Completing the Resolution of Technical Issues Identified by Two Major Reviews of the Waste Treatment Plant - 10474

Garth M. Duncan*, Richard E. Edwards**, Dr. Walter L. Tamosaitis**
*Bechtel National, Inc., Richland, WA 99354
**URS - Energy and Construction, Richland, WA 99354

ABSTRACT

The Department of Energy is constructing the Hanford Tank Waste Treatment and Immobilization Plant (WTP) at the Hanford site in Washington to treat and immobilize approximately 53 million gallons of high level radioactive waste. The Hanford tank waste has diverse characteristics, and the technologies to treat and immobilize the waste are often either first-of-a-kind or significant extrapolations from prior experience. To ensure that the WTP can process the waste reliably and satisfy mission completion goals, the Department of Energy, Office of River Protection and the WTP contractor, Bechtel National, Inc., have engaged in two significant technical reviews.

This paper describes the two reviews, the significant issues identified in each, and how the issues have been resolved.. The External Flowsheet Review Team recommended 28 issues be evaluated and the subsequent Technology Readiness Assessment evaluation identified 8 issues where actions were indicated to demonstrate technical maturity. Significant issues involved line plugging, vessel erosion , mixing of vessels, ultrafiltration and leaching, process limits, post-filtration precipitation, and the estimate of plant availability. These issues, with one exception, have been resolved thereby allowing the completion of the WTP design to proceed with confidence that the plant will operate and have the intended reliability and throughput rates. The remaining issue involving mixing, is slated for closure in 2010.

INTRODUCTION

On the Hanford site, a few miles west of the Columbia River, 53 million gallons of radioactive and chemical waste from cold war plutonium production are stored in 177 underground tanks. Design and construction of the world's largest radioactive waste treatment plant is underway to immobilize the waste into glass and place it in stainless steel canisters for safe and permanent disposal. To provide greater assurance that the WTP can process the waste as intended and at the throughput rates specified, the Department of Energy, Office of River Protection and the WTP contractor, Bechtel National, Inc., have sponsored an External Flowsheet Review Team (EFRT) and Technical Readiness Assessment (TRA). Each identified design and operational issues requiring resolution. The issues were identified in 2006 and 2007 and were largely resolved by the end of 2009.

The WTP is composed of three main facilities: The Pretreatment (PT) facility performs separation and concentration of the waste received from the underground tanks. The High Level Waste (HLW) vitrification facility immobilizes the high level fraction of the waste in glass using melters. Similarly, the Low Activity Waste (LAW) facility vitrifies the low-level waste fraction. The WTP reached the 50% completion mark in October, 2009 and is on track for hot operations by 2019.

THE REVIEWS

The External Flowsheet Review Team (EFRT) was established in the fall of 2005 to examine the adequacy of research and testing to underpin the design, whether the design achieve the specified throughput rates, and the adequacy of planned commissioning activities and operability. Some 40 participants from other DOE sites, national laboratories, academia, and industry were involved in focused reviews of key technologies. In their report, provided in Bechtel [1], 28 issues were recommended for follow-up and resolution, 17 issues were categorized as major and 11topics were considered potential issues.

The Technology Readiness Assessment (TRA) was conducted by DOE's Office of River Protection (ORP) in 2007 using assessment techniques adapted from DOD and NASA. The resulting report in USDOE [2] suggested 8 issues that needed further work to demonstrate that the technology was sufficiently mature to proceed to the operations phase. Two of the eight issues were already being addressed by the EFRT issues resolution effort, resulting in 6 added issues for evaluation.

Further details of both evaluations are provided in Duncan, et al. [3].

A deliberate process, shown in Figure 1,was used to address and close the issues. For the EFRT issues, detailed issue response plans (IRPs) were developed to describe the scope of the evaluation and the closure criteria. Concurrence from the lead EFRT member was obtained on the plan. Both WTP and ORP technical and project management approved the IRPs. With the completion of the various activities in the IRP, closure plans were developed that outlined all the actions and documentation related to the topic. In some cases residual risks and follow-on actions were identified. Concurrence that that an issue was closed required the same level of approval as the IRP. Closure was approved by a Technical Steering Group (TSG) comprised of representatives from WTP, ORP, and PNNL. The same process was followed for TRA issues.

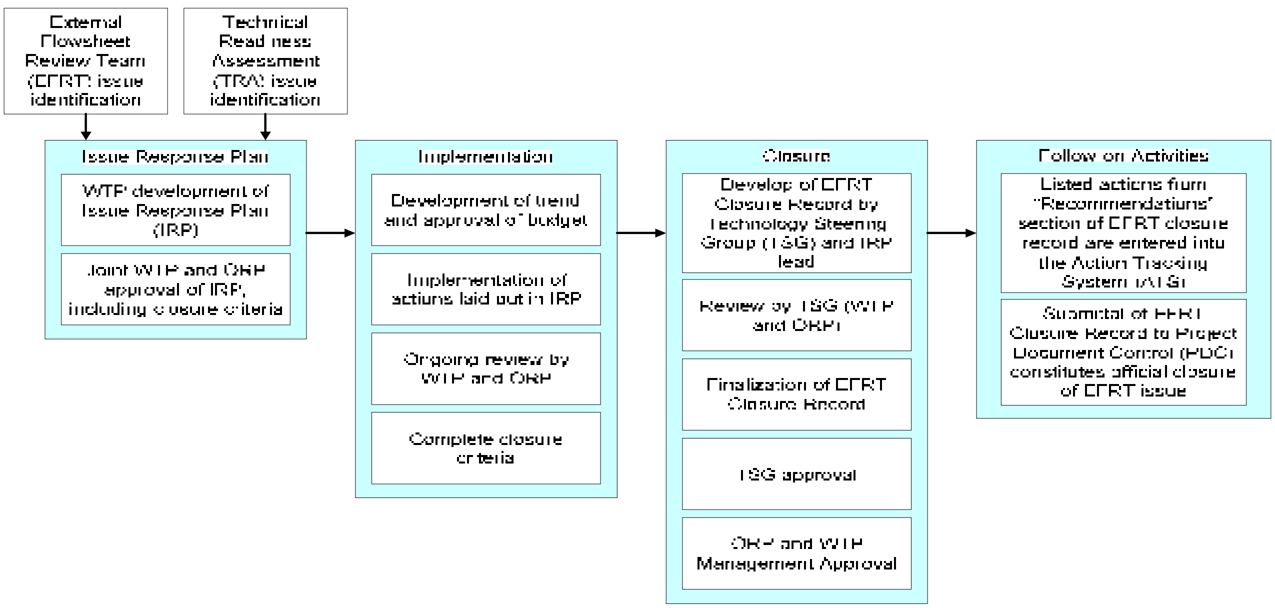

Fig. 1 . EFRT and TRA resolution process

THE MAJOR ISSUES

The more significant major issues identified by the EFRT, and discussed further in this report, were:

- Potential for line plugging due to settling of waste particles in lines and gelation of waste
- Potential for excessive erosion under pulse jet mixers (PJMs)
- Potential that wastes that settle in vessels with Newtonian waste properties may not be able to be resuspended
- Inadequate evaluation of the complete range of feeds that would be fed to the WTP
- Inadequate knowledge of processing limits for a range of feeds
- Uncertainty about the effectiveness of the leaching process
- Potentially inadequate ultrafilter capacity, and
- Uncertainties in the estimation of plant availability

The EFRT also identified as apriority the conversion of cesium ion exchange media from the original baseline resin to resorcinol formaldehyde resin. The project was in the process of making this conversion when the review took place which has since been completed.

Among the 6 open TRA issues, one was considered to be major and in the same category as the EFRT issues. That was the potential for post-filtration precipitation in the permeate feed from the ultrafiltration system to the cesium ion exchange system.

SETTING THE STAGE - ADDITIONAL INPUT DATA DEVELOPMENT

In assessing the plans for the various issues it became apparent the evaluations and resolutions were dependent on the nature of the feed being processed. It was determined that more information on the following was needed to support closure:

- Waste particle size and density distribution
- Waste rheology, and
- Waste chemistry

Three studies were initiated to address these topics and develop better information to assess and close the issues.

Battelle-Pacific Northwest Division (PNWD) formed a Particulate Characterization Working Group to evaluate waste particle size, density, and distribution in tank farm waste. A team of 19 scientists and engineers from Battelle, the tank farm operator, CH2M HILL, and the WTP project participated. The group developed representative particle size and density distributions (PSDDs) of Hanford insoluble solids. A new approach was used for relating measured particle size distributions to solid-phase compounds. The PSDDs from this approach proved a 'best representation" of a volume based probability for the waste in terms of particle size and density. In comparison to earlier work, this study used more (in fact, all) particle data available and developed the PSDDs based on volume averaging of the available data. The report, *Estimate of Hanford Waste Insoluble Solid Particle Size and Density Distribution*, Wells and Knight [4], was issued in February 2007 and provided input into testing plans and simulant development for EFRT issues including line plugging, erosion, and mixing, and underpins the basis for WTP waste acceptance criteria relative to PSDD.

A similar endeavor was performed by the Pacific Northwest National Laboratory (PNNL) on waste rheology and settling. A team of PNNL, CH2M HILL, and WTP personnel evaluated rheological and sedimentation data from Hanford tank farm core samples and core samples diluted with process water. The range of rheological parameters (heel shear strength, slurry/heel Bingham yield stress, slurry/heel Bingham consistency, and supernatant viscosity) was produced. Regrowth times for shear strength, yield stress, and consistency were also developed for 10 hours, 100 hours, and 1000 hours. The report, *Estimate of Hanford Waste Rheology and Settling Behavior,* Poloski et al. [5], provided input into testing plans and simulant development for several issues including line plugging and mixing.

One of the EFRT issues dealt with a lack of evaluation of the complete range of feeds that would be fed to the WTP relative to the ability to process the feed. Development of this information was important to the closure of other EFRT issues and an exhaustive evaluation of the feed was conducted. WTP Engineering used data for 518 waste feed batches in Tank Farm Contractor Operations and Utilization Plan (TFCOUP), revision 6, Kirkbride, et al [6]. It was determined that the tank farm inventory could be categorized into 14 waste groups that were identifiable by their constituents that represented an appreciable influence to either facility chemical processes or low- or-high level glass formulations. The project report[1], was issued in September 2007. Information from this report was used in the process limits analysis, development of ultrafiltration testing simulant, and in the evaluation of post-filtration precipitation.

[1] "WTP Waste Feed Analysis and Definition", Bechtel National, Inc., 24590-WTP-RPT-PE-07-001, Rev. 1, September 18,2007.

These studies of waste feed PSDD, rheology, and chemistry provided key input to other studies and testing programs related to resolving EFRT issues. Figure 1 shows the information flow and the interrelationships among issue resolutions.

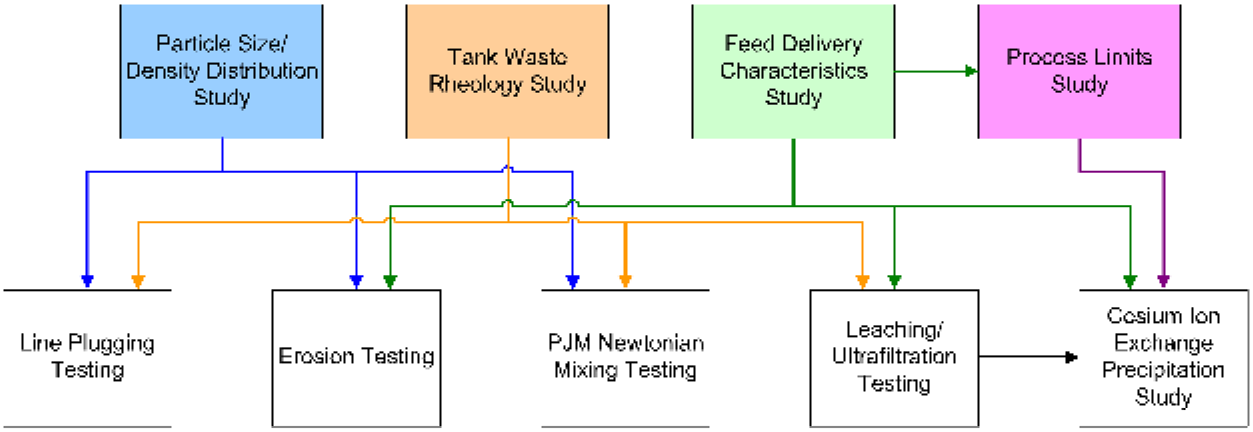

Fig. 1. Interrelationships among data inputs and issue resolutions

HOW THE ISSUES HAVE BEEN RESOLVED

The following provides a brief summary of how the selected major issues noted above were closed.

Line plugging: the project performed a thorough review and update its design criteria to prevent line plugging. An evaluation of all lines was made against the criteria. In a few cases, where the necessary velocity to prevent settling was not practicably achievable, high velocity flushes were added. Testing was performed over a range of particle sizes and densities, and shear strengths to confirm the design guidance was appropriate. The testing report in Poloski, et al [7] stated that "experimental results indicate that for Newtonian fluids, the design guide is conservative". Post-closure follow-up actions require updating of the design guide to reflect information found in the testing program and to incorporate interim guidance that had been used before the testing was completed to assure adequate design margins.

Erosion under pulse jet mixers: Based on the advice of experts, who concluded that the WTP erosion estimates were probably bounding, but should be confirmed by prototypical testing, a test program was initiated to collect data. Using PSDD information from the WTP-153 report noted above, one-quarter scale tests were conducted and erosion rates measured for varying particle velocities, particles sizes and hardness, impingement materials, concentrations, and hardness. The test data showed that the design contained considerable margin. The erosion testing setup is shown in Figure 2. Results are contained in Papp and Duncan [8]. Post-closure actions include updating the acceptance criteria in the waste feed interface control document to use more appropriate units of measure and limits as established in the erosion testing and analysis program. The conclusions of the effort are also required to be revisit on the completion of the PJM mixing testing (discussed below), particularly with respect to how any changes in mixing design might affect predicted erosion rates.

Fig. 2. Erosion Testing Rig

Pulse jet mixing: The mixing program has involved a initial testing phase collecting parametric data, a second prototypical phase that demonstrated the need for further evaluation and improvements, and a third phase that evaluates design enhancements to improve mixing. Adequacy of the original mixing design has been confirmed for 26 of 38 PJM-mixed vessels[1,2]. The initial testing phase was parametric in nature, using a non-prototypic constant jet in lieu of a pulse jet mixer. The data from it, reported in Meyer, et al. [9], was used in developing following testing. The current testing is being conducted on a prototypical 4-foot (1/10 scale) acrylic vessel. Testing and analysis to date has shown that mixing in 9 of the remaining 12 vessels may not be adequate with the original PJM designs. Modifications and additional testing and analysis is proceeding. In addition to the testing program, computational fluid dynamics is being used extensively to assess the design and confirm probable improvements.

Evaluation of Feeds: As noted above, this evaluation supported resolution of several issues. The assessment concluded that all the 14 waste groups were capable of being processed by the WTP. Follow-on actions after closure included sharing the report with the tank farm operating contractor to aid in their development of waste feed stage pl and, and to acknowledge in ORP's formal risk program, that a complete understanding of tank waste chemistry does not exist, resulting in uncertainty about processing rates throughout the mission. The information in the feed evaluation report is also being used as input to an update of the process mass and energy balance calculation for the project.

Process Limits Evaluation: In the first phase of the evaluation[3], a detailed gap assessment was performed to identify risks, strategies to fill the gaps, and a cost-benefit analysis of the potential strategies. Ten risks were identified, of which 4 were considered likely to occur and 6 unlikely to occur. Eight issues were

---

[1] Technology Steering Group Closure record EFRT Issue M-3 (Closure Package 1A - Inadequate Mixing System Design (CCN 186346)

[2] Technology Steering Group Closure record EFRT Issue M-3 (Closure Package 1B - Inadequate Mixing System Design (CCN 195208)

[3] M6/P4 Phase 1-A Summary Report - Process Operating Limit Gap Assessment Results, Bechtel National, Inc., 24590-WTP-RPT-PET-07-005, July, 2008

selected for follow-up evaluation/testing evaluation in Phase 2 (after closure of the issue). One of the issues, involving the cesium ion exchange (CXP) system has considerable overlap with TRA issues on the same system, and were worked in conjunction with that issue. An R&T Plan Addendum was issued to document and track the follow-on work[1].

Insufficient demonstration of the leaching process: The EFRT's concern was that leaching of aluminum and chrome has only been demonstrated at laboratory scale, and therefore there was considerable uncertainty about scale-up to plant operations. A 4.5 to 1 scale Pretreatment Engineering Platform (PEP) test platform was built and tested in several operating configurations. Lab scale testing was done on actual waste and simulant samples to provide benchmarks. The PEP testing showed a 1:1 scale-up. The lab testing also showed that simulants could accurately predict actual waste behavior in the areas tested. The PEP testing also confirmed the efficiency of the ultrafilters, as discussed below. Details of the comparison between the laboratory and PEP testing results are contained in Daniel et al.[10]. During the course of the PEP testing, significant post-filtration precipitation was observed in the post-caustic leachate and wash solutions, under conditions where that was not predicted to occur. This leaching testing observation became an important input to the post-filtration precipitation issue discussed below. Follow-up testing was conducted, as reported in Russell, et al. in [11]. The PEP provided a wealth of lessons learned for the actual plant design, the conduct of future testing, and in the operation of the WTP. These lessons were compiled in a project report[2]. The closure package[3] specifies five follow-up actions from the report on process control, oxalic and nitric acid cleaning, filter back-pulsing, and the post-filtration precipitation issue noted above.

The PEP has been placed in a long-term layup status and custody has been transferred to the tank farm operating contractor, who is developing proposals for further testing.

Potentially inadequate ultrafilter capacity. A study[4] was performed to determine how much additional ultrafilter capacity could be accommodated in the Pretreatment facility hot cell. It was concluded the capacity could be doubled, changing from three eight-foot long filters in series to 3 ten foot filters and 2 eight-foot units. Two centrifugal pumps in series were needed to accommodate the added pressure drop. The PEP test platform discussed above, was prototypic in filter length and the testing demonstrated effective operation. Filter flux rates were uniform on all the filters and back-pulsing was effective in maintaining flux rates as loadings increased. Details of the integrated performance were documented in a project memorandum[5] The closure record[6] identifies 12 required post-closure follow-up actions on air entrainment, filter flux control, vessel level control, temperature monitoring and response, flow measurement, spiral-wound heat exchanger design, pump specifications, and ultrafilter procurement.

Uncertainties in estimation of plant availability: The EFRT believed that a variety of assumptions used in the operational research (OR) model that estimates availability , and omissions in the analysis yielded questionable results. .Assumptions included Pretreatment hotcell valve reliability and how failed valves are replaced. The response included documenting valve reliability, revising the assumed operations involved in replacing a valve, and adding detail to the model. Results were documented for closure

[1] "Research and Technology Plan Addendum: M6/P4 Phase 2", Bechtel National, Inc., 24590-WTP-PL-RT-07-0002, Rev. 0, September,30, 2008.
[2] "Pretreatment Engineering Platform Lessons Learned, Bechtel National, Inc., 24590-WTP-RPT-RT-09-004, Rev. 0, June 29, 2009
[3] "Technology Steering Group - Issue Closure Record EFRT Issue M12 - Undemonstrated Leaching Process", CCN 195043, September 29, 2009
[4] "Technical Report - Design Evaluations Supporting Resolution of External Flowsheet Review Team (EFRT) Issue M12 and Plant Capacity Issues Related to Ultrafiltration and Leaching", Bechtel National, Inc., 24590-WTP-RPT-ENG-06-014, Rev. 0, January 2007
[5] Memorandum, Steven M. Barnes to Richard E. Edwards, "Detailed Bases for Issue M-12 Closure", September 21, 2009 (CCN 184903)
[6] "Technology Steering Group - Issue Closure Record EFRT Issue M13 - Inadequate Ultrafilter Surface Area adn Flux", CCN 195034, September 29, 2009

purposes[1,2] . Subsequent updates to the model show that target availabilities in the individual facilities and overall are met. The closure record required a follow-on assessment of the assumed ultra-filter lifetime in the OR model after the completion of PEP testing. Initial conclusions are that the assumptions would not be adjusted based on PEP experience.

Potential for post-filtration precipitation: The issue identified in the TRA addressed the risk that there could be post-filtration precipitation in the permeate stream out of ultrafiltration. Precipitation would interfere with ion exchange column operation and affect throughput, potentially very significantly. This issue was also identified in the process limits evaluation discussed above. Follow-on actions for both the process limits evaluation and this issue are contained in the addendum to project R&T plan cited above. The PEP testing discussed above showed that the precipitation could occur even under conditions where it was presumed it would not. A task team was assembled that evaluated various options to mitigate the problem. The solution involves operating at higher temperatures and segregating filter effluent types to preclude precipitation. A guard filter was also added to the design as a precaution. The evaluation is documented in a project report.[3]

CONCLUSION

A considerable amount of effort has been expended over the last 2-1/2 years in addressing the issues identified in the two reviews. Design and operational changes have been identified in some cases. The information developed and the documentation collected offer significant assurance to DOE and the various stakeholders that, with plant completion, cleanup of tank waste can proceed as planned.

REFERENCES

1. Bechtel National, Inc., Report of External Flowsheet Review Team for the Hanford Tank Waste Treatment and Immobilization Plant - Final Report Titled: "Comprehensive Review of the Hanford Waste Treatment Plant Flowsheet and Throughput", letter to ORP (CCN 132846) (2006). (available online at http://www.hanford.gov/orp)
2. U. S. D. O. E., , Office of River Protection, Richland, Washington, "Technology Maturation Plan for the Waste Treatment and Immobilization Plant", DOE/ORP-2007-02 (2007).
3. G. M. DUNCAN, DONALD H. ALEXANDER, LANGDON K. HOLTON, . CRAIG A. MYLER, "Assessing Technological Readiness and Maturity on the Waste Treatment and Immobilization Plant - 8271, WM2008 Conference, February, 2008
4. B.E. WELLS and M.A. KNIGHT, "Estimate of Hanford Waste Insoluble Solid Particle Size and Density Distribution", WTP-RPT-153, Rev. 0, Battelle-Pacific Northwest Division, February 2007.
5. A.P. POLOSKI, B.E. WELLS, J. M. TINGEY, L. A. MAHONEY, M. N. HALL, S. L. THOMSON, G. L . SMITH, M. E. JOHNSON, M. A. KNIGHT, J. E. MEACHAM, M. J. THIEN, J. J. DAVIS, Y. ONISHI, "Estimate of Hanford Waste Rheology and Settling Behavior", WTP-RPT-154, Rev. 0, Pacific Northwest National Laboratory, October, 2007
6. R. A. KIRKBRIDE, G. K. ALLEN, P. J. CERTA, T. W. CRAWFORD, P. G. HAIGH, , "Tank Farm Contractor Operations and Utilization Plan", HNF-SD-WM-SP-012, Rev. 6, CH2M Hill Hanford Group, Inc., January, 2007
7. A. P. POLOSKI, H. E. ADKINS, J. ABREHAH, A. M. CASELLA, R. E. HOHIMER, F. NIGL, M. J. MINETTE, J. J. TOTH, J. M. TINGEY, S. T. YOKUDA, "Depostion Velocities of Newtonian and Non-Newtonian Slurries in Pipelines, WTP-RPT-175, Rev. 0, Pacific Northwest National Laboratory, March 2009
8. I. G. PAPP and G. M. DUNCAN, "Investigation of Erosion from High Level Waste Slurries on the Hanford Waste Treatment Plant", Bechtel Technical Journal, December, 2009.

---

[1] "Pretreatment Facility Availability - Phase 1 Evaluation Report, Bechtel National, Inc. , 24590-WTP-RPT-PO-06-002, Rev. 2, December 8, 2009.

[2] "External Flowsheet Review team (EFRT) Issue M15 Pretreatment Facility Availability - Phase 2 Evaluation Report", Bechtel National, Inc., 24590-WTP-RPT-PET-07-004, February, 2008

[3] "Recommendation of Alternative to Mitigate Solids Precipitation after Ultrafiltration", Bechtel National, Inc., 24590-WTP-RPT-PET-09-006, January 2010.

9. P.A. MEYER, C. W. ENDERLIN, B. E. WELLS, P. A. SCOTT, G. L. SMITH, M. S. GREENWOOD, E. B .K. BAER, M. WHITE, B. G. AMIDAN, J. A. BAMBERGER, J. A. FORT, S. K. SUNDARAM, M. J. MINETTE, C. A. BURNS, G. P. MORGAN, S. F. SNYDER, G. F. PIEPEL, A., HEREDIA-LANGNER, "Pulse Jet Mixing tests With Noncohesive Solids", WTP-RPT-182, Rev. 0, Pacific Northwest National Laboratory, May 2009
10. R.C. DANIEL, J. M. BILLING, J. R. BRONTHA, C.F.BROWN, P. W. ESLINGER, B.D. HANSON, J.L. HCKABY, N. K. KARRI, M.L. KIMURA, D. E. KURATH, M J. MINETTE, "EFRT M-12 Issue Resolution: Comparison of Filter Performance at PEP and CUF Scale, WTP-RPT-185, Rev. 0, Pacific Northwest National Laboratory, August 2009
11. R. L. RUSSELL, R. A. PETERSON, D. E. RINEHART, J. V. CRUM, Laboratory Tests on Post-Filtration Precipitation in the WTP Pretreatment Process", WTP-RPT-205, Rev. 0, Pacific Northwest National Laboratory, November 2009.