SUCCESSES IN HLW TANK RETRIEVAL — THE RUSSIAN-AMERICAN EXPERIENCE

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ABSTRACT

This paper describes the development, testing, and fielding of advanced equipment for retrieval of high-level radioactive wastes from the tanks used to store the residues of nuclear-weapons materials production. Because both the Russian and US governments produced weapons materials during the Cold War, both have comparable needs to reduce the potential environmental threats from these storage tanks. Over the past few years, laboratories and other facilities of the Russian Ministry of Atomic Energy (MINATOM) have successfully implemented several technologies for remediation and processing of their nuclear wastes. Through a program by the US Department of Energy/ National Nuclear Security Agency for cooperative testing and demonstrations, these technologies are becoming available for use at the US sites.

The waste-removal processes described here are based on Pulsating Pump Technology™ (PPT). PPT equipment can be configured for multiple applications, including mobilization of compacted wastes, for transfer of the resultant waste slurry to subsequent processing stations, and for sluicing of surfaces of the emptied tanks for decontamination purposes.

The PPT system has been used in Russia for several tank-retrieval campaigns over the past few years and a similar system was deployed at the Gunite Tanks at Oak Ridge. Currently, a retrieval project has been completed at the Mining and Chemical Combine (MCC) in Zheleznogorsk, Russia. At MCC the pulsating equipment has been used for emptying 3200 m^3 volume tanks containing compacted sludge 25 meters deep. As part of the US/Russian cooperative program, retrieval and operational data are being collected. The successes documented at the Russian facilities offer direct and significant opportunities for accelerating the cleanup efforts at the US facilities.

INTRODUCTION

Both the US and Russia must address the legacy of their separate Cold-War nuclear-weapons production activities. Over approximately 50 years, the production of plutonium has resulted in many millions of liters of high-level wastes being produced and stored in each country. Both the US and Russian governments recognize the urgent need to remediate these conditions to avoid serious environmental problems in the future. The Mining and Chemical Combine (MCC) located in Zheleznogorsk, Russia (the former Krasnoyarsk-26 site), in conjunction with other Russian scientific institutes, has been in the forefront of technology development for tank-waste retrieval. Through the US Department of Energy/ National Nuclear Security Agency's Initiatives for Proliferation Prevention (IPP) program, a project involving MCC, Sandia National Laboratories, and several of the US production sites has been established for cooperative testing and demonstrations of state-of-the-art technologies. From this project (the Tank Retrieval and Closure Demonstration Center – TRCDC) has come technologies for retrieval of tank wastes, chemical processes for aiding the mobilization and transfer of compacted sludges, and separations technologies for removing transuranic radionuclides from aqueous waste streams. After considerable development and demonstrations in Russia (as well as the fielding of the technology in the US), these technologies are becoming available for consideration by the US sites that must resolve their nuclear-waste problems.

SYSTEM CHARACTERISTICS

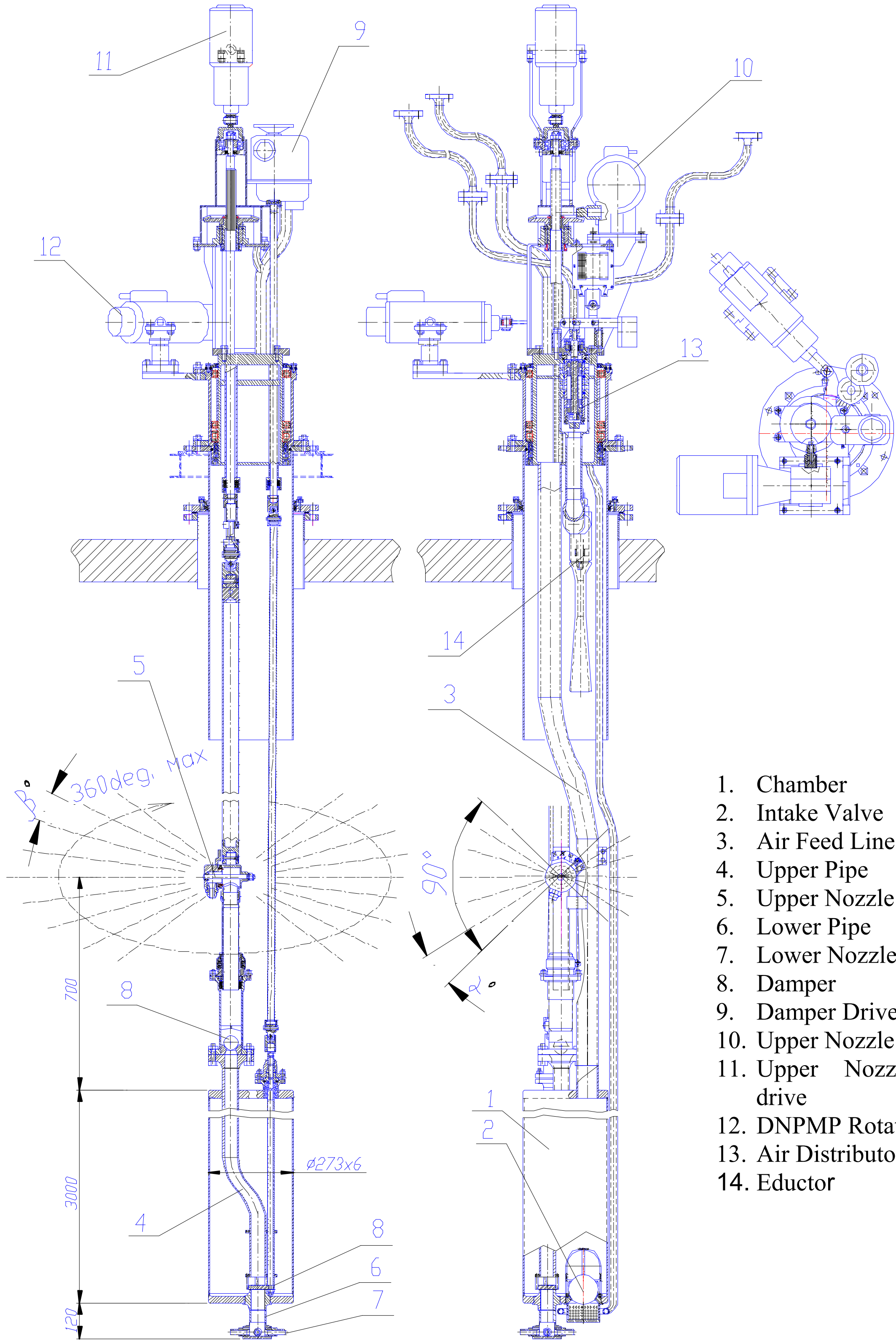
Given the age, the hazards, and the sometimes unknown constituents in the radioactive wastes stored in tanks at the former production facilities, retrieval methods require considerable flexibility of approach and robustness of operation. MCC scientists have developed and placed into industrial-scale operation a system for mobilizing and transferring liquid and solid wastes from storage tanks, and subsequently cleaning and decontaminating the emptied tanks.

Pulsating Pump Technology™ (PPT) is a method of mobilizing and transporting liquids and slurries in an efficient and economical way. The pumps operate on compressed air as the power source, and have essentially no moving parts subject to failure in the contaminated volume. A single pump can be configured to mobilize compacted sludges, transfer slurries of the mobilized sludge for further processing, and to wash the tank walls for decontamination. The entire assembly is light enough that only a minimal support structure is needed over the tank risers. The components in the contaminated volume consist of a charge vessel, which includes a compressed-air supply orifice, an intake orifice with a ball check valve, and discharge orifices. Current configurations can be mounted on 30-cm diameter risers, although smaller- or larger-diameter units can be made. Figure 1 shows the current configuration of the Dual-Nozzle Pulsating Mixing Pump.

Specific construction and operational characteristics include:

- The system operates on compressed air in a pulsating mode; therefore, the amount of working fluid used for mobilization and transfer of solids is minimized. Either water or supernatant liquids from the tank being emptied can be used in the pump. The pump circulates the working fluid until the solids concentration reaches the desired value, at which time the pump transfers the slurry to downstream processing. If an intermediate settling tank is used, the liquid clarified in the settling tank can be returned to the tank being emptied for further use as the working fluid.

- The pump relies on a very simple and robust ball valve to control flow in the charge vessel. During tests of the unit, foreign matter and obstructions were unable to cause valve failure. Examples of materials introduced into the valve intake included a large mat of steel wool and lathe turnings, rubber gloves, and Styrofoam "peanuts". None of this foreign matter prevented the system from performing normally. Additionally, a 2-mm-diameter steel wire was inserted into the ball-valve seat. This obstruction also did not put the pump out of operation. Lastly, the ball valve was deliberately "seized" by packing salt around it in its closed position. After the salt hardened, the ball could not be moved by hand. Again, after very few cycles, the valve cleared itself and was able to operate normally [1].



1. Chamber
2. Intake Valve
3. Air Feed Line
4. Upper Pipe
5. Upper Nozzle
6. Lower Pipe
7. Lower Nozzle
8. Damper
9. Damper Drive
10. Upper Nozzle Rotation drive
11. Upper Nozzle Inclination drive
12. DNPMP Rotation drive
13. Air Distributor
14. Eductor

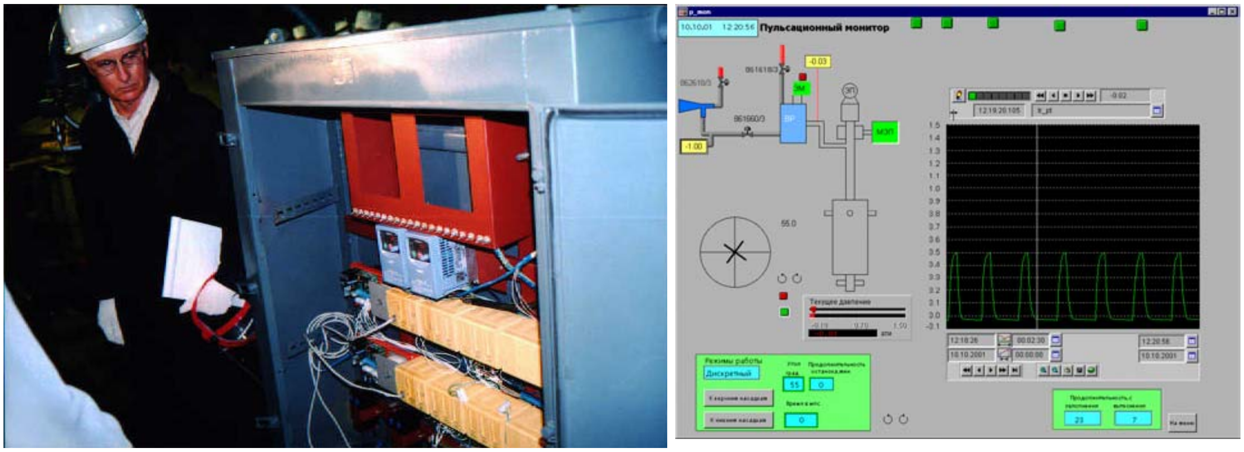
Fig. 1 Illustration of 0.15 m^3 Dual-Nozzle Pulsating Mixing Pump

- The system can be configured with great flexibility, with charge-vessel capacities ranging from a few liters to hundreds of liters. Several nozzle configurations are possible. A set of steerable bottom nozzles is included for mobilization of sludges near the pump body. Current configuration has four horizontal nozzles at right angles, and a fifth nozzle aimed downward. Pump design allows the system to operate within about 2 cm of the tank bottom because the height above the tank bottom of the intake pipe can be adjusted independently of the lower nozzles. Additionally, an upper nozzle can be included. Tests have shown that the upper nozzle can project a stream of liquid about 20 m from the pump, and can be used for washing sludges back toward the pump for further mixing, or for transferring from the tank. After the bulk of tank sludges have been removed, the upper nozzles can be used for washing down the tank walls for final decontamination. The upper nozzle can also be located remotely from the pump for situations where internal tank obstructions shadow some areas. Consequently, the system has been shown to be effective in a wide variety of tank geometries and sizes, including those with interior obstructions, such as cooling coils.

- The system uses a closed cycle for the working fluid; consequently, additional reagents can be introduced to facilitate softening of hard heels, or for final decontamination.

- The pump operates on compressed air, capable of operating at pressures ranging from 8 to 15 atmospheres. A vacuum is drawn by an eductor to fill the charge vessel. Compressed air is then used to expel the liquid through the nozzles selected. The compressed air can be vented into the tank volume, or through filters to the outside. Programmable logic controllers (PLCs) control operation of the system control valves, as shown in Figure 2(a). The logic has been configured so that neither operational errors nor off-normal events can cause releases of contaminants to the environment. Visualization of system status and operator control of the functions (e.g., mode of operation, or direction of nozzles) is effected through a computer program and communications equipment to the PLCs. Figure 2(b) shows the operator display. As with the underlying PLCs, the operator cannot cause the system to release contaminants into the environment. The computer control permits the selection of cycle times, of active nozzles, and of the elevation and azimuth of the upper nozzle. This nozzle can operate within 90^{o} vertically and 360° horizontally. Hence, the computerized control system can direct the nozzle to any point of the tank.

- MCC has completed their ISO 9000 certification and the PPT equipment is being built to those standards. Additionally, MCC Technologies has established a Quality Assurance program that includes the requirements of NQA-1.



(a) (b)

Fig. 2. (a) System-controlling PLCs and (b) Screen shot of operator's workstation

RUSSIAN OPERATIONAL EXPERIENCE WITH THE PPT EQUIPMENT

Installation of PPT equipment requires electrical power (120 or 240 V, 30 A), compressed air (1 MPa maximum pressure and 3 m^3/min maximum throughput), and a support structure. Given that the entire device weighs less than 600 kg for a 0.15 m^3 capacity charge vessel, a heavy-duty support is not required. The charge vessel (which is the largest-diameter component of the pump) must fit through the tank riser. The 0.15 m^3 system has been deployed through 30-cm risers. The compressed air can either be vented into the tank, which requires that the tank ventilation and filtration system be able to accommodate the resulting pressure pulses, or a separate filtration system for the exhaust can be installed. Shielding around the pump head is a worthwhile precaution, although the head-end components are designed to not be contaminated. The PLC equipment can be installed remotely from the pump, as can the operator's workstation [2].

Initial operation of the pump for sludge mobilization consists of operating the lower jets to excavate a depression in the sludge to hold the working fluid and the mobilized sludges. For the 0.15 m^3 system, the lower jets have an effective radius of 2 – 3 m, and the depth of the excavated depression is only limited by the desired volume of working fluid to be used. The pump can operate in a fluid depth of as little as 4 cm. A typical cycle consists of a 15 to 30-second fill cycle, followed by a 7 to 10-second fluid-discharge time. The filling is achieved by the eductor generating a vacuum in the charge vessel of about 0.05 MPa; the discharge pressure is approximately 0.7 MPa. Approximately 150 l of fluid are pumped out through the five lower nozzles for each cycle.

After the excavation step, the upper nozzle can be used to mobilize sludges away from the pump body. Working fluid is discharged though the upper nozzle from the charge vessel by means of a diverter valve that directs the fluid flow to that nozzle. For the 0.15 m^3 system the jet pulse is of about 8-12 s duration, and it is designed to operate at an effective cleaning radius of approximately 13 m. Figure 3 shows the upper nozzle in operation at a test facility. The computer-control system can be set for automatic horizontal or vertical sweeping of the upper nozzle. The upper nozzle is used to wash the mobilized wastes back toward the pump, where the slurry can be transferred when it reaches the proper density. A separate TV camera is usually installed in the tank to observe the processes.

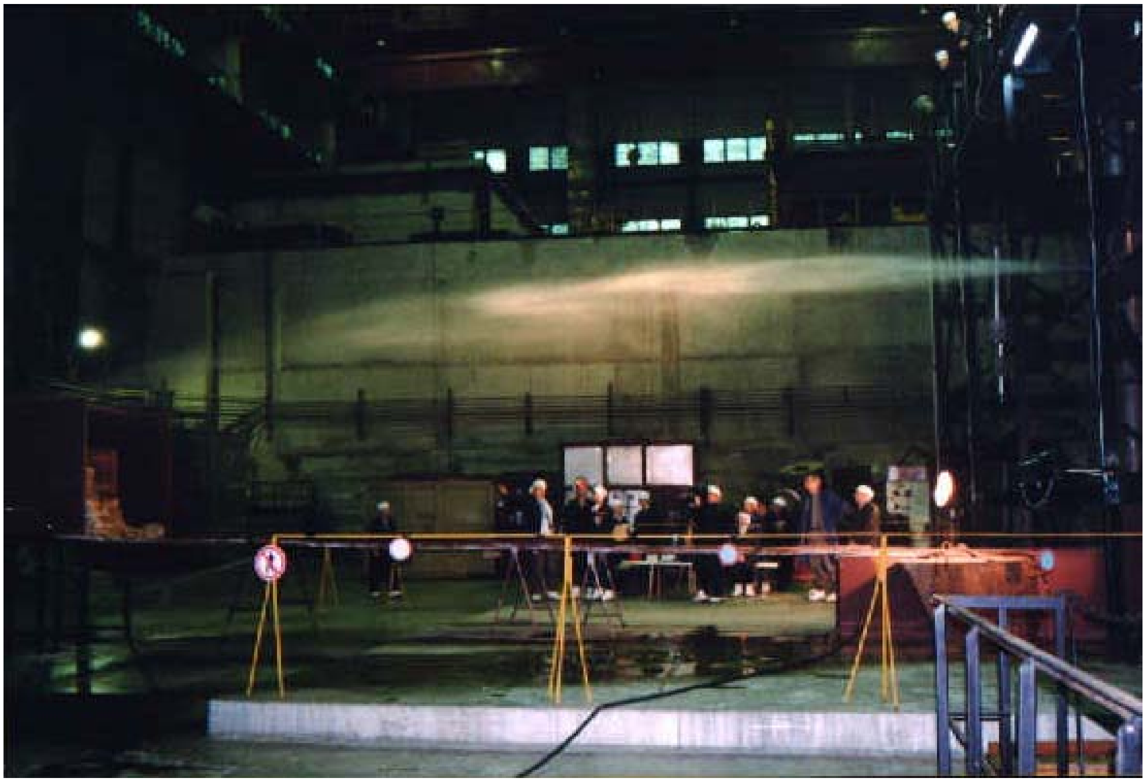


Fig. 3 Pump upper jet in operation at cold-test facility

Transfer from the tank involves directing the discharged fluid to another pipe that transports the slurry from the tank. Slurries with up to 30 volume percent solids can be transported.

REVIEW OF TANK-RETRIEVAL CAMPAIGNS WITH PPT EQUIPMENT

Pulsating Pump Technology™ has been used at Russian sites for over ten years. At MCC, for example, waste from several 3200 m^3 tanks has been retrieved. In one instance, as part of a demonstration of reagents that could aid in the mobilization of hard, dense sludges, approximately 3 m^3 were mobilized and transferred from a tank. This tank is approximately 12 m in diameter and 30 m deep, and sludge concentrations up to 800 g/l. In anticipation of another retrieval campaign in a second 3200 m^3 tank containing approximately 2600 m^3 of waste, the PPT retrieval equipment was installed in a 315 m^3 tank for life-test purposes. The PPT equipment was used to mobilize simulants of the same density and physical properties as the actual waste. The tests demonstrated satisfactory operational life, and resulted in design and operational modifications that improved system efficiency and reliability [2].

The PPT equipment was installed in the tank containing 2600 m^3 of waste, and the waste removal operations have been underway since December 2002. Figure 4 shows the accessible portions of the retrieval site.

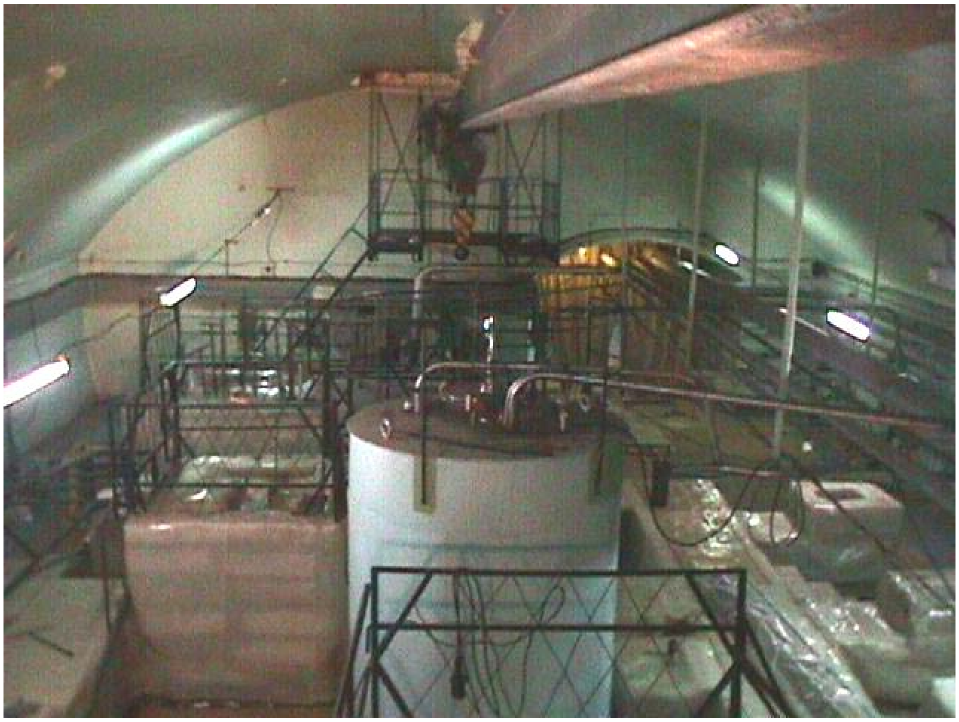


Fig. 4 Support equipment above 3200 m^3 tank being retrieved at MCC

The operational sequence is as follows:

- A 1-m layer of supernatant in the tank was left for use as the working liquid; the rest of supernatant was discharged to the adjacent tank.
- With immersed jets a 4 – 5 m diameter depression of approximately 1.5m depth was created in the center of the tank. The upper jets then washed a bare waste layer at the periphery of the depression. The sludge draining to this depression was removed by the pump.
- As the sludge was removed from the tank, the pump and the monitor were lowered (in approximately 1-m increments) by installing additional tubing at the tank riser.
- The erosion cycle and discharge cycle were then repeated.

Waste removal was performed along with a study of the operating characteristics of the equipment, composition of the removed waste, and safety aspects. Records were kept during operation of the equipment levels of radioactive contamination in the tank and at the instrumentation hall. Radiation doses accumulated by the personnel were also recorded.

The PPT equipment has proved its reliability during the one-year operational campaign. There was one occasion when a body of dense sludge fell into the created depression and buried the entire pump chamber. But even in this case, the pump restored its operability after the preventive backflushing was done.

Reports resulting from these retrieval tests included the following:

- Operational characteristics of the retrieval equipment and control system, (period of operation, performance, failures and repairs, description of defects),
- Quantitative and qualitative characteristics of the retrieved sludge, (volume, solid phase content, radioactivity),
- Radioactive contamination in the waste tank, in the shielded box, and the room where the tank is installed, and
- Dose exposures for the personnel directly involved in the sludge retrieval equipment maintenance.

The MCC specialists are positive that the experience gained in cleaning this tank will allow more effective and reliable equipment to be designed both for using at MCC and at potential users' sites.

PPT APPLICATIONS TO US ACCELERATED HLW CLEANUP AND SITE CLOSURE

In fiscal year 1998, PPT equipment was selected for deployment in one of the Gunite and Associated Tanks at Oak Ridge National Laboratory to mobilize settled solids. The pump was deployed in Tank TH-4 during January 2001. The deployment reduced the costs of operation and maintenance of more expensive mixing and robotic retrieval systems. The Effective Cleaning Radius of the system was 2.6 m, resulting in retrieval of approximately 82% of the sludge originally in the tank. The tank cleaning results are consistent with the operations seen during cold testing of the PPT system, and fall well within the risk range established by the Environmental Protection Agency based on their modeling. Additional details are given in Reference [3].

The considerable flexibility of the PPT concept suggests a number of ways that it could support the US accelerated HLW cleanup effort. Relative to the waste-retrieval needs:

- PPT operation in leaking tanks can reduce the risk of contaminant loss to the environment because of the ability to operate with a limited amount of working fluid.
- The effective cleaning radius achieved by use of the upper nozzle would permit a single PPT system to mobilize wastes in the biggest tanks at Hanford or Savannah River.
- Its ability to operate in very shallow liquid depths allows the system to retrieve almost all the contents of a tank.
- In salt tanks, the PPT equipment could retrieve salt solutions, and mobilize and retrieve the insoluble residues in these tanks.

Beyond waste retrieval, when combined with reagents added to the tanks, the PPT equipment can:

- Wash down the tank walls with decontamination solutions using the upper jet.
- Perform agitation of acid solutions with the lower nozzles during the final chemical cleaning and heel removal.

- Neutralize acidic cleaning solutions immediately during discharge of waste from the tank when the neutralizing solution is supplied to the charge vessel.

Other applications of PPT technology include:

- Use of a mixing pump for mixing grout with tank residual liquids.

- Configuring the PPT equipment as a Pulse-Jet Mixer for use in the waste-treatment plant operations.

SUMMARY

With many years' experience, and a robust, efficient, and economical design, Pulsating Pump Technology™ developed by the Mining and Chemical Combine in Russia can provide significant benefits for the US's Accelerated HLW Cleanup effort. The PPT system has proven itself in both Russia and the US; systems can now be provided that conform to the Quality Assurance standards demanded by the applications in the US.

REFERENCES

1 Deliverable 9.4.2 of IPP Contract 5991, Sandia National Laboratories (2001).

2 Deliverable 4.6 of IPP Contract 5991, Sandia National Laboratories (2002).

3 B. HATCHELL, B. LEWIS, J. RANDOLPH, and M. JOHNSON, "Russian Pulsating Mixer Pump Deployment in the Gunite and Associated Tanks at ORNL," PNNL-SA-34056, Pacific Northwest National Laboratory (2001).