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Stabilization of Underground Solvent Storage Tanks

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Abstract

The Old Solvent Tanks (OST), located at the Savannah River Site (SRS) Old Radioactive Waste Burial Ground (ORWBG), are comprised of 22 underground storage tanks that were used to store spent radioactive solvent and aqueous wastes generated from the plutonium-uranium extraction (PUREX) process. The OSTs were installed at various dates between 1955 and 1968 and used to store the spent solvents until 1974. The spent solvents stored in the OSTs were transferred out from 1976 through 1981 leaving only residual liquids and sludges that could not be pumped out.

Final remediation goals for the ORWBG include an overlying infiltration control system. If the tanks were to structurally fail, they would collapse causing potential for onsite worker exposure and release of tank contents to the environment. Therefore, as an interim action, methods for stabilizing the tanks were evaluated. The preferred remedial action was "Grouting of the Tank Wastes In-situ". The primary function of the grout is to provide structural stability of the tanks by filling void space with material that prevents tank collapse. Incidental to any mixing that may occur, residual material in the tanks will be incorporated into the grouting mixture. The incidental grouting will ultimately improve environmental protection by rendering the residual material immobile.

To accomplish this task, the SRS Environmental Restoration Division (ERD) teamed with the Savannah River Technology Center (SRTC) to determine a remedial design strategy and to translate this strategy into a construction specification and drawings for implementation. The OST remedial design strategy contained the following key aspects for performance requirements and acceptance criteria:

- Grout mix
- Tank atmosphere testing
- Grout delivery system and camera monitoring system
- Off-Gas HEPA filter system and environmental monitoring
- OST Sealing and labeling

On November 15, 2001, the first Old Solvent Tank was successfully grouted. To date (December 31, 2002), an additional nineteen tanks have been completed. This paper will discuss the systems designed to perform and monitor the grouting operation, the grouting process, and the radiological controls and wastes associated with grouting the Old Solvent Tanks.

Introduction

The Old Solvent Tanks (OSTs) are located at the Old Radioactive Waste Burial Ground

(ORWBG), at the Savannah River Site (SRS). The ORWBG is part of the central disposal area for solid radioactive waste at SRS known as the Burial Ground Complex. The ORWBG is being closed under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). As part of this closure, the OSTs are being stabilized as an Interim Remedial Action before final closure of the site.

The OSTs comprise 22 underground storage tanks designated S01 through S22. The tanks were installed at various dates between 1955-1968; Attachment #1 contains a summary of the physical data for the tanks. All OSTs were constructed of thin-walled (approximately 0.02m) milled steel. Fourteen (14) of the tanks contain two riser/vent pipes, while the other eight contain only one riser/vent pipe. The tanks range in diameter from 2.86 to 3.35 meters and in length from 5.99 to 11.73 meters. The capacities range from 25.62 to 102.27 cubic-meters. The tanks were buried in the horizontal position on a small incline. See Figure 1 below for a typical underground solvent tank installation.

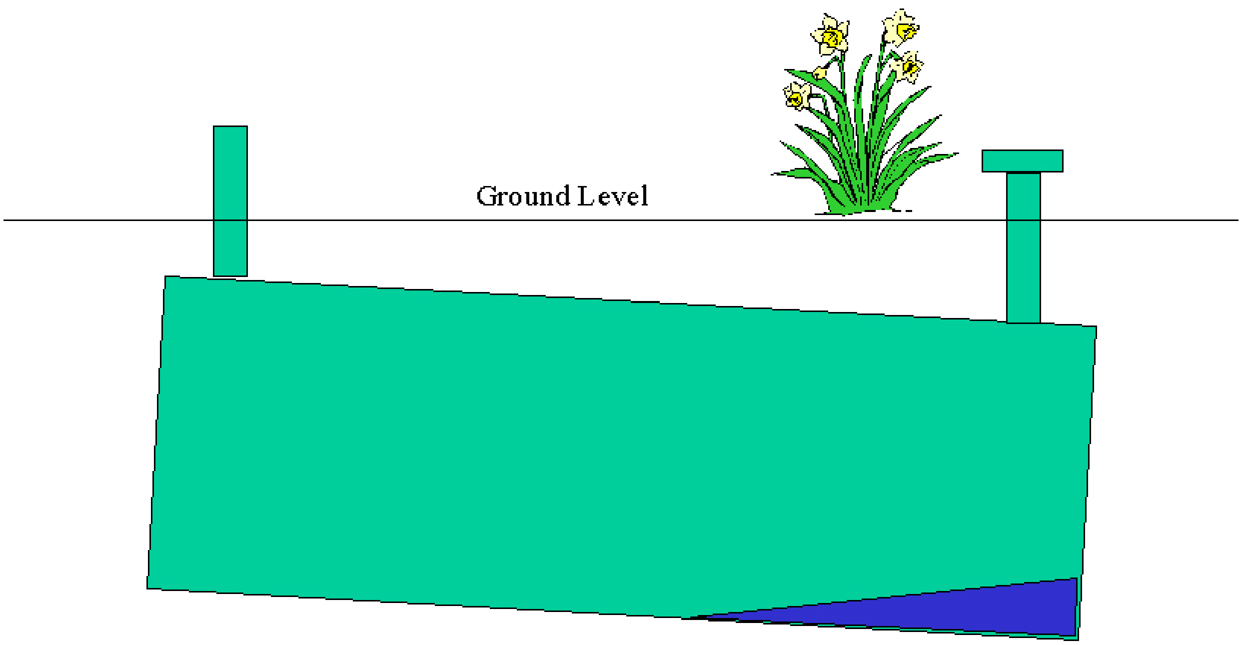

Figure 1. Typical Installation of Underground Solvent Tank

Spent solvent waste generated from the plutonium-uranium extraction process (PUREX) was stored for aging in the OSTs. The mixture, consisting of tri-n-butyl phosphate and dodecane, was classified as low-level radioactive waste. During the aging period, most of the short-lived gamma-emitting fission products decayed and the heavy alpha emitters settled out of the solvent. After phase separation during aging, the volume was reduced by periodically drawing off the organic phase and burning it.

A solvent relocation program was carried out in the late 1970’s and early 1980’s. Tanks S01 through S18 were pumped to "unpumpable heel" into tanks S19 through S22. Starting in November 1980, the solvent was transferred into new, double walled, corrosion resistant tanks in the Low-Level Radioactive Waste Disposal Facility. No additional waste was placed in the OSTs after January 1981. Currently, the OSTs area is controlled as a Contamination Area (CA). The riser/vent pipes are a controlled Fixed Contamination Area (FCA). A FCA is defined as an area with radioactive material that cannot be readily removed from surfaces by nondestructive means.

Because leakage from the OSTs and structural collapse can be expected in the future, the

OSTs were remediated with the following objectives.

- Minimize the exposure risk to workers.
- Prevent groundwater and surface water contamination.
- Stabilize the tanks to prevent collapse.

The closure process is defined as solidifying any liquid waste and then filling the OSTs with grout (1).

A description of the stabilization process is as follows: if the subject tank contains residual liquids, a solidification agent is placed in the tank. A camera inspection of the tank then follows to determine if freestanding liquids still exist. This process is repeated until all residual liquids are solidified. It is important to note that partial lifts of wet grout may be used to maneuver the freestanding liquid into an accessible position. After all the residual liquid is solidified, wet grouting is conducted.

The grout is mixed via conventional cement mixing processes and pumped into the tank with a conventional grout pump. The type of grout, a zero-bleed controlled low strength material, is compatible with the tank waste and does not present a hazard to human health during transportation, handling, mixing and pumping. The grout hardens into a cement-like matrix, thus structurally stabilizing the tanks and reducing the spread of contamination.

In addition to the engineering, radiological, industrial hygiene and construction requirements placed on the project team, weather and land ownership proved to be obstacles as well. The Burial Ground Complex is owned by the SRS Solid Waste Division, but closure of the OSTs is the responsibility of the SRS Environmental Restoration Division (ERD). Therefore, problems encountered during stabilization of the tanks affected more than one division.

The project team consisted of the following organizations:

Owner:	Environmental Restoration Division – responsible for task oversight, budget, scheduling, radiological controls, industrial hygiene and safety
Design Authority:	Environmental Restoration Division – responsible for development of the Task Requirements and Criteria Document, waste disposal and approval of all engineering designs
Design Agency:	Engineered Equipment and Systems (EES) of SRTC – responsible for engineering design and fabrication of equipment and interfacing with design authority, radiological, construction, and industrial hygiene personnel to ensure design is acceptable by all parties involved

Discussion

The flowchart below describes the process used to remediate an OST. Each process step of the flowchart (i.e. rectangular box) will be discussed in detail in this section. It is important to note that since the material in the tanks is considered low level radioactive mixed waste, all intrusive work performed was done so within a 20 millimeter thick plastic glovebox or sleeve.

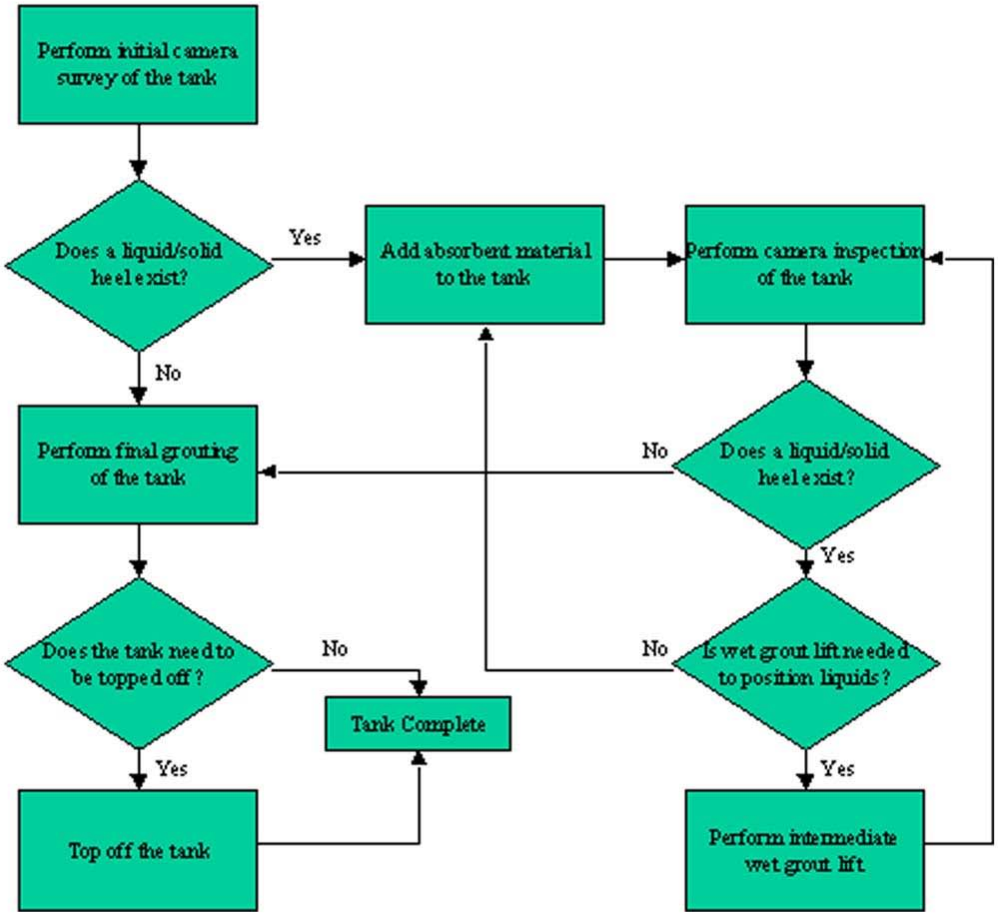

Figure 2. Flowchart of Process for Remediating an OST

Initial Camera Survey

Prior to any intrusive activities within an OST, the tank's internal atmosphere was tested for combustible gases using a Mine Safety Appliance (MSA) Model 261 Combustible Gas and Oxygen Indicator. Upon verification that the tank atmosphere lower-explosive-limit was below 15%, as set by industrial hygiene, closure activities commenced.

A "pole camera", developed by EES, was deployed to perform a camera survey of the tank internals. A Sony FCB-IX10 Color Camera Module and light were installed in a camera housing with the ability to tilt the camera 90 degrees in the vertical profile. The camera module provided the operators the ability to remotely zoom and focus the lens allowing the entire tank to be viewed. The camera assembly was attached to approximately 1-meter poles that screwed together. This allowed the operators to lower the camera into the tank riser in sections, thus eliminating the need for tall glovebags.

Camera surveys were recorded on digital videotapes for review. Based on the survey, the Design Authority determined the next course of action. If no liquid or sludge heel was present, the tank was prepared for final grouting. Otherwise, the tank was prepared to receive dry absorbent materials.

Addition of Dry Materials

Solidification materials are added to an OST through a funnel and PVC piping arrangement. The initial system consisted of a plastic funnel, with a 0.06m neck, and 1-meter pieces of 0.05m PVC that screwed together. The final piece of PVC, the piece that protruded into the tank, could be configured to contain a straight end, a 45-degree end, or a 90-degree end depending on the desired projection of material throw. The pieces were screwed together and lowered into the tank riser. Lastly, the funnel was added and used to support the assembly on the tank riser during the material addition.

The system was redesigned after problems were encountered during material placement. A burst of contaminated air exited the tank through the PVC delivery tube and caused the Constant Air Monitors to alarm. A section of PVC pipe, the same diameter as the riser, was added with HEPA filters to ensure proper ventilation during material placement. In addition, a plumb bob was designed that would plug the funnel after all material was placed. This redesign has proved very important when placing dry materials in single riser tanks, where the displaced air does not have an additional riser through which to vent.

All dry material placement systems built were tested through a mock-up riser system into a skid pan. The materials used to stabilize the residual liquids included Setcrete for the water, Toxi-Dry for the solvents, and Oil-Dry. Each material was tested to ensure free flow and throw distance of the placement system. This was completed to ensure the system could deliver dry materials to any part of the OST.

Intermediate Grouting

Intermediate grouting is defined as any grout addition to the tank for the purpose of moving residual liquids into place for stabilization. This is important to note, because, while the same systems are used for both intermediate and final grouting of the OST, the cameras and level alarms are not used during intermediate grouting. This is also the first step where different systems are used depending on the riser configuration of the OST. For double riser tanks, a separate grout delivery and off-gas system are used, while for the single riser tanks, one system has been designed to serve both purposes.

The primary grout delivery system for double riser tanks consists of a 0.06m carbon steel delivery pipe with a dual valve assembly. The dual valve assembly was designed and installed to support isolation and containment of any radiological materials. The lower end of the delivery piping contains a 45-degree elbow that directs the grout towards the riser wall. This is necessary due to the pulsating grout pump and subsequent splash back up the riser when the grout is allowed to drop straight into the tank. The system connects to the low-end riser through the existing 0.10m carbon steel flange or spool piece provided for the straight pipe risers.

The high-end riser of the dual riser tanks is fitted with a filter assembly to prevent the release of particulate contaminants or radioactive materials to the environment. The filter assembly contains a HEPA filter and charcoal-scrubbing filter to perform these operations. Both filters were sized to allow the grout pump to operate at maximum speed and to handle the worst case scenario for contaminants within the tanks. A Constant Air Monitor is attached to the off-gas system for monitoring during grouting. In addition to the filters, the assembly contains the following:

- A secondary grout delivery system. This system is used for grout delivery during the tank top-off procedures.
- A sample port was also provided to support insertion of an MSA Model 261 combustible gas and oxygen analyzer system if needed.
- A pressure gauge is installed for monitoring breakthrough or clogging of the filter system.

Eight of the tanks contain a single riser/vent pipe. In addition, four of these tank riser/vent pipes were only 0.07m in diameter. Therefore, a separate system was designed that incorporated the grout delivery piping and off-gas filter system for these tanks. The grout delivery system is similar to the double riser system except that the pipe diameter is only 0.04m. Also, the grout delivery tube is extended into the tank to mitigate grout/air exchange in the small diameter riser. A 0.07m carbon steel wye is located within the system. One branch contains the off-gas system, identical to the double riser system, and the other contains the connection to the grout delivery system. A pressure gauge is also installed on the single riser system.

The systems developed were all prototyped and tested on a mock-up tank assembly prior to field deployment. A 4.16 cubic-meter tank was modified to contain the appropriate number and size of riser/vent pipes. Water was initially used for testing so that the tank could be emptied and reused as modifications to the system were made. After all system modifications/enhancements were made, the mock-up tank was grouted. The use of mock-ups allowed the field operators, design authority, design agency and radiological control personnel to better understand the process and its potential pitfalls or problems.

Final Grouting

Final grouting is defined as any grout addition to the tank that fills the tank into the riser pipe, which stabilizes the tank per the remedial action. During final grouting, the systems used for intermediate grouting are reused with the cameras and grout level probes attached and monitored to ensure the tank is not overflowed.

The primary grout delivery system on a double riser tank contains a "lipstick camera" (Genwac Camera, Model #GW-704R) and light pack attached to the grout delivery pipe as shown in Figure 3, located on the next page. The camera is monitored during grouting to ensure that grout is flowing, i.e. no plug in the line, and the low-end riser does not fill with grout before grout is seen in the high-end riser.

The high-end riser off-gas system contains two cameras for viewing the grouting activities. One is located in the riser to ensure that the tank is not overfilled. The second is located approximately 0.025m in the tank to view the grout approaching the riser. This camera is consumed during grouting process. In addition, two conductivity level probes are situated 0.15m and 0.30m into the tank. The probes, with audible alarms, warn the operator that the grout is approaching the riser pipes.

The single riser system contains one camera and the grout level probes. This system also requires that the level probes be protected from the topside as grout is poured over them into the tank. The level probes warn the operator that the grout is approaching the riser pipe. As the grout level rises towards the riser pipe, the grout pump is set to an almost idle speed. This allows the operator maximum control of filling the tank into the riser using the camera as an aide.

Tank Top-Off

Tank top-off is necessary for double riser tanks where the slope of the tank does not allow the self-leveling grout to enter both risers during final grouting. The high-end riser system contains a smaller 0.02m grout delivery pipe to complete the top-off. The high-end riser system camera is used to monitor this activity. The riser is topped-off to approximately 0.46m above ground level.

For the single riser tanks, if top-off was needed, Setcrete was added by hand until the riser pipe was full.

Riser Caps/Waste Disposal

After grouting, the tank riser pipes were stabilized. This was accomplished by placing a 0.91m diameter, 1.22m tall piece of HDPE over the riser and filling it with grout. This ensures that during capping of the ORWBG, the riser pipes are not inadvertently damaged.

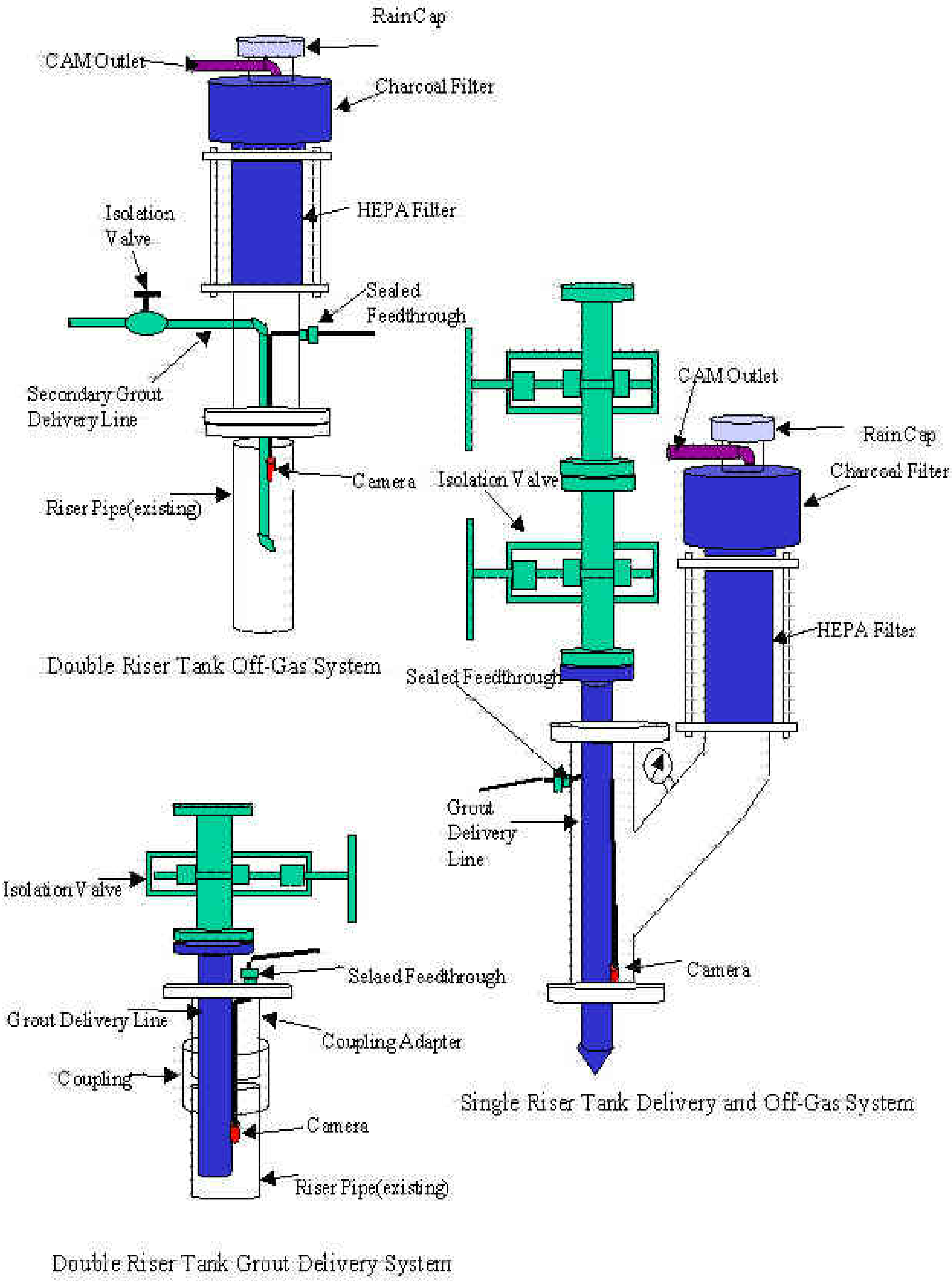

Figure 3. OST Delivery and Off-Gas Systems

All radiological waste generated during tank closure is stored in a B-12 waste box. At the conclusion of the project, the B-12 boxes will be stored in two rows in the original Contamination Area created by the tanks. Forms will be built around the B12 boxes to secure them and the form will be filled with grout. The impending cover system for the ORWBG will then be placed over this B12 form site.

Results

To date, 20 OSTs have been successfully stabilized. The systems developed for recording tank conditions, grout delivery, off-gas filtering and monitoring grouting activities have been slightly modified as anomalies or new requirements have arisen. The following is a discussion of the anomalies that have occurred and the resulting engineering/process improvements.

During the placement of dry materials into Tank S19, a radioactive release occurred when a burst of air entered the glovebox/glovebag through the dry material placement piping. Upon inspection, it was discovered that the glovebag material had developed a pinhole around the attachment to the riser pipe. To reduce the risk of additional releases, the following engineering improvements were made.

- A thicker glovebag material was used for future tanks. (20 mil instead of 12 mil)
- Padding was placed around the glovebag where it encountered the riser connection.
- The improved dry material placement system described in the "Addition of Dry Materials" section was installed. This system incorporates a place for the escaping air to be filtered before entering the glovebox/glovebag.
- Radiological Control personnel increased the number of inspections completed on all glovebox/glovebag systems.

During the placement of an intermediate grout lift in Tank S14, the glovebag connecting the off-gas filtering system to the high-end riser pipe pressurized. The intermediate grout pour was immediately stopped and the situation assessed. It was determined that during the installation of the off-gas system to the riser pipe, the camera and grout level probe wires were pinched between the flanges. The Design Authority now requires that all wires, protruding into the riser pipe, be securely fastened to the secondary grout line on all off-gas systems.

Closure of Tank S14 continued to be problematic as the final pour was attempted. At the start of the third grout truck placement the sleeve on the upper pinch valve became pressurized and exploded. An error occurred in communication between the grout pump operator and valve operator. After a radiological survey revealed that no contamination was present, the sleeve was replaced and the pour continued. During the placement of the fourth truck of grout (five trucks were expected to fill the tank), water was seen exiting the off-gas system through the charcoal filter. After several critiques, the final cause was determined to be a combination of several items. These items include: the incorrect tank volume based on old procedures, inadequate monitoring due to the expectation of five trucks of grout to fill, no audible warnings on the grout level probes, and the downtime caused from the sleeve replacement that affected grout properties.

The process improvements that came out the critique to allow work to continue are as follows:

- All personnel will be stationed upwind during grouting
- Enhanced communication between the operators(headsets)
- Additional radiological monitoring in the area
- Increase downwind buffer area during grouting

The engineering improvements that came out of the critique are as follows:

- Audible alarms were added to the grout level probes.
- All cameras will have their own screens for viewing; previously split screens were

used.
- An additional camera was added to the high-end riser pipe in the tank.

After restart of work following the Tank S14 incidents, no additional anomalies have occurred.

Conclusions

Success of the OSTs stabilization project relied heavily on the teamwork of the project personnel. Role definitions and interfaces for key project personnel ensured all engineering designs and construction aids were compatible prior to implementation in the field. The project team was able to cut design, fabrication and rework time during critical production times because of the direct interaction between the Design Agency and all involved personnel. In addition, the project outcome, stabilization of the OSTs was clearly defined for all project personnel prior to work initiation. This allowed the project team to make decisions based on the desired outcome instead of being driven by cost and schedule issues.

Summary

The Old Solvent Tanks (OSTs), located at the Savannah River Site (SRS) Old Radioactive Waste Burial Ground (ORWBG), are to be stabilized as an interim remedial action prior to an overlying infiltration control system being placed over the ORWBG. To accomplish this task, the SRS Environmental Restoration Division (ERD) teamed up with the Savannah River Technology Center (SRTC) to determine a remedial design strategy and translate this strategy into a construction specification and drawings for implementation. The OST remedial design strategy contained the following key aspects for performance requirements and acceptance criteria:

- Grout mix
- Tank atmosphere testing
- Grout delivery system and camera monitoring system
- Off-Gas HEPA filter system and environmental monitoring
- OST Sealing and labeling

The Engineered Equipment and Systems Department (EES) of SRTC designed, fabricated and tested all of the necessary systems used to fill the OSTs with grout. These systems included a dry material delivery system, a wet grout delivery system and an off-gas system. Extensive testing was completed on all systems using an above ground mock-up tank and simulating actual field working conditions. Due to the testing, design problems were corrected prior to any system being placed in service.

This teamwork and testing led to the first Old Solvent Tank was successfully grouted on November 15, 2001. To date, December 31, 2002 an additional nineteen tanks have been completed.

References

1. M.R. Welty, "Safety Evaluation for the Closure of the Old Solvent Tanks Facility at the Old Radioactive Waste Burial Ground (U)", WSRC-TR-2001-00233, Westinghouse Savannah River Company (2001).

Attachment #1

Old Solvent Tank Physical Data

Tank Number	Length (m)	Diameter (m)	Volume (cu m)	Volume of Liquid Heel (cu m)	Volume of Solid Heel (cu m)	Number of Risers	Riser Diameter (m)	Slope (m/m)
S1	8.153	2.438	38.075	0.443	0.019	1	0.10	0.0031
S2	8.153	2.438	38.075	0.424	0.125	1	0.10	0.0210
S3	8.153	2.438	38.075	1.507	0.015	1	0.10	0.0093
S4	8.153	2.438	38.075	1.397	0.023	1	0.08	0.0093
S5	11.735	3.200	94.407	0.348	0.424	1	0.10	0.0262
S6	7.315	2.438	33.273	1.041	0.000	1	0.08	0.0052
S7	5.486	2.591	28.923	1.120	0.008	1	0.08	0.0093
S8	5.486	2.591	28.923	0.519	0.023	1	0.08	0.0278
S9	6.096	2.438	28.472	0.000	0.049	2	0.08	0.0083
S10	6.096	2.438	28.472	0.038	0.117	2	0.10	0.0125
S11	6.096	2.438	28.472	0.053	0.049	2	0.10	0.0063
S12	6.096	2.438	28.472	0.019	0.019	2	0.10	0.0125
S13	7.010	3.048	51.156	0.825	0.163	2	0.10	0.0326
S14	11.582	3.353	102.267	1.389	0.447	2	0.10	0.0121
S15	9.754	2.286	40.032	0.000	0.549	2	0.10	0.0078
S16	9.754	2.286	40.032	0.000	1.033	2	0.10	0.0078
S17	5.486	2.438	25.620	0.000	0.026	2	0.10	0.0046
S18	5.486	2.438	25.620	0.019	0.008	2	0.10	0.0370
S19	11.735	3.200	94.407	2.169	0.102	2	0.10	0.0314
S20	11.735	3.200	94.407	7.552	0.034	2	0.10	0.0130
S21	11.735	3.200	94.407	0.693	0.117	2	0.10	0.0043
S22	11.735	3.200	94.407	1.696	0.026	2	0.10	0.0065