U.S. Department of Energy
[redacted]
P.O. Box 450, MSIN H6-60
Richland, Washington 99352

SEP 1 9 2007

07-WTP-226

Mr. C. M. Albert, Project Manager
Bechtel National, Inc.
2435 Stevens Center Place
Richland, Washington 99354

Dear Mr. Albert:

CONTRACT NO. DE-AC27-01RV14136 – TRANSMITTAL OF U.S. DEPARTMENT OF ENERGY, OFFICE OF RIVER PROTECTION (ORP) DESIGN ASSESSMENT NUMBER D-07-DESIGN-040: REVIEW OF ALUMINUM ENTRAINMENT IN BECHTEL NATIONAL, INC.'S (BNIs) FEED RECEIPT AND EVAPORATOR SYSTEMS

The purpose of this letter is to transmit ORP's Design Oversight Report, "Review of Aluminum Entrainment in Bechtel National, Inc.'s Feed Receipt and Evaporator Systems." The report has no Findings and is provided for your information.

During the course of the Design Oversight Assessment, BNI and ORP agreed to conduct independent analyses of the impact of carbon dioxide on the potential precipitation of alumina species within the Pretreatment Facility. The analyses conducted by ORP are attached.

If you have any questions, please contact me, or your staff may call Robert Griffith, Acting Director, WTP Project Engineering Division, (509) 372-2821.

Sincerely,

John R. Eschenberg, Project Manager
Waste Treatment and Immobilization Plant Project

WTP:DHA

Attachment

cc w/attach:
W. Clements, BNI
W. S. Elkins, BNI
K. Reutell, BNI
J. Roth, BNI
G. Shell, BNI
BNI Correspondence

THE U.S. DEPARTMENT OF ENERGY (DOE), OFFICE OF RIVER PROTECTION (ORP) DESIGN OVERSIGHT REPORT

REVIEW OF ALUMINUM ENTRAINMENT IN BECHTEL NATIONAL, INC.'S FEED RECEIPT AND EVAPORATOR SYSTEMS

March 2007

Design Oversight: D-07-DESIGN-040

Team Lead:

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EXECUTIVE SUMMARY

The U.S. Department of Energy, Office of River Protection Waste Treatment and Immobilization Plant (WTP) Engineering Division staff conducted an assessment of Bechtel National, Inc.'s (BNI) design of the feed receipt vessels, feed evaporators, and their support systems. The following are the specific objectives of this oversight:

- Review the thermodynamic flowsheet evaluations to identify potential areas where aluminum species precipitation may be problematic.
- Review the chemical operating environment in processing equipment located in the feed evaporators black cell (FEP-SEP-01 A/B) to determine if precipitation and accumulation of aluminum species can lead to fouling or precipitation.
- Review the accessibility to equipment located in the feed evaporators black cell (FEP-SEP-01 A/B) to determine if precipitated aluminum species can be readily removed.
- Review selected bounding waste feed receipt envelopes to be delivered to the four Waste Feed Receipt Process System vessels and to High-Level Waste Lag Storage and Feed Blending Process System (HLP-22) to determine if aluminum precipitation could pose an issue in these vessels.

BNI met and agreed to conduct joint flowsheet calculations. The following summarizes the primary observations of the DOE team:

1. Carbon dioxide (CO_2) mass balance in the Waste Treatment and Immobilization Plant may result in under-estimation of sodium hydroxide (NaOH) consumption especially in pulse jet mixer tubes and in post-overblow conditions (Appendix B).
2. The accumulation of aluminum and phosphate species may result in local non-Newtonian conditions in tanks designed with Newtonian mixing systems.
3. There is a potential for recycle streams to promote the precipitation of aluminum species which will require the need for more frequent vessel flushes during facility operations.
4. The evaporator design appears to provide maintenance for removal of scaling or solids buildup due to aluminum.
5. Because of dynamic processing conditions in the WTP, pH measurements will be very important. Design accommodations in the Hot Cell appear to mitigate this concern.

BNI is developing plans to respond to many of these issues raised independently by the External Flowsheet Review Team and the DOE Technology Readiness Assessments. In addition, a guide is being developed for *Avoiding Chemical Line Plugging – Plant Design Considerations* (24590-WTP-GPG-M-0059). These efforts adequately address many of the lines of inquiry in the Oversight Plan (Appendix A), which served as the basis for this assessment.

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APPENDICES

ACRONYMS

AFI	Assessment Follow-up Item
BHRG	British Hydromechanical Research Group
BNI	Bechtel National, Inc.
CO_2	carbon dioxide
DOE	U.S. Department of Energy
EFRT	External Flowsheet Review Team
FEP	Waste Feed Evaporation Process System
FRP	Waste Feed Receipt Process System
HLP	High-Level Waste Lag Storage and Feed Blending Process System
HLW	high-level waste
LAW	Low-Activity Waste [Facility]
NaOH	sodium hydroxide
ORP	Office of River Protection
PJM	pulse jet mixer
PT	Pretreatment [Facility]
PWD	Plant Wash and Disposal System
SCFM	Standard Cubic Feet per Minute
TWINS	Tank Waste Information Network System
UFP	Ultrafiltration Process System
WTP	Waste Treatment and Immobilization Plant

1.0 INTRODUCTION

A major component of the U.S. Department of Energy (DOE), Office of River Protection's (ORP) mission is the design and construction of the Hanford Tank Waste Treatment and Immobilization Plant (WTP) in the 200 East Area of the Hanford Site. The design and construction contractor for the WTP is Bechtel National, Inc. (BNI) (the Contractor). As part of its oversight responsibilities, ORP performs various assessments of BNI activities during the design and construction phase. This design oversight assessment reviews BNI's design of the feed receipt vessels, feed evaporators, and their support systems, to assess their ability to manage potential phosphate, aluminum hydroxide, alumino-silicate scale or gel formation and entrainment, and potential impacts of aluminum on waste feed rheology.

2.0 BACKGROUND

Historically, the tendency for aluminum to readily precipitate or dissolve due to minor changes in pH and temperature continues to pose a number of issues in the processing of Hanford and Savannah River radioactive wastes (Hobbs 1986; 1987).

Aluminum species can precipitate as gels or as solids. Gels are high viscosity, non-settling, thixotropic suspensions of precipitated amorphous solids. Amorphous gels were encountered in the early 1980's during partial neutralization of the waste processed through the 242-S Evaporator. These gels have also been responsible for several pipeline plugging incidents in the tank farms (Boomer et al. 2004). Numerous compounds have been identified as having the potential to lead to the formation of gels in tank wastes. Four compounds that have a high potential to form gel in the Waste Treatment Plant include: aluminum hydroxide, sodium carbonate, sodium aluminate, and sodium phosphate. For more details on their occurrence in tank wastes see the summary by Boomer et al.

Aluminum containing phases represent prevalent solids that can appear or disappear during the processing of radioactive tank wastes. Processes such as sludge washing and leaching are designed to dissolve aluminum-containing phases, thereby minimizing the volume of high-level waste glass required to encapsulate radioactive waste sludges. However, in order to retain aluminum in solution, slurries require the addition of a substantial quantity of caustic (sodium hydroxide [NaOH]), which is a primary chemical constituent that drives glass volume and therefore, mission duration. Therefore, there is a "crucial" balance between NaOH consumption and retention of aluminum in solution.

Of all the constituents of tank waste, limited solubility cementitious aluminum hydroxides, aluminosilicates, and sodium phosphates have the greatest potential for clogging pipes and transfer lines, fouling ultrafilters and ion exchangers, and completely shutting down operations. Aluminum deposits have even shut down the evaporators at the Hanford and Savannah River Sites (Wilmarth et al. February 2002). ORP's External Flowsheet Review Team (EFRT) recently (CCN: 132846, March 2006) raised similar concerns with the WTP Project flowsheet.

3.0 OBJECTIVES, SCOPE, AND APPROACH

3.1 Objectives

ORP staff conducted this assessment with the following specific objectives:

1. Review the thermodynamic flowsheet evaluations to identify potential areas where aluminum, phosphate, and sodium carbonate species precipitation may be problematic.
2. Review the chemical operating environment in processing equipment located in the feed evaporators black cell (FEP-SEP-01 A/B) to determine if precipitation and accumulation of aluminum species can lead to fouling or precipitation in equipment and/or in associated piping.
3. Review the accessibility to equipment and piping located in the feed evaporators black cell (FEP-SEP-01 A/B) to determine whether precipitated aluminum species can be readily removed.
4. Review selected bounding waste feed receipt envelopes to be delivered to the four Waste Feed Receipt Process System (FRP) vessels and to the High-Level Waste Lag Storage and Feed Blending Process System (HLP-22) to determine if aluminum precipitation could pose an issue in these vessels or associated piping and support systems.

3.2 Scope

This oversight assessment includes review of project plans, procedures, and records associated with the process design in the two targeted areas: FRP and HLP waste receipt vessels and the Waste Feed Evaporation Process System (FEP). The Oversight Team also examined plans, procedures, and records associated with the avoidance or removal of plugging or scale formation.

3.3 Approach

ORP conducted this oversight within the guidelines of the WTP Engineering Division Desk Instruction (DI) 220.1, Rev. 1, "Conduct of Design Oversight," as revised January 2006, and is based on DOE O 226.1, *Implementation of Department of Energy Oversight Policy*, and ORP M 220.1, *ORP Integrated Assessment Program*, Rev. 4. ORP collected information from various BNI and DOE documents and conducted interviews with BNI design staff (see Section 6.0 for a full listing of reviewed documents and personnel contacted). The approved design oversight plan, *Aluminum Entrainment in Feed Receipt and Feed Evaporator Systems*, is provided in Appendix A.

The design review team initiated the following steps to obtain information required to meet the oversight objectives. The order of review and depth of each step was left to the individual reviewer's discretion.

1. The team interviewed ORP and Contractor personnel and reviewed documentation, including relevant test reports, test plans, Tank Waste Information Network System (TWINS) database, and external flowsheet review plans, and completed a literature survey.
2. Chemical processing personnel at Savannah River National Laboratory were interviewed

with respect to aluminum precipitation and its relationship to rheology in Savannah River high-level waste tank waste slurries (Dr. Bond Calloway), and the management and uptake of carbon dioxide (CO_2) as it pertains to the precipitation of carbonates, aluminum species, and phosphate species (David Hobbs).

3. DOE and BNI met and agreed to conduct flowsheet analyses. The results of the DOE analyses are presented in Appendix B.

4.0 RESULTS

4.1 Assessment of Carbon Dioxide Absorption

The absorption of CO_2 from the atmosphere by strongly alkaline waste slurries is known to lower solution pH. CO_2 in air reacts continuously with NaOH to produce carbonate precipitates. When NaOH is brought in contact with air, it acts as a CO_2 absorber:

$$CO_2 + 2\ Na+ +2\ OH- \rightarrow\ CO_3^{-2} + 2\ Na+ +H_2O \qquad \textbf{\textit{Eq. 1}}$$

As long as there is an excess of hydroxide (OH) ions (>0.1 molar free hydroxide), CO_2 will be absorbed, resulting in the precipitation of carbonates.

In Hanford Site tank wastes, hydroxide ions are typically in great excess in solution since NaOH is periodically added to the waste slurry system to control the corrosion of the low-carbon steel waste tanks. More importantly, as it relates to this review, NaOH is planned to be added at the WTP to keep aluminum (in the form of the aluminate anion) in solution so that it can be sent to the Low-Activity Waste (LAW) Vitrification Facility.

Unfortunately, as more NaOH is added to the system, the rate of CO_2 uptake is increased. Approximately 75% of the CO_2 entering waste tanks at Savannah River was absorbed when the free hydroxide concentration was above 0.1 molar (Hobbs 1986: 1987). The rate of absorption is much greater at a pH of above 10.4 than below because at 10.4 there is a carbonate-bicarbonate buffer. The change in CO_2 absorption rate in waste slurries at pH= 10.4 can be seen in the data presented in Hobbs (1986), Figures 2 and 5. Since the pH operating conditions for the WTP are typically greater than 13, the absorption of CO_2 will be significant.

In addition to the impact on CO_2 uptake due to ventilation air studied at Savannah River (Hobbs 1986; 1987), air will also be provided by pulse jet mixers (PJM) and air spargers at the WTP. Air spargers are used in the five "non-Newtonian" vessels in the Pretreatment (PT) Facility (UFP 2A, UFP 2B, HLP 27A, HLP 27B, and HLP 28). The results of the Hybrid Mixing System test data for these vessels indicate a range of air supplied by spargers at 362 scfm for the smaller diameter Ultrafiltration Process System (UFP) vessels, and up to 1638 scfm for the HLP 28 blend vessel (24590-PTF-RPT-RT-04-0003).

It appears that CO_2 absorption has been inadequately accounted for at the WTP, especially when spargers are used in the mixing process. Spargers are used in combination with PJMs to mix slurries that are anticipated to experience a non-Newtonian condition. The spargers and PJMs vigorously mix waste slurries in order to maintain design specifications for rheology. The non-Newtonian mixing systems are designed to manage wastes with yield strengths in the bounding 20 to 30 Pa range.

The vessels assessed in the scope of this oversight review do not utilize air spargers. However, the use of PJMs alone could substantially increase the absorption of CO_2 over that experienced in infrequently mixed tank farm waste slurries. The evaluation of carbonate behavior based on feed values and potential increases has been evaluated for some feeds and processing needs.

The mixing requirement to manage non-Newtonian rheology requires increased introduction of air into the waste slurry and hence will increase the absorption rate of CO_2 by the wastes. The consequence is that larger additions of NaOH will be required to manage pH than have been estimated through equilibrium and kinetic considerations involving the Equation 1.

Because of the compositional variation in aluminum and phosphate in Hanford Site tank farms, it appears that insufficient modeling has been completed to characterize the importance of CO_2 absorption and the corresponding NaOH requirements to minimize aluminum precipitation.

Hobbs (personal communication) reports that Savannah River high-level waste (HLW) "waste tanks absorbed about 75% of the carbon dioxide from the air that passes through the vapor space of the waste tanks." If the increased requirement for NaOH additions due to air sparging and pulse jet mixing is substantially greater than specified in the Basis of Design, it could impact mission duration. Hobbs expects "carbon dioxide absorption to occur when strongly alkaline waste solutions are contacted with air containing carbon dioxide via jet pulse mixers and air spargers such as that planned for the Hanford Waste Treatment Plant."

Spargers directly introduce large quantities of air, and thus CO_2, into waste slurries. PJMs also increase the rate at which the waste is exposed to air because the PJMs are designed to mix the wastes by cycling slurries at the bottom of the vessels with those at the air interface. Additionally, for PJM systems there is an air-slurry interface within each pulse tube. Therefore, the Oversight Team expects that CO_2 absorption will be substantially increased due to ventilation air, sparger air, and PJM air.

4.2 Potential Non-Newtonian Conditions in Newtonian Vessels

At least one vessel, and potentially several, in the feed receipt and recycle systems at the front end of the WTP pretreatment process may have underpowered mixing systems (24590-WTP-RTP-PR-07-002, 2007). These recent evaluations are based on British Hydromechanical Research Group (BHRG) methodology. The extent to which the vessels are underpowered has not been fully considered since the BHRG methodology does not consider the additional effect of the absorption of CO_2 by the waste slurries (Strieper, personal communication).

The continuous absorption of CO_2 in the waste slurries from air can lead to the precipitation of a number of simple (hydroxides) and complex aluminum and phosphate species. The precipitation of these species is known to adversely affect the system rheology since the species precipitate as microcrystalline solids and amorphous gels (Calloway et al. 2004).

The absorption of CO_2 from ventilation, PJM mixing, or sparge air in the presence of aluminum or phosphate species will have an impact on the yield stress of waste slurries; see Figure 1.

As CO_2 is absorbed, the pH of the waste slurry will drop due to the formation of carbonic acid (H_2CO_3). In turn, aluminum (if present) will precipitate and the yield stress of the waste slurry will increase. The Oversight Team recognizes that Calloway et al. (2004) (Figure 1) will also be affected by waste slurry temperature.

Figure 1. Impact of pH on Yield Stress (Calloway et al. 2004)

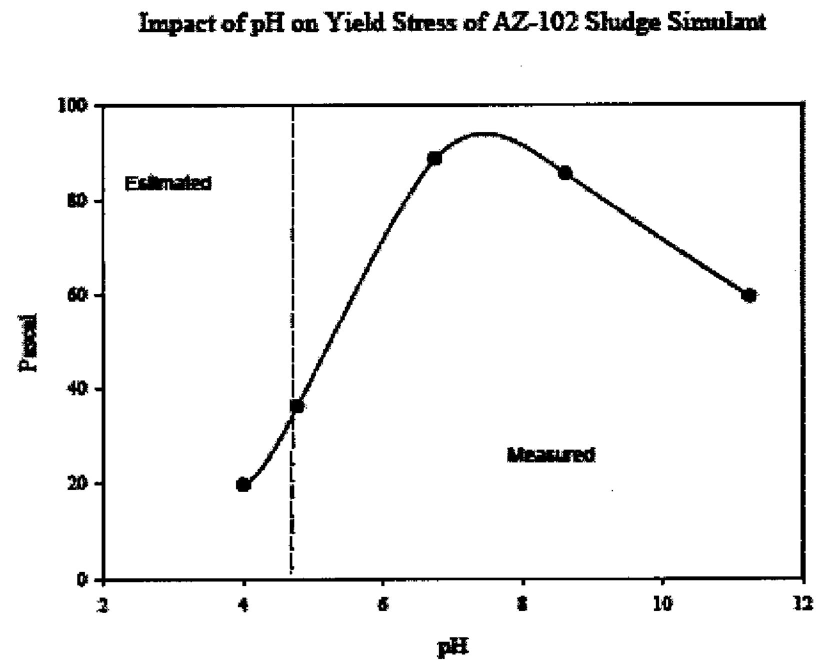
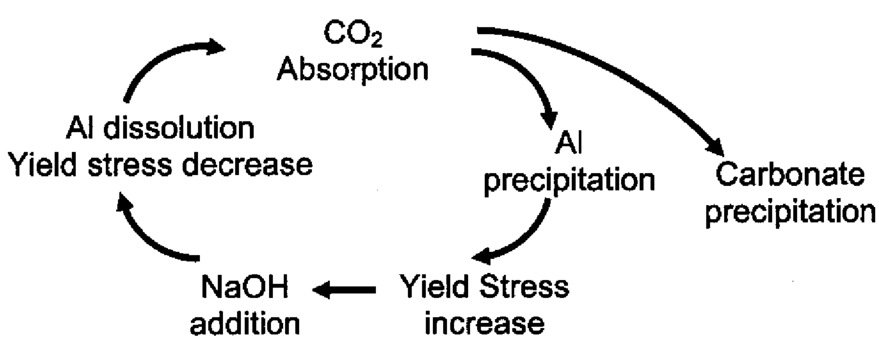


Figure 5 – Impact of pH on Yield Stress of AZ102 Sludge Simulant – Note Sludge Simulant was Not Treated Using Current WTP Recipes (Heat Treatment) which are Likely to Reduce Yield Stress even Further – Curve is Extrapolated to pH for WTP Pulse Jet Program Planning

The absorption of CO_2 has been estimated at approximately 75% for waste slurries above 0.1 molar hydroxide (Hobbs 1987). The absorption of CO_2 at the high pH range in the PT Facility will result in a complex cycle: CO_2 → aluminum and carbonate precipitation→yield stress increase → NaOH addition → Al dissolution + yield stress decrease. This cycle is illustrated in the Figure 2.

Figure 2. Absorption of CO_2 Cycle



The removal of CO_2 from the system will result from the precipitation of carbonates including metals and alkaline earths.

If the accumulation of aluminum and/or phosphate amorphous gels and solids is substantial, then the waste slurry may exhibit non-Newtonian behavior.

The vessels in the feed receipt and recycle streams currently have mixing systems designed to mix Newtonian slurries. If non-Newtonian conditions gradually arise because of a near-saturation or over-saturation of aluminum and/or phosphate, the current mixing systems may be underpowered compared to the recent evaluations based on BHRG methodology.

According to BNI (unpublished e-mail response to lines of inquiry), the operation of the following vessels designed to be operated under Newtonian conditions is dependent on a feed and batch mode during operations.

> "The following is dependent on the approach selected by the operating contractor. However, the approach taken by contractors at other vitrification facilities in the complex has been to develop unique campaign plans for each feed transfer campaign from the tank farm to the processing facilities. Applied to WTP these plans would address residence time in the front end vessels and processing strategies specific to those feeds. These types of plans are also those that would be used to evaluate the flowsheet for a specific feed, perform prequalification testing, and plan any non-routine maintenance such as vessel flushes."
>
> Note: Underpowered mixing also is being evaluated for Newtonian feeds in the resolution to the M3 EFRT task."

Specific vessels that should be further evaluated include:

1. HLP-VSL-00022 vessel: The Basis of Design allows receipt of up to 16.68 weight% solids (~200 grams of solids/liter of waste) in the HLP-00022 vessel. BNI has identified the potential need for increasing the power of the mixing system for this vessel based on the quantity of solids alone (24590-WTP-RTP-PR-07-002, pp. 11-13). The final sizing of the mixing system for this vessel should factor in the potential formation of amorphous gels that could lead to non-Newtonian conditions.

   > "Consistency and yield stress were shown to increase significantly past 7 wt% solids. Consistency was 4-6cP below 7w% solids and 12 cP at 9% solids while yield stress went from 3 dynes/cm2 at 7% solids to 27 dynes/cm2 at 9% solids." (WSRC-TR-2003-00212, p. 4).

   According to BNI (unpublished e-mail response to lines of inquiry):

   > "This vessel is anticipated to have at the most weeks of retention time, not months or longer. This should assist with preventing the opportunity for precipitation to occur as batches are processed through the vessel. Water and NaOH solutions are available to this vessel if needed."

2. PWD-VSL-00015/16/44: The Plant Wash and Disposal System (PWD) vessels have the potential to accumulate solids over a prolonged period. Aluminum in the recycle streams passing through the PWD will experience frequent pH excursions resulting from high-level waste and from ultrafiltration acid/caustic effluent. The periodic change in pH can lead to the accumulation of aluminum solids. Aluminum goes through three primary phase changes: aluminate anion at high pH (>13) to gel at moderately high pH (10-13) and solids at moderate pH levels (<10). Aluminum or phosphate solids, once formed, are difficult to re-dissolve and have the potential to accumulate in the PWD.

"The formation of gels in the WTP could impact processing and should be mitigated. Given the possible variations in compositions of the UF recycle streams and amounts of acid cleaning solution, accurate measurement or prediction of the pH of the blended UF recycle streams will be necessary to adjust the pH as required to mitigate the gel formation or excess NaOH added to ensure that the required pH of the blended recycle is maintained." (WSRC-TR-2003-00212, p. 6)

According to BNI (unpublished e-mail response to lines of inquiry):

"The residence time in PWD is relatively short. PWD vessels 15 and 16 are relatively dilute. PWD is a mixture of several process streams. These vessels undergo caustic adjustment to a pH of 12 under an administrative hold point prior to being fed forward in the facility. Each of these vessels is equipped with spray rings and is hard piped to demineralized water, plant condensate, and concentration sodium hydroxide. Dilute 2M NaOH and 2M HNO3 solutions can be accessed through hose connections. Plans for vessel flushes would need to be developed during the campaign planning activity mentioned above."

3. FEP-00017A/B: Waste slurries from the PWD are combined with waste slurries from the FRP slurries in the feed evaporator process vessels (FEP). Although not as subject to the wide swings in pH, the FEP vessels may also experience occasional aluminum and phosphate gel formation or solids accumulation.

   According to BNI (unpublished e-mail response to lines of inquiry):

   "Caustic additions can be made to these vessels. Spray rings as in the PWD system are also present."

4.3 Potential Recycle Stream Upset Conditions

Aluminum in the tank farms is managed on a batch-by-batch basis. However, at the WTP, the interactions among feed streams are dynamic. Aluminum can accumulate in the recycle streams and be deposited in the PWD, FEP, UFP, and FEP evaporator.

"Filtration tests were conducted with Envelope A waste/recycle blends to determine the impact of adding recycle to the waste feed. The tests indicated that the primary impact of adding the recycle was to increase the initial solids content of the filtration feed. The increased solids loading led to lower initial permeate rates." (WSRC-TR-2003-00212, p. 5)

According to BNI (unpublished e-mail response to lines of inquiry): "The process flowsheet has been updated and aluminum feeds are fed forward through the process. This is due to the implementation of the caustic leach strategy and update in the filter capacity in the referenced R&T report was issued."

4.4 Potential Formation of Solids and Evaporator Fouling

Since the FEP evaporators are located in a black cell, the Contractor has made provisions for conducting remote de-fouling (unpublished e-mail response to lines of inquiry):

"There are demineralized water, plant condensate, sodium hydroxide, and nitric acid solutions available to de-foul the evaporators if necessary."

If the FEP drains should accumulate scale or sludge, there are provisions to clear the drains remotely. According to BNI (unpublished e-mail response to lines of inquiry):

> "There is capability present to wash the evaporator demister pads. To clean a drain, the evaporator could be filled with water, acid, caustic etc. to attempt to flush the drain."

4.5 Potentially Inadequate Measurement of pH in Black Cell Radwaste Slurries

If pH measurements are not monitored in black cell processing vessels, precipitation and solids accumulation could occur unchecked.

> "An ISFET pH probe was utilized in the lab to accurately measure the pH but the probes were difficult to keep clean and may not be feasible in the WTP."
> (WSRC-TR-2003-00212, p. 6)

Continuous monitoring of pH in the dynamic waste slurry streams involving continuous recycle streams will be important to avoid process upsets.

During the interview process, the Oversight Team was informed that pH probes were removed from processing streams within the black cells. If the frequency of pH monitoring is insufficient, aluminum and phosphate precipitation could ensue.

According to BNI (unpublished e-mail response to lines of inquiry):

> "The ISARD (24590-WTP-PL-PR-04-0001) Appendix C gives the frequency and the summarized analyses. Appendix B provides the analytes derived from the analysis. pH is one of the instruments in several of the hotcells where all samples from those sample points arrive.
>
> There are:
>
> 2 FRP samples/Mo = 24/year Identified as PT 2
>
> 0.5 HLP samples/Mo = 6/year Identified as PT 17
>
> 1 PWD sample/Week = 52/year from PWD-VSL-00045 Identified as PT 11
>
> 1 PWD sample/Mo = 12/year from PWD-VSL-00044 Identified as PT 12
>
> 1 PWD sample/Mo - 12/year from PWD-VSL-00015/16 Identified as PT 14
>
> No FEP samples are scheduled on a routine basis. In section 6 of the ISARD there is a non-routine sampler available if required by process upset and is designated PT 33."

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5.3 Personnel Contacted

B. Calloway
F. Damerow
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J. Meehan
E. Strieper

Appendix A

Design Product Oversight Plan

U.S. DEPARTMENT OF ENERGY, OFFICE OF RIVER PROTECTION DESIGN PRODUCT OVERSIGHT PLAN

WASTE ENGINEERING DIVISION ASSESSMENT OF ALUMINUM ENTRAINMENT IN FEED RECEIPT AND FEED EVAPORATOR SYSTEMS

FEBRUARY 2007

Design Product Oversight: D-07-DESIGN-040

DESIGN PRODUCT OVERSIGHT PLAN

WASTE ENGINEERING DIVISION ASSESSMENT OF ALUMINUM ENTRAINMENT IN FEED RECEIPT AND FEED EVAPORATOR SYSTEMS

February 5, 2007

Design Oversight: D-07-DESIGN-040

Team Lead: Donald Alexander
C. K. Liu
Dr. Jennifer Holland

Submitted by:

_______________________________ Date ______________
Donald Alexander, Team Lead
WTP Engineering Division

1.0 BACKGROUND, PURPOSE AND OBJECTIVES

1.1 BACKGROUND

Historically, the tendency for aluminum to readily precipitate or dissolve due to minor changes in pH and temperature continues to pose a number of issues in the processing of Hanford and Savannah River radioactive wastes. Aluminum containing phases represent the most prevalent solids that can appear or disappear during the processing of radioactive tank wastes. Processes such as sludge washing and leaching are designed to dissolve aluminum-containing phases, thereby minimizing the volume of high-level waste glass required to encapsulate radioactive waste sludges.

Of all the constituents of tank waste, limited solubility cementitious aluminum-hydroxides and aluminosilicates have the greatest potential for clogging pipes and transfer lines, fouling ultrafilters and ion exchangers, and completely shutting down operations. Aluminum deposits have even shut down the evaporators at the Hanford and Savannah River Sites (during the tank waste volume reduction campaign in October 1999). The U.S. Department of Energy (DOE), Office of River Protection's (ORP) External Flowsheet Review Team (EFRT) recently (2005) raised similar concerns about the Waste Treatment and Immobilization Plant (WTP) Project flowsheet.

1.2 PURPOSE

This design oversight assessment will focus on the potential for design and operational impacts due to the precipitation and dissolution of aluminum in the WTP Pretreatment (PT) Facility flowsheet from feed receipt to the Waste Feed Evaporation Process System (FEP)-Waste Feed Evaporator Separator (SEP) system. Ultrafiltration and post-ultrafiltration oversights are scheduled for later in the summer of 2007.

1.3 OBJECTIVES

The following are the specific objectives of this oversight:

1. Review the thermodynamic flowsheet evaluations to identify potential areas where aluminum species precipitation may be problematic.
2. Review the chemical operating environment in processing equipment located in the feed evaporators black cell (FEP-SEP-01 A/B) to determine if precipitation and accumulation of aluminum species can lead to fouling or precipitation in equipment and/or in associated piping.
3. Review the accessibility to equipment and piping located in the feed evaporators black cell (FEP-SEP-01 A/B) to determine whether precipitated aluminum species can be readily removed.
4. Review selected bounding waste feed receipt envelopes to be delivered to the four Waste Feed Receipt Process System (FRP) vessels and to High Level Waste Lag Storage System (HLP)-22 to determine if aluminum precipitation could pose an issue in these vessels or associated piping and support systems.

2.0 PROCESS

This oversight shall be conducted within the guidelines of ORP M 220.1 and the WTP Engineering Division Desk Instruction DI 220.1, Rev. 1, "Conduct of Design Oversight," as revised January 13, 2006.

2.1 SCOPE

This oversight will include review of project plans, procedures, and records associated with the process design in the two targeted areas: FRP and HLP waste receipt vessels and the FEP evaporator system. Plans, procedures, and records associated with the avoidance or removal of plugging or scale formation will be examined.

2.2 PREPARATION

1. Identify the Contractor Point of Contact (POC) for the Review.

2. Obtain from Bechtel National, Inc. (BNI) a list of design procedures and construction procedures involved with the design and maintenance of the FRP and HLP feed receipt systems and the FEP evaporator systems.

3. Obtain the research and technology (R&T) plans dealing with the avoidance or mitigation of aluminum precipitation in the identified unit operations and lines.

4. Obtain EFRT issue response plans dealing with aluminum precipitation as they pertain to the objectives of this oversight.

5. Obtain EFRT report information dealing with aluminum precipitation.

2.3 DOCUMENT REVIEW

The oversight will review the requested documentation and prepare lines of inquiry for use in interviews and field observations, and may be used to identify any further documents that may need to be requested. This should take place prior to the assessment entrance, if at all possible, but, in any case, prior to start of field assessment. Notes should be retained identifying the document title and number reviewed and any results of the review for use in preparing assessment notes. Assessment notes will be written by each team member as input to the report.

The Team Lead will:

1. De-brief ORP and Contractor (BNI) management periodically as required.
2. Prepare a draft report that summarizes the activities, the results, conclusions, and recommendations of the review.
3. Issue the Draft Design Oversight Report for review and comment by ORP management and cognizant Contractor personnel. The final report will resolve comments received on the draft report.

3.0 SCHEDULE OF ACTIVITIES

Table 2 summarizes the schedule for completion of this oversight.

4.0 DOCUMENTATION

The final report of this task shall contain the sections and content as summarized in ORP DI 220.1 Rev. 1, "Conduct of Design Oversight," draft as revised March 2006.

The issues identified in this oversight shall be listed in the final report. Each issue shall be assigned a type of issue and item number for tracking to resolution through the Consolidated Action Reporting System. Issues shall also be tracked to resolution by the Contractor through the Correspondence Control Number that ORP will assign to the Contractor's transmittal.

5.0 CLOSURE

The Team Lead with concurrence of the WTP Federal Project Director shall confirm that the items from this oversight are adequately resolved.

Table 1 – Initial Information Requirements

1.	R&T plans and reports that address aluminum precipitation, evaporator operation, and mixing systems in feed receipt vessels.
2.	EFRT response plans that address aluminum precipitation.
3.	General design and Computer Aided Design (CAD) drawings of the FRP and HLP black cells.
4.	General design and CAD drawings of the FEP evaporator black cell.
5.	Thermodynamic calculations indicating the concentration of aluminum throughout the PT Facility for a range of feed types.

Table 2 – Schedule

Activity Description	Responsibility	Complete By
Develop Design Oversight Plan.	Alexander	1/26/07
Identify Team members.	Alexander/Miller	1/26/07
Obtain approved plan and advise Contractor of planned oversight, provide Design Process Oversight Plan to identify needed Contractor support, and obtain POC.	Eschenberg/Miller	1/30/07
Obtain Contractor documentation defined in Table 1 above to support review and provide to team members.	Alexander	2/02/07
Qualify Team members – Attachment 9.1	Alexander	2/07/07
Kick-off meeting with Contractor to outline objectives, scope, schedule, and establish POCs.	Team	2/09/07
Review documents from Contractor and provide oversight strategy, lines of inquiry, and interview requests to Team Lead.	Team	2/16/07
Review Contractor documents, participate in relevant Contractor internal meetings, and meet with Contractor as required.	Team	2/26/07
Prepare Draft Design Oversight Report Notes.	Team	2/28/07
ORP and Contractor Exit Briefing.	Team and Contractor	3/02/07
Draft Report	Team	3/ 08/07
Resolve comments and place Final Report into concurrence including factual accuracy review with Contractor.	Alexander	3/16/07
Approve Final Report.	All on Concurrence	3/22/07

Appendix B

Evaluation of Tank Waste Carbon Dioxide Absorption Estimations within the Hanford Waste Treatment Plant Pretreatment Facility

EVALUATION OF TANK WASTE CARBON DIOXIDE ABSORPTION ESTIMATIONS WITHIN THE HANFORD WASTE TREATMENT PLANT PRETREATMENT FACILITY

JENNIFER E. HOLLAND, PH.D.

prepared for

The United States Department of Energy, Office of River Protection
Under contract number DE-AB27-03RV14546

JULY 27, 2007

JEH CONSULTING, INC.
Richland, WA

EXECUTIVE SUMMARY

The possible interference of carbon dioxide (CO_2) absorption during tank waste processing in the Hanford Waste Treatment Plant Pretreatment Facility was evaluated. Estimations provided by Bechtel National, Inc. and thermodynamic flowsheet modeling performed by Areva, Inc. both indicate CO_2 will not significantly affect tank waste processing during normal operation of Pretreatment facility baseline flowsheet. However, thermodynamic modeling results data predict CO_2 absorption experienced during a PJM overblow will neutralize tank waste to a pH lower than acceptable. Therefore, the possible localized of effects of CO_2 on tank waste retained in the PJM nozzle during normal operation has become a concern; it is recommended that possible unwanted effects of solids precipitation in the PJM nozzle be evaluated.

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LIST OF ACRONYMS

USDOE = United States Department of Energy
ORP = Office of River Protection
BNI = Bechtel National, Inc.
WTP = Waste Treatment Plant
PTF = Pretreatment Facility
CO_2 = carbon dioxide
ESP = Environmental Simulation Program
PJM = pulsed jet mixer
OH^- = hydroxide
pH = $-\log[H^+]$
NaOH = sodium hydroxide (caustic)
$Al(OH)_3$ = aluminum hydroxide

1. INTRODUCTION

During recent oversight assessment D-07-DESIGN-040, the United States Department of Energy Office of River Protection (USDOE-ORP) became concerned that the Bechtel National Inc. (BNI) flowsheet for the Hanford Waste Treatment Plant (WTP) Pretreatment Facility (PTF) would not adequately provide for the effects of atmospheric carbon dioxide (CO_2) absorption on the pH and viscosity of the tank waste during processing. In order to further evaluate this issue, ORP asked Bechtel National, Inc. (BNI) to provide a calculation of CO_2 absorption by tank waste within PTF. ORP then contracted Areva, Inc. to model tank waste processing conditions in the PTF baseline flowsheet using OLI Systems Inc. Environmental Simulation Program (ESP) with specific attention to the effect of tank waste absorption of atmospheric CO_2. ORP has contracted JEH Consulting, Inc. to analyze and compare BNI calculations and the ESP modeling runs, the results of which are included in this report.

2. OVERVIEW OF BNI ESTIMATION AND ESP MODEL RESULTS

2.1. BNI ESTIMATION

BNI completed calculations to estimate the effect of CO_2 absorption for all vessels in the pretreatment facility using an Excel spreadsheet. Only passive/forced purged air and sparge air were considered as sources of CO_2. Pulsed jet mixers (PJMs) were not considered as a source of CO_2 because the air within the PJMs is not to be dispersed into the tank waste during normal PJM operation. Expected normal residence times for each vessel were assumed. Calculation input parameters and results are shown in Table 2, Appendix A.

Vessel HLP-28 experiences the greatest airflow rate from spargers, therefore this vessel was used as a bounding case to demonstrate the effect of CO_2 on the pH of the waste. The change in CO_2 was calculated iteratively for each hour in an Excel spreadsheet. The Hobbs correlation was assumed to estimate absorption rate of CO_2 based on hydroxide concentration ($[OH^-]$); this correlation is derived from observations of Savannah River tank waste exposed to CO_2 (Hobbs, 1987) and provides an expression to model CO_2 absorption rate as it linearly declines with $[OH^-]$. Although this correlation was not derived from observations of Hanford tank waste, it is reasonable to use this correlation for an estimate since it is based solely on $[OH^-]$[1]. Figure 1 graphically depicts the calculated change in vessel pH and $[OH^-]$ with time. Over 80 days, the pH is shown to decrease from 13.3 to 11.9 and approximately 0.19 M hydroxide is consumed.

The normal operating residence time in HLP 28 is designed to be approximately 30 days, therefore it was concluded that a nominal pH change would be experienced. This drop in pH was estimated to maximally require an additional 2% (66 gallons/day assuming a Hobbs coefficient of 1 (100% absorption of CO_2)) of the total sodium hydroxide requirement to maintain an appropriately alkaline operating pH (pH = 13.3).

[1] Hobbs also observed a linear trend between nitrate and CO_2 absorption, however this term was not included in the least squares analysis since the coefficient was equal to only 0.641.

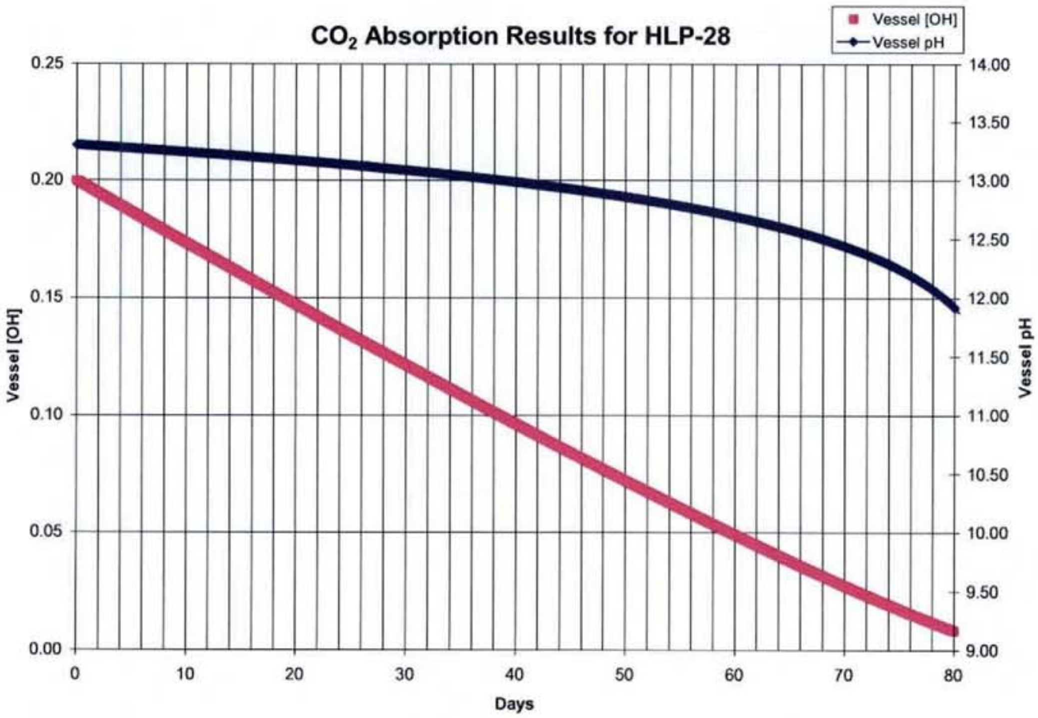


Figure 1. BNI Estimated Change in pH and [OH⁻] over 80 days in Vessel HLP28.

2.2. ESP Modeling

ESP equilibrium model calculations were performed by Areva, Inc. using the input chemistry of tank AZ-101. Species considered in the model are included in Appendix B. Eleven different cases were input to the model; assumptions for vessel vent system operation, CO_2 atmospheric concentration, and caustic addition rate are listed for each case in Table 2. Vessel vent system rates (specified by purge, PJM and sparge) are listed on flowsheet printouts for each case in Appendix C. PJM airflow rates greater than zero represent overblowing of the PJMs system, i.e. a percentage of the air within PJMs is being discharged into the waste; therefore, cases in which PJMs airflow rate is set at greater than zero model plant conditions during malfunctioning of the PJM system.

Table 1. Vessel Vent Air Flow Rates, CO_2 Concentration, and Caustic Addition Rates for ESP Model Cases.

Case	*Purge Air*	*PJM Airflow*	*Sparge Air*	*CO_2 (ppm)*[†]	*Caustic Addition*[*] *(lb/hr)*
A	100%	0%	None	481[‡]	61.7
B	100%	0%	None	0	61.7
C	100%	100%	100%	481	61.7
D	100%	100%	100%	481	264.4
E	100%	100%	100%	481	368.2
F	100%	100%	100%	481	387.7
G	100%	100%	60%	481	61.7
H	100%	100%	30%	481	61.7
I	100%	50%	50%	481	61.7
J	100%	100%	100%	481	398.9
K	100%	0%	100%	481	61.7

* Baseline rate = 61.7 lb/hr

† Concentration adjusted for humidity gained upon interaction with heated tank waste

‡ 481 ppm ~ 350 ppv

Changes in tank waste pH are shown in Figure 2. The pH is predicted to remain within acceptable alkaline operating levels in all cases except those in which PJMs are overblowing at 100%.

Mass of precipitated aluminum hydroxide ($Al(OH)_3\downarrow$) as gibbsite is shown in Figure 3. Cases in which the baseline addition rate of NaOH is employed are shown in Figure 4, and cases in which an increased rate of NaOH is employed are shown in Figure 5. Maximal overblow of PJMs results in an approximate 15% increase in predicted $Al(OH)_3\downarrow$. The use of spargers with PJMs operating normally (no overblow) is predicted to also increase $Al(OH)_3\downarrow$ by approximately 5% but only in HLP receiving vessel 28 post caustic leaching.

Mass of plutonium solubilized during processing is shown in Figure 6. No significant increase in plutonium dissolution is predicated in any of the cases.

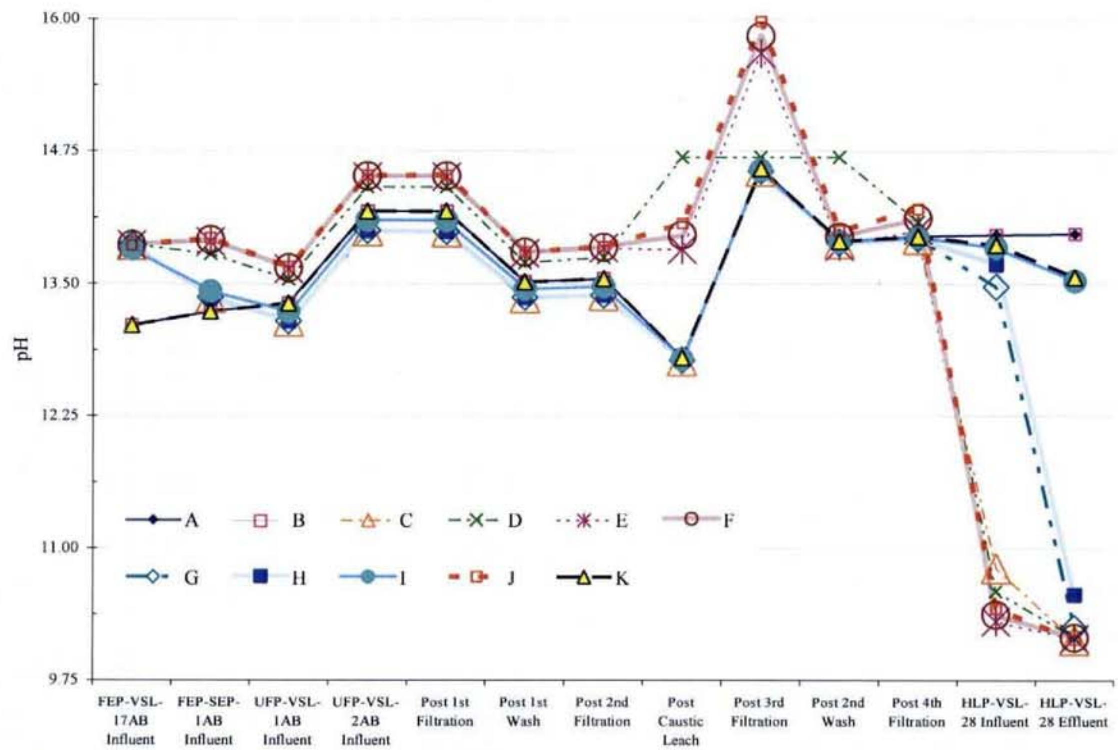


Figure 2. ESP Predicted pH During PTF Processing.

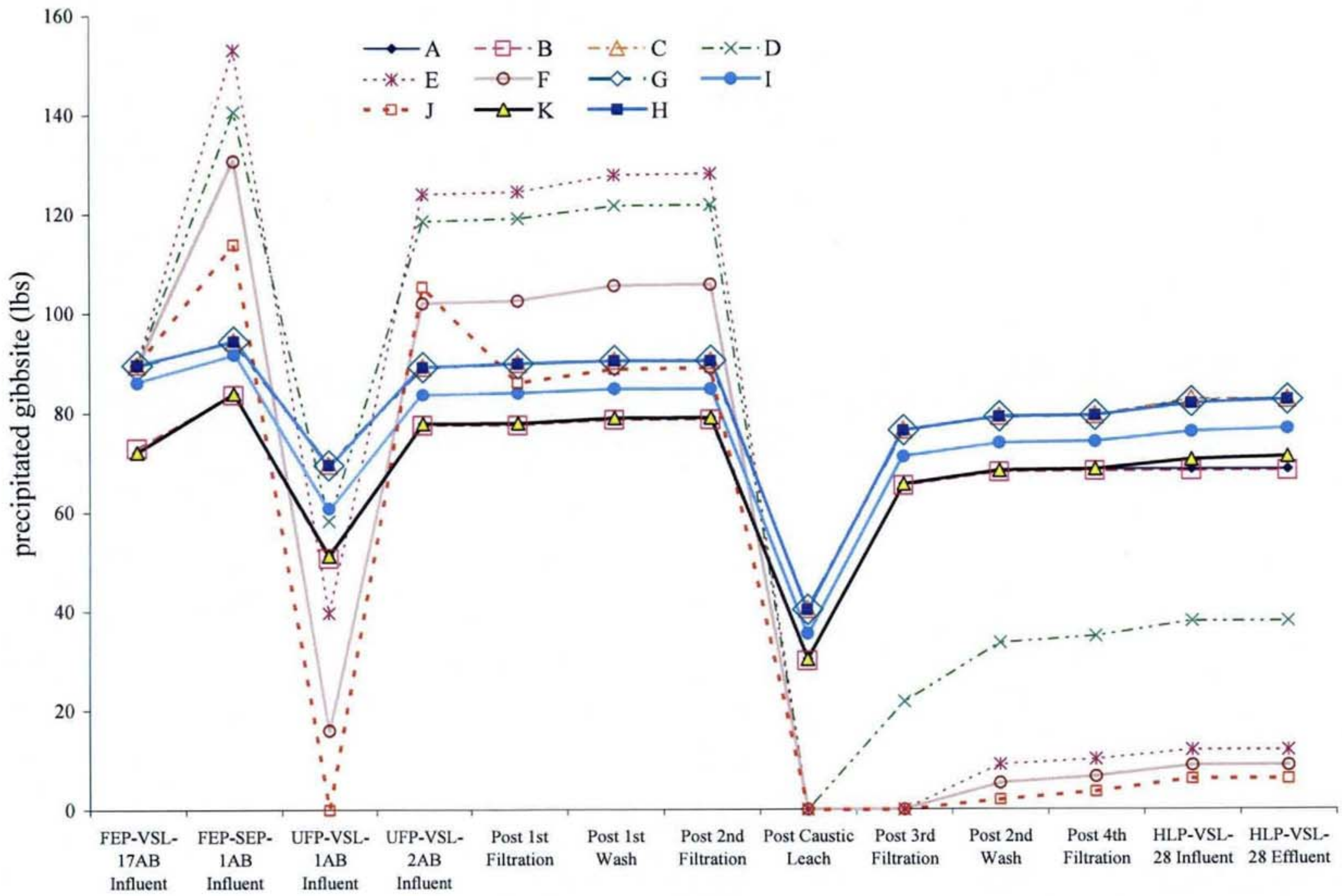


Figure 3. ESP Predicted Precipitation of $Al(OH)_3$ during PTF Processing. All Cases.

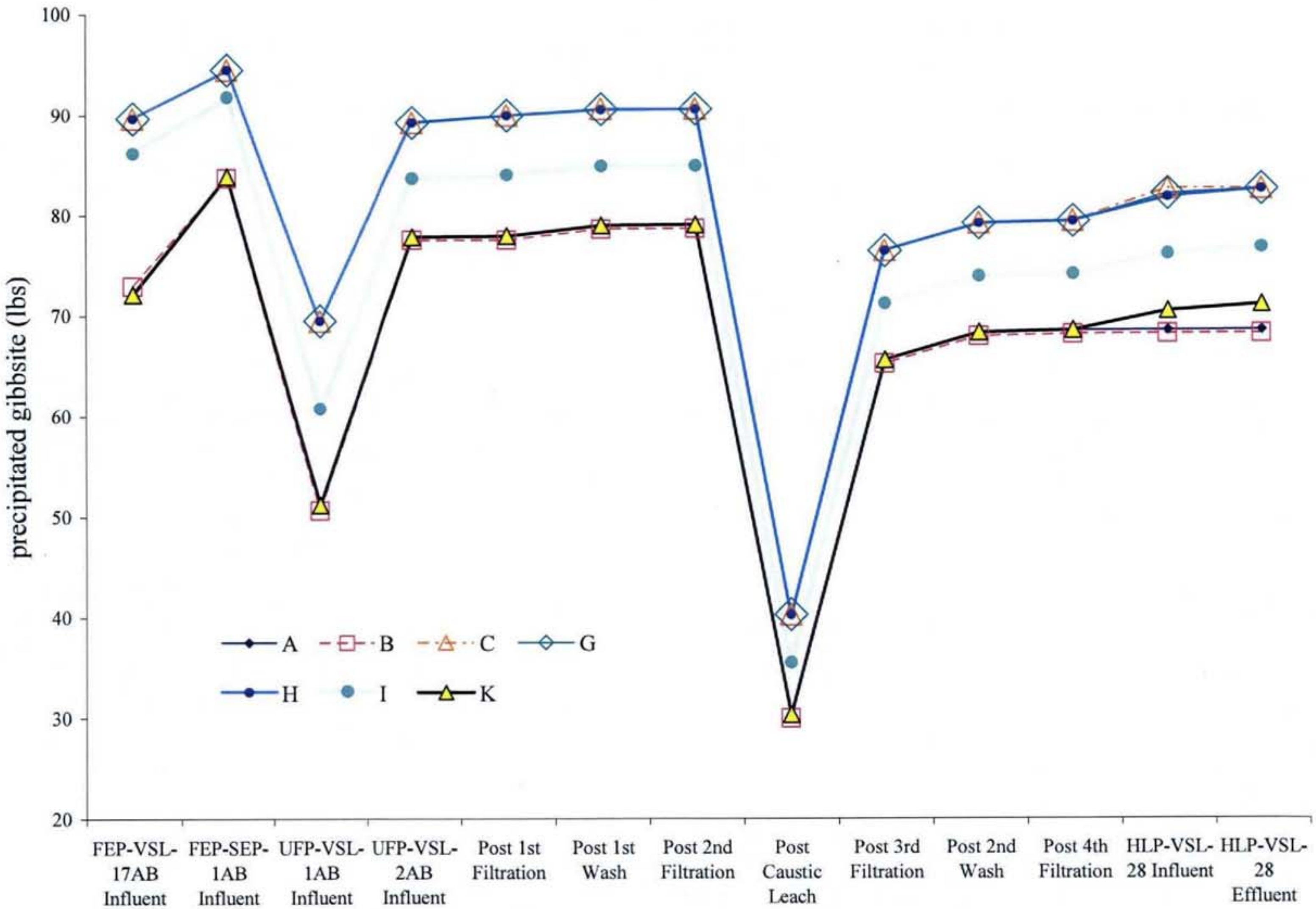


Figure 4. ESP Predicted Precipitation of $Al(OH)_3$ during PTF Processing. Baseline NaOH addition.

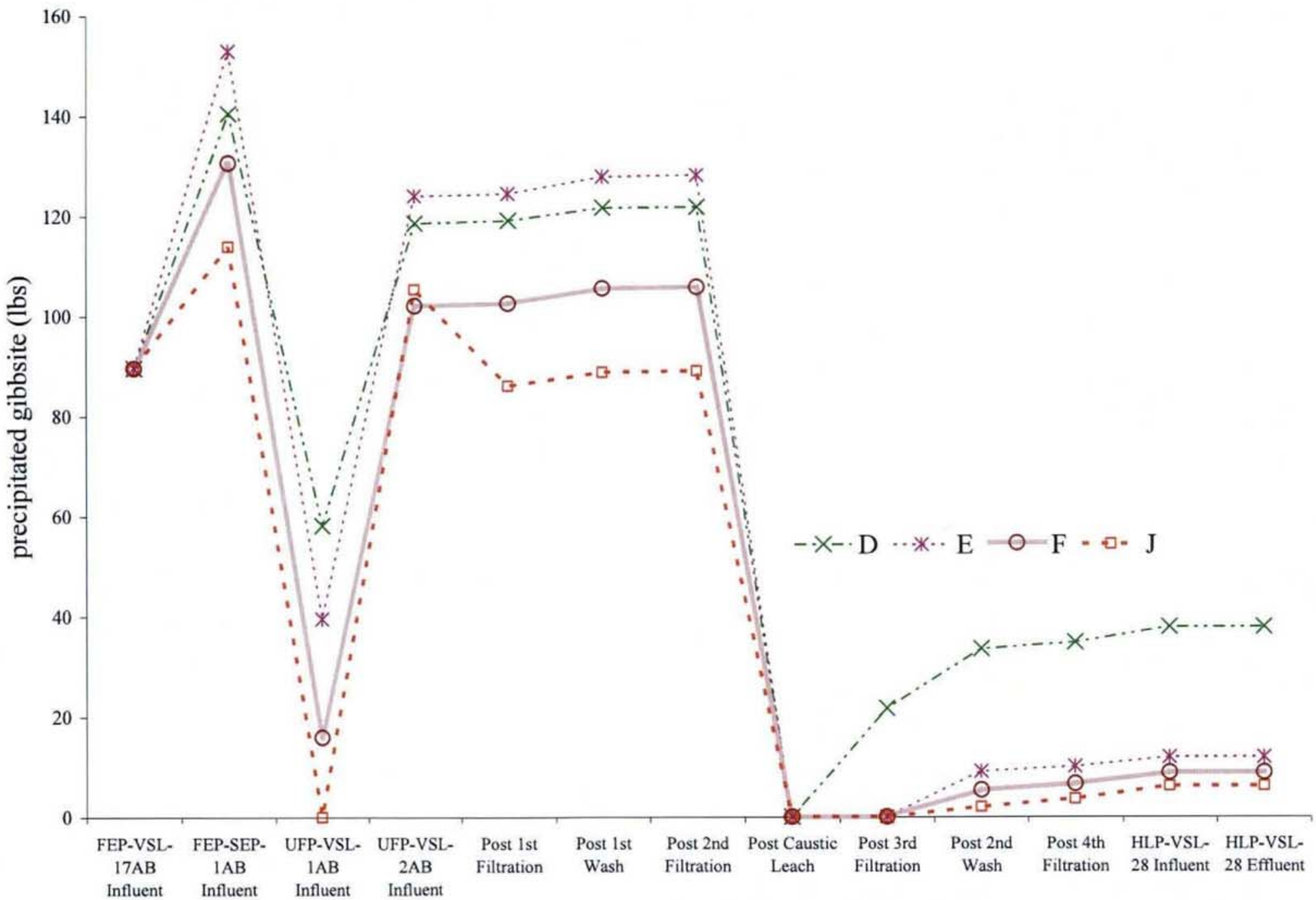


Figure 5. ESP Predicted Precipitation of $Al(OH)_3$ during PTF Processing. Increased NaOH addition.

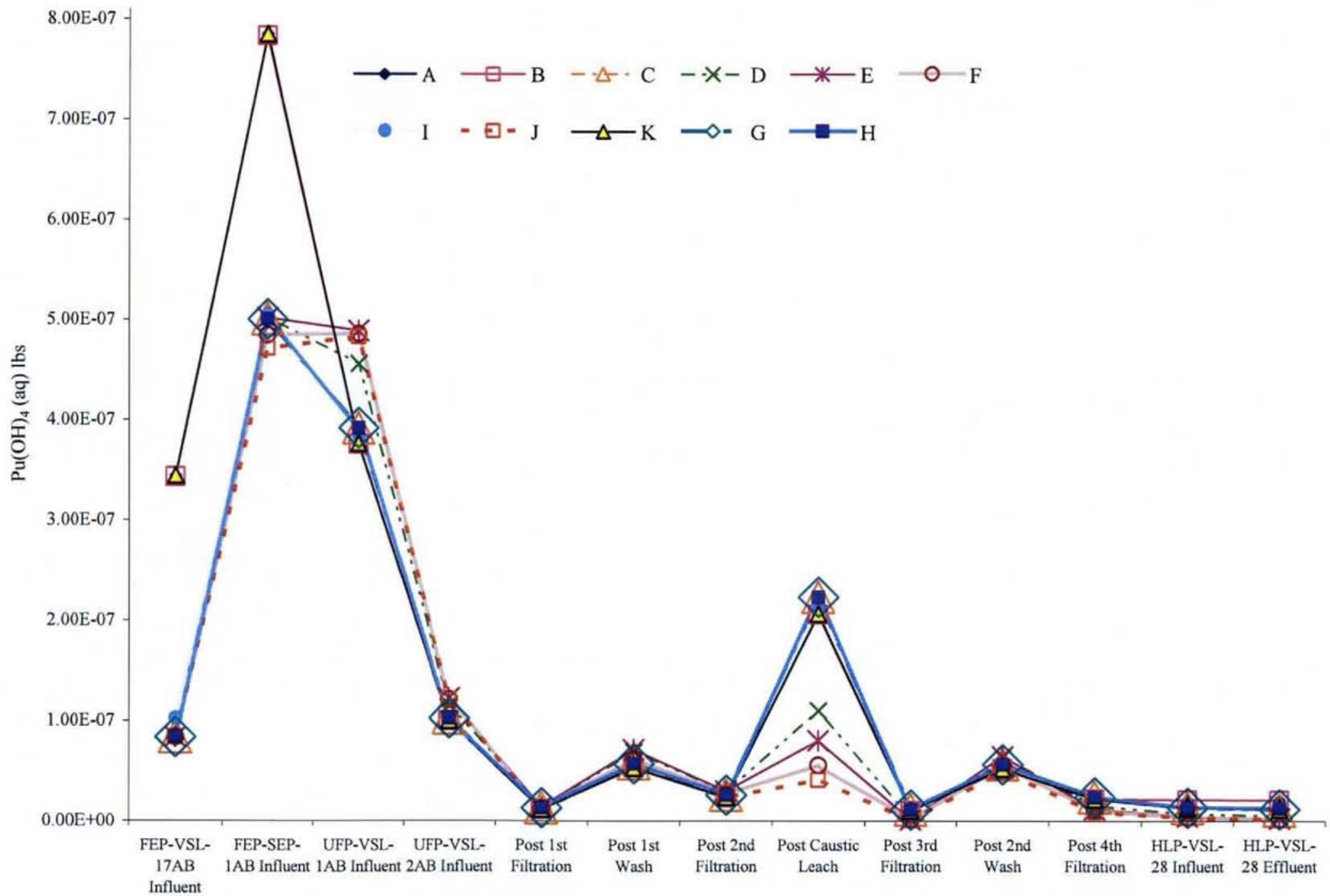


Figure 6. ESP Predicted Dissolution of Plutonium during PTF Processing.

3. DISCUSSION

Both the BNI estimate and ESP model predictions indicate that absorption of CO_2 is not likely to significantly affect the operating pH and, therefore, the solubility of aluminum or waste viscosity during normal operating conditions in PTF. Certain operating conditions must be maintained to keep the system within "normal" conditions so that absorption of CO_2 does not cause major processing issues.

First, the pH must be maintained above 12.9. As shown in Figure 7, the decline in pH follows a modest slope in the highly alkaline range and can be maintained above the aluminum hydroxide precipitation region with small doses of caustic. If the pH is allowed to drift into the aluminum hydroxide precipitation region, particularly below a value of 12, pH does then have the potential to decrease drastically over a relatively short time period and much of the aluminum in solution would precipitate (dependent on total aluminum, temperature and ionic strength). It has been documented though that adequate provisions have been included to maintain an appropriately alkaline pH within all vessels in PTF (Alexander et al., 2007).

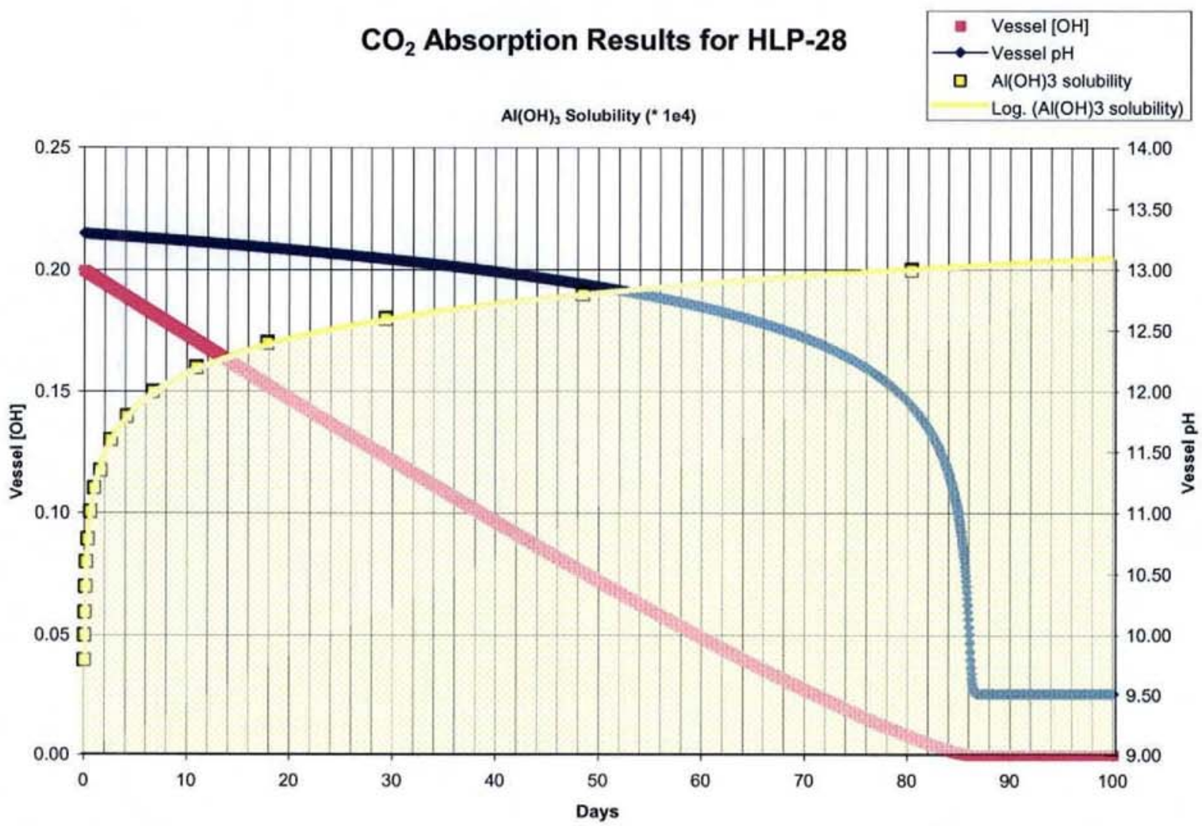


Figure 7. Estimated Changes in pH and [OH⁻] over 100 Days in HLP28 (data from BNI) Compared to Solubility of Gibbsite ($[Al^{3+}]_{TOT}$ = 1.0 M in H_2O at 25 °C) over pH (ESP calculation); $Al[OH]_3$ Solids Precipitate in Shaded Region.

Second, the PJMs must not operate in overblow mode for any appreciable period of time. Should this event occur, then tank waste viscosity would increase due to aluminum gelation/precipitation and an additional dose of hydroxide would somehow need to be mixed into the tank waste to elevate pH.

4. RECOMMENDATIONS

Further analysis should be performed to:

1. Ensure that localized effects of CO_2 absorption, specifically gel formation within waste not ejected from PJMs during discharge, will not inhibit functionality of PJMs.
2. Analyze the appropriateness of the Hobbs Correlation for use with Hanford Tank Waste.

REFERENCES

Alexander. D.H., Holland, J.E., Liu, C.K. 2007. "Review of Aluminum Entrainment in Bechtel National, Inc.'s Feed Receipt and Evaporator Systems." D-07-DESIGN-40. United States Department of Energy, Office of River Protection. Richland, Washington.

Hobbs, D.T. 1987. "Absorption of Carbon Dioxide in Waste Tanks." DPST-87-596. Savannah River Laboratory. Aiken, South Carolina.

Appendix A

Table 2. BNI Estimations of CO_2 Absorption in PTF Vessels.

Vessels Using Passive/Forced Air

0.075 # air / ft3

0.0361% CO_2 wt% in air

	Flowrate (scfm)										Reacted					Starting				
Vessel	Passive	Forced	Total	# air/min	# CO2/min	Vessel Residence Time (hrs)	conversion	# CO2 reacted	kg CO2	mole CO2	mole OH cons	liter 19M NaOH	gal 19M NaOH	Vessel Volume (gal)	[OH] Molarity Max	[OH] Molarity Nominal	Starting mol OH	Final mol OH	Final [OH] Molarity	gal 19M NaOH/yr
CNP-BRKPT-00002	20	5	25	1.875	0.0006769	0.083	0%	0.000	0.000	0.000	0.0	0.0	0.0	39.00	8.0	0.0	0	0	0.0	0
CNP-EVAP-00001		5	5	0.375	0.0001354	480	69%	2.695	1.223	27.780	55.6	2.9	0.8	3500.00	5	0.5	6626	6570	0.5	14
CNP-VSL-00003	20	5	25	1.875	0.0006769	480	0%	0.000	0.000	0.000	0.0	0.0	0.0	13500.00	8	0	0	0	0.0	0
CNP-VSL-00004	20		20	1.5	0.0005415	33	0%	0.000	0.000	0.000	0.0	0.0	0.0	7772.25	0	0	0	0	0.0	0
CXP-VSL-00001	20	5	25	1.875	0.0006769	70	86%	2.434	1.104	25.091	50.2	2.6	0.7	84431.54	8	5	1598388	1598338	5.0	87
CXP-VSL-00004	20		20	1.5	0.0005415	33	74%	0.794	0.360	8.188	16.4	0.9	0.2	6000.00	8	1	22717	22701	1.0	60
CXP-VSL-00005	20		20	1.5	0.0005415	33	74%	0.794	0.360	8.188	16.4	0.9	0.2	486.00	8	1	1840	1824	1.0	60
CXP-VSL-00026A	20		20	1.5	0.0005415	48	86%	1.335	0.606	13.764	27.5	1.4	0.4	29926.81	8	5	566550	566522	5.0	70
CXP-VSL-00026B	20		20	1.5	0.0005415	48	86%	1.335	0.606	13.764	27.5	1.4	0.4	29926.81	8	5	566550	566522	5.0	70
CXP-VSL-00026C	20		20	1.5	0.0005415	48	86%	1.335	0.606	13.764	27.5	1.4	0.4	29926.81	8	5	566550	566522	5.0	70
FEP-SEP-00001A		5	5	0.375	0.0001354	6	86%	0.042	0.019	0.434	0.9	0.0	0.0	7000.00	8	5.5	145770	145769	5.5	18
FEP-SEP-00001B		5	5	0.375	0.0001354	6	86%	0.042	0.019	0.434	0.9	0.0	0.0	7000.00	8	5.5	145770	145769	5.5	18
FEP-VSL-00005	20		20	1.5	0.0005415	12	0%	0.000	0.000	0.000	0.0	0.0	0.0	500.00	0	0	0	0	0.0	0
FEP-VSL-00017A	20	5	25	1.875	0.0006769	12	81%	0.393	0.178	4.052	8.1	0.4	0.1	57000.00	9	2.5	539539	539530	2.5	82
FEP-VSL-00017B	20	5	25	1.875	0.0006769	12	81%	0.393	0.178	4.052	8.1	0.4	0.1	57000.00	9	2.5	539539	539530	2.5	82
FRP-VSL-00002A	20	15	35	2.625	0.0009476	180	89%	9.109	4.132	93.880	187.8	9.9	2.6	380000.00	10	8	11510156	11509968	8.0	127
FRP-VSL-00002B	20	15	35	2.625	0.0009476	180	89%	9.109	4.132	93.880	187.8	9.9	2.6	380000.00	10	8	11510156	11509968	8.0	127
FRP-VSL-00002C	20	15	35	2.625	0.0009476	180	89%	9.109	4.132	93.880	187.8	9.9	2.6	380000.00	10	8	11510156	11509968	8.0	127
FRP-VSL-00002D	20	15	35	2.625	0.0009476	180	89%	9.109	4.132	93.880	187.8	9.9	2.6	380000.00	10	8	11510156	11509968	8.0	127
HLP-VSL-00022	62	100	161.55	12.12	0.0043740	720	87%	164.277	74.515	1693.139	3386.3	178.2	47.1	203920.00	8	6	4632535	4629149	6.0	573
Pipeline for CRP		5	5	0.375	0.0001354	1	0%	0.000	0.000	0.000	0.0	0.0	0.0				0	0	#DIV/0!	0
Pipeline for CXP		25	25	1.875	0.0006769	1	0%	0.000	0.000	0.000	0.0	0.0	0.0				0	0	#DIV/0!	0
PWD-VSL-00015	20		20	1.5	0.0005415	144	74%	3.467	1.573	35.731	71.5	3.8	1.0	85272.00	19	1	322860	322788	1.0	60
PWD-VSL-00016	20		20	1.5	0.0005415	144	74%	3.467	1.573	35.731	71.5	3.8	1.0	85272.00	19	1	322860	322788	1.0	60
PWD-VSL-00033	20	5	25	1.875	0.0006769	24	84%	0.815	0.370	8.405	16.8	0.9	0.2	15350.00	5	3.8	220851	220834	3.8	85
PWD-VSL-00043	20	5	25	1.875	0.0006769	24	84%	0.815	0.370	8.405	16.8	0.9	0.2	22900.00	5	3.8	329478	329461	3.8	85
PWD-VSL-00044	20	5	25	1.875	0.0006769	24	74%	0.722	0.328	7.444	14.9	0.8	0.2	72406.40	3	1	274148	274133	1.0	76
RDP-VSL-00002A	40	40	80	6	0.0021660	24	74%	2.311	1.048	23.821	47.6	2.5	0.7	7507.69	2	1	28426	28378	1.0	242
RDP-VSL-00002B	40	40	80	6	0.0021660	24	74%	2.311	1.048	23.821	47.6	2.5	0.7	7507.69	2	1	28426	28378	1.0	242
RDP-VSL-00002C	40	40	80	6	0.0021660	24	74%	2.311	1.048	23.821	47.6	2.5	0.7	7507.69	2	1	28426	28378	1.0	242
RLD-TK-00006A	4		4.183	0.31	0.0001133	24	74%	0.121	0.055	1.246	2.5	0.1	0.0	291932.00	1	1	1105323	1105321	1.0	13
RLD-TK-00006B	4		4.184	0.31	0.0001133	24	74%	0.121	0.055	1.246	2.5	0.1	0.0	291932.00	1	1	1105323	1105321	1.0	13
RLD-VSL-00017A	20		20	1.5	0.0005415	24	74%	0.578	0.262	5.955	11.9	0.6	0.2	21572.00	2	1	81677	81665	1.0	60
RLD-VSL-00017B	20		20	1.5	0.0005415	24	74%	0.578	0.262	5.955	11.9	0.6	0.2	21572.00	2	1	81677	81665	1.0	60
TCP-VSL-00001	20		20	1.5	0.0005415	168	89%	4.858	2.204	50.069	100.1	5.3	1.4	102699.00	10	8	3110741	3110641	8.0	73
TLP-VSL-00002	20		20	1.5	0.0005415	0.25	0%	0.000	0.000	0.000	0.0	0.0	0.0	1300.00	0	0	0	0	0.0	0
TLP-VSL-00009A	20		20	1.5	0.0005415	24	74%	0.578	0.262	5.955	11.9	0.6	0.2	87138.00	5	1	329925	329913	1.0	60
TLP-VSL-00009B	20		20	1.5	0.0005415	24	74%	0.578	0.262	5.955	11.9	0.6	0.2	87138.00	5	1	329925	329913	1.0	60
UFP-VSL-00001A	20	5	25	1.875	0.0006769	48	86%	1.683	0.763	17.342	34.7	1.8	0.5	54536.00	10	5.5	1135674	1135639	5.5	88
UFP-VSL-00001B	20	5	25	1.875	0.0006769	48	86%	1.683	0.763	17.342	34.7	1.8	0.5	54536.00	10	5.5	1135674	1135639	5.5	88
UFP-VSL-00062A	20	5	25	1.875	0.0006769	24	88%	0.853	0.387	8.791	17.6	0.9	0.2	25501.56	8	6.5	627607	627589	6.5	89
UFP-VSL-00062B	20	5	25	1.875	0.0006769	24	88%	0.853	0.387	8.791	17.6	0.9	0.2	25501.56	8	6.5	627607	627589	6.5	89
UFP-VSL-00062C	20	5	25	1.875	0.0006769	24	88%	0.853	0.387	8.791	17.6	0.9	0.2	25501.56	8	6.5	627607	627589	6.5	89
																		Total NaOH loss		3588 gals/yr

APPENDIX B

Table 3. Species Considered in ESP Model.

Water	H2O
Nitrogen	N2
Oxygen	O2
Carbon Dioxide	CO2
Nitrous Acid	HNO2
Nitric Acid	HNO3
Hydrogen Chloride	HCl
Hydrogen Fluoride	HF
Aluminum Hydroxide	Al(OH)3
Boehmite	AlOOH
Calcium Hydroxide	Ca(OH)2
Chromium (III) Hydroxide	Cr(OH)3
Iron(II) Hydroxide	Fe(OH)2
Iron (III) Oxide	Fe2O3
Dichromium Iron Tetraoxide	FeCr2O4
Potassium Hydroxide	KOH
Lanthanum Trihydroxide	La(OH)3
Sodium Hydroxide	NaOH
Sodium Nitrite	NaNO2
Sodium Nitrate	NaNO3
Sodium Carbonate	Na2CO3
Sodium Sulfate	Na2SO4
Sodium Chloride	NaCl
Sodium Fluoride	NaF
Sodium Hydrogen Orthophosphate	Na2HPO4
Sodium Orthophosphate	Na3PO4
Sodium Bicarbonate	NaHCO3
Sodium Chromate	Na2CrO4
Nickel (II) Hydroxide	Ni(OH)2
Zirconium(IV) Oxide	ZrO2
Hydroxyapatite	Ca5OH(PO4)3
Formic Acid	CH2O2
Sodium Acetate	Na(C2H3O2)
Sodium Oxalate	Na2C2O4
Sodium Glycolate	Na(C2H3O3)
Cesium Hydroxide	CsOH
Strontium Carbonate	SrCO3
Strontium Hydroxyapatite	Sr5(PO4)3OH
Sodium Pertechnetate	NaTcO4
Disodium Diuranate	Na2U2O7
Plutonium(IV) Hydroxide	PuIV(OH)4

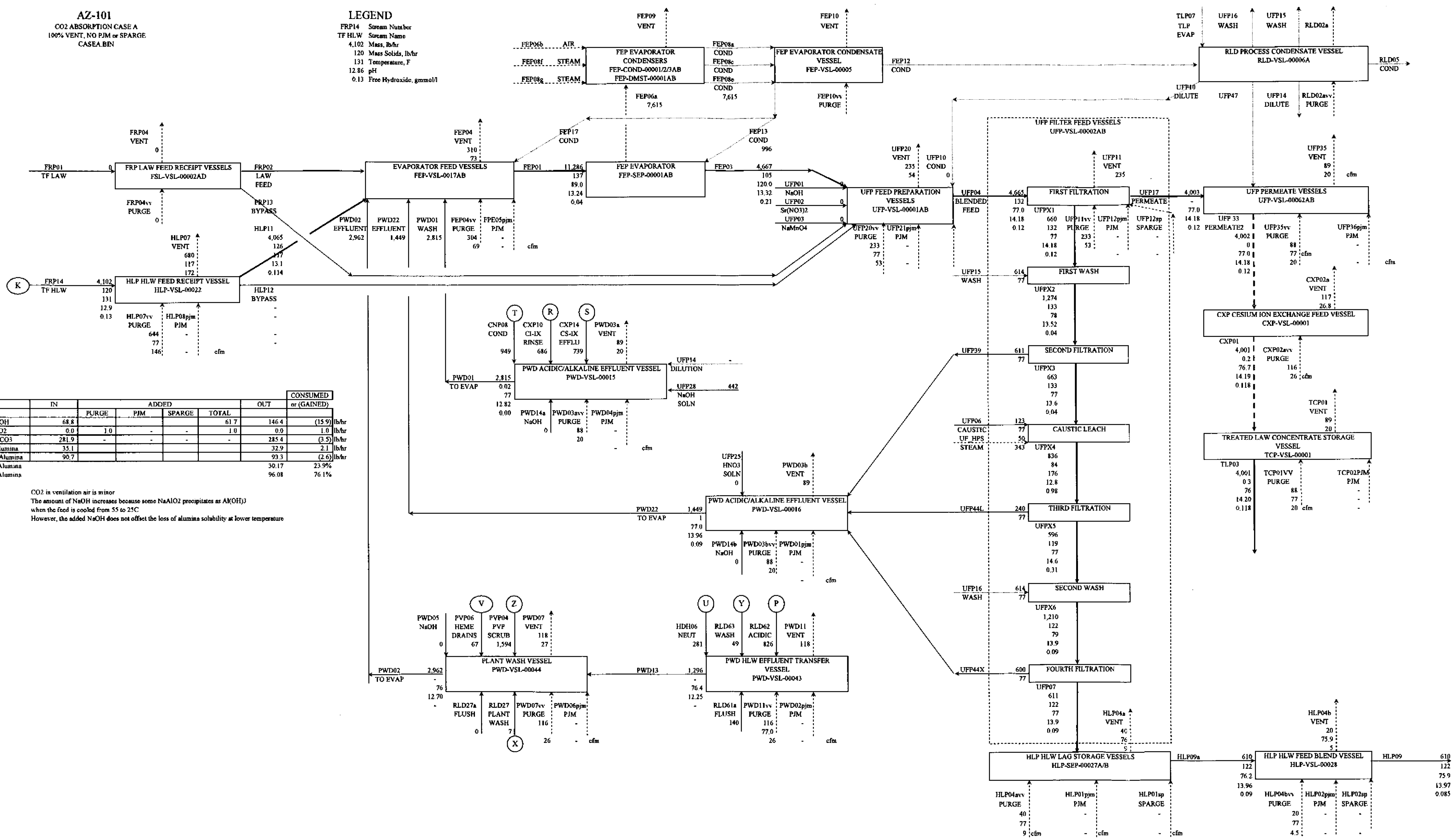
APPENDIX C

AZ-101

CO2 ABSORPTION CASE A
100% VENT, NO PJM or SPARGE
CASEA.BIN

LEGEND

FRP14 Stream Number
TF HLW Stream Name
4,102 Mass, lb/hr
120 Mass Solids, lb/hr
131 Temperature, F
12.86 pH
0.13 Free Hydroxide, gmmol/l



	IN	ADDED				OUT	CONSUMED or (GAINED)	
		PURGE	PJM	SPARGE	TOTAL			
NaOH	68.8				61.7	146.4	(15.9)	lb/hr
CO2	0.0	1.0	-	-	1.0	0.0	1.0	lb/hr
Na2CO3	281.9	-	-	-	-	285.4	(3.5)	lb/hr
Soluble Alumina	35.1					32.9	2.1	lb/hr
Insoluble Alumina	90.7					93.3	(2.6)	lb/hr
LAW Alumina						30.17	23.9%	
HLW Alumina						96.08	76.1%	

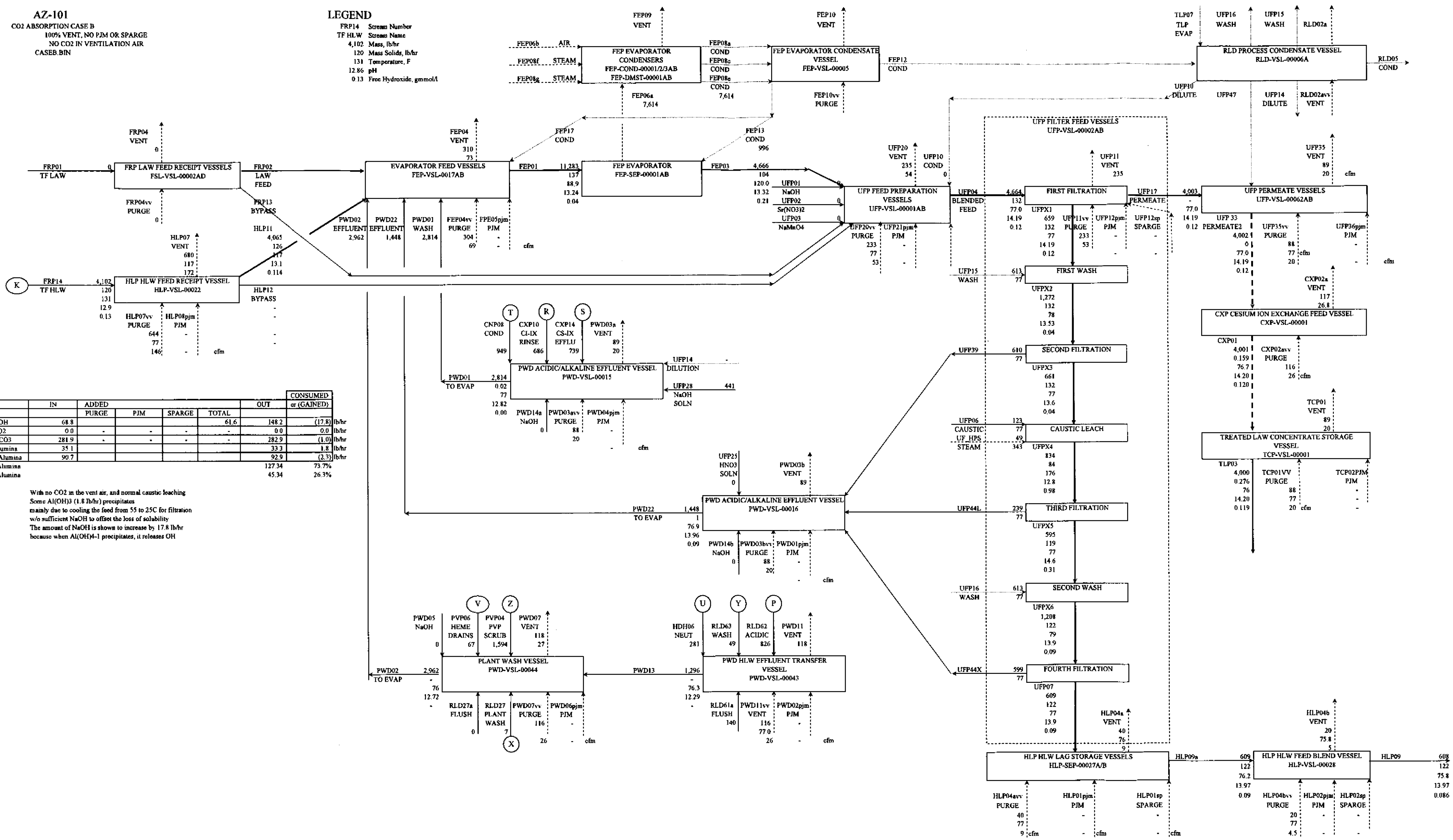
CO2 in ventilation air is minor
The amount of NaOH increases because some NaAlO2 precipitates as Al(OH)3
when the feed is cooled from 55 to 25C
However, the added NaOH does not offset the loss of alumina solubility at lower temperature

AZ-101

CO2 ABSORPTION CASE B
100% VENT, NO PJM OR SPARGE
NO CO2 IN VENTILATION AIR
CASEB.BIN

LEGEND

FRP14 Stream Number
TF HLW Stream Name
4,102 Mass, lb/hr
120 Mass Solids, lb/hr
131 Temperature, F
12.86 pH
0.13 Free Hydroxide, gmmol/l



	IN	ADDED				OUT	CONSUMED or (GAINED)	
		PURGE	PJM	SPARGE	TOTAL			
NaOH	68.8				61.6	148.2	(17.8)	lb/hr
CO2	0.0	-	-	-	-	0.0	0.0	lb/hr
Na2CO3	281.9	-	-	-	-	282.9	(1.0)	lb/hr
Soluble Alumina	35.1					33.3	1.8	lb/hr
Insoluble Alumina	90.7					92.9	(2.3)	lb/hr
LAW Alumina						127.34	73.7%	
HLW Alumina						45.34	26.3%	

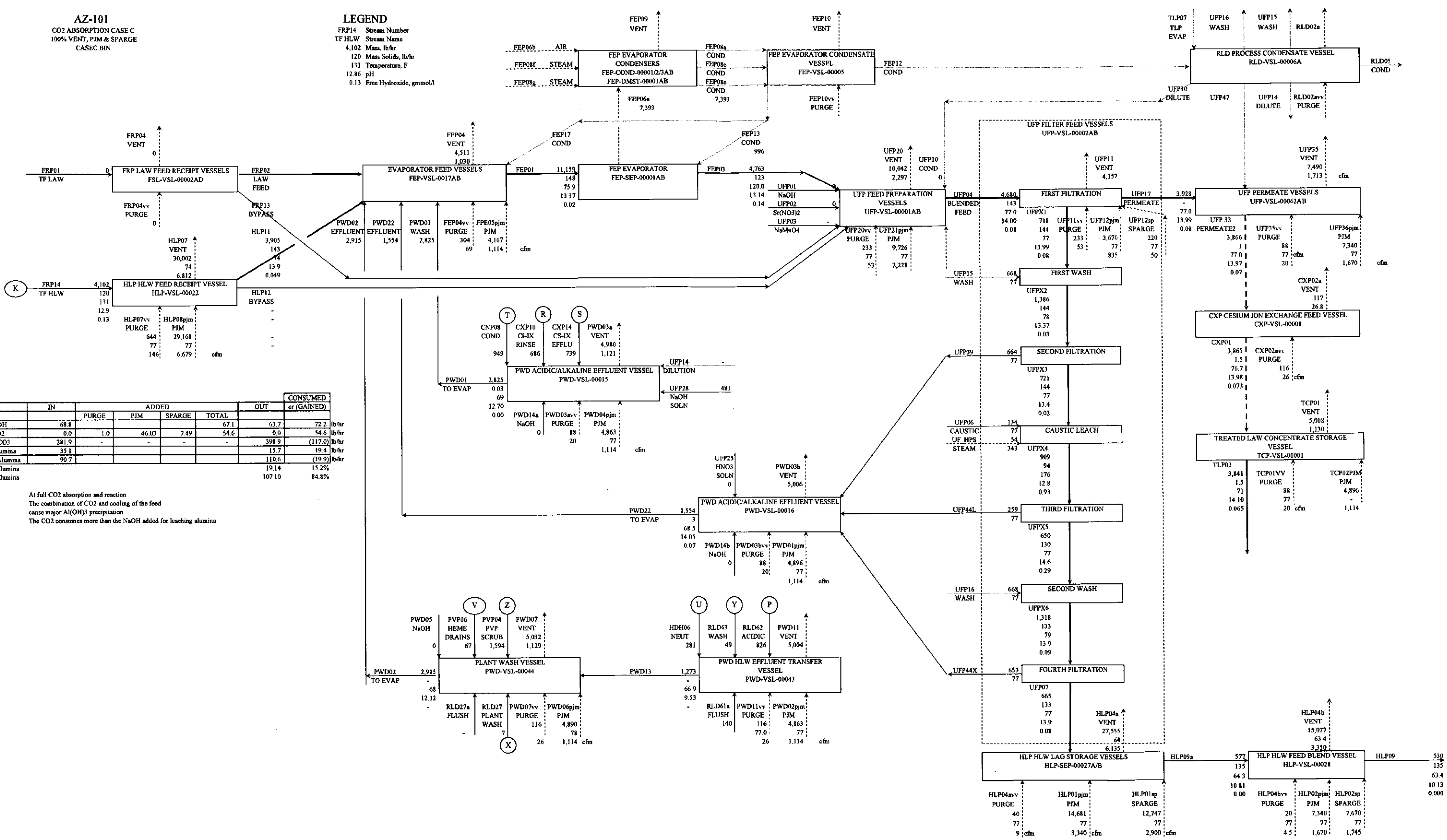
With no CO2 in the vent air, and normal caustic leaching
Some Al(OH)3 (1.8 lb/hr) precipitates
mainly due to cooling the feed from 55 to 25C for filtration
w/o sufficient NaOH to offset the loss of solubility
The amount of NaOH is shown to increase by 17.8 lb/hr
because when Al(OH)4-1 precipitates, it releases OH

AZ-101

CO2 ABSORPTION CASE C
100% VENT, PJM & SPARGE
CASEC.BIN

LEGEND

FRP14 Stream Number
TF HLW Stream Name
4,102 Mass, lb/hr
120 Mass Solids, lb/hr
131 Temperature, F
12.86 pH
0.13 Free Hydroxide, gmmol/l



	IN	ADDED				OUT	CONSUMED or (GAINED)	
		PURGE	PJM	SPARGE	TOTAL			
NaOH	68.8				67.1	63.7	72.2	lb/hr
CO2	0.0	1.0	46.03	7.49	54.6	0.0	54.6	lb/hr
Na2CO3	281.9	-	-	-	-	398.9	(117.0)	lb/hr
Soluble Alumina	35.1					15.7	19.4	lb/hr
Insoluble Alumina	90.7					110.6	(19.9)	lb/hr
LAW Alumina						19.14	15.2%	
HLW Alumina						107.10	84.8%	

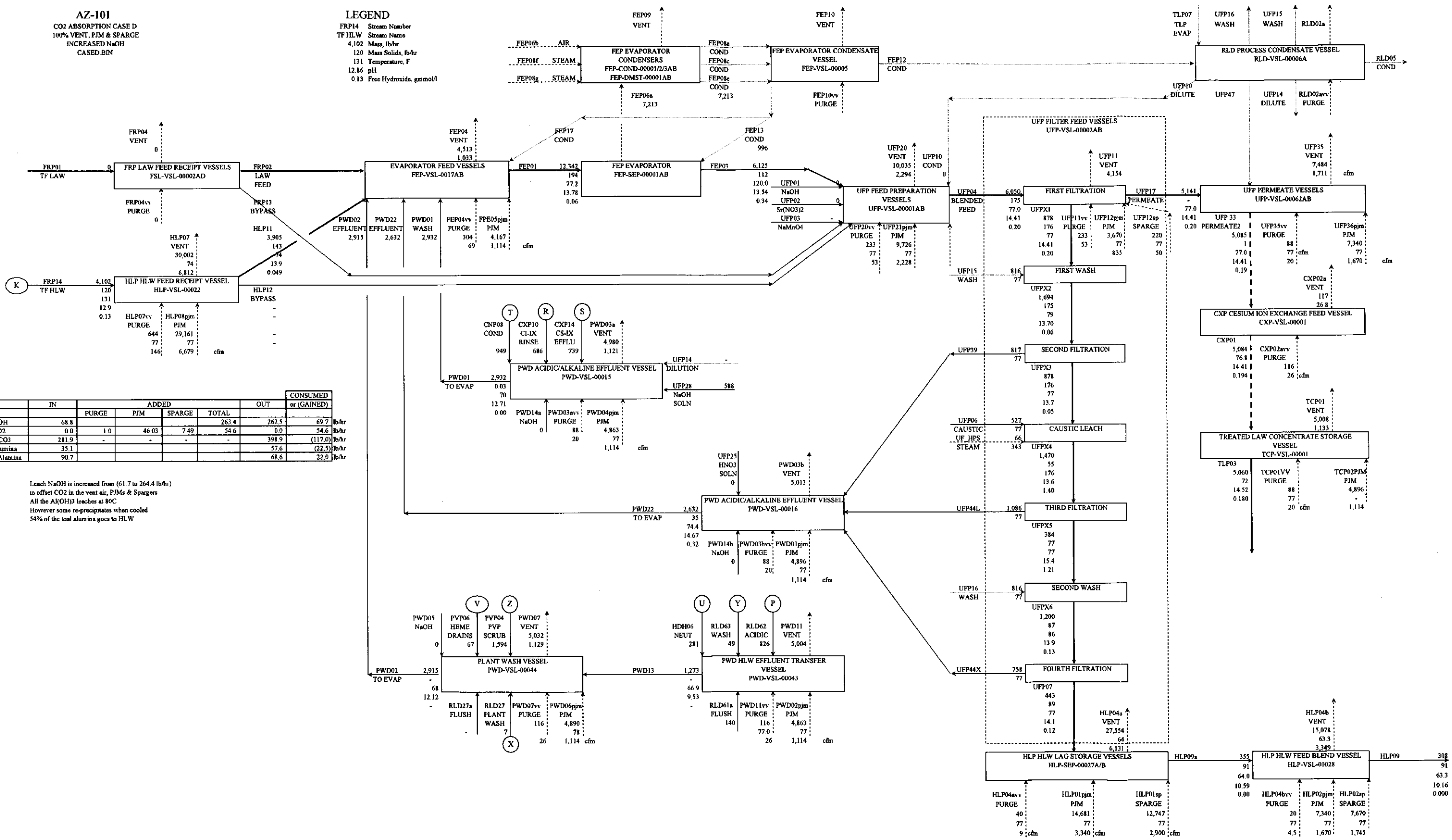
At full CO_2 absorption and reaction
The combination of CO_2 and cooling of the feed
cause major $Al(OH)_3$ precipitation
The CO_2 consumes more than the NaOH added for leaching alumina

AZ-101

CO2 ABSORPTION CASE D
100% VENT, PJM & SPARGE
INCREASED NaOH
CASED.BIN

LEGEND

FRP14 Stream Number
TF HLW Stream Name
4,102 Mass, lb/hr
120 Mass Solids, lb/hr
131 Temperature, F
12.86 pH
0.13 Free Hydroxide, gmol/l



	IN	ADDED				OUT	CONSUMED or (GAINED)	
		PURGE	PJM	SPARGE	TOTAL			
NaOH	68.8				263.4	262.5	69.7	lb/hr
CO2	0.0	1.0	46.03	7.49	54.6	0.0	54.6	lb/hr
Na2CO3	281.9	-	-	-	-	398.9	(117.0)	lb/hr
Soluble Alumina	35.1					57.6	(22.5)	lb/hr
Insoluble Alumina	90.7					68.6	22.0	lb/hr

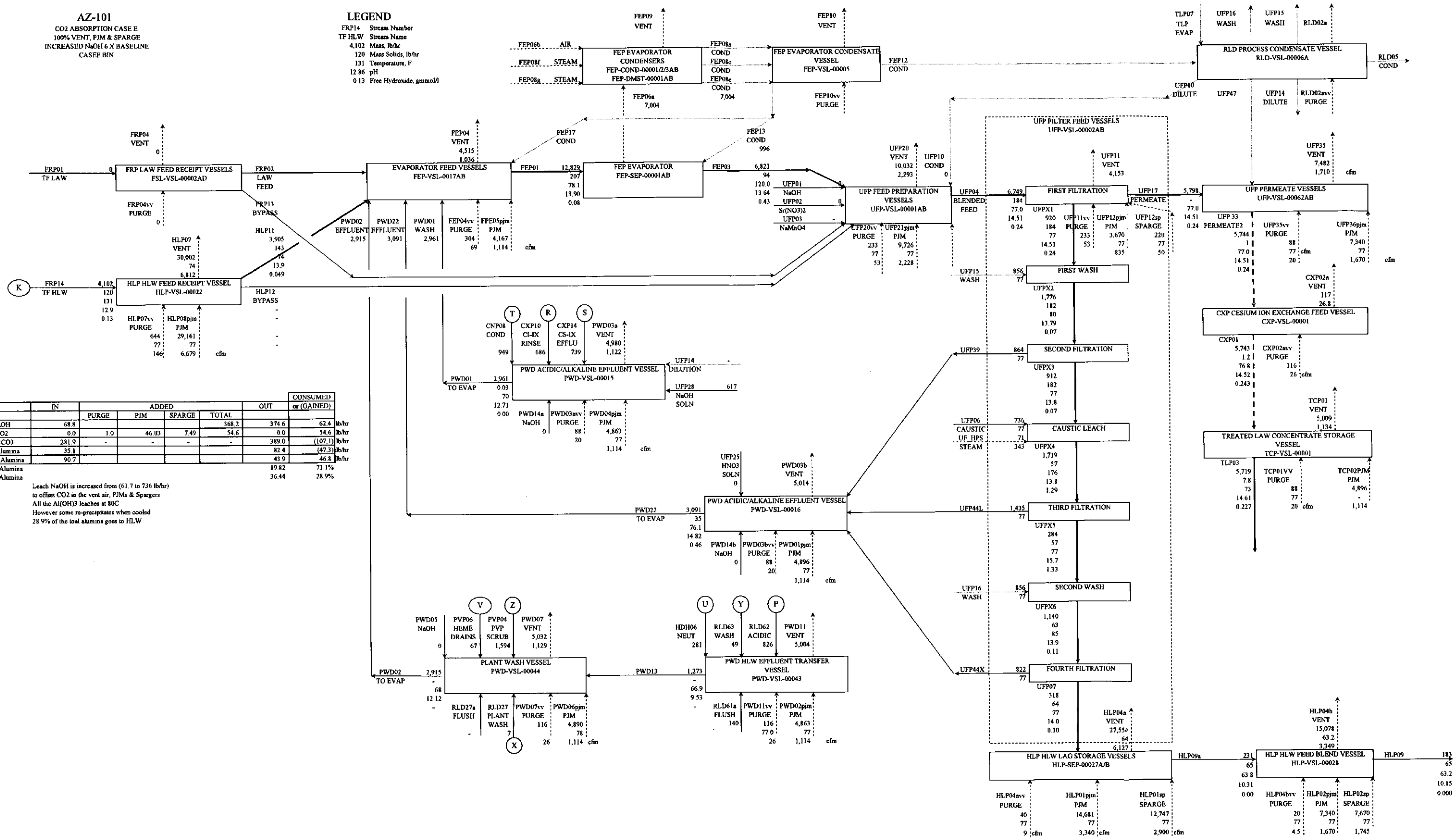
Leach NaOH is increased from (61.7 to 264.4 lb/hr)
to offset CO2 in the vent air, PJMs & Spargers
All the Al(OH)3 leaches at 80C
However some re-precipitates when cooled
54% of the toal alumina goes to HLW

AZ-101

CO2 ABSORPTION CASE E
100% VENT, PJM & SPARGE
INCREASED NaOH 6 X BASELINE
CASEE BIN

LEGEND

FRP14 Stream Number
TF HLW Stream Name
4,102 Mass, lb/hr
120 Mass Solids, lb/hr
131 Temperature, F
12.86 pH
0.13 Free Hydroxide, gmmol/l



	IN	ADDED				OUT	CONSUMED or (GAINED)	
		PURGE	PJM	SPARGE	TOTAL			
NaOH	68.8				368.2	374.6	62.4	lb/hr
CO2	0.0	1.0	46.03	7.49	54.6	0.0	54.6	lb/hr
Na2CO3	281.9	-	-	-	-	389.0	(107.1)	lb/hr
Soluble Alumina	35.1					82.4	(47.3)	lb/hr
Insoluble Alumina	90.7					43.9	46.8	lb/hr
LAW Alumina						89.82	71.1%	
HLW Alumina						36.44	28.9%	

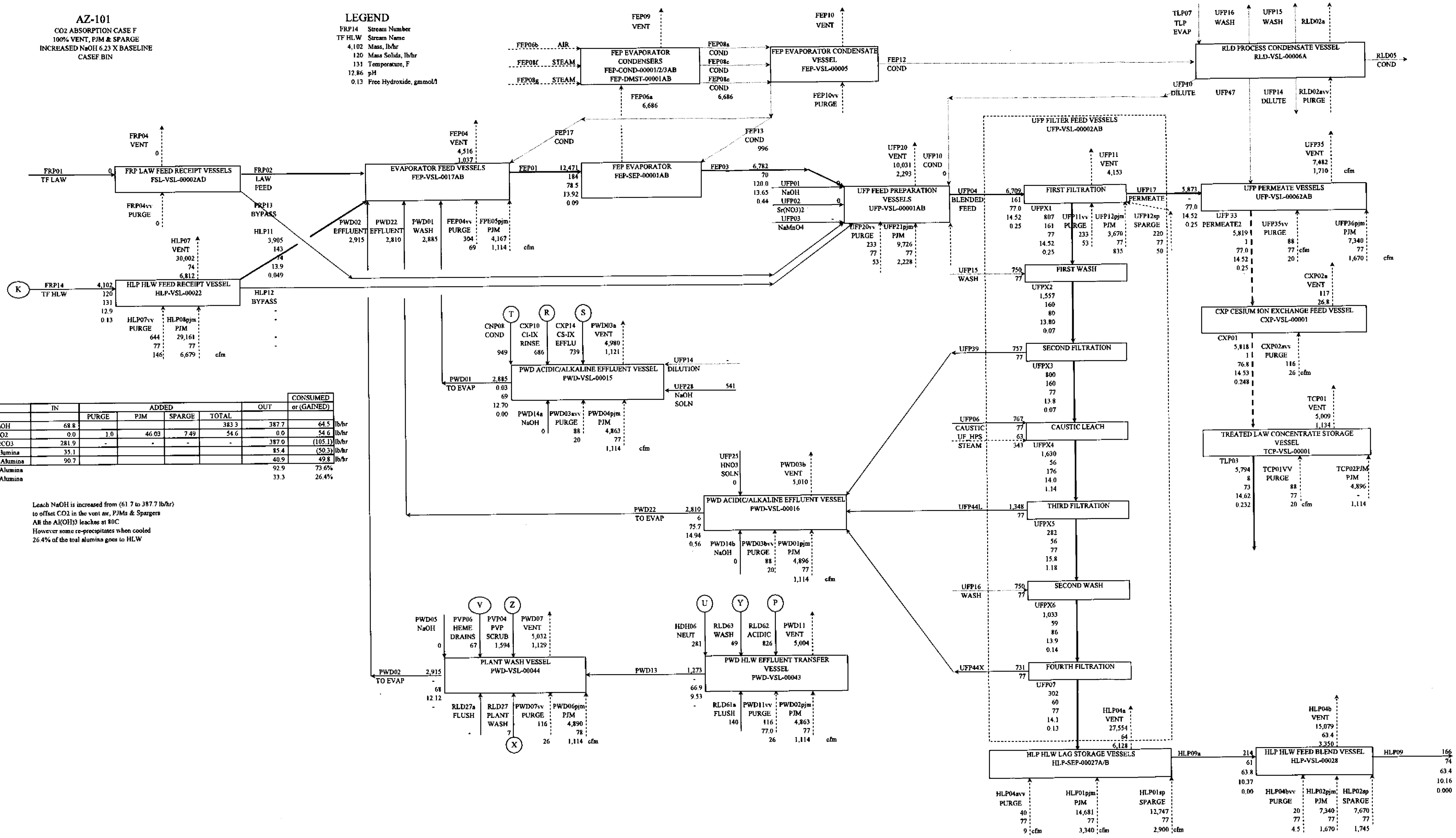
Leach NaOH is increased from (61.7 to 736 lb/hr)
to offset CO2 in the vent air, PJMs & Spargers
All the Al(OH)3 leaches at 80C
However some re-precipitates when cooled
28.9% of the toal alumina goes to HLW

AZ-101

CO2 ABSORPTION CASE F
100% VENT, PJM & SPARGE
INCREASED NaOH 6.23 X BASELINE
CASEF BIN

LEGEND

FRP14 Stream Number
TF HLW Stream Name
4,102 Mass, lb/hr
120 Mass Solids, lb/hr
131 Temperature, F
12.86 pH
0.13 Free Hydroxide, gmmol/l



	IN	ADDED				OUT	CONSUMED or (GAINED)	
		PURGE	PJM	SPARGE	TOTAL			
NaOH	68.8				383.3	387.7	64.5	lb/hr
CO2	0.0	1.0	46.03	7.49	54.6	0.0	54.6	lb/hr
Na2CO3	281.9	-	-	-	-	387.0	(105.1)	lb/hr
Soluble Alumina	35.1					85.4	(50.3)	lb/hr
Insoluble Alumina	90.7					40.9	49.8	lb/hr
LAW Alumina						92.9	73.6%	
HLW Alumina						33.3	26.4%	

Leach NaOH is increased from (61.7 to 387.7 lb/hr)
to offset CO2 in the vent air, PJMs & Spargers
All the Al(OH)3 leaches at 80C
However some re-precipitates when cooled
26.4% of the toal alumina goes to HLW

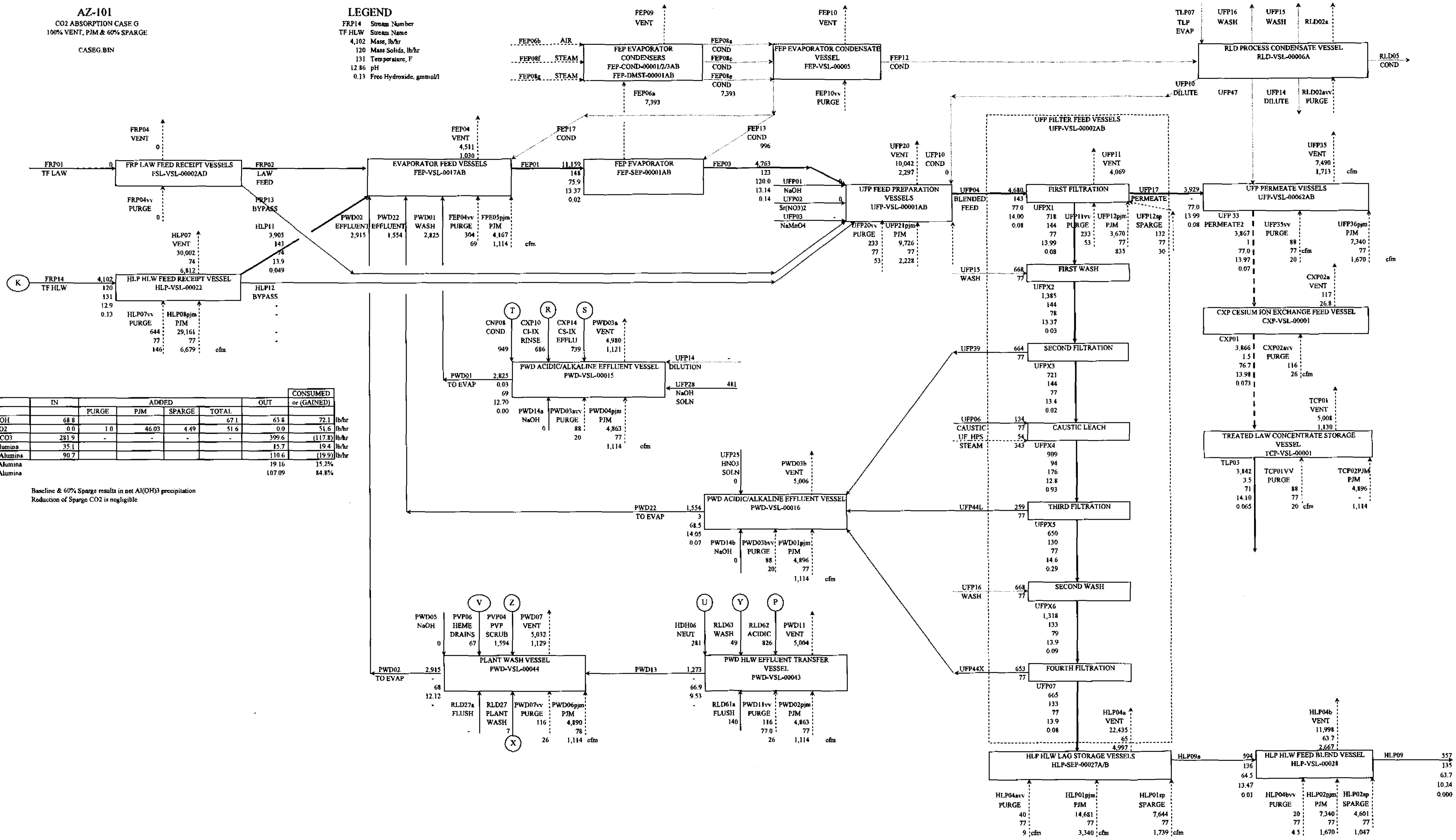
AZ-101

CO2 ABSORPTION CASE G
100% VENT, PJM & 60% SPARGE

CASEG.BIN

LEGEND

FRP14 Stream Number
TF HLW Stream Name
4,102 Mass, lb/hr
120 Mass Solids, lb/hr
131 Temperature, F
12.86 pH
0.13 Free Hydroxide, gmmol/l



	IN	ADDED				OUT	CONSUMED or (GAINED)	
		PURGE	PJM	SPARGE	TOTAL			
NaOH	68.8				67.1	63.8	72.1	lb/hr
CO2	0.0	1.0	46.03	4.49	51.6	0.0	51.6	lb/hr
Na2CO3	281.9	-	-	-	-	399.6	(117.8)	lb/hr
Soluble Alumina	35.1					15.7	19.4	lb/hr
Insoluble Alumina	90.7					110.6	(19.9)	lb/hr
LAW Alumina						19.16	15.2%	
HLW Alumina						107.09	84.8%	

Baseline & 60% Sparge results in net Al(OH)3 precipitation
Reduction of Sparge CO2 is negligible

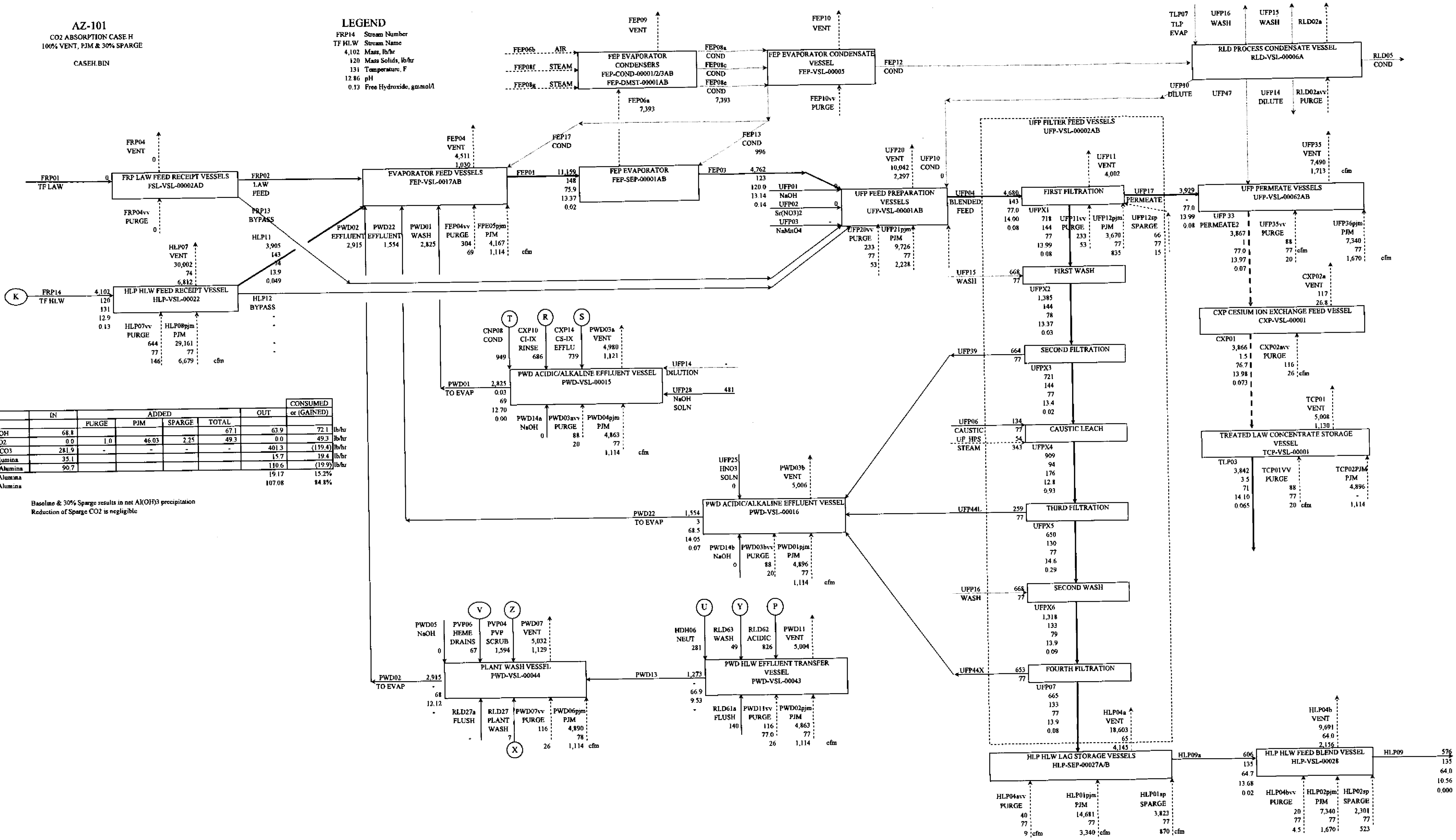
AZ-101

CO2 ABSORPTION CASE H
100% VENT, PJM & 30% SPARGE

CASEH.BIN

LEGEND

FRP14 Stream Number
TF HLW Stream Name
4,102 Mass, lb/hr
120 Mass Solids, lb/hr
131 Temperature, F
12.86 pH
0.13 Free Hydroxide, gmmol/l



	IN	ADDED				OUT	CONSUMED or (GAINED)	
		PURGE	PJM	SPARGE	TOTAL			
NaOH	68.8				67.1	63.9	72.1	lb/hr
CO2	0.0	1.0	46.03	2.25	49.3	0.0	49.3	lb/hr
Na2CO3	281.9	-	-	-	-	401.3	(119.4)	lb/hr
Soluble Alumina	35.1					15.7	19.4	lb/hr
Insoluble Alumina	90.7					110.6	(19.9)	lb/hr
LAW Alumina						19.17	15.2%	
HLW Alumina						107.08	84.8%	

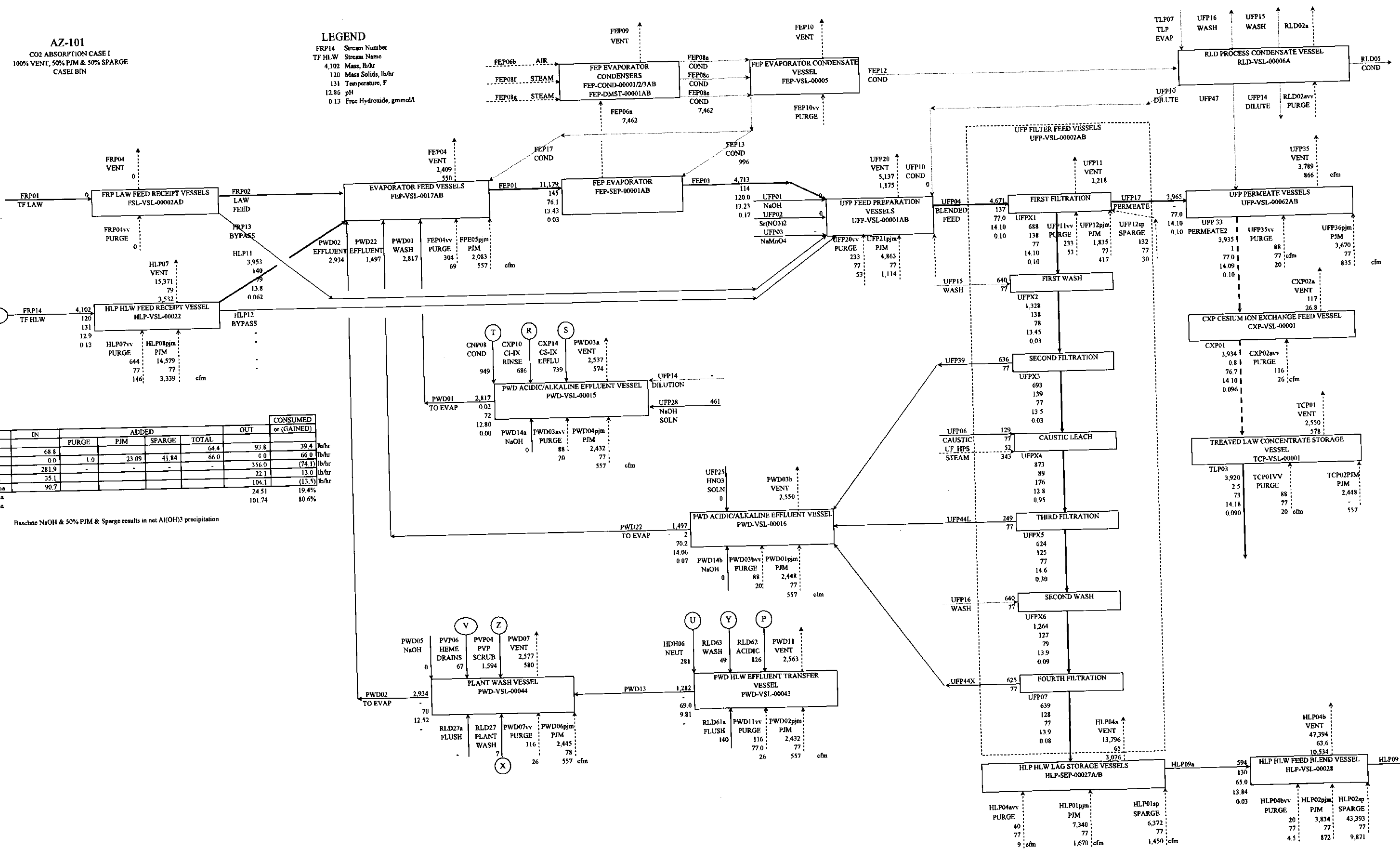
Baseline & 30% Sparge results in net Al(OH)3 precipitation
Reduction of Sparge CO2 is negligible

AZ-101

CO2 ABSORPTION CASE I
100% VENT, 50% PJM & 50% SPARGE
CASE1 BIN

LEGEND

FRP14 Stream Number
TF HLW Stream Name
4,102 Mass, lb/hr
120 Mass Solids, lb/hr
131 Temperature, F
12.86 pH
0.13 Free Hydroxide, gmmol/l



	IN	ADDED				OUT	CONSUMED or (GAINED)	
		PURGE	PJM	SPARGE	TOTAL			
NaOH	68.8				64.4	93.8	39.4	lb/hr
CO2	0.0	1.0	23.09	41.84	66.0	0.0	66.0	lb/hr
Na2CO3	281.9	-	-	-	-	356.0	(74.1)	lb/hr
Soluble Alumina	35.1					22.1	13.0	lb/hr
Insoluble Alumina	90.7					104.1	(13.5)	lb/hr
LAW Alumina						24.51	19.4%	
HLW Alumina						101.74	80.6%	

Baseline NaOH & 50% PJM & Sparge results in net Al(OH)3 precipitation

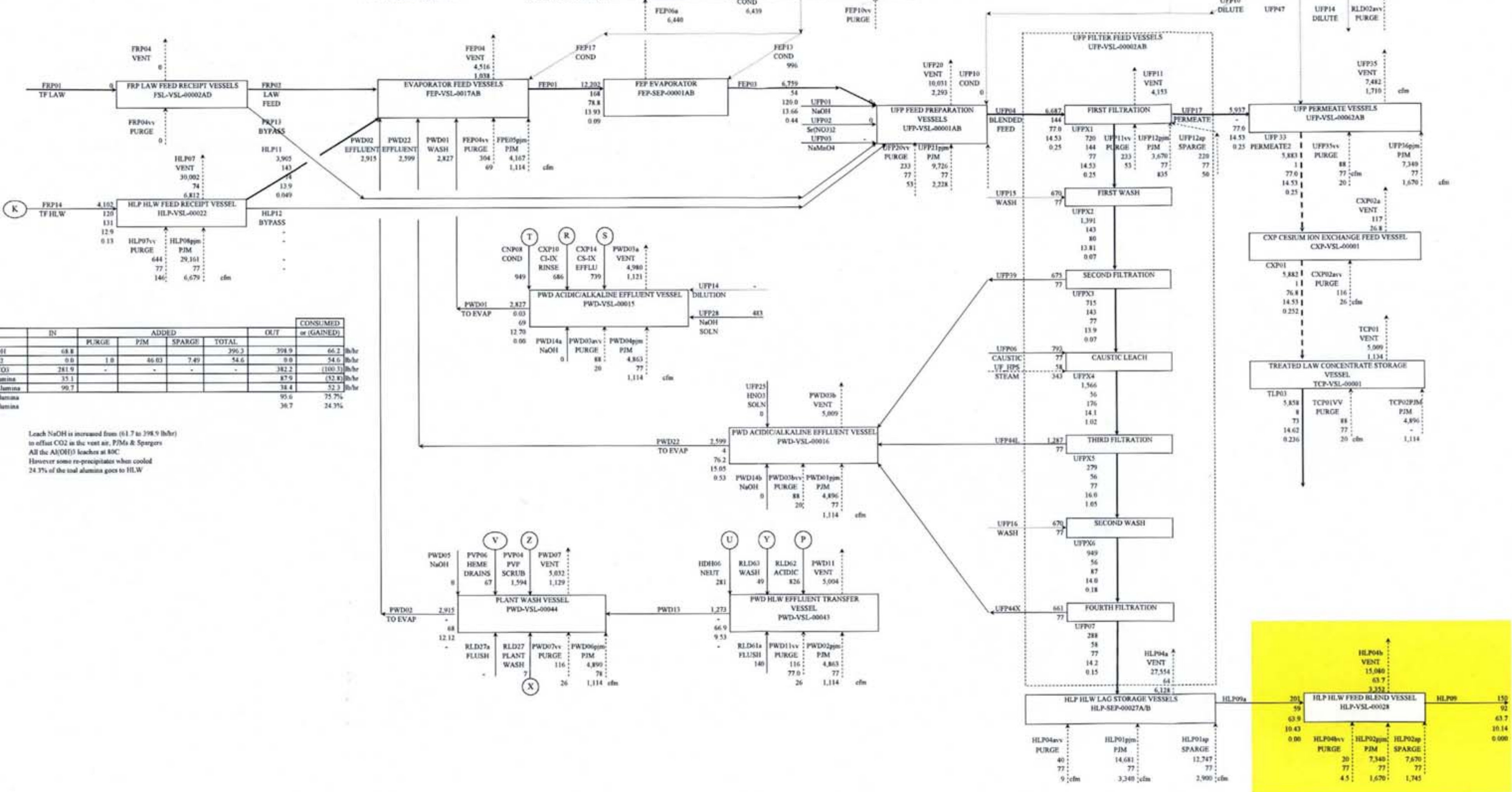
7/27/2007

AZ-101

CO2 ABSORPTION CASE J
100% VENT, PJM & SPARGE
INCREASED NaOH 6.44 X BASELINE
CASEJ.BIN

LEGEND

FRP14 Stream Number
TF HLW Stream Name
4,102 Mass, lb/hr
120 Mass Solids, lb/hr
131 Temperature, F
12.86 pH
0.13 Free Hydroxide, gmmol/l



	IN	ADDED				OUT	CONSUMED or (GAINED)	
		PURGE	PJM	SPARGE	TOTAL			
NaOH	68.8				396.3	398.9	66.2	lb/hr
CO2	0.0	1.0	46.03	7.49	54.6	0.0	54.6	lb/hr
Na2CO3	281.9	-	-	-	-	382.2	(100.3)	lb/hr
Soluble Alumina	35.1					87.9	(52.8)	lb/hr
Insoluble Alumina	90.7					38.4	52.3	lb/hr
LAW Alumina						95.6	75.7%	
HLW Alumina						30.7	24.3%	

Leach NaOH is increased from (61.7 to 398.9 lb/hr)
to offset CO2 in the vent air, PJMs & Spargers
All the Al(OH)3 leaches at 80C
However some re-precipitates when cooled
24.3% of the toal alumina goes to HLW

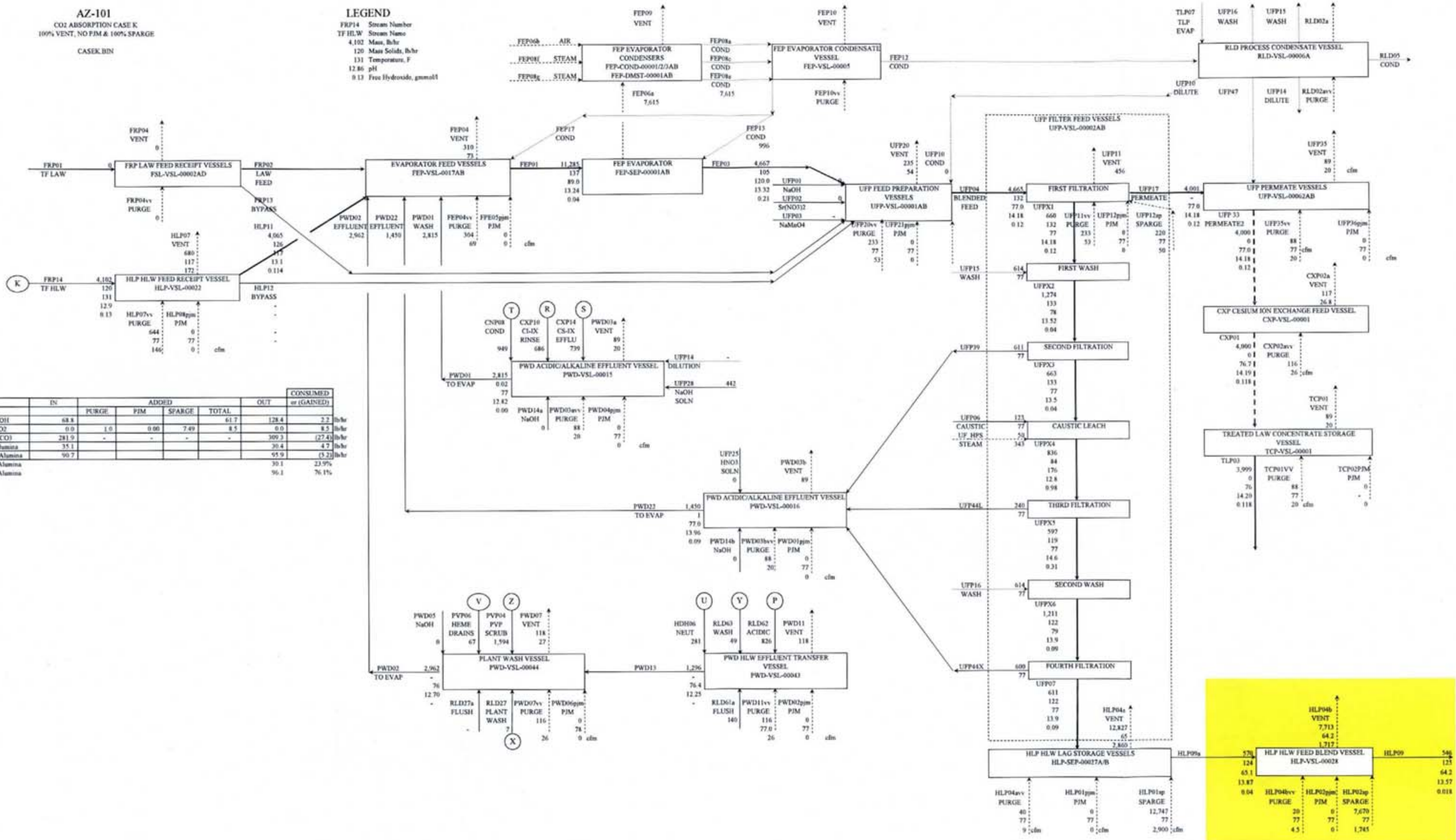
AZ-101

CO2 ABSORPTION CASE K
100% VENT, NO PJM & 100% SPARGE

CASEK.BIN

LEGEND

FRP14 Stream Number
TF HLW Stream Name
4,102 Mass, lb/hr
120 Mass Solids, lb/hr
131 Temperature, F
12.86 pH
0.13 Free Hydroxide, gmmol/l



	IN	ADDED				OUT	CONSUMED or (GAINED)	
		PURGE	PJM	SPARGE	TOTAL			
NaOH	68.8				61.7	128.4	2.2	lb/hr
CO2	0.0	1.0	0.00	7.49	8.5	0.0	8.5	lb/hr
Na2CO3	281.9	-	-	-	-	309.3	(27.4)	lb/hr
Soluble Alumina	35.1					30.4	4.7	lb/hr
Insoluble Alumina	90.7					95.9	(5.2)	lb/hr
LAW Alumina						30.1	23.9%	
HLW Alumina						96.1	76.1%	

Task# ORP-WTP-2007-0227

E-STARS[R] Report
Task Detail Report
09/19/2007 1239

TASK INFORMATION			
Task#	ORP-WTP-2007-0227		
Subject	Concurrence: 07-WTP-226 Transmittal of DOE ORP Design Assessment Number D-07-DESIGN-040; Review of Aluminum Entrainment in BNI Feed Reciept and Evaporator Systems		
Parent Task#		**Status**	CLOSED 09/19/2007
Reference	07-WTP-226	**Due**	
Originator	Perez, Anez (Perez, Anez)	**Priority**	High
Originator Phone	(509) 373-0068	**Category**	None
Origination Date	08/20/2007 0942	**Generic1**	
Remote Task#		**Generic2**	
Deliverable	None	**Generic3**	
Class	None	**View Permissions**	Normal
Instructions	bcc: WTP Off File WTP Rdg File MGR Rdg File T. M. Williams, AMD T. Z. Smith, DEP-MGR D. H. Alexander, WTP J. R. Eschenberg, WTP J. S. Treadwell, WTP		

ROUTING LISTS

1	Route List	Inactive
	• Alexander, Donald H - Review - Cancelled - 09/19/2007 1239 *Instructions:*	
	• Treadwell, John S - Review - Cancelled - 09/19/2007 1239 *Instructions:*	
	• Eschenberg, John R - Review - Concur - 09/07/2007 0822 *Instructions:*	
	• Olinger, Shirley J - Review - Concur - 09/19/2007 0810 *Instructions:*	
	• Eschenberg, John R - Approve - Approved - 09/19/2007 1238 *Instructions:*	

ATTACHMENTS

Attachments	1. 07-WTP-226 DHA.Albert.doc

COLLABORATION

RECEIVED
SEP 1 9 2007
DOE-ORP/ORPCC

COMMENTS

No Comments

TASK DUE DATE HISTORY

No Due Date History

SUB TASK HISTORY

Task# ORP-WTP-2007-0227

No Subtasks

-- end of report --

Task# ORP-WTP-2007-0227

E-STARS[R] Report
Task Detail Report
08/20/2007 0949

TASK INFORMATION

Task#	ORP-WTP-2007-0227		
Subject	Concurrence: 07-WTP-226 Transmittal of DOE ORP Design Assessment Number D-07-DESIGN-040; Review of Aluminum Entrainment in BNI Feed Reciept and Evaporator Systems		
Parent Task#		**Status**	Open
Reference	07-WTP-226	**Due**	
Originator	Perez, Anez (Perez, Anez)	**Priority**	High
Originator Phone	(509) 373-0068	**Category**	None
Origination Date	08/20/2007 0942	**Generic1**	
Remote Task#		**Generic2**	
Deliverable	None	**Generic3**	
Class	None	**View Permissions**	Normal
Instructions	bcc: WTP Off File WTP Rdg File MGR Rdg File T. M. Williams, AMD T. Z. Smith, DEP-MGR D. H. Alexander, WTP J. R. Eschenberg, WTP J. S. Treadwell, WTP		

ROUTING LISTS

1	Route List	Active
	• Alexander, Donald H - Review - Awaiting Response - Due Date *Instructions:* DA Sept 6/2007	
	• ~~Treadwell, John S~~ - Review - ~~Awaiting Response - Due Date~~ *Instructions:* Griffith Robert W. RWG 9/6/07	
Rec'd 9/6/07	• Eschenberg, John R - Review - Awaiting Response - Due Date *Instructions:* 9/7/07	
	• Olinger, Shirley J - Review - Awaiting Response - Due Date *Instructions:* SJO 9/14	
	• Eschenberg, John R - Approve - Awaiting Response - Due Date *Instructions:*	

ATTACHMENTS

Attachments	1. 07-WTP-226 DHA.Albert.doc

COLLABORATION

COMMENTS

No Comments

TASK DUE DATE HISTORY

No Due Date History

SUB TASK HISTORY

Task# ORP-WTP-2007-0227
No Subtasks

-- end of report --