Video Camera Improvements to Support Hanford Tank Farms – 17141

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ABSTRACT

Hanford Tank Farms consist of 177 underground storage tanks that contain 56 million gallons of radioactive waste. The current mission is to safely manage this waste in preparation to feed the Waste Treatment Plant. Fulfilling this mission includes inspecting each tank regularly to ensure tank integrity and support ongoing operations such as transferring waste from older single-shell tanks to the newer double-shell tanks.

Video cameras derived from commercially available equipment have provided the ability to remotely see inside the tanks, reducing some of the challenges of fulfilling this mission. However, there are many challenges and limitations with the currently used video systems. Among some of the challenges are limited tank interior entry points for camera deployment, high radiation dose rates, limited equipment longevity in the environmental conditions, need for high resolution image quality, low light conditions, and in-tank obstructions. Washington River Protection Solutions (WRPS) has identified and tested new video systems that will effectively manage these challenges and increase capability, efficiency, and improve safety.

The new camera systems are planned for deployment to support the next Single Shell Tank Retrieval Project in the A/AX tank Farm complex.

INTRODUCTION

Nuclear waste is stored at Hanford in underground storage tanks ranging from 55,000 gallons to 1,000,000 gallons in capacity. 149 of these tanks were built between 1943 and 1964 and have a singular exterior shell. 28 additional tanks were built between 1968 and 1986 and employed a double shell construction. These tanks were not intended as a permanent storage solution. [1] The current mission of WRPS is to safely and efficiently manage, retrieve and treat the stored waste to protect the environment, and prepare it for transfer to the Waste Treatment Plant where it is intended to be prepared for long term storage. [2]

Many engineering challenges are presented in accomplishing this mission. One of them is having visibility to the internals of the tanks. Internal visibility is necessary in each part of the WRPS mission, from inspecting and maintaining the tanks to retrieving and transferring waste out of the tanks.

At Hanford the A/AX Retrieval and Closure team is designing the next retrieval system for AX tank farm. AX tanks are single shell, 1,000,000 gallon tanks from which the waste will be retrieved and transferred into a double shell tank. Previous tank waste retrievals have revealed several challenges for in-tank video monitoring equipment. AX tank retrievals will have many of the same challenges, along with a few that will be unique. Some of the major challenges include limited entry points, in-tank obstacles, low-light conditions, and higher radiation dose rates. While current camera systems have been sufficient for past tanks and retrieval campaigns, they have been plagued with multiple failures, replacements, and product customization to accomplish each campaign. Advancements in camera technology will help mitigate the impacts of these challenges, increase efficiency, and reduce costs.

UNDERSTANDING THE CHALLENGES

Limited Entry Into Tanks

Access into the tanks is limited to existing metal pipes installed through the tank dome, providing openings to the tanks which are called risers. Risers range in diameter from four to twelve inches. The larger diameter risers are primarily dedicated for the retrieval hardware, i.e., pumps, Extended Reach Sluicers, ventilation and exhausters, etc. This leaves the smaller diameter risers for cameras and lighting.

Small diameter access areas limit the amount of shielding that can be integrated into the hardware to protect it from radiation. Shielding increases the effective size of the hardware, and a design solution that balances technical feasibility, operational capability and system life is needed to complete a retrieval campaign successfully.

The majority of cameras in AX tanks will be installed in four inch diameter risers with a few being installed in larger risers shared with other hardware. [3] Fig. 1 shows the riser assignments of hardware for one of the AX Tanks. Four inch diameter significantly reduces the potential shielding the camera electronics can have and still fit within the riser.

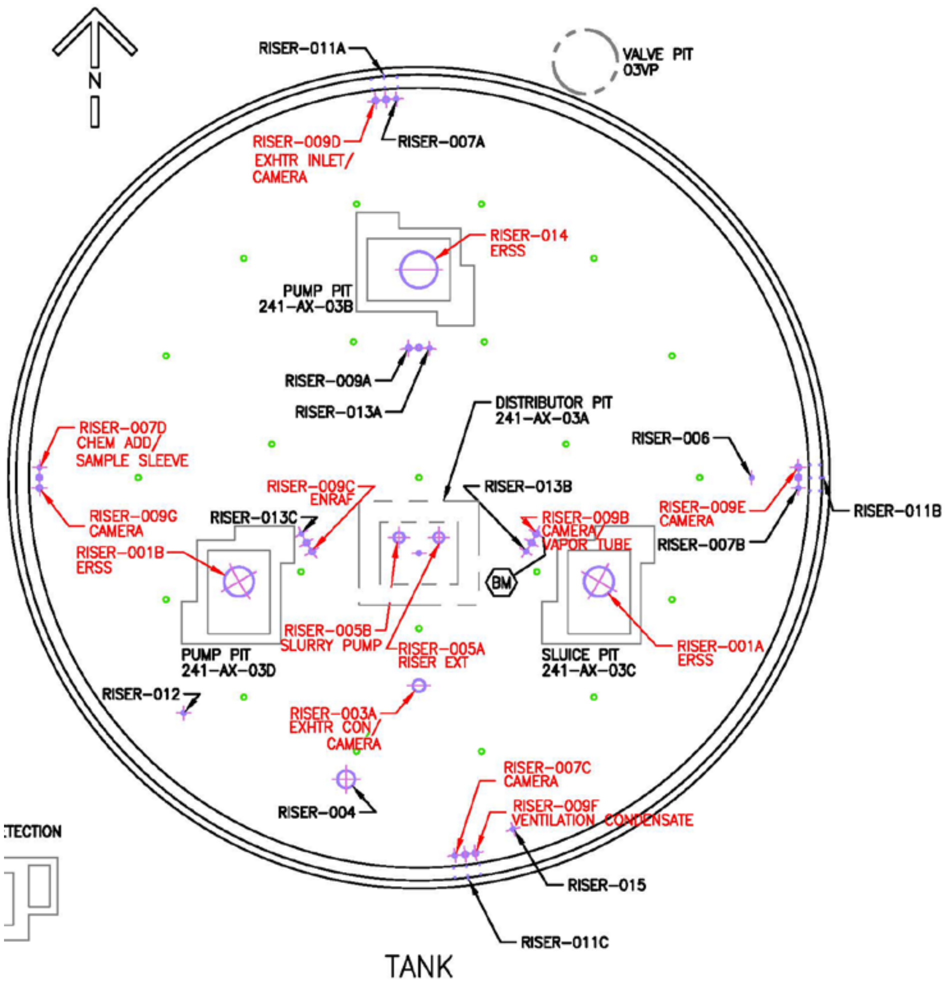

Fig. 1. Top view of tank with riser assignments

In-Tank Obstacles

Obstacles within tanks are barriers to operation of the retrieval equipment and limit the field of view of the video systems. A general depiction of an AX tank interior is shown in Fig. 2. The primary obstacles are the airlift circulators. Retrieval hardware will also impede visual capability. As seen in Fig. 1, there will be six cameras installed in each AX tank to provide adequate visual coverage. In addition to being able to see around obstacles, multiple cameras will provide multiple viewing angles of the sluicers which will give added advantage to the operators to successfully perform the retrieval.

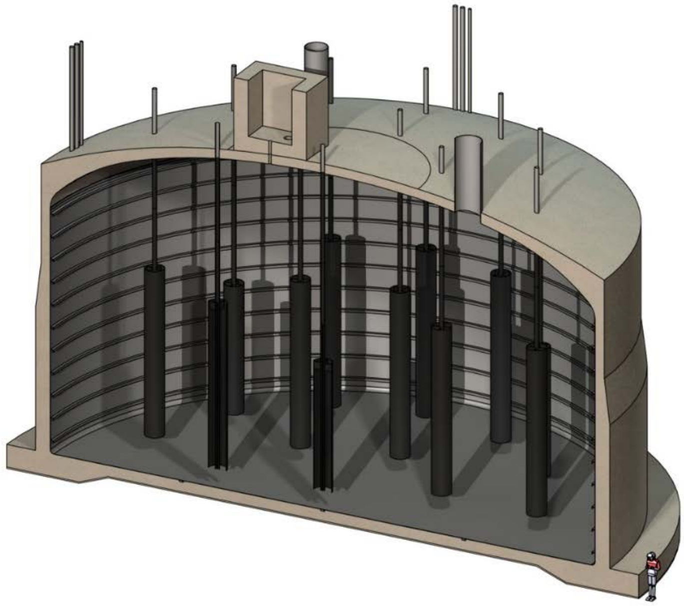

Fig. 2. General Depiction of AX tank interior

Low Light Conditions

Low light conditions make visual imaging a challenge and can significantly impact image quality. Omni-directional lights are typically installed in addition to the onboard camera lights to provide adequate lighting within the tank. Additional lighting is not a singular solution to low light imagery. Each camera product may employ different hardware and technology that will impact the camera effectiveness in low light conditions such as lens, aperture, processor, etc. Thus, in addition to supplemental lighting, the camera will be assessed on its ability to produce quality images in different lighting settings.

High Radiation Exposure Rates

Each tank contains a unique waste composition and radiation levels vary. Calculated radiation levels in the AX tanks predict that installed cameras will see higher levels of exposure then previous retrieval campaigns. [4] Table I shows the calculated gamma exposure for the four different AX tanks at different distances to the waste.

TABLE I: Calculated Exposure Rates for AX Tanks

Tank	Gamma Submersion Exposure Rate (R/hr)	Gamma One Foot Above Surface Exposure Rate (R/hr)	Gamma Ten Feet Above Surface Exposure Rate (R/hr)
241-AX-101	209.6	128.0	47.9
241-AX-102	163.0	99.6	37.2
241-AX-103	214.3	130.9	49.0
241-AX-104	1167.8	351.1	131.3

Current cameras will not survive long when exposed to these high levels of radiation. In previous tanks, camera failures have been associated with many things, from operational use to chemical exposure, but the most common has been associated with radiation exposure.

Obtaining sufficient shielding against radiation exposure is difficult given the previous discussion on limited access size to the tank interior.

DOWNSELECTION

WRPS deployed a technology development effort to investigate the camera products currently available to determine if there was a camera that could meet a set of unique criteria. An initial set of requirements were derived and identified for the selection of a new camera; see Table II.

TABLE II: Initial Camera Requirements Identified for Tank Retrieval

Camera Requirements	
Size	Fits in 4 inch pipe
Camera Sensor	Color
Radiation Tolerance	2.0×10^5 R, Total Radiation Dose
Readiness	Commercially Available
Focus	Auto Focus
Positioning System	Pan (360^o), Tilt (120^o)
Zoom	10x Optical
Lighting	Onboard fully independent
Transmission Range	1000 feet from camera to control trailer

65 camera product lines were assessed from 37 companies. Unfortunately, there was not a single product that met all the criteria of this unique requirement set. The limiting requirements were the size, total dose, and the independent onboard lighting criteria. The selections were narrowed down to 4 companies and 6 products that met the most requirements. The 6 products were investigated

further by technical conversations with the manufacturing companies. Some of the requirements were a necessity and could not be compromised, such as the size restriction.

Finally, a single camera was selected to purchase and test in house: the Ahlberg HI-RAD XS.

PRODUCT ASSESMENT

The Ahlberg HI-RAD XS met the requirements in Table II, with the exception of the radiation tolerance. It should be noted that while most of the cameras have on board lighting, the effectiveness of each varied significantly and the above requirement was somewhat subjective for quality. Purchasing a test system allowed the HI-RAD XS to be compared directly to the current cameras being used for tank retrievals and inspections. Fig. 3 depicts the Ahlberg HI-RAD XS, Extra Small HD PTZ camera.

Fig. 3. Ahlberg HI-RAD XS, Extra Small HD PTZ-Camera

Limited Entries And In-Tank Obstacles

The Alhberg HI-RAD XS satisfied the 4 inch diameter requirement. It has a maximum diameter of 3.65 inches. A mocked up riser was created to test the physical fit of the camera to verify installation and usability processes.

An added benefit is the physical design of the camera. While it is not necessarily unique in general terms, it is somewhat unique to implement such a design on a small diameter camera. This allows for easier installation and removal without damage.

On-Board Lighting

The HI-RAD XS contains four LED lights with a total of 3600 lumens. Lighting tests were performed in a test tank at the Cold Test Facility (CTF) at Hanford. Testing was performed with and without the same primary lighting that would be installed in tandem with the cameras. The primary light is a standalone 2000W omnidirectional bulb and is standard design for retrieval operations. Typically the current on-board lights are ineffective in the presence of the 2000W primary light.

On-board LED lights on the HI-RAD XS were impressive as they were capable of visually adding to the lighting condition of the image in the tank. This is a benefit that will be very advantageous in how the camera is utilized.

Radiation Tolerance

Table III lists the radiation tolerance levels for the HI-RAD XS versus the current cameras. [5]

TABLE III: Radiation Tolerances of Cameras

Camera Radiation Tolerance			
	X	Y	Ahlberg
Dose rate (rad/hr)	1,000	1,000	5,000
Total Dose (rad)	10,000	20,000	100,000

Current cameras that are used in tank retrievals are labeled as Camera X and Camera Y. Data was taken from the product specification sheets provided by manufacturer.

The specified radiation tolerance of the Ahlberg is significantly higher, as much as 10 times the total dose at 100,000 RAD. The direct correlation to life expectancy suggests a reduction in camera replacement efforts, ultimately contributing to less time delay in retrieval campaigns, and lower costs. Using the specification radiation tolerances for each camera in Table III and the calculated radiation levels in each tank in Table I(Gamma Ten Feet Above Surface Exposure Rate) shows how the life expectancy can be calculated for each camera, in each tank; see Table IV.

TABLE IV: Calculated Life Expectancy Based on Camera Specifications (Table III) and Calculated Radiation Levels (Table I)

	Life Expectancy per Tank (in days)			
	AX-101	AX-102	AX-103	AX-104
Camera X	8.7	11.2	8.5	3.2
Camera Y	17.4	22.4	17.0	6.3
Ahlberg HI-RAD XS	87.0	112.0	85.0	31.7

While there has not been specific data collected on past camera failures in previous tank retrievals, the operation logs suggest some correlation to support the type of calculations made in Table IV when done for other tanks.

WRPS subjected Camera Y and the HI-RAD XS to an irradiation test to assess the veracity of the specified radiation tolerances. Testing was conducted at the Pacific Northwest National Laboratory (PNNL) in Richland, Washington using a 3,500 Ci Co-60 source. Fig. 4 shows the test setup at the PNNL facility.

Fig. 4. Test Configuration at PNNL Facilities

Camera Y lost controls (pan, tilt, etc.) when accumulative dose reached roughly 25,100 R (22,012 rad). It is of interest to note that the first failure mode of Camera Y was the controls.

The Ahlberg HI-RAD XS received a total dose of 116,659 R (102,309 rad) when its first failure occurred. The failure was a loss of the video image. The camera controls were not impacted at this exposure level. This was verified by a test camera inside the test chamber for monitoring the test setup. The HI-RAD XS was subjected to further exposure for a total dose of 171,130 R (150,081 rad), and controls (pan, tilt, etc.) were still functioning at the end of the test. The video module was replaced and a functional test was performed and verified outside the test setup that the camera operated appropriately.

OPERATIONAL MANAGEMENT

Many of the challenges presented will be able to be addressed with the HI-RAD XS camera, which is directly due to the robustness of the camera design as described above. An additional method of addressing them will be through operational management, or how it is used during operation. Increased capability of the camera, such as the high resolution image (720x1280), 10X optical zoom, high radiation tolerance, and physical design will allow operators to use the camera differently.

The high resolution and zoom will allow the camera to be installed higher in the tank and still provide an adequate image, effectively reducing exposure to the harsh environment and radiation source. The camera would not need to be completely through the riser in order to have full operational capability, which will allow the riser to provide added radiation shielding, even against sluicing spray during retrieval operations.

The HI-RAD XS will survive longer inside the tank than current cameras. Longer longevity translates to less replacements and installations. Logistically, this reduces the entries by maintenance and operation workers, limiting them to both radiation and chemical vapor exposure which is a key mission of the “As Low As Reasonably Achievable” (ALARA) safety program.

CONCLUSION

Evaluation and testing of the Ahlberg HI-RAD XS demonstrates that retrieval efficiency will be improved compared to the products currently employed in Hanford Tank Farms. The HI-RAD XS has been selected to be installed in the AX tank farms for retrieval and closure of those tanks. Testing has verified the technical specifications and supports the conclusion that the camera will have a significantly longer life cycle than current cameras, which will ultimately save costs and schedule time. In addition to cost and schedule, the HI-RAD XS will provide higher quality imaging, which will ultimately produce higher visual reliability.

REFERENCES

1. Tank Farms History, United States Department of Energy, Office of River Protection, found at http://www.hanford.gov/page.cfm/TankFarms, 2016.
2. WRPS Mission Statement, Washington River Protection Solutions (WRPS) found at http://wrpstoc.com/about-wrps/mission-vision/, 2016.
3. J. P. Witherspoon, “241-AX Farm Riser Utilization”, RPP-RPT-57187, Revision 1, November 23, 2015.

4. R. C. Winslow, “In-Tank Exposure Rate Estimation for A-100 and AX-100 Series Waste Tanks”, RPP-CALC-57060, Revision 0, July 25, 2014.
5. Ahlberg HI-RAD XS Specification Sheet, found at http://www.ahlbergcameras.com/products/cameras/hi-rad-xs/, 2016.