


Memorandum

DATE: JUL 29 2011
REPLY TO:
ATTN OF: WTP:JAR 11-WTP-266

SUBJECT: Design and Engineering Process Evaluation of Bechtel National, Inc's. (BNI's) Recommendation to Install Vessel Top Heads on the Five Non-Newtonian Vessels, UFP-VSL-0002A/B, HLP-VSL-00027A/B, AND HLP-VSL-00028

TO: Dale Knutson, Delmar Noyes, and Wahed Abdul

This memorandum provides the results of the Waste Treatment Immobilization Plant Engineering Division evaluation of documentation provided in support of BNI's recommendation to weld top heads on the Non-Newtonian Vessels. The results of the evaluation are attached.


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Waste Treatment and Immobilization Plant Project

Attachment:

Design and Engineering Process Evaluation of BNI's Recommendation to Install Vessel Top Heads on the Five Non-Newtonian Vessels, UFP-VSL-0002A/B, HLP-VSL-00027A/B, AND HLP-VSL-00028

Attachment 5

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**Design and Engineering Process Evaluation of
BNI's Recommendation to Install Vessel Top Heads on the
Five Non-Newtonian Vessels, UFP-VSL-0002A/B,
HLP-VSL-00027A/B, AND HLP-VSL-00028**

July 29, 2011

Pages 12 (including coversheet)

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U.S. Department of Energy, Waste Treatment and Immobilization Plant Project

Executive Summary

Bechtel National Inc. (BNI) has recommended that vessel top heads be welded on to the five Waste Treatment and Immobilization Plant (WTP) Non-Newtonian Vessels, UFP-VSL-0002A/B, HLP-VSL-00027A/B, AND HLP-VSL-00028. This decision represents a continued construction step, to be taken with the knowledge that design inputs for these vessels have changed, and the resulting impacts to their designs and operability are not completely understood. BNI's recommendation is documented in CCN: 226344, *Recommendation for Installation of Vessel Top Heads for the Five Non-Newtonian Vessels*, UFP-VSL-0002A/B, HLP-VSL-00027A/B, AND HLP-VSL-00028, dated July 7, 2011.

The DOE WTP Engineering Division (WED) evaluated the references and bases provided by BNI to support the recommendation. WED also evaluated the requirements and obligations associated with continued construction of designs that include unverified aspects.

The conclusions developed in this evaluation are summarized below:

1. The WTP project has no requirement that would prevent the installation of the vessel top heads at this time. The applicable timing requirement is that design verification must be complete before installation becomes irreversible (i.e., requiring extensive demolition and rework).
2. The Risk Evaluation did not clearly describe how a delay in welding the vessel heads would create a significant impact at the vendor's facilities or the WTP Project schedule.
3. A number of aspects of the vessels' designs are unverified, and there is considerable risk that the vessels as currently designed may not be able to perform their intended process and safety functions in accordance with the Authorization Basis. Proposed mitigations are concepts that are also unverified.
4. The risk reduction measures taken since August 2010 have not reduced the risk associated with the unverified designs.
5. Consistent with DOE Order 413.3A, WED recommends aggressive risk management actions for these vessels, including investigation of an alternative, verifiable design. The need to pursue and complete design verification before landing the vessels in the pretreatment facility is not affected by the decision to weld the heads on the vessels.

1.0 BACKGROUND

The WTP is a design-build project that is fast track. It is close-coupled with respect to release for procurement/construction. This is documented in the *Project Execution Plan for the Waste Treatment and Immobilization Project*, MGT-PM-PL-06, Rev 0, July 2009, and in BNI's self assessment of readiness for Critical Decision 3C, CCN: 039965, Attachment 7, Page 38.

Under normal circumstances, Critical Decision 3 requires that “with design and engineering essentially complete, a final design review performed, all environmental and safety criteria met, and all security concerns addressed, the project is ready to begin construction, implementation, procurement, or fabrication.”

In the case of design-build projects, however, this requirement is tailored so that construction can occur before the design is complete. At the same time, DOE Order 413.3a requires that:

“to address potential complications, aggressive risk mitigation strategies are required to address the unique characteristics of close-coupled or fast-track design-build projects. Risk management strategies must be outlined in the risk management plan and at a minimum address:

- (1) all technical uncertainties,*
- (2) the establishment of design margins to address the unique nature of the design, and*
- (3) increased technical oversight requirements.”*

For design-build, the timing requirements of ASME NQA-1 (NQA-1) for design and design verification apply. NQA-1 is implemented through the WTP *Quality Assurance Manual*, 24590-WTP-QAM-QA-06-001.

The WTP Quality Assurance Manual states that “in all cases the design verification shall be completed prior to relying upon SSCs or computer programs to perform its function and before installation becomes irreversible (i.e., requires extensive demolition and rework).”

The original non-Newtonian vessel designs were considered verified for mixing by using the test method for design verification (qualification testing) per CCN: 234565. The basis for the tests included non-Newtonian fluids, but the tests used nominal particle sizes and densities that did not reflect the full range of waste conditions (small particles, average particle density below 2.9 g/ml). This was contrary to the requirements for qualification testing that are documented in 24590-WTP-QAM-QA-06-001, Rev 6, *Quality Assurance Manual*, which requires that “qualification tests shall demonstrate the adequacy of performance under conditions that simulate the most adverse design conditions, including consideration of operating modes and environmental conditions.”

This condition was observed by the External Flowsheet Review Team (EFRT) and documented in their report, CCN: 132846, *Comprehensive Review of the Hanford Waste Treatment Plant Flowsheet and Throughput*. The EFRT stated that the particle properties selected (density 2.9 g/ml and median size of 22 microns) were “not the worst case for solids suspension,” and that one of the mixing issues was the re-suspension of solids and mixing times in non-Newtonian fluids.

As a result, the Non-Newtonian vessel designs require re-evaluation for the updated waste conditions, and they require re-verification – to be completed before the installation becomes irreversible.

2.0 OBJECTIVES, SCOPE AND APPROACH

The WTP Engineering Division (WED) reviewed and evaluated the technical information provided in the following three references, which were cited in BNI's recommendation.

1. 24590-WTP-RPT-ENG-11-147, Rev 1, *Risk Evaluation for Installation of Heads on the Five Non-Newtonian Vessels*, June 29, 2011.
2. 24590-WTP-RPT-ENG-11-001, Rev 0, *Determination That Non-Newtonian Vessels Can Be Evaluated Using Non-Newtonian Techniques*, June 3, 2011.
3. 24590-WTP-RPT-ENG-11-013, Rev 0, *Low Order Accumulation Model Testing with Non-Newtonian Vessel Arrangement*, June 3, 2011.

Note: This supplemental review builds on comments provided in 11-WTP-221, *Conclusions from the WED Review of Non-Newtonian Vessels Design Supporting Documentation*, dated June 16, 2011. This supplemental review was also performed in light of three meetings held from June 16 to June 21, 2011 to discuss facts regarding non-Newtonian Vessel design and associated testing (CCN: 204844, CCN: 204846, and CCN: 204847).

3.0 RESULTS

The results of this review show that some progress has been made. However, the BNI evaluation of risk was incomplete; the risks are more serious than described in BNI's recommendation, and an aggressive risk management, design margin, and oversight process is needed to ensure that the vessels have a verified design before the installation is irrevocable.

BNI issued an assessment entitled "Risk Evaluation for Installation of Heads on the Five Non-Newtonian Vessels" (24590-WTP-RPT-ENG-11-147, Rev 1) to address the proposed construction step. The BNI evaluation concluded that the vessel heads should be welded on the non-Newtonian vessels (NNVs) based on confidence in the current design and a "wide suite of viable vessel changes (i.e. mitigations)" that would not require head removal. The mitigations included: relocation of the suction line, modifying the viscosity of the fluid, altering the firing sequence of the pulse jets, and adjusting the PJM drive stroke. The Risk Evaluation only partially addressed the mixing requirements for hydrogen gas release (Mixing Requirement 8) and for no solids accumulation (Mixing Requirement 10).

Technical issues are addressed below.

3.1 Hydrogen Gas Release

The safety basis for achieving the hydrogen gas release is not clearly and completely demonstrated and demonstration may require vessel configuration changes. BNI's analyses to demonstrate compliance with the safety function for hydrogen gas release did not account for the range of solid and liquid compositions, all of the required vessel operating modes, bounding estimates of solids accumulation in the vessels, gas retained in un-sheared fluids that would act

as a yield stress solid, and solids sediments that would increase the concentration of heat emitting isotopes and the corresponding hydrogen generation rates.

The evaluations of hydrogen gas release and no-solids accumulation did not include an assessment of the complete set of WTP Basis of Design fluid properties. The Risk Evaluation (24590-WTP-ENG-11-147) indicated that particles greater than “~210 to 300 micron” would accumulate. LOAM benchmark Testing (24590-WTP-ENG-11-013) tested a particle size distribution up to ~770 micron. A recent BODCN (24590-WTP-BODCN-ENG-10-0003) provided two conditions for the waste feeds to the five NNVs. These are:

“For vessels, UFP-VSL-00002A/B, HLP-VSL-00027A/B, and HLP-VSL-00028, the WTP will use process control to condition the slurry viscosity and shear strength for leached, washed, and concentrated waste to be within the range of 6cP and 6 Pa to 30 cP and 30 Pa as the lower and upper bounds respectively. The post leaching, washing, and concentration non-Newtonian slurry solids are ≤ 300 micron and ≤ 3.8 g/ml bulk average density, and a maximum plutonium oxide particle of 10 micron.”

And for as-received waste that is concentrated:

“The bulk maximum of the average solids density distribution (mass averaged density) expected for mixing of the tank farm as-received HLW feed is 2.9 g/ml. The maximum for the particle size distribution expected for tank farm transfers to WTP is 700 micron, and a maximum plutonium oxide particle in tank farm transfers is expected to be 10 micron.”

Section 3.8.2 of the Risk Evaluation (24590-WTP-RPT-ENG-11-147) proposes an approach for determination that the vessels comply with their safety function for hydrogen gas release. The estimates for hydrogen gas release did not include impacts from:

- Solids accumulated on top of the chandeliers,
- PJM operating and sparging uncertainties (related to variability in fluid characteristics) on the estimated volume of solids buildup and location,
- Unmixed fluid zones in which the un-sheared fluid would behave as a yield stress solid and retain hydrogen gas,
- Hydrogen generation rate increases due to the concentration of heat emitting isotopes in sediment layers, and
- A bounding estimate for solids accumulation.

3.2 Solids Accumulation and Enrichment/Segregation of Particles

Even though the total concentration (all simulant solid components) in the heel was less than the starting concentration, individual solid simulant components (glass beads, bismuth oxide and tungsten carbide) were shown experimentally to accumulate in the vessels in a single batch pump down. The solids contain fissile material and impact the safety function for criticality prevention. An assessment of heel dilution as a criticality control mitigation strategy was projected to be ineffective in the Risk Evaluation. Solids accumulation was projected (based on an assumption of a fixed particle removal efficiency) to level off asymptotically, regardless

of the performance of heel dilution. BNI has not demonstrated that a criticality is incredible with the NNV designs.

Based on these results, an evaluation is needed of the potential impact to the *Unit Dose Factors For Use In Updated MAR Accident Analysis (24590-WTP-ZOC-W14T-00020)* due to solids buildup (including on the vessel bottom, on support structures and/or on top of the chandelier). This information is an input to the accident analyses and HPAV design and to determine if the effect of mixing deficiencies is either to enrich the retained solids in radiological content within an NNV or to transfer an enriched stream to the next vessel or HLW. Note: The ULD estimate assumes that the Pu/absorber ratio is maintained in post solids leach conditions per the Preliminary Criticality Safety Evaluation Report (24590-WTP-CSER-ENS-08-0001).

An evaluation is also needed to determine whether the NNV vessel design conditions (e.g. fluids having a viscosity $\leq 30\text{cP}$ and a yield strength $\leq 30\text{Pa}$) continue to be met following the settling and accumulation of solids. The effect of solids accumulation on the rheological properties has not been addressed.

The proposed mitigation measures to correct vessel design and operational deficiencies are conceptual in nature and have not been tested or verified. Projections of success in the risk evaluation were therefore premature.

3.3 LOAM Model was Not Successfully Benchmarked

Low Order Accumulation Model Benchmark testing determined that the LOAM model inaccurately projected that solids above ~200 micron in size will not accumulate. A definite accumulation of large particles was observed in testing and smaller dense particles were also observed to concentrate in one of the LOAM Benchmarking Tests.

The LOAM model underestimated cloud height and it overestimated the PJM bottom clearing area when compared to test data. DOE has stated that the LOAM model will be used for mixing assessments, but it will not be used for design verification, in 11-WTP-257, *Concern Regarding the Use of the "Low Order Accumulation Model" (LOAM) for the Waste Treatment and Immobilization Plant Vessels*. Benchmarking the LOAM model was intended to increase confidence in vessel performance. Instead, the benchmark tests revealed inadequate mixing of large particles and potential accumulation of small, dense particles.

BNI's risk evaluation employed the LOAM model to predict bottom clearing in the Non-Newtonian vessels, but the prediction did not correct or explain the observed inaccuracy.

3.4 Use of Newtonian Methods to Model Non-Newtonian Fluids

The assumption that the non-Newtonian vessels can be modeled using Newtonian fluid conditions is not supported by the evaluations completed and considering the following major issues: a) the required velocities to shear the non-Newtonian fluid to create Newtonian-like conditions are not identified in the study, b) the PJM vessel mixing velocities are not correlated

to the shear velocities and c) the non-Newtonian conditions were not evaluated. The method has not been tested using a non-Newtonian fluid.

DOE has committed to performing design verification using computational fluid dynamics (CFD) for design verification, per 11-WTP-257, and BNI has additionally committed to using verification (qualification) tests as well as CFD per 24590-WTP-RPT-0P-10-007, Rev 0, *2010 Contract Compliant WTP Commissioning Strategy with Sequential ORR*. The commissioning strategy makes the assumption that: *"The ability to mix both Newtonian and non-Newtonian waste will have been verified by a combination of computational fluid dynamic analysis and Process Engineering and Technology testing (EFRT M3 testing and other PE&T mixing tests)."* If CFD is used for design verification of non-Newtonian fluids, and if it adopts the Newtonian methods approach, the validity of the theoretical development of the critical shear stress for mobilization of solids from a cohesive/adhesive particle bed, τ_{cc} , will need to be verified with an experiment that addresses the complete range of its application.

The strategy used in the Newtonian Techniques report was to argue that the sheared non-Newtonian fluid would behave as a Newtonian fluid. Therefore, for an appropriately sheared non-Newtonian fluid, Newtonian methods of assessment could be used. The assessment did not however:

- Identify the required velocities and fluid conditions (viscosity, yield strength) that would result in the creation of a Newtonian fluid from a non-Newtonian fluid.
- Relate the velocity profiles in the specific PJM vessel to conditions required for shear. The assessment used anecdotal information for previous scaled testing to support the argument that the fluid can be sheared in the plant scale NNV.
- Provide a comparison of the projected and actual ECRs using test data having high solids concentration and fluid viscosities comparable to WTP NNV design basis conditions to evaluate the fidelity of the calculation methods.

The computational approach, if used by BNI for design verification, will likely lead to a limiting condition of operation [e.g., Technical Safety Requirement (TSR)] of the NNV's, which may be difficult to prove during design verification or operations. This TSR will be that the vessel fluid be sufficiently sheared to produce a Newtonian fluid within the entire contents of the vessel, including in the shadow of vessel internal components and regions that are not mixed. The implications of this requirement for design verification and establishment of the safety basis may be very difficult to evaluate. The requirement to support verification of this proposed design basis assumption is not currently included in the Large Scale Integrated Test plan.

3.5 Additional Risks

Additional risks were not established as part of the BNI recommendation scope. These risks include:

- a) Re-evaluation of erosion wear of the vessel bottom heads caused by the PJMs in light of the updated slurry properties,
- b) PJM and vessel head space venting entrainment and vent system capacity,

- c) Adequacy of the materials of construction for the UFP vessels to prevent caustic/chloride stress corrosion cracking (S-11-WED-RPPWTP-020), Surveillance Report, Ultrafiltration Process Vessels Caustic Stress Corrosion Cracking),
- d) The ability to control the PJMs using bubbler (dip tube) equipment for density and level measurement, and
- e) Lack of design margin associated with the cooling jacket design pressure limits.

When combined with the mixing risks, the number of unverified aspects of design becomes a larger concern. The effects of the additional risks on mixing and on vessel operating life have not been considered as a whole. BNI's self assessment of readiness for Critical Decision 3C, CCN: 039965, asserted that the remaining risks were "understood and bounded" at the time of the design-build approval. This is no longer the condition for the non-Newtonian vessels.

BNI's recent and ongoing effort to update the hazards analysis may have addressed some or all of the risks described above. A check to ensure the complete list has been addressed in the hazards analysis would be useful. These risks should be addressed as part of the updated vessel assessment and prior to/as part of design verification.

3.6 Procurement and Design Verification Documentation Lacks Rigor/Accuracy

WED found a lack of rigor and accuracy in the material requisition and design verification documentation associated with the non-Newtonian vessels. This condition adds to the risk that the vessel design will not be successfully managed through to design verification and commissioning.

Based on recent discussions with BNI regarding approved and recognized design stages, it was determined that in terms of maturity, a WTP design can only be classified as either "verified" or "unverified" with all the upper tier applicable requirements that such designation carries. Therefore it is appropriate to modify any previous documented references to "committed" and/or "confirmed" designs in order to move forth with a clear understanding of the upcoming activities, objectives and applicable requirements.

The Material Requisition Readiness Checklist (MRRC) for vessels HLP-VSL-00027A, HLP-VSL-00027B, HLP-VSL-00028, and HLP-VLS-00022 indicated that design verification for these vessels was complete. The MRRC contradicts the Design Verification Matrix (DVM), which specifically states "incomplete verification" for vessels HLP-VSL-00027A & B, HLP-VSL-00028, and HLP-VSL-00022. The vessels' procurement readiness review was determined to be (S-11-WED-RPPWTP-019) inadequate in fully identifying the risk involved in moving forth with procurement of equipment with unverified portions in its design. Additional evaluation of design verification activities has shown that design verification action items refer back to "committed" and "confirmed" categories, which are not relevant descriptions. WED has a concern that the design verification matrix may not address all of the unverified aspects of the non-Newtonian vessel designs, and is continuing its evaluations.

The decision to weld the top heads on the vessels requires a determination that delays in the proposed activities would have a significant (adverse) effect on DOE interests. The Risk Evaluation did not clearly describe how a delay in welding the vessel heads would create a significant impact at the vendor's facilities or the WTP Project schedule. The Risk Evaluation also did not explain why vessel HLP-VSL-00022, which is on the WTP's critical path, cannot be fabricated prior to fabrication completion of the five non-Newtonian vessels.

4.0 SUMMARY ASSESSMENT OF TECHNICAL RISK

The risk associated with successful performance of the non-Newtonian vessels has not changed substantively since the M3 Inadequate Vessel Mixing design issue was closed in August 2010. Actions completed to further understand the uncertainties in performance of the five non-Newtonian vessels have provided insights into potential vessel performance, confirmed some concerns associated with the vessel designs, and focused the project on potential changes that may be necessary to improve performance.

Report 24590-WTP-RPT-ENG-11-001, *Determination that Non-Newtonian Vessels can be Evaluated using Newtonian Techniques*, provided improved understanding of theoretical performance and analytical approaches to assess non-Newtonian vessel performance. However, testing to validate the proposed analytical approach and quantify associated uncertainty and error are needed to support future vessel assessments. Vessel assessments utilizing the proposed approach have not yet been completed.

Report 24590-WTP-RPT-ENG-11-013, *Low Order Accumulation Model Testing with Non-Newtonian Vessel Arrangement*, demonstrated that bulk solids transfer for small particles out of the test vessel was reasonably consistent with LOAM predictions. The testing also identified that large particles had an increase in concentration in the heel after pump-out relative to the concentration in the initial vessel batch and that some small, dense particles also accumulated, to a lesser extent. This behavior substantiated the concern that large particles could accumulate from batch to batch. Options to potentially improve vessel and transfer system performance in removing large particles have been identified by BNI and are recommended to be tested in future Large Scale Integrated Testing. This condition and performance concern is similar to concerns raised in 2010 leading to the decision to test the non-Newtonian vessel configuration. The risk associated with this concern has not substantively changed from the time M3 was closed in August 2010.

Report 24590-WTP-RPT-ENG-11-147, *Risk Evaluation for Installation of Heads on the Five Non-Newtonian Vessels*, recommended release of the vendors to install the vessel heads on the non-Newtonian vessels. The report also identified reasonable and prudent conceptual options and actions to further assess non-Newtonian vessel performance and correct any performance deficiencies.

The primary risk associated with the non-Newtonian vessels is that future testing and analysis could confirm a performance deficiency that would require vessel PJM array redesign or vessel replacement. Options that require a revised PJM array or vessel redesign would require significant time for design, testing, analysis, construction, and installation into WTP. This time

would have a direct impact to the project critical path and potentially extend the time required to initiate and complete treatment of the Hanford tank waste.

The intent in performing the actions directed by the Issue Resolution Team (LOAM benchmarking and evaluation of whether assessment using Newtonian techniques bounded non-Newtonian performance) in September 2010 (CCN: 220520) were aimed to understand and reduce risk prior to accepting the PJM array as viable for continued non-Newtonian vessel fabrication. Information gained in testing and analysis since September 2010 does not provide sufficient information to conclude whether the current non-Newtonian vessel PJM mixing system design is acceptable, will require modification, or in the worst case requires redesign.

The decision to weld (or not weld) the heads has been evaluated, but not thoroughly and in the context of potential required vessel design changes. A feasibility assessment for implementing the proposed potential design changes (e.g. movement of the pump-suction line) was not been completed. In addition, other potential changes such as methods to clean the chandelier or provide better vessel sampling and monitoring capability, were not evaluated, and could be more difficult to implement.

At present BNI has a limited design improvement initiative, e.g., moving the pump suction line/altering firing sequence. Other modest design changes which have not been evaluated may allow the vessels to be salvaged if the pump suction relocation is determined to be unsuccessful.

5.0 RECOMMENDATIONS

1. An integrated evaluation of the complete set of technical issues associated with the NNVs should be completed to ensure that the current designs are acceptable, or if not, what actions are required to ensure an effective, licensable design. The vessel technical issues include: a) erosion wear of the vessel bottom heads caused by the PJMs, b) PJM and vessel head space venting, c) materials of construction for the UFP vessels, d) mixing, e) ability to control the PJMs, and f) the cooling jacket design pressure limits. Additional modest design changes should be identified and evaluated that could mitigate these issues prior to vessel fabrication completion and vessel head welding as required.
2. Consistent with DOE Order 413.3A, a design margin program should be adopted to address uncertainties. This recommendation is consistent with, and enhances the BNI Design Process, 24590-WTP-3DP-G03B-00001, which requires an integrated strategy that includes:
 - a. Adding margin to input information to account for uncertainties and maturity of the information, and
 - b. Adding margin to provide flexibility in implementing design details.
3. An aggressive project activity should be conducted to design, test and evaluate an alternative design for the non-Newtonian vessels and also UFP-01. The alternative should be focused on mitigation of the design deficiencies currently identified with consideration of the technical issues identified above. The alternative should also be

designed for ease of verification. These designs should be evaluated along with the baseline designs, and baseline design with identified mitigation measures, leading to a project decision on the preferred design. This project activity is consistent with the requirement for the aggressive management of this high technical risk area as required by DOE Order 413.3A.

4. The resolution of outstanding comments on the Volume 3 NNV Vessel Assessment should be accelerated compared to the January 2012 resolution date. WED recommends that the vessel assessment be divided into the UFP-2 vessels, and the HLP vessels. These steps will sharpen the focus on the unique issues associated with each vessel design type, and allow the project to resolve questions and issues in a timely manner.
5. The testing basis to date to support the NNVs is incomplete in terms of simulants tested and vessel operating modes evaluated. This testing basis is required to support a determination of the vessel design margin, vessel operating margins and finally the vessel safety margin. The vessel designs and their performance should be brought into compliance with the Authorization Basis prior to landing of the vessels in the Pretreatment facility. In addition, the point of irrevocable installation should be established so that there is an integrated schedule to complete the design verification.

6.0 REFERENCES

- CCN: 039965, *Contract No. DE-AC27-01RV14136 – Hanford Tank Waste Treatment and Immobilization Plant Critical Decision 3C Declaration of Readiness*, Bechtel National, Inc., Dated August 28, 2002, Attachment 7, Page 38.
- CCN: 132846, *Comprehensive Review of the Hanford Waste Treatment Plant Flowsheet and Throughput*, March 17, 2006.
- CCN: 204844, *Non-Newtonian Vessel Review*, June 27, 2011.
- CCN: 204846, *Non-Newtonian Data Review and Vessel Assessment (2)*, June 20, 2011.
- CCN: 204847, *Non-Newtonian Vessel Review (3)*, June 21, 2011.
- CCN: 220456, *Technology Steering Group-Issue Closure Record-Partial Closure EFRT M3 (Closure Package Volume 3, UFP-VSL-00002A/B, HLP-VSL-00027A/B, HLP-VSL-00028), Inadequate Mixing System Design*, August, 20, 2010.
- CCN: 220520, *Meeting Minutes, Issues Resolution Team*, September 29, 2010.
- CCN: 234565, *EFRT Issue 3-TSG Closure Item 8-Committed Portion of Non-Newtonian Vessel Design-PIER 10-1115-C*, May 17, 2011.
- CCN: 226344, *Recommendation for Installation of Vessel Top Heads for the Five Non-Newtonian Vessels*, UFP-VSL-00002A/B, HLP-VSL-00027A/B, AND HLP-VSL-00028, Bechtel National, Inc., dated July 7, 2011.
- DE-AC27-01RV14136, *Bechtel National, Inc., Design, Construction, and Commissioning of the Hanford Tank Waste Treatment and Immobilization Plant*, U.S. Department of Energy, Office of River Protection, Richland, Washington, 2000, as amended.

- DOE Order 413.3A, *Program and Project Management for the Acquisition of Capital Assets*, Change 1, 11-17-2008.
- MGT-PM-PL-06, *Project Execution Plan for the Waste Treatment and Immobilization Project*, U. S. Department of Energy, July 2009.
- S-11-WED-RPPWTP-019, *Review of High Level Waste Lag Storage and Feed Blending Vessels Material Requisition Readiness Checklist*, July 22, 2011.
- S-11-WED-RPPWTP-020, *Ultrafiltration Process Vessels Caustic Stress Corrosion Cracking*, July 27, 2011.
- 11-WTP-257, *Concern Regarding the Use of the "Low Order Accumulation Model" (LOAM) for the Waste Treatment and Immobilization Plant Vessels*, Memorandum, D. Knutson to David Huizenga, dated July 20, 2011.
- 24590-WTP-QAM-QA-06-001, Rev 6, *Quality Assurance Manual*.
- 24590-WTP-RPT-ENG-11-147, Rev 1, *Risk Evaluation for Installation of Heads on the Five Non-Newtonian Vessels*, June 29, 2011.
- 24590-WTP-RPT-ENG-11-001, Rev 0, *Determination That Non-Newtonian Vessels Can Be Evaluated Using Non-Newtonian Techniques*, June 3, 2011
- 24590-WTP-RPT-ENG-11-013, Rev 0, *Low Order Accumulation Model Testing with Non-Newtonian Vessel Arrangement*, June 3, 2011.
- 24590-WTP-3DP-G03B-00001, Rev 10, *Design Process*, March 1, 2011.