U-ESS-S-00002
Revision 2
December 2016

Evaluation of the Safety of the Situation (ESS): Retained Hydrogen in DWPF Vessels (PISA PI-2014-0013)

APPROVALS

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1.0 PISA Description/Summary

Potential Inadequacy in the Safety Analysis (PISA) PI-2014-0013 pertains to the Defense Waste Processing Facility (DWPF) Documented Safety Analysis (DSA), WSRC-SA-6, and is described in the PISA Database as follows:

"The DWPF Safety Basis does not specifically address the issue of flammable gas retention in DWPF vessels. If agitation in DWPF vessels is stopped, there is a potential for radiolytically generated gasses to be retained in the sludge and subsequently released on agitator restart. The current preventative safety controls for CPC and Low Point explosion do not address the release of retained gases."

Additional information pertaining to PISA PI-2014-0013 includes:

- Date of Discovery: 12/16/2014
- ORPS Report Number: EM-SRR-WVIT-2014-0018

References pertaining to PISA PI-2014-0013 and/or this ESS include:

1. WSRC-TS-95-0019/S-TSR-S-00001, Rev. 53, November 2014, "Technical Safety Requirements Defense Waste Processing Facility."
2. WSRC-SA-6, Rev. 33, July 2014, "Final Safety Analysis Report Savannah River Site Defense Waste Processing Facility."
3. PISA: PI-2014-0009, November 19, 2014 "Melter Feed Rate Temperature Correlation Basis."
4. SBD-S-12-001, Rev. 3 (11/4/14) "Revised process description of steam supplied to HVAC system" (Change to FSAR, Rev. 33, Chapter 5).
5. SBD-S-14-002, Rev. 1, (8/14/14) "Revision to add SWPF/DWPF Interarea Transfer Line cathodic protection bonding cable" (Change to FSAR, Rev. 33, Chapter 1).
6. SBD-S-14-006, Rev. 1. (11/4/14) "Revision to add REDC electric steam boiler" (Change to FSAR, Rev. 33, Chapters 1, 5, and 9).
7. SBD-S-14-007, Rev. 0, (12/04/14) "Revision to allow the use of an alternate drain line for the Gas Chromatograph sample return line" (Change to FSAR, Rev. 33, Chapter 6)
8. WSRC-TR-2007-00174 Rev. 1, DWPF's SME De-Inventory Plan Configuration Managed Documents.
9. WSRC-TS-95-0019/S-TSR-S-00001, Rev. 2014-B, TBD, "Defense Waste Processing Facility Technical Safety Requirements."
10. WSRC-TS-95-0019/S-TSR-S-00001, Rev. 2014-C, TBD, "Defense Waste Processing Facility Technical Safety Requirements."
11. WSRC-TS-95-0019/S-TSR-S-00001, Rev. 2014-D, TBD, "Defense Waste Processing Facility Technical Safety Requirements."
12. SBD-S-14-003, Rev. 0, DWPF Interim Purge Modifications.

13. SBD-S-14-003, Rev. 1, DWPF Final Purge Modifications.
14. SBD-S-14-004, Rev. 0, DWPF Antifoam Tracking Program.
15. S-CLC-S-00148, Rev. 0, Consequences of Explosions in the DWTT, RCT, and LPPP RPT.
16. S-CLC-S-00106, Rev. 3, DWPF Natural Phenomena Consequences, Earthquake and Tornado (U).
17. S-CLC-S-00101, Rev. 1, Hydrogen Explosion Accident Analysis for Actinide Removal Process in DWPF.
18. USQ-WD-2014-00745, PI-2014-0013, Retained Hydrogen in DWPF Vessels.
19. S-CLC-S-00104, Rev. 1, 512-S Facility Consolidated Hazard Analysis Process (CHAP) Basis (U).
20. WSRC-TR-95-0198, DWPF Mode C Probabilistic Safety Analysis.
21. WSRC-TR-2002-00223, Rev. 5; 512-S Facility and Defense Waste Processing Facility Transfer Lines Consolidated Hazard Analysis (U).
22. N-CLC-S-00025, Rev. 0, DWPF Mode C Accident Selection (U).
23. DOE-STD-1020-94, Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities.
24. WSRC-SA-2002-0007, Rev. 16; Concentration, Storage, and Transfer Facilities, Documented Safety Analysis.
25. X-CLC-S-00329, Rev. 0, Quiescent Times for the Recycle Pump Tank and Sludge Pump Tank.
26. X-CLC-S-00333, Rev. 0, Justification for Vessels Not Included in PI-2014-0013.
27. X-ESR-H-00551, Rev. 1, Evaluation of ISDP Batch 7 Qualification Compliance to 512-S, DWPF, Tank Farm, and Saltstone Waste Acceptance Criteria.
28. S-CLC-S-00103, Rev. 2, Explosions in ARP/DWPF Process Cells (U).
29. X-ESR-S-00247, Rev. 0, Quiescent Times for Vessels in the Chemical Process Cell.

2.0 Compensatory Measures / Operational Restrictions

2.1 PISA Compensatory Measures / Operational Restrictions

The following Compensatory Measures are documented in the PISA Database for PI-2014-0013:

"Prohibit starting a stopped agitator in the following vessels without performing an engineering evaluation to determine that the release of retained gas will not exceed 95% CLFL. Restart after temporary shutdown (<1hr for operation evolutions) is allowed without evaluation.

LPPP SPT
LPPP RPT
SRAT
SME
MFT
DWTT
RCT
SMECT (the scrubber and sample pumps are the source of agitation for the SMECT so restart of either is prohibited without evaluation if both were secured. If only one is secured, it may be restarted without evaluation).

Engineering Evaluation may consider the following:
• Actual tank inventory
• Actual waste characteristics
• Agitator down-time
• Actual tank temperature
• Gas retention rate based on tank inventory
• Maximum retention potential (maximum bubble fraction of 0.2)
• Hydrogen fraction in total gas based on WSRC-SA-2002-00007 revision 15 section 3.4.1.5.2.
• Exclusion of catalytic hydrogen generation"

According to PI-2014-0013, the actions listed above are justified by the following:

"Tanks not listed above do not contain sufficient solids inventory to retain gasses
By prohibiting agitator start, the unanalyzed retained gas is not released. The evaluations use assumptions consistent with the CSTF DSA for similar applications (actual waste etc). Use of CSTF DSA assumptions is considered acceptable because the DWPF process has the same material as CSTF until SRAT acid addition. The acid addition tends to lower the yield stress of the material which should tend to reduce the capacity to retain gas bubbles.
Exclude catalytic hydrogen generation based on settling rate, cooling, loss of agitation

slows reaction, acid addition significantly alters material rheology affecting ability to retain gasses."

2.2 ESS Compensatory Measures / Operational Restrictions

2.2.1 Prohibit starting a stopped agitator in the following vessels without performing an engineering evaluation to determine that the release of retained gas will not exceed 95% CLFL. Restart after temporary shutdown (< 1hr for operation evolutions) is allowed without evaluation.

SRAT
SME
MFT
DWTT
RCT
SMECT (the scrubber and sample pumps are the source of agitation for the SMECT so restart of either is prohibited without evaluation if both were secured. If only one is secured, it may be restarted without evaluation).

The Engineering Evaluation will consider the following:
• Actual tank inventory
• Actual waste characteristics
• Agitator down-time
• Actual tank temperature
• Gas retention rate based on tank inventory
• Gas retention potential based on WSRC-SA-2002-00007 Rev. 16 Section 3.4.1.5.3
• Hydrogen fraction in retained gas based on WSRC-SA-2002-00007 Rev. 16 Section 3.4.1.5.3
• Inclusion of catalytic hydrogen generation for tanks having potential catalytic hydrogen (SRAT and SME)
• Ventilation

Tanks not listed above are excluded based on Reference 26. They are not capable of retaining enough gas to challenge LFL. The Engineering Evaluation may use assumptions consistent with the CSTF DSA for similar applications (actual waste, etc). The use of CSTF DSA assumptions is considered acceptable because the DWPF process has the same material as CSTF until SRAT acid addition. The acid addition tends to lower the yield stress of the material which tends to reduce the capacity to retain gas bubbles; therefore, this approach is conservative. Additionally, the adequacy of this compensatory measure regarding CPC vessels is due to the low catalytic hydrogen generation rate of Sludge Batch 8. It is assumed Sludge Batch 9 is similar. If not, this compensatory measure will be re-evaluated.

2.2.2 Agitate the LPPP SPT and the LPPP RPT for two hours at the time interval determined in Reference 25 or an equivalent evaluation. The Gas Chromatograph (GC) readings given in Reference 29 indicate that two hours is adequate.

2.2.3 Ensure that DWPF is processing either Sludge Batch 8 or a sludge batch coupled with a salt batch where the Inhalation Dose Potential (IDP) of the resulting SRAT stream is less than or equal to 20% of the current DSA IDP for the SRAT stream based on DSA Table 9.4-1a.

3.0 Safety Assessment Results

3.1 Immediate Safety Assessment

This PISA affects the following FSAR events:

1. Explosions in CPC/SPC Vessels
2. Explosions in 512-S Vessels
3. Explosions in LPPP Vessels
4. Earthquake
5. High Winds

Two additional events, a cell explosion following a process spill and a cell explosion following an earthquake-caused spill, are eliminated in the FSAR on the basis of the time to CLFL being greater than four days. Based on the following, the justification for eliminating these events continues to be valid considering the possible release of additional retained gas.

a) The release of retained gas as a result of a process spill would occur simultaneous with the spill. The cell continues to be ventilated during the spill and appreciable amounts of hydrogen will not accumulate in the cell vapor space.

b) The seismic cell explosion scenario (either CPC or LPPP) postulates spilling various process tanks into the cell. It is shown in Reference 28 that the time to reach CLFL in either cell under conservative spill volumes, generation rates, etc., is greater than four days.

The LPPP cell explosion scenario assumes transfers into the cell are ongoing at the time of the DBE. Prior to the initiation of a transfer, the receiving tank can be assumed to be at heel. This limits the amount of hydrogen retaining sludge that may be present during the scenario and, therefore, limits the effect that the release of retained sludge might have on the time to CLFL in the cell. This effect is judged not to be sufficient to reduce the calculated time to CLFL to less than four days. Alternate scenarios that eliminate the

transfers and assume instead that LPPP tanks are at their maximum levels, including levels of hydrogen-retaining sludge, remain bounded by the analyzed scenario.

Two CPC seismic scenarios are analyzed. Both assume multiple tanks spill. The high temperature scenario assumes the spills occur at 105 deg C. Tanks at 105 deg C are being agitated and contain no retained gas. The high volume scenario assumes a greater total spill volume but at a lower temperature. CPC tanks other than the DWTT are normally agitated or at heel. If they are agitated, they will contain no retained gas. If they are at heel, the inventory of retained gas would be small and the total hydrogen generation rate (in ft^3/hr) would be lower than the rate used in the DSA analysis, which is based on greater liquid levels. Furthermore, a larger cell vapor space would exist following a spill of tanks at heel compared to the vapor space that exists when those tanks contain the DSA assumed spill volumes. The DWTT contains a limited amount of sludge (~ 1000 gal at most), and, therefore, retained gas, even when it is near capacity. Based on these considerations, the release of the maximum possible retained gas inventory into the CPC in the event of a DBE would not reduce the time to CLFL to less than four days as required per the DSA to eliminate the event.

Per Reference 2, screening analyses have been performed on postulated chemical releases from accidents involving DWPF. These analyses are extremely conservative and the presence of retained gas would not alter their conclusions.

3.1.1 Explosions in CPC/SPC Vessels

Explosions are possible in CPC/SPC vessels (SEFT, PRFT, SRAT, SME, SMECT, MFT, RCT, and DWTT) as a result of the accumulation of flammable vapors in the vapor space of the vessels. Radiolytic hydrogen is generated in all vessels. Catalytic hydrogen is generated in the SRAT, SME, SMECT, MFT, RCT, and DWTT. Flammable gases other than hydrogen (e.g., Isopar L and ammonia) are present in some of the vessels.

The unmitigated scenario begins with a detonation in one of the tanks. The detonation causes cell covers to lift and fall causing the failure of the purge system on the other tanks and breeching of the melter off-gas system. Other tanks, except the melter, detonate and spill their contents leading to a pool fire. Molten glass from the melter is vented to the cell. Finally, falling debris or structural failure crushes glass containers within the vitrification building.

The contributions from explosions in CPC/SPC vessels other than the DWTT and the RCT are based on empty-tank stoichiometric conditions (Reference 17). As such, these are the maximum theoretical consequences for the given volume and the release of additional retained hydrogen, would not increase them. The contributions from explosions in the DWTT and the RCT are calculated as a function of liquid level in each tank with the worst-case occurring when a stoichiometric concentration is reached

(Reference 15). The release of retained gas would lower the level at which this concentration occurs and would increase the calculated consequences.

The unmitigated consequences of this scenario do not challenge offsite guidelines. The DSA-reported total offsite consequences are less than 9.5 rem including a contribution from the RCT explosion of 0.164 rem and a contribution from the DWTT explosion of 0.222 rem. These contributions are relatively small and increases in them caused by the release of retained gas would not result in the total consequences from the scenario challenging offsite guidelines.

The unmitigated consequences of this scenario exceed onsite evaluation guidelines. The consequences of the safety significant mitigated scenario are zero because explosions are prevented. The Compensatory Measures identified in Section 2.2 will ensure that 95% of LFL (or CLFL as appropriate) will not be exceeded upon agitation and the release of retained gas. Therefore, explosions continue to be prevented.

The unmitigated frequency of this event is judged to be Beyond Extremely Unlikely (BEU) (Reference 20). Per the USQE (Reference 18), the frequency of this event has increased.

3.1.2 Explosions in 512-S Vessels

Hydrogen is generated in 512-S vessels (LWHT, LWPT, backpulse tank, and crossflow filter) by radiolysis. The consequences of an explosion in any of these vessels are evaluated in Reference 19. The bounding unmitigated scenario is a deflagration in the LWPT (which contains 1600 gal of MST/Sludge Solids) that fails the vessel and produces enough collateral damage to cause detonations in the LWHT (at overflow), the crossflow filter (90% empty), and the backpulse tank (empty). Additional contributions result from liquid spills and damage to HEPA filters.

The selection of a deflagration instead of a detonation in the LWPT is based on the times to LFL and to stoichiometric. The release of trapped gas would not change this selection based on the limited inventory of trapped gas present in the LWPT (see Reference 26).

The mitigated consequences (safety class and safety significant) are identical to the unmitigated consequences, i.e., mitigation is not credited.

The unmitigated frequency of this event was determined to be Unlikely (Reference 21). Per the USQE (Reference 18), the frequency of this event has increased.

3.1.3 Explosions in LPPP Vessels

Hydrogen is generated in LPPP vessels (SPT, PPT, and RPT) by radiolysis. In addition, the RPT may contain Isopar L and ammonia. The bounding unmitigated scenario

addressed in the FSAR assumes one tank initially detonates, dislodges the cell covers which causes the failure of the purge system, and results in detonations of the other two tanks. Additional contributions to the consequences for the event include spills and a pool fire.

According to Reference 26, the PPT does not retain significant hydrogen because of its low inventory of solids. The detonation consequences for the SPT are based on an empty tank at the stoichiometric concentration of hydrogen (Reference 17). The release of retained gas would not affect this contribution. The detonation consequences for the RPT are based on the liquid level that gives the stoichiometric concentration in the vapor space (Reference 15). The release of retained gas would lower the level at which the stoichiometric concentration is reached and would, therefore, increase the consequences.

The unmitigated consequences of this event do not challenge offsite evaluation guidelines. The DSA-reported offsite consequences are < 1 rem. According to Reference 15, this includes a contribution of 0.0595 rem from the RPT. An increase in the contribution from the RPT as a result of retained gas would not cause the total consequences of the scenario to challenge offsite evaluation guidelines.

The unmitigated consequences of this event exceed onsite evaluation guidelines. The consequences of the safety significant mitigated scenario are zero because explosions are prevented by the LPPP Safety Grade purge system. Compensatory Measure 2.2.2 ensures that 95% of LFL (or CLFL as appropriate) will not be exceeded upon agitation of the SPT or the RPT and the release of retained gas. Therefore, the explosion continues to be prevented when retained gas is included.

The unmitigated frequency of this event was determined to be BEU (Reference 22). Per the USQE (Reference 18), the frequency of this event has increased.

3.1.4 Earthquake

The DBE event is a scenario involving many sub-events that contribute to the over-all consequences of the event (Reference 16). These sub-events include:

a) Explosions in process tanks in the vitrification building, 512-S, and the LPPP

b) Spills from process tanks in the vitrification building, 512-S, the LPPP, and transfer lines

c) Pool fires in the vitrification building and the LPPP

d) Releases from the melter and melter off-gas system

e) Releases from HEPA filters in 512-S

f) Releases from spent melters

g) Releases from crushed/damaged glass canisters.

The unmitigated consequences of this event exceed offsite and onsite guidelines. The presence of retained gas has the potential to increase the consequences of the explosion contributors to the total consequences. As mentioned previously, the explosion consequences for process tanks other than the RCT, DWTT, and RPT are based on empty tank, stoichiometric mixtures and will, therefore, not be increased with the addition of retained gas. The contributions from explosions in the RCT, the DWTT, and the RPT are calculated as a function of liquid level and may be increased by the release of trapped gas. However, as discussed previously with respect to the individual non-DBE events, the increases in these contributions will not have a significant effect on overall consequences. This remains true for the DBE.

In the DSA safety class mitigated and safety significant mitigated scenarios, explosions in the CPC/SPC and the LPPP tanks are prevented by the purge system. Because the DBE is not a planned agitation, however, Compensatory Measure 2.2.1 is not applicable and the purge system cannot be credited with preventing explosions in CPC/SPC tanks. Compensatory Measure 2.2.2 is applicable and allows the LPPP purge system to continue to be credited with preventing explosions in LPPP tanks. Explosions in 512-S are not prevented in the current DSA analysis. The Zone 1 ventilation system is credited in the DSA for the mitigation of onsite consequences, not for the mitigation of offsite consequences.

The DSA DBE analysis (Reference 16) is extremely conservative. According to Reference 27, the sludge IDP appropriate for current operations (Sludge Batch 8) is only 16.1% of the IDP assumed for sludge in Reference 16. The IDPs for other waste streams are expected to be similarly reduced. The DSA reported offsite consequences for the DBE are ≤ 11.5 rem. Per Compensatory Measure 2.2.3, the IDP will be restricted to 20% of the DSA value. The consequences using the new IDP would be about 0.2* 11.5 rem or 2.3 rem. Additional conservatisms present in the analysis include the assumption of multiple participating tanks, the assumption of detonations instead of deflagrations, and the assumption of a stoichiometric hydrogen-air mixture in an empty tank for several tanks. These conservatisms are judged to bring the offsite consequences down to an acceptable level without the need for compensatory measures other than Compensatory Measures 2.2.2 and 2.2.3.

The onsite consequences benefit from the reduction in IDP discussed with respect to offsite consequences, the available Zone 1 ventilation system, which reduces the contribution of the largest contributor to consequences (releases from the vitrification building) by a factor of 200, and Compensatory Measure 2.2.2, which eliminates the contribution of the second largest contributor to consequences (explosions in the LPPP). The analytical conservatisms discussed with respect to offsite consequences also apply to the onsite consequences. As a whole, these systems and conservatisms are judged to

provide adequate margin such that compensatory measures other than Compensatory Measures 2.2.2 and 2.2.3 are not required.

The unmitigated frequency of the DBE is Unlikely (Reference 23). The presence of retained gas does not affect this frequency.

3.1.5 High Winds

As in the case of the DBE, the bounding High Wind scenario involves many sub-events that contribute to the consequences of the over-all event. Because the 221-S process tanks are contained within wind-resistant structures, this event will not cause the agitation required to release retained hydrogen. The LPPP vessels are located below grade and as such are not impacted directly by the High Wind. However, as described in the DSA, these tanks are assumed to detonate in the safety class mitigated scenario. The release of retained gas would increase the calculated consequences for a detonation in the RPT because they are not based on an empty tank, stoichiometric mixture. The calculated consequences from explosions in the SPT and PPT are not affected by the release of trapped hydrogen because they are based on an empty tank, stoichiometric mixture. As mentioned in Section 3.1.3, the consequences of an explosion in the RPT are very small. An increase in those consequences would not result in the over-all unmitigated consequences increasing significantly.

With respect to the contributions from explosions, the safety significant mitigated High Wind scenario includes consequences from 512-S which are identical to those for the mitigated DBE scenario. It excludes contributions from 221-S and the LPPP because of DSA-credited controls. Compensatory Measure 2.2.2 is judged not to be necessary because the safety significant High Wind event will not agitate LPPP tanks.

The unmitigated frequency of this event was determined to be Extremely Unlikely (Reference 23). This frequency is independent of the presence of retained gas.

3.2 Final Safety Assessment

An Unreviewed Safety Question Evaluation (USQE), USQ-WD-2014-00745 (Reference 18), was performed for PISA PI-2014-0013 and resulted in a “positive” evaluation.

The USQE was “positive” based on a “Yes” answer to the following Questions:

1. Increase in probability of occurrence of an accident.
2. Increase in consequences of an accident previously evaluated.
3. Increase in the probability of occurrence of a malfunction of equipment important to safety.

4. Increase in in the consequences of a malfunction of equipment important to safety.

7. Decrease in margin of safety.

The current operational status of the facility is impacted by the Compensatory Measures of this PISA and ESS. As discussed in Section 3.1, the Compensatory Measures discussed in Section 2.2 are adequate to protect the safety basis of the facility until such time that necessary controls have been established.

3.3 Path Forward

1. Implement the Compensatory Measures discussed in Section 2.2.

2. Revise the DWPF Safety Basis (SB) documents to include a discussion of the issue and the documentation of necessary controls.

3.4 Summary of Recommendations and Conclusions

Based on the results of this evaluation, the Compensatory Measures detailed in Section 2.2 shall remain in place until necessary controls have been incorporated into the SB documents. In order to support the milestones for the Alternate Reductant Project, the SB changes for this PISA will be incorporated into the DWPF FY2016 Annual Update, which will be implemented by March 31, 2017.