Integrity Assessment of Hanford 242-A Evaporator Facility E-A-1 Reboiler Vessel via Fluorescein Liquid Tracer Test Methods – 17357

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ABSTRACT

The 242-A Evaporator Facility is critical to the United States Department of Energy's (DOE) Hanford Site clean-up mission due to limited space within the existing Double-Shell Tanks (DSTs) used to store nuclear and chemical waste until future processing. The 242-A Evaporator Facility is currently the sole waste volume reduction process used at Hanford, and the E-A-1 Reboiler is essential to the Evaporator process. Due to the potential for cross-contamination between the Reboiler tubes through which waste passes and the tube sheets of uncontaminated steam, an assessment of the Reboiler vessel's integrity is required for continuing operations of the facility. In order to meet these requirements, an independent integrity assessment was designed to use fluorescein liquid tracer (LT) to verify the leak-tightness of the Reboiler vessel in accordance with Washington River Protection Solutions, LLC (WRPS) tightness test standards, as well as, the ASME Boiler and Pressure Vessel (B&PV) Code, Section III, Division 1, NB-6300 [1]. LT test methodologies were evaluated and determined to be appropriate for a vessel with restricted access, such as the E-A-1 Reboiler, as it provided the needed sensitivity, reliability, and cost; as well as, exceeded the leak-tightness specifications required by both WRPS and ASME B&PV Code standards.

The integrity test requires water laced with fluorescein be circulated through the waste processing loop of the 242-A Evaporator and samples of steam condensate be collected and analyzed for traces of fluorescein to determine leak-tightness. Liquid condensate sampling was conducted prior to and during testing and the samples were analyzed for fluorescein tracer to determine the amount of fluorescein that flowed out of the tubes of the Reboiler into the steam side of the vessel. Given the established criteria for "leak-tight," test results determined that the Reboiler passed the integrity assessment. After further scrutiny of the 2014 test and data results, it was determined that although the Reboiler was "leak-tight," as established by the test criteria, there was concern of future leakage.

The DOE and the DOE Office of River Protection (ORP) requested that WRPS repeat the integrity assessment in two and a half years to determine if the potential leak was growing, which could threaten continuing operations of the 242-A Evaporator. The 2017 test has been redesigned using lessons learned from the 2014 test and was modified to account for ergonomic and safety considerations, ease of repeatability, and accuracy of results. The liquid tracer methodology and test plan developed for the Reboiler will continue to be implemented in 5 year increments to monitor current and future integrity. The method may also prove useful for other aging components across the Hanford Site, where appropriate.

BACKGROUND

The 242-A Evaporator Facility is located in the 200 East Area of the Hanford Site and was built between 1974 and 1977. The 242-A Evaporator Facility receives radioactive liquid waste, which is pumped through underground pipes from DSTs on the Hanford Site. The 242-A Evaporator Facility's mission is to reduce the waste volume stored in the tanks by evaporating the waste liquids in a low-pressure evaporation process. The remaining waste is pumped back into the DSTs and the liquid products are sent to other facilities for treatment and disposal. The 242-A Evaporator Facility is critical to Hanford's cleanup mission since there are no current plans to build more underground waste storage tanks at the Site, and the space within the existing DSTs at Hanford is limited. By evaporating the liquids, the evaporator process creates space in the existing tanks, which will be used to store waste being retrieved from the aging single-shell tanks. The space is also needed because the Waste Treatment Plant (WTP), which is designed to vitrify the wastes, is currently under construction and operations have yet to begin.

The 242-A Evaporator Facility removes water from the liquid waste by means of low pressure evaporation. Waste enters the facility from a feed tank and is pumped into a recirculating evaporation system consisting of multiple elements including the C-A-1 Vessel, E-A-1 Reboiler, P-B-1 Recirculation Pump, and P-B-2 Slurry Pump. The Reboiler vessel is crucial to the reduction of the waste volume and waste containment. It is a safety significant cylindrical vessel containing inner tubes in which waste is contained and outer tube sheets where uncontaminated steam is used to heat the waste as it passes through the Reboiler. The steam used to heat the Reboiler does not come in contact with any waste and is collected after it condenses and sent to the Treated Effluent Disposal Facility (TEDF). Due to the potential for cross-contamination, the integrity of the tubes and tube sheets must be confirmed on a regular interval. A Reboiler integrity assessment is required by Section 6.1 of WRPS RPP-RPT-52352, "242-A Evaporator E-A-1 Reboiler Functions and Requirements Evaluation Document" (FRED) [2] and the facility Documented Safety Analysis (DSA).

Following a recent upgrade to the facility in 2013, a test of the E-A-1 Reboiler vessel in the 242-A Evaporator was required to safely recommence operations in 2014 and will be repeated at regular intervals. Multiple test methods were initially considered in accordance with the WRPS tightness test standard described in the FRED, as well as, the ASME B&PV Code, Section III, Division 1, NB-6300 [1]. The primary inspection technique in the B&PV Code is a hydrostatic pressure test at 1.25 times the design pressure, where the vessel is then visually inspected for leaks [1]. This approach is not practical for the E-A-1 Reboiler since it is impossible to visually inspect inside the steam side of the Reboiler. The B&PV Code allows an alternative pressure decay test for those cases where the hydrostatic pressure test cannot be conducted [1]. A liquid tracer test was developed as an alternate methodology. The integrity test method used in both the 2014 and 2017 assessments is designed to determine whether the E-A-1 Reboiler is able to maintain a leak-tight boundary to the specifications required by WRPS and involves an independent liquid tracer leak-tightness assessment. Water laced with fluorescein is circulated through the waste processing loop as part of a liquid leak test. Fluorescein dye is an orange powder with no odor and is the most commonly used dye for water tracing studies. Fluorescein Disodium has a color index number of Acid Yellow #73 and a CAS # 518-47-8. The fluorescein used for this testing was is ABCOL®[1] Uranine Powder (Fluorescein Disodium). Steam condensate from the Reboiler is sampled and analyzed for fluorescein concentration. If fluorescein tracer concentrations are below the test standard, then the LT test is considered a PASS and the Reboiler meets the standard and will be tested again in 5 years. If fluorescein is detected above the test standard, then the liquid tracer test is considered a FAIL, and the Reboiler does not meet the standard and will require replacement.

The Reboiler integrity test was developed as an alternative test method to the hydrostatic pressure test prescribed by the B&PV Code. The hydrostatic pressure test consists of holding a pneumatic pressure of 1.1 times the design pressure for a period of 10 minutes. The ASME B&PV Code is the basis of the design of the Reboiler and applicable in terms of a testing basis. The FRED establishes a pneumatic testing pressure of 16-18 psi, which is 2.63 to 4.63 psi above the worst-case pressure difference of 13.37 psi on the tube sheet [2]. This assumes the steam system fails and the pressure is atmospheric on the steam side. A 2.25 psi gradient will exist during the LT test due to the hydraulic head over the upper tube sheet. This achieves a pressure differential of 1.2, which meets the intent of the B&PV Code.

The testing approach meets a standard of 1 liquid drop or less per hour. This exceeds the requirements of both the FRED and the B&PV Codes requirements [1,2]. Should the pressure boundary of the Reboiler be compromised, calculations indicate that holes or their slit equivalents larger than 0.00127cm (0.0005 in.) are detectable using this alternative LT test method [3]. With a pressure gradient of 2.25 psi between the inside and outside of the hole or slit equivalent, one liquid drop or less (0.32 cm or 1/8-in. diameter) will be produced every 60 minutes (this equates to less than 24 drops per day or 0.15 liter [0.04 gallons] per year assuming constant 24-hr operation) [3].

ASTM E432-91, *Standard Guide for Selection of a Leak Testing Method* [4], was also consulted in support of developing this test methodology. ASTM E432-91 states that the “correct choice of a leak testing method optimizes sensitivity, cost, and reliability of the test” and further states “various testing methods must be individually examined to determine their suitability for the particular system being tested. Only then can the appropriate method be chosen [4].” Using this guidance, comparisons were made between the gas pressure decay standards in both the FRED and the ASME B&PV Code, as well as, traditional helium leak detection tests and other industry standards. ASTM E499/E499M-11, *Standard Practice for Leaks Using the Mass Spectrometer Leak Detector in the Detector Probe Mode*, Section 11.1.6.2, states that gas leaks smaller than 1×10^{-5} scc/sec will not show visible leakage for liquids that evaporate quickly such as water (or 1×10^{-6} scc/sec

[1] ABCOL® is a registered trademark of Abbey Color Incorporated, Philadelphia, Pennsylvania.

for slowly evaporating liquids such as oil) [5]. ASTM E515-11 utilizes 1 x 10^{-4} scc/sec as the test standard for locating leaks on a go, no-go basis [6]. Utilizing these leak rates for air, a comparable hole size can be determined for liquid. Calculated hole sizes can then be used to determine an equivalent number of drops per day using a pressure differential of 2.25 psi across the Reboiler tubes. Due to the very low leakage rates (1 x 10^{-4} or 1 x 10^{-5} scc/sec), the equivalent liquid leakage rate is very low at 0.15 drop/year (estimating a hole diameter of 8 x 10^{-5} cm [3.15 x 10^{-5} in.]) for 1 x 10^{-4} scc/sec the equivalent of 1.81 x 10^{-5} drops/hr) and 0.0016 drop/year (estimated hole diameter = 2 x 10^{-5} cm [1 x 10^{-5} in.]) for 1 x 10^{-5} scc/sec or 1.87 x 10^{-7} drops/hr) [7,8].

Based upon the prior discussion of the various ASTM standards, an appropriate duration for a liquid tracer test on the Reboiler was determined to be 1 day. With a reporting limit of 60 ppt for fluorescein from an analytical perspective, leaks as small as 1 drop an hour can be detected by the designed liquid tracer testing method. This method has been compared through calculations to gas flow rate through holes sized as determined by a gas pressure decay requirement. These comparisons show that the liquid tracer test, as designed, exceeds the leak-tight specifications required in both the FRED and ASME B&PV Code standards. The FRED and ASME B&PV Code Standards are based upon gas pressure decay tests due to the inability to utilize visual observation methods to confirm leakage as part of standard hydrostatic tests, which represents the industry standard for component leak-tightness testing.

2014 INTEGRITY TEST

Method

A liquid tracer test was used to verify the integrity of the E-A-1 Reboiler vessel and the identification of a possible leak by monitoring for the presence of fluorescein tracer in the steam condensate. Before conducting the test, five baseline samples and a duplicate of the steam condensate were collected from the selected steam condensate flow measurement tank, TK-C-103, to ensure no fluorescein existed in the system and to establish the background value for the test comparison. The fluorescein was introduced into the process water, using the anti-foam injection system which feeds directly into the C-A-1 vessel. The process water was recirculated mixing of the fluorescein with roughly 98,420 liters (26,000 gallons) of water to a concentration of approximately 331 ppm [7,8].

After the fluorescein was introduced and mixed into the system, P-B-1 recirculation pump was turned off and the fluorescein was allowed to “soak” for 24 hours. The process water was intermittently agitated, to ensure that the fluorescein did not settle, by pulsing P-B-1 for five minutes at hourly intervals. After completion of the 24-hour “soak” period, the steam system was turned back on along with the recirculation pump P-B-1 allowing the steam to flush any fluorescein from the E-A-1 Reboiler and into the condensate line.

Calculations were made assuming an initial minimum fluorescein concentration of

331 ppm in the system and assuming water cross-contaminates the steam condensate line at one drop per hour for 24 hours. Following these assumptions, approximately 0.410 cm^3 (0.025 in^3) [7,8] of fluorescein laced water would be present on the steam side of the Reboiler. As steam is reintroduced into the steam system after the 24-hour recirculation test period, the fluorescein is collected in the steam condensate and sampled at TK-C-103 flow measurement tank. The liquid tracer test checked for the presence of fluorescein that may have flowed out of the waste tubes in the Reboiler into the steam side over the soak period. Flow of saturated steam through the steam side of the system was utilized to transport the fluorescein tracer to TK-C-103, where samples were collected for analysis.

Since the steam is saturated and the process fluid temperature is significantly lower than the saturation temperature, film condensation will occur along the entire length of the Reboiler tubes because the process fluid is heated by the latent heat of condensation provided by the steam. Five sets of samples were collected at the same location and analyzed against the threshold value since it is unknown exactly when the fluorescein pulse had come through with the steam front.

If the presence of fluorescein was detected above 673 ppt, or 3 standard deviations above the baseline mean, whichever is greater, in any of the five samples collected, this would indicate the presence of a leak between the steam side and the waste side of the Reboiler [3]. Setting the test threshold at three standard deviations above the mean of the baseline samples captures a confidence interval which covers 99.7% of the population, assuming a normal distribution. This implies a probability of 99.7% that the possible results will be above the noise level [3]. By using five samples to compute the standard deviation, the uncertainty on the error is reduced and therefore probability of false alarm is also reduced. The estimated sample concentration (assuming 24 drops of 331 ppm fluorescein diluted in approximately 196 liters [52 gallons] of water) was 673 ppt in the steam condensate. Due to an unknown potential hole size in the Reboiler, and therefore, an unknown leak rate, the test statistic was the maximum concentration from the five samples collected. This approach takes the maximum fluorescein concentration from the initial steam front, which should clean and collect any leaked fluorescein from the reboiler tubes. The maximum concentration provides the most conservative test statistic.

Sampling & Analysis

Prior to and during testing, liquid grab sampling was conducted of steam condensate from the TK-C-103 flow measurement tank, where steam condensate is collected prior to discharge. These samples were analyzed for fluorescein dye that was inserted into the E-A-1 Reboiler only for this integrity test. Grab sampling was conducted of the steam condensate in TK-C-103 using Masterflex®[2] tubing and a peristaltic pump as shown in Figure 1. Figure 2 is a photograph of TK-C-103, showing the weir. All samples were collected on the sump side of TK-C-103, left of the weir [9].

[2] Masterflex® is a registered trademark of Cole-Parmer, Vernon Hills, Illinois

Five baseline samples and a duplicate of the steam condensate were collected from tank TK-C-103 prior to injection of the dye into the system, to ensure no fluorescein exists in the system. Additionally, an equipment blank was collected on the tubing and brass fitting prior to collecting any samples. Finally, one radiological screening sample was collected during the collection of the baseline samples.

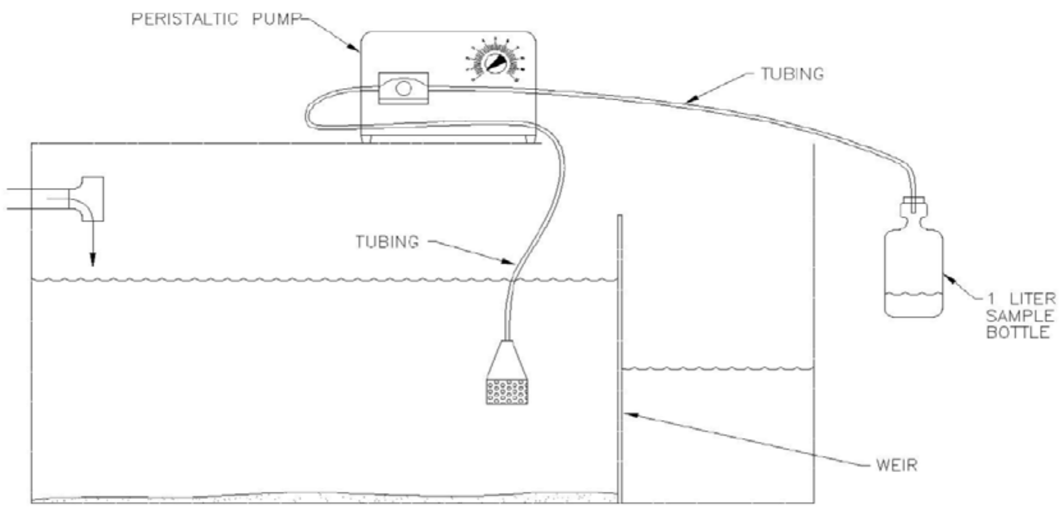

Figure 1: Schematic of TK-C-103 with Sampling Apparatus

Figure 2: Photograph of Tank TK-C-103 Weir

Once all baseline sample were taken, the test commenced in accordance with the "Test Plan for Leak-Tightness of Reboiler Vessel E-A-1 at 242-A Evaporator Facility", RPP-PLAN-56931 [3]. After completion of the 24-hour "soak" period, as the steam condensate entered the sump side of TK-C-103, it was pumped out and collected in sample bottles when the tank was 1/3 full, 2/3 full, just before the condensate began to spill over the weir, 150 gallons after the sump side of the tank was full, and 300 gallons after the sump side of the tank was full [9]. Three 1 liter bottles and one 125 milliliter bottle (for radiological screening samples) were collected at each of the five sampling times. Additionally, one duplicate sample and a field blank were also collected.

All samples were analyzed both on the Hanford Site and at an off-site third party laboratory. The 222-S Laboratory received the samples initially to perform radiological screening analyses of the 125-milliliter radiological screen sample bottles and arrange shipment of the remaining sample bottles to the offsite laboratory, based on the results of the radiological screens. These screens were comprised of Gamma Energy Analysis (GEA) and gross alpha/beta (also known as total activity). After the samples were received at the off-site laboratory, the samples were analyzed for Uranine (Fluorescein Disodium) via Solids Phase Extraction followed by High Performance Liquid Chromatography (HPLC) with fluorescence detecting [9].

Results

Operational difficulties caused variations from the test plan, but the objective of the test plan was still met. The major operational difficulty was injecting the fluorescein into the recirculation line after being mixed in the anti-foam tank. The plugging of the strainer/flow meter on March 8, 2014 caused a delay and allowed some of the fluorescein to “soak” in the system for a much longer period than the planned 24-hours [10]. The injection was restarted on March 10th and the remaining fluorescein was injected into the system. The “soak” period was then restarted on March 11th for the 24-hour test. Samples were collected on March 12th after the 24-hour soak period [10]. The calculation that supported “Test Plan for Leak-Tightness of Reboiler Vessel E-A-1 at 242-A Evaporator Facility,” RPP-PLAN-56931, were redone to consider the different injection sequence, the additional soak time, as well as, different sampling volumes.

All five of the baseline samples returned non-detect (ND) results, indicating that no fluorescein existed in the system prior to the testing initiation. The five baseline samples that were collected prior to the mixing and injection of the fluorescein into the Reboiler system were analyzed in the same batch as the test samples. All samples were analyzed by Southwest Research Institute (SwRI) in San Antonio, Texas. All baseline sample results were reported as non-detect (ND) and the detection limit was 0.54 ppt [10].

As seen in Table 1, the first four of the five test samples after loading the system with fluorescein produced results that were above the non-detect (ND) level. The first three samples (TK103-14-06, TK103-14-07, TK103-14-08) were above the analytical threshold and do not have any data qualification issues. The fourth sample (TK103-14-09) was above the non-detect limit of 0.54 ppt, but was below the reporting limit of 5 ppt and resulted in a flag, indicating that fluorescein concentration is simply an estimate of the concentration. The fifth sample (TK103-

14-10) was again a non-detect, indicating concentrations below 0.54 ppt. All five samples were below the tank tightness standards established in *Test Plan for Leak-Tightness of Reboiler Vessel E-A-1 at 242-A Evaporator Facility,* RPP-PLAN-56931 [3] and the revised test plan calculation, utilizing the actual test conditions, indicating that the Reboiler is leak-tight [10].

Table I: Summary of Sample Analysis [10]

Sample ID	Collection Time	Volume (gal)	Fluorescein Concentration (ppt)
TK103-14-01	07 MAR 2014	NA	ND
TK103-14-01D	07 MAR 2014	NA	ND
TK103-14-02	07 MAR 2014	NA	ND
TK103-14-03	07 MAR 2014	NA	ND
TK103-14-04	07 MAR 2014	NA	ND
TK103-14-05	07 MAR 2014	NA	ND
TK103-14-EB	07 MAR 2014	NA	ND
TK103-14-06	12 MAR 2014, 13:35	65.5	15.4
TK103-14-07	12 MAR 2014, 13:56	129	8.06
TK103-14-08	12 MAR 2014, 14:18	197	5.37
TK103-14-08D	12 MAR 2014, 14:19	197	5.24
TK103-14-09	12 MAR 2014, 14:35	325	1.90 J
TK103-14-10	12 MAR 2014, 14:43	364	ND
TK103-14-FB	UNKNOWN	NA	ND

Notes: J = estimate only, NA = not available, ND = non-detect

The maximum recorded fluorescein concentration was in the first sample collected and had a concentration of 15.4 ppt [10]. Since four of the five post-test samples indicated some fluorescein level in the steam condensate lines, but at levels well below the established tightness standard, an actual leak rate and estimated potential hole-size were calculated. Utilizing the same approach as "Fluorescein Tracer Test Analysis," RPP-CALC-57003 [7] with the actual leak rate and test duration, the results can be compared to the assumed value of 1 drop per hour. Provided that there is no indication that the samples collected are not representative of the leak tightness of the Reboiler, the calculations conducted showed the Reboiler has a maximum leak rate of 0.0261 drops/hr. That leak rate corresponds to a maximum hole-size of 0.000442 cm (0.000174 inches) in diameter or slit equivalent [10]. The samples collected are significantly less than the test standard established in RPP-PLAN-56931. This demonstrates that, under established criteria, the Reboiler is leak-tight [10].

LESSON LEARNED

Several lessons were learned from the first integrity test in 2014, which have led to a revised test plan and engineering modification of the 242-A Evaporator Facility. First, the use of powdered fluorescein led to many operational difficulties that caused the test to deviate from the original plan. The anti-foam system through which the fluorescein was introduced into the process water relies upon an agitator in a tank. This agitator did not adequately mix the fluorescein prior to injection causing plugging of the strainer/flow meter which halted injection 5 hours into the test on March 8, 2014. Approximately 34.5 gallons of the dye tracer had been injected into the C-A-1 vessel at that time. Dye injection resumed on March 10, 2014 after operations personnel was able to clear the plugging and the 24-hour "soak" period officially began at 0900 on March 11, 2014, 82 hours after the beginning of injection. The anti-foam tank also had to be refilled twice during injection with powdered fluorescein due to capacity limits which did not allow for a smooth injection of the dye tracer all at once and allowed the dye to accumulate in the process system at different intervals. Due to the plugging and delay in the test, it is uncertain what the actual starting concentration of fluorescein was once the soak period began.

Second, sample timing of the steam condensate was based off predetermined levels of accumulation in the weir of TK-C-103. However, once all the fluid was pumped out of the weir on March 12, 2014, it was discovered that there was approximately 6.35 cm (2.5 inches) of sediment that remained in the weir, which was unaccounted for in the original calculations. Furthermore, when the condensate isolation valve was opened after turning on steam, 3.81 cm (1.5 inches) of residual condensate was released into the sump, bringing the beginning level of the weir to 10.16 cm (4 inches). In order to remedy these issues, calculations were redone to account for inconsistencies in sampling timing. Unfortunately, due to these difficulties, multiple assumptions were made to account for the deviations from the test plan.

Finally, after reviewing the 2014 test in order to improve the 2017 test, many questions and inconsistencies arose. Calculations for the test initially assumed a 331 ppm concentration in the recirculation loop at the beginning of the test. However, with the plugging and refilling of the anti-foam tank with a powder, which was noted to have left a layer of fluorescein dust all over the room in which the anti-foam tank is located, it is uncertain how much of the 32.5 kg of powder was injected into the process. Assumptions were made that the fluorescein was evenly dissolved in the whole volume, which were never verified. Also, assumptions were made to conservatively estimate the accumulation of fluorescein in TK-C-103 over time as more liquid condensate was pumped into the weir. This required the use of an average of current sample concentrations and previous concentrations to determine leak rate.

Lastly, one key assumption was that all the leaked fluorescein would be captured in the first sample. Although data did support this assumption since there was a steady decline in sample concentration with respect to time and an exponential decay of sample concentration with respect to volume, the exact timing of the pulse and whether it was all captured is uncertain.

REVISED 2017 INTEGRITY TEST

Due to uncertainties and difficulties during the original test and because there are no other data points to which to compare the first test results, DOE and ORP requested that WRPS perform a second integrity test 2.5 years following the 2014 test. Results from the 2014 test determined that the Reboiler was “leak-tight,” given the criteria, however, the concentrations of fluorescein found in the steam condensate did indicate a potential small leak. Questions still exist on how quickly a potential leak could grow, also prompting a repeat test. Using the lessons learned from the 2014 test, a revised test has been developed for 2017. Overall, the revised test follows the same method used in the 2014 test and will adhere to both WRPS standards and B&PV code. The execution of the test method has changed to address issues that arose in the 2014 test and to aid in repeating the test in the future.

First, since the anti-foam system injection method caused the largest delay in the testing process, it has been removed as the primary means of injecting the dye tracer into the process water. Instead, a dedicated injection connection and valve has been installed onto the water system that is used to fill the C-A-1 vessel and recirculation system. Liquid fluorescein of a known concentration will be pumped into the raw water system of the 242-A Evaporator via this new connection and valve. Furthermore, this injection valve will only be used for the integrity test to ensure no other possible contaminants interfere with the results.

Second, in addition to the baseline and steam condensate samples, samples will be taken of the recirculation line during the soak period, in order to determine initial concentration. This initial concentration will aid in determining how much of the fluorescein was dissolved into the system and how much leaked from the tubes to the tube sheets in the Reboiler.

Finally, the utilization of TK-C-103 flow measurement tank as a sample collection location proved difficult during the 2014 test. Contamination and radiological protocols had to be implemented to open the tank and operators were required to work in a small, cramped area to collect the samples. In order to alleviate these issues and ensure that the integrity test could be reasonably repeated with few to no deviations, a dedicated sampling system has been installed. The new sampling system is located in an easily accessible area of the facility and utilizes a catch tank, isolation valves, and dedicated sample valve. Steam condensate can be entirely redirected to the sampling system, using an isolation ball valve installed on the current steam condensate system. Once liquid condensate is flowing from the Reboiler into the sample assembly, it will be collected in a 94.6 liter (25 gallons) catch tank, ensuring capture of the initial pulse of fluorescein and alleviating any uncertainty of the volume of condensate at the time of sampling. Samples will be collected per a sample plan from the sample valve downstream of the catch tank.

Once the pre-determined number of samples are taken, the tank will be drained and re-filled at intervals, again in accordance with the sample plan. All samples will be analyzed in the same manner as the 2014 integrity test.

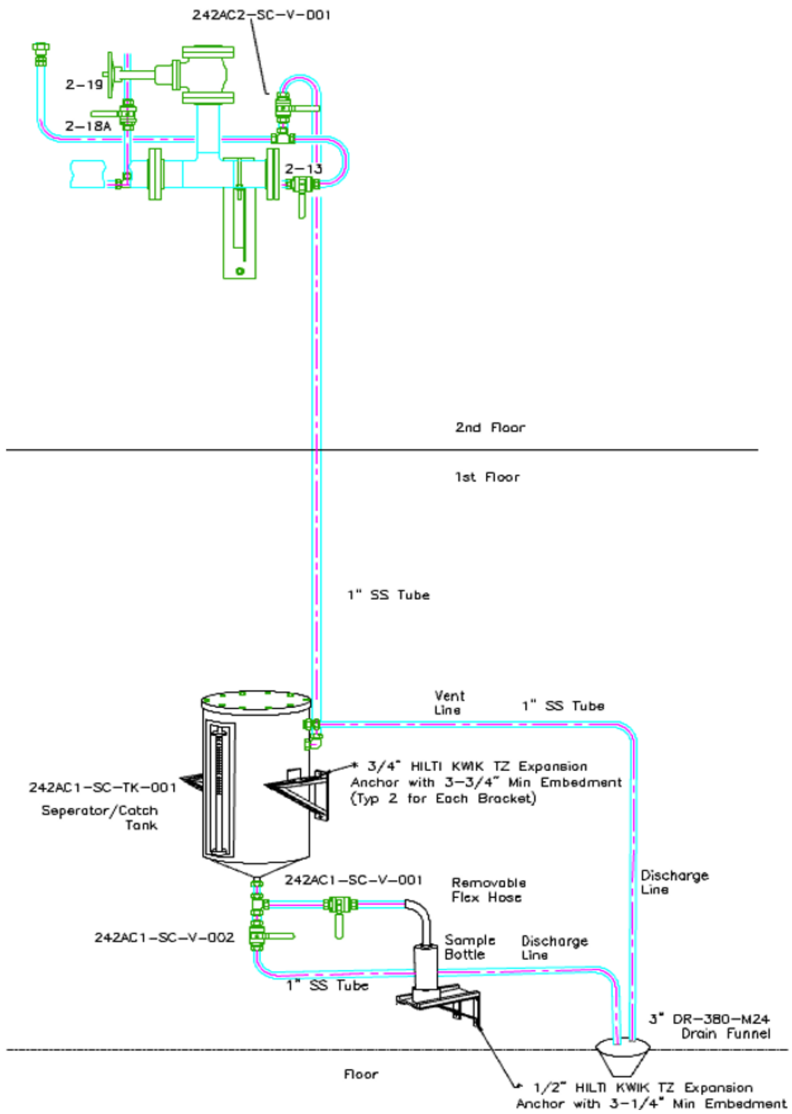

Figure 3: Sampling Tank & Valve Assembly Concept Design

CONCLUSION

The fluorescein leak test as described above can detect holes up to 7.5 times smaller in diameter and more than an order of magnitude smaller in leak rate than is required by the FRED standard established by WRPS and DOE. The nature of working with hazardous nuclear waste presents many difficulties not applicable to other mechanical systems. Although the B&PV code provides for prescribed integrity testing methodologies, alternatives must be considered when not all conditions required by the code can be met. In the case of the 242-A Evaporator E-A-1 Reboiler, which cannot be visually inspected for leaks inside the tube sheets, an alternative liquid tracer test has proven to be invaluable for meeting testing requirements. The 2014 integrity test was the first of its kind to be performed at the 242-A Evaporator on the Hanford site and compares favorably to other industry standards. These methodologies and lessons learned from the initial Reboiler Test will continue to be useful when testing other sealed vessels throughout the facility and Site, to ensure the safety of Hanford workers and equipment.

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