ORNL/TM-1999/283

STATUS AND NEEDS FOR TANK ISOLATION SYSTEM CONTINGENCIES AT THE OAK RIDGE NATIONAL LABORATORY

J. B. Chesser
B. E. Lewis

January 2000

Prepared by the
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831
Managed by
LOCKHEED MARTIN ENERGY RESEARCH CORPORATION
For the
U.S. DEPARTMENT OF ENERGY
Under contract DE-AC05-96OR22464

ABSTRACT

This document assesses the need for additional tank isolation systems and tooling at the Oak Ridge National Laboratory (ORNL). Locations for future operations at ORNL include the South and North Tank Farms and various Federal Facilities Agreement tanks. The goal of this report is to identify future needs for development of remote tools and systems to isolate inactive waste storage tanks.

Remote tools have been developed to support waste-retrieval and tank-isolation operations at the Gunite and Associated Tanks (GAATs) at ORNL. The tools developed for in-tank remote operations include a pipe-cutting tool (a modified band saw), a pipe-cleaning tool (a modified drill with a wire brush), and a pipe plug. A review of the planned future operations revealed several desirable modifications to improve the efficiency, operability, and flexibility of the existing tank-isolation tools. For example, the pipe-cutting tool needs improvements to provide better alignment, a blade-cutting-release device, improved tire replacement, sensors to prevent operation of the saw when the blade stops, blade speed controls, and force feedback sensors. In addition, the need to test the existing pipe plug for use on corroded piping was identified. The pipe plug has been used on only relatively clean in-tank stainless steel (SS) piping to date. However, there may be a need later to use the plug on corroded SS and other types of pipes. Improvements to the pipe plug for use on flush wall pipes and small-diameter openings in tanks are also desirable.

Besides tank isolation, those performing tank closures may need to use cutting and capping equipment on buried pipes. The current cutting and capping equipment may have to be modified for deployment systems other than the Modified Light Duty Utility Arm, for which they were initially designed. Improved cutting and other remote systems may also be needed to dispose of contaminated equipment and tank shells. These requirements will be defined jointly by the U.S. Department of Energy, the U.S. Environmental Protection Agency, and the state of Tennessee as part of the overall remedial decision for the ORNL Bethel Valley area.

Contents

1. BACKGROUND

Throughout the operational history of the Oak Ridge National Laboratory (ORNL), the production of radioactive and other hazardous chemical wastes has resulted from normal facility operations. Underground storage tanks have been used to collect, neutralize, and store liquid wastes. The tanks were removed from service at ORNL because of leaks in the service pipelines, in the ancillary equipment, or in the tanks themselves; groundwater infiltration; or expiration of further requirements for their use. Usually, at the time a tank became inactive, the resident waste solution was pumped out, thus leaving only small quantities of solid sludge and liquid which exhibit varying levels of radioactivity.

Starting in 1997, an effort was begun for final cleanout of the tanks at the North Tank Farm (NTF) and South Tank Farm (STF). This work involves removing the sludge, cleaning the tank surfaces, and removing the mobile contaminants. The systems used include the modified light-duty utility arm (MLDUA) and the Houdini™ remotely operated vehicle (ROV). The MLDUA, which is a multi-degree-of-freedom, long-reach, hydraulic arm, was designed and fabricated by SPAR Aerospace. The Houdini is a tethered, hydraulically powered, track-driven vehicle. The ROV features a folding chassis to allow it to be introduced through 24-in.-diam tank penetrations. Houdini carries a bulldozer blade and a Schilling manipulator for performing work. RedZone Robotics designed and fabricated the Houdini vehicle.

The work required on one of the tasks involved in the cleanout operations is pipe cutting and removal. Pipe cutting is necessary to provide a clear workspace for the remote-handling equipment used in remediating the tanks and is required for pipes that are pathways for groundwater infiltration or that are not isolated from a source of potential inflows. During FY 1998, three tools were developed by ORNL and Pacific Northwest National Laboratory (PNNL) to cut and plug pipes and tubes.[1, 2] These tools were developed for use at the STF Gunite and Associated Tanks (GAATs) at ORNL.

Following the cleanout of the tanks at the NTF and STF closeout of other tanks at ORNL will be undertaken. This report will briefly examine current and potential activities. The goal is to determine if additional development of pipe-cutting and -plugging tools is required.

2. BASELINE APPROACH FOR ISOLATING IN-GROUND PIPING

Currently, the baseline approach for isolating and capping buried pipes is to excavate down to the pipe, cut the pipe using hand-held power tools, and then weld on an end-cap.[3] This approach is labor intensive and prone to result in personnel radiation exposure and contamination from Resource Conservation Recovery Act (RCRA) and radioactively contaminated soil and residual material in the piping. The current approach requires an operator to enter the pit in which the pipe is located, which presents an additional hazard—soil cave-in. The use of remotely operated tools would allow the operator to work in a safer (i.e., more distant) environment. The remotely operated tools to be used for in-tank applications could easily be adapted to use to cap buried pipes.

3. DESCRIPTIONS OF TANK-ISOLATING TOOLS

Tank isolation tools have been previously described in more depth in prior publications.[1, 2] A brief description of the tools is included in Sects. 3.1 through 3.3 for the benefit of the reader.

3.1 Pipe-Cutting Tool

ORNL investigated several methods of pipe cutting. Initially, a Jaws of Life™ hydraulic shear was used. This solution was not entirely satisfactory because of the limited range of pipe sizes that could be handled and because it compressed the cut end of the pipe, thus making plugging difficult.

The pipe-cutting tool is required to be lightweight, to be easy to use, to operate with minimal vibration, and to leave a clean-cut surface. The tool is required to be deployable using the MLDUA and Houdini. A standard portable industrial band saw was procured by ORNL and provided to PNNL to develop and cold-test the tool in Hanford, Washington. PNNL successfully completed the detailed design, modification, and cold-testing of the band-saw cutting tool, which has been used extensively during the GAAT Remediation Project.

3.2 Pipe-Cleaning Tool

A buildup of material from the discharge of liquids and slurries may be expected at the ends of the discharge pipes. If this buildup forms a visible lip on the pipe, it should be removed before the pipe is plugged to ensure a good seal. ORNL reviewed a variety of pipe-cleaning concepts and recommended a simple drill motor and wire-brush system. The system has been available for use since August 1998.

3.3 Pipe-Plugging Tool

Three available methods of isolating the pipes in the GAATs were considered: plugging the pipes with commercially available pipe plugs, filling the interior of the pipe with grout, or capping the end of the pipe with a sealant cup. After a review of these methods, capping the end of the pipe with a sealant cup was selected because it could be easily performed as a remote operation. The selected pipe-plugging concept uses a metal cup filled with an epoxy sealant to cover and plug the exposed end of the pipe. A central locking mechanism and centering guide hold the plug in place while the epoxy sets. The cup is placed over the pipe end with either the MLDUA or the ROV. A pipe plug was successfully deployed in GAAT W-6 on July 27, 1998, to prevent groundwater inleakage and off-gas loss through a horizontal overflow line between tanks W-5 and W-6. A patent application covering the design and use of this device was filed with the U.S. Patent Office on May 26, 1999.

4. SUMMARY OF TANK ISOLATION NEEDS

Tank isolation is a major part of the closure process for inactive waste storage tanks. As a result of the relationship between tank isolation and tank closure, a brief discussion of the tank closure tasks and needs is presented.

Waste tanks can be isolated from the environment either before or during tank-closure actions. If leakage occurs after waste retrieval actions are completed and the final closure of the tank is delayed, then isolating the tank before its closure should be considered. Some of the factors that may affect the decision as to whether to isolate a tank before its closure include the following:[3, 4]

1. *Quantity of inleakage*. Significant quantities of inleakage would require constant monitoring and handling. If tank shells are contaminated and residual waste is in the tank, then the inleakage may present a significant handling and dispositioning problem.
2. *Costs for tank isolation vs those for handling and processing inleakage*. The costs for continual waste removal and processing to ensure that the tank does not overflow must be weighed against the costs for isolating the tank and preventing inleakage.
3. *Source of inleakage*. Groundwater provides a source of relatively clean inflow. Inleakage from other sources (abandoned piping networks, shutdown facilities, etc.) may present a serious source of additional contaminated waste entering a tank.
4. *Risks to personnel and the environment.* The risks associated with handling and processing additional inleakage into an empty waste storage tank must be weighed against the risks associated with isolating the tank.

Tank closure typically involves selection of the appropriate disposition of the following items:

1. Tank shells
2. Contaminated equipment
3. Buried piping
4. Valve pits

An overview of the use of the tank-isolation tools at ORNL and brief descriptions of the proposed isolation techniques for the tank shells, contaminated equipment, buried piping, and valve pits follow.

4.1 DESCRIPTION OF NEEDS FOR TANK-ISOLATION TOOLS - GAAT REMEDIATION PROJECT

The information presented in this section was compiled from comments from the GAAT Remediation Project remote systems operators.[5] These personnel have been directly responsible for the day-to-day operation of the MLDUA, Houdini, tank isolation tools, and other systems used in the remediation of the Gunite tanks at ORNL.

4.1.1 Pipe-Cutting Tool

The pipe-cutting tool has been extensively used in the STF during the GAAT Remediation Project. The primary reason for engaging in pipe cutting is to provide a clear workspace for the MLDUA. The goal of the current remediation effort is to remove sludge from the GAATs.

Generally, the pipe-cutting tool has performed satisfactorily under less than ideal conditions throughout the GAAT Remediation Project. However, various modifications would improve the efficiency, operability, and overall flexibility of the pipe-cutting tool. These desired modifications include the following:

1. During certain cutting operations, the band saw blade will become trapped within either the partially cut pipe or at some point after the pipe is completely cut and where the cut end of the pipe extends from the ceiling through the center of the blade all the way to the floor. Under this situation, the saw must be forcibly removed from the tank by either dislodging or breaking the saw blade. A device has been designed to allow the band saw blade to be released by cutting the blade.[6]
2. Tire replacement has been one of the most time-consuming operations for the band saw. The rubber tires used to provide friction between the band saw blade and metal drive wheel either wear out from continued use or are cut up when a blade breaks. To replace the tires, the drive wheels must be removed from the saw. A quick-release drive wheel with remote fasteners is needed to improve the efficiency of this operation.
3. A permanently attached blade guard is needed on the saw. In order to prevent harm to personnel and glove port gloves, a blade guard is used to cover the band saw blade. Problems have arisen with misplacement or loss of blade guards. A permanently attached blade guard is needed that can (a) be easily retracted just before deployment into the tank and (b) be put back into place when the saw is removed for the tank.
4. Since there is no force feedback from the saw or robotic arm, the initial alignment of the saw against the pipe is difficult. An alignment sight to properly ensure that the alignment stop—finger is resting against the pipe wall before cutting is needed. A laser-type sight or additional gross guides could be used to improve the alignment ability of the saw.
5. The operators have little or no feedback to tell when a band saw blade breaks during a cutting operation. Therefore, most of the time, the saw is allowed to continue to rotate with a broken blade. This type of operation results in disintegration of the rubber tires around the metal wheels on the band saw. A sensor is needed that will automatically cut the power to the saw when a broken blade is detected to prevent the tires for being

damaged. The sensor must be made rugged to withstand decontamination-water spray and rough handling.

6. A simple, two-plane leveling device is needed to ensure that the saw blade is perpendicular to the pipe to be cut. Small plumb-bob-type of leveling devices mounted on the saw frame could be used for this service. An alternate leveling device could be an electronic level with feedback through the tether to the control room. Proper alignment of the band saw blade against the pipe is essential to make a successful cut.
7. There is currently no force feedback during cutting operations with the band saw. Therefore, it is difficult for the operators to know exactly how much force to apply for a particular cutting operation. An ampere meter is used to determine if the band saw is actually cutting a pipe. The ampere meter measures the current to the band saw drive motor and shows an increase in current when the saw blade is cutting the pipe. A force feedback system would provide the operator with improved control over the pipe-cutting process.
8. There is no speed control for the band saw. A speed control would provide operators with a wider range of applicability for the saw when they are cutting different types and hardnesses of materials. This need arises out of a single occurrence in which the cutting tool was unable to cut a pipe that was fabricated from a hard material (believed to be a high nickel alloy). The current cutting tool bounced off the pipe and produced an oscillation in the MLDUA. A slower operating speed and improved blade design would possibly have allowed the pipe cutting to proceed successfully.

4.1.2 Pipe-Cleaning Tool

The pipe-cleaning tool, which was designed to clean pipe surfaces before the pipes were plugged, has not yet been used.

4.1.3 Pipe-Plugging Tool

The pipe-plugging tool has seen only limited use during the GAAT Remediation Project because of the following reasons:

1. Pipe plugging has not been a priority because of the aggressive tank waste retrieval schedule and the associated performance milestones for the GAAT Remediation Project.
2. There is currently no regulatory pressure to plug pipes inside the tanks. Schedule pressures have discouraged pipe plugging.
3. Very few of the pipes in the tanks have been inleakage pathways for groundwater and have therefore not required plugging.
4. Many of the vertical pipes that have been cut have fallen completely out of the ceiling, leaving only a hole in the ceiling and no pipe stub to plug. The current pipe-plugging tool is not designed to plug holes or flush piping.

Although it has seen only limited use, the pipe-plugging tool has performed very well in GAAT. One improvement that could be useful during tank-isolation tasks is modifying the plug so that it can be used with piping that is flush with the tank walls.

4.2 ANTICIPATED NEEDS FOR ISOLATING TANK SHELLS

The tentative plan for the final disposition of the tank shells is to grout them in place. However, the final decision on the disposition of the tank shells will be made jointly by the U.S. Department of Energy, the U.S. Environmental Protection Agency, and the state of Tennessee as part of the overall remedial decision for the ORNL Bethel Valley area. If the tank shells are to remain in the ground, then isolating the tank inlets and outlets must be effected to prevent a significant loss of grout during closure. The inlets and outlets may be plugged either before closure using techniques similar to those employed at GAAT or as part of the closure process. If the decision is made to exhume the tank shell, then a remotely operated excavation system may be needed.

4.3 ANTICIPATED NEEDS FOR ISOLATING CONTAMINATED EQUIPMENT

Although every effort will be made to reuse as much of the remediation equipment as possible; some of the contaminated equipment that has no further use will be disposed of as contaminated waste. Remotely operated tools may be needed to cut the equipment before its disposal. Tools similar to the pipe-cutting tool used in GAAT may be useful. The requirements for dismantling and cutting the equipment for final disposal have not yet been determined. Most of the large, remotely operated equipment such as the MLDUA, Houdini vehicle, and hose management arm will be stored on-site either until a need arises for their reuse or a final decision is made on the dispositioning of this equipment.

4.4 ANTICIPATED NEEDS FOR ISOLATION OF BURIED PIPING

Currently, no plans exist to cut or plug buried pipes that are external to the tanks at ORNL. Piping networks between the tanks will be abandoned in place for the current waste-removal activities, and a final disposition will be determined as part of the overall ORNL site remedial action. The pipes to the STF tanks are routed through valve boxes, which allow the tanks to be isolated during tank closure. Closing the valves in the valve boxes will prevent grout from flowing through the piping beyond the tank farm. Another action that will be taken to prevent grout from flowing back through the pipes is to grout the tanks in stages, limiting the pressure head available to force the grout through the piping system.[3]

4.5 ANTICIPATED NEEDS FOR ISOLATION OF VALVE PITS

The closure of valve pits is a future activity that is not yet in the planning stage. Valve pit closure requirements are not yet defined. Whether remote or hands-on operation will be required for closure depends on radiation dose rates. Because of the current lack of planning relating to this activity, it is impossible to anticipate the remote tooling requirements.

4.6 ISOLATION OF FEDERAL FACILITY AGREEMENT (FFA) TANKS AT OAK RIDGE

A significant number of small FFA tanks at ORNL have not been isolated and closed. A list of the inactive low-level liquid waste FFA tanks is included in the appendix.[7]

Following remediation of the Gunite tanks, one of the next tanks to be remediated is the SS horizontal FFA tank W-1A. Remediating W1A will involve excavation, cutting, and capping 13 pipes. The option of deploying a remote system to do that work is not feasible because the tank is so small that remote options are limited. The epoxy-cup method for capping might still be used but will likely be deployed manually. The plan is to remove the tank and the surrounding soil because the soil around W-1A is contaminated from leakage from buried piping. It is anticipated that because of the leaks, the pipes to be capped may be corroded.

The other small, FFA tanks following W-1A will be remediated by retrieving the radioactive sludges and filling them with grout. Since these tanks are constructed of SS, sludge retrieval using acid dissolution and pumping can be used. The bulk of the radionuclide content in these tanks is contained in the acid-soluble sludge fraction. The non-acid-soluble fraction has minimal radionuclide content. How the grout will be kept from entering the piping system for these small tanks has yet to be determined. The pipes supplying these tanks may be candidates for cutting and capping.

5. RECOMMENDATIONS FOR FUTURE DEVELOPMENT AND TESTING

Based on the overview presented in this report, currently only a limited need exists for additional tools and other tooling development to support operations at ORNL. However, as the waste retrieval and closure plans for each tank become better defined, the need for additional tooling development may arise. Improvements in tank-isolating techniques to better protect personnel and the environment will likely be needed.

The need exists to determine the sealing efficacy of the epoxy-cup method of plugging corroded pipes. The pipes plugged to date have all been SS, and corrosion has not been evident. However, there is the potential for that tool to be deployed on corroded piping at W-1A and potentially the other small FFA tanks at ORNL. Improvements to the pipe-plugging tool to facilitate plugging of open holes and flush wall pipes are also needed for future applications.

A variety of improvements to the pipe-cutting tool would be useful to improve the operational efficiency and flexibility of the tool in future uses. These improvements include the following:

1. a saw blade cutter attachment to allow the saw to be released when trapped,
2. a quick-release drive wheel for more convenient tire replacement,
3. improved blade guards,
4. an alignment sight,
5. sensors to stop saw operation when a blade is broken,
6. leveling devices to assist in proper blade alignment,
7. force feedback sensors to allow operators better control saw positioning and feeding, and

8. a speed control to provide flexibility of the type of materials cut with the saw.

Tooling requirements for closing the valve boxes have yet to be determined. It is foreseen that improved tools for valve box closure to protect personnel and the environment will be needed. Likewise, tooling requirements for disassembly of contaminated remediation equipment has yet to be determined. There may be a need to use the cutting and capping equipment on buried pipes. This equipment may have to be modified to be used with deployment systems other than the MLDUA and Houdini vehicle, for which the equipment was initially designed.

A number of large tanks at ORNL remain in active service as part of the liquid waste system. Because these tanks are projected to remain in use for several years, detailed planning for their remediation and closure has not been initiated. It is likely that pipe cutting and plugging will be a part of these actions, but it is not possible to predict what these needs will be.

6. REFERENCES

[1] R. L. Glassell and B. E. Lewis, *Initial Performance Report on the Tank Isolation Tools Deployed in the Gunite and Associated Tanks at the Oak Ridge National Laboratory*, (letter report), Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Oak Ridge, Tennessee, January, 1999.

[2] R. L. Glassell, S. M. Babcock, and B. E. Lewis, *Design, Test, and Operation Description for the Gunite and Associated Tanks Tank Isolation System,* (project document), Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Oak Ridge, Tennessee, August, 1998.

[3] J. B. Chesser, Lockheed Martin Energy Research Corp., personal communication with M. A. Johnson, Lockheed Martin Energy Systems, Inc., July, 1999

[4] J. B. Chesser, Lockheed Martin Energy Research Corp., personal communication with R. L. Glassell and B. L. Burks, both of The Providence Group, June, 1999.

[5] B. E. Lewis, Lockheed Martin Energy Research Corp., personal communication with R. L. Glassell, and W. Glover, both of The Providence Group, October 8, 1999.

[6] J. B. Chesser and B. E. Lewis, *Tank Isolation System: Update on Utilization and Modifications,* (letter report), Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Oak Ridge, Tennessee, August, 1999.

[7] *Waste Characterization Data Manual for the Inactive Liquid Low-Level Waste Tanks at Oak Ridge National Laboratory, Oak Ridge, Tennessee,* DOE/OR/01-1159&D1, Bechtel National, Inc/CH2M Hill, Oak Ridge, Tennessee, December, 1997.

Appendix: List of Liquid Low-Level Waste Tanks

Tank identifier	Installed	Capacity (gal)	Location	Construction
W-5	1943	170,000	Central laboratory area, STF	Gunite
W-6	1943	170,000	Central laboratory area, STF	Gunite
W-7	1943	170,000	Central laboratory area, STF	Gunite
W-9	1943	170,000	Central laboratory area, STF	Gunite
W-10	1943	170,000	Central laboratory area, STF	Gunite
W-11	1943	1,500	Central laboratory area, STF	Gunite
T-1	1963	15,000	Melton Valley, old hydrofracture facility	Carbon steel
T-2	1963	15,000	Melton Valley, old hydrofracture facility	Carbon steel
T-3	1963	25,000	Melton Valley, old hydrofracture facility	Carbon steel
T-4	1963	25,000	Melton Valley, old hydrofracture facility	Carbon steel
T-9	1963	25,000	Melton Valley, old hydrofracture facility	Carbon steel
TH-1	1943	2,500	Central laboratory area, Bldg 3503	SS
TH-2	1952	2,400	Central laboratory area, Bldg 3503	SS
TH-3	1952	3,300	Central laboratory area, Bldg 3503	SS
TH-4	1952	14,000	Central laboratory area, Bldg 3503	Gunite
WC-1	1950	2,150	Central laboratory area	SS
WC-15	1951	1,000	Central laboratory area, Bldg 4500	SS
WC-17	1951	1,000	Central laboratory area, Bldg 4500	SS
W-1	1943	4,800	Central laboratory area, NTF	Gunite
W-1A	1951	4,000	Central laboratory area, NTF	SS
W-2	1943	4,800	Central laboratory area, NTF	Gunite
W-3	1943	42,500	Central laboratory area, NTF	Gunite
W-4	1943	42,500	Central laboratory area, NTF	Gunite
W-13	1945	2,000	Central laboratory area, NTF	SS
W-14	1945	2,000	Central laboratory area, NTF	SS
W-15	1945	2,000	Central laboratory area, NTF	SS
7560	1957	1,000	Melton Valley, Homogeneous Reactor Experiment	SS
7562	1957	12,000	Melton Valley, Homogeneous Reactor Experiment	SS
T-30	1961	825	Central laboratory area, Bldg 4507	SS
W-20	1955	2,250	Central laboratory area, STF	SS
3003-A	1943	16,000	Central laboratory area, Bldg 3003	Concrete
H-209	1961	2,500	Central laboratory area, Bldg 3517	SS
7503-A	1962	11,000	Melton Valley, Molten Salt Reactor Experiment	SS
3002-A	1943	2,200	Central laboratory area, Graphite Reactor	SS
S-424		500	Central laboratory area, Bldg 3517	SS, glass lined
T-14	1979	48,500	Melton Valley, new hydrofracture facility	Concrete
W-1I	1950	500	Central laboratory area, Bldg 3028	SS
WC-4	1944	1,700	Central laboratory area, Bldg 3026	SS
W-17	1951	1,000	Central laboratory area, STF	SS
W-18	1951	1,000	Central laboratory area, STF	SS
WC-11	1951	4,000	Central laboratory area, WC tank farm	SS
WC-12	1951	1,000	Central laboratory area, WC tank farm	SS
WC-13	1951	1,000	Central laboratory area, WC tank farm	SS
WC-14	1951	1,000	Central laboratory area, WC tank farm	SS
LA-104	1960	296	Central laboratory area, Bldg 3047	SS
2026-A	1962	700	Central laboratory area, Bldg 2026	Hastelloy C
WC-19	1955	2,000	Central laboratory area, Bldg 3047	SS
W-12	1947	700	Central laboratory area, STF	SS

INTERNAL DISTRIBUTION

1. J. B. Chesser
2. J. N. Herndon—Record Copy
3-5. B. E. Lewis
6. M. A. Johnson
7. ORNL Central Research Library
8. ORNL Laboratory Records
9. K. E. Plummer
10. S. L. Schrock
11. S. D. VanHoesen

EXTERNAL DISTRIBUTION

12. D. H. Bolling, Bechtel Jacobs Company, P. O. Box 2008, MS 6402, Oak Ridge, TN 37831-6402
13. B. L. Burks, The Providence Group, 11020 Solway School Road, Suite 107, Knoxville, TN 37931
14. L. D. Bustard, Sandia National Laboratory, P. O. Box 5800, MS 0728, Albuquerque, NM 87185-5800
15. J. R. Noble-Dial, U.S. Department of Energy, Oak Ridge Operations Office, P. O. Box 2009, Oak Ridge, TN 37831
16. R. L. Glassell, The Providence Group, 11020 Solway School Road, Suite 107, Knoxville, TN 37931
17. Office of Scientific and Technical Information, DOE Oak Ridge Field Office, P. O. Box 62, Oak Ridge, TN 37831
18. T. P. Pietrock, U.S. Department of Energy, Richland Operations Office, P. O. Box 550, MS K8-50, Richland, WA 99352
19-26. B. J. Williams, Pacific Northwest National Laboratory, P. O. Box 999, MSIN K9-69, Richland, WA 99352