Specialized Video Systems for Use in Underground Storage Tanks (U)

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DISCLAIMER

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ABSTRACT

The Robotics Development Groups at the Savannah River Site and the Hanford site have developed remote video and photography systems for deployment in underground radioactive waste storage tanks at Department of Energy (DOE) sites as a part of the Office of Technology Development (OTD) program within DOE. Figure 1 shows the remote video/photography systems in a typical underground storage tank environment.

Viewing and documenting the tank interiors and their associated annular spaces is an extremely valuable tool in characterizing their condition and contents and in controlling their remediation. Several specialized video/photography systems and robotic End Effectors have been fabricated that provide remote viewing and lighting. All are remotely deployable into and from the tank, and all viewing functions are remotely operated. Positioning all control components away from the facility prevents the potential for personnel exposure to radiation and contamination.

Overview video systems, both monaural and stereo versions, include a camera, zoom lens, camera positioner, vertical deployment system, and positional feedback. Each independent video package can be inserted through a 100 mm (4") diameter opening. A special attribute of these packages is their design to never get larger than the entry hole during operation and to be fully retrievable. The End Effector systems will be deployed on the large robotic Light Duty Utility Arm (LDUA) being developed by other portions of the OTD-DOE programs. The systems implement a multi-functional "over the coax" design that uses a single coaxial cable for all data and control signals over the more than 900 foot cable (or fiber optic) link.

The monaural video system uses fully radiation hardened components and can also be used with conventional components in lower radiation, cost-sensitive applications. The stereo systems are radiation resistant, using conventional components, and provide multiple magnification viewing while avoiding the inherent difficulties of matching zoom lenses. The remote deployment method is a unique flexible methodology that gives the system stability during deployment while retaining ease of handling.

The End Effector systems are remotely positioned by the LDUA to provide specialized viewing functions. The stereo close-up video unit provides remote stereo viewing for the characterization of suspect

anomalies. The stereo photography unit implements the inherent higher resolution of film-based systems while providing the remote operator with real time scene composition on fully automatic cameras. All system controls use the "over the coax" technology to address the long distances to remotely located personnel.

The stereo close-up system includes an adjustable optical system that allows the distance between the LDUA and object to vary so that there is no significant change in the remotely viewed size of the suspect anomaly. The size predictability eliminates the potential confusion associated with over or under magnification that can occur in totally remote operations.

All systems are designed to NFPA-70 Class 1, Division 1 requirements to satisfy those deployments that require flammable atmosphere protection. Protection is included for all portions, including cabling, with constant pressurization and interlocking.

All systems were developed for the nominal 4.5 million liter (1.2 million gallon) underground tanks used to store liquid high level radioactive waste at the Savannah River and Hanford sites. The remediation of these tanks will require detailed knowledge of their condition and contents. The remote video/photography systems are provided for direct characterization and to visually guide the more aggressive characterization tools used on the LDUA.

BACKGROUND

A cooperative program is underway with multiple Department Of Energy (DOE) sites to develop remediation systems and techniques for Underground Storage Tank (UST) high level waste containments typical of many sites. The Savannah River Site (SRS) and the Hanford Site contain the largest number of UST's and are the major players in developing specialized video systems for deployment within these tanks.

In response to a need for new and improved technology, the DOE Office of Technology Development (OTD) was created. To complete this task, several major new technology demonstration efforts were initiated. One such effort is the Underground Storage Tank-Integrated Demonstration (UST-ID). This program focuses on the characterization and remediation of underground radioactive waste storage tanks and is funding the development of the LDUA system. The LDUA system consists of a seven degree of freedom robotic arm, which will function as a deployment platform for various surveillance and inspection end effectors, and a mobile deployment vehicle to maneuveur the system to waste tanks. End effectors that will assist in these tasks will be developed by DOE laboratories, industry, and academia.

The Savannah River Site and the Hanford Site are developing the remote viewing systems to be used in conjunction with the LDUA. Remote viewing will be used to assist in positioning and controlling the LDUA in UST's and as the end product of a portion of its work. Remote close-up, high resolution, and stereo views of tank components and contents will be gathered by the LDUA using the remote viewing End Effectors.

In the past, tank surveillance and inspection was performed by lowering film cameras and other instruments through existing risers to positions directly below the riser and obtaining data from a single location, possibly at multiple elevations. The capability for positioning cameras, sensors, etc. at multiple positions and orientations away from the riser axis did not previously exist, and remote visual inspection operations have been hindered by these limitations. The photographic methods, which have predominated, are particularly limiting, since they are not useful in real time.

The field of remote video/viewing is now being used extensively, in other areas, to extend the data gathering and control of personnel into environments not suitable for entry. The provision for viewing remote locations from a safe distance has allowed inspection, documentation, and verification of pipes, tanks, vessels, ducts, rooms, and pits.

This report addresses the development of the remote video and photography technology for the LDUA, both in the form of "stand off" devices, which view the LDUA from an offset perspective, and End Effectors, which are positioned by the LDUA. All will be used in conjunction with the "hot" deployment of the LDUA at Hanford but may also be used in other applications.

1.0 INTRODUCTION

The UST's are nominal 4.5 million liter (1.2 million gallon) tanks used to store liquid high level radioactive waste that is generated by the sites and awaiting final disposal. Approximately 200 UST's exist at SRS and Hanford, and smaller numbers exist at other DOE sites.

The waste tanks are of two general configurations, single shell and double shell. A wide variety of internal tank configurations are in use depending on tank service. These configurations vary from nearly free of obstructions to containing hundreds of distributed vertical cooling coils.

Both general types are of flattened shape (i.e.wider than high), with all having a sealed carbon steel primary tank. The double shell tanks have a dry secondary containment pan. The annular space between the tank wall and the secondary containment wall is continuously monitored for liquid intrusion and periodically inspected and documented. The single shell tanks have only a concrete support structure around the primary tank wall with no annular space. Wells have been drilled in the surrounding areas to monitor for any tank leakage.

The interior conditions of the tanks and dry annular spaces have been historically monitored with remote still photography. A wide variety of 35 mm or 120 mm film cameras have been manually deployed to record and document tank structures and conditions.

2.0 Light Duty Utility Arm Program

The Light Duty Utility Arm (LDUA) Integrated System is a truck-mobile robotic in-situ surveillance and inspection system designed to remotely inspect, map, and characterize waste and waste tank conditions. The LDUA Integrated System is being initially developed for use in the single shell tanks, of which Hanford has a total of 149.

A major objective of the UST-ID program is to demonstrate waste retrieval technologies in preparation for UST remediation and waste disposal. Waste retrieval is directly dependent on knowledge of chemical and physical properties of waste and on operating experience in the tank environment. Because the in-tank environment precludes human entry, a remote system is required to deploy characterization and retrieval devices. The requirement for a light duty device to meet the characterization needs and operating experience will be addressed with the LDUA. The system will include the robotic arm and all required subsystems to work as an autonomous field unit. See Figure 2 for a typical in-tank view of multiple systems deployed.

The deployed LDUA system will include the truck-based robotic arm, the tank top support frame, the remotely located control trailer, the required end effectors, and all other support devices. The overview video units will be deployed as separate units that interface to the control trailer. All controls and services will be consolidated in tank top interfaces prior to transmission on the more than 900 foot tether to and from the control trailer. The long distance is required to allow most personnel to work only in "clean" areas.

The final LDUA system will minimize any potential for personnel exposure to radiological hazards. A special emphasis is being placed on minimizing any set up time or maintenance time requiring personnel to be present on the tank top.

3.0 Remote Video and Photography Systems

A group of remote video and photography systems are being provided for the LDUA system. They are either "stand alone" overview systems or robotic End Effectors. The overview units are positioned prior to the LDUA deployment into the tank and remain in use until the arm is removed. Once deployed, the overview systems provide assurance that the LDUA deployment and subsequent operation are free from

collision potentials. The End Effectors are used by the deployed LDUA to make specialized inspections and documentation, as required throughout the UST environment.

Overview video systems (see Figure 3), both monaural and stereo versions, include a camera, zoom lens, camera positioner, vertical deployment system, and positional feedback. Each independent video package can be inserted through a 100 mm (4") diameter opening. A special attribute of these packages is their design to never get larger than the entry hole during operation and to be fully retrievable. The End Effector systems will be deployed on the large robotic LDUA being provided by other portions of the OTD-DOE programs. All video and photography systems implement a multi-functional design that uses a single coaxial cable for all data and control signals over the more than 900 foot cable (or fiber optic) link.

The monaural video system utilizes fully radiation hardened components and can also be used with conventional components in lower radiation, cost-sensitive applications. The stereo systems are radiation resistant using conventional components and provide multiple magnification viewing while avoiding the inherent difficulties of matching zoom lenses. The remote deployment method is a unique flexible methodology that gives the required stability during deployment while retaining ease of handling.

The End Effector systems are remotely positioned by the LDUA to provide specialized viewing functions. The stereo close-up video unit provides remote stereo viewing for the characterization of suspect anomalies such as corrosion and cracking. The stereo photography unit implements the inherent higher resolution of film-based systems while providing the remote operator with real time scene composition on fully automatic cameras. All system controls use the "over the coax" technology to address the long distances to remotely located personnel.

The stereo close-up system includes an adjustable optical system that allows the distance between the LDUA and object to vary so that there is no significant change in the remotely viewed size of the suspect anomaly. The size predictability eliminates the potential confusion associated with over or under magnification that can occur in totally remote operations.

All systems are designed to NFPA-70 Class 1, Division 1 requirements to satisfy those deployments that require flammable atmosphere protection. Protection is included for all portions, including cabling, with constant pressurization and interlocking.

4.0 Overview Video System

The Overview Video System (OVS) was designed to provide routine and troubleshooting views of tank interiors during the characterization and remediation phases of UST processing. The OVS is a fully radiation hardened system designed to provide continuous black-and-white video in a Class 1, Division 1 flammable atmosphere.

The tank top portion of the OVS is positioned over a previously opened four inch tank riser, while already connected to a very simple cable interface. All personnel then depart to a protected area, 900+ feet away, and control all movements and functions from a remote location. A new type of "no slip ring" cable reel deployment technology has been provided on the deployment stand to improve reliability and signal quality, while reducing costs.

Vertical motion, rotation, lighting, and lens functions are operated remotely by either stand alone controls or by a supervisory computer, such as the S-DAS. The maximum vertical deployment for the tanks at Hanford is fifty feet, and longer distances are easily achievable. The positional data of the deployed video package is provided on screen and for serial input to another computer system. All data and control functions are combined into a pair of inexpensive coaxial cables.

The OVS was designed to perform a "first in, last out" role in UST operations. It has provisions to minimize any potential for collisions on deployment and has no potential for tank damage. The OVS will be deployed before any other equipment and monitor all entries that follow to provide optimum collision avoidance and anomaly resolution.

5.0 Overview Stereo Video System

The Overview Stereo Video System (OSVS) is very similar to the OVS, involving all of the same deployment and control features, but providing a specialized form of remote viewing to assist in the tank characterization and collision avoidance roles. Stereo video views are provided by a package suitable for entry through the four inch riser and are displayed as remote views with depth perception.

All of the data and remote control features of the OVS are combined with non radiation hardened color video cameras and stereo adjustment features. Current state of the art does not provide radiation color cameras suitable for this task, but radiation tolerant chip cameras are available and used in this application. Recent experience has shown using chip cameras to be very practical for reasonable deployment periods.

The remote adjustments required for stereo have all been provided along with multiple lenses of different magnification. Magnification step changes are a preferred solution to zoom lenses in this type of configuration. As before, "no slip ring" cable reel deployment technology has been used to improve reliability and signal quality.

6.0 Close-up Stereo Video End Effector

The Close-up Stereo Video System (CSVS) (see Figure 4 - foreground) is an End Effector system to be deployed by the LDUA and provide high resolution predictable size inspection of suspect anomalies. A special lens system is used to allow constant size viewing from an adjustable standoff distance, and shadow producing lighting is provided to resolve potential crack anomalies. Color stereo video is provided by non radiation hardened cameras. Black-and-white radiation hardened cameras are applicable to this device but are a less desirable choice.

7.0 Stereo Still Photography End Effector

The Stereo Photography System (SPS) (see Figure 4 - background) provides for stereo film based documentation and archiving of tank interiors. Using film provides ten times higher resolution as compared to modern video systems. The SPS incorporates electronic 35 mm film cameras and color video cameras. The 35 mm cameras have been modified for remote control and coupled to video cameras for remote scene viewing. The remote video viewing provides for scene composition, aiming, and magnification. The system is intended to support off-line stereo film comparisons and is not necessarily intended for remote stereo direct view.

The SPS is an End Effector system to be deployed by the LDUA and shares a common control system with the CSVS. In Figure 4, the SPS is shown on a conventional pan and tilt device that was used to simulate LDUA positioning.

8.0 Fiscal 1994 Program Demo

All of the above systems were successfully operated at the FY'94 End Effector and Data Acquisition Demonstration at the Hanford site. The demonstration was conducted at the Fuels Maintenance and Examination Facility on the Hanford site, and an empty work cell was used to simulate the interior of a typical UST. The size of the cell allowed for full scale demonstration of all components and will be used to demonstrate the LDUA at a later date. The deployed video packages are shown above the simulated tank floor in Figure 2, which also shows the laser rangefinder and minilab systems currently under development.

9.0 Future Plans

The demonstration provided valuable development experience for all of the remote video/photography systems. Improvements identified during the demonstration and during the past year will be incorporated into the FY'95 development of the systems.

These improvements include the conversion of all systems to fiber optic control links, to assure compatibility with all other tank top systems and reduce the potential for electrical noise. Also, the sealing of the overview systems to the tank risers will be remote, to further reduce any potential for personnel exposure.

The improved video and photography systems will be demonstrated at the FY'95 LDUA Demonstration along with the actual LDUA and its field deployment system.

10.0 Summary

Remote video and photography systems for deployment in UST's will significantly increase the information available concerning the tank conditions and contents during all phases of remediation. The low cost and light weight remote systems capable of small port entry into hazardous, or flammable, environments provide another valuable tool in the assessment and remediation of limited knowledge areas. The systems will enhance the operation of other equipment in the tank, such as the LDUA, and will provide a "first-in, last-out" view of all remote operations, further increasing the confidence in remediations. The potential for personnel exposure to hazardous materials and radiation will be reduced with the application of such equipment.

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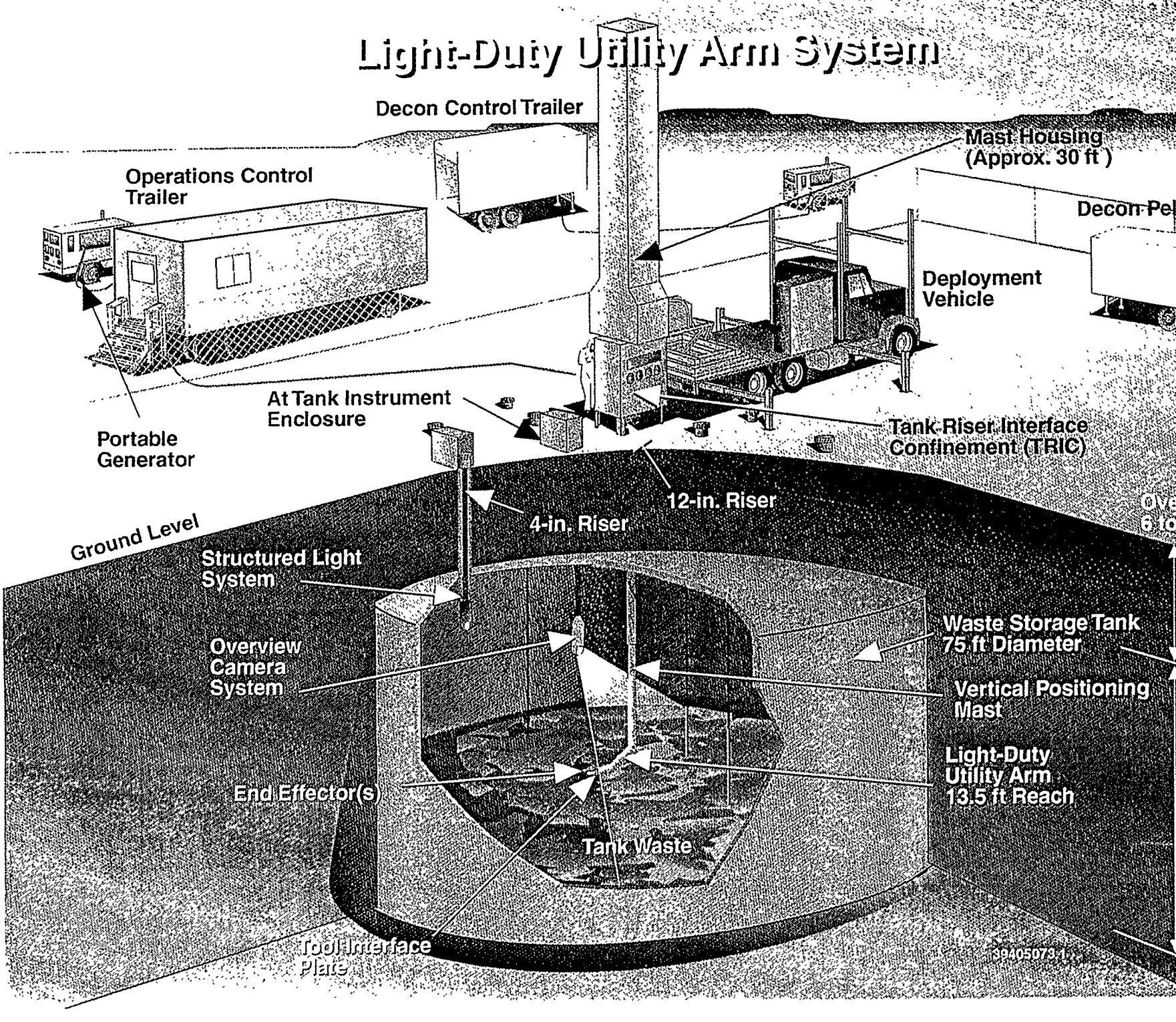
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