washington river protection solutions

Tank S-102 Lessons Learned – Engineering Processes

2009 DOE Office of Waste Processing Technical Exchange

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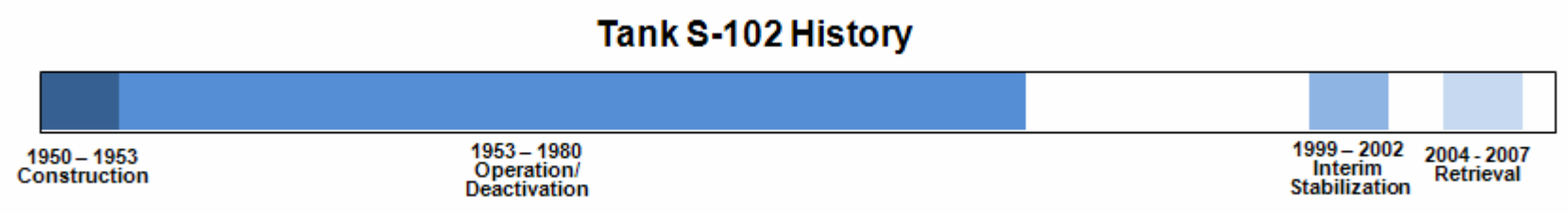
Tank S-102* Event

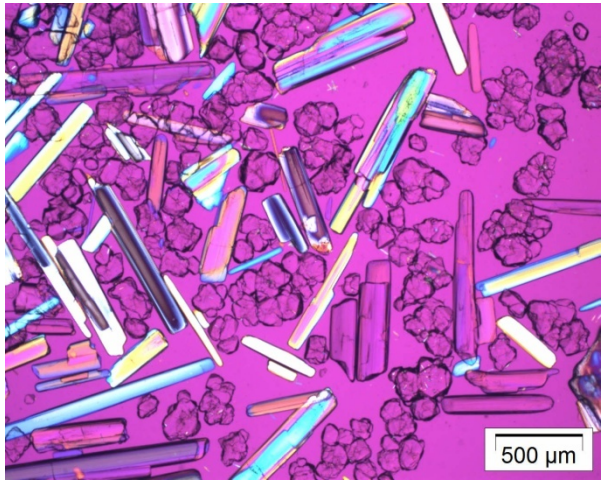
- During trouble-shooting of the tank S-102 waste retrieval pump in the early morning of July 27, 2007, tank waste was forced backwards into a dilution water line, rupturing the line and spilling ~ 85 gallons of waste onto the ground
- Six investigations resulted from the event
- Waste retrieval operations were indefinitely suspended



*758,000 gallon steel-lined, concrete single-shell tank located in 200-West Area

I. S-102 Retrieval Prehistory – Interim Stabilization

- Part of 09/1999 29 Tank Interim Stabilization Consent Decree
  - S-102 Interim stabilization to be completed by 03/30/2001
- Interim Stabilization Requirements
  - Remove tank liquids to <50 kgal drainable liquid; < 5 kgal supernatant
  - Jet pump and saltwell screen deployed
- 1st Attempt 03/1999 – 05/1999
  - Jet pump legs plugged and replaced
  - Restarted 07/1999; valve failed 08/1999
  - Restarted 10/1999; pump failed 11/1999

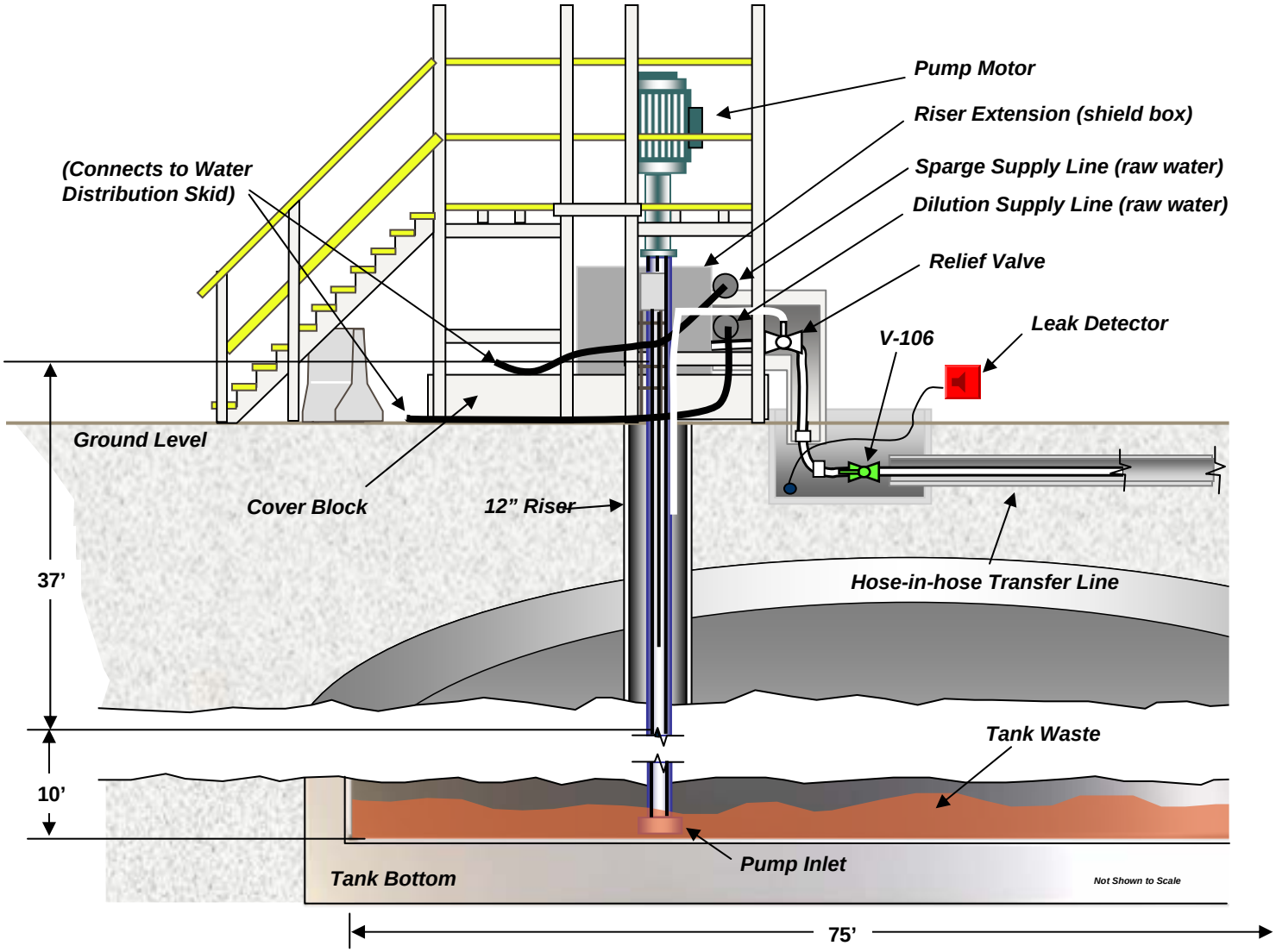


Sodium phosphate (needle) and sodium fluoride phosphate (spud) crystals from S-102

II. S-102 Retrieval Prehistory – Interim Stabilization

- 2nd Attempt 02/2000 – 03/2000
  - Pump failed after one month's operation 03/2000
- 3rd Attempt 05/2000 – 06/2000
  - Pump failed after one month's operation 06/2000
- 4th Attempt 04/2002 – 10/2002
- Third amendment to Consent Decree 09/09/2003 abeyed interim stabilization if waste retrieval started by 03/30/2005 (TPA M-45-05A);
  - Extended in later steps to 07/31/2005
- Beginning retrieval volume 464 kgal – 185"

Tank S-102 Retrieval Schematic



I. S-102 Retrieval Evolution

- Started S-102 retrieval with progressive cavity Seepex # 1 pump in 12/2004
  - Seepex #1 copied successful S-112 Retrieval
  - Pump intake at tank bottom under 120 inches saltcake
  - Frequent intake suction screen plugs
  - Suspended operation with ~7% waste retrieved
- Installed and operated Gorman-Rupp submersible pump 05/2005 – 03/2006
  - Adjustable height pump lowered as retrieval progressed
  - Retrieved additional 38% of waste before pump internal passages plugged

II. S-102 Retrieval Evolution

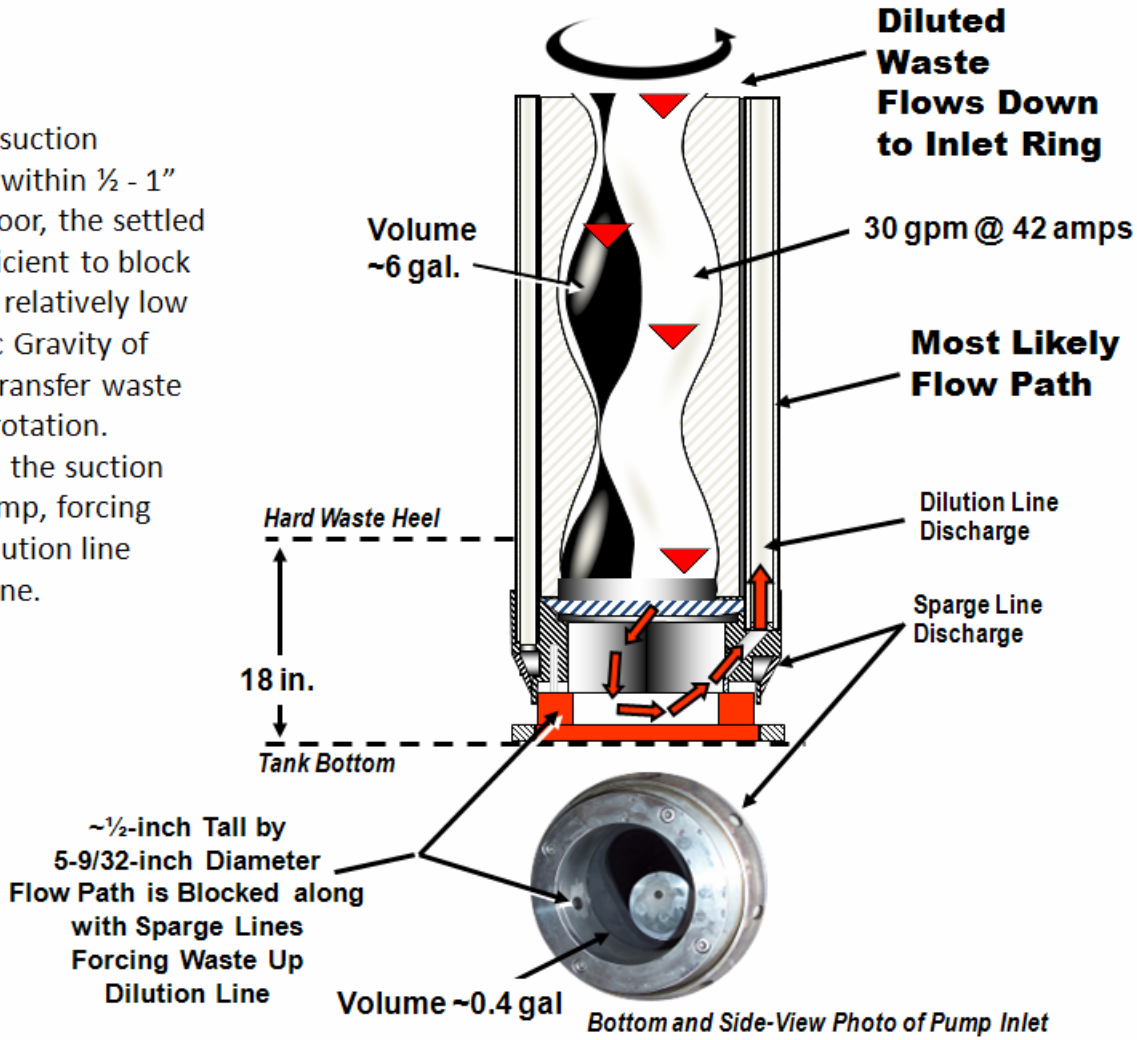
- Restarted and operated Seepex #1 pump until 03/2007 failure with 92% waste retrieved
  - Used 32 kpsi High Pressure Mixer in adjacent riser to clear suction screen
  - 18 inches of waste remained in tank
- 3rd Generation (Seepex # 2) pump installed 07/17/2007
- Resumed retrieval 07/25/2007; 60 kgal transferred by planned shutdown at 20:18
- Restarted pump 07/26/2007 at 09:55
  - Automatic shut down due to closed discharge valve; cleared, and pump restarted at10:32
  - Pump starved for liquid and stopped; transfer restarted at 15:11;
  - Automatic shut down due to VFD ground fault; cleared at 22:00

III. S-102 Retrieval Evolution

- Early in 07/27/2009 troubleshooting efforts to restart or rotate pump manually in reverse were unsuccessful
  - Pump operated twice in reverse for 105 seconds at 01:30
  - Pump operated again in reverse at 02:10
- At 02:10 HPT noticed an increase in radiation background
- ~ 85 gallons of dilution water/tank waste spilled onto the ground from burst dilution water hose

Probable Leak Scenario

With the pump suction "strainer plate" within ½ - 1" from the tank floor, the settled solids were sufficient to block the free flow of relatively low density (Specific Gravity of about 1.05) of transfer waste during reverse rotation. This pressurized the suction cavity of the pump, forcing water up the dilution line and/or sparge line.



S-102 Post-Leak Stabilization Response Actions

Before

After

- Radiation readings: 200 mR/hr @ 10’ – 12’ from riser extension; 100 mR/hr @ 6’ from pump box
- 6” – 18” of soil removed over ~200 ft^2 area (55 drums dirt)
- Backfilled with clean soil and down-posted by September, 2008

S-102 Event Investigations

- Tank Farm Contractor Reviews
  - Event Investigation/Root Cause Analysis – completed 09/17/07
  - Emergency Response Investigation – completed 08/27/07
  - Health Effects Investigation – completed 10/4/07
  - Engineering Design Program Review – completed 10/9/07
- DOE/ORP Reviews
  - DOE Type A – completed 09/19/07
  - DOE EM-62 – completed 09/27/07
  - Corrective Action Effectiveness – completed 04/24/2009

Consequences of S-102 Leak

- Retrieval shutdown – S and C Tank Farms
  - S-102 retrieval never restarted
    - Currently active ventilation is evaporating some additional supernatant
  - C-109 heel retrieval soak pumped out in 08/2007, then retrieval suspended until 06/2008
  - 226 Corrective Actions generated from 6 Investigations
    - All are closed

I. Engineering Lessons Learned

Holistic design reviews are needed

- Many small, individual changes contributed to an unproven copy of S-112 Seepex pump design
  - Increased reverse pump speed from 15 Hz to 45 Hz; reduced reverse run time from 120 seconds to 105 seconds; automated reverse run sequencing
  - Replaced suction screen with strainer plate
  - Moved dilution line discharge from inside suction screen to inside pump suction cavity
  - Added sparge line and distribution ring
  - Added 4” – 12” height adjustment from tank bottom
- Undispositioned leak path design review comment became a Smoking Gun

II. Engineering Lessons Learned

Hazards reviews can be impeded by Mindset

- Mindset was that backflow pressure could not be generated in suction housing because it was open to the tank, i.e., backflow prevention was not required
  - Reviews noted position of water lines but concluded they were not “physically connected”
  - Review of 09/2005 Tank C-202 contamination accumulating from vacuum cycling in an airlift line concluded similar failure mechanism was not credible for Seepex design.
  - Design, and Design Changes were USQ’d and Δ HAZOP’d
- Mindset is subtle; recognizing it is difficult
  - External reviews can help

III. Engineering Lessons Learned

When operating performance is different from predictions, stop and review

- System design was based on a set of waste behavior assumptions; system response was different than expected
  - Air and water sparge observed to create waste channels distant from pump column
  - Inability to create saltcake brine collection cavity around pump
- System operation was adjusted without formal reassessment
  - “Small things that seemed startling at first were rationalized and operation continued on.”
  - Gradual, accumulating changes never analyzed in the aggregate

When is the right time to stop and review the validity of design assumptions?

I. Engineering Changes after S-102

I. Process Hazards Analysis - PrHA

- Rigorous, structured screening and review of designs, processes, and operations for high probability, low consequence events
- Meets methods and expectations of hazard analysis and control:
  - DOE-STD-3009-94, “Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Documented Safety Analyses”
  - DOE-STD-1189, “Integration of Safety into the Design Process”
  - DOE-STD-1186, “Specific Administrative Controls”

II. Process Hazards Analysis – PrHA

- Methodology from 29 CFR 1910.119, “Process Safety Management of Highly Hazardous Chemicals,” (e), “Process Hazard Analysis”
- Key Tank Farm PrHA Elements
  - PrHA Screening
  - Qualified, low turnover PrHA Leadership
  - Formal classroom instruction for PrHA participants
- Application
  - Project Designs
  - Design Modifications
  - Process Modifications

I. Waste Leak Path Evaluations and the Waste Leaks due to Waste Channeling Evaluations

Typical Scenario:

- A pressurized source of fluid is introduced below the solids surface in a waste tank
  - Examples: waste transfer drop legs, waste transfer suction lines connected to reversible, positive displacement waste transfer pumps, high pressure mixers, dilution water lines, water lances, air lift circulators, weight factor dip tubes
- The waste solids have sufficient strength to confine/ channel the pressurized fluid.
- The pressurized fluid is released from the tank through other equipment that has an open path from the waste solids to outside the tank or associated tank structures
  - Examples: the 241-S-102 dilution water line, thermocouple trees with water lances, failed liquid observation wells

II. Waste Leak Path Evaluations

Applicability: Waste Transfers and Ready-to-Install In-Tank Equipment

1. Identify boundary of “physically connected” waste transfer structure that will be pressurized
2. Verify transfer system components meet design (i.e., pressure) criteria
3. Verify non-waste transfer systems are “physically disconnected” from transfer system
4. Identify possible leak flow paths outside of the waste transfer-associated structures (e.g., pump seals, hydraulic lines)
5. Identify other leak motive forces (e.g., syphoning, eduction, wicking, loss of hydrostatic head)

III. Waste Channeling Evaluations

Applicability: Operations that can cause pressurization below the surface of the settled solids, or…

Presence of tank equipment that provides a flow path from below the settled solids surface to a location outside of the tank

1. Identify waste solids properties and level present during planned operation
2. Identify equipment located below solids level, barriers to waste flow through equipment, and operations capable of pressurizing equipment
3. Evaluate plausible leak scenarios and recommend changes to address them

IV. Waste Transfer Confinement Review Board

Precursors - Design Completed; USQ Determination Completed; Leak Path/Waste Channeling Technical Evaluation Completed

1. Present Technical Evaluation to Waste Transfer Confinement Review Board
2. Incorporate Review Board Guidance
3. Obtain Review Board approval
4. Issue Technical Evaluation

Key Engineering Instructions Affected by S-102

1. TFC-ENG-FACSUP-C-26 Waste Leak Path Evaluations

   Contact: E. A. Eric Nelson (509)372-0216 Eric_A_Nelson@rl.gov

2. TFC-CHARTER-37 Waste Transfer Confinement Review Board

   Contact: E. R. Ernie Hamm (509)372-0310 Earnest_R_Hamm@rl.gov

3. TFC-ENG-STD-03 Waste Transfer Confinement Configuration

4. TFC-ENG-STD-28 Process Hazards Analysis Standard

   Contact: M. A. Knight (509)373-1199 Mark_A_Knight@rl.gov

5. TFC OPS-OPER-C-49 Development of Waste Retrieval and Transfer Operating Procedures

6. TFC-PLN-03 Engineering Program Management Plan

Contact: E. A. Eric Nelson (509)372-0216 Eric_A_Nelson@rl.gov

- Engineering Qualification Cards
- Engineering Management Observation Program Improvements
- Rotational Engineer Program reestablishment