Tank Closure Progress at the Department of Energy's Idaho National Engineering Laboratory Tank Farm Facility - 9554

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ABSTRACT

Significant progress continued at the U.S. Department of Energy (DOE) Idaho National Laboratory (INL) with the completion of the closure process to empty, clean and close radioactive liquid waste storage tanks at the Idaho Nuclear Technology and Engineering Center (INTEC) Tank Farm Facility (TFF). The TFF includes eleven 1,135.6-kL (300,000-gal) underground stainless steel storage tanks and four smaller, 113.5-kL (30,000-gal) stainless steel tanks, along with tank vaults, interconnecting piping, and ancillary equipment. The TFF tanks had historically been used to store a variety of radioactive liquid waste, including wastes associated with past spent nuclear fuel reprocessing. Four of the large storage tanks remain in use for waste storage while the other seven 1,135.6-kL (300,000-gal) tanks and the four 113.5-kL (30,000-gal) tanks have been emptied of waste, cleaned and filled with grout. Recent issuance of an Amended Record of Decision (ROD) in accordance with the National Environmental Policy Act, and a Waste Determination complying with Section 3116 of the Ronald W. Reagan National Defense Authorization Act (NDAA) for Fiscal Year 2005, allowed commencement of grouting activities on the cleaned tanks. The first three 113.5-kL (30,000-gal) tanks were grouted in the Fall of 2006 and the fourth tank and the seven 1,135.6-kL (300,000-gal) tanks were filled with grout in 2007 to provide long-term stability. During 2008 over seven miles of underground process piping along with associated tank valve boxes and secondary containment systems was stabilized with grout. Lessons learned were compiled and implemented during the closure process and will be utilized on the remaining four 1,135.6-kL (300,000-gal) underground stainless steel storage tanks.

INTRODUCTION

Background

The INTEC TFF is located on the INL Site. The INL is an approximately 2,305-km^2 (890-mi^2) reservation owned by the United States government and located in southeastern Idaho. In 1953, the Idaho Chemical Processing Plant, now INTEC, was chartered to recover fissile uranium by reprocessing spent nuclear fuel (SNF). In 1992, the DOE officially discontinued reprocessing SNF at INTEC. This decision changed INTEC's mission to manage, store, and treat reprocessing wastes generated from past and current operations and activities. The INTEC facility is located approximately 29 km (18 mi) from the closest eastern boundary, approximately 23 km (14 mi) from the closest western boundary, approximately 16 km (10 mi) from the closest southern boundary, and approximately 29 km (18 mi) from the closest northern boundary.

The TFF, located within the northern portion of INTEC, comprises eleven 1,135.6-kL (300,000-gal) below grade stainless steel tanks in unlined concrete vaults of various construction, four inactive 113.5-kL (30,000-gal) stainless steel tanks, interconnecting waste transfer lines, and associated support instrumentation and valves.

The DOE is closing the TFF tanks in response to a January 1990 Notice of Noncompliance and subsequent Consent Order. The Idaho Department of Health and Welfare and U.S. Environmental Protection Agency (EPA) issued the Notice of Noncompliance to the DOE because the tanks in the TFF did not meet the secondary containment requirements as set forth by Idaho Administrative Procedures Act (IDAPA) 58.01.05.009 (40 Code of Federal Regulations [CFR] 265.193). The resulting 1992 Consent Order (and subsequent modifications) required the DOE to permanently cease use of the five 1,135.6-kL (300,000-gal) tanks that are contained in five pillar-and-panel vaults by June 30, 2003. The Consent Order also required the DOE to permanently cease use of the remaining 1,135.6-kL (300,000-gal) tanks by December 31, 2012, or bring the tanks into compliance with secondary containment requirements. The DOE decided to close the TFF tanks because radiation fields would make compliance with secondary containment requirements impractical, and because the DOE did not anticipate a need for such storage after 2012.

The DOE evaluated options for tank waste treatment and INTEC facility disposition. This evaluation is discussed in the *Idaho High-Level Waste and Facilities Disposition Final Environmental Impact Statement* (EIS) [1]. DOE issued the *Record of Decision for the Idaho High-Level Waste and Facilities Disposition Final Environmental Impact Statement* on December 19, 2005 (70 Federal Register [FR] 75165), in which DOE decided, among other things, to select steam reforming as a treatment technology for the remaining tank waste and pursue a phased decision-making process by issuing an amended ROD in 2006. [1]The initial 2005 ROD stated that the 2006 Amended ROD would specifically address closure of the TFF in coordination with the Secretary of Energy's Determination pursuant to Section 3116 of the NDAA for Fiscal Year 2005.

The TFF tank waste is a mixed waste (radioactive and hazardous), so the tanks are being closed in accordance with DOE requirements as a radioactive waste storage facility and with State of Idaho Hazardous Waste Management Act (HWMA) and Resource Conservation and Recovery Act (RCRA) requirements for closure of an interim status HWMA/RCRA tank system. (Some of the soils surrounding the TFF components have been contaminated by past leaks from transfer piping. Decisions regarding the remediation of these contaminated soils are being made pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act [CERCLA].) These requirements include preparing several documents. The documents describe DOE's actions to close tanks and meet closure objectives. The DOE requires closure plans, a performance assessment (PA), and a composite analysis (CA) to address radioactive constituents. To meet HWMA/RCRA requirements, closure plans and sampling and analysis plans (SAPs) addressing the hazardous waste constituents are required.

1. DOE was sued in 2002 regarding its authority to determine whether certain reprocessing wastes associated with reprocessing of spent nuclear fuel are high-level waste. The NDAA clarified this authority by including provisions allowing the Secretary of Energy, in consultation with the Nuclear Regulatory Commission, to determine that certain reprocessing wastes associated with reprocessing of spent nuclear fuel are not high-level waste provided certain criteria are met.

[2]In general, the closure process includes removing the tank waste for treatment then closing the tanks to meet RCRA and Section 3116 NDAA criteria. The TFF tank system's closure process includes waste removal; cleaning of the tanks, piping, and ancillary equipment (to remove waste to the maximum extent

practical); and removal of remaining liquid and solid waste residue to the maximum extent practical from the tanks and ancillary equipment. Following waste removal from the tanks and TFF cleaning activities, confirmatory sampling and analysis are performed to assess the decontamination effectiveness and for waste characterization.

Some residuals that cannot be removed by the cleaning process or other technically practical means will remain. The residuals will be sampled and analyzed to determine the concentrations of radioactive and hazardous constituents remaining in the tanks. As each TFF component is cleaned and analytical data show that performance objectives are expected to be met, each of the applicable TFF components will be stabilized by filling them with grout. Process lines will be decontaminated and capped, and all lines (including process lines) that provide a pathway to the tanks will be grouted and capped.

Since the TFF remains operational to provide interim storage of approximately 900,000 gal of radioactive liquid waste awaiting final treatment, the first step for tank closures was to consolidate the tank waste into three of the newest 1,135.6-kL (300,000-gal) tanks. (In addition, one 1,135.6-kL [300,000-gal] tank remains operational as a spare tank.) This was accomplished in 2002.

Since that time, extensive efforts have taken place to clean and begin closure of several TFF components including the incorporation of many lessons learned during the process. Those efforts include cleaning of seven 1,135.6-kL (300,000-gal) tanks and the four 113.5-kL (30,000-gal) tanks, and their associated vaults, interconnecting piping, and ancillary equipment. The four 113.5-kL (30,000-gal) and seven 1,135.6-kL (300,000-gal) tanks TFF tanks were grouted in place in 2006 and 2007. Ancillary piping and valve boxes associated with these tanks were grouted in 2008. The work involved in accomplishing the TFF cleaning and grouting is described below.

2. Section 3116(a) of the NDAA states, “In General—Notwithstanding the provisions of the Nuclear Waste Policy Act of 1982, the requirements of section 202 of the Energy Reorganization Act of 1974, and other laws that define classes of radioactive waste, with respect to material stored at a Department of Energy site at which activities are regulated by a covered State pursuant to approved closure plans or permits issued by the State, the term “high-level radioactive waste” does not include radioactive waste resulting from the reprocessing of spent nuclear fuel that the Secretary of Energy (in this section referred to as the “Secretary”), in consultation with the Nuclear Regulatory Commission (in this section referred to as the “Commission”), determines—(1) does not require permanent isolation in a deep geologic repository for spent fuel or high-level radioactive waste; (2) has had highly radioactive radionuclides removed to the maximum extent practical; and (3) (A) does not exceed concentration limits for Class C low-level waste as set out in Section 61.55 of title 10, Code of Federal Regulations, and will be disposed of— (i) in compliance with the performance objectives set out in subpart C of part 61 of title 10, Code of Federal Regulations; and (ii) pursuant to a State-approved closure plan or State-issued permit, authority for the approval or issuance of which is conferred on the State outside of this section; or (B) exceeds concentration limits for Class C low-level waste as set out in section 61.55 of title 10, Code of Federal Regulations, but will be disposed of— (i) in compliance with the performance objectives set out in subpart C of part 61 of title 10, Code of Federal Regulations, and (ii) pursuant to a State-approved closure plan or State-issued permit, authority for the approval or issuance of which is conferred on the State outside of this section; and (iii) pursuant to plans developed by the Secretary in consultation with the Commission.”

Tank Farm Facility Description

Placed into service between 1953 and 1966, the eleven 1,135.6-kL (300,000-gal) tanks (WM-180 through WM-190) are approximately 15.2 m (50 ft) in diameter and 6.4–7.0 m (21–23 ft) in height. Nine of the eleven 1,135.6-kL (300,000-gal) tanks are constructed of Type 304L stainless steel; two tanks (WM-180 and WM-181) use Type 347 stainless steel. The 1,135.6-kL (300,000-gal) tanks are housed in concrete vaults, with the bottom of the tanks located approximately 13.7 m (45 ft) below grade level. The vaults have one of three different designs: (1) octagonal pillar-and-panel vaults (five tanks), (2) cast-in-place square vaults (four tanks), and (3) cast-in-place octagonal vaults (two tanks). Cooling coils on the floor and walls of eight of the tanks (WM-180, WM-182, WM-183, WM-185, and WM-187 through WM-190) provide heat transfer capabilities. The 15-cm (6-in.) thick concrete vault roofs are covered with approximately 3 m (10 ft) of soil to provide radiological protection to workers and the public.

Each tank has four or five 30-cm (12-in.) diameter risers to provide access to the tank. Most of the risers had installed equipment and instrumentation, including radio frequency probes for level measurement, corrosion coupons, and steam jets and airlifts for waste transfer operations installed in them that required removal for closure equipment to be installed. High-pressure steam is forced through a steam jet to create a suction pumping action to remove liquid from the tank.

A single steam-jet pump can transfer waste out of a tank at approximately 189-Liters per minute (50-gpm). The original design of the suction pumps restricts the ability of the pumps to clear the tanks of liquid completely. Using the original steam jet placement prior to any actual cleaning activities, an 8–30-cm (3–12-in.) deep residual containing both liquid and solids remains on the floor of the tanks. Therefore, steam-jet pumps are lowered to the bottom of the tank for final tank cleaning. Figure 1 presents the dimensions and structure of a typical 1,135.6-kL (300,000-gal) tank.

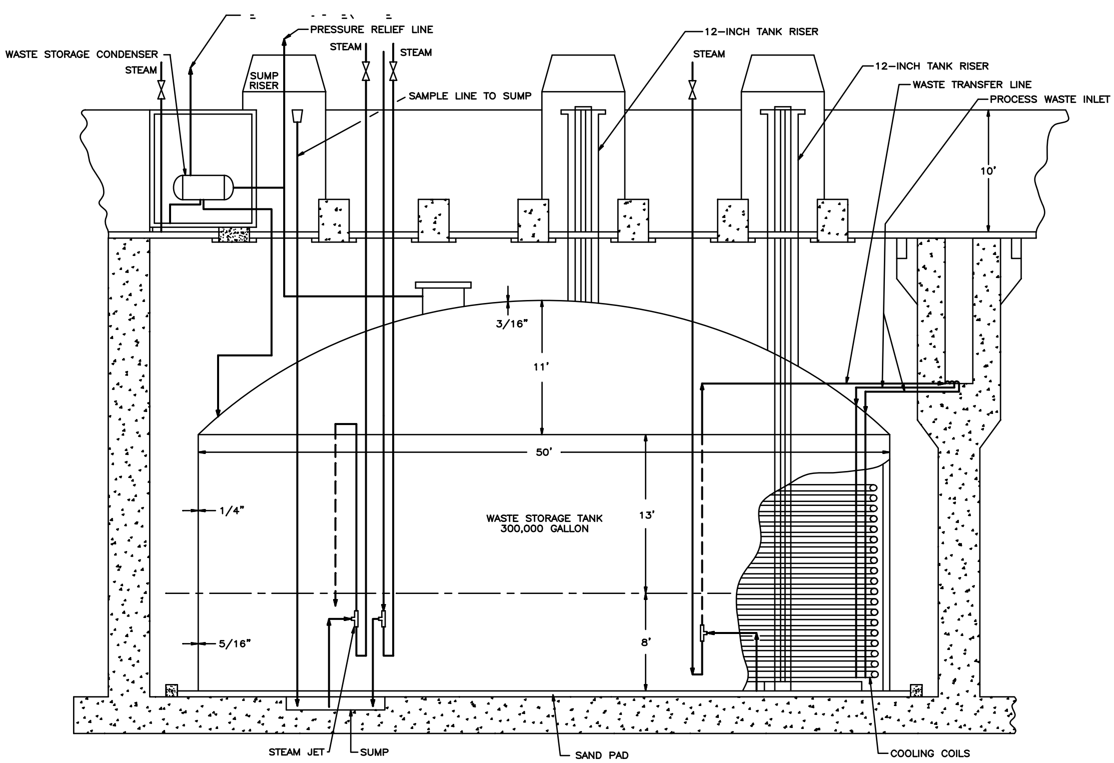

Fig. 1. Cross-sectional view of a typical tank with cooling coils.

When the TFF was constructed, the 1,135.6-kL (300,000-gal) tanks (WM-180 through WM-190) were designed with flat bottoms. The concrete floors of the tank vaults were designed with sloped floors to promote drainage of any liquid toward the perimeter of the vaults for efficient removal. In order for the tank to rest on the sloped floor without causing unacceptable stresses in the tank, a leveling pad of sand was installed to support the tanks. The sandpad is 15 cm (6 in.) thick at the perimeter and 5 cm (2 in.) thick at the center. The exterior of the sandpad extends 15 cm (6 in.) beyond the outer edge of the tanks and is confined by a curb measuring 15 by 15 cm (6 by 6 in.). The volume of the sandpad is 23.39 m^3 (30.6 yd^3).

Constructed in 1954, the four inactive 113.5-kL (30,000-gal) stainless steel below grade storage tanks (WM-103 through WM-106) sit on reinforced concrete pads. The tanks are horizontal cylinders approximately 3.5 m (11.5 ft) in diameter and 11.6 m (38 ft) in length. The 113.5-kL (30,000-gal) tanks do not have vaults. All four tanks contain stainless steel cooling coils to provide heat transfer capabilities. Three 15-cm (6-in.) diameter risers and one 8-cm (3-in.) diameter riser that reach to grade level provide tank access. Tank steam jets are provided for liquid waste removal (nominal flow rate of 189-Liters per minute [50-gpm]). These tanks were removed from service in February 1983.

Liquid waste transfers to, from, and among the tanks are managed through a system of lines, valves, and diversion boxes. Waste transfer lines are contained within one of the following types of secondary encasements: split tile, carbon steel, stainless steel-lined concrete troughs, double-walled stainless steel pipes, or buried directly in concrete. Because of upgrades over the years, the pipe sections encased within carbon steel and split tile have either been replaced or abandoned in place, except for two small (about 1.5-m [5-ft]) sections that are no longer used. The majority of the upgraded piping is contained in stainless steel-lined concrete trenches with the remainder in double-walled stainless steel piping. Double-walled stainless steel piping was used primarily in areas where single pipe runs were upgraded or where access did not allow lined trench installation. Liquid waste is routed through waste transfer valves located below grade, in stainless steel-lined concrete boxes (referred to as valve boxes). The waste transfer valves are operated manually using reach rods. The valve boxes are designed to provide access to the valves for inspection and maintenance.

Cleaning Approach for TFF Tanks and Vaults

A tank cleaning system comprising a washball, directional nozzle, and modified steam-jet pumping system has been developed and used successfully thus far in the TFF tank cleaning operations (see Figure 2). During washball and directional nozzle operations, the steam-jet ejectors (shown in Figure 1) are operated to remove the waste-containing slurry from the tank. The goal of tank cleaning is to remove as much waste as practical. During this operation, radiation levels are monitored on the steam-jet transport line as an indication of cleaning effectiveness. Monitoring the radiation levels near the transport line provides the cleaning system operators and project manager with an indication of when continued tank cleaning ceases to be effective. When radiation levels decrease to the lowest value and remain constant, cleaning is stopped and the tanks are inspected. If visual inspection via a remote-controlled camera confirms that the tank has been cleaned to the extent practical, then samples are collected and analyzed to verify performance objectives are met. The radiation monitor allows tank cleaning to proceed without repeated visual inspection or sample collection and aids in ensuring that as much waste as practical is removed from the tanks. Samples of the residuals are collected with small positive-displacement pumps. Submersible pumps are lowered into the bottom of tanks or vaults through risers. The pump is activated and liquid and solids are pumped to sample containers on the surface. However, because the residuals will be agitated before sampling, it is reasonable to assume that the liquid in the tank is homogeneous and the flocculent solids may be in suspension.

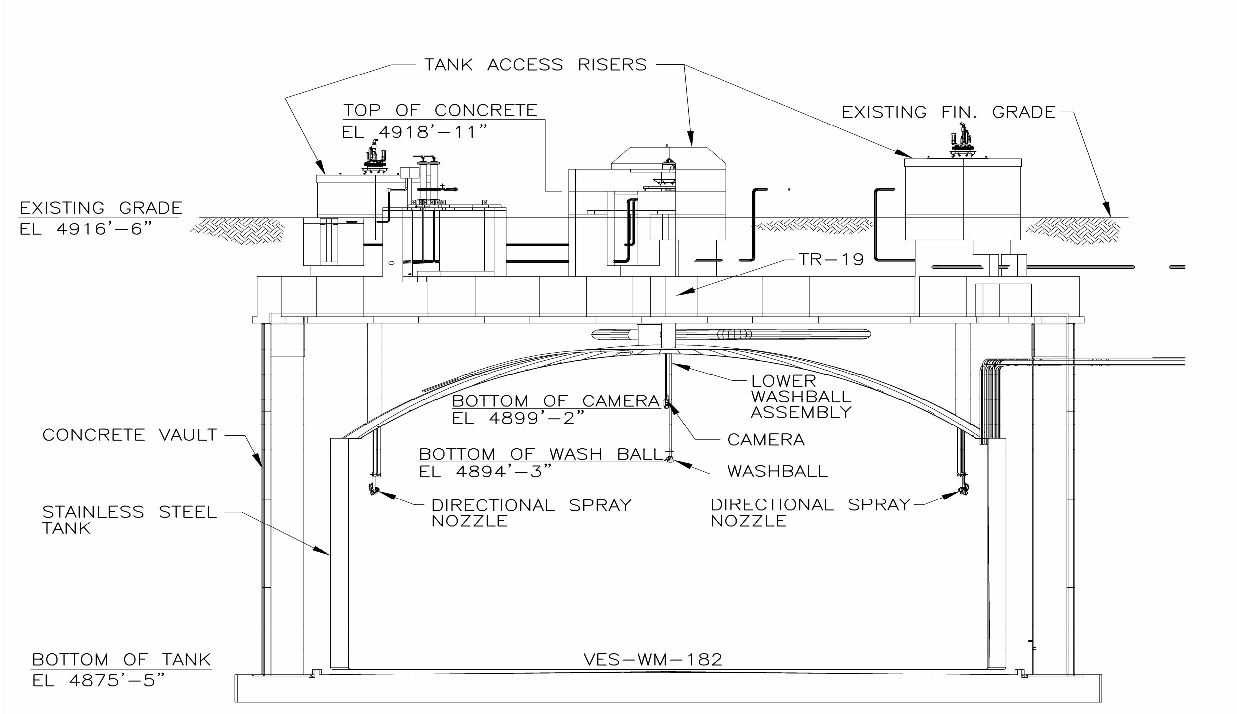

Fig. 2. Typical tank cleaning system.

Prior to its implementation, the TFF tank cleaning system was tested in a full-scale mockup tank using simulated waste [2]. The system demonstrated effectiveness in subsequent tank cleaning. The washball/directional nozzle tank cleaning system and the modified steam-jet pumping system were used to slurry the solid and liquid wastes and remove them from the tanks. Steam jets were modified by cutting the steam supply and discharge lines and installing a new steam jet lower in the tank. During cleaning system development, the INL Site and the DOE Tanks Focus Area (TFA) performed a review of tank cleaning technologies. The DOE formed the TFA to address all aspects of remediating radioactive wastes from underground storage tanks DOE-wide, including tank cleaning technology. The TFA review is described in a report prepared by the Pacific Northwest National Laboratory [3]. This review focused not only on the technical feasibility and appropriateness of the approach selected by the INL Site but also on technology gaps that could be addressed by using technologies or performance data available at other DOE sites and in the private sector. The review supported the design and implementation of the INL Site cleaning system. As a result of this development and testing work, the cleaning system (washball, directional nozzle, and modified steam-jet pumping system) has performed better than expected.

The tank vaults are cleaned by iterative flushing with water. The water is removed using the existing steam jets. Access to the vaults is limited and initial radionuclide inventories are considerably less than the tanks; therefore, flushing is a practical and effective cleaning method. Process piping in the TFF is cleaned by triple flushing, which consists of flushing three piping system volumes through the system with a pressure equal to previous waste transfers to ensure that the pipe area contacted by waste has been contacted by water and rinsed during the flushing operations; this method has been shown to be effective based on analytical data. The acidic nature of the waste, and the procedures that required flushing with water after waste transfers during operations, limited accumulation of residuals in piping that needed to be removed.

The vaults provide secondary containment for tank leakage. The tanks have not leaked during the life of the TFF. The contamination in the vaults for Tanks WM-185 and WM-187 resulted from two back-siphoning events that occurred early in TFF operations. In all tank vaults, rainwater/snowmelt in-leakage through the vault roof has been pumped periodically from the vault sumps to waste tanks.

Tank residuals remaining after cleaning and before grouting consist of a relatively small amount of solids and contaminated flush water. Extensive mockup testing shows that most of the remaining flush water and some solids will be removed during the grouting process for stabilizing the residuals. This action was accomplished by using the grout to push and corral the residuals toward the removal equipment (jet pumps). Any remaining residual liquid was stabilized with a grout material.

RESULTS OF TANK AND ANCILLARY EQUIPMENT CLEANING FROM 2002 TO 2005

The results of visual inspection and sampling and analysis performed after tank cleaning operations were completed to provide evidence that the cleaning technology used for the 1,135.6-kL (300,000-gal) tanks, 113.5-kL (30,000-gal) tanks, and ancillary equipment effectively removed the majority of highly radioactive radionuclides from the tanks while keeping occupational exposure to radiation as low as reasonably achievable (ALARA).

For the seven 1,135.6-kL (300,000-gal) tanks that have been cleaned as of May 2005 (Tanks WM-180 through WM-186), the washball and directional nozzle tank cleaning system was used to wash the tank walls and ceiling. The high-pressure water from the washball and directional nozzle also agitated the tank heel to suspend the solids and facilitate heel removal. The washball and directional nozzle were lowered into the tank through one of the tank risers. The water from the washball and nozzles hit the tank walls, roof, and heel, and dislodged the bulk of the contamination on the walls and ceiling of the tank to allow subsequent removal using the steam jets. A camera and lighting system was used to monitor the decontamination and heel removal effectiveness. Existing tank equipment and new equipment used for waste removal and decontamination operations were left inside that tank after these operations were completed for permanent disposal when practical. However, the washball and directional nozzle were decontaminated when moved to a new tank. The four remaining 1,135.6-kL (300,000-gal) tanks (WM-187 through WM-190) will be cleaned using the same methods after the sodium-bearing waste is removed for future treatment.

Visual examination indicated that the water spray removed solids from the tank walls easily. After tank cleaning operations were completed, post-decontamination samples of the residuals were obtained from the tanks and ancillary equipment. Samples from Tanks WM-180 through WM-186 were collected. A minimum of five samples were collected from each tank. The remaining tank contents were agitated between sample collections to ensure random selection of the samples. Because few solids remained on the tank bottoms, only a few grams of solids from one tank (WM-183) were retrieved during the sampling activities. Attempts to sample solid material in other tanks failed because of a lack of solid material available to collect. After cleaning, the tank floors have only isolated areas of solid residuals. Figure 3 shows how effective the tank washing has been in Tank WM-186; cleaning of other tanks has shown similar results.

The four 113.5-kL (30,000-gal) tanks (WM-103 through WM-106) were flushed with water to remove any residual waste. A tank cleaning system was not used for these tanks because of the low radionuclide concentrations remaining after previous tank flushing. Post-decontamination samples (at least five from each tank) from Tanks WM-103 through WM-106 were also collected.

Sampling and analysis were performed in accordance with Sample and analysis Plans (SAPs) prepared in conjunction with the tank and ancillary equipment closure plans. Each SAP used the data quality objective (DQO) process to determine the sampling strategy, number of samples, and analytical methods to be used. Issues such as the representativeness of the samples obtained and the homogeneity of the population sampled are also addressed. The DQO process is a planning approach developed by the EPA for use in preparing sampling designs for data collection activities that support decision-making. The process is used to ensure that the type, quantity, and quality of data used in decision-making are appropriate for the intended application. The analytical results have been reported in a series of data quality assessment (DQA) reports, which are summarized in the Section 3116 Basis Document [4]. A DQA is a scientific and statistical evaluation of the quality of the collected characterization data to determine whether the data can be used to meet the DQOs that were established.

Fig. 3. TFF Tank WM-186 post-decontamination interior.

In this case, the results of post-decontamination sampling and analysis were used to determine the concentrations of the radioactive and hazardous constituents remaining in the tanks and ancillary equipment. Analysis results were used to confirm that the radionuclide concentrations met the closure requirements, and that they were bounded by the concentrations assumed in the conservative inventory in a 2003 PA [5]. The results were also used to estimate the residual TFF radionuclide inventories. Results of sampling and analysis of the residuals indicate that the radionuclide inventory in the tanks after cleaning is an order of magnitude lower than that estimated in the 2003 PA.

Residual Inventory in Tank Farm Facility Structures, Systems, and Components

Although the tank and ancillary equipment cleaning activities have been shown to be successful, some residuals remain in the TFF components after cleaning is complete. The residual inventory at closure is based on validated analytical data from tanks sampled between 2002 and 2005, after cleaning operations. This inventory describes the radionuclide concentrations in the TFF tank system residuals, assuming that the residuals in the four 1,135.6-kL (300,000-gal) tanks (WM-187 through WM-190) and ancillary equipment remaining to be cleaned have a radionuclide inventory similar to that of the residuals in the seven tanks and ancillary equipment that have already been cleaned. Radionuclide concentrations are decayed to 2012, the year of final TFF closure.

Tank volume estimates in the 1,135.6-kL (300,000-gal) tanks (WM-180 through WM-186) for solid residuals and interstitial water used in the residual inventory at closure are based on viewing videotapes of the tanks taken before, during, and after the final cleaning and sampling events. From the videotapes, residual solid depths were estimated by comparing the solids depths to the cooling coil support brackets and associated welds. Depth assumptions were based on the bottom weld and stainless steel bracket thickness measuring 0.97 cm (0.38 in.). Close-ups from the video were critical in determining the depths of residuals next to the brackets and areas where no apparent solid residuals were observed. Depths of solid residuals ranged from 0 to 0.97 cm (0 to 0.38 in.). Areas where no solids were present on the bottom of the tank were apparent by the reflection from the stainless steel bottom. The volume of solids and the density of the solid material were used to determine the mass of residuals in each tank. Videos and photographs of the tank walls show staining and discoloration, and no discernible buildup of residuals. Therefore, no source term for the tank walls was included in the tank inventory. Inventories in the seven 1,135.6-kL (300,000-gal) tanks cleaned to date range from 475 Ci in Tank WM-181 to 2,394 Ci in Tank WM-182, almost entirely (~95%) made up of Cs-137 and its daughter product Ba-137m.

The vaults surrounding the 1,135.6-kL (300,000-gal) tanks (WM-180 through WM-190) provide secondary containment for the tanks. Since these tanks have never developed leaks, the tank vaults do not normally contain a significant radioactive inventory. However, a back-siphon event in Tank WM-185 and a second back-siphon event in Tank WM-187 occurred early in the TFF history and contaminated these two tanks vaults. Although the waste was promptly transferred out of these vaults after the events, and recent samples from the vault sumps did not indicate any significant inventory of radionuclides, a conservative estimate of 3,850 Ci per tank vault has been made for PA models of a remaining source term in the vault sandpads that underlie these two tanks.

The residual inventory at closure for the 113.5-kL (30,000-gal) tanks is based on analytical data from post-cleaning sampling. Solid residual samples were not collected because an adequate volume of material was not present in the tanks. A film layer was observed on the lower half of all four tanks that appeared to be algae or another form of biological growth. This film layer was clearly not residual solids as found in the 1,135.6-kL (300,000-gal) tanks and is not likely to contain any significant radioactivity. However, to establish a conservative estimate, the film is assumed to be 5 mil (0.005 in.) thick and contains the concentrations of radionuclides found in Tank WM-183 solid samples. The inventories for each 113.5-kL (30,000-gal) tank vary from 36.2 to 36.7 Ci.

Residual inventories were also calculated for interconnecting process piping in the TFF. The residual inventory at closure for TFF piping is based on analytical results from sampling pipe sections that had been removed from the Tank WM-182 process waste lines after decontamination. The samples were obtained and analyzed as described in the associated SAP. From these results, the amount of residuals remaining in 3,231 linear m (10,600 linear ft) of process waste piping is calculated to be 15.5 kg of solid residuals in the piping. The radionuclide concentration from the tank residual inventory is then apportioned to the mass to estimate a conservative residual inventory of 30 Ci at closure for the piping.
To quantitatively address how effective the waste removal techniques have been, a mass balance approach was developed [4]. Historically, radionuclides were removed from the total TFF waste stream by removing the liquid waste for a calcination process. This inventory was identified by preparing a mass balance of radionuclides received from SNF reprocessing and sent to the TFF for storage and disposition.

The mass balance relied on analytical data, numerical modeling, and data extrapolation to arrive at the total radioactivity present at INTEC from SNF reprocessing. The mass balance, which also considered nuclear material shipped to other DOE facilities for further processing, was used to determine the total radioactivity of waste generated from spent fuel reprocessing, which was 36 million Ci. Of the approximately 36 million Ci in 9.4 million gal of waste generated during spent fuel reprocessing operations, approximately 25,800 Ci are estimated to remain in the tank system following closure, representing about 0.07% of the initial spent fuel waste inventory.

COMMENCEMENT OF TANK GROUTING

Grouting activities in support of final tank closure commenced on November 20, 2006, after the necessary authorizations discussed above had been received. Original planning for commencement of tank grouting assumed that the Section 3116 Determination, Amended ROD, and other relevant authorizations, would be received early in summer 2006. With this assumption, baseline schedules showed grouting to occur first in four of the 1,135.6-kL (300,000-gal) tanks (WM-180 through WM-183), followed by grouting of the four smaller 113.5-kL (30,000-gal) tanks (WM-103 through WM-106).

Commencement of grouting in July 2006 would allow completion of these eight tanks by late in calendar year 2006. Grouting of the other three cleaned 1,135.6-kL (300,000-gal) tanks (WM-184 through WM-186) would occur in 2007, followed by grouting of all the interconnecting piping and ancillary equipment. Those activities were scheduled to complete during summer 2008.

However, due to the late start of grouting activities and the difficulties of grouting during winter weather conditions in Idaho, plans were shifted to focus on grouting of the four 113.5-kL (30,000-gal) tanks (WM-103 through WM-106), as these tanks required a much shorter duration of favorable weather. (Cold weather restricts grout batch plant operations and jeopardizes the ability to produce grout meeting minimum temperature requirements. Grouting of the 113.5-kL [30,000-gal] tanks was estimated to only require a few days of favorable weather, whereas the larger 1,135.6-kL [300,000-gal] tanks would require a several-week period of continuously favorable weather conditions.) As such, three of the four 113.5-kL (30,000-gal) tanks (WM-104, WM-105, and WM-106) were filled with grout during the week of November 20, 2006. Preparations were completed for grouting of the fourth tank by November 27, 2006; however, due to the onset of severely cold weather, grouting operations were suspended, with plans to resume grouting in spring 2007.

GROUTING OF THE 1,135.6-kL (300,000-GAL) TANKS

Grouting in 2007 included completion of several of the large 1,135.6-kL (300,000-gal) tanks (WM-181, WM-184 and WM-186). The grouting of the large tanks was based upon significant mock-up engineering efforts, and provided the opportunity for additional residual liquid and solids in the bottom of the tanks to be removed.

The initial grouting process for the 1,135.6-kL (300,000-gal) tanks (WM-180 through WM-186) comprised of: (1) an engineered grout placement sequence to move remaining solids and liquid toward the steam jets, aid in the mixing of residuals with the grout, and provide a reducing environment; (2) an encapsulation grout pour to stabilize residuals on the surface of the grout placements and level the engineered grout placements, (3) placement of a Controlled Low Strength Material (CLSM) to fill the tanks and vaults up to the beginning of the tank dome, (4) isolation from the existing Ventilation Off-gas system and continued fill of CLSM to within the top foot, (5) placement of a pipe fill grout (containing no sand for maximum flow) to fill the top of the vaults and tanks and the vessel of gas piping connected to the top of each tank, (6) filling of the tank and vault risers to the surface with pipe fill grout. This final layer was controlled during the grouting process with an electronic sensing device that would alarm on contact with the grout itself allowing the process to be stopped in a controlled manner so that grout was not pushed up a riser and out of the tank at this time.

The engineered grout placement sequence to move remaining solids and liquid toward the removal pumps is estimated to use 85 m^3 (111 yd^3) of grout. The grout was introduced through two available risers with specially designed grout masts. The first two placements go in directly below the available risers to a height of 0.9–1.2 m (3–4 ft). The purpose of the first two placements is to begin moving residuals toward the steam jet for removal and to provide troughs to direct placements 3 through 5 to the other areas of the tank. In the grout mockup, these placements were successful in moving solid and liquid surrogate materials. Placements 3 and 4 use the same riser access as placements 1 and 2, and displace the residuals between the tank wall and the steam jet. The purpose of placement 5 is to displace the residuals on the opposite side of the tank from the steam jet. These placements sweep residuals toward the steam jet. Placement 5 may be replaced with two separate placements to allow better residual removal, but the purpose of the placement is the same. Figure 4 shows a schematic of the grout placement approach.

Based upon mockup results and verified through the radiation detectors used on transfer piping, some portion of remaining residuals are pushed towards the steam jet and removed during grouting. Once the engineered grout placements are completed, a final encapsulation grout pour will be used to: (1) ensure adequate immobilization of any remaining residuals on the surface of the grout placements and (2) level the engineered grout placements.

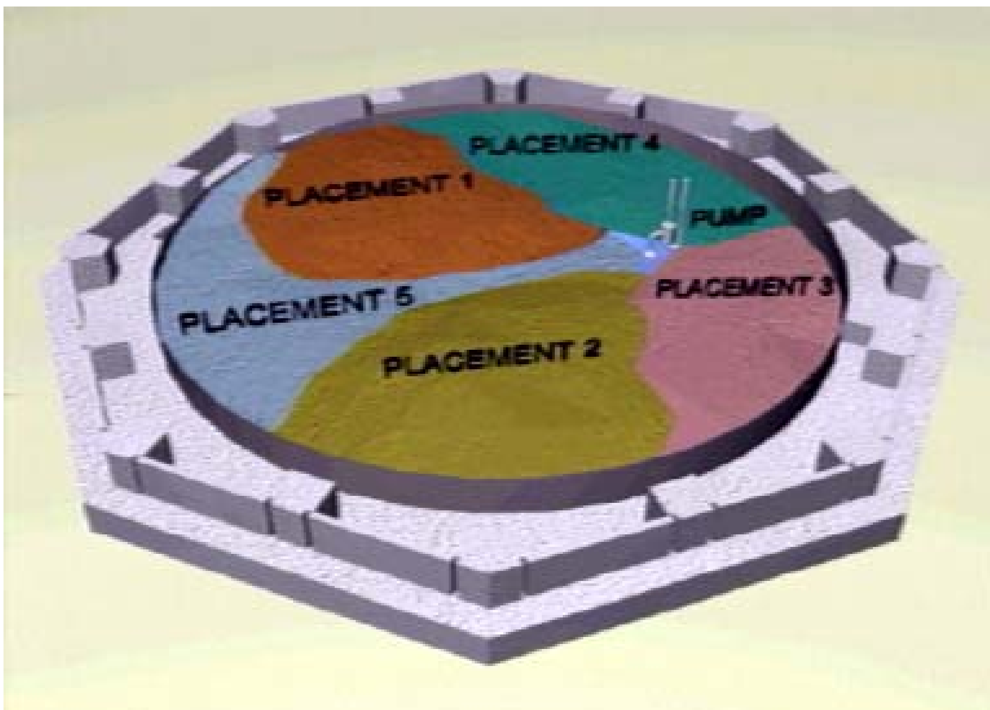

Fig. 4. Schematic of the engineered grout placement sequence.

Once the engineered grout placements and encapsulation grout pour was completed for a 1,135.6-kL (300,000-gal) tank, the remaining 1,135.6-kL (300,000-gal) tank and vault was filled with grout in alternating pours to provide long-term stability of the tank structure.

The grout formula utilized for these pours was a controlled low-strength material grout (CLSM). The CLSM layers placed in the tank was always kept had a higher level than the vault until each tank was full to avoid collapse of the tank. This alternating process continued until the final layer shown was placed in the vault only.

This final layer was primarily a thin leveling grout that would provide maximum flow into the far reaches of the vault itself. During the grouting process the displaced air in the tank was collected and filtered through the existing tank vessel off-gas (VOG) system until the final tank placement. The tank was permanently isolated from the existing VOG system by cutting the ventilation piping outside the tank and vault in a separate ventilation pit for each 1,135.6-kL (300,000-gal) tank. Following the isolation of the VOG piping the remaining grout placement with made by filtering the displaced air through a temporary HEPA ventilation system.

The final step in the grouting process of a 1,135.6-kL (300,000-gal) tank required that each riser of the vault and tank be filled separately in a controlled manner that filtered the displaced air through HEPA filters until it was approximately even with ground level.

GROUTING OF THE 113.5-kL (30,000-GAL) TANKS

The grouting of the 113.5-kL (30,000-gal) (WM-103 through WM-106)tanks was rather simple in comparison with the grouting being done to two basic placements using the CLSM grout and displacing the air through the existing VOG system through piping at the top of each tank. There are no vaults associated with the 113.5-kL (30,000-gal) tanks. Following the grouting of the 113.5-kL (30,000-gal) tanks each tank riser was grouted to approximately ground level in a manner similar to the that performed on the 1,135.6-kL (300,000-gal). The primary difference being the rad-con controls imposed to the process.

GROUTING OF THE UNDERGROUND PIPING SYSTEMS AND VALVE BOXES

The grouting of the underground piping systems was complicated by the fact that the piping to be grouted was still connected to active waste piping and only separated by waste transfer valves. Isolation points were established and the piping systems to be closed were isolated from the active sides and grout connections were installed prior to the grouting process.

The grouting of the underground piping systems was performed much like a liquid transfer with a valve line-up sheet and numerous walk downs of the piping systems. Each piping system was evaluated and grouped with other systems when possible and a grout injection point was established and where possible a vent point was established above ground or in an underground valve box. The displaced air at each vent point was filtered through a temporary HEPA system.

The temporary HEPA systems were one of two methods. The primary method to vent a piping system was to construct a piping header with ball valves to each vent point. Each valve connected to the collection header had a 208.2-L (55-gal) drums connected to collect water and/or grout pushed out the vent point during the grouting process. If a waste drum filled to a designated level or radiation reading the valve to the waste drum was shut and another opening until the line was determined to be grouted. Each drum was connected to a HEPA filter so that the displaced air would be filtered. The second method used was to install a rad-con approved containment constructed of a tube steel frame and herculite fabric over a valve box or ventilation point. This containment was connected to a HEPA exhauster which kept the containment structure under a negative pressure to ensure that there was no release to the environment during the grouting process.

TANK FARM CLOSURE LESSONS LEARNED

After each initial major phase of the project lessons learned were compiled so that they could be implemented before starting the same process on the next tank. The major phases that lessons learned were conducted on were after the mockup testing of the closure processes, the first tank washing, and following initial grouting activities. Smaller lessons learned were conducted throughout the project for continued improvement.

A full scale mockup of a 1,135.6-kL (300,000-gal) tank bottom (if cut in half resulting in a half-circle) was constructed to test the wash process using simulated solids. Results of the tests conducted of the wash process resulted in a couple of significant improvements to the wash process. These improvements were instrumental to the success of the overall cleaning of the underground storage tanks at the INL below closure requirements. The first improvement was that during the wash ball testing it was recognized that solids would build up at the floor-wall interface of the 1,135.6-kL (300,000-gal) tank. Two directional nozzles were simulated which showed this buildup could be removed efficiently. Testing of the proposed 3.8-cm (1.5-in) steam jets showed the ability to transfer mixtures containing a higher percent solids and increased flow rates over what was anticipated. When the jet was operated in a box containing settled and decanted solids, it was still capable of pumping 303-Liters per minute (80-gpm) down to a level of 38-mm (1.5-in) above the floor at 689,476-pascal (100 psi) steam pressure. This knowledge along with successful transfers later with the actual waste in the first tank system allowed us to increase the size of the steam jet from 38-mm (1.5-in) to 50-mm (2-in). This size increase allowed for an even higher rate of transfer of waste and flush solutions during the washing process leading to an even cleaner tank with less flush water to dispose.

Finally a 15.24-m (50-ft) diameter carbon steel ring used as a storage/settling pond for the transferred surrogate solids was also used to test the grout displacement process and finally could serve as a containment system during grouting operations to collect truck rinse water and again for the containment of excess grout during the grouting process. A hyplon roofing material was installed to the inside of the 15.24-m (50-ft) diameter carbon steel ring to prevent any leakage. Excess water could then evaporate leaving the waste grout behind for proper disposal.

The lessons learned from the first 1,135.6-kL (300,000-gal) tank (WM-182) washing activities revealed that the high rate of service required to our camera systems operating properly during cleaning coupled with the high cost of the systems itself showed a need to evaluate other camera systems and to add a lens cleaning reservoir to the directional nozzle cameras. This reservoir would allow liquid to be blown down through the airline directly onto the camera lens. This allowed the lens to be washed down without using the other directional nozzle. The airline can then be used to blow off the water if desired.

A change in the wash process was implemented to install a directional nozzle rather than the washball in a spare or empty riser where possible. This change of equipment allowed the operator to spray the existing equipment directly prior to removal. This provided better control of the wash water along with a reduction in the total amount of water used in the decon process. Equipment that was to be removed was turned from above into new positions to achieve total surface coverage which significantly reduced rad exposure to workers.

The new jet jet was installed down within 9.5-mm (.375-in) to the floor of the first tank (WM-182) wash performed better than expected. It was able to remove solids and liquids at an average rate of 189-Liters per minute (50-gpm). The steam jet was also able to start with very little liquid in the tank. Both of these areas allowed the project to successfully complete its cleaning objectives. Even with the steam jet's success there was room for improvement. Configuration changes were identified and incorporated into the piping that was used to back flush the jet piping following waste water transfers. These changes eliminated trapped solids and hot spots in the line. The new configuration was then used for the remaining 1,135.6-kL (300,000-gal) tanks.

Some of the other issues that the project encountered was the need to increase the inventory of spare parts of cleaning equipment during the cleaning process. A fully operational washball and two directional nozzles were added to the inventory that allowed equipment to be swapped out if repairs were needed. It was also recommended that in addition to the fabrication of the additional cleaning equipment that any parts that had a high rate of failure during the cleaning of the first 1,135.6-kL (300,000-gal) tanks WM-182 and WM-183) be purchased before additional cleaning campaigns. Some of these parts were the cameras, controllers, hoses and remote controlled valves.

A good practice that was noted during the cleaning phase of the project was the installation of whip checks on all connections. This proved to be an excellent decision as the factory ends from two different vendors failed during cleaning operations. The whip checks performed as designed with no damage occurring to any structure or equipment.

The lessons learned during the grouting phase of the project were minor but contributed to the safety and control of the grouting process. Even though the project involved the use of a standard commercial concrete pump truck pumping into an empty 1,135.6-kL (300,000-gal) tank some pressure was noted at the groutmast used to connect the tank risers. A pressure relief spool piece with a gauge allowed us to avoid any over pressurization at this point.

During grout operations an articulating grout arm was used to perform the heel displacement grout placements in the 1,135.6-kL (300,000-gal) tanks (WM-180 through WM-190). After these placements were made the articulating grout arm was removed and a shorter grout mast would be used for the CLSM placements on each 1,135.6-kL (300,000-gal) tank. The height of the grout piles left from the heel displacement grout placements in the first 1,135.6-kL (300,000-gal) tank (WM-182) was found to be too high of an elevation relative to the depth the articulating grout arm installed through the tank riser. This was the result of many factors such as poor visibility during grouting operations, questionable elevations at the surface due to the removal existing shield blocks, and a higher than anticipated pile than observed in previous grout mockups. A new survey for the actual field elevations was performed on the above ground structures where grout equipment would be installed and a comparison against the as built drawings for each 1,135.6-kL (300,000-gal) tank was conducted. This new information indentified any similar circumstances where this could occur and spacers were added to a tank riser before the grout equipment was installed. A fixed camera with a 28° fisheye lens was replaced with a pan and tilt camera similar to that used during wash operations to allow close up viewing of the spacing between grout piles and the articulating grout arms. High visibility colored stripes and a break-a-way chain was added to the end of the grout arm as viewing aids to the camera operator.

SUMMARY

Significant progress has been made to clean and close emptied tanks at the INTEC TFF. Between 2002 and 2005, seven of the eleven 1,135.6-kL (300,000-gal) tanks and all four 113.5-kL (30,000-gal) tanks were cleaned and prepared for grouting to support final closure. Several key authorization basis documents, including a Section 3116 Determination and an Amended National Environmental Policy Act ROD, to support tank closures were issued by the DOE in November 2006. Also in November 2006, grouting began and was completed in December 2007.

Prior to a winter shutdown of grouting activities in 2006, three of the 113.5-kL (30,000-gal) tanks were filled with grout to provide long-term stability. During the following spring of 2007 the seven cleaned 1,135.6-kL (300,000-gal) tanks, as well as the remaining 113.5-kL (30,000-gal) tanks was grouted.

Beginning in 2008 the associated tank and vault risers along with the interconnecting piping was stabilized with grout. Over 24,000 yd^3 of grout was placed to fill the tanks and vaults followed by the grouting of over 7 miles of underground piping process and cooling coil piping. The remaining four 1,135.6-kL (300,000-gal) tanks(WM-180 through WM-190) in the TFF will be cleaned, sampled, and grouted when they are no longer needed for waste storage. Closure of the TFF is planned to be complete by 2014.

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