

Performance Testing of a System for Remote Ultrasonic Examination of the Hanford Double- Shell Waste Storage Tanks

Prepared for the U.S. Department of Energy
Office of Environmental Restoration and
Waste Management



Westinghouse
Hanford Company Richland, Washington

Hanford Operations and Engineering Contractor for the
U.S. Department of Energy under Contract DE-AC06-87RL10930

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PERFORMANCE TESTING OF A SYSTEM FOR REMOTE ULTRASONIC EXAMINATION OF THE HANFORD DOUBLE SHELL WASTE STORAGE TANKS

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ABSTRACT

A mobile robotic inspection system is being developed for remote ultrasonic examination of the double wall waste storage tanks at Hanford. Performance testing of the system includes demonstrating robot mobility within the tank annulus, evaluating the accuracy of the vision based navigation process, and verifying ultrasonic and video system performance. This paper briefly describes the system and presents a summary of the plan for performance testing of the ultrasonic testing system. Performance test results will be presented at the conference.

INTRODUCTION

Raytheon Service Company and RedZone Robotics have been contracted by Westinghouse Hanford Company to develop a system for inspection of the double shell waste storage tanks at the Department of Energy Hanford Site. The system must be able to perform Ultrasonic Testing (UT) over 100% of the primary and secondary tank walls and the primary tank knuckle as well as over a small percentage of the tank bottom which is accessible via air slots under the tank. The system must also be capable of executing a specified initial inspection sequence in a 36 hour period, including cleaning, visual verification of surface preparation and ultrasonic inspection.

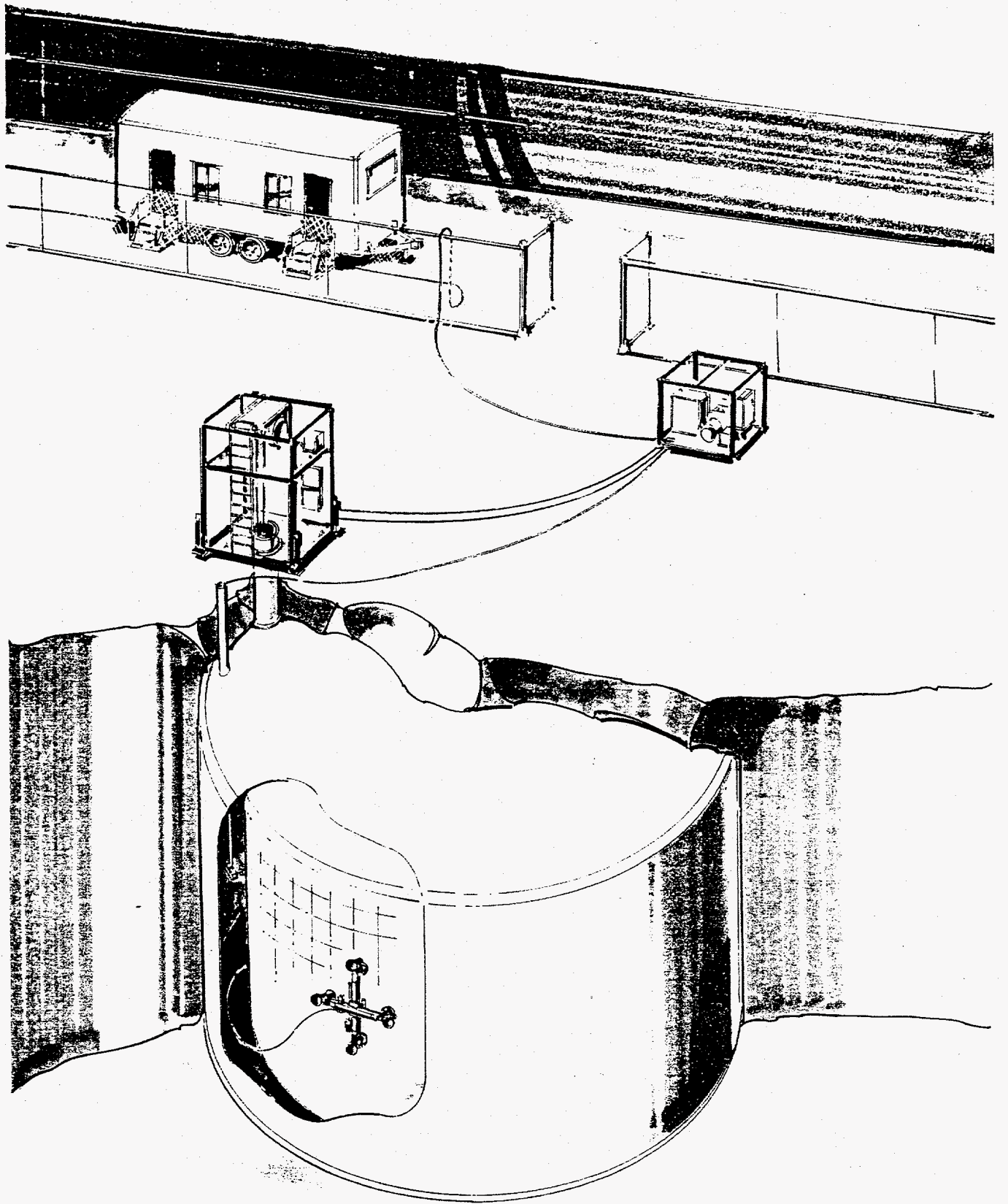
The Double Shell Tank Inspection system consists of a Mobile Control Center, Deployment Module, Cable Management Assembly, Robotic Mechanism, Ultrasonic Testing (UT) System, Visual Testing (VT) System, Robot Control System, Pneumatic Distribution System and Electrical Distribution System. An artists rendition of the system is shown in Figure 1. A rigorous testing program is necessary to ensure that operations in the actual tank farm are smooth and trouble free and that the system will meet the requirements of the intended application. This paper focuses on performance testing of the Ultrasonic Testing system.

PLACE FIG. 1 HERE

Figure 1: Double Shell Tank Inspection System

TEST FACILITY

Complete and safe testing of the system requires a dedicated test facility. A full scale, partial section of a double-shell tank has been constructed in RedZone Robotics' Pittsburgh facility. The mockup is



approximately 35 feet long and 12 feet high, constructed of three courses of four by eight foot sheets of rolled steel. A section of the mockup includes simulated haunch and knuckle regions, along with air slots. A platform mounted above the tank section represents ground level, and is used for deployment of the system through a riser. Westinghouse Hanford Company has constructed a similar, but somewhat larger facility at the Hanford site for testing and training. The performance test will be conducted at the RedZone facility.

ROBOT MECHANISM

The robotic mechanism supports deployment of the UT and VT systems. The mechanism consists of a cable management assembly, a storage enclosure, a mobile vehicle called the scan carriage and a cleaning system to prepare the tank surface for inspection. To the extent possible, the scan carriage is constructed of materials that can withstand a total radiation dose up to 1×10^6 Rads. Electronics are kept to a bare minimum, and no on-board electronics are used for components needed for recovery. An artist's rendition of the scan carriage is shown in Figure 2.

Scan Carriage

The scan carriage vehicle is a walking platform that carries cleaning and inspection hardware between the walls of the annulus of the waste tanks. The vehicle supports inspection of the primary and secondary tank walls and the floor of the primary tank via the air slots. From any location, a rectangular scan area of 64 in. high by 22 in. wide can be accessed. In order to inspect the secondary tank wall, the scan carriage must be retrieved and rotated 180 degrees. The scan carriage is able to negotiate obstacles (air supply pipes) that are up to 15 in. from the primary tank wall, and 15 in. from the secondary tank wall. A separate tool package is used to access the air slots under the tank. The vehicle is sized to fit through a 24 in. access riser. The scan carriage vehicle navigates with the aid of an industrial machine vision system which tracks weld seams and identifies weld intersections using edge detection and line fitting algorithms.

The performance of the scan carriage will be tested by executing a series of maneuvers, including deployment, negotiation of obstacles, carrying out cleaning and inspection tasks and fail safe recovery.

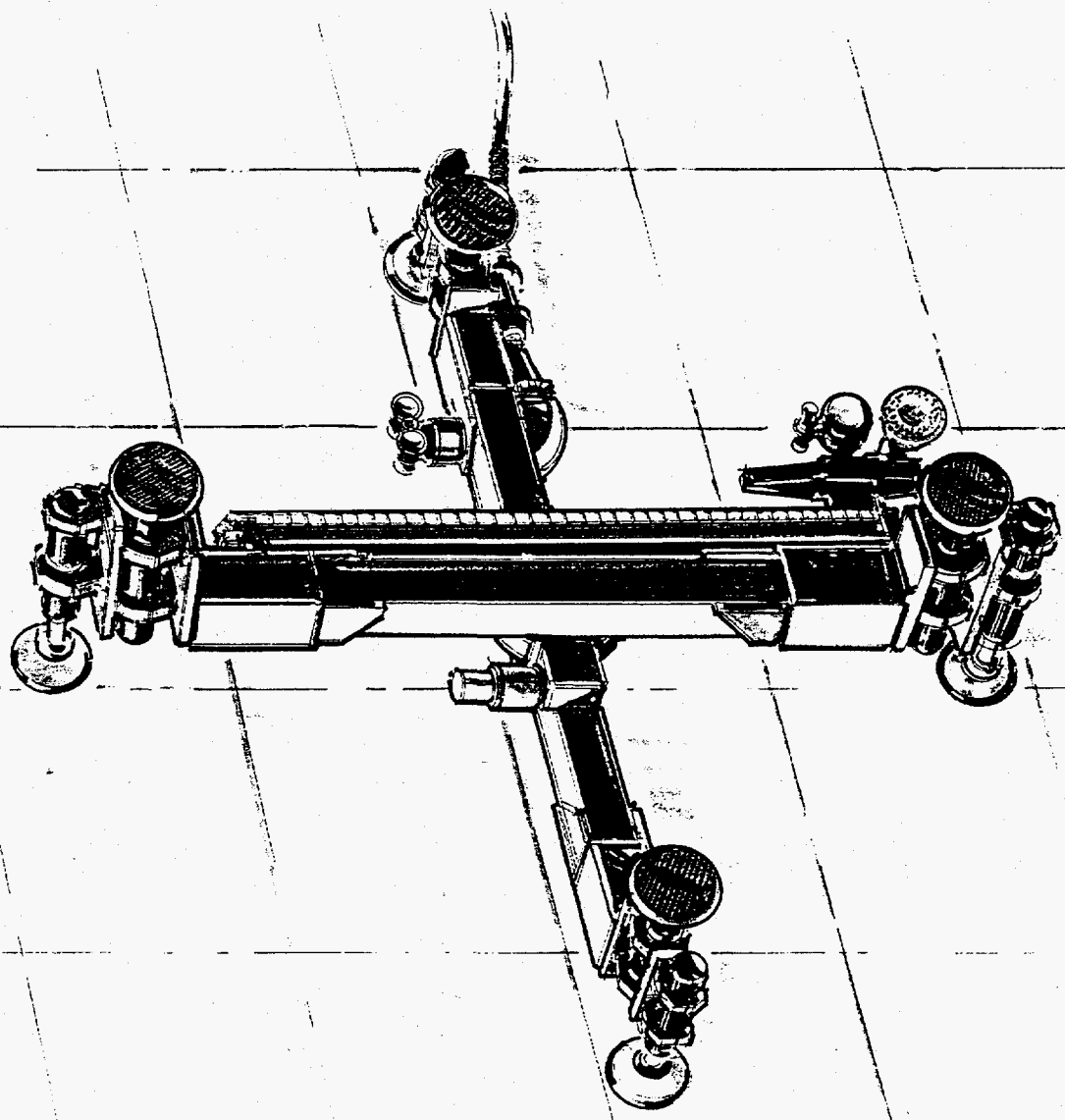
INSERT FIG. 2 HERE

Figure 2: Scan Carriage

Cleaning System

Effective ultrasonic examination requires that the weld, the heat-affected zone and surrounding area be free of excessive rust build-up, scale and debris. To meet this requirement, each inspection tool is outfitted with a maneuverable cleaning head. Each cleaning system consists of a cleaning head, power sources (air and electric) and attachment hardware for the corresponding payload delivery device. The cleaning system removes loose material from the base metal, but leaves tightly adhering mill scale.

An application based test will be used to demonstrate the performance of these tools. In operation, the cleaning tools are used to prepare the surface for inspection. So, the test will start with realistic surface conditions. The robot will clean the surface, and a UT inspection will be performed. Success is demonstrated by good ultrasonic coupling.



conditions. The robot will clean the surface, and a UT inspection will be performed. Success is demonstrated by good ultrasonic coupling.

Visual Testing System

Preparation of the tank surface for ultrasonic inspection is verified by the Visual Testing system. Additional functions of the VT system are to monitor cleaning and ultrasonic operations, and to provide video image feedback to the robot navigation system and the operator. The VT functions are performed by four cameras, one (mounted on a pan and tilt on the scan carriage) to provide a view of the general area around the scan carriage, one to perform wall inspection, one to perform air slot inspection and one (deployed through a 3 or 4 inch tank riser) to provide an overview of the scan carriage as it enters, leaves and moves within the annulus.

DESCRIPTION OF THE ULTRASONIC TESTING SYSTEM

The UT examination is designed to determine tank wall thickness, and detect and size corrosion induced pitting and cracking. The P-Scan Ultrasonic testing system, manufactured by the Force Institute in Denmark, will be used for data collection and analysis. The multi-channel data acquisition capabilities of the P-Scan system allow for simultaneous and continuous acquisition of data from four transducers. There are two transducer array modules in the DSTI system.

Tank Wall Transducer Array Module

The tank wall transducer array module contains transducers oriented at a variety of angles, using various wave modes, and frequencies to provide detection and sizing of planar reflectors and wall thickness measurements within the specified examination volume. The module can be moved to and from the weld centerline and along the weld axis. It is also capable of ± 180 degree rotation to provide maximization of echoes for detection, discrimination, and sizing of indications in the specified examination area regardless of their orientation to the weld centerline.

The scan pattern begins at the uppermost point of the examination area and proceeds down the tank wall, following the shortest or most convenient combination of vertical and horizontal welds. Scanning will be from both sides of the weld where access allows. Scan motion is provided by the Scan Carriage. The nominal scanning speed is 3 inches per second.

Knuckle and Air Slot Transducer Array Module

The knuckle and air slot transducer array is capable of movement in a straight line beginning at the upper most examination point of the knuckle and extending 24" into the air slot. Data is also obtained while retracting the head from the air slot. Due to the restricted area in the air slot, indexing of the transducer array module is not possible. Required examination volume coverage is provided by the orientation of the transducers within the module. The nominal scanning speed is 3 inches per second. The knuckle and air slot UT transducer module mounts to the scan carriage on the output of one of the payload reels mounted on the secondary slide of the y-member. Vertical and horizontal motion are provided by the scan carriage.

UT SYSTEM PERFORMANCE TESTING

The flaw detection and sizing methodology for planar flaws evolves from techniques proven in the nuclear power industry for the detection and sizing of intergranular stress corrosion cracking. These techniques provide accuracy meeting the specification, but are dependent on surface condition. Testing of the UT

System will verify the accuracy of these techniques by examining test plates with known flaws under expected operating conditions. The mockup tank surface will be heated to test the effect of heating of the couplant on UT scanning. Testing of the VT system will be conducted to confirm the ability of the system to provide the required support for ultrasonic testing and the robot navigation and tele-operation functions. A dusty environment will be created inside the mockup annulus to confirm the ability of the VT system to function under realistic conditions.

The UT system performance test is to be conducted in a manner that simulates the way in which examination is conducted in the field and shall be performed in accordance with a written procedure provided by the contractor.

Performance Demonstration Samples

Performance demonstration specimens shall be fabricated from the same DST wall material or equivalent materials and shall have surface condition representative of the general condition of the DST scanning surface. Performance demonstration specimens shall have sufficient area to minimize spurious reflections and shall include thickness, pitting, and crack samples. The ultrasonic reflectors will be distributed to cover the through-wall thickness (t) in a minimum range from 0.25t to 1.0t.

Performance demonstration specimens shall be divided into grading units. A grading unit is defined as a minimum of 3-inches of continuous vertical or horizontal length. If a grading unit is designed to be flawed, then one (1) inch of unflawed material must exist on either side of the grading unit. The specific segment of length used in one grading unit may not be used in another grading unit.

Orientation of the cracks shall be either perpendicular or parallel to the major axis of the performance demonstration specimen. Flawed and unflawed grading units shall be randomly mixed. Performance demonstration specimens shall be embedded in the primary tank wall with their sound entry surface facing the annulus; sound entry surface of the samples shall be flush with the surrounding wall surface; exposed back surface of the samples shall be masked. The same performance demonstration specimens may be used for both detection and through-wall sizing.

Calibration

An initial calibration shall be performed and documented at the start of the performance test. The examination methodology requires multiple calibrations corresponding to 25°F temperature increments. To verify the function of the temperature detectors in the UT modules at least two widely different readings shall be taken at location where the temperature can be independently measured. The high reading should be about 200 ±10 °F.

Examination Procedure

All ultrasonic indications which exceed 20% reference shall be investigated to determine their maximum amplitude. All ultrasonic indications which exceed 50% reference shall be recorded on the indication report form. Any indication determined to be originating from a surface connected planar flaw shall be tagged and reported, regardless of amplitude.

Wall thickness measurements less than 87.5% of specified original wall thickness will be tagged and reported. Stress corrosion cracks greater than 0.5 in. in length will be tagged and reported. Corrosion pitting greater than 0.35 times specified original wall thickness in depth will be tagged and reported.

For reportable indications, data shall indicate the location, area extent, and maximum amplitude for each indication. For thin areas, the reported data shall summarize the thickness measurement results.

Reports

An Indication Report Form shall be prepared for each Performance Test Plate. Location, orientation and size of cracks shall be reported on the Indication Report Form and marked on the P-Scan printouts. A detailed Tank Inspection Report shall also be prepared summarizing findings during the entire performance test.

All P-Scan examination data shall be printed in hard copy form identifying any areas with shear wave amplitudes exceeding 50% reference. The report shall note the maximum amplitude location in the X and Y axis, and the global robot coordinates. Any area that exhibits ultrasonic echoes exceeding 50% reference, but which are determined to be geometric in nature, shall have a brief written statement outlining the basis for the conclusion. Any area determined to contain planar oriented flaws shall be identified on the hard copy printout and in a written report describing the techniques utilized and basis for the conclusion.

Performance Criteria

To complete the detection performance test successfully, the system must perform in accordance with Table 1:

PLACE TABLE I HERE

N-1 crack depth from a total of N shall be reported. A depth result on one (1) crack is allowed to be left blank. If depth of all N cracks is reported, the first N consecutive samples will be evaluated. A false call is defined as calling an uncracked grading unit cracked. A crack parallel to the major axis direction is detected successfully if a minimum of 50% of its actual length has been reported. An allowance of 0.5 inch is permitted in one direction or the other from the actual crack location.

All detected flaws shall be sized to the following requirements:

- a.. For circumferential flaws the minimum detected flaw shall be t in length ± 0.5 inches and $0.5t$ in depth ± 0.050 inch;
- b. For longitudinal flaws the minimum detected flaw shall be 12 inches in length ± 0.5 inches and $0.2t$ in depth ± 0.050 inch;
- c. For Pitting the minimum detectable pit shall be $0.7t$ in diameter and $0.35t$ in depth ± 0.02 inch.

The following criteria apply to depth sizing and wall thickness measurement :

- d. Each successfully reported depth-sizing measurement shall be within ± 0.050 inch of the true depth.
- e. Wall thickness measurement shall be accurate to within ± 0.0025 inch.

Timing Documentation

The time required for data acquisition, analysis and reporting on each sample shall be documented. The following tasks must be performed during this time:

TABLE 1: Detection Performance Criteria

No. of Flaws	Minimum No. of Detected Flaws	Maximum No. of False Calls
6	6	1
7	6	1
8	7	2
9	7	2
10	8	3

- a. Repositioning the scan carriage within one performance demonstration specimen.
- b. Scanning one performance demonstration specimen for reflectors oriented perpendicularly and parallel to the major axis. This activity will consist of some number of complete scans.
- c. Data analysis and generation of required documentation.

The following items are not included in the acquisition time:

- d. Initial UT system calibration or calibration check.
- e. Positioning scan carriage at the scan start on the performance demonstration specimens.

PROJECT STATUS

The fabrication of the Double Shell Tank Inspection System is complete and testing will have been completed by the time this paper is presented. Results of performance testing will be presented at the conference. Tank inspection operations are expected to begin in June 1995.