.2.3.5 Excess Water and Flush Water Processing. A 500-gal (304-L) stainless-steel pH adjustment tank is provided to store NaOH used to adjust the pH of returned excess water and decontamination flush water to meet grout mixer feed requirements or DST storage specifications.

Chemicals used for pH adjustment are pumped from the pH adjustment tank using a positive displacement, variable-stroke diaphragm metering pump. A pressure relief valve is provided to maintain a preset maximum supply pressure of approximately 100 lb/in². The solution relieved through the valve will be returned to the supply tank. A pulsation dampener is provided in the line to maintain a steady flow. Pressure is monitored locally at the discharge of the metering pump. [illegible]

An isolok sampling system, housed within a glovebox-style containment enclosure, is provided in the motor pit to obtain 100-mL samples from the LCT. Samples are removed from the glovebox through a double-door port assembly. [illegible] After receipt of acceptable analytical laboratory results, the LCT contents will be pumped to DST or the grout mixer to produce grout slurry.

3.2.4 Near-Surface Disposal Facility

3.2.4.1 Vault Filling. Liquid grout slurry is received from the TGF via the 2-in.-dia. SR-200 pipeline. There are two, 20-ft² layers of 60-mil-thick HDPE used as a splash pad to protect the upper leachate collection system and liner from the falling grout slurry. A small volume of water remaining from liner leak testing activity may be present in the vault when processing begins. At a grout slurry flow rate of 50 gpm the vault will be filled at a rate of approximately 18 in./24 h of operation. At this rate, the first half campaign will last approximately 10 operating days; and the second half will bring the grout level up to approximately 30 ft, leaving approximately 3.5 ft of vault space available for excess water accumulation.

Grout slurry curing (hydration or hardening) begins as soon as it is mixed and continues at varying rates for several years. Approximately 70% to 80% of the curing process occurs within the first 28 days and a corresponding amount of the total heat of hydration is released in the same time span. The grout slurry formulation planned for this campaign has the capability of raising the temperature of the grout by 100 to 130 °F.

[redacted]

Some expansion during grout curing can be expected. However, expansion occurs only when the grout monolith is in a plastic state, and is directed by the vault floor and walls in the upward direction. Upon curing, slight (i.e., 0.2%) shrinkage is observed (PNL 1987).

3.2.4.2 Leachate and Excess Water Processing. The upper liner is expected to leak some volume of liquid at a slow rate during vault filling operations. This liquid is collected in a sump by the leachate collection systems between the upper and lower liners and is pumped back into the vault periodically. Approximately 7.3% of the grout monolith volume is expected [redacted]

3.2.4.3 Vault Void Fill, Isolation, and Closure. After excess water has been removed, the void space between the grout surface and vault roof will be filled with nonradioactive grout to prevent unacceptable subsidence. [redacted]

ATTACHMENT I.2

CCN 258256

Ashfall Criteria Change Conceptual Design
Comments / Questions

[Response by Mechanical Systems - Jerid Mauss]

Baseline compressor demand loads (based on 24590-PTF-M6C-PSA-00005) are as follows:

Baseline Air Demand Break Down	SCFM
UFP steam rack purging	495
HPAV purge	50
PJM/RFD purge	226
Forced purge	265
Instrument air	50
System leakage	200
Baghouse pulse air serving compressors	150
Continuous sparge PTF	280
HLW continuous sparge	138
PJM mixing (scheduled HLP27A 1/2 of PJMs)	652
Total	**2506**

Baseline Safety Air Demand	**SCFM**
PTF-M6C-PSA-00005	2506
Air Demand Baseline w/ Extended Ash Fall Event Duration 3653 = 2506 + (1784 from Next Page) - (652 from Above)	3653
Existing capacity @ 118°F, 3, 400HP, 1500 SCFM	~3600
Margin: 3% (> 24 hour DBE) and 30% (Ashfall)	

The compressor loads adjusted for the revised ashfall NPH are as follows: Source 24590-PTF-M6C-PSA-00005, with **BOLD** provided for ashfall air demand loads, note extended event duration increases PJM mixing loads as well.

Revised NPH Air Demand Break Down	SCFM
UFP steam rack purging	495
HPAV purge	50
PJM/RFD purge	226
Forced purge	265
Instrument air	50
system leakage	200
Continuous sparge PTF	280
HLW continuous sparge	138
PJM mixing (scheduled, 1784 FEP17, 1566 HLP28,1476 HLP22 [6 PJMs], 1470 UFP1A/B [6 PJMs], 1304 HLP27A/B, 978 UFP2A/B)	1784
Baghouse pulse air serving 400 ton chiller supporting compressors (224,000 SCFM)	**300**
Baghouse pulse air serving 400 ton chiller supporting condensers (224,000 SCFM)	**300**
Baghouse pulse air serving PTF C5V (44,000 SCFM)	**72**
Baghouse pulse air serving HLW C5V (26,000 SCFM)	**72**
Purge air lost in producing baghouse instrument air	**157**
ETG requires 300 SCFM baghouse compressed air, but will be provided by a dedicated compressor in the ETG Building	0
Total	**4389**

Potential to eliminate 600 cfm w/ settling + cap. des + manual filters

145 cfm savings

Eliminates need for 2 SC-II filtration buildings (combined value $33M)

Ability to demonstrate existing capacity works eliminates need for 3 new SC-II or SC-II facilities (combined value $70M)

could be ~3600 (within existing capacity)

Page 2 of 14

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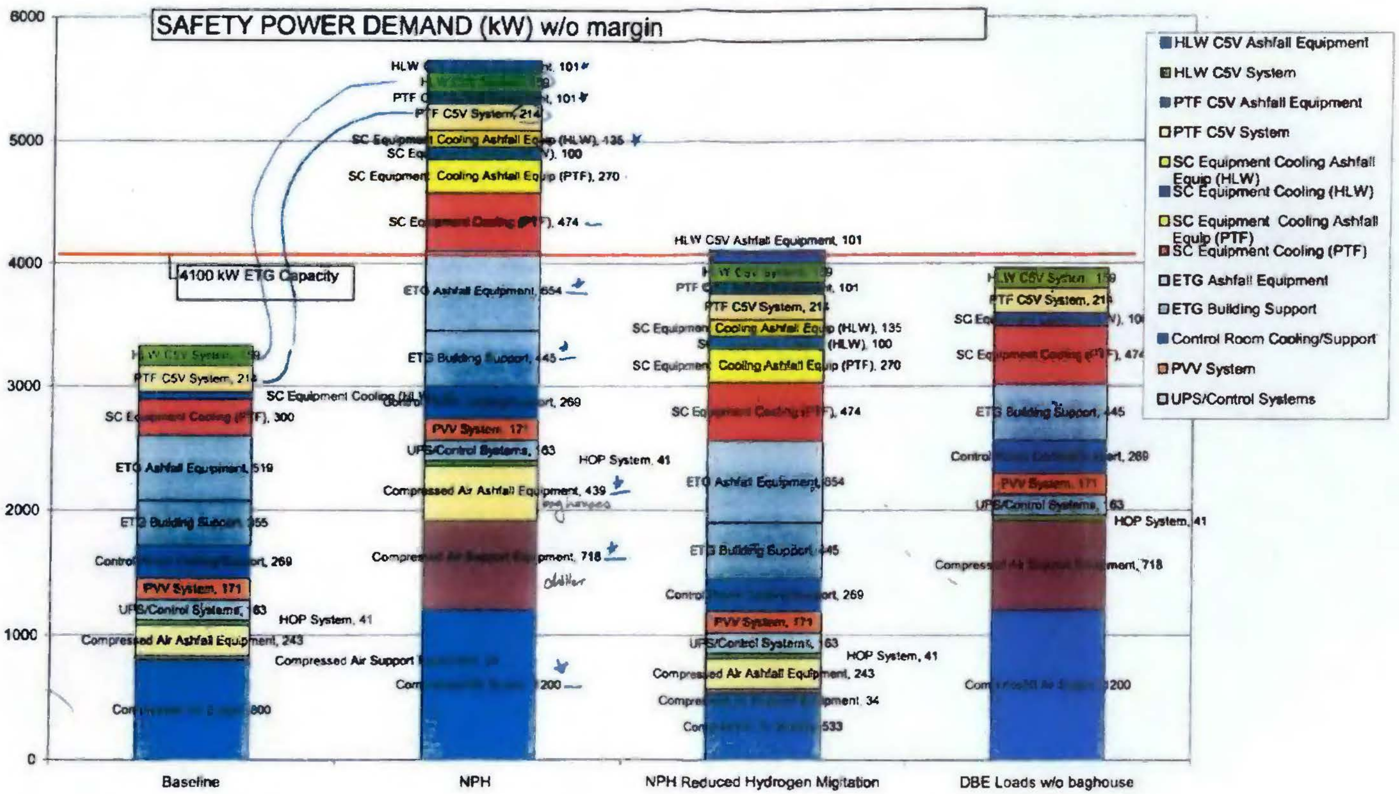
SAFETY POWER DEMAND (kW) w/o margin
4100 kW ETG Capacity
0
1000
2000
3000
4000
5000
6000
Baseline
NPH
NPH Reduced Hydrogen Migitation
DBE Loads w/o baghouse
HLW C5V Ashfall Equipment
HLW C5V System
PTF C5V Ashfall Equipment
PTF C5V System
SC Equipment Cooling Ashfall Equip (HLW)
SC Equipment Cooling (HLW)
SC Equipment Cooling Ashfall Equip (PTF)
SC Equipment Cooling (PTF)
ETG Ashfall Equipment
ETG Building Support
Control Room Cooling/Support
PVV System
UPS/Control Systems
HLW C5V Ashfall Equipment, 101
PTF C5V System, 214
SC Equipment Cooling Ashfall Equip (HLW), 135
SC Equipment Cooling Ashfall Equip (PTF), 270
ETG Ashfall Equipment, 519
ETG Ashfall Equipment, 654
ETG Building Support, 445
PVV System, 171
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HOP System, 41
Compressed Air Ashfall Equipment, 243
Compressed Air Ashfall Equipment, 439
Compressed Air Support Equipment, 718
Compressed Air Support Equipment, 34
SC Equipment Cooling (PTF), 300

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ATTACHMENT I.4

width	50
length	125
depth	34

available vaults: 4

Terminal settling velocity:

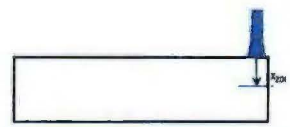
Vts = [density x (diameter)^2 x gravity x Cs] / [18 x dynamic viscosity of air]

Source: slides from In-Place Filter Testing Workshop, Harvard School of Public Health, July 25-29, 2011
Extracted from slides by Stephen Rudnick, MS, ScD, CIH, "Dynamic Properties of Aerosols"

density of ash = 1000 kg/m3 Reference: USGS OF2011-1064 used lowest density to decrease settling (bounding)
Particle size = (varied...see table)
g = 9.8 m/s2
Cs = 1 slip correction factor, 1.0 for 1 micron and above
dynamic viscosity of air = 1.80E-05 Pa-s

Assumed design of exhaust header from grout vault:

Airflow per vault	40000 cfm	Exhaust plenum size		
	1120 m3/min		Assume	40 ft wide
Velocity	24 fpm		Assume	5 ft deep
	7 m/min		Flow	200 fpm
Time in settling chamber	4.8 min			



Zone of influence for plenum

Hood capture	50 fpm	(boundingly low based upon ACGIH section 3.4.2 hood flow determination)
Azoi =	ft2	
xzoi=	11.0 ft	Zone of Influence based upon calculation from ACGIH, "Industrial Ventilation, A Manual of Recommended Practice," 22nd Edition, page 3-9, hood on bench or floor (to simulate wall next to hood).
	3.3 meters	

Particle Size (Micron)	Vts (m/min)	Settling Distance in chamber
150	40.8	198 meters
125	28.4	137 meters
100	18.1	88 meters
75	10.2	49 meters
50	4.5	22 meters
25	1.1	5.5 meters
20	0.7	3.5 meters
15	0.4	2.0 meters
10	0.2	0.9 meters
5	0.0	0.2 meters
1	0.0	0.0 meters

Pros:
Everything 20 micron and above (96% by weight of the Hanford ash challenge) drops out.
Passive, almost zero energy system (just need a fan)
No question it will work...can't clog or fail...no moving parts
Could duct air direct to PTF and HLW as HVAC supply
Could install duct during warning period
Cons:
Capacity is limited to 160,000 cfm (4 systems at 40,000 cfm)
(could get higher flow but sacrifice efficiency...20 micron stays suspended)
Still need a filter for the 4% (0.108 grams/m3) of <20 micron ash
(except for HVAC supplies)

Source: Science, Vol 209, 5 Sep 1980, MSH Ash from the 18 May 1980 Eruption: Chemical, Physical, Mineralogical, and Biological Properties

Project HEPAs hold approx. 7 kg of PSD 4 material...
700 m3/min Assume 25,000 cfm (NPH 50% flow)
75.6 grams/min
245000 CSV filter capacity, grams (assuming primaries only load, 7 banks online)
54.0 hours to clog filters at 25,000 cfm
Filter capacity is based upon current project calculations.
Gram loading of redesigned filters still TBD.
May not need additional filtration for HVAC supply.
Do need additional filtration for other equipment (based on cooling and intake air filtration requirements).

Ash accumulation:
2.9 kg/min
4.2 m3/day
147.6 ft3/day
0.024 ft/day
1.4 ft in 60 days

NSDF Settling Chamber

Vault Dimensions (ft):

width	50
length	125
depth	34

available vaults: 4

Terminal settling velocity:

Vts = [density x (diameter)^2 x gravity x Cs] / [18 x dynamic viscosity of air]

Source: slides from In-Place Filter Testing Workshop, Harvard School of Public Health, July 25-29, 2011
Extracted from slides by Stephen Rudnick, MS, ScD, CIH, "Dynamic Properties of Aerosols"

density of ash = 1000 kg/m3 — Reference: USGS OF2011-1064 used lowest density to decrease settling (bounding)
Particle size = (varied...see table)
g = 9.8 m/s2
Cs = 1 slip correction factor, 1.0 for 1 micron and above
dynamic viscosity of air = 1.80E-05 Pa-s

Assumed design of exhaust header from grout vault:

Airflow per vault	40000 cfm
	1120 m3/min
Velocity	24 fpm
	7 m/min
Time in settling chamber	4.8 min

Exhaust plenum size

Assume	40 ft wide
Assume	5 ft deep
Flow	200 fpm

Zone of influence for plenum

Hood capture	50 fpm
Azoi =	ft2
xzoi=	11.0 ft
	3.3 meters

(boundingly low based upon ACGIH section 3.4.2 hood flow determination)

Zone of influence based upon calculation from ACGIH, "Industrial Ventilation, A Manual of Recommended Practice," 22nd Edition, page 3-9, hood on bench or floor (to simulate wall next to hood).

Particle Size (Micron)	Vts (m/min)	Settling Distance in chamber
150	40.8	198 meters
125	28.4	137 meters
100	18.1	88 meters
75	10.2	49 meters
50	4.5	22 meters
25	1.1	5.5 meters
20	0.7	3.5 meters
15	0.4	2.0 meters
10	0.2	0.9 meters
5	0.0	0.2 meters
1	0.0	0.0 meters

Pros:
Everything 20 micron and above (96% by weight of the Hanford ash challenge) drops out
Passive, almost zero energy system (just need a fan)
No question it will work...can't clog or fail...no moving parts
Could duct air direct to PTF and HLW as HVAC supply
Could install duct during warning period
Cons:
Capacity is limited to 160,000 cfm (4 systems at 40,000 cfm)
(could get higher flow but sacrifice efficiency...20 micron stays suspended)
Still need a filter for the 4% of <20 micron ash but very low concentration
(except for HVAC supplies)

Source: Science, Vol 209, 5 Sep 1980, MSH Ash from the 18 May 1980 Eruption: Chemical, Physical, Mineralogical, and Biological Properties

Project HEPAs hold approx. 7 kg of PSD 4 material...
700 m3/min Assume 25,000 cfm (NPH 50% flow)
6.16 grams/min
245000 C5V filter capacity, grams (assuming primaries only load, 7 banks online)
27.6 days to clog filters at 25,000 cfm
Filter capacity is based upon current project calculations.
Gram loading of redesigned filters still TBD.

NSDF Settling Chamber

Vault Dimensions (ft):

width	50
length	125
depth	34

available vaults: 4

Terminal settling velocity:

Vts = [density x (diameter)^2 x gravity x Cs] / [18 x dynamic viscosity of air]

Source: slides from In-Place Filter Testing Workshop, Harvard School of Public Health, July 25-29, 2011
Extracted from slides by Stephen Rudnick, MS, ScD, CIH, "Dynamic Properties of Aerosols"

density of ash = 1000 kg/m3 Reference: USGS OF2011-1064 used lowest density to decrease settling (bounding)
Particle size = (varied...see table)
g = 9.8 m/s2
Cs = 1 slip correction factor, 1.0 for 1 micron and above
dynamic viscosity of air = 1.80E-05 Pa-s

Assumed design of exhaust header from grout vault:

Airflow per vault	100000 cfm	Exhaust plenum size		
	2800 m3/min	Assume	40 ft wide	
Velocity	59 fpm	Assume	5 ft deep	
	18 m/min	Flow	500 fpm	
Time in settling chamber	1.8 min			
		Zone of Influence for plenum		
		Hood capture	50 fpm	(boundingly low based upon ACGIH section 3.4.2 hood flow determination)
		xzoi=	19.0 ft	Zone of Influence based upon calculation from ACGIH, "Industrial Ventilation, A Manual of Recommended Practice," 22nd Edition, page 3-9, hood on bench or floor (to simulate wall next to hood).
			5.8 meters	

Particle Size (Micron)	Vts (m/min)	Settling Distance in chamber
150	40.8	74 meters
125	28.4	51 meters
100	18.1	33 meters
75	10.2	18 meters
45	3.7	7 meters
25	1.1	2.0 meters
20	0.7	1.3 meters
15	0.4	0.7 meters
10	0.2	0.3 meters
5	0.0	0.1 meters
1	0.0.	0.0 meters

Pros:
Everything 45 micron and above (75% by weight of the Hanford ash challenge) drops out
Passive, almost zero energy system (just need a fan)
No question it will work...can't clog or fail...no moving parts
Could duct air direct to PTF and HLW as HVAC supply
Could install duct during warning period
Cons:
Capacity is limited to 400,000 cfm (4 systems at 100,000 cfm)

Still need a filter for the 25% (0.108 grams/m3) of <20 micron ash
(except for HVAC supplies)

Source: Science, Vol 209, 5 Sep 1980, MSH Ash from the 18 May 1980 Eruption: Chemical, Physical, Mineralogical, and Biological Properties

Project HEPAs hold approx. 7 kg of PSD 4 material...
700 m3/min Assume 25,000 cfm (NPH 50% flow)
472.5 grams/min
245000 CSV filter capacity, grams (assuming primaries only load, 7 banks online)
8.6 hours to clog filters at 25,000 cfm
Filter capacity is based upon current project calculations.
Gram loading of redesigned filters still TBD.

NSDF Settling Chamber

Vault Dimensions (ft):

width	50
length	125
depth	34

available vaults: 4

Terminal settling velocity:

Vts = [density x (diameter)^2 x gravity x Cs] / [18 x dynamic viscosity of air]

Source: slides from In-Place Filter Testing Workshop, Harvard School of Public Health, July 25-29, 2011
Extracted from slides by Stephen Rudnick, MS, ScD, CIH, "Dynamic Properties of Aerosols"

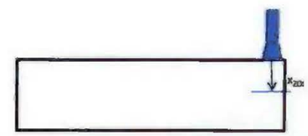
density of ash = 1000 kg/m3 Reference: USGS OF2011-1064 used lowest density to decrease settling (bounding)
Particle size = (varied...see table)
g = 9.8 m/s2
Cs = 1 slip correction factor, 1.0 for 1 micron and above
dynamic viscosity of air = 1.80E-05 Pa-s

Assumed design of exhaust header from grout vault:

Airflow per vault	10000	cfm
	280	m3/min
Velocity	6	fpm
	2	m/min
Time in settling chamber	21.3	min

Exhaust plenum size

Assume	40	ft wide
Assume	5	ft deep
Flow	50	fpm



Zone of influence for plenum

Hood capture	50	fpm
Azoi =		ft2
xzoi=	0.0	ft
	0.0	meters

(boundingly low based upon ACGIH section 3.4.2 hood flow determination)

Zone of Influence based upon calculation from ACGIH, "Industrial Ventilation, A Manual of Recommended Practice," 22nd Edition, page 3-9, hood on bench or floor (to simulate wall next to hood).

Particle Size (Micron)	Vts (m/min)	Settling Distance in chamber
150	40.8	868 meters
125	28.4	603 meters
100	18.1	386 meters
75	10.2	217 meters
50	4.5	96 meters
25	1.1	24.1 meters
20	0.7	15.4 meters
15	0.4	8.7 meters
10	0.2	3.9 meters
3.5	0.0	0.5 meters
1	0.0	0.04 meters

Pros:
Everything 3.5 micron and above (98% by weight of the Hanford ash challenge) drops out
Passive, almost zero energy system (just need a fan)
No question it will work...can't clog or fail...no moving parts
Could duct air direct to PTF and HLW as HVAC supply
Could install duct during warning period
Cons:
Capacity is very limited to 40,000 cfm (4 systems at 10,000 cfm)
(could get higher flow but sacrifice efficiency)

Source: Science, Vol 209, 5 Sep 1980, MSH Ash from the 18 May 1980 Eruption: Chemical, Physical, Mineralogical, and Biological Properties

Project HEPAs hold approx. 7 kg of PSD 4 material...

700	m3/min Assume 25,000 cfm (NPH 50% flow)
37.8	grams/min
245000	C5V filter capacity, grams (assuming primaries only load, 7 banks online)
4.5	days to clog filters at 25,000 cfm at 2.7 g/m3

Filter capacity is based upon current project calculations

APPENDIX J

ASHFALL PLANNING TEAM REVIEW:
WATER COOLING OPTIONS AND INVESTIGATION OF SAND FILTER OPTION

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APPENDIX J

ASHFALL PLANNING TEAM REVIEW: WATER COOLING OPTIONS AND INVESTIGATION OF SAND FILTER OPTION

INVESTIGATOR(S)

Elaine Diaz

Ken Wells

ISSUE DESCRIPTION

An option identified by the Ashfall Planning Team was for use of water cooling to reduce the outside air demand, and a sand filter for mitigating the impacts of an ashfall event and also for addressing other ventilation related technical issues.

Sand filters have been successfully used at U.S. Department of Energy (DOE) sites for over 60 years. Because they are constructed of rock and sand, they are better suited than standard high-efficiency particulate air (HEPA) filters for many of the design basis events (DBE) currently being evaluated for the High-Level Waste (HLW) and Pretreatment (PT) Facilities. Examples include ashfall, spray leaks, fires, and seismic.

Design Basis Event	Sand Filter Advantages
Ashfall	Sand filter can be used for combined duty: • Filter C5 area exhaust • Filter emergency turbine generator combustion air and safety air compressor inlet. Large surface area of inlet plenum and sand filter media allows for better management of ash particulate.
Spray leaks	Sand filter is not susceptible to failure due to wetted filter media because it is constructed of stone and sand. Sand filters are design to allow any accumulated liquids (condensate) to be collected in a sump and pumped back to a C5 drain collection vessel.
Fires	Large surface area of inlet plenum and sand filter media allows for better management of soot from facility fires.
Seismic	Sand filters can be constructed with metal seismic screens that serve to keep the layers of sand filter media in place and to prevent channeling. A sand filter can be designed for 40-year life of facility and, unlike current remote change high-efficiency particulate air filters, would not require post-seismic operation of an in-cell filter changeout crane.

REQUIREMENTS REVIEWED

N/A

DOCUMENTS REVIEWED

- CCN 258256, 2013, "Responses to DOE Comments/Questions Concerning Ashfall Conceptual Design," memorandum to J. Weamer from M.D. Axup, Bechtel National, Inc., Richland, Washington, August 6.

PERSONNEL CONTACTED

N/A

DISCUSSION

Figure J-1 shows one potential configuration to enable the use of sand filter for post-DBE use.

The total airflow needs for the current ashfall solution are nearly 1,000,000 cfm. At this flow, the sizing of a sand filter would need to be four football fields. However, 75 percent of the outside air demand is for cooling. By combining this approach with water cooling alternatives, the sand filter option is feasible.

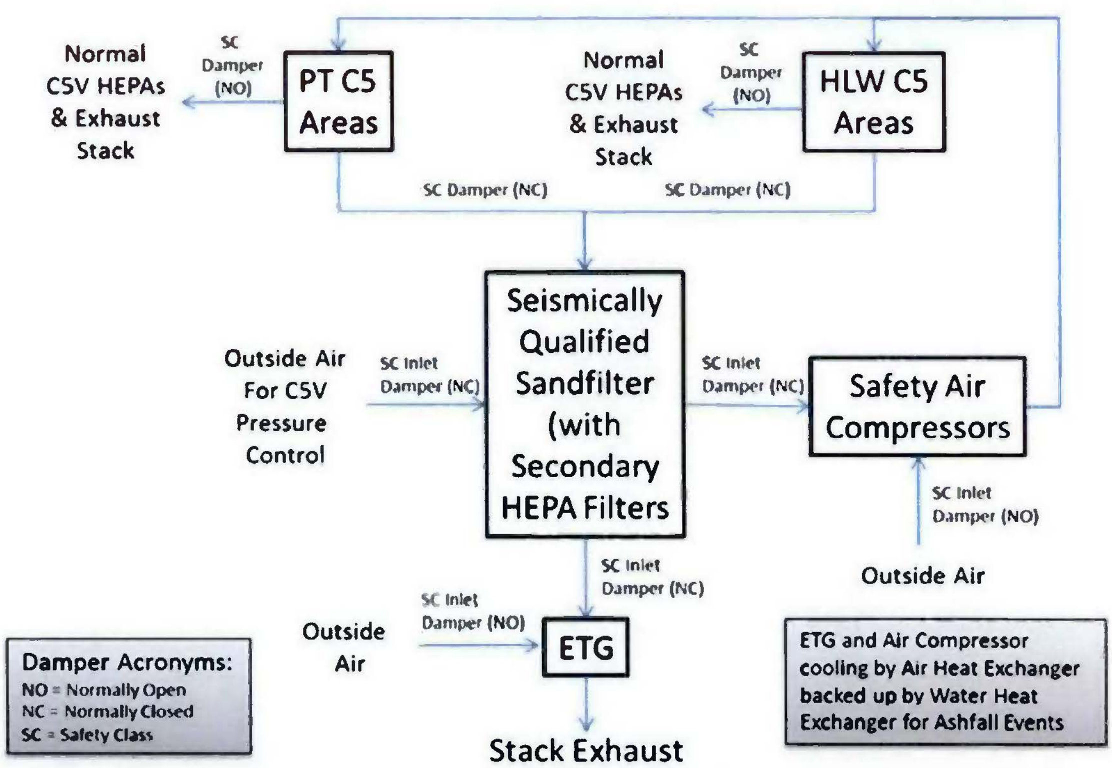

Figure J-1. Sand Filter Exhaust Option.

Water Cooling Options

Considering values from CCN 258256 regarding chiller cooling load, the chiller to support safety cooling is 300 tons. The chiller serving safety mixing is 400 tons. The chiller serving the PT Facility control room is approximately 100 tons, and the emergency turbine generator (ETG) oil cooler requires 100,000 cfm for cooling, so, assuming 60 percent efficiency, 150 tons. Thus, the total cooling load of 950 tons, 11 million Btu/hr, equates to roughly 2,200 gpm, perhaps more if efficiency is not already factored into these capacity estimates.

Options for water cooling include pumping groundwater or storing water in a large underground tank or cooling pond. The tank option may be preferable because the groundwater would require a reservoir or holding pond before release back to ground, and the pond would also be susceptible to ash causing filter plugging. The underground tank option provides some cooling of the returned water due to contact with the ground. Assuming a 1 million-gallon underground tank, and a 10 °F temperature gain, and neglecting ground cooling for conservatism, the tank would start heating up within 7–14 hours, causing heat transfer to be less efficient.

It should be noted that 400 tons of the load are HVAC cooling, which will not be at the constant value of 105 °F assumed by Bechtel National, Inc., (BNI) in the impact estimate, but will fluctuate between lows overnight and highs in late afternoon. Still, the ETG oil cooler and compressor cooling loads are fairly constant. This is likely not a 60-day solution unless safety mixing loads are reduced, and therefore ETG loads and compressor loads.

Air Needs Remaining if Water Cooling Option is Invoked

Remaining air needs (non-cooling), based on CCN 258256 (the current BNI design alternative) with the exception that only one ETG is needed, are as follows:

ETG combustion air is 38,000 cfm
ETG enclosure air is 15,000 cfm
ETG building vent air is 15,000 cfm
ETG electrical room vent is 23,000 cfm
Total ETG air demand = 91,000 cfm

Compressor Building ventilation = 15,000 cfm
Compressor Building Electrical = 23,000 cfm
Intake air = 4,000 cfm
Total Compressor Building air demand = 42,000 cfm
(Assumed numbers for vent and electrical based on same loads for ETG.)

Control Room Vent = 15,000 cfm
Control Room Electrical = 23,000 cfm
Total Control Room air demand = 38,000 cfm
(Assumed numbers for vent and electrical based on same loads for ETG.)

HLW and PT Facility Ventilation = 75,000 cfm

Therefore total air demand, given a water cooling option, is 246,000 cfm, which requires a sand filter approximately 49,000 ft^2 in size.

Alternatives to recirculate air could also be considered, particularly if ETGs, compressors, control room, ventilation intakes, and sand filters could be collocated. One alternative for partial recirculation is shown in Figure J-2. Recirculated air may not require a sand filter because it would not be ash-laden, so another option would be to use standard filters for recirculated air from the ETG building to supply ventilation to the compressor and control rooms, for instance.

Another option would be a once-through system, but using the same air, multiple times. Air could be cleaned of ash to supply the compressor building ventilation and control room ventilation , then reused to supply the ETG building, then the same air could be reused again to supply C5V confinement systems with makeup air (note sand filters do not remove chemicals, so buildup of chemicals such as NOx from the ETG would have to be evaluated before this alternative was chosen). This would reduce outside air needs by 155,000 cfm, to a sand filter with 91,000 cfm capacity, 18,000 ft^2 in size. Because cooling water demand is already included in electrical loads, as are fans for each separate system, this option only adds ductwork. Collocation of the sand filter, safety cooling water supply, ETGs, and safety air compressors at single Seismic Category I facility near the HLW and PT Facilities would simplify this alternative.

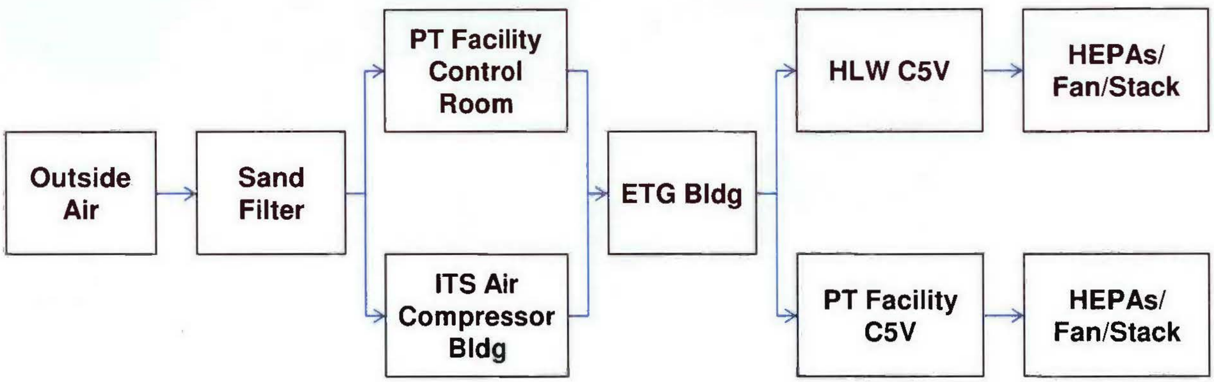

Figure J-2. Once-Through Option Showing Air Reuse.

Other considerations if a sand filter option were selected for further development include the following:

1. Use a seismically qualified duct bank to connect the sand filter to HLW and PT C5V exhaust ductwork. This allows current design to progress for C5V HEPA filtration for normal operations.
2. Size the sand filter to support C5V flow rates and cell depression requirements with a filter efficiency that is compatible with ETG combustion air and safety air compressor inlet air demands. Use modulating outside air inlet as needed to control flows/pressure. This layout essentially recirculates the C5V exhaust air (75,000 cfm) to support safety air compressor inlet.
3. Reduce filtered airflow for ETG and safety air compressor by using water cooling as the heat sink for oil coolers for ashfall events. The safety-related water source could be collocated underground near the new sand filter. This would allow assumption that starting temperature of the water less than 60 °F because ground temperature is constant and not impacted by higher air temperatures during summer. It could also be chilled to 40 °F by non-safety chillers that operate pre-DBE. Sizing of the water storage tank would need to be calculated. Air cooling could continue to be used for non-ashfall DBEs and, if cooling water became too warm, could be used in ashfall mitigation. The water could be used to rinse the air-cooled radiators.

4. Water cooling options: Looking at values from CCN 258256 regarding chiller cooling load, the chiller to support safety cooling is 300 tons. The chiller serving safety mixing is 400 tons. The chiller serving the PT Facility control room is approximately 100 tons, and the ETG oil cooler requires 100,000 cfm for cooling, so, assuming 60 percent efficiency, 150 tons. So, a total cooling load of 950 tons, 11 million Btu/hr, equates to roughly 2,200 gpm, perhaps more if efficiency is not already factored into these capacity estimates.

   Options for water cooling include pumping groundwater or storing water in a large underground tank or cooling pond. The tank was preferable because the groundwater would require a reservoir or holding pond before release back to ground, and the pond would also be susceptible to ash causing filter plugging. The underground tank option provides some cooling of the returned water due to contact with the ground. Assuming a 1 million-gallon underground tank, and a 10 °F temperature gain, and neglecting ground cooling for conservatism, the tank would start heating up within 7 to 14 hours, causing heat transfer to be less efficient.

   It should be noted that 400 tons of the load are HVAC cooling, which will not be at the constant value of 105 °F assumed by BNI in the impact estimate, but will fluctuate between lows overnight and highs in late afternoon. Still, the ETG oil cooler and compressor cooling loads are fairly constant. This is likely not a 60-day solution unless safety mixing loads come down, and likewise ETG loads and compressor loads.

5. According to ERDA 76-21, Section 9.6, the pressure drop across a sand filter is 7-11 inches, and the superficial face velocity should be around 5 fpm. This solution would have significant impacts to site layout, and may have impacts to ventilation system fan sizing due to the differential pressure, but would solve other technical issues regarding ventilation on the project.

CONCLUSIONS

This option provides an extremely robust solution, but may be costly and requires considerable space.

RECOMMENDATION

Viable Alternative by Itself?

No. This option has the potential to support safety mixing at a reduced flow rate for an ashfall event, but layout/sizing is a challenge and it would require implementation of a water cooling option in addition to a sand filter, and probably also reduction in the 60-day resuspension requirement.

Viable Alternative in Combination with other Alternatives?

Yes. Combined with a water-cooling alternative, reduction in the resuspension duration, and changes to the ventilation fan sizing, this solution is viable. However, layout/sizing is very challenging. This alternative could be used to address only the confinement ventilation piece of the problem, or ventilation and air needs for the compressors and ETGs, in combination with water cooling, with the added benefit of solving seismic and other issues with that equipment.

Estimated Impacts and Other Considerations:

The installation of a sand filter and water cooling for WTP would be expensive, requiring modification or replacement of key components of the ventilation systems. However, this would provide a robust solution to the ventilation portion of the problem and several other design basis accidents that challenge the current HEPA filter design. Sand filtration for the intake air for safety mixing would be extremely challenging due to sizing/layout issues.

SIGNATURE

Investigation Lead: Ken Wille **Date:** 12/17/2014

APPENDIX K

ASHFALL PLANNING TEAM REVIEW: PUMP-BACK OR DRAIN-BACK OPTIONS AND PROCESS-FORWARD OPTION CONTROL WASTE FEED OPTION

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APPENDIX K

ASHFALL PLANNING TEAM REVIEW
PUMP-BACK OR DRAIN-BACK OPTIONS AND PROCESS-FORWARD OPTION
CONTROL WASTE FEED OPTION

INVESTIGATOR(S)

Elaine Diaz

Mark Hall

Fred Hidden

Cecil Swarens

ISSUE DESCRIPTION

Data was gathered to address each of the following items in order to determine, given 7 days' warning from the U.S. Geological Survey (USGS) of an imminent major volcanic event at Mount St. Helens, could waste be put in a configuration where no mixing is required to address hydrogen generation (i.e., time to lower flammability limit [TTLFL] > 60-day duration of new ash airborne suspension for all vessels with sufficient material at risk [MAR])?

- Determine headspace needed for TTLFL > 60 days
- Determine time needed to pump back/process forward to reach TTLFL > 60 days
- Does TTLFL calc need to be based on supertank? Current MAR?
- Separate tank for pump back? FRP?

DOCUMENTES REVIEWED

- 24590-WTP-M4C-V11T-00011, 2010, *Revised Calculation of Hydrogen Generation Rates and Times to Lower Flammability Limit for WTP*, Rev. C, Bechtel National, Inc., Richland, Washington.

PERSONNEL CONTACTED

- Bob Voke, Bechtel National, Inc., (BNI) Process Engineering Group Supervisor
- Kevin Eager, BNI Process Engineer
- Jerid Mauss, BNI Mechanical Engineer

DISCUSSION

Assumptions were necessary due to the very preliminary status of the standard high-solids vessel design (SHSVD) and safety mixing. The progress of Technical Teams T1, T4, and T6 will determine the final vessel design and safety mixing configurations. Assumptions upon which investigations were based include the following:

1. SHSVD is 16 ft diameter, approximately 25,000 gallon capacity
2. There are nine SHSVD vessels: HLP-22A/B, HLP-27A/B, HLP-28, UFP-1A/B, UFP-2A/B
3. Safety mixing still requires rheology reset every 24 hours
4. Three pulse-jet mixers per set versus the previous six.

5. No safety sparging in the Pretreatment (PT) Facility.
6. Safety sparging still required in High-Level Waste (HLW) Facility.

This same assumption set was used to support inputs to the alternate air supply (liquid nitrogen) investigation. The results of these investigations could change significantly if these assumptions change, and would possibly result in a different alternative being recommended.

Upon completion of T1, T4, and T6, but (if possible) before implementation of the final ash solution, it is recommended that the assumptions be reviewed against final tech team resolutions.

The team investigated the following areas:

1. Determine headspace needed for TTLFL > 60 days.

   A calculation was prepared to first scale the TTLFL numbers in BNI's referenced calculation to account for changing vessel volume due to SHSVD, then to scale the numbers again for liquid pumped or drained from the vessel, iterating to a final answer based on TTLFL > 60 days. The idea was that if the vessel could be drained, pumped, or processed forward to achieve a level that creates enough headspace to increase TTLFL beyond the duration of the ash event during the 1-week warning period, the plant could be placed in a safe configuration where safety mixing is not required.

2. Determine time needed to pump back/process forward to reach TTLFL > 60 days.

   The next step of the calculation was to determine (based on inputs from BNI) the plant capacity to pump back or process forward. Finally, this de-inventory capacity was compared to the amount required to be pumped, assuming bounding waste with very low TTLFL. One HLW melter has the capacity to de-inventory the HLW lag storage in 1 week to a TTLFL > 60-day level. Using BNI's inputs, and a safety factor of 2 for pumpback (to account for time for jumper installation), the calculation indicates there is 5–40-percent spare capacity to de-inventory in 1 week.

   The preliminary result indicates that de-inventory is a feasible alternative, given 1-week notice.

   A notable limitation is that the tank farms need to install a crane, flush a valve pit, plan a work package, and make an entry to reconfigure a valve before they can accept returning waste. In addition, the waste that has been processed within PT Facility may not be returnable to the tank farms because it may fall outside of their authorization basis.

3. Does TTLFL calc need to be based on supertank? Current MAR?

   In the process of discussing these details with BNI, Kevin Eager raised a very good point: 90 percent of the waste is low hydrogen generating and can be expected to already have TTLFL approaching or beyond 60 days. Another 9 percent could require some pumping, but only a fraction of what is forecast above, and there is about 0.05 percent of the waste to be processed by PT Facility that will actually resemble the design case discussed above in terms of TTLFL. Given this information, there may be an option to use tank farm sampling results to tailor operations to the waste being processed: Process normally for 90 percent of the waste, adjust batches by balancing tanks within PT Facility for 9 percent of the waste if volcanic event warning is received or by blending or processing in smaller batches, and tailor allowable vessel levels by running half batches, direct-feeding to HLW, or blending when processing the < 1 percent of high hydrogen-generating waste.

The advantage of this unique solution, beyond that fact that it requires no design change, is that it would also resolve safety mixing for the seismic event.

Another alternative would be to consult tank farm samples if the volcanic warning were received, and tailor tank transfers based on the waste inventory.

4. Separate tank for pump back? FRP?

   The limitation of the pump-back option is the tank farms' readiness to receive waste. Another option would be to leave one or two FRP vessels empty or leave space in the FRP vessels to receive waste. This would not only alleviate concerns regarding interface with tank farms, but would also make transfer faster and eliminate the additional hazard of transferring waste around the site.

   Another similar alternative would be to add a tank dedicated for the purpose of receiving waste. This tank could be equipped with a mechanical mixer.

CONCLUSIONS

Given the likelihood of 7-day warning time for the volcanic ash fall event, the options above are extremely compelling. They do not address the continued need for confinement ventilation and some cooling, but these are much smaller loads than the safety mixing and could be sustained with other alternatives reviewed.

The most compelling option is to use feed samples to tailor PT Facility operational batch sizes, such that "supertank" waste was processed slower or differently. This option does not require advanced warning, and could solve the ashfall and the seismic safety mixing issues, eliminating the need for 5 MW emergency turbine generators, safety air compressors, chillers...*this approach could significantly simplify the project safety strategy*.

RECOMMENDATION

Viable Alternative by Itself?

Pump back to TF: No. Needs tank farms, likely tank farms cannot support 7-day turnaround.

Pump back to a dedicated FRP or other tank and process forward: Yes, partially. Solves safety mixing for ashfall. Does not solve confinement ventilation or cooling, see note below.

Tailor operations based on TF sampling results: Yes, partially. Solves safety mixing for ashfall and seismic. Does not solve confinement ventilation or cooling, see note below.

Viable Alternative in Combination with other Alternatives?

Yes. Pump back or tailor operations does not solve confinement ventilation or cooling, but those are much smaller loads and therefore easier to sustain via other alternatives investigated.

Estimated Impacts and Other Considerations:

- Recommend further study of this option to determine impact to throughput.
- Recommend further investigation of this option as tech team resolution is achieved.
- Normal mixing could be tailored based on waste sampling as well, reducing burden on Balance of Facilities air compressors and significantly reducing site power demand.

ATTACHMENTS

K.1 CALCULATION EXCERPTS, HYDROGEN GENERATION RATE PER LITER

K.2 PUMP BACK AND PROCESS FORWARD RATE CALCULATION

K.3 COMPARISON OF PUMP-BACK VOLUME, HIGH HGR WASTE VS STANDARD WASTE

SIGNATURE

Investigation Lead: E Diaz **Date:** 12-15-14

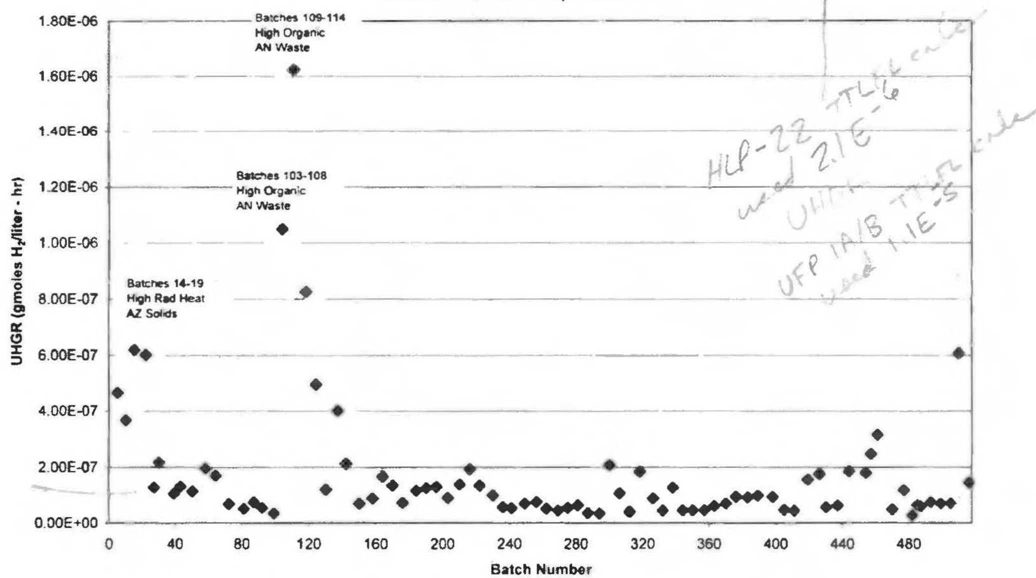
CALCULATION SHEET

PROJECT: RPP-WTP
JOB NO.: 24590
CALC NO.: 24590-PTF-M4C-V11T-00018
SHEET REV: A
SHEET NO.: 49

BY: Kevin Eager and Jeff Flora
DATE: July 24, 2012

SUBJECT: HLP-VSL-00022 Calculation of Hydrogen Generation Rate Distribution and Temperature Distribution for HPAV, for TFCOUP Rev 6 Feed

Figure 7-7 UHGRs for TFCOUP Rev 6 HLW Batches at Bounding Temperature (150°F) As-Received wt% Suspended Solids



"Supertank" = AY-102 solids + AP-103 supernate

* Problem batches = 2, 5, 8-19, 103-114, 365, 376 (28 of 518) ~5%

CALCULATION SHEET

PROJECT: [illegible]
JOB NO.: [illegible]

BY: [illegible]

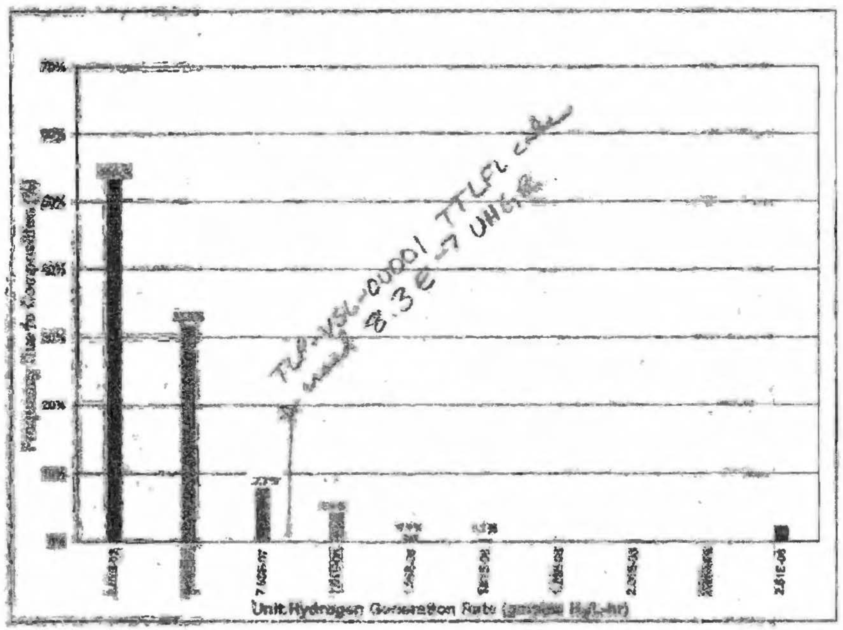
DATE: [illegible] 2014

CALC NO.: 24590-PTF-M4C-V11T-[illegible]

SHEET [illegible]

SUBJECT: [illegible] TCP03 [illegible] HGR Calculation, Including UHGR and Temperature Distributions

[illegible] Plot of UHGR Distribution for Stream TCP03, Frequency of UHGR due to Chemical Composition, at High Temperature of 140 °F



24590-[illegible] (02/05/2013)

Ref: [illegible]

CALCULATION SHEET

PROJECT: RPP-WTP
JOB NO.: 24590
CALC NO.: 24590-HLW-M4C-V11T-00002

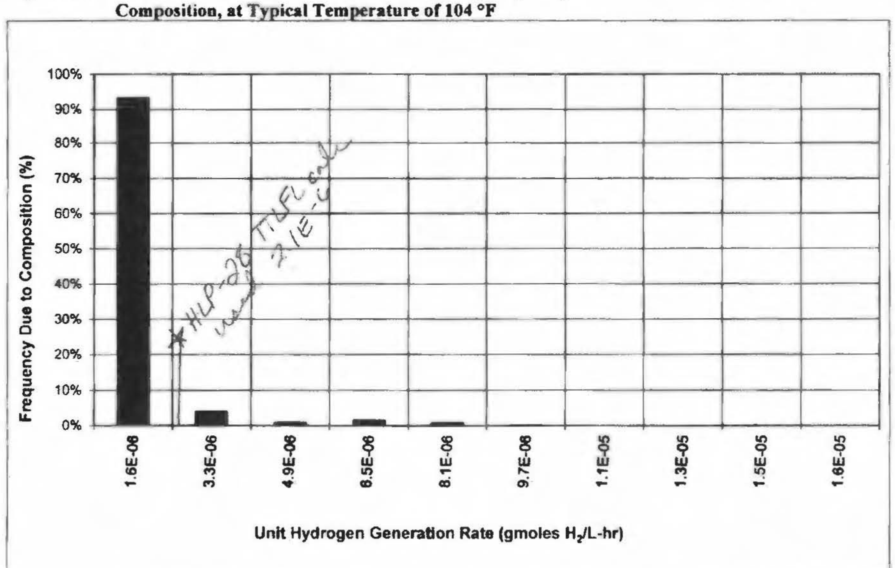
BY: Kevin Eager, Wilson Tang and Maureen Alvarez

DATE: Oct 2, 2013

SHEET REV: A
SHEET NO.: 95

SUBJECT: Stream HFP06: HPAV HGR Calculation, Including UHGR and Temperature Distributions

Figure 8-1 Plot of UHGR Distribution for Stream HFP06, Frequency of UHGR due to Chemical Composition, at Typical Temperature of 104 °F

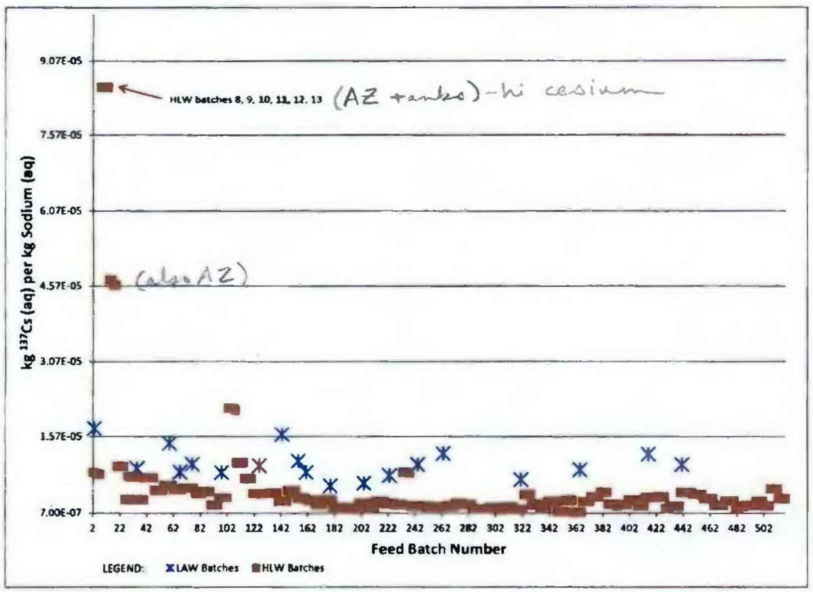


BY: Kevin Eager, Wilson Tang and Maureen Alvarez

DATE: Oct 2, 2013

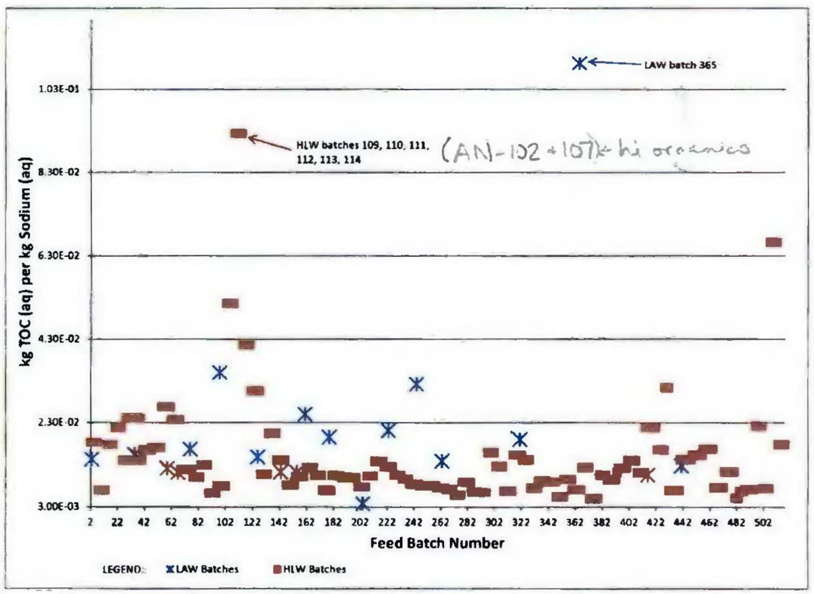
SUBJECT: Stream HFP06: HPAV HGR Calculation, Including UHGR and Temperature Distributions

Figure 7-10 Hydrogen Generation Potential of Feed Batches due to ^{137}Cs



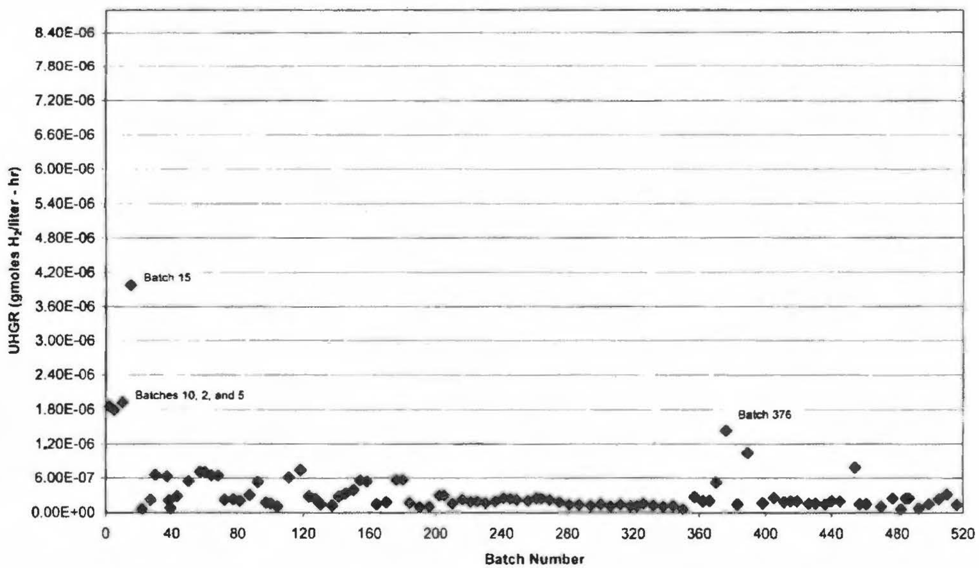
Att. K.1-5

Figure 7-9 Hydrogen Generation Potential of Feed Batches due to TOC



DOE/ORP-2014-07 REV 0

Figure 7-2 UHGRs for Representative Feed Batches at Stream UFP07 at 140°F, 21.1 wt% TSS, Run 12 Operating Config



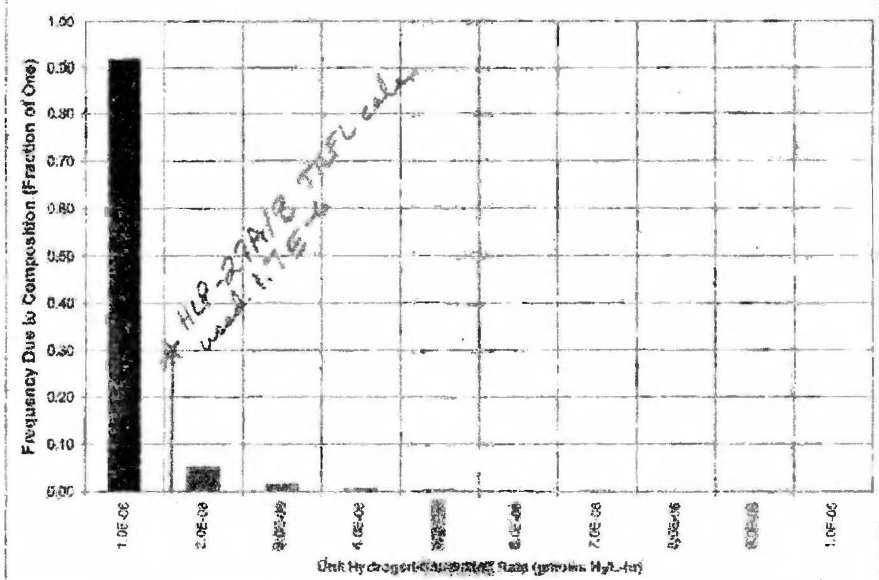
CALCULATION SHEET

PROJECT: RPP-WTP
JOB NO.: 24590
CALC NO.: 24590-WTP-M4C-V11T-00018
SHEET REV. A
SHEET NO.: 39

BY: Kevin Eager
DATE: September 26, 2011

SUBJECT: Stream UFP07: Calculation of Hydrogen Generation Rate Distributions and Temperature Distributions for HPAV

Figure B-3. Frequency of UHGR due to Composition versus Unit Hydrogen Generation Rate for Stream UFP07, Temperature 1 (184.0°F)



CALCULATION SHEET [redacted]ORP-WTP

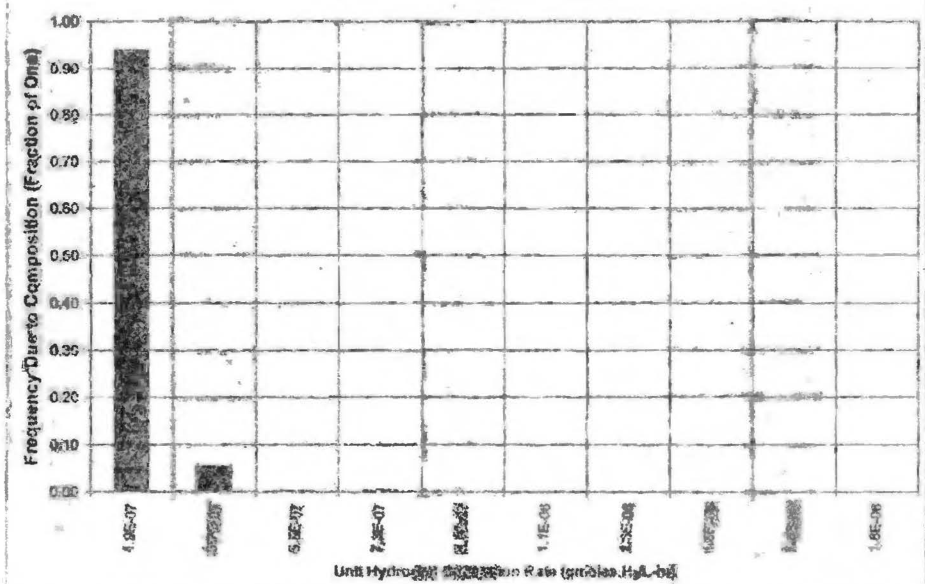
[redacted]: 24590

BY: Kevin Eager and Jeff [redacted]
DATE: July 24, 2012

CALC NO.: [redacted]-00018
[redacted] REV: A
[redacted] NO.: 54

SUBJECT: HLP-VSL-0[redacted] Calculation of Hydrogen Generation [redacted] Distribution and Temperature [redacted] AV, for TFCOUP Rev 6 Feed

Figure 8-1 Frequency [redacted] due to Composition versus Unit Hydrogen Generation Rate for the HLP-VSL-00022 Discharge, at Typical Temperature (113°F)



↑ HLP-22 TTLFL calc used 7.1E-6

Ratio Calc for TTLFL>60 days for PTF and HLW non-neutonian vessels of concern:

Vessel Tag#	Original Liquid Volume, gallons	Original head space volume, gallons	Volume Drained	SHSVD volume, gallons	SHSVD head space volume, gallons	original TTLFL per M4C-V11T-000011 rev C, hours	SHSVD TTLFL (volume and headspace per K Eager for 16' vessel), hours	TTLFL after draining, hours (adjusted vol drained to get 60 days), hrs	Ratio of drained volume to original liquid volume
CNP-EVAP-00001	3061	1656	2978	N/A	N/A	14		1444.8	97%
CNP-VSL-00003	4,670	16,900	4608	N/A	N/A	15		1437.9	99%
HLP-VSL-00022	146368	14636.8	18000	26812	6081	120	272.2	1445.9	67%
HLP-VSL-00027A/B	109774	14365	12800	26812	6081	140	242.6	1441.6	48%
HLP-VSL-00028	122565	16777	13750	26812	6081	130	215.4	1441.9	51%
UFP-VSL-00001A/B	60192	6019.2	24560	26812	6081	24	54.4	1439.8	92%
UFP-VSL-00002A/B	35428	4219	21950	26812	6081	30	57.1	1452.4	82%
HFP-VSL-00001/5	7650	661	5410	N/A	N/A	46		1442.9	71%
HFP-VSL-00002/6	7646	665	5450	N/A	N/A	45		1440.8	71%
FEP-SEP-00001A/B	10257	9096	800	N/A	N/A	1220		1439.6	8%
FEP-VSL-00017A/B	50000	5000	11400	N/A	N/A	340		1444.6	23%
FRP-VSL-00002A-D	375000	37500	32000	N/A	N/A	710		1438.6	9%
PWD-VSL-00033	15000	1500	4240	N/A	N/A	270		1440.3	28%
PWD-VSL-00043	15000	1500	4240	N/A	N/A	270		1440.3	28%
PWD-VSL-00044	60000	6000	8320	N/A	N/A	520		1440.9	14%
TCP-VSL-00001	128845	16775	58000	N/A	N/A	178		1443.0	45%
UFP-VSL-00062A-C	30058	4642	3820	N/A	N/A	690		1440.9	13%

Total: 436336 gallons Problem tanks only (TTLFL<150 hours) 197676 gallons

Problem tanks only (TTLFL<150 hours)

Problem tanks minus HLW feed: 175956 gallons

NOTE: On technical review, BNI proposed an alternate calculation, which is attached and should be used instead of the numbers above. This spreadsheet is included to show the pumping and processing capacity, below, and to show the team's process.

Simple calculation - scales TTLFL by ratio of fluid volume decrease divided by ratio of head space volume increase

This assumption assumes HGR is by volume and neglects head space purge air (conservative)

Pump back rate:	90 gpm min	140 gpm max	
Feed melter rate:	2 gpm min	4 gpm max	
Warning duration:	1 week		
	10080 min		
Pump back capacity:	453600 gal min	705600 gal max	Applies a safety factor of 2 for jumper installation.
Feed melter capacity	20160 gal min	40320 gal max	
	473760	745920 Total one week capacity	
	436336	436336 Total gallons to be removed	
	8%	42% spare capacity	

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ATTACHMENT K.3

Time to Hydrogen LFL [illegible] Headspace

[illegible]

Item	Vessel	[illegible]	[illegible]	[illegible]	New contents (gallons)	[illegible]	Volume of air in headspace (gallons)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Time to [illegible]	[illegible]	Max Waste to [illegible] to Reach [illegible] LFL (gallons)
1	[illegible]														
2	[illegible]														
3	[illegible]														
4	[illegible]														
5	[illegible]														
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	31,893
7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	9,402
8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] than 85%
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] than 85%
10	[illegible]														
11	[illegible]														
12	[illegible]														
13	[illegible]														
14	[illegible]														
15	[illegible]														
16	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	29,177
17	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] than 85%
[illegible]	[illegible]														
														[illegible]	[illegible]9,091

Time to Hydrogen LFL [illegible] Headspace

[illegible]

Item	Vessel	[illegible]	[illegible]	[illegible]	[illegible] (gallons)	[illegible] (gallons)	Volume of air in headspace (gallons)	[illegible] Temperature [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Time to [illegible]	[illegible]	Max Waste to [illegible] to Reach [illegible] LFL (gallons)
1	[illegible]														
2	[illegible]														
3	[illegible]														
4	[illegible]														
5	[illegible]														
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0
7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0
8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible],325
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible],784
10	[illegible]														
11	[illegible]														
12	[illegible]														
13	[illegible]														
14	[illegible]														
15	[illegible]														
16	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0
17	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible],325
18	[illegible]														
														[illegible]	[illegible],085

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APPENDIX L

SUGGESTED APPROACH TO RESOLUTION OF ASHFALL EVENTS

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APPENDIX L

SUGGESTED APPROACH TO RESOLUTION OF ASHFALL EVENTS

Suggested Approach to Resolution of Ashfall Events

Michael V. Frank, Senior Technical Advisor, Nuclear Safety Engineering

Introduction

The objective of this paper is to suggest an approach to resolution of ashfall events for the Ashfall Planning Team. This paper represents the opinion of the author and does not necessarily reflect a BNI and NSE opinion. The approach described herein is one of many suggestions submitted to that planning team. This suggestion should be considered within the context of a comprehensive evaluation of alternatives.

Two key design and nuclear safety questions associated with severe volcanic ashfall events are roof loading and air. The current roof loading ashfall criteria are provided in SRD Tables 4-1, 4-2, and 4-3, for Performance Category 3, 2, and 1, respectively:

- PC-3: 12.5 lb/ft^2
- PC-2: 5 lb/ft^2
- PC-1: 3 lb/ft^2

A design basis ashfall event is defined as that event associated with a 10,000 year return period. Severe ashfall could interfere with filtration by overburdening filters with particulates and reducing the amount of air intake needed for PJM operations and emergency power. Emergency power is typically assumed to be needed because a 10,000 year event might broadly disrupt the availability of offsite power sources, in part because the ash itself is conductive. For example the eruption could hamper switching circuitry by insulation flashover in major switchyards, cause power lines to break, short circuit electrical transformers, cause forest fires that would burn power distribution equipment and lines, and cause generation stations to shut down for reasons similar to those affecting the WTP site. One key underlying cause of the need for emergency power, air supply to PJMs, and ventilation to carry away the air introduced by PJMs is the concern over potential hydrogen explosions in vessels. Hydrogen explosion potential in piping is unaffected by PJM availability because it depends solely on the inventory of slurry within piping and the robustness of the piping to withstand potential explosive events should they occur.

Between 2011 and 2013, USGS updated the report WTP uses for ashfall criteria (HNF-SD-GN-ER-501). The USGS update significantly increased the ashfall design basis loading for WTP facilities. DOE requested WTP to provide an estimate of the potential cost and schedule impact to incorporate the updated USGS report into the WTP ashfall design criteria (CCN 251782, CCN 256901). Given the current set of safety controls that must be protected, WTP determined that incorporating the USGS report update would have significant cost and schedule impact to WTP (CCN 254129).

The increased cost and, therefore, increased focus on this issue is predicated on two assumptions, both of which are re-examined herein. The two assumptions are that a) hydrogen explosions that pose a significant threat to nuclear safety are inevitable following a design basis event and b) plant redesign or design/construction modifications are needed to cope with the event. Clearly, if hydrogen explosions are not a significant threat to nuclear safety, then much of the pressure to provide air, ventilation and emergency power would be alleviated. Furthermore, if a strategy that does not involve significant redesign or design/construction modifications can be devised, the cost of coping with the event could be significantly reduced.

Risk of Hydrogen Explosions in Vessels

Hydrogen explosions emerged as an issue because of the postulated challenge to WTP vessel integrity and potential entrainment of particulates into the ventilation system. There is currently a perception that such events are high probability. However, a nuclear safety threat would occur only if an explosion caused a breach in a vessel or/and released radioactive material at a rate and in a mode that building ventilation systems could not mitigate. Currently vessels are designed with sufficient robustness to withstand hydrogen explosions without breach. Future engineering work will demonstrate this.

Hydrogen generation occurs within waste slurries processed in WTP vessels at a variety of rates depending on the composition, radioactive inventory and temperature. During normal operation, an active ventilation system coupled with PJM operation maintains hydrogen concentrations in vessel headspaces to less than 1% by volume. The lower flammability limit is 4% and the lower explosive limit is 10%. The following discussion lends some perspective to understanding the hydrogen issue.

Let's postulate that each molecule of hydrogen produced will find its way into the head space unless it is retained in the slurry. If it is retained in a slurry, then that portion that is retained does not contribute to hydrogen explosion potential until it is released. Let's also postulate that the headspace starts with air and no diluents (e.g. zero humidity and other species that would reduce flammability) and that hydrogen will nicely mix with air within a vessel. Realistically, open ventilation paths and purge air would act to remove hydrogen-air mixtures from the head space. Nevertheless, the postulate is convenient and conservative. There are four relevant conditions for which we evaluate the need for PJMs.

	Venting available	Venting failed (no path)
Slurry does not retain gas (continuous release)	PJM mixing is irrelevant to gas release. Hydrogen-air mixtures would flow out of the vent.	PJM mixing is irrelevant. Hydrogen would find its way to the vessel headspace and stay there. (*)
Slurry can retain and then release gas (retain and release)	The only way for an explosive mixture to accumulate would be via retention and a sudden release that might make the head atmosphere temporarily have an explosive mixture. Development of an explosive mixture, if possible, would be a long term phenomenon (*) even if PJMs were unavailable.	PJM mixing is irrelevant. Hydrogen might be delayed but it would eventually find its way to the vessel headspace and stay there.

(*) Estimates of the time to accumulate an explosive mixture (10% in dry air) in HLP-22 in the absence of PJM operation range from weeks to months, depending on the assumptions made in the calculation and the particular batch of slurry being processed. Typically, explosion energy increases to approximately a stoichiometric mixture, 29.5% H2 in dry air. To get to this point would take approximately three times as long, if in fact such a concentration could be developed within a headspace.

The yellow box condition (slurry can retain and then release gas with venting available) is the only one in which mixing may be relevant. The risk associated with this event depends on the likelihood of getting a hydrogen explosion. To get a hydrogen explosion in the headspace of a vessel would require at least 10% hydrogen and an ignition source. Let's look at a simple example of that likelihood for HLP-22 in the PTF.

Let's postulate the occurrence of the design basis ashfall with its defined frequency of 1/10000 – $1x10^{-4}$/yr

Let's say that this event fails all mixing with no possibility of recovery (very conservative). This means that PJMs have failed. Therefore, there is no need for their air requirement.

Let's say that we have a gas retaining slurry in the vessel at the time the ashfall occurs (conservative).

Let's say that HLP-22 is continuously filled to its operational limit which provides a conservative hydrogen generation and a conservative headspace.

Let's say we have mixing in the headspace so that at the time that there is sufficient hydrogen produced to create an explosive mixture, there is also homogenous mixing of air and hydrogen.

With these multiple conservative assumptions, the unmitigated frequency of explosion could be approximated as the frequency of the ashfall event times the probability of ignition.

The conditional probability of ignition, given a flammable or explosive mixture of hydrogen in the vessel, is conservatively derived from worldwide data and an expert elicitation at tank farms to be on the order of 0.01 to 0.000001. These estimates are conservative because an ignition source is always present or assumed present with the events in the databases. Taking the high value:

$1x10^{-4}$/yr x 0.01 = $1x10^{-6}$/yr which in the terminology of DOE-STD-3009 is extremely unlikely (EU) and on the cusp of beyond extremely unlikely (BEU).

Theoretical maximum deflagration pressure challenge to the vessel can be obtained by simple thermodynamic calculations assuming 100% hydrogen consumption in an adiabatic and isochoric reaction. Pressures would on the order of 10^2 psi which would be highly unlikely to fail the vessel. In other words, there would be no radiological consequence.

The above provides the ingredients for an acceptable consequence/likelihood combination per DOE-STD-3009 (Risk Bin IV). This is the unmitigated case in which we have postulated that PJMs do not work and are not recovered. These numbers can easily be lowered by relaxing one or more of the conservative approximations. For example, the above assumes that the conditional probability of an explosive mixture is one. Clearly, any probability less than one or a slightly less conservative ignition probability would tip the likelihood to BEU.

However, we can add simple controls to reduce the risk even further. These controls do not involve PJM operation but they do involve some sort of ventilation to avoid a buildup of hydrogen.

Suggested Control Strategy

The occurrence of a Level 5 volcano does not happen without warning. There will be, perhaps, days to weeks of warning but only hours may be required. Common safety practice for rare natural phenomena hazards for which there is sufficient warning, as in this case, is to treat the response as part of an emergency plan or within the scope of emergency operating procedures rather than by design modifications. An unmitigated risk that is in Risk Bin IV would have no need for SS or SC controls as part of the design.

With warning and a good emergency plan to respond to that warning, all facilities that do not pose a hydrogen generation threat can be put into a safe state.[1] The development of an explosive mixture within a vessel such as HLP-22 would take weeks to months. Ample time is available, therefore, to bring in pre-staged equipment to provide measures such as:

1. purge of headspace.
2. inerting of headspace
3. bubble producer or agitator within a slurry[2]

Items 1 or 2 would be needed to avoid the occurrence of an explosive mixture. Item 3 is needed only if a slurry can retain hydrogen. These measures can be staged and manually connected when needed. They are consistent with the idea of FLEX measures used for severe but not design basis accidents for nuclear power plants. These measures need not be continuous. Periodic purging, inert gas addition or bubbling should be sufficient. Because of the long times to develop an explosive mixture, the measures need not be highly reliable. There would be time to repair should they initially fail. Indeed, a reliability of only 90%, which is very low for nuclear facilities, would reduce the frequency of a hydrogen explosion another order of magnitude well below the threshold for Beyond Extremely Unlikely.

Purge and bubbler rely on the continued existence of a ventilation path as well as staged equipment that can be installed and activated during the warning period before the volcano erupts or even after the volcano erupts. Keeping ashfall away from plugging building air intakes and ventilation are manual actions. Ash that falls dry on dry surfaces is easily cleaned by air blasting or brushing. Ash that falls wet or is wetted before cleaning would require more aggressive measures such as high pressure water.

Conclusion

PJM mixing is irrelevant for 3 out of the 4 conditions. For the yellow condition, the likelihood of an explosion and consequence is such that the risk is acceptable unmitigated and even lower mitigated. Therefore, there is no need for air and emergency power to sustain PJMs after a design basis ashfall event. This is fortunate in that loss of offsite power for an extended period of time

[1] As part of the overall nuclear safety position, the precise meaning of a safe state must be defined. For this exercise, a safe state is one in which no processing is done, vessel cooling and air needs are minimal and emergency power needs are minimal.

[2] Indications are that it takes little agitation to release retained hydrogen, although this should be experimentally or analytically verified.

would be likely. Emergency power may not be available for reasons similar to loss of offsite power, and if initially available, may not be sustainable because of the need for refueling. Therefore, even if sufficient air were available, fixed installation electric power may not be relied upon after this ashfall event to power PJMs. The power needs of the staged equipment would be minimal and could rely on portable generators. Sufficient storage for an inert substance (e.g. halon or nitrogen) and sufficient fuel for portable generators are feasible and currently being studied within Nuclear Safety Engineering.

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